Semi-annual water column monitoring report: February-July 1996

Massachusetts Water Resources Authority

Environmental Quality Department
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Semi-Annual Water Column Monitoring Report 96-1
February - July 1996

submitted to

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CONTENTS

CONTENTS
(Cont'd)

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES
(Cont'd)

LIST OF FIGURES
(Cont'd)

SEMI-ANNUAL WATER COLUMN REPORT, 96-1
EXECUTIVE SUMMARY

Water quality data have been collected in Massachusetts and Cape Cod Bays by the Massachusetts Water Resources Authority (MWRA) Harbor and Outfall Monitoring (HOM) Program since 1992. This monitoring is in support of the HOM Program mission to assess the potential environmental effects of effluent discharge relocation from Boston Harbor into Massachusetts Bay. The data are being collected to establish baseline water quality conditions and ultimately to provide the means to detect significant departure from that baseline. The data include physical water properties, nutrients, biological production and respiration, and plankton measurements. Two types of surveys are performed: nearfield surveys with stations located in the area around the future outfall site, and more comprehensive combined nearfield/farfield surveys that include stations in Boston Harbor, Massachusetts Bay, and Cape Cod Bay.

Water quality monitoring data presented in this report were collected during the first half of 1996 in the Massachusetts Bay system. The scope of this semi-annual report includes a synthesis of water column data, and a brief analysis of integrated physical and biological results. The objective of the report is to provide a visual presentation of the monitoring data submitted to MWRA five times per year in tabular format, and to discuss key biological events which occurred. To this end, graphical presentations of the horizontal and vertical distribution of water column parameters in the farfield and nearfield from the first nine surveys of 1996 are presented.

An overview of the data from the first semi-annual period is presented below. The Massachusetts Bay system undergoes strong seasonal stratification of the water column, and the timing of the onset of vertical stratification influences seasonal nutrient cycling and its effect on critical issues such as dissolved oxygen depletion in stratified bottom water. Results are discussed, therefore, in terms of the structure of the water column. In 1996, stratification began around the end of April.

During the first survey conducted during the pre-stratification period in early February of 1996, the water column was well-mixed, and maximum regional nutrient concentrations for the reporting period were measured. A localized phytoplankton bloom in eastern Cape Cod Bay was the only area showing evidence of surface water nutrient depletion. By the second regional survey in late February, a system-wide bloom was indicated by peak semi-annual chlorophyll concentrations (ranging from 5-12 μg/L) measured in Cape Cod Bay, Massachusetts Bay, and in the nearfield. Cape Cod Bay had the highest regional phytoplankton densities, dominated by centric diatoms (*Chaetoceros*, *Thalassiosira*). Boston Harbor was the only region sampled that had relatively low chlorophyll concentrations (<2 μg/L). Peak production in the outer nearfield occurred at this time, reaching around 3,000 $mgCm^{-2}d^{-1}$.

By the third (nearfield only) survey conducted in March, nutrients were largely scavenged from surface water, ending the late winter bloom in Massachusetts Bay. The bulk of chlorophyll and carbon from the bloom was found in the lower water column, resulting in high bottom water respiration. Horizontally, chlorophyll peaked inshore and in the more seaward stations of the nearfield. As compared with data collected for the MWRA Boston Harbor Water Quality Monitoring Program, the coastal chlorophyll component appeared associated with an extension of the seasonal bloom within the harbor and coastal regions, which lasted into May. The offshore component appeared to be continued productivity (at depth) by the late winter bloom. Regional data collected during the combined nearfield/farfield survey in April documented the continued dominance of centric diatoms at harbor and coastal stations, while chlorophyll and phytoplankton densities remained low at more offshore stations in Mass Bay and at Cape Cod Bay stations throughout the spring.

The onset of vertical stratification was occurring in the inner nearfield by mid-April, but setup was not complete until mid-May in the outer nearfield. Stratification was augmented by an intrusion of low salinity surface water to the outer nearfield during May, resulting from a Gulf of Maine spring freshet. This intrusion apparently resupplied nutrients to the impoverished surface water, with evidence of between-survey phytoplankton production found in productivity, particulate carbon, and respiration results. However, chlorophyll concentrations in the water column remained low during the surveys, potentially a result of grazing as total zooplankton abundances peaked at outer nearfield stations N04 and N16 during the June survey. A localized surface bloom of the centric diatom *Rhizosolenia fragilissima* did occur at nearfield station N04 in early July, causing a secondary peak in productivity for the reporting period (2,000 $mgCm^{-2}d^{-1}$). Based on continuous monitoring results from the USGS mooring, this bloom may have developed throughout the nearfield in the ensuing week after the survey.

Inshore waters were also productive through the period, with the *Chaetoceros*-dominated harbor bloom in evidence at N10 in late April, comprising 60% of the total phytoplankton abundance there. Maximum semi-annual productivity measurements were made at harbor station F23 in June (5,200 $mgCm^{-2}d^{-1}$). The plankton assemblage was still dominated by centric diatoms, but the dominant at this time was *Skeletonema costatum*. Peak production for the reporting period at station N10 also occurred during June, reaching around 4,500 $mgCm^{-2}d^{-1}$.

1.0 INTRODUCTION

1.1 Program Overview

The Massachusetts Water Resources Authority (MWRA) has implemented a long-term Harbor and Outfall Monitoring (HOM) Program in the Massachusetts Bay system. The objective of the HOM Program is to verify compliance with the discharge permit, and to assess the potential environmental effects of the relocated effluent discharge into Massachusetts Bay. To establish baseline water quality conditions with respect to nutrients, water properties, phytoplankton and zooplankton, and water-column respiration and productivity, ENSR is conducting water quality surveys in the nearfield and farfield region of Massachusetts and Cape Cod Bays.

This semi-annual report summarizes water column monitoring results for the first 9 of 17 surveys conducted in 1996 (Table 1-1). Two types of surveys were performed during the first half of 1996: nine nearfield surveys with stations located in the area over the future outfall site (Figure 1-1), and four comprehensive surveys that included sampling of stations in Boston Harbor, Massachusetts Bay, and Cape Cod Bay (Figure 1-2). The stations in these surveys were further separated into regional groupings according to geographic location.

Raw data summaries, along with specific field information, are available in individual survey reports submitted immediately following each survey. In addition, nutrient data reports (including calibration information, sensor and water chemistry data), plankton data reports, and productivity and respiration data reports are each submitted five times annually. Raw data summarized within this or any of the other reports are available from MWRA in hard copy or electronic formats.

1.2 Organization of the Semi-Annual Report

The scope of the semi-annual report is focused primarily towards providing a compilation of all of the water column data collected during the reporting period. Secondarily, integrated physical and biological results are discussed for key water column events. The report first provides a summary of the survey and laboratory methods (Section 2). The bulk of the report, as discussed in further detail below, presents results of water column data from the first nine surveys of 1996 (Sections 3-5). Finally, the major findings of the semi-annual period, including integrated physical and biological water column results during water column events, are synthesized in Section 6.

In the results sections, data are first provided in summary tables (Section 3). The data summary tables include the major results of water column surveys in the semi-annual period. A description of data selection, integration information, and summary statistics are included with that section.

Each of the summary results sections (Sections 4-5) includes presentation of the horizontal and vertical distribution of water column parameters in both the farfield and nearfield. The horizontal distribution of physical parameters is presented through regional contour plots. The vertical distribution of water column parameters is presented using both time-series plots of averaged surface and bottom water column parameters, and along vertical transects in the survey area (Figure 1-3). The time-series plots utilize average values of the surface water sample (the "A" depth, as described in Section 3), and the bottom water sample (the "E" depth). Examining data trends along three farfield transects (Boston-Nearfield, Cohassett, and Marshfield), and one nearfield transect, allows three-dimensional analysis of water column conditions during each survey.

Results of water column physical data, including water properties, nutrients, chlorophyll, and dissolved oxygen, are provided in Section 4. Survey results were organized according to the physical characteristics of the water column during the semi-annual period. The timing of water column vertical stratification, and the physical and biological status of the water column at the onset of stratification, to a large degree control ecological water quality parameters that are a major focus in assessing effects of the outfall. Because of the importance of this dynamic, this report describes the horizontal and vertical characterization of the water column during the pre-stratification stage (W9601-W9605), and then further delineates processes occurring during the early stratification stage (W9606-W9609). Time-series data are commonly provided for the entire semi-annual period for clarity of data presentation.

Productivity, respiration, and plankton measurements, along with corresponding discussion of chlorophyll and dissolved oxygen results, are provided in Section 5. Discussion of the biological processes and trends during the semi-annual period is included in this section. A summary of the major water column events of the semi-annual period is presented in Section 6, and finally, references are provided in Section 7.

TABLE 1-1

Water Quality Surveys for W9601-W9609
January to July 1996

Survey #	Type of Survey	Survey Dates
W9601	Nearfield/Farfield	February 5-10
W9602	Nearfield/Farfield	February 23-28
W9603	Nearfield	March 18-20
W9604	Nearfield/Farfield	April 1-6
W9605	Nearfield	April 22-26
W9606	Nearfield	May 13-14
W9607	Nearfield/Farfield	June 17-20
W9608	Nearfield	July 1-2
W9609	Nearfield	July 23-24

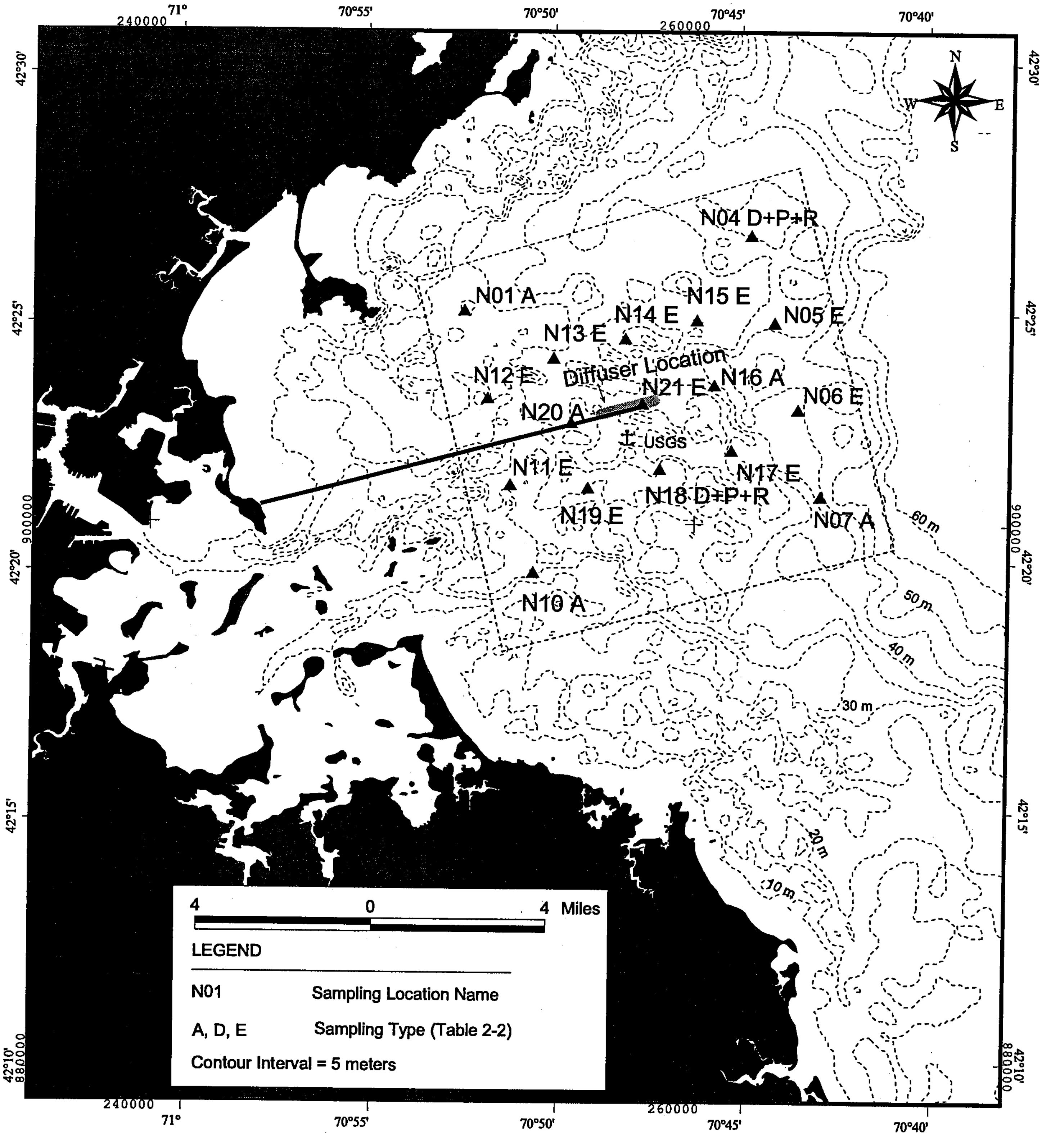


FIGURE 1-1
Location of Nearfield Stations and USGS Mooring

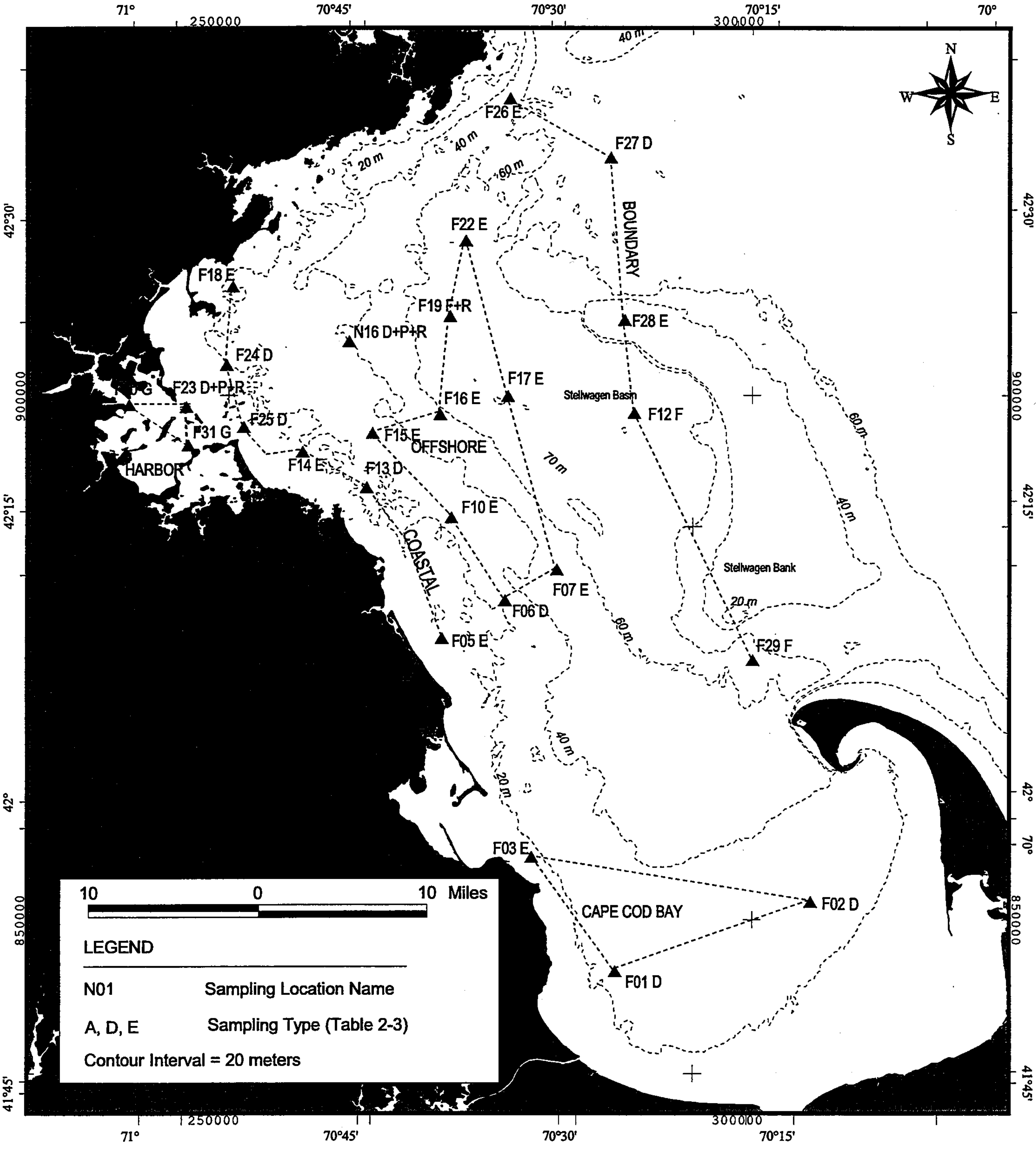


FIGURE 1-2
Location of Farfield Stations Showing Regional Classifications

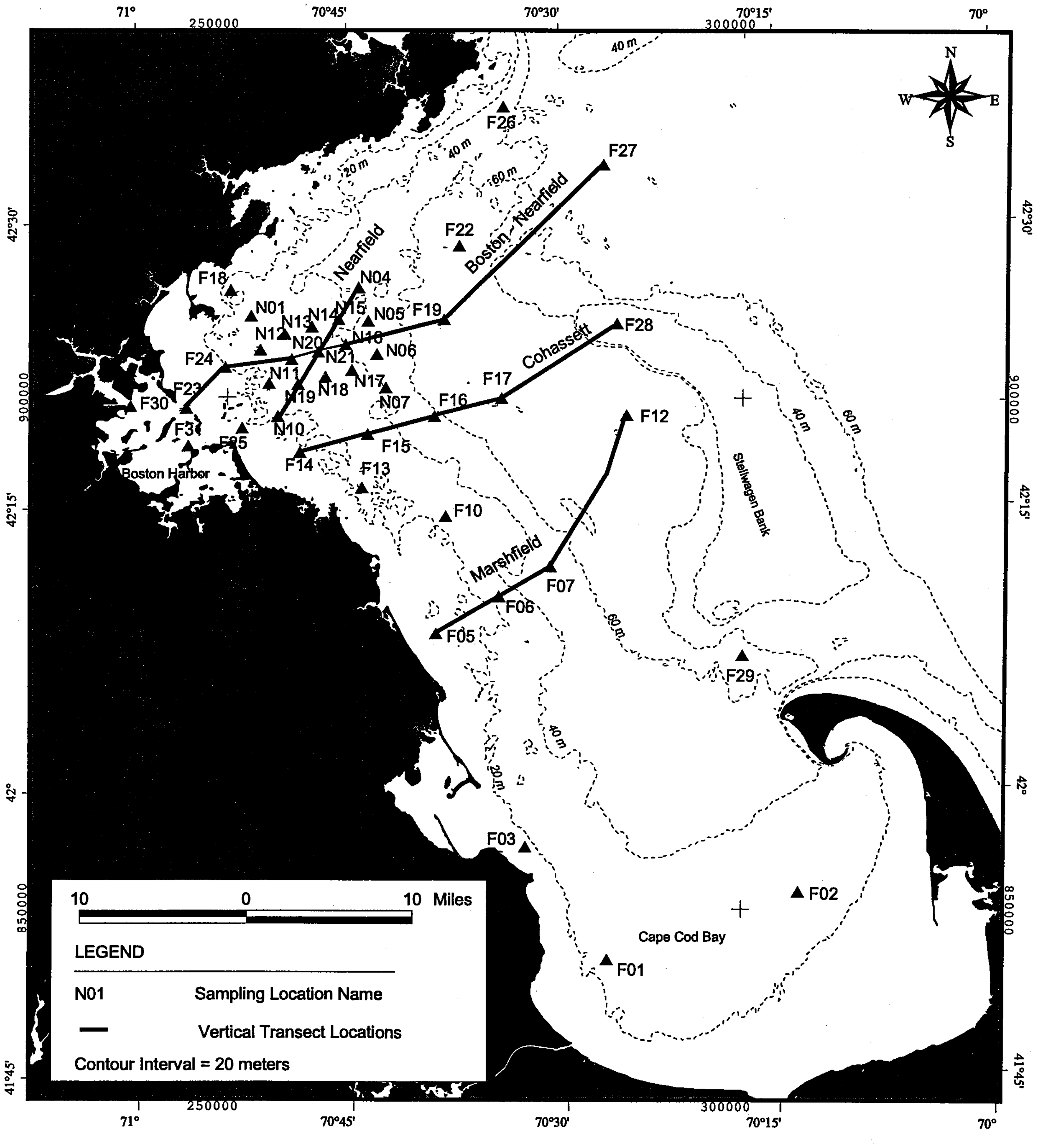


FIGURE 1-3
Location of Stations Selected for Vertical Transect Graphics Showing Transect Names

2.0 METHODS

This section describes general methods of data collection and sampling for the first nine water column monitoring surveys of 1996. Section 2.1 describes data collection methods, including survey dates, sampling platforms, and analyses performed. Section 2.2 describes the sampling schema undertaken, and Section 2.3 details specific operations for the first 1996 semi-annual period. More specific details on field sampling and analytical procedures, laboratory sample processing and analysis, sample handling and custody, calibration and preventive maintenance, documentation, data evaluation, and data quality procedures are discussed in the Water Quality Monitoring CW/QAPP (Bowen *et al.*, 1997). Details on productivity sampling procedures and analytical methods are available in Appendix A.

2.1 Data Collection

Water quality data for this report were collected from the sampling platforms *R/V Christopher Andrew* and *R/V Isabel S.* Continuous vertical profiles of the water column and discrete water samples for analysis were collected using a CTD/Niskin Bottle Rosette system. This system includes a deck unit to control and store data, and an underwater unit comprised of several environmental sensors, including conductivity/salinity, temperature, depth, dissolved oxygen, transmissometry, irradiance, and relative fluorescence. These measurements were obtained at each station by deploying the CTD; in general, one cast was made at each station. Water column profile data were collected during the downcast, and water samples were collected during the upcast by closing the Niskin bottles at selected depths, as discussed below.

Water samples were collected at five depths at each station. These depths were selected during CTD deployment based on positions relative to the pycnocline or subsurface chlorophyll maximum. The bottom depth (within 5 meters of the sea floor) and the surface depth (within 4 meters of the water surface) of each cast remained constant and the mid-bottom, middle and mid-surface depths were selected to represent any variability in the water column. In general, the selected middle depth corresponded with the chlorophyll maximum and/or pycnocline. Should the chlorophyll maximum have occurred closer to the surface or the bottom of the water column, the mid-surface or mid-bottom depths were selected to capture that layer. Water samples for analyses that are dependent on chlorophyll were taken from the bottles closed at the chlorophyll maximum, regardless of the depth at which the bottles were closed.

Exceptions to the water sampling procedure included productivity and respiration casts at Stations F23 and N16 during each farfield survey, and at Stations N04 and N10 during each nearfield survey. At these stations, two casts were necessary in order to obtain a sufficient amount of water for the additional analyses. Productivity samples are also light dependent, and a "split-bottom" cast was sometimes necessary during the respiration and productivity cast in an attempt to capture not only bottom water, but also water associated with the 0.5% light level. This resulted in six depths being sampled. These two casts were made in succession during a station visit, with time in between to relocate the vessel within a 300 meter radius of the station location.

Samples from each depth at each station were collected by subsampling from the Niskin bottles into the appropriate sample container. Analyses performed on the water samples are summarized in Table 2-1. Samples for dissolved inorganic nutrients (DINuts), dissolved organic carbon (DOC), total dissolved nitrogen (TDN) and phosphorous (TDP), particulate organic carbon (POC), biogenic silica, chlorophyll *a* and phaeopigments, total suspended solids (TSS), urea, and phytoplankton were filtered and preserved immediately after obtaining water from the appropriate Niskin bottles. Whole water phytoplankton samples (unfiltered) were obtained directly from the Niskin bottles and immediately preserved. Zooplankton samples were obtained by deploying a zooplankton net overboard and making an oblique tow of two-thirds of the water column or up to 30 meters of depth. Productivity and respiration samples were collected from the Niskin bottles and incubated either on board the vessel or at a laboratory, but not more than six hours after initial water collection.

2.2 Sampling Schema

A synopsis of the sampling schema for the analyses described above is outlined in Tables 2-1, 2-2, and 2-3. Stations were assigned a letter (A, D, E, F, or G) according to the types of analyses performed at that station. Productivity and respiration analyses were also conducted at certain stations and represented by the letters P and R, respectively. Since different analyses were performed at different depths, each depth at each station is assigned an analysis group (G1, G2, G3, G4, G5, G6, G7, G8, or G9; Table 2-1). Tables 2-2 (nearfield stations) and 2-3 (farfield stations) provide the station name and type, and give the analysis group that represents the analyses performed at each depth. Station N16 is considered both a nearfield station (where it is designated as type A) and a farfield station (where it is designated as type D+P+R).

2.3 Operations Summary

Changes in the 1996 sampling schema from prior monitoring years included the reduction of the number of nearfield stations sampled, and a change of analyses at selected stations. During 1996, nearfield stations N02, N03, N08 and N09 were not sampled. At all type D stations, POC and PON analyses were expanded to include the bottom depth. Field operations for water column sampling and analysis during the first semi-annual period were conducted as described above, with the exceptions detailed below.

2.3.1 Deviations in Scope

Principal deviations from the CW/QAPP plan for each survey and the sampling schema are described below. For additional information about a specific survey, the individual survey reports may be consulted.

Deviations from the CW/QAPP for the nearfield/farfield survey in early February (W9601):

- Stations F22 and F26 were sampled according to an F sampling scheme (DO samples were collected) instead of an E sampling scheme. This was done because of suspicion about the accuracy of the dissolved oxygen sensor due to extremely cold working conditions.

- At Station F29, fluorometer sensor readings were abnormally low for most of the downcast. The reason for this occurrence was not determined, and a recast of the station was not performed due to time limitation.

- At Stations F30 and F07, the CTD pump was blocked, and the data collected for the downcast profile were not valid. Water samples were collected anyway, and these stations were recast to collect accurate profile data as time allowed.

Deviations from the CW/QAPP for the nearfield/farfield survey in late February/early March (W9602):

- The DOC sample for Station N16 was not sealed properly and over 90 percent of the sample was lost. The remainder was shipped to the lab with an explanatory note.

Deviations from the CW/QAPP for the nearfield survey in late March (W9603):

- At Station N04 the mid-depth particulate phosphate sample was lost.

- WHOI replaced E3I as the laboratory for DO analysis. An inter-laboratory calibration had been conducted as part of an internal Quality Assurance (QA) procedure.

Deviations from the CW/QAPP for the nearfield/farfield survey in early April (W9604):

- Because of technical difficulties, two casts were performed at Station F22. The bottom, mid-bottom, and middle depths were collected during one cast, and the mid-surface and surface depths during another.

- Due to processing problems, sensor data for the surface sample at Station N15 are not available.

Deviations from the CW/QAPP for the late April nearfield survey (W9605):

- No DOC results are available because the samples were discarded by the analytical laboratory before analysis.

- WHOI replaced E3I as the laboratory for chlorophyll *a* and phaeophytin analysis and UNH replaced E3I as the laboratory for TSS and DOC analyses. An inter-laboratory calibration was conducted as part of an internal QA procedure.

- No zooplankton results are available because the sample containers leaked during transport to the laboratory.

Deviations from the CW/QAPP for the nearfield survey in mid-May (W9606):

- At Stations N07 and N16, TSS samples were not collected at bottom depths.

Deviations from the CW/QAPP for the nearfield/farfield survey in late June (W9607):

- Due to technical difficulties with on-board power use, the CTD experienced power fluctuations that resulted in invalid data during parts of the casts. Subsequent processing was able to remove the invalid data and compensate for the loss by averaging the remaining data. This problem affected subsequent surveys W9608 and W9609 before resolution.

- At Station N10, the DO sample for the mid-bottom depth was collected during the water quality cast while all other dissolved oxygen samples were collected during the productivity and respiration cast.

- At Station N16, the underwater irradiance data were not valid as the instrument cover was left on.

Deviations from the CW/QAPP for the nearfield survey in early July (W9608):

- Due to technical difficulties, the Niskin bottles were not fired at the correct depth and labels produced for samples were incorrect. Subsequent processing on deck corrected this problem.

Deviations from the CW/QAPP for the nearfield survey in mid-July (W9609):

- At Station N05, the underwater irradiance data were not valid as the instrument cover was left on.

TABLE 2-1

Water Column Sample Analyses

Analysis	Analysis Group										
	G1	G2	G3	G4	G5	G6	G7	G8	G9	P	R
Dissolved Inorganic Nutrients	X	X	X	X	X	X	X	X			
Dissolved Organic Carbon	X	X	X								
Total Dissolved N & P	X	X	X								
Particulate C & N	X	X	X								
Particulate P	X	X	X								
Biogenic Silica	X	X	X								
Chlorophyll & Phaeopigments	X	X	X	X	X	X			X		
Total Suspended Solids	X	X	X	X					X		
Dissolved Oxygen	X	X	X	X	X		X		X		
Urea	X	X									
All Phytoplankton	X	X									
Screened Phytoplankton	X	X									
Zooplankton	X										
Areal Productivity										X	
Respiration											X

TABLE 2-2

Analysis Group for Each Nearfield Station and Depth

Station Name	N01	N04	N05	N06	N07	N10	N11	N12	N13	N14	N15	N16	N17	N18	N19	N20	N21
Station Type	A	D+P+R	E	E	A	D+P+R	E	E	E	E	E	A	E	E	E	A	E
Nearfield Stations																	
Surface	G3	G1+P+R	G8	G8	G3	G1+P+R	G8	G8	G8	G8	G8	G3	G8	G8	G8	G3	G8
Mid-surface	G6	G6+P	G8	G8	G6	G6+P	G8	G8	G8	G8	G8	G6	G8	G8	G8	G6	G8
Middle	G3	G2+P+R	G8	G8	G3	G2+P+R	G8	G8	G8	G8	G8	G3	G8	G8	G8	G3	G8
Mid-bottom	G5	G5+P	G8	G8	G5	G5+P	G8	G8	G8	G8	G8	G5	G8	G8	G8	G5	G8
Bottom	G4	G3+P+R	G8	G8	G4	G3+P+R	G8	G8	G8	G8	G8	G4	G8	G8	G8	G4	G8

TABLE 2-3

Analysis Group for Each Farfield Station and Depth

Station Name[1]	F01	F02	F03	F05	F06	F07	F10	F12	F13	F14	F15	F16	F17	F18	F19	F22	F23	F24	F25	F26
Station Type	D	D	E	E	D	E	E	F	D	E	E	E	E	E	F+R	E	D+P+R	D	D	E
Farfield Stations																				
Surface	G1	G1	G8	G8	G1	G8	G8	G7	G1	G8	G8	G8	G8	G8	G7+R	G8	G1+P+R	G1	G1	G8
Mid-surface	G6	G6	G8	G8	G6	G8	G8	G8	G6	G8	G8	G8	G8	G8	G8	G8	G6+P	G6	G6	G8
Mid-depth	G2	G2	G8	G8	G2	G8	G8	G7	G2	G8	G8	G8	G8	G8	G7+R	G8	G2+P+R	G2	G2	G8
Mid-bottom	G5	G5	G8	G8	G5	G8	G8	G7	G5	G8	G8	G8	G8	G8	G7	G8	G5+P	G5	G5	G8
Bottom	G3	G3	G8	G8	G3	G8	G8	G7	G3	G8	G8	G8	G8	G8	G7+R	G8	G3+P+R	G3	G3	G8

Station Name	F27	F28	F29	F30	F31	N16
Station Type	D	E	F	G	G	D+P+R
Surface	G1	G8	G7	G1	G1	G1+P+R
Mid-surface	G6	G8	G8	G0	G0	G6+P
Mid-depth	G2	G8	G7	G2	G2	G2+P+R
Mid-bottom	G5	G8	G7	G0	G0	G5+P
Bottom	G3	G8	G7	G4	G4	G3+P+R

[1] Stations F04, F08, F09, F11, F20 and F21 have been replaced by or changed to stations F27, F28, F29, F30, F31 and N16.

3.0 DATA SUMMARY PRESENTATION

Data from each survey were compiled from the complete HOM Program 1996 database and organized to facilitate regional comparisons between surveys, and to allow a quick evaluation of results for contingency planning purposes (Tables 3-1 through 3-9). Each table provides summary data from one survey; the survey dates are provided at the top of each table. A discussion of which parameters were selected, how the data were grouped and integrated, and the assumptions behind the calculation of statistical values (average, minimum, and maximum), are provided below. All raw data summarized in this report are available from MWRA either in hard copy or electronic form.

The spatial pattern of data summary follows the sample design over major geographic areas of interest in Massachusetts Bay, Cape Cod Bay, and Boston Harbor (Section 3.1). Compilation of data both horizontally by region and vertically over the entire water column was conducted in order to provide an efficient way of assessing the status of the regions during a particular survey. Maximum and minimum values are provided because of the need to assess extremes of pre-outfall conditions relative to criteria being developed for contingency planning purposes (MWRA, 1997).

Regional compilations of nutrient and biological water column data were conducted first by averaging individual laboratory replicates, followed by field duplicates, and then by station visit. Prior to regional compilation of the sensor data, the results were averaged by station visit. Significant figures for average values were selected based on the precision of the specific dataset. Detailed considerations for individual datasets are provided in the sections below.

3.1 Defined Geographic Areas

The primary partitioning of data is between the nearfield and farfield stations (Figures 1-1 and 1-2). Farfield data were additionally segmented into five geographic areas: three stations in Boston Harbor (F23, F30, and F31), six coastal stations (F05, F13, F14, F18, F24, F25), eight offshore stations (F06, F07, F10, F15, F16, F17, F19, and F22), five boundary region stations (F12, F26, F27, F28, F29), and three Cape Cod Bay stations (F01, F02, and F03). These regions are shown in Figure 1-2.

The data summary tables include data that are derived from all of the station data collected in each region. Average, maximum, and minimum values are reported from the cumulative horizontal and vertical dataset as described for each data type below.

3.2 Sensor Data

Six CTD profile parameters provided in the data summary tables include: temperature, salinity, density (σ_t), fluorescence (chlorophyll *a*), transmissivity, and dissolved oxygen (DO) concentration. Statistical parameters (maximum, minimum, and average) were calculated from the five upcast sensor readings collected at five depths through the water column (defined as A-E). The five depth values, rather than the entire set of profile data, were selected in order to reduce the statistical weighting of deep water data at the offshore and boundary stations. Generally, the samples were collected in an even depth-distributed pattern. One of the mid-depth samples (B, C, or D) was typically located at the fluorescence (chlorophyll) peak in the water column, depending on the relative depth of the chlorophyll maximum. Details of the collection, calibration, and processing of CTD data are available in the Water Column Monitoring CW/QAPP (Bowen *et al.*, 1997), and are summarized in Section 2.

Following standard oceanographic practice, patterns of variability in water density will be described using the derived parameter σ_t, which is calculated by substracting 1,000 kg/m^3 from the recorded density. During this semi-annual period, density varied from 1,021.6 kg/m^3 to 1,025.9 kg/m^3, meaning σ_t varied from 21.6 kg/m^3 to 25.9 kg/m^3.

Fluorescence data were calibrated to the amount of chlorophyll *a* in discrete water samples collected at the depth of the sensor reading for a subset of the stations (see CW/QAPP or Tables 2-1, 2-2, 2-3). The calibrated chlorophyll sensor values were used for all discussions of chlorophyll in this report. The concentration of phaeopigments, included in the summary data tables as part of the nutrient parameters, also was included as part of the summary results.

In addition to DO concentration, the derived percent saturation was also provided. Percent saturation was calculated prior to averaging station visits from the potential saturation value of the water (a function of the physical properties of the water) and the calibrated DO concentration (see CW/QAPP). Finally, the derived beam attenuation coefficient from the transmissometer ("transmissivity") was provided on the summary tables. Beam attenuation is calculated from the ratio of light transmission relative to the initial light incidence, over a particular distance in the water column, and is provided in units of m^{-1}.

3.3 Nutrients

Analytical results for nutrient concentrations were extracted from the HOM database, and include: ammonia (NH_4), nitrite (NO_2), nitrite + nitrate (NO_2 + NO_3), phosphate (PO_4), and silicate (SiO_4). Nutrients were measured in water samples collected at each of the A-E depths during the CTD casts. Information on the collection, processing, and analysis of nutrient samples can be found in the CW/QAPP (Bowen *et al.*, 1997).

3.4 Biological Water Column Parameters

Three productivity parameters were selected for inclusion in the data summary tables. Areal production, which is determined by integrating the measured productivity over the photic zone, is included for the productivity stations (F23 representing the harbor, and N04, N10, and N16, representing the nearfield). Because areal production is already depth-integrated, averages were calculated only among productivity stations for the two regions sampled. The derived parameters α ($gC[gChla]^{-1}h^{-1}[\mu Em^{-2}s^{-1}]^{-1}$) and Pmax ($gC[gChla]^{-1}h^{-1}$) were also included (Appendix A).

A suite of other water column biological parameters was summarized on the data tables. Respiration rates were averaged over the respiration stations (the same harbor and nearfield stations as productivity, and additionally one offshore station [F19]), and over the three water column depths sampled (upper, mid-, and lower water column). The water column depths of the respiration samples typically coincided with the water depths of the productivity measurements.

Dissolved and particulate organic parameters were also summarized for the tables, including: biogenic silica (BIOSI), dissolved and particulate organic carbon (DOC and POC), particulate and total dissolved phosphate (PART P, TDP), particulate organic and total dissolved nitrogen (PON and TDN), and urea. Total suspended solids (TSS) data are provided as a baseline for total particulate matter in the water column. Dissolved and particulate constituents were measured from water samples collected from each of the five (A-E) depths during CTD casts. Detailed methods of sample collection, processing, and analysis are available in the CW/QAPP (Bowen *et al.*, 1997).

3.5 Plankton

Plankton results were extracted from the HOM database and include whole water phytoplankton, screened phytoplankton, and zooplankton. Phytoplankton measurements included whole-water collections at the surface (depth A) and at the water column chlorophyll *a* maximum (depth C) during the water column casts. Additional samples were taken at these two depths and screened through 20μm Nitex mesh to retain and concentrate larger dinoflagellate species. Zooplankton measurements were collected through oblique tows at all stations. Detailed methods of sample collection, processing, and analysis are available in the CW/QAPP (Bowen *et al.*, 1997).

Final plankton values were derived for each station by first averaging analytical replicates, then averaging station visits. Regional results were summarized for total phytoplankton, total centric diatoms, nuisance algae (*Alexandrium tamarense, Phaeocystis pouchetii*, and *Pseudo-nitzschia pungens*), and total zooplankton (Tables 3-1 through 3-9). Only the maximum of each plankton parameter is presented in the summary tables based on the program emphasis on the magnitude of plankton response to nutrient concentrations.

Results for total phytoplankton and centric diatoms reported in Tables 3-1 through 3-9 were restricted to whole water surface samples. Results for the nuisance species *Phaeocystis pouchetii* and *Pseudo-nitzschia pungens* include the maximum of both whole water and screened analyses, at both the surface and mid-depth. Although the size and shape of both taxa might allow them to pass through the Nitex screen, both have colonial forms which in low densities might be overlooked in the whole-water samples. For *Alexandrium tamarense*, only the screened samples were reported.

3.6 Additional Data

Three additional data sources were utilized during interpretation of HOM Program semi-annual water column data. Satellite images collected near survey dates were preliminarily interpreted for evidence of surface water events, including intrusions of surface water masses from the Gulf of Maine and upwelling. Continuous monitoring data, collected from a mooring located between nearfield stations N21 and N18 (Figure 1-1), were provided by the USGS. Hourly temperature and salinity (Figure 3-1) data from the surface (upper 5 m) and near-bottom (1m above bottom) were averaged over each day, and plotted with HOM survey data from station N16. Discrete data from N16 were selected from water depths that were most consistent with the depths of mooring data, and plotted with the continuous data for comparison. Finally, major meteorological events that occurred over the year, including hurricanes, northeasters, and records of precipitation, were investigated and used for additional data interpretation.

TABLE 3-1
Semi-Annual Data Summary Table
Event W9601 (2/05/96 - 2/10/96)
Combined Nearfield/Farfield Survey

		Nearfield			Farfield														
Region					Harbor			Coastal			Offshore			Boundary			Cape Cod Bay		
Parameter	Unit	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
Physical																			
Chlorophyll a	µg/L	0.29	5.00	2.21	0.90	1.54	1.16	0.63	2.46	1.57	0.62	3.50	1.52	0.00	3.78	1.54	0.58	13.36	4.71
Salinity	psu	30.7	32.4	31.7	29.9	31.2	30.6	30.8	31.8	31.3	31.4	32.5	32.0	31.3	32.7	32.2	31.5	31.8	31.7
Sigma_T	kg/m^3	24.6	25.7	25.3	24.0	25.0	24.5	24.7	25.4	25.1	25.1	25.8	25.5	25.0	25.9	25.6	25.3	25.4	25.3
Temperature	°C	0.9	3.8	2.4	0.5	1.5	0.9	0.8	2.5	1.4	1.6	4.2	2.7	1.9	4.5	3.1	0.9	1.9	1.2
Transmissivity	m-1	0.33	1.04	0.88	0.46	1.92	1.22	0.70	1.17	0.93	0.75	1.42	0.87	0.77	2.52	0.93	1.10	2.17	1.58
Nutrients																			
NH_4	µM	0.18	3.62	0.63	3.55	17.14	6.16	0.50	5.70	2.05	0.09	0.79	0.27	0.04	0.43	0.21	0.06	2.68	1.66
NO_2	µM	0.11	0.23	0.14	0.23	0.46	0.31	0.11	0.27	0.19	0.10	0.18	0.15	0.06	0.12	0.10	0.01	0.25	0.18
$NO_2 + NO_3$	µM	7.4	11.0	9.7	11.5	14.9	12.6	10.2	11.8	10.9	7.4	10.9	10.2	7.6	10.6	9.5	0.4	12.0	8.0
PO_4	µM	0.75	1.12	0.95	1.04	1.64	1.14	0.92	1.15	0.99	0.74	1.08	0.96	0.84	1.01	0.93	0.26	1.12	0.82
SIO_4	µM	11.3	16.4	13.9	17.2	23.9	19.4	14.4	18.1	15.8	11.7	15.1	14.0	8.3	14.5	11.8	1.2	16.0	10.6
Phaeopigment	µg/L	-0.06	1.65	0.61	0.02	0.96	0.44	0.45	0.76	0.61	0.04	0.67	0.47	0.31	0.76	0.50	0.37	4.80	2.28
DO																			
Concentration	mg/l	9.7	11.3	10.6	10.6	10.9	10.8	10.0	10.9	10.7	9.7	11.3	10.4	9.6	10.9	10.2	10.5	11.6	11.0
Saturation	%	91%	98%	96%	93%	93%	93%	91%	94%	94%	92%	100%	95%	92%	97%	94%	93%	101%	96%
Productivity																			
Alpha	see text	0.03	0.23	0.11	0.03	0.04	0.04												
Areal Production	mgC/m^2/d	369.4	1293.6	903.5	215.9	215.9	215.9												
Pmax	see text	4.6	26.5	14.2	4.1	6.1	4.8												
Respiration	µmol/h	0.02	0.07	0.05	0.08	0.10	0.08				0.03	0.04	0.04						
Water Column																			
BIOSI	µM	1.3	3.8	2.7	1.5	2.8	2.0	1.5	2.1	1.8	1.9	2.0	2.0	1.4	2.3	1.9	2.1	11.2	6.5
DOC	mg/L	0.9	1.4	1.1	1.1	1.8	1.3	0.5	1.3	1.0	0.8	1.0	0.9	0.6	0.9	0.7	0.7	1.2	0.9
PART P	µM	0.11	0.33	0.24	0.27	0.68	0.45	0.20	0.40	0.27	0.17	0.20	0.18	0.13	0.23	0.17	0.17	0.70	0.44
POC	µM	6.3	25.4	16.7	17.4	46.4	26.6	11.2	25.9	16.5	9.8	20.6	12.2	6.3	15.9	10.8	15.2	62.9	33.9
PON	µM	0.73	3.73	2.50	1.92	4.84	3.50	1.01	3.95	1.94	1.10	3.48	1.81	0.88	1.74	1.22	1.95	11.23	5.74
TDN	µM	12.2	23.2	18.3	19.4	42.4	26.6	17.7	30.4	21.5	12.3	16.6	14.1	12.6	14.4	13.4	7.0	25.3	15.4
TDP	µM	0.82	1.18	0.97	1.13	1.88	1.32	0.95	1.32	1.11	0.94	1.02	0.98	0.92	1.16	1.01	0.36	1.34	0.80
TSS	mg/L	0.4	2.4	1.5	0.8	3.0	1.9	0.3	2.0	1.3	0.1	0.1	0.1	0.1	0.9	0.5	0.9	4.0	2.3
Urea	µM	0.08	0.53	0.22	0.43	0.99	0.76	0.33	0.78	0.52	0.12	0.91	0.52	0.10	0.20	0.15	0.10	0.58	0.34
Plankton																			
Total Phytoplankton	Mcell/L		0.70			1.15			0.93			0.89			0.85			3.38	
Centric diatoms	Mcell/L		0.26			0.11			0.11			0.09			0.26			1.91	
Alexandrium tamarense	Mcell/L		NP			NP			NP			NP			NP			NP	
Phaeocystis pouchetii	Mcell/L		2.00E-03			1.00E-03			1.00E-03			NP			1.00E-03			NP	
Pseudo-nitzschia sp	Mcell/L		6.00E-03			2.00E-03			6.00E-03			4.00E-03			5.00E-03			6.00E-03	
Total Zooplankton	#/m^3		8238			3088			2843			2778			3138			6858	

NP - Not Present

TABLE 3-2
Semi-Annual Data Summary Table
Event W9602 (2/23/96 - 2/28/96)
Combined Nearfield/Farfield Survey

		Nearfield			Farfield														
Region					Harbor			Coastal			Offshore			Boundary			Cape Cod Bay		
Parameter	Unit	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
Physical																			
Chlorophyll a	μg/L	1.43	10.54	4.29	1.56	2.76	2.37	1.83	4.52	3.11	0.98	9.04	4.89	0.20	11.24	4.06	2.68	11.72	7.74
Salinity	psu	31.5	32.0	31.7	29.2	30.9	30.5	31.0	31.8	31.5	31.4	32.3	31.8	31.2	32.5	32.0	31.4	31.9	31.6
Sigma_T	kg/m^3	25.1	25.5	25.3	23.4	24.7	24.4	24.8	25.4	25.2	25.0	25.7	25.3	24.9	25.8	25.5	25.0	25.5	25.2
Temperature	°C	2.0	2.8	2.3	1.9	2.2	2.0	1.9	2.3	2.1	1.7	3.4	2.5	1.8	3.9	2.9	1.2	2.7	2.0
Transmissivity	m-1	0.33	1.08	0.88	0.66	1.87	1.45	0.89	1.08	1.01	0.75	1.47	0.92	0.66	1.09	0.86	1.06	1.54	1.28
Nutrients																			
NH_4	μM	0.31	1.58	0.70	3.92	6.22	5.09	0.69	3.43	1.57	0.42	1.54	0.70	0.27	0.87	0.56	0.39	2.11	0.85
NO_2	μM	0.11	0.19	0.14	0.27	0.37	0.30	0.12	0.24	0.17	0.09	0.17	0.12	0.03	0.18	0.12	0.04	0.18	0.14
$NO_2 + NO_3$	μM	1.9	8.0	4.9	7.7	11.3	8.6	5.5	7.3	6.3	2.1	9.5	4.9	0.4	10.3	5.7	0.3	6.8	3.5
PO_4	μM	0.37	0.83	0.56	0.77	0.87	0.81	0.61	0.75	0.66	0.37	0.96	0.57	0.24	1.02	0.63	0.21	0.79	0.45
SIO_4	μM	4.6	12.2	7.2	10.5	18.6	12.8	7.4	9.5	8.5	4.5	14.7	7.3	3.2	14.9	8.0	1.4	8.7	4.7
Phaeopigment	μg/L	0.02	11.58	4.49	0.16	1.68	1.12	1.14	6.30	2.53	6.02	11.89	8.19	1.00	8.37	3.31	2.64	8.89	4.90
DO																			
Concentration	mg/l	10.3	12.4	11.3	11.1	11.2	11.1	11.0	11.4	11.2	10.1	12.2	11.3	9.6	12.6	10.9	10.9	13.1	11.8
Saturation	%	95%	111%	102%	99%	99%	99%	100%	102%	101%	94%	108%	102%	91%	112%	100%	99%	115%	106%
Productivity																			
Alpha	see text	0.14	0.25	0.18	0.09	0.12	0.11												
Areal Production	mgC/m^2/d	2171.1	3053.8	2725.2	967.0	967.0	967.0												
Pmax	see text	18.5	29.9	23.8	14.4	17.4	15.1												
Respiration	μmol/h	0.04	0.09	0.06	0.09	0.10	0.10				0.04	0.09	0.06						
Water Column																			
BIOSI	μM	3.0	5.4	4.0	2.5	4.8	3.5	2.5	4.4	3.6	5.0	5.6	5.3	1.2	6.2	3.0	7.0	7.7	7.3
DOC	mg/L	0.1	11.0	1.6	0.6	1.4	1.1	0.9	1.2	1.1	1.0	1.1	1.0	0.9	1.1	1.0	0.7	1.2	1.0
PART P	μM	0.17	0.39	0.28	0.41	0.58	0.49	0.26	0.34	0.30	0.24	0.37	0.31	0.06	0.47	0.21	0.38	0.55	0.46
POC	μM	13.7	36.9	24.6	30.0	43.5	35.4	21.2	30.0	25.4	20.3	34.6	25.3	7.1	37.7	17.9	23.8	46.4	36.6
PON	μM	1.17	5.40	3.62	3.50	5.50	4.58	3.10	4.48	3.69	2.95	5.63	4.24	0.78	4.62	2.12	3.59	7.12	5.24
TDN	μM	8.6	21.7	14.0	21.4	38.0	27.6	11.8	27.1	17.5	7.9	18.2	12.0	12.5	22.4	17.3	8.1	17.2	13.8
TDP	μM	0.54	1.06	0.74	0.95	1.16	1.09	0.63	1.03	0.82	0.54	0.67	0.62	0.41	0.82	0.68	0.40	0.86	0.62
TSS	mg/L	0.6	2.1	1.4	1.5	3.0	2.1	0.3	1.4	1.1	2.1	3.3	2.7	1.0	3.4	2.0	2.8	5.1	3.8
Urea	μM	0.02	0.63	0.30	0.64	1.06	0.86	0.06	0.76	0.39	0.09	0.09	0.09	0.41	0.41	0.41	0.03	0.42	0.16
Plankton																			
Total Phytoplankton	Mcell/L		0.87			1.14			0.98			1.20			0.34			2.32	
Centric diatoms	Mcell/L		0.52			0.36			0.46			0.86			0.17			1.31	
Alexandrium tamarense	Mcell/L		NP			NP			NP			NP			NP			NP	
Phaeocystis pouchetti	Mcell/L		5.70E-02			1.10E-02			1.00E-03			6.00E-03			3.36E-04			4.70E-02	
Pseudo-nitzschia sp	Mcell/L		2.00E-03			1.20E-02			3.00E-03			3.00E-03			NP			1.10E-02	
Total Zooplankton	#/m^3		19185			6880			8500			23905			6147			10762	

NP - Not Present

TABLE 3-3
Semi-Annual Data Summary Table
Event W9603 (3/18/96 - 3/21/96)
Nearfield Survey

		Nearfield		
Region				
Parameter	Unit	Min	Max	Avg
Physical				
Chlorophyll a	μg/L	0.00	9.75	3.60
Salinity	psu	31.0	31.8	31.6
Sigma_T	kg/m^3	24.7	25.4	25.2
Temperature	°C	2.2	2.8	2.4
Transmissivity	m-1	0.40	4.25	0.86
Nutrients				
NH_4	μM	0.25	2.13	0.67
NO_2	μM	0.01	0.09	0.04
$NO_2 + NO_3$	μM	0.0	3.4	0.7
PO_4	μM	0.16	0.68	0.32
SIO_4	μM	0.0	2.7	0.6
Phaeopigment	μg/L	0.02	5.36	1.63
DO				
Concentration	mg/l	10.4	12.9	11.9
Saturation	%	95%	116%	107%
Productivity				
Alpha	see text	0.06	0.30	0.17
Areal Production	mgC/m^2/d	1508.6	2771.3	2139.9
Pmax	see text	5.2	39.2	19.1
Respiration	μmol/h	0.06	0.12	0.08
Water Column				
BIOSI	μM	0.8	3.8	2.0
DOC	mg/L	0.9	1.4	1.1
PART P	μM	0.15	0.54	0.26
POC	μM	13.9	48.4	27.3
PON	μM	1.82	7.89	4.12
TDN	μM	1.2	18.3	7.9
TDP	μM	0.10	6.31	0.68
TSS	mg/L	1.0	5.6	2.3
Urea	μM	0.22	1.37	0.59
Plankton				
Total Phytoplankton	Mcell/L		2.23	
Centric diatoms	Mcell/L		1.67	
Alexandrium tamarense	Mcell/L		NP	
Phaeocystis pouchetii	Mcell/L		0.002	
Pseudo-nitzschia sp	Mcell/L		2.00E-03	
Total Zooplankton	#/m^3		13203	

NP - Not Present

TABLE 3-4
Semi-Annual Data Summary Table
Event W9604 (4/01/96 - 4/06/96)
Combined Nearfield/Farfield Survey

		Nearfield			Farfield														
Region					Harbor			Coastal			Offshore			Boundary			Cape Cod Bay		
Parameter	Unit	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
Physical																			
Chlorophyll a	µg/L	0.00	5.78	0.31	1.35	11.94	5.77	0.06	8.42	2.77	0.00	0.75	0.12	0.00	2.19	0.37	0.05	1.25	0.36
Salinity	psu	30.6	31.9	31.4	29.5	31.1	30.4	30.3	31.5	31.1	30.9	32.0	31.5	29.9	32.1	31.6	31.3	31.4	31.3
Sigma_T	kg/m^3	24.2	25.4	25.0	23.4	24.7	24.1	24.0	25.1	24.7	24.5	25.5	25.1	23.7	25.5	25.2	24.8	25.0	24.9
Temperature	°C	2.4	4.4	3.5	3.9	5.2	4.4	3.2	4.7	3.9	2.2	3.8	3.2	2.5	4.1	3.3	3.5	3.8	3.7
Transmissivity	m-1	0.48	1.45	0.59	0.38	2.46	1.58	0.57	1.85	1.01	0.47	1.59	0.58	0.50	1.04	0.62	0.67	0.98	0.81
Nutrients																			
NH$_4$	µM	0.33	3.88	1.22	0.62	3.75	2.61	0.15	2.60	1.07	0.30	3.52	1.46	0.25	3.02	1.43	0.59	1.50	0.89
NO$_2$	µM	0.02	0.14	0.07	0.06	0.12	0.10	0.03	0.10	0.07	0.01	0.15	0.07	0.03	0.12	0.07	0.05	0.08	0.06
NO$_2$ + NO$_3$	µM	0.0	3.5	0.6	0.1	0.4	0.3	0.0	0.9	0.2	0.0	3.8	1.0	0.1	3.4	1.0	0.1	0.4	0.2
PO$_4$	µM	0.16	0.78	0.31	0.14	0.46	0.28	0.13	0.39	0.23	0.12	0.78	0.38	0.06	0.63	0.39	0.23	0.39	0.29
SIO$_4$	µM	0.3	3.8	1.2	0.6	1.6	1.1	0.2	2.5	0.8	0.3	4.2	1.2	0.5	2.9	1.4	0.4	2.7	1.2
Phaeopigment	µg/L	0.00	2.74	0.29	0.02	5.32	2.33	0.25	3.46	1.80	0.07	0.16	0.11	0.62	1.03	0.84	0.10	0.31	0.19
DO																			
Concentration	mg/l	9.3	11.2	10.7	10.9	12.0	11.4	10.4	11.8	11.2	9.5	11.2	10.7	10.1	11.3	10.8	10.4	11.0	10.8
Saturation	%	88%	102%	100%	105%	113%	107%	99%	108%	105%	89%	101%	99%	94%	102%	100%	98%	102%	100%
Productivity																			
Alpha	see text	0.00	0.19	0.03	0.17	0.26	0.23												
Areal Production	mgC/m^2/d	72.5	1332.6	513.2	2536.1	2536.1	2536.1												
Pmax	see text	0.3	39.2	5.7	26.6	35.2	31.8												
Respiration	µmol/h	0.02	0.15	0.07	0.06	0.12	0.10				0.02	0.04	0.03						
Water Column																			
BIOSI	µM	0.3	3.0	1.0	1.1	7.5	4.7	0.8	4.8	2.3	0.3	0.4	0.3	1.0	2.3	1.6	0.9	1.5	1.2
DOC	mg/L	0.9	1.3	1.0	1.1	1.8	1.5	1.0	2.6	1.4	0.9	1.0	0.9	0.9	1.6	1.2	0.8	1.1	1.0
PART P	µM	0.10	0.55	0.17	0.34	0.87	0.65	0.16	0.66	0.38	0.08	0.10	0.09	0.14	0.23	0.19	0.09	0.23	0.15
POC	µM	8.5	54.5	21.5	32.4	109.9	59.8	10.1	77.7	37.0	7.2	65.9	20.6	10.0	14.1	12.0	10.1	57.8	24.5
PON	µM	0.84	8.75	2.99	3.50	14.97	8.07	1.72	11.21	5.70	0.88	7.59	2.88	1.50	2.02	1.82	1.40	6.88	3.64
TDN	µM	5.5	21.6	9.1	9.8	15.6	13.1	6.9	14.4	9.8	8.2	8.9	8.4	7.1	16.7	10.4	6.8	10.4	7.9
TDP	µM	0.22	0.83	0.39	0.26	0.56	0.42	0.21	0.54	0.38	0.31	0.38	0.35	0.34	0.59	0.45	0.41	0.52	0.47
TSS	mg/L	1.0	2.0	1.6	2.0	8.0	3.9	1.0	3.0	2.1	1.0	1.0	1.0	1.0	2.0	1.3	1.0	3.5	1.6
Urea	µM	0.14	0.39	0.24	0.14	0.35	0.25	0.14	0.38	0.23	0.24	0.67	0.46	0.10	0.33	0.21	0.10	0.43	0.21
Plankton																			
Total Phytoplankton	Mcell/L		2.81			6.27			2.82			0.25			1.00			2.82	
Centric diatoms	Mcell/L		1.89			5.13			2.42			0.01			0.28			0.03	
Alexandrium tamarense	Mcell/L		NP			NP			NP			NP			NP			NP	
Phaeocystis pouchetti	Mcell/L		1.00E-03			1.08E-04			1.00E-03			3.97E-05			1.79E-01			1.00E-03	
Pseudo-nitzschia sp	Mcell/L		3.50E-06			NP			2.00E-03			NP			5.00E-03			NP	
Total Zooplankton	#/m^3		24769			7612			11832			22377			41716			10608	

NP - Not Present

TABLE 3-5
Semi-Annual Data Summary Table
Event W9605 (4/22/96 - 4/25/96)
Nearfield Survey

Region		Nearfield		
Parameter	Unit	Min	Max	Avg
Physical				
Chlorophyll a	μg/L	0.04	6.89	1.65
Salinity	psu	30.3	31.7	31.1
Sigma_T	kg/m^3	23.8	25.2	24.6
Temperature	°C	3.5	7.3	5.1
Transmissivity	m-1	0.31	1.60	0.92
Nutrients				
NH_4	μM	0.27	2.18	1.15
NO_2	μM	0.05	0.17	0.10
$NO_2 + NO_3$	μM	0.1	1.4	0.7
PO_4	μM	0.09	0.51	0.31
SIO_4	μM	1.0	4.1	2.1
Phaeopigment	μg/L	0.02	2.51	0.35
DO				
Concentration	mg/l	9.9	11.1	10.4
Saturation	%	100%	103%	100%
Productivity				
Alpha	see text	0.06	0.30	0.17
Areal Production	mgC/m^2/d	619.9	5052.9	2836.4
Pmax	see text	5.2	39.2	19.1
Respiration	μmol/h	0.01	0.12	0.06
Water Column				
BIOSI	μM	0.5	3.2	1.4
DOC	mg/L			
PART P	μM	0.1	0.5	0.2
POC	μM	3.87	40.66	19.61
PON	μM	0.7	7.1	3.1
TDN	μM	6.03	17.18	10.62
TDP	μM	0.2	0.5	0.3
TSS	mg/L	1.30	4.30	2.63
Urea	μM	0.27	0.30	0.28
Plankton				
Total Phytoplankton	Mcell/L		3.33	
Centric diatoms	Mcell/L		2.44	
Alexandrium tamarense	Mcell/L		NP	
Phaeocystis pouchetii	Mcell/L		NP	
Pseudo-nitzschia sp	Mcell/L		NP	
Total Zooplankton	#/m^3		NA	

NP - Not Present
NA - Not Analyzed

TABLE 3-6
Semi-Annual Data Summary Table
Event W9606 (5/13/96 - 5/14/96)
Nearfield Survey

		Nearfield		
Region				
Parameter	Unit	Min	Max	Avg
Physical				
Chlorophyll a	µg/L	0.00	3.72	0.97
Salinity	psu	29.3	31.9	31.1
Sigma_T	kg/m^3	22.9	25.4	24.5
Temperature	°C	3.7	8.4	5.9
Transmissivity	m-1	0.28	0.92	0.68
Nutrients				
NH_4	µM	0.26	2.25	0.98
NO_2	µM	0.02	0.20	0.08
$NO_2 + NO_3$	µM	0.2	3.5	1.4
PO_4	µM	0.08	0.70	0.39
SIO_4	µM	1.1	7.5	3.3
Phaeopigment	µg/L	0.03	0.69	0.16
DO				
Concentration	mg/l	9.3	10.4	10.0
Saturation	%	96%	97%	98%
Productivity				
Alpha	see text	0.00	0.05	0.02
Areal Production	mgC/m^2/d	485.6	994.2	739.9
Pmax	see text	0.6	7.9	3.5
Respiration	µmol/h	0.03	0.11	0.07
Water Column				
BIOSI	µM	0.5	1.6	1.0
DOC	mg/L	0.6	1.1	0.9
PART P	µM	0.00	0.41	0.21
POC	µM	7.4	32.9	17.1
PON	µM	0.77	4.72	2.20
TDN	µM	7.5	12.9	10.0
TDP	µM	0.29	0.69	0.43
TSS	mg/L	0.0	2.9	0.8
Urea	µM	0.21	0.40	0.28
Plankton				
Total Phytoplankton	Mcell/L		0.79	
Centric diatoms	Mcell/L		0.18	
Alexandrium tamarense	Mcell/L		NP	
Phaeocystis pouchetii	Mcell/L		NP	
Pseudo-nitzschia sp	Mcell/L		NP	
Total Zooplankton	#/m^3		16834	

NP - Not Present

TABLE 3-7
Semi-Annual Data Summary Table
Event W9607 (6/17/96 - 6/20/96)
Combined Nearfield/Farfield Survey

		Nearfield			Farfield														
Region					Harbor			Coastal			Offshore			Boundary			Cape Cod Bay		
Parameter	Unit	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
Physical																			
Chlorophyll a	µg/L	0.00	5.62	1.19	0.04	6.27	3.28	0.00	3.11	1.13	0.00	2.63	0.39	0.00	2.68	0.55	0.26	4.22	1.39
Salinity	psu	29.9	31.8	30.9	30.1	30.9	30.3	30.1	31.5	30.7	29.8	32.1	31.3	29.9	32.2	31.5	30.6	31.7	31.1
Sigma_T	kg/m^3	21.8	25.2	23.6	22.1	23.8	22.5	22.0	24.8	23.3	21.6	25.5	24.3	21.9	25.5	24.5	21.7	25.0	23.6
Temperature	°C	5.2	16.7	10.2	9.8	15.7	14.4	6.0	16.3	11.3	4.0	16.6	8.1	4.0	16.4	7.6	5.1	19.1	10.8
Transmissivity	m-1	0.60	1.97	0.96	1.12	2.63	2.04	0.78	2.08	1.15	0.58	1.31	0.78	0.61	1.12	0.83	0.90	1.92	1.17
Nutrients																			
NH$_4$	µM	0.12	1.57	0.48	0.43	3.73	1.60	0.11	1.84	0.45	0.11	1.63	0.61	0.09	1.77	0.48	0.11	3.32	0.76
NO$_2$	µM	0.01	0.24	0.09	0.04	0.10	0.07	0.01	0.19	0.06	0.01	0.35	0.14	0.02	0.30	0.17	0.01	0.49	0.14
NO$_2$ + NO$_3$	µM	0.2	3.8	1.0	0.2	0.5	0.4	0.2	2.2	0.6	0.2	8.3	2.4	0.2	9.6	3.7	0.2	3.2	1.0
PO$_4$	µM	0.09	0.73	0.32	0.25	0.58	0.39	0.11	0.64	0.32	0.08	0.97	0.47	0.07	1.01	0.56	0.17	0.84	0.42
SIO$_4$	µM	0.6	6.5	2.8	1.0	2.6	1.5	0.5	5.8	2.4	0.6	13.1	4.7	0.7	13.0	5.7	1.0	13.2	5.1
Phaeopigment	µg/L	0.01	2.98	0.39	0.09	2.58	1.03	0.04	1.02	0.44	0.02	0.56	0.29	0.09	0.36	0.24	0.01	0.89	0.24
DO																			
Concentration	mg/l	9.1	11.2	10.1	9.1	10.2	9.8	9.1	10.5	9.9	8.9	11.6	9.9	8.7	11.5	9.5	8.1	10.4	9.2
Saturation	%	112%	109%	108%	110%	110%	115%	112%	103%	109%	109%	109%	102%	107%	109%	97%	106%	101%	100%
Productivity																			
Alpha	see text	0.00	0.20	0.06	0.26	0.33	0.30												
Areal Production	mgC/m^2/d	589.2	4454.6	1962.3	5203.5	5203.5	5203.5												
Pmax	see text	0.4	128.7	22.1	90.0	131.1	112.2												
Respiration	µmol/h	0.01	0.29	0.12	0.12	0.65	0.43				0.03	0.17	0.08						
Water Column																			
BIOSI	µM	0.3	3.7	1.6	2.8	4.3	3.7	0.5	2.7	1.8	0.6	1.7	1.0	0.2	2.9	1.2	0.4	4.5	1.6
DOC	mg/L	0.9	1.7	1.3	1.2	1.6	1.4	1.1	1.4	1.3	1.0	1.4	1.1	0.8	1.3	1.0	0.9	1.4	1.1
PART P	µM	0.09	0.44	0.23	0.45	0.81	0.68	0.18	0.67	0.34	0.04	0.26	0.16	0.09	0.13	0.10	0.05	0.28	0.18
POC	µM	7.2	41.5	20.3	25.7	77.9	47.5	13.2	46.0	29.3	7.4	35.2	16.1	4.9	17.8	12.6	17.3	31.9	21.9
PON	µM	0.89	6.94	2.99	3.61	11.20	7.34	1.95	7.18	4.37	0.97	5.58	2.23	0.63	2.45	1.38	1.98	3.68	2.65
TDN	µM	7.4	15.8	10.0	9.9	20.8	15.3	8.7	15.8	11.0	12.6	17.4	14.3	7.9	15.4	11.9	7.8	13.0	11.1
TDP	µM	0.22	0.81	0.42	0.60	0.89	0.72	0.33	0.77	0.51	0.25	0.68	0.44	0.12	0.97	0.63	0.28	0.84	0.58
TSS	mg/L	0.5	2.8	1.2	1.4	4.3	2.6	0.5	1.3	1.0	1.1	3.3	1.9	0.7	5.4	2.8	1.2	3.3	1.6
Urea	µM	0.08	0.83	0.41	0.62	0.85	0.72	0.37	2.17	0.83	0.07	0.21	0.14	0.12	0.54	0.33	0.16	0.59	0.30
Plankton																			
Total Phytoplankton	Mcell/L		1.25			2.79			3.63			0.93			0.51			0.69	
Centric diatoms	Mcell/L		0.06			0.86			2.56			0.01			0.002			0.02	
Alexandrium tamarense	Mcell/L		NP			NP			NP			NP			NP			NP	
Phaeocystis pouchetti	Mcell/L		NP			NP			NP			NP			NP			NP	
Pseudo-nitzschia sp	Mcell/L		NP			1.00E-03			4.71E-04			4.71E-04			6.00E-03			4.71E-04	
Total Zooplankton	#/m^3		115382			27375			111387			20066			31104			25112	

NP - Not Present

TABLE 3-8
Semi-Annual Data Summary Table
Event W9608 (7/01/96)
Nearfield Survey

		Nearfield		
Region				
Parameter	Unit	Min	Max	Avg
Physical				
Chlorophyll a	μg/L	0.00	2.32	0.65
Salinity	psu	30.3	31.9	31.0
Sigma_T	kg/m^3	21.9	25.2	23.6
Temperature	°C	5.3	17.1	10.9
Transmissivity	m-1	0.60	1.69	1.02
Nutrients				
NH_4	μM	0.24	2.47	0.86
NO_2	μM	0.01	0.33	0.12
$NO_2 + NO_3$	μM	0.1	4.1	1.2
PO_4	μM	0.11	0.79	0.40
SIO_4	μM	1.4	12.5	4.1
Phaeopigment	μg/L	0.01	0.71	0.19
DO				
Concentration	mg/l	6.8	10.7	9.5
Saturation	%	85%	104%	103%
Productivity				
Alpha	see text	0.02	0.09	0.05
Areal Production	mgC/m^2/d	1832.7	2610.4	2221.6
Pmax	see text	9.8	40.7	23.8
Respiration	μmol/h	0.01	0.25	0.14
Water Column				
BIOSI	μM	0.2	2.4	1.0
DOC	mg/L	1.1	1.5	1.3
PART P	μM	0.03	0.56	0.24
POC	μM	8.9	57.4	24.1
PON	μM	1.01	6.70	3.39
TDN	μM	7.2	16.1	10.4
TDP	μM	0.22	0.76	0.43
TSS	mg/L	0.4	2.2	1.2
Urea	μM	0.30	0.63	0.45
Plankton				
Total Phytoplankton	Mcell/L		2.58	
Centric diatoms	Mcell/L		0.93	
Alexandrium tamarense	Mcell/L		NP	
Phaeocystis pouchetii	Mcell/L		NP	
Pseudo-nitzschia sp	Mcell/L		1.00E-03	
Total Zooplankton	#/m^3		30579	

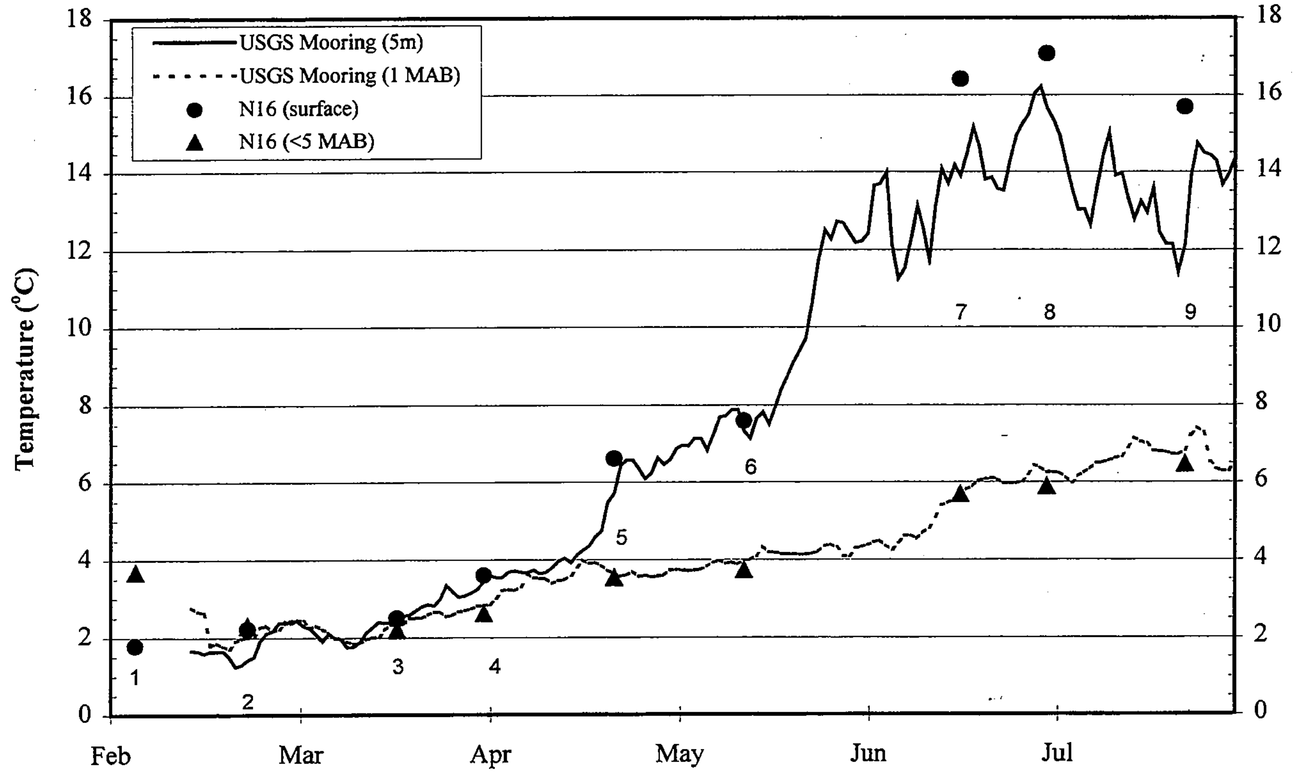
NP - Not Present

TABLE 3-9
Semi-Annual Data Summary Table
Event W9609 (7/24/96)
Nearfield Survey

		Nearfield		
Region				
Parameter	Unit	Min	Max	Avg
Physical				
Chlorophyll a	µg/L	0.00	3.14	0.64
Salinity	psu	30.6	32.0	31.3
Sigma_T	kg/m^3	22.4	25.2	23.9
Temperature	°C	5.4	16.4	10.5
Transmissivity	m-1	0.63	1.33	0.87
Nutrients				
NH_4	µM	0.01	1.81	0.62
NO_2	µM	0.01	0.39	0.15
$NO_2 + NO_3$	µM	0.1	8.2	1.3
PO_4	µM	0.13	1.02	0.47
SIO_4	µM	2.3	9.9	4.6
Phaeopigment	µg/L	0.05	0.74	0.33
DO				
Concentration	mg/l	8.4	10.1	9.2
Saturation	%	103%	99%	100%
Productivity				
Alpha	see text	0.02	0.06	0.03
Areal Production	mgC/m^2/d	1159.2	1516.7	1337.9
Pmax	see text	2.8	35.0	11.5
Respiration	µmol/h	0.06	0.15	0.10
Water Column				
BIOSI	µM	0.3	1.5	0.8
DOC	mg/L	0.6	1.7	1.2
PART P	µM	0.11	0.38	0.24
POC	µM	8.9	38.8	22.8
PON	µM	1.22	6.54	3.28
TDN	µM	6.9	29.7	12.0
TDP	µM	0.22	1.01	0.66
TSS	mg/L	0.4	1.8	1.0
Urea	µM	0.62	0.75	0.70
Plankton				
Total Phytoplankton	Mcell/L		0.96	
Centric diatoms	Mcell/L		0.02	
Alexandrium tamarense	Mcell/L		NP	
Phaeocystis pouchetii	Mcell/L		NP	
Pseudo-nitzschia sp	Mcell/L		NP	
Total Zooplankton	#/m^3		30575	

NP - Not Present

(a) Temperature



(b) Salinity

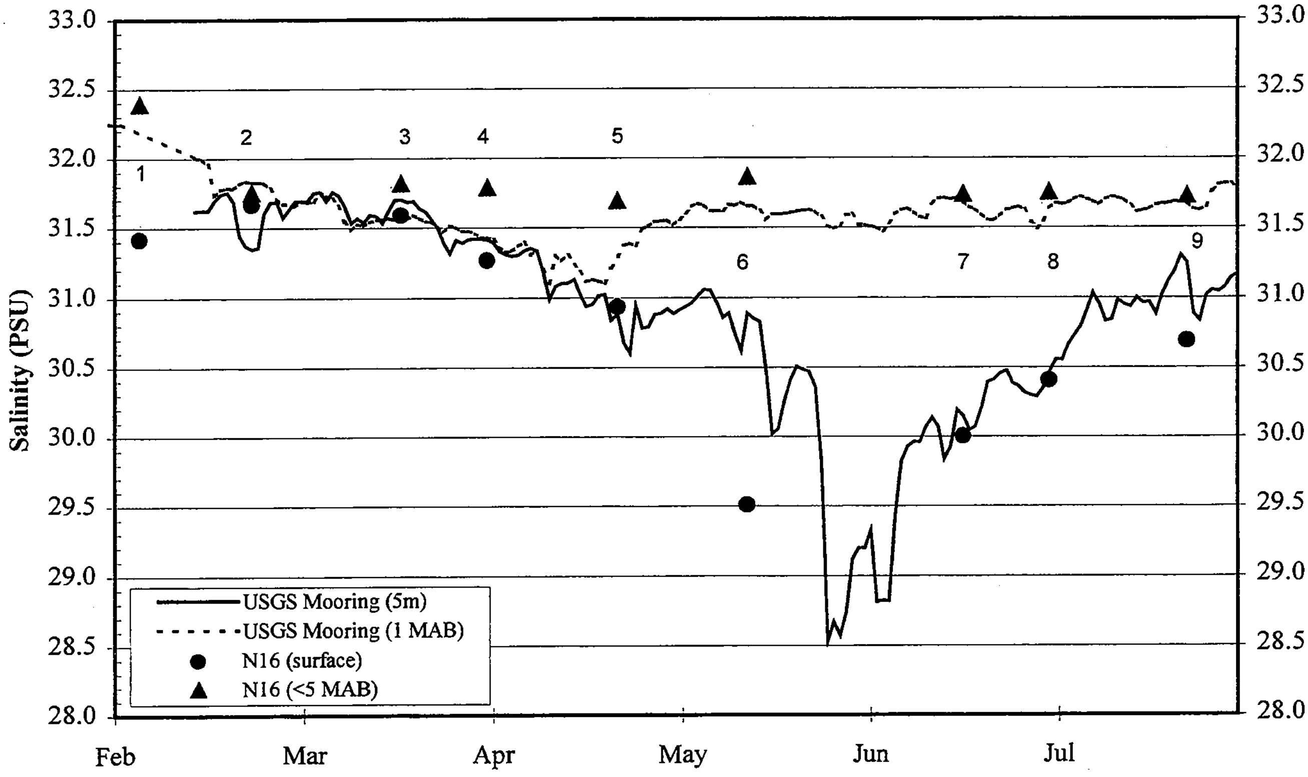


FIGURE 3-1

Moored Temperature and Salinity Sensor Data: February - July, 1996
(MAB = meters above bottom)

4.0 RESULTS OF WATER COLUMN MEASUREMENTS

The timing of the annual setup of vertical stratification in the water column is an important determinant of water quality, primarily because of the trend towards continuously decreasing dissolved oxygen in bottom water in the summer and early fall. The pycnocline, defined as a shallow water depth interval over which density increases rapidly, is caused by a combination of freshwater input during spring runoff, and warming of surface water in the summer. Above the pycnocline the surface water layer is well-mixed, and below the pycnocline density increases more gradually (Figure 4-1). For the purposes of this report, vertical stratification will be defined by the presence of a pycnocline with a density (σ_t) gradient over a relatively narrow depth range (~10 m) of greater than 1.0. Using this definition, a stable pycnocline developed by late April (W9605) in the inner nearfield and mid-May (W9606) in the outer nearfield (Figure 4-2).

Four of the nine surveys conducted during the semi-annual period were combined nearfield/farfield surveys. The first three combined surveys in February (W9601, W9602) and April (W9604) were conducted prior to stratification of the water column, and the last survey in June (W9607) was conducted during early stratification. Data collected during these farfield surveys were evaluated for trends in regional water masses throughout Boston Harbor, Massachusetts Bay, and Cape Cod Bay. The variation of regional surface water properties is presented using contour plots of surface water parameters, derived from the A (surface) water sample. Classifying data by regions allows comparison of the horizontal distribution of water mass properties over the farfield area.

The vertical distribution of water column parameters is presented in the following sections along three farfield transects in the survey area, and one transect across the nearfield (Figure 1-3). Examining data trends along transects provides a three-dimensional perspective of water column conditions during each survey. Nearfield surveys (W9601-W9609) were conducted more frequently than farfield surveys, allowing better temporal resolution of the changes in water column parameters and onset of stratification. In addition to one nearfield vertical transect (Figure 1-3), vertical variability in nearfield data is examined and presented by comparing surface and bottom water concentrations (A and E depths), and by plotting individual parameters with depth in the water column.

Data presented in this section were organized by the type of data. Physical data, including temperature, salinity, density, and beam attenuation are presented in Section 4.1. Nutrient data results are discussed in Section 4.2, chlorophyll *a* in Section 4.3, and dissolved oxygen in Section 4.4. Finally, a summary of the major results of water column measurements (excepting biological measurements) are provided in Section 4.5.

4.1 Physical Characteristics

4.1.1 Horizontal Distribution

During the first two regional winter farfield surveys in February (W9601-02), there was a horizontal gradient of surface water temperature and salinity from the inshore regions of the harbor, coast, and Cape Cod Bay, to the offshore/boundary regions. In early February (W9601), surface water temperatures ranged from 0.6°C at station F23 outside of the harbor, to 3.3°C at boundary station F12 (Figure 4-3). Surface water in the harbor was also the least saline (approximately 30 PSU), while the rest of Massachusetts and Cape Cod Bay surface water ranged between 31 and 32 PSU (Figure 4-4). In late February (W9602), regional surface water was more uniform, with warmer coastal water (approximately 2°C) and no change in the offshore/boundary regions. The distribution of surface water salinity was similar to that in early February. A complete set of surface contour maps of water properties during the farfield surveys is provided in Appendix B.

During the pre-stratification period, surface water temperatures and salinities generally were representative of the entire water column at each station due to the well-mixed water column, thus the regional water masses were identifiable from distinct TS (temperature-salinity) characteristics for each survey. During W9601 and W9602, for example, the offshore and boundary regions (only boundary station data are plotted) were distinct from coastal, Cape Cod Bay, and harbor water masses (Figure 4-5a). The boundary and offshore regions had the highest regional temperatures (approximately 3-5°C) and salinities (32-33 PSU). For the other water masses, water temperatures were in a similar range during the first two surveys (approximately 1-3°C), but the harbor stations had the lowest salinity. Station F23, at the entrance to Boston Harbor, had TS characteristics more similar to the coastal region during W9601. The coastal and Cape Cod Bay regions were in the same temperature range, but Cape Cod Bay was slightly more saline during the winter surveys. Stations at the northern end of the coastal transect (F18 and F24) had water mass characteristics that were transitional to the boundary/offshore regions.

By April (W9604), horizontal differences in surface water temperature were less pronounced, with a narrower temperature range (Figure 4-5b). Cape Cod Bay was noticeably warmer than during the prior two surveys, exhibiting a warming trend comparable to Boston Harbor and coastal waters. Coastal water had also warmed relative to the more offshore stations (Figure 4-6). The salinity gradient was consistent with the prior surveys, with fresher to more saline waters from the harbor to offshore, with an anomalous pool of low salinity water (<30 PSU) at the northern end of the boundary region (Station F26; Figure 4-7). This fresh water intrusion may be related to the spring freshet documented by continuous monitoring data, discussed in more detail using higher resolution nearfield data (Section 4.1.2). The freshet may have been a catalyst for the relatively early setup of vertical stratification in 1996, and may have resupplied the surface water of the nearfield region with nutrients (Section 4.2.2).

In contrast to the pre-stratification period, during the final farfield survey in June (W9607) horizontal gradients of water column properties were less defined, while distinctions among water masses were controlled by depth because of vertical stratification. Surface waters had warmed considerably, ranging from 13.3°C (F05) to 19.1°C in Cape Cod Bay (F02), and the salinity distribution was very narrow in surface waters (30.6 to 31.4 PSU; Appendix B).

4.1.2 Vertical Distribution

Farfield. Regionally, the water column was well-mixed throughout the winter and early spring. The density gradient ($\Delta\sigma_t$), representing the difference between the bottom and surface water σ_t value, can be used as a relative indicator of a mixed or vertically stratified water column (Figure 4-8). During the winter and early spring, a slight density gradient of ~0.5 kg/m^3, except in coastal and Cape Cod Bay regions, was reflective of slightly higher bottom water salinity in these regions. The temperature remained uniform in all regions during this period. Salinity data indicated that Boston Harbor surface water was the least saline over the semi-annual period (Figure 4-9). All water regions in the survey area were vertically stratified ($\Delta\sigma_t$ >1.0 kg/m^3) by June (W9607) except in the harbor, which remained relatively well-mixed throughout the semi-annual period and continued to be relatively productive (Section 4.3; Figure 4-8).

Transects from west to east (Figure 1-3) in Massachusetts Bay show the gradients of physical characteristics within the water column from Boston Harbor and coastal stations seaward (Appendix C). For example, σ_t during the first winter survey in early February (W9601) showed a gentle vertical and horizontal gradient, ranging from 24 kg/m^3 in the surface water inshore to greater than 25.5 kg/m^3 in deep water offshore (Figure 4-10). The water column was extremely homogenous during the second survey in late February, apparently due to mixing during several February northeasters. During the final farfield survey of the semi-annual period in June (W9607), the water column was vertically stratified except in the shallow water of the harbor (Figure 4-11). Density ranged from 22 kg/m^3 in the surface water, increasing to 25 kg/m^3 within the upper 20m offshore. A complete set of farfield transect plots for water properties is contained in Appendix C.

Nearfield. More frequent sampling of nearfield stations provides a detailed dataset showing the onset of vertical stratification, and local variability, within the nearfield water column. The onset of vertical stratification in the nearfield, defined by a $\Delta\sigma_t$ of >1.0 kg/m^3, occurred relatively early in 1996. By April (W9605), the inner nearfield was already stratified and remained stratified through the semi-annual period (Figure 4-2). The onset of stratification was evident in the outer nearfield by April, but $\Delta\sigma_t$ remained <1.0 kg/m^3 until May (W9606). The sequence of events associated with the setup of stratification is described below.

The winter density gradient between the surface and bottom water of the nearfield in early February (W9601; Figure 4-2) was caused by a layer of fresher (<31 PSU) cooler surface water, and relatively higher bottom water salinity (>32 PSU). In the nearfield, this layer originated from the harbor, as can be seen in the southwest-northeast nearfield transect (Figure 1-3) showing contoured salinity data (Figure 4-12). Two weeks after the first survey in late February (W9602), the water column was uniform with respect to both temperature and salinity, indicating that the water was mixed during that interval as a result of a series of February northeasters.

The water column was well-mixed with respect to temperature during the first four nearfield surveys (Figure 4-13), again except during the first survey in early February (W9601). The water column in the nearfield was progressively stratified as surface water started to warm in early April (W9604). Following the early April survey, surface water warmed 2°C within the upper 10-20 meters of the nearfield water column prior to the late April survey (W9605), resulting in the onset of thermal stratification along the nearfield transect (Figure 4-14). Continuous monitoring data from the USGS mooring in the nearfield show the seasonal surface water temperature increase began in earnest by the time of the late April survey W9605 (Figure 3-1). Surface water temperatures continued to increase, with a sharp rise associated with a heat wave during the latter part of May (NRCC, 1997). Bottom water temperatures rose relatively slowly throughout the semi-annual period (Figure 4-13).

Overall, the salinity in the nearfield decreased in both bottom and surface water during the late winter and early spring as a result of winter precipitation (Figure 3-2). Following the late April survey (W9605), nearfield bottom water salinity began to increase upon the initiation of stratification. Surface water salinity, however, began a steep decline between surveys W9606 and W9607 that persisted through May, reaching minimum values of <29 PSU by the end of May/beginning of June (Figure 3-2). The low salinity surface water was apparent only in the outer nearfield during the May survey (W9606; Figure 4-15). Satellite data confirmed an intrusion of a water mass from the Gulf of Maine in May. In addition, spring fluvial discharge was at a peak during mid-April through mid-May (Figure 4-16), suggesting that a freshet from the northeast was the cause of the low salinity intrusion on the outer nearfield surface water.

Results from the first early stratification survey in June (W9607) showed a strong density gradient ($\Delta\sigma_t$) of at least 2.0 kg/m^3 in both the inner and outer nearfield (Figure 4-2). The surface water temperature increased by 8°C between the May and June surveys, but then remained at approximately 16°C during the early July nearfield survey (W9608), and actually decreased by up to 2°C during the final semi-annual late July nearfield survey (W9609). The temperature decrease through July was well documented in the moored temperature data (Figure 3-1). The surface water temperature in the outer nearfield decreased from a high of approximately 16°C in the beginning of July, to approximately 12°C immediately prior to the final semi-annual survey in late July (W9609; Figure 3-1).

The anomalous surface water temperature decrease in July is probably related to several meteorological events recorded during the month of July. The year 1996 had the wettest month of July for a century (NRCC, 1997). An early season hurricane (Bertha) and a series of strong thunder storms had an impact on New England weather and were responsible for the precipitation record set in July. The input of colder, less saline surface water also affected surface readings.

4.1.3 Transmissometer Results

Water column beam attenuation was measured for each CTD cast at all nearfield and farfield stations. The transmissometer determines beam attenuation by measuring the percent transmission of light over a given path length in the water. Given that light transmission decays exponentially with beam attenuation and path length (which varies between instruments), the beam attenuation coefficient is computed over a standardized path length of 1 meter, signifying that the value is independent of light path length.

Secchi disk measurements, which provide an indicator of light transmission in the upper water column, are collected during farfield surveys only. Secchi disk measurements were compared with surface water transmissometer data for the 1996 monitoring year; results are presented in the second semi-annual report.

The beam attenuation coefficient is indicative of particulate concentration in the water column. The two possible sources of particles in coastal waters are biogenic material (plankton or organic detritus), or suspended sediment. To evaluate the contribution of biogenic material in the total particulate matter, beam attenuation was compared to fluorescence data (calibrated to chlorophyll *a*). Non-biogenic material may originate from suspended matter in coastal runoff or from resuspension of bottom sediment.

Surface water (A depth) transmissometer data from the combined nearfield/farfield surveys suggested that plankton growth and coastal runoff caused seasonal changes in beam attenuation. In February (surveys W9601-02), the beam attenuation values (range 0.3 - 0.9/m) indicated that the surface water at all farfield stations was relatively clear. Surface beam attenuation remained uniform across all regions outside of the harbor and eastern Cape Cod Bay (Figure 4-17). The attenuation documented in eastern Cape Cod Bay was likely due to a phytoplankton bloom occurring at the time (Sections 4.3 and 5.3).

The April survey (W9604) was marked by high water clarity in the offshore and boundary regions (<0.3/m; Figure 4-18). The harbor stations, however, showed increases in total particulate matter, likely associated with the harbor spring diatom bloom (Section 4.3). Spring river discharge and coastal runoff also may have contributed to the total particulate matter.

In June (W9607), the highest beam attenuation values were concentrated near the harbor and coastal regions. The Boston-Nearfield and Cohassett transects (Figure 4-19) revealed a beam attenuation gradient from near the coast to offshore. Fluorescence data also indicated high levels of chlorophyll *a* in this region (Section 4.3), suggesting that beam attenuation was influenced by the concentration of biogenic material. Suspended material in coastal runoff and harbor export also may have contributed to the high beam attenuation in the coastal region.

During the June survey (W9607), the bottom waters of stations F16, F17, and F19 showed local maxima of beam attenuation values (Figure 4-19). Deep water particulate matter may be a result of resuspension of bottom sediment, but the lack of physical mechanisms for deep water resuspension in the summer suggests that the particulate matter was from settling of material from the water column. Chlorophyll data are consistent with a deep water component of biogenic particulate matter in the boundary region (Section 4.3), potentially contributing to the bottom water beam attenuation data.

4.2 Nutrients

Regional and nearfield nutrient data from the first semi-annual period of 1996 demonstrate the typical progression of seasonal events in the Massachusetts Bay system. Maximum nutrient concentrations were measured throughout the water column during the well-mixed early winter surveys. The late winter bloom documented during the first two combined farfield/nearfield surveys (Section 4.3) resulted in regional depletion of nutrients by March (W9603) in the nearfield, and by the third combined survey in early April (W9604) in the farfield. Phosphate and ammonium remained at modest levels in the surface water of the harbor and near the coast, primarily due to the current outfall source in Boston Harbor. During the stratified season, bottom water nutrient concentrations begin to increase due to remineralization of nutrients from organic matter.

Nutrient data were preliminarily analyzed using x/y plots of nutrient relationships. In Appendix D, nutrient distributions are organized for each survey showing the following relationships for regional areas (Figure 1-2): nutrients vs. depth, nutrient:nutrient relationships, and nutrient:salinity relationships. As with the physical characteristics, surface water contour maps (Appendix B) and vertical cross sections (Appendix C) were also created using nutrient data.

4.2.1 Horizontal Distribution

During the pre-stratification period, the spatial distribution of nutrient concentrations in surface water indicated that Boston Harbor, followed by the coastal region, consistently had the highest concentration of all nutrients measured. As discussed below, during the pre-stratification period, depletion of surface water nutrient concentrations closely paralleled areas of chlorophyll production (Section 4.3). Regional surface water was nutrient-depleted beginning during the third combined nearfield/farfield survey in April (W9604), and remained depleted through to the early stratification survey in June (W9607).

Nutrient concentrations throughout regional surface waters during the first combined nearfield/farfield survey in early February were the highest measured in the semi-annual period. Nitrate (NO_3), for example, ranged from 7.3-14.5 µM, except for a single station (F02) located in eastern Cape Cod Bay (0.5 µM), indicating that the surface water there was nutrient-depleted (Figure 4-20). Similarly, silicate (SiO_4) and phosphate (PO_4) had minima at F02 (1.3 µM and 0.3 µM, respectively), while regionally, surface water was replete with these nutrients (8.3-23.9 µM and 0.8-1.6 µM, respectively). The depletion in eastern Cape Cod Bay was related to the late winter bloom (Section 4.3). Relatively low concentrations (7.3 µM) in the nearfield suggested the onset of a bloom there as well (Figure 4-20). A complete set of farfield contour maps of nutrient concentrations is available in Appendix B.

By the second survey in late February (W9602), nutrient concentrations had decreased throughout the region except in Boston Harbor, indicating a relatively widespread late winter bloom (Figure 4-21). Maximum nutrient depletion during this period was notable in Cape Cod Bay, in the boundary region, and in the nearfield. Outside of Boston Harbor, surface water nutrient concentrations during this survey were reduced to: <1 to 7 µM (NO_3), 1.4-9.5 µM (SiO_4), and <0.8 µM (PO_4). Boston Harbor concentrations were highest regionally, but lower than in early February, suggesting the onset of a bloom there as well.

Ammonium (NH_4) concentrations did not follow the same pattern as the other dissolved inorganic nutrients. The distribution of NH_4 is strongly influenced by the tidally-dependent effects of the existing outfall in Boston Harbor. In evaluating nutrient:nutrient and nutrient:salinity relationships (Appendix D), the DIN:PO_4 ratio indicated that harbor and coastal waters were relatively enriched with DIN due to the NH_4 component. In addition, NH_4 was the only nutrient that showed a relationship with salinity, indicating a similar trend of decreasing NH_4 with increasing salinity following the transition from inside to outside of the harbor.

Regional surface waters, including Boston Harbor, were consistently nutrient-depleted during the final pre-stratification farfield survey in April (W9604), and were generally the lowest measured regionally during the semi-annual period (<1 µM NO_3, 0.3-1.9 µM SiO_4, and 0.1-0.4 µM PO_4). The surface water remained nutrient-depleted until the final farfield survey in June (W9607), although there were slightly higher nutrient concentrations measured in Boston Harbor due to the mixed water column (Section 4.1) and the cessation of the harbor spring bloom (Section 4.3).

4.2.2 Vertical Distribution

Farfield. During the first combined nearfield/farfield survey in early February, nutrient concentration transects (Appendix C) show that the water column was replete with nutrients, with an inshore/offshore gradient of all nutrients measured. By the second farfield survey in late February, deep water concentrations remained similarly elevated as in early February, but surface water concentrations had decreased. For example, maximum SiO_4 depletion was located in the upper 20 m of the offshore region of all three transects (Figure 4-22). Depletion of NO_3+NO_2 and PO_4 showed similar patterns, while NH_4 was depleted throughout the water column (Appendix C).

The range of nutrient concentrations throughout the water column was lowest during the early April combined survey, resulting in a spring marked by low productivity outside of the harbor (Section 5.0). Outside of the harbor, NO_3+ NO_2, SiO_4, and NH_4 were depleted in surface water, while PO_4 was present in low levels (0.2-0.4 μM). The distribution of nutrients with depth (Appendix D) indicated that Boston Harbor also was depleted with respect to NO_3+ NO_2 (<0.5 μM) and SiO_4 (<2 μM). During this survey, the upper water column of the boundary region had the highest nitrogen nutrients (NO_3+ NO_2 approximately 1.0 μM), and Cape Cod Bay had the highest SiO_4 (approximately 2 μM). The water column was beginning to be vertically stratified with respect to nutrients, with deeper water maximum concentrations reaching approximately 4 μM of NO_3+NO_2, 3 μM SiO_4, and 0.8 μM PO_4.

During the final combined nearfield/farfield survey in June, the upper water column remained depleted of nutrients, again except for low levels of PO_4. The stratified lower water column, however, showed the beginning of nutrient-enrichment, as maximum concentrations reached approximately 10 μM of NO_3+NO_2, 14 μM SiO_4, and 1.0 μM PO_4.

Nearfield. Because of the increased frequency of sampling, the nearfield data showed higher temporal resolution of nutrient concentrations at all nearfield stations throughout the monitoring period. Surface and bottom water SiO_4 concentrations from five nearfield stations representing the four corners of the nearfield grid (N01, N04, N07, and N10), and the center station (N21) were plotted to demonstrate several observations from the semi-annual period (Figure 4-23). Overall, the highest nutrient concentrations were measured during the first semi-annual survey in early February. Following nutrient minima in March (W9603), a gradient between surface and bottom water nutrient concentrations increased throughout the spring and summer. An early summer bloom in June (W9607), especially in the harbor (Section 4.3), caused a surface water depletion at several stations. Following the June survey, the final two surveys in July indicated that both surface and bottom water began to re-establish nearfield nutrient concentrations. These trends, and several specific events, are discussed in more detail below.

Data from the first survey in February (W9601) resulted in the highest measured values of all nutrients in the nearfield water column. The winter bloom documented in late February (W9602; Section 4.3) resulted in overall nutrient depletion, including a decrease from approximately 8-11 μM to 2-6 μM of NO_3+NO_2, 0.8-1.1 μM to 0.4-0.6 μM PO_4, and 12-17 μM to 5-8 μM SiO_4 (Appendix D).

Bloom-related depletion of nutrients in the surface water of the nearfield reached a maximum in March (W9603). The distribution of nutrient concentrations with depth (Appendix D) indicated that the onset of vertical stratification with respect to nutrients was early in the year, demonstrating that a nearfield nutrient surface to bottom water gradient existed as early as the March survey. Phosphate and the nitrogen nutrients especially showed depth-dependent gradients that persisted throughout the semi-annual period. Measurements in March resulted in gradients of approximately 0.5 µM for PO_4, and 4 µM NH_4 and NO_3+NO_2. Silicate was relatively low throughout the water column during this survey (<3 µM at depth).

The distribution and concentrations measured in the following surveys in early (W9604) and late (W9605) April were relatively unchanged from the prior survey (Appendix D). Beginning in May (W9606), bottom water nutrient concentrations increased as the summer stratified season began to develop. Overall, the surface/bottom water gradient-driven nutrient profiles in the water column were similar as the prior spring surveys. An exception was an incursion of higher SiO_4 surface water (>7 µM) among the outer nearfield stations (Figure 4-24a). This water mass also had very low salinity (Figure 4-24b; Section 4.1), and was associated with the intrusion of the low salinity freshet documented in continuous mooring data.

Nutrient:depth profiles in the nearfield in June (W9607) were similar to the spring surveys except for an overall reduction of surface water SiO_4 from the prior survey at many nearfield stations. Bottom water SiO_4 was also depleted at station N10, nearest Boston Harbor. The reduction of SiO_4 was related to diatom production during this period (Section 5.3).

The final two surveys of the annual period conducted in early and late July (W9608, W9609) indicated that the surface water remained relatively depleted in nutrients. The nutrient:depth profiles, however, show more scatter in the data in the mid-water column due to a "mounding" of nutrient concentrations along the nutricline. The trend towards increased nutrient concentrations with depth during remineralization of organic matter during the summer may provide a nutrient source for the mid-summer periods of productivity in the nearfield suggested by biological data (Section 5).

Nearfield surface water in the summer was the most nitrogen-depleted during the semi-annual period. Nutrient:nutrient ratios were plotted, showing the relative depletion of all the nitrogen nutrients relative to PO_4 and SiO_4 (Appendix D: Figures 4-110, 4-112, 4-127). Nutrient trends showed the DIN:PO_4 ratio to be below the Redfield value of 16 during the entire semi-annual period, decreasing from a high of 10-14 in the nearfield during the first survey in February, to 2-6 in June (W9607) and early July (W9608), reaching a minimum range of 1-5 during the final survey in late July (W9609).

4.3 Chlorophyll *a*

Maximum chlorophyll *a* production (referred to simply as chlorophyll in the text) during the first semi-annual period occurred regionally during late February (W9602), and in Boston Harbor throughout April-June. HOM Program chlorophyll data were compared with data collected in Boston Harbor through the Boston Harbor Water Quality Monitoring Program (Harbor Studies Program) to provide a link between nearfield and harbor productivity.

4.3.1 Horizontal Distribution

Surface water chlorophyll concentrations were regionally low during the first semi-annual survey in early February, ranging from 0.6 to 3.8 µg/L, except for a high concentration measured at station F02 (13.1 µg/L) in eastern Cape Cod Bay, indicating the presence of a local bloom (Appendix B). The limited extent of chlorophyll in Cape Cod Bay during this survey can be demonstrated by the fact that the lowest regional concentrations (approximately 0.6 µg/L) were measured in western Cape Cod Bay. Aside from eastern Cape Cod Bay, the highest regional concentrations were in the nearfield (approximately 4 µg/L).

Two weeks following the first survey, in late February (W9602), a system-wide late winter bloom had developed, resulting in multiple localized maxima of chlorophyll (Figure 4-25). The focus of the local maxima were in Cape Cod Bay (9-12 µg/L), off the Marshfield area (9 µg/L), in the nearfield (5 µg/L), and at the northern end of the boundary region (10-12 µg/L).

By the third combined nearfield/farfield survey in early April (W9604), chlorophyll concentrations were reduced generally to <1 µg/L throughout Massachusetts and Cape Cod Bays, except in and near Boston Harbor. A local harbor bloom resulted in concentrations ranging from 9-11 µg/L in the harbor, and 2-8 µg/L in the inner nearfield and along the coast south of the harbor (Figure 4-26). Chlorophyll monitoring in Boston Harbor through the Harbor Studies Program, in conjunction with available farfield phytoplankton data, supported the potential presence of a spring diatom bloom that peaked in late March-early April, with concentrations reaching 20 µg/L.

The regional surface water distribution of chlorophyll during the final farfield survey in June (W9607) was similar to that measured in early April, except with an overall lower range of concentrations (3-6 µg/L in harbor, 1-4 µg/L in the nearfield).

4.3.2 Vertical Distribution

Farfield. The three farfield cross sections (Figure 1-3) show the distribution of chlorophyll in the water column both regionally and with depth in the water column (Appendix C). For example, the first survey was conducted during a period of relatively low biomass in early February, except for higher chlorophyll in the outer nearfield and offshore regions of the transects, reaching concentrations of 3-4 µg/L in the upper 20 m.

The winter bloom in late February (W9602) resulted in a patchy distribution of chlorophyll regionally, generally concentrated in the surface water of the boundary and offshore regions of the transects (Figure 4-27). Maximum concentrations (up to 10 µg/L) were measured at stations F06 (Marshfield transect), F16 (Cohassett transect), and F27 (Boston-Nearfield transect). The highest concentrations were actually below the surface at station F16.

Regionally, chlorophyll was relatively low during the final two combined nearfield/farfield surveys in April (W9604) and June (W9607). In April, chlorophyll was <0.5 µg/L everywhere except in the harbor and near the coast, and in the mid-water (20m) of the offshore region (0.5-1 µg/L). The early April farfield survey was conducted during the beginning of the peak spring bloom in Boston Harbor, documented by data collected through the Harbor Studies Program. In June, chlorophyll again was <0.5 µg/L everywhere except the harbor (up to 3 µg/L), concentrated along the pycnocline (Figure 4-11) of the Cohassett and Marshfield transects (1-3 µg/L), and very deep in the boundary region (1-3 µg/L).

Nearfield. Chlorophyll data collected in the nearfield during the first semi-annual period of 1996 demonstrate the relative productivity of the nearfield, and the importance of harbor-nearfield interaction dynamics. Calibrated *in situ* fluorescence data, averaged over 0.5 m bins, were contoured over the vertical cross section through the nearfield (Figure 1-3), showing the patchiness of chlorophyll during the nine nearfield surveys. These transects will be used, in tandem with the Harbor Studies Program data, to evaluate the nearfield chlorophyll trends during the first semi-annual period.

Chlorophyll production in the nearfield during the first early February survey (W9601) indicated plankton growth isolated in the outer nearfield, without a harbor component (Figure 4-28). Concentrations of >4 µg/L in the nearfield were widespread in the upper 20 m of the central and outer nearfield. Harbor chlorophyll data collected through the Boston Harbor Studies program consistently showed only trace chlorophyll concentrations of <1 µg/L from January to mid-February.

By late February (9602), the regional winter bloom resulted in nearfield chlorophyll concentrations of >6 µg/L, with a subsurface maximum (10-20 m) located in the central nearfield (station N21). The nearfield was more productive than the harbor during the winter bloom, which showed concentrations of generally <2 µg/L.

The third nearfield survey in March (W9603, nearfield stations only) resulted in a bimodal distribution of chlorophyll (Figure 4-28). There was a clear harbor and coastal influence, with station N10 near the harbor mouth showing concentrations of >6 µg/L in the upper 10 m. By the third week of March when the W9603 survey was conducted, Boston Harbor Studies data indicated the beginning of a productive local spring bloom that climaxed in early April. In contrast to the harbor-related chlorophyll, a second area of chlorophyll was present in the deep water (20-40 m) of the outer nearfield (N04), also reaching concentrations of >6 µg/L. This may either represent sinking (but still photosynthetically active) phytoplankton, or localized production at depth as the surface water cleared (e.g., N04 data in Figures 4-28 and 5-3).

Chlorophyll was scarce in the nearfield during early April (W9604), except at station N10 which showed evidence of the harbor bloom where concentrations of approximately 10 µg/L were measured (as discussed above). Similarly, the nearfield reflected continuing bloom conditions in Boston Harbor in late April (W9605), where peak annual chlorophyll measurements were made of >20 µg/L during the Harbor Studies program. Concentrations of >6 µg/L were measured in the nearfield during this survey at approximately 10 m water depth at station N10 (Figure 4-28).

Harbor-influenced chlorophyll continued throughout May and June, with maximum concentrations of >6 µg/L in May (W9606) and >4 µg/L in June (W9607). During the final two nearfield surveys in July, chlorophyll concentrations were <2 µg/L in the nearfield (Figure 4-29), despite continued concentrations in the harbor of approximately 5-10 µg/L (Harbor Studies Program). Chlorophyll in the nearfield was concentrated in the surface and mid-water of the outer nearfield. Evidence also was found that a nearfield bloom occurred between the two July surveys (Sections 5.1 and 5.3). Particulate organic carbon (POC) results were consistent with these chlorophyll data (Section 5.2). The distribution of chlorophyll in the summer months was investigated further using biological monitoring results (Section 5).

4.4 Dissolved Oxygen

The distribution of dissolved oxygen (DO) in the water column was examined first for temporal and spatial trends in the farfield (Section 4.4.1) and then in the nearfield (Section 4.4.2). For contingency purposes, individual bottom water DO minima were investigated. The minimum measured bottom water DO concentration during the semi-annual period was 7.6 mg/L in the nearfield in July (W9609). Regionally, the minimum DO concentrations was in the bottom water of Cape Cod Bay (8.1 mg/L) in June (W9607).

4.4.1 Regional Trends of Dissolved Oxygen

Average bottom water DO concentrations throughout the farfield area ranged from 10 to 11.5 mg/L throughout the winter and spring (Figure 4-30a). Regionally, DO maxima were consistent with the observed distribution of the late winter/spring bloom. During the final combined nearfield/farfield survey in June (W9607), DO concentrations in bottom water had decreased to a range of 9-10 mg/L. Cape Cod Bay had the lowest farfield bottom water DO, with an individual station minimum value of 8.1 mg/L measured in June (Figure 4-30 represents bottom water values averaged over all stations in each region).

DO saturation for the most part was consistent with the DO concentration, with peaks occurring in March or April (Figure 4-30b). The one exception was Boston Harbor, which showed the highest saturation in June, consistent with the high productivity measured at the time (Section 5.1). The observed decline in regional bottom water DO concentration between April and June was due to increasing temperatures and the effects of respiration after the onset of stratification.

The vertical distribution of dissolved oxygen shows that during the winter bloom in late February (W9602), maximum DO concentrations of >11.5 mg/L were located in the nearfield and offshore regions of the farfield transects (Figure 4-31), generally following the pattern of chlorophyll production (Figure 4-27). Bottom water concentrations during this survey remained relatively high (10 mg/L) because of the vertically mixed water column.

Regionally, bottom water DO decreased to levels of around 9.5 mg/L by June, and DO maxima of around 11 mg/L remained in the mid-water depths, above the pycnocline (Figure 4-32). Although there was relatively little chlorophyll measured in the water column, the DO pattern provided supportive evidence for summer productivity (Section 5.1). The biological activities during the summer surveys are discussed further in Section 5.

4.4.2 Nearfield Trends of Dissolved Oxygen

Dissolved oxygen and saturation in nearfield surface (A) and bottom (E) water were averaged among the 17 nearfield stations and plotted for each nearfield survey. The concentration of surface water DO was highest in the water column during the first three nearfield surveys, increasing from around 11 mg/L during the first two surveys as the winter bloom progressed, to a semi-annual maximum of >12.0 mg/L during the third nearfield survey in March (Figure 4-33a). The seasonal decline of surface water DO concentration was apparent by early April (W9604) and continued to the end of the semi-annual period as the surface water warmed. Bottom water DO was lower than surface water by approximately 1 mg/L during the pre-stratified period, and followed the same pattern throughout winter and spring until June. In June, the bottom water DO concentration was higher than the surface water concentration due to the large temperature difference (around 8°C, Figure 4-13). In July, the trend towards decreasing bottom water DO continued, but bottom water DO remained higher than surface water for all three summer nearfield surveys.

Surface water DO concentrations were consistently at or above 100 percent saturation throughout the semi-annual period (Figure 4-33b). Peaks in saturation were evident during March (W9603) and June (W9607), coincident with reported peaks in productivity (Section 5.1). In contrast, bottom water DO concentrations were at or below saturation throughout the period. Periodic maxima were similar to those seen in the surface samples.

The observed increases in both DO concentration and DO saturation during June (W9607) are the subject of continued investigation. This event followed the large-scale advection of fresher water from the north and its possible resupply of nutrients to the surface water of the nearfield. The DO increases also coincided with a number of remarkable observations discussed in Section 5: increased productivity (Figure 5-3), higher respiration (Figure 5-6), elevated POC (Figure 5-7), and higher carbon-specific respiration (Figure 5-8). All of these observations suggest that a significant bloom may have occurred in the nearfield between surveys W9606 and W9607. The large error bars displayed in the DO results shown in Figure

4-33 indicate substantial spatial variability within the nearfield, which will be further resolved in the 1996 Annual Water Column Report.

4.5 Summary of Water Column Results

Physical Characteristics

- Regional horizontal gradients of temperature and salinity during the winter-spring surveys allowed differentiation of boundary/offshore, coastal, harbor, and Cape Cod Bay water masses;
- The boundary/offshore regions had the highest temperatures and salinities during the winter, and the harbor had distinctively lower salinity;
- An early February regional density gradient, caused by a layer of fresher, cooler surface water, was not present two weeks later during the late February survey, indicating that mixing had occurred, potentially due to February northeasters;
- The surface water started to warm in Boston Harbor and Cape Cod Bay as early as April (W9604);
- The annual onset of vertical stratification, defined by a $\Delta\sigma_t$ of >1.0 kg/m^3, developed by mid-April (W9605) in the inner nearfield, and by mid-May (W9606) in the outer nearfield, primarily due to an increase in surface water temperature;
- Early spring stratification was augmented by calm weather in early May, and a persistent surface water salinity decline through April and May (which resulted in minimum values of <29 PSU), caused by a water mass intrusion of low salinity water (freshet) from the Gulf of Maine, potentially related to spring fluvial discharge;
- Regional water masses were vertically stratified by June (W9607) except in the harbor, which remained relatively well-mixed throughout the semi-annual period, encouraging harbor productivity throughout the summer;
- An early season hurricane (Bertha) contributed to a precipitation record set for the month of July, resulting in cooling of nearfield surface water in late July;
- Beam attenuation data indicated influence from harbor chlorophyll as well as fluvial runoff in surface water, and an offshore bottom water particulate component potentially related to deep water chlorophyll;

Nutrients

- The first winter survey in February resulted in the highest concentrations of nutrients regionally for the entire semi-annual period, except for a single station in eastern Cape Cod Bay signaling the beginning of a late winter bloom;

- Nutrient scavenging during the early winter bloom in February was consistent with chlorophyll patterns;

- Depletion of water column nutrients in the nearfield was evident in March, as was the initial formation of a nearfield nutrient surface to bottom water gradient;

- Depletion of nutrients which resulted in the collapse of the spring bloom in the nearfield continued throughout the spring, except for an apparent resupply of nutrients to the surface water (especially higher SiO_4) associated with the spring freshet;

- The elevated silicate was stripped in surface waters by the June survey as a result of diatom production;

- Nutrient concentrations in the bottom water began to increase in May due to remineralization of organic matter;

- Nearfield surface water in the summer was the most nitrogen-depleted during the semi-annual period;

Chlorophyll *a*

- Surface water chlorophyll concentrations were regionally low in early February, except for eastern Cape Cod Bay;

- In late February, a system-wide winter bloom had developed, resulting in multiple local maxima in Cape Cod Bay, off the Marshfield area, in the nearfield, and at the northern end of the boundary region;

- The winter bloom resulted in nearfield chlorophyll concentrations of >6 µg/L, with a subsurface maximum (10-20 m) located in the central nearfield, while the harbor showed concentrations of generally <2 µg/L;

- Two chlorophyll maxima were evident in the nearfield during March, including an inshore surface peak at N10 caused by coastal influences, and an offshore peak at N04 caused by continued production by the late winter/spring bloom in deeper water, apparently as surface water became clearer;

- Chlorophyll was low regionally (<1 µg/L) in early April, except in Boston Harbor with the beginning a spring bloom;

- Harbor-influenced chlorophyll in the nearfield, concentrated at station N10, continued throughout May and June, with maximum subsurface concentrations of >6 µg/L;

- Patchy regional chlorophyll in June showed concentrations of up to 3 µg/L in Boston Harbor and along the pycnocline;

- Summer chlorophyll concentrations were relatively low (<2 µg/L), but indications existed that nearfield bloom events may have occurred between surveys W9606 and W9607, and again between W9608 and W9609;

Dissolved Oxygen

- The minimum measured bottom water DO concentration during the semi-annual period was 7.6 mg/L in the nearfield in July;

- The highest surface water DO concentrations were measured in the nearfield during the first three winter surveys related to the late winter bloom, reaching a peak in March;

- Surface water DO concentrations began to decrease in the nearfield after the mid-March survey (W9603) due to lower solubility (production appeared to offset any respiration effects), while the bottom water DO concentrations declined due to both increased temperature and respiration effects;

- Surface water DO concentrations were at or above saturation throughout the semi-annual period, whereas bottom water DO concentrations were at or below saturation;

- The observed temporal patterns of surface and bottom water DO saturation were similar throughout the study period;

- The observed increase in both DO concentration and DO saturation between May and June (surveys W9606 and W9607) may have been a result of horizontal advection, local production, or a combination of both.

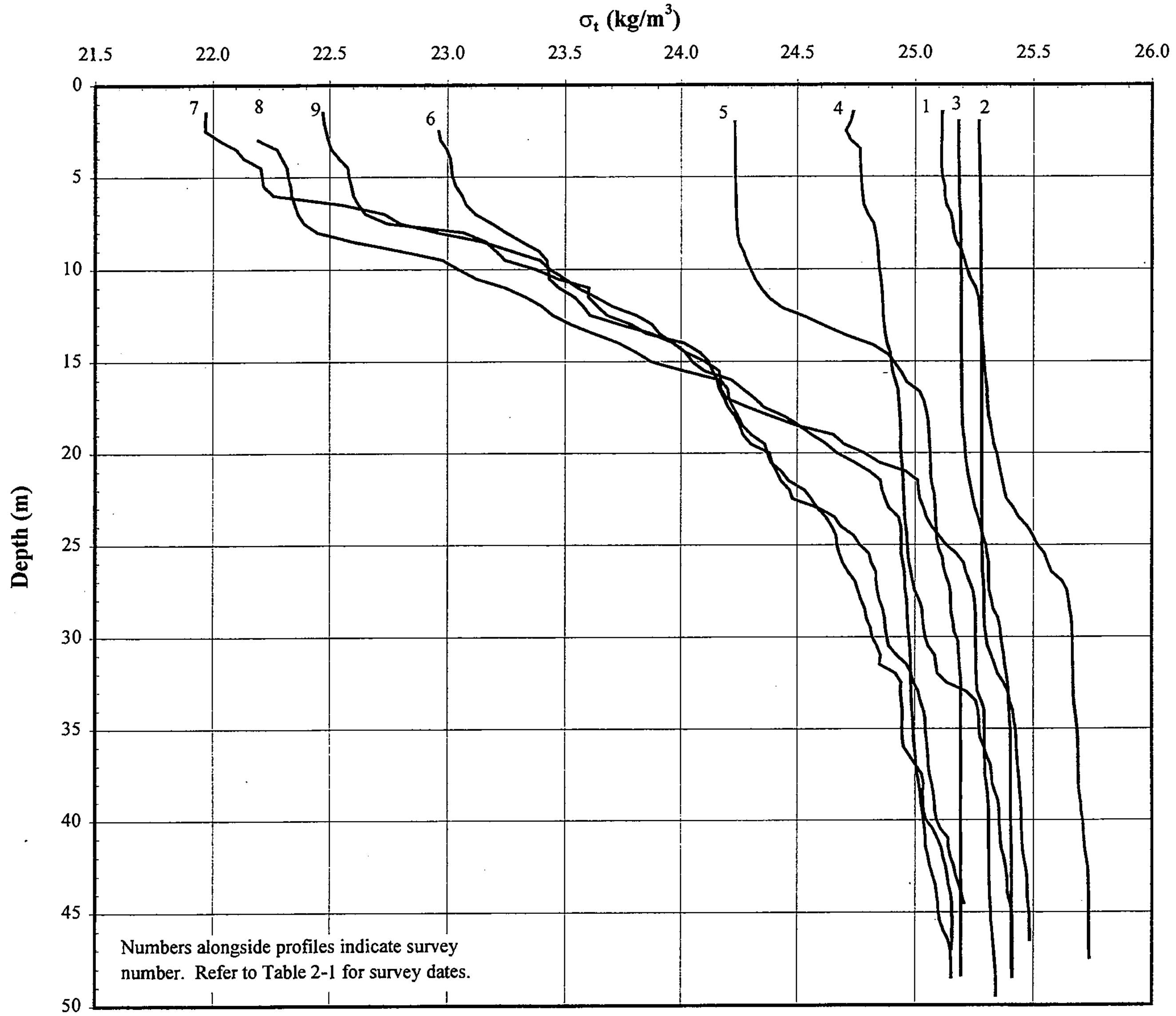
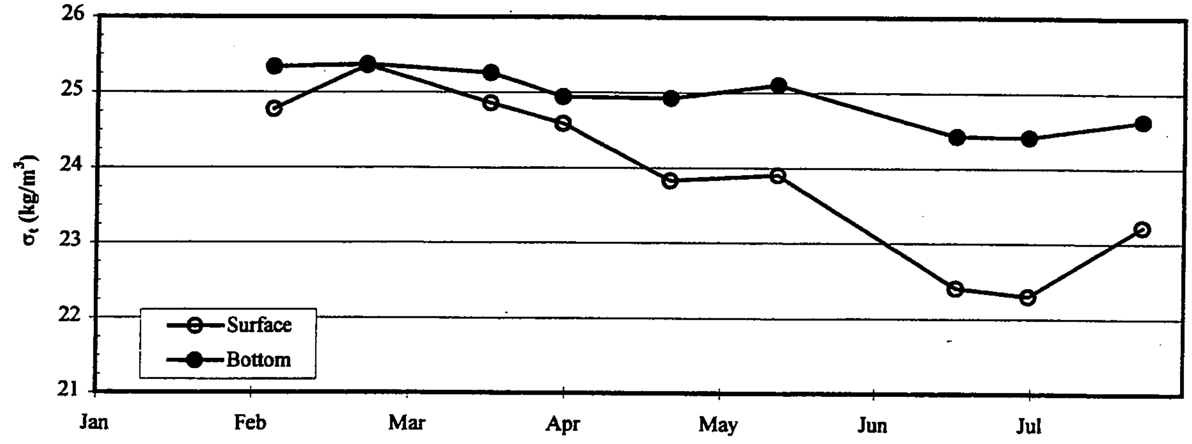


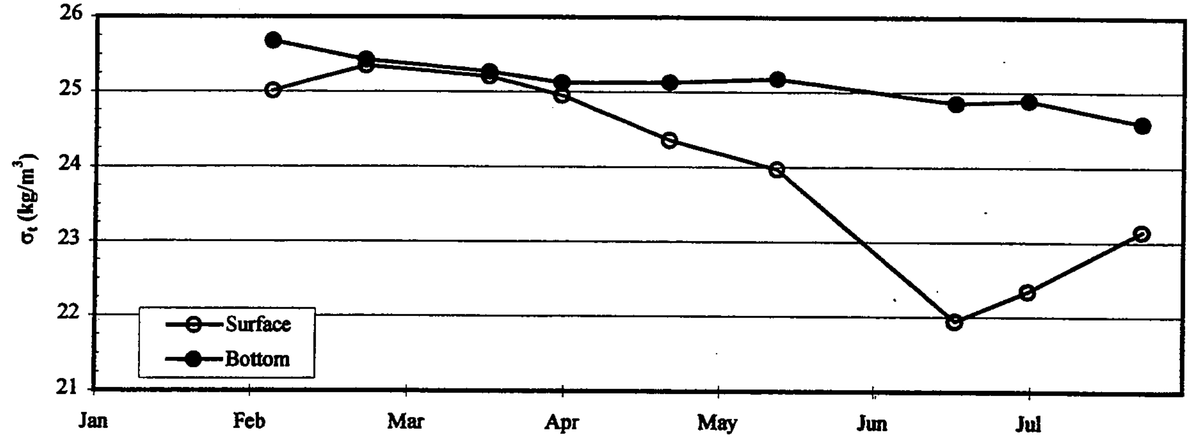
FIGURE 4-1

Density (σ_t) Profiles at Station N04

(a) Inner Nearfield: N10, N11



(b) Broad Sound: N01



(c) Outer Nearfield: N04, N07, N16, N20

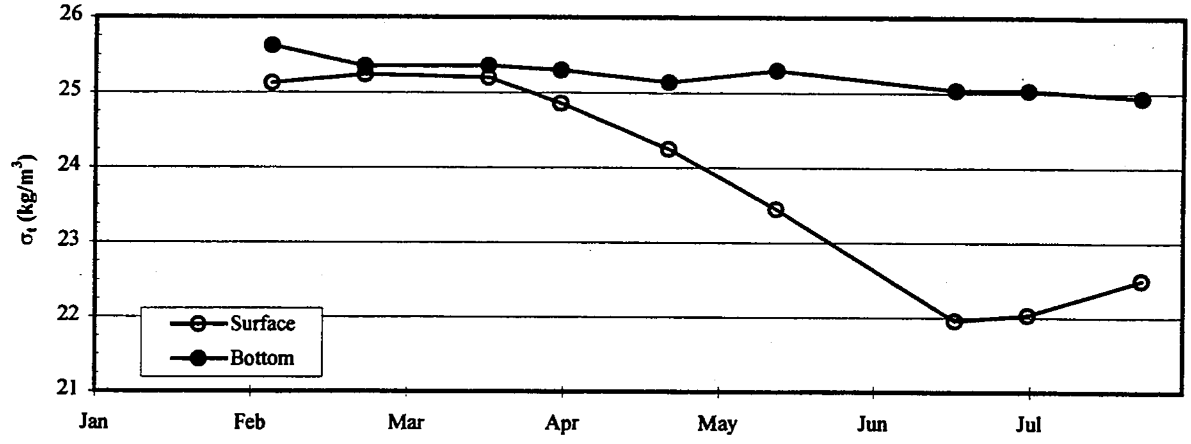


FIGURE 4-2

Time-Series of Average Surface and Bottom Water Density (σ_t) in the Nearfield

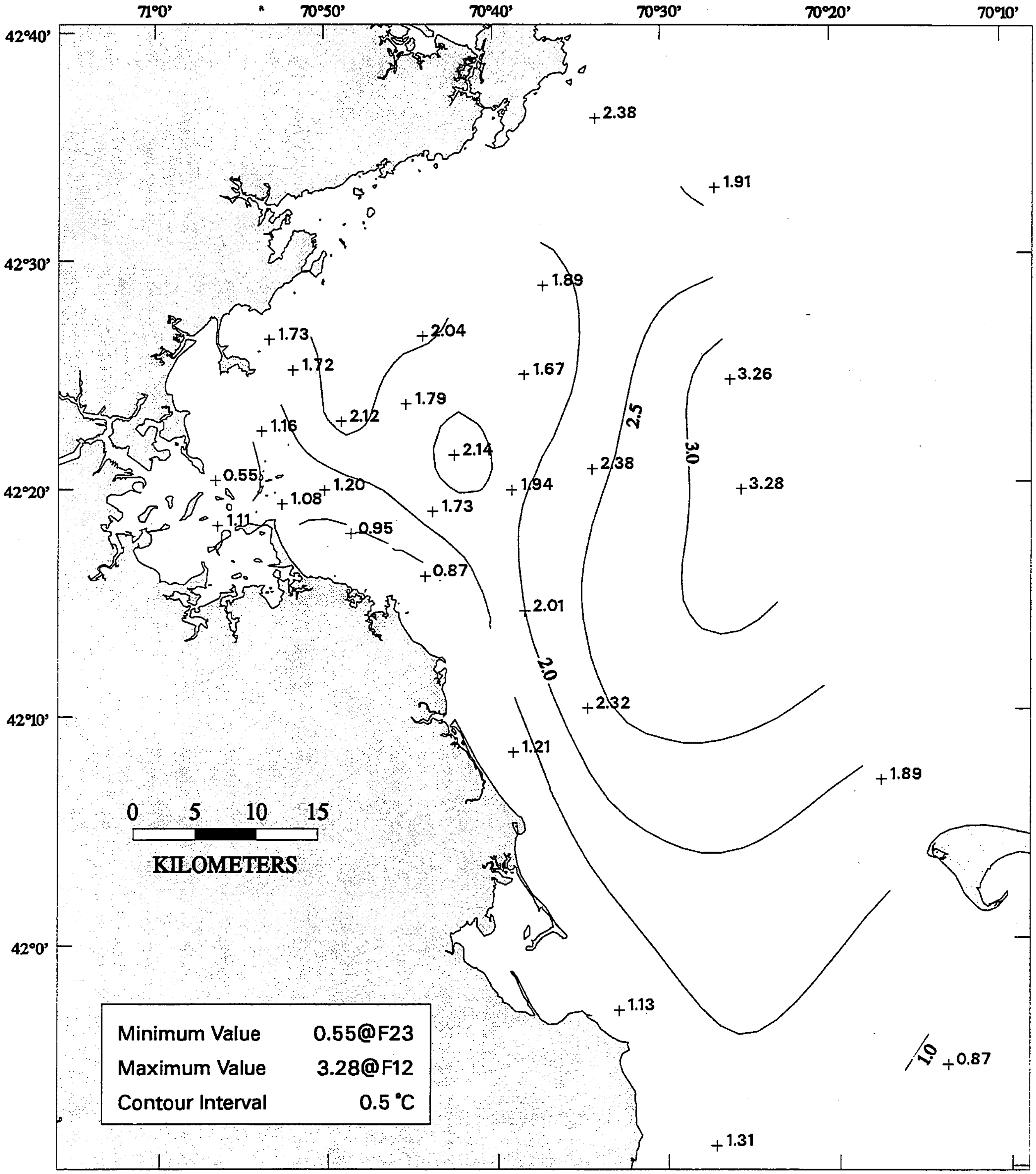


FIGURE 4-3
Surface Water Contour Plot of Temperature (°C) in Early February (W9601)

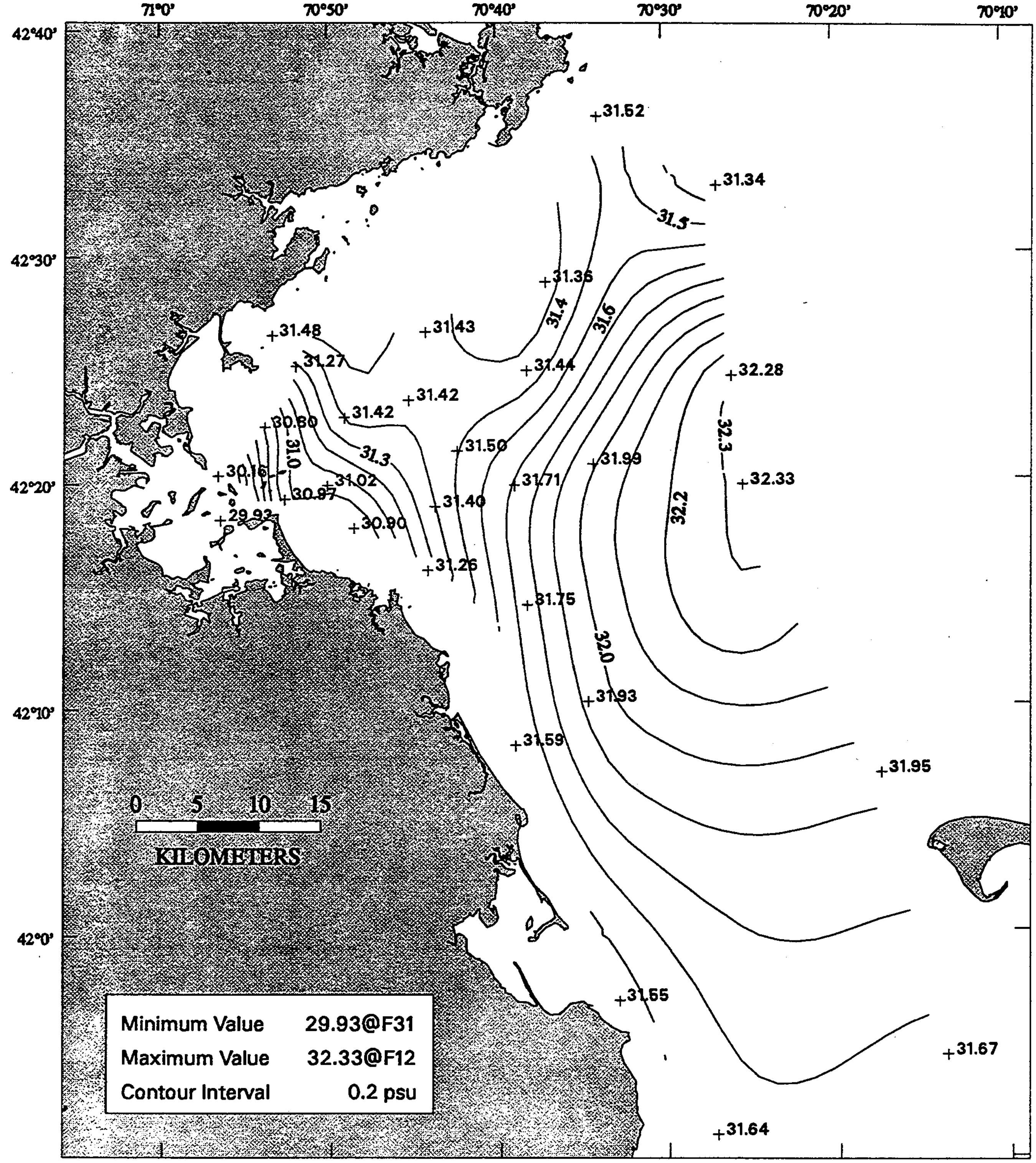
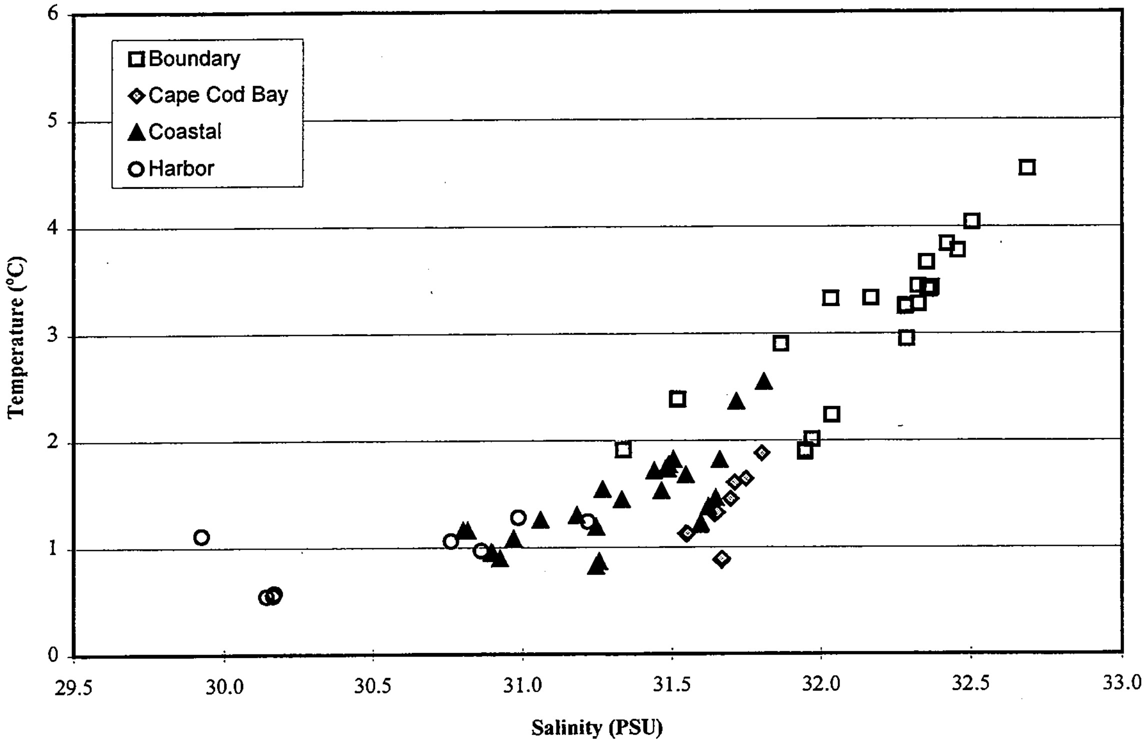


FIGURE 4-4
Surface Water Contour Plot of Salinity (PSU) in Early February (W9601)

(a) W9601: Early February



(b) W9604: April

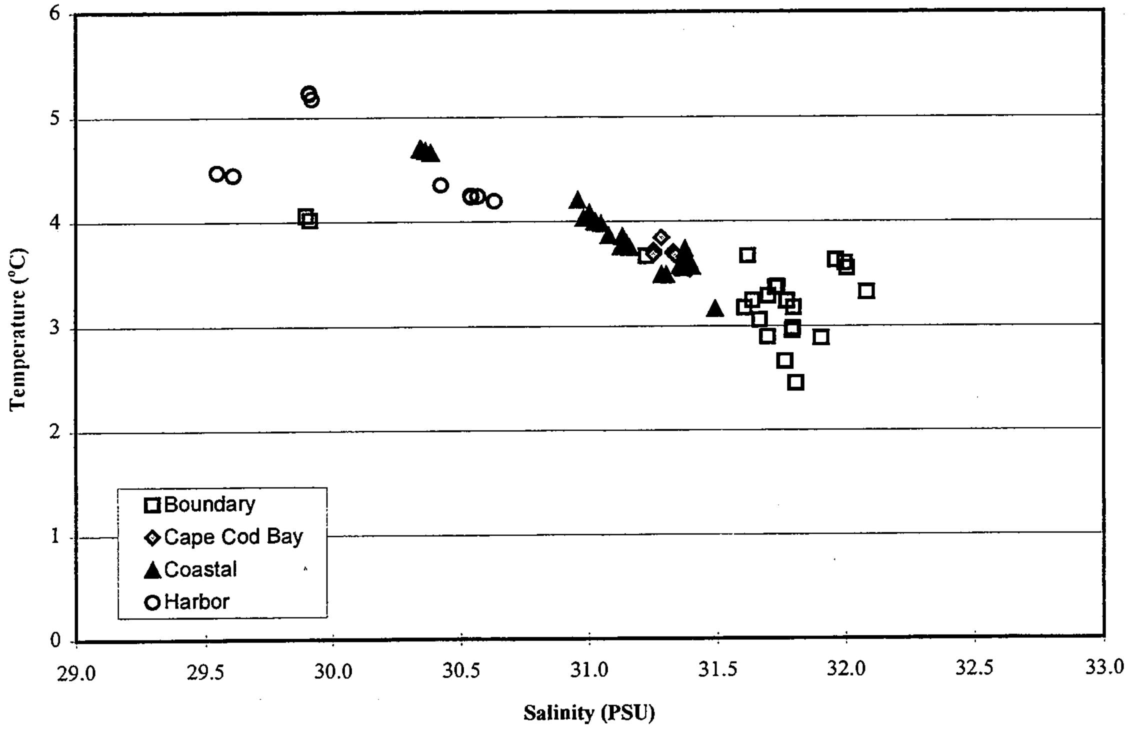


FIGURE 4-5

Temperature/Salinity Distribution during February and April

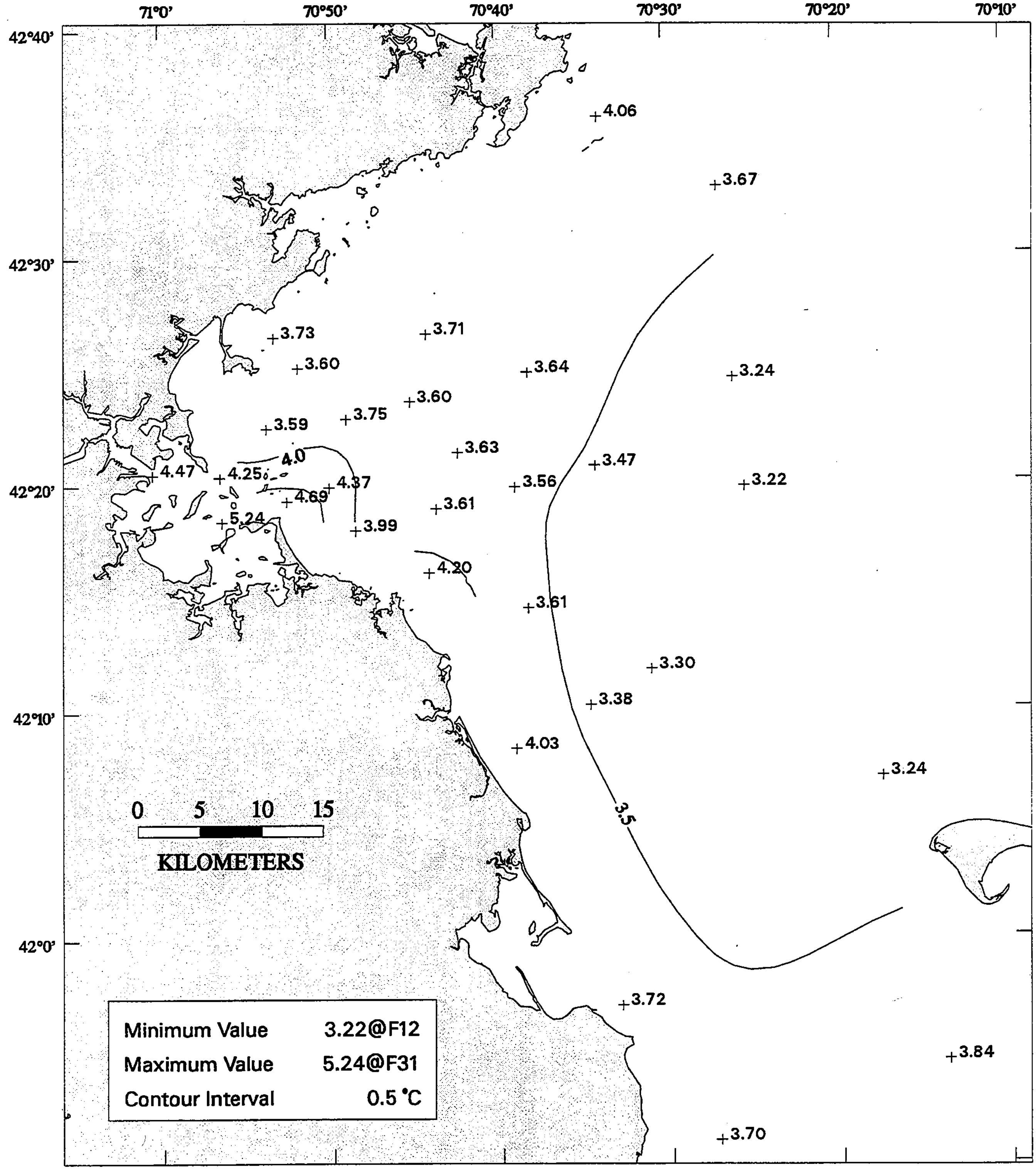


FIGURE 4-6
Surface Water Contour Plot of Temperature (°C) in Early April (W9604)

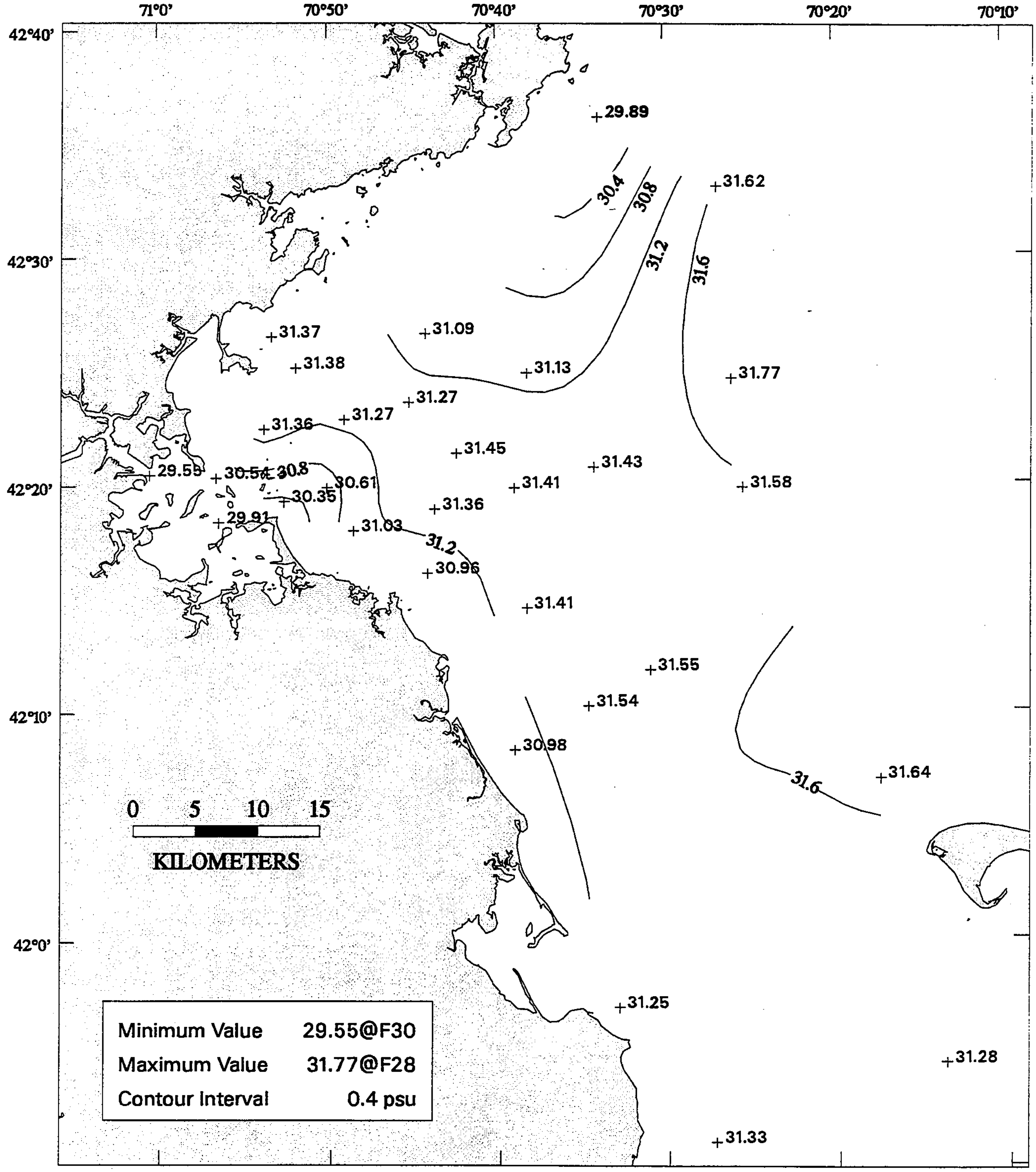
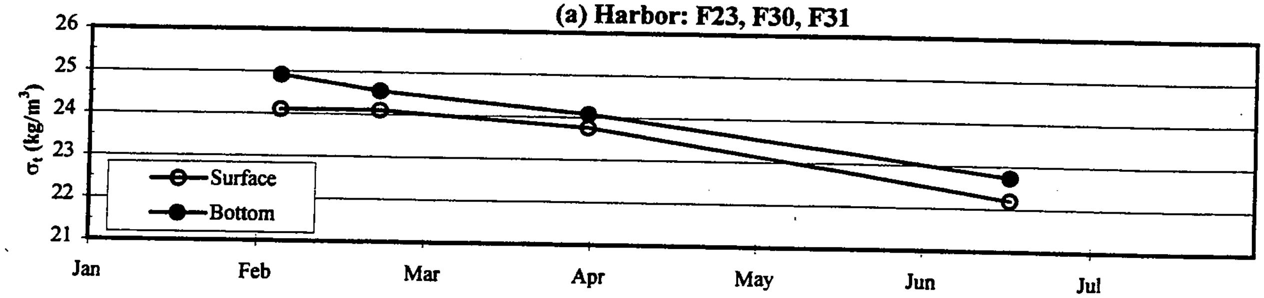
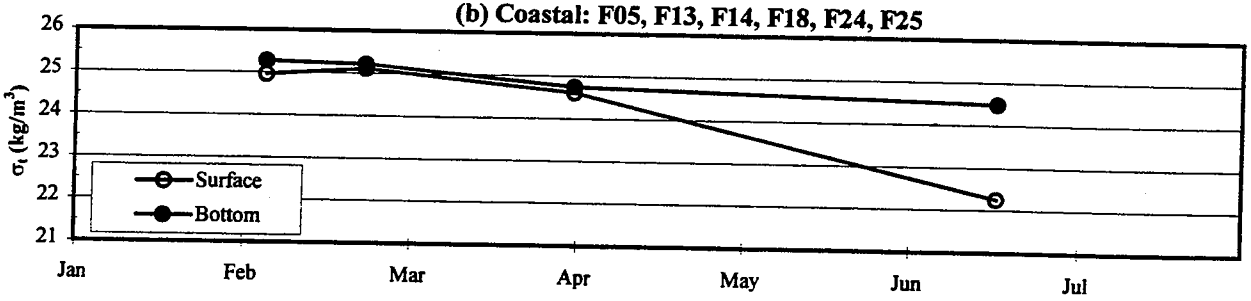


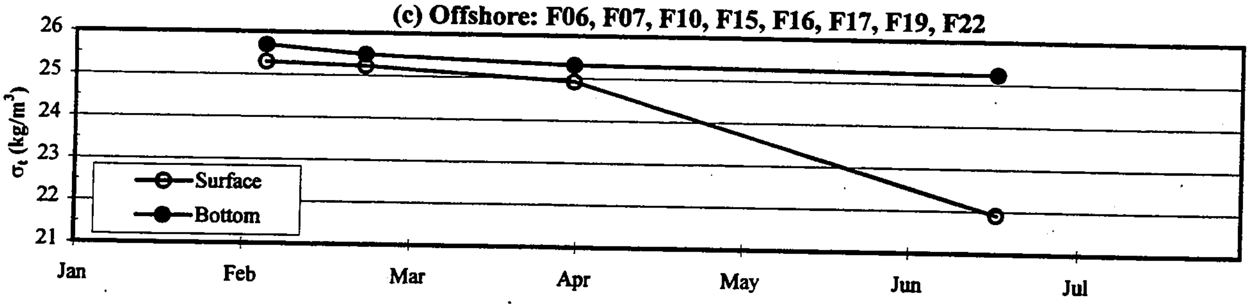
FIGURE 4-7
Surface Water Contour Plot of Salinity (PSU) in Early April (W9604)



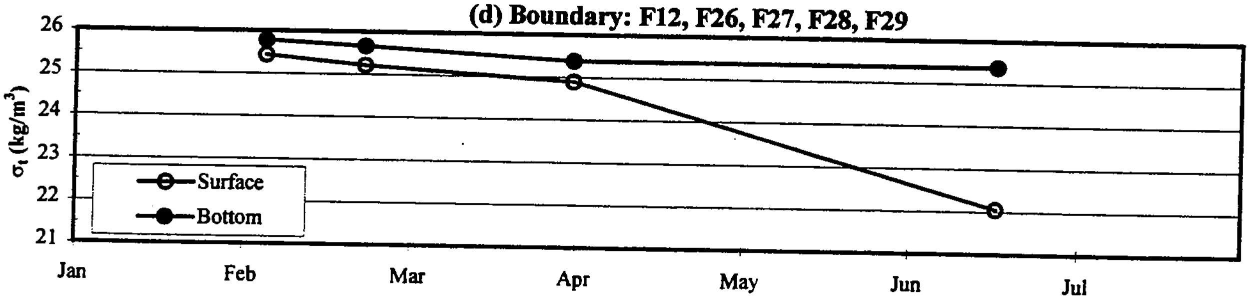
(a) Harbor: F23, F30, F31



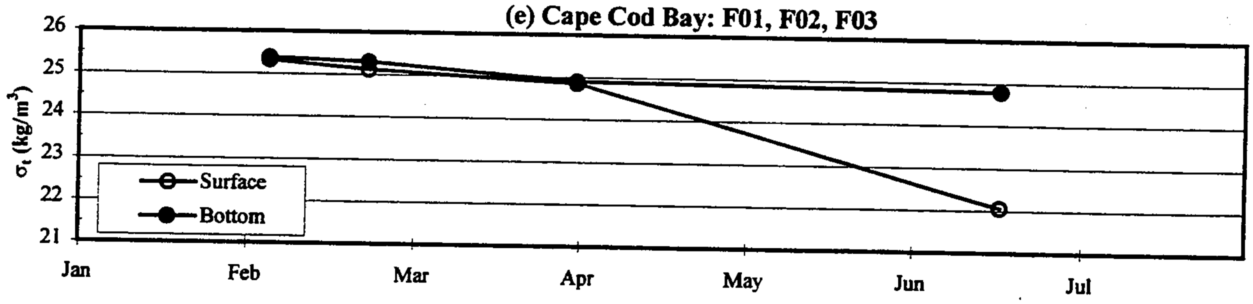
(b) Coastal: F05, F13, F14, F18, F24, F25



(c) Offshore: F06, F07, F10, F15, F16, F17, F19, F22



(d) Boundary: F12, F26, F27, F28, F29

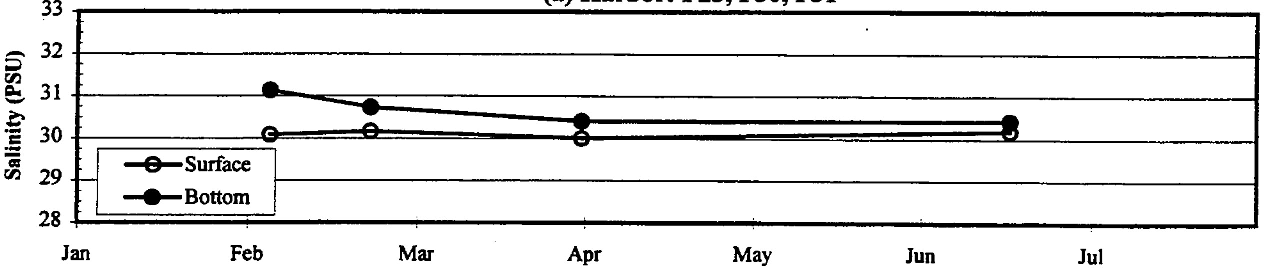


(e) Cape Cod Bay: F01, F02, F03

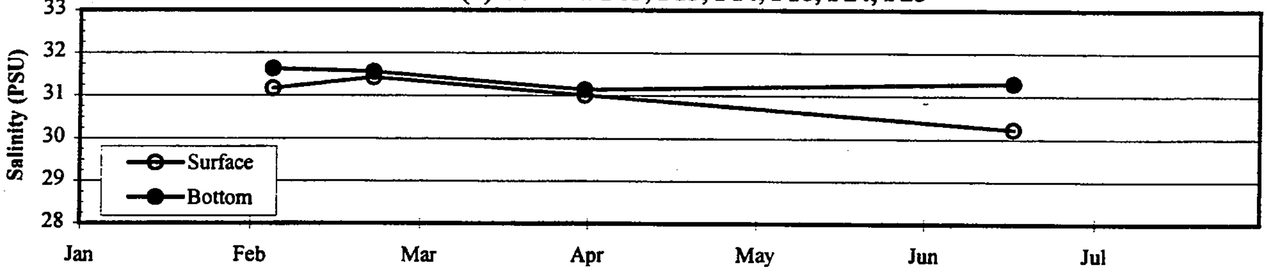
FIGURE 4-8

Time-Series of Average Surface and Bottom Water Density (σ_t) in the Farfield

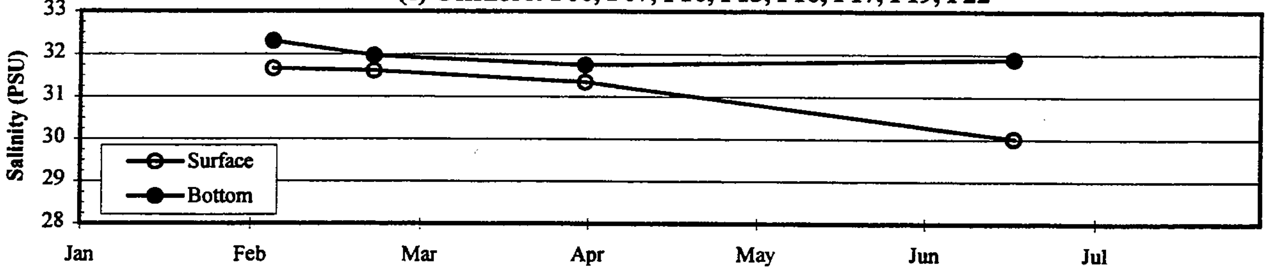
(a) Harbor: F23, F30, F31



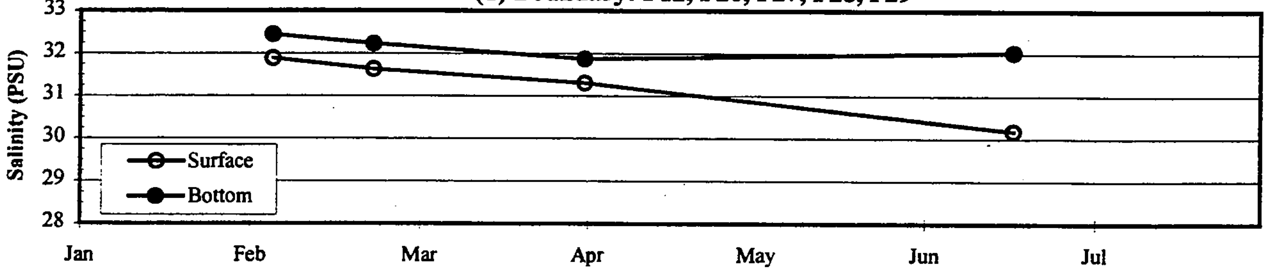
(b) Coastal: F05, F13, F14, F18, F24, F25



(c) Offshore: F06, F07, F10, F15, F16, F17, F19, F22



(d) Boundary: F12, F26, F27, F28, F29



(e) Cape Cod Bay: F01, F02, F03

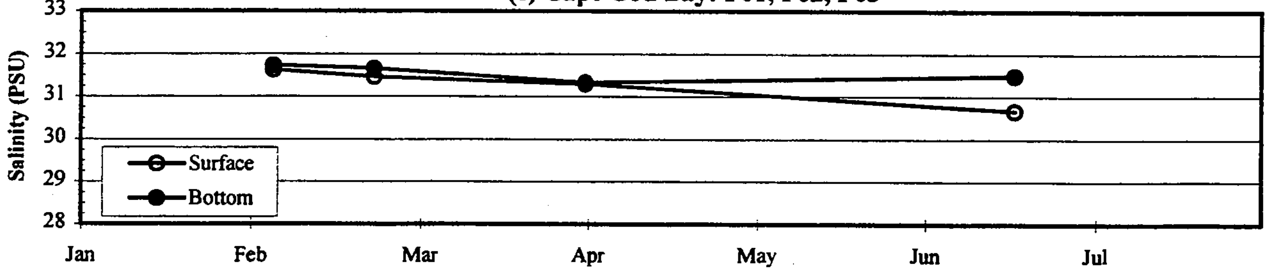


FIGURE 4-9
Time-Series of Average Surface and Bottom Water Salinity (PSU) in the Farfield

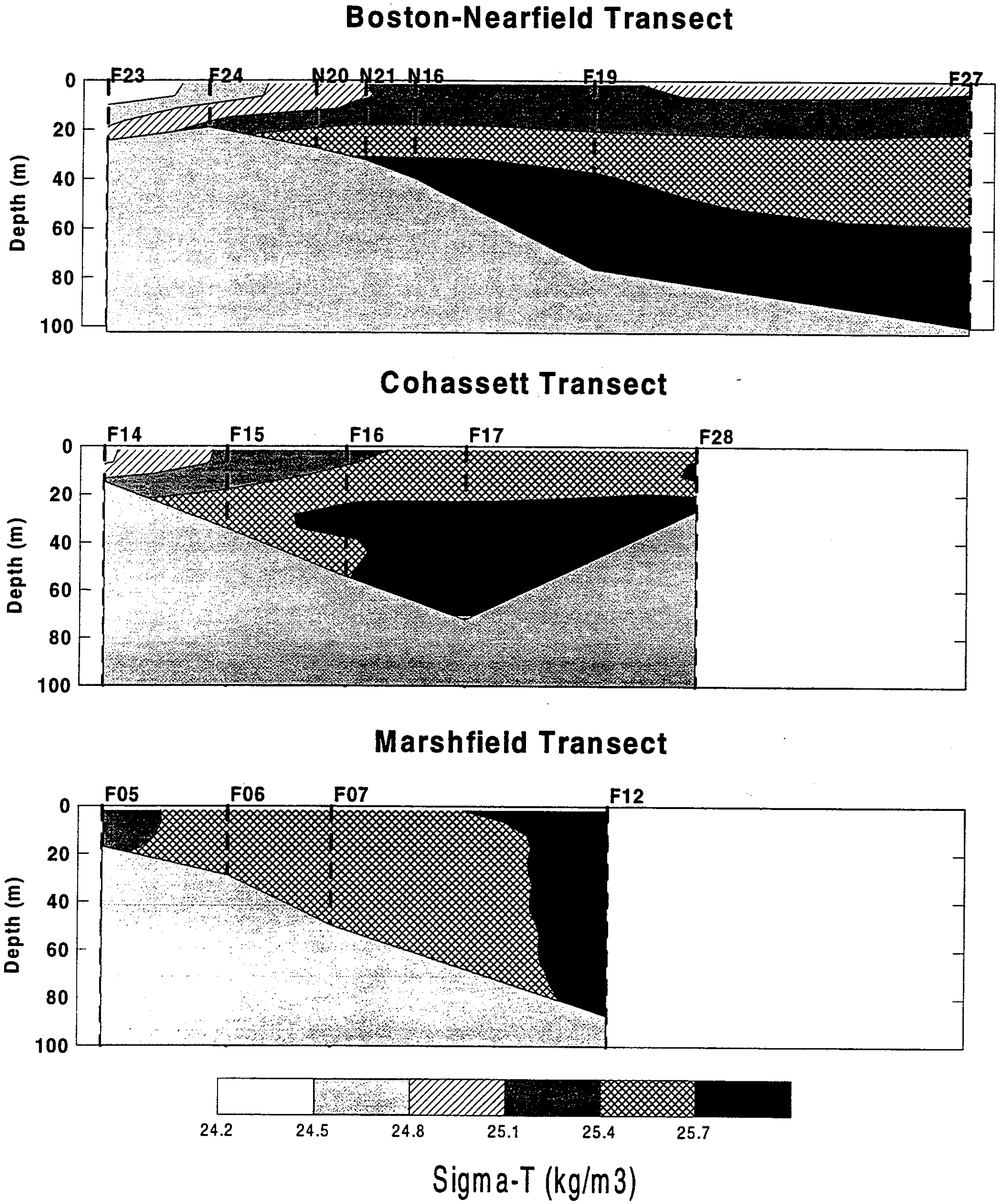


FIGURE 4-10
Density (σ_t) Contours Along Three Farfield Transects in Early February (W9601)

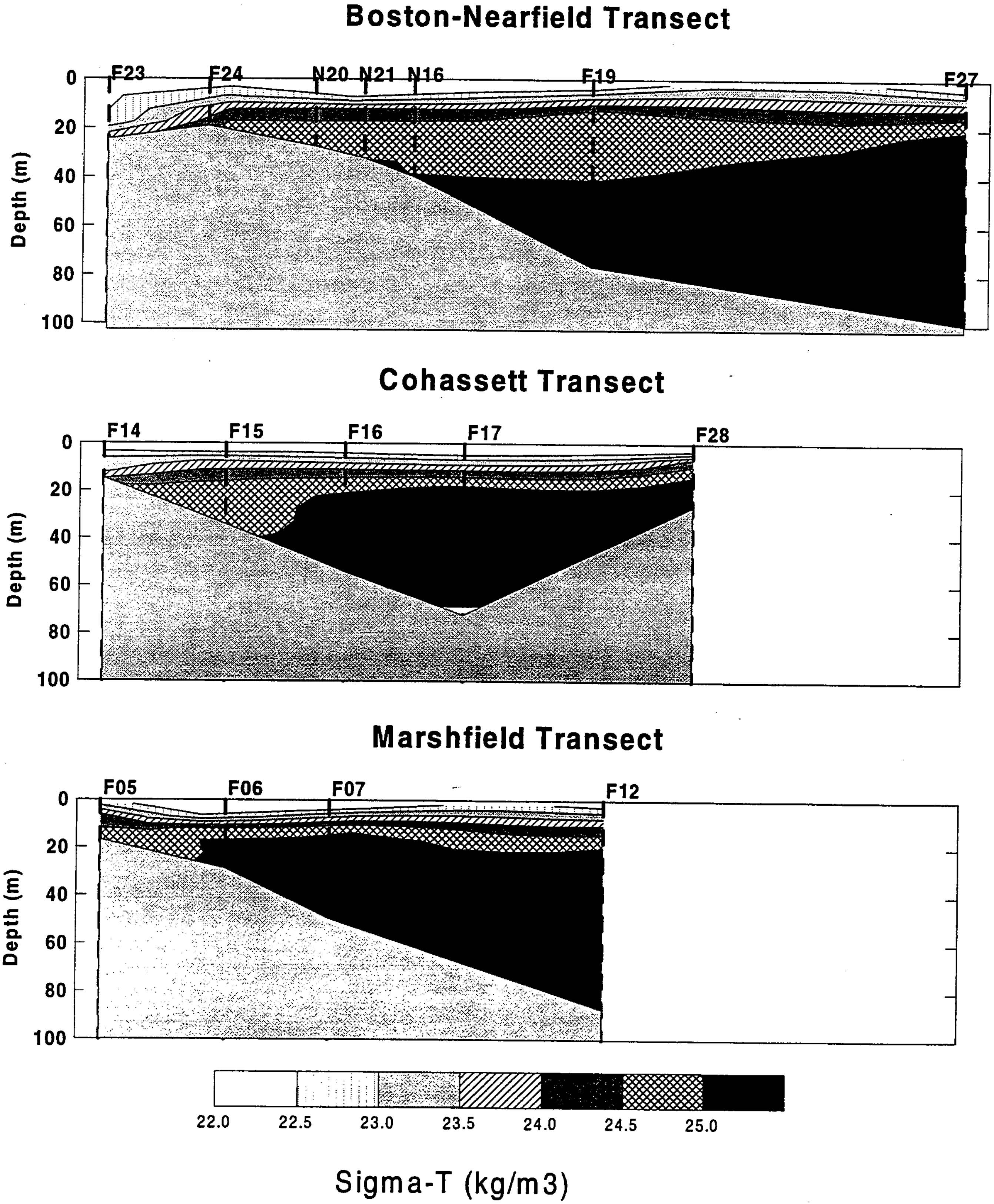


FIGURE 4-11
Density (σ_t) Contours Along Three Farfield Transects in June (W9607)

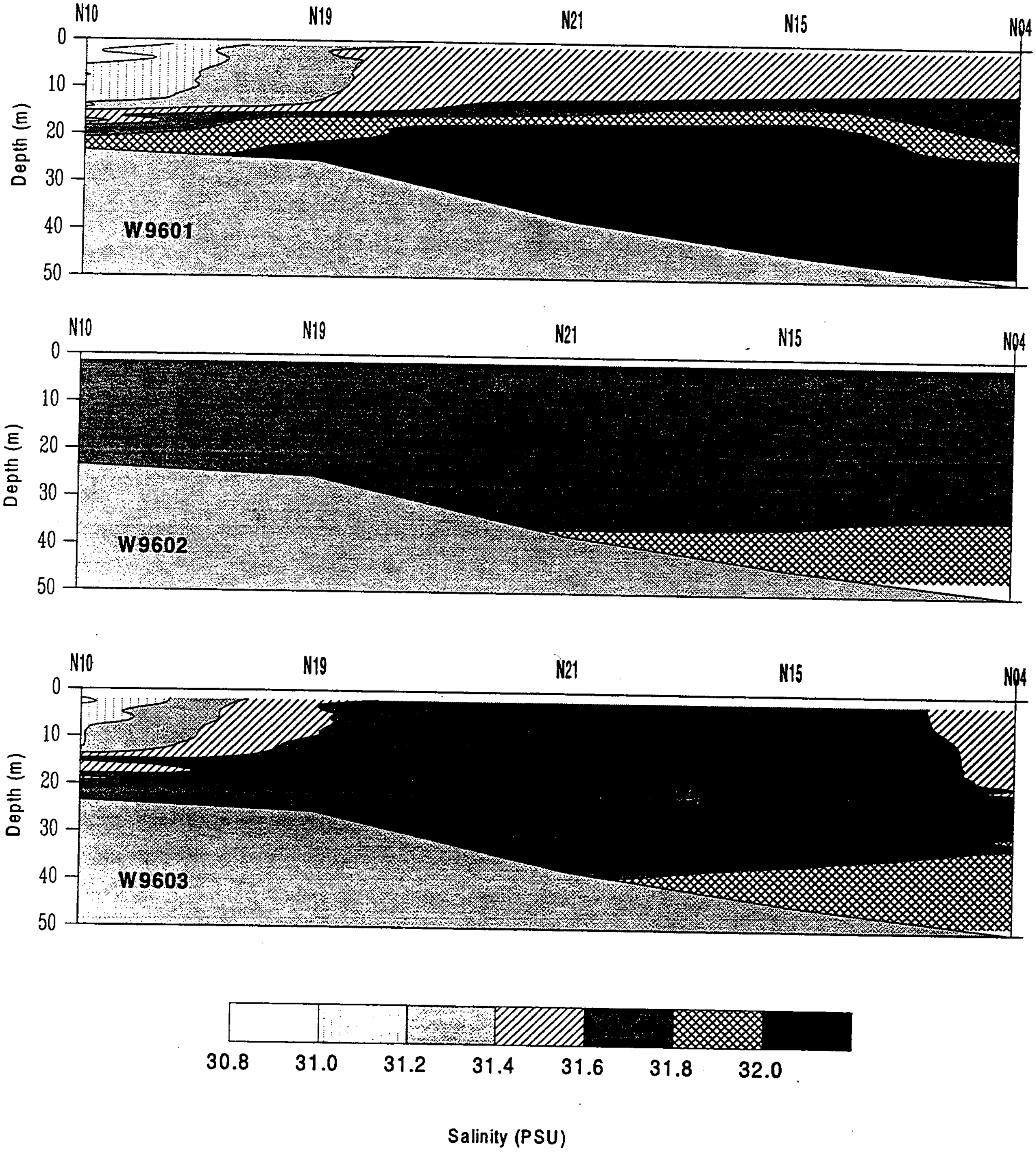
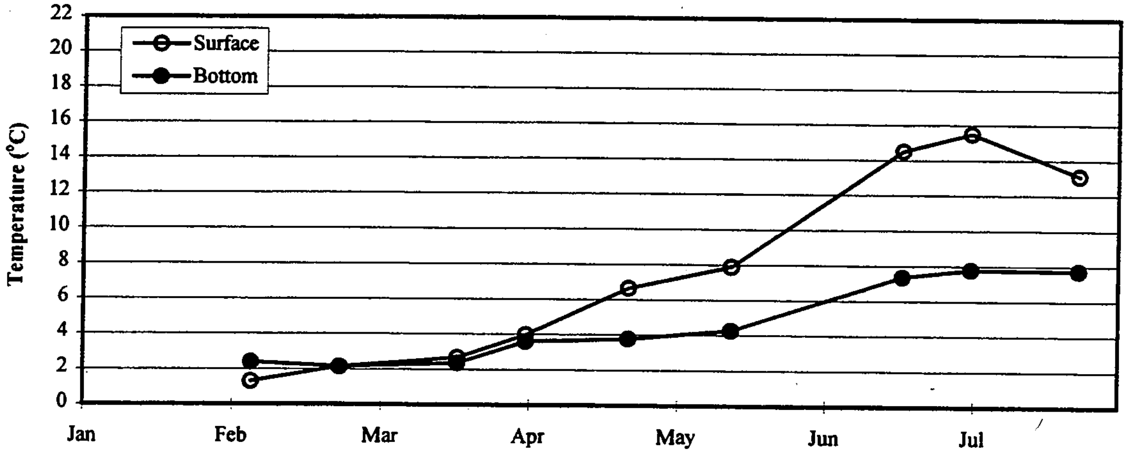
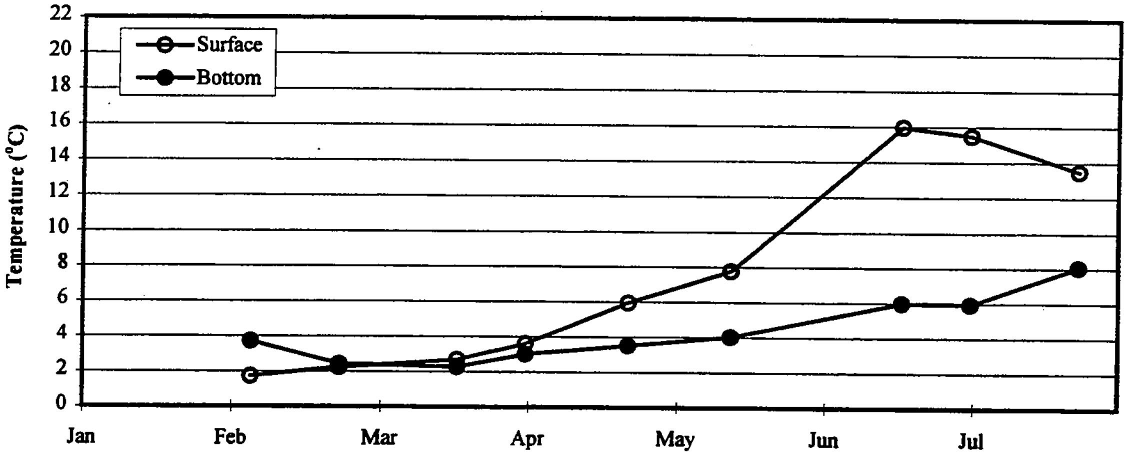


FIGURE 4-12
Salinity (PSU) Contours Along the Nearfield Transect During February-March

(a) Inner Nearfield: N10, N11



(b) Broad Sound: N01



(c) Outer Nearfield: N04, N07, N16, N20

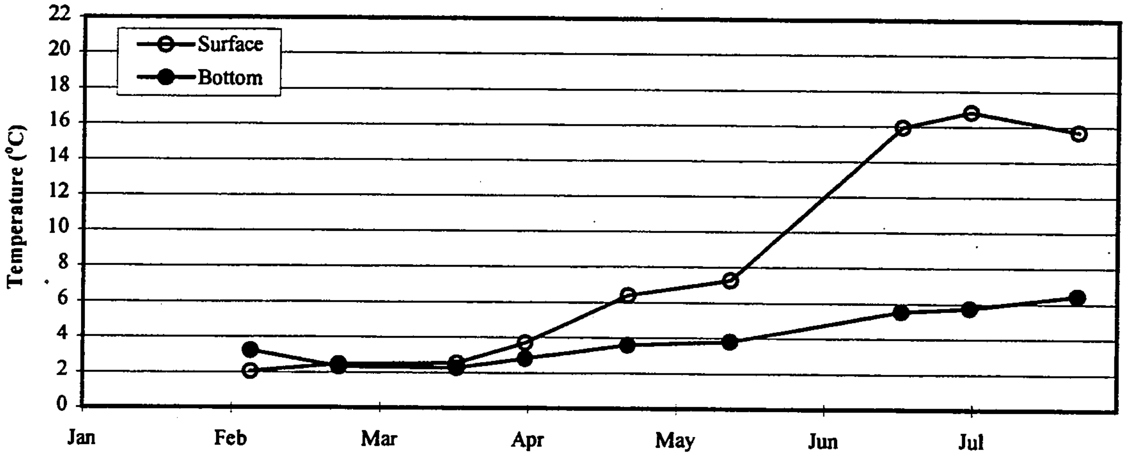


FIGURE 4-13

Time-Series of Average Surface and Bottom Water Temperature (°C) in the Nearfield

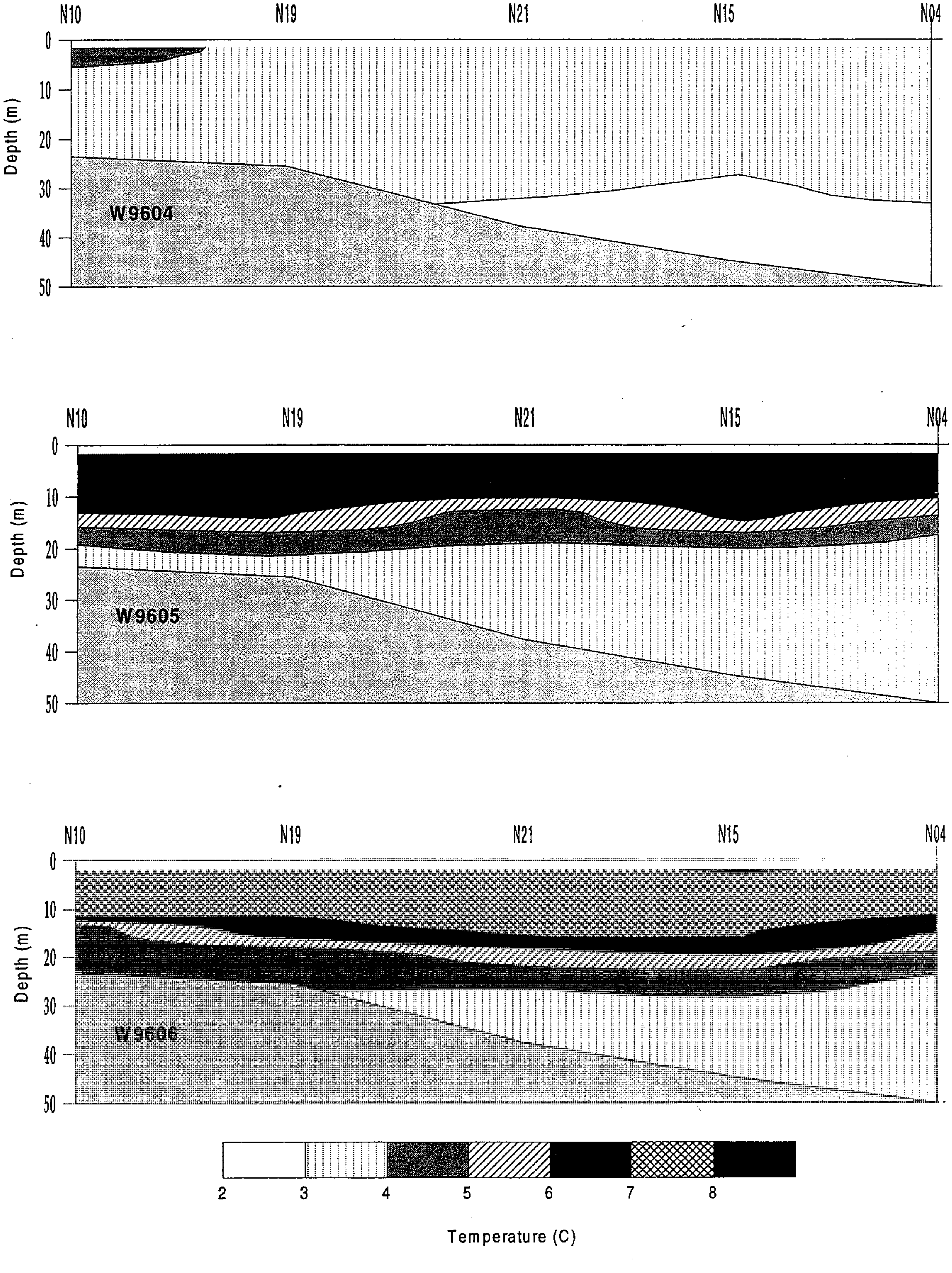


FIGURE 4-14
Temperature (°C) Contours Along the Nearfield Transect During April-May

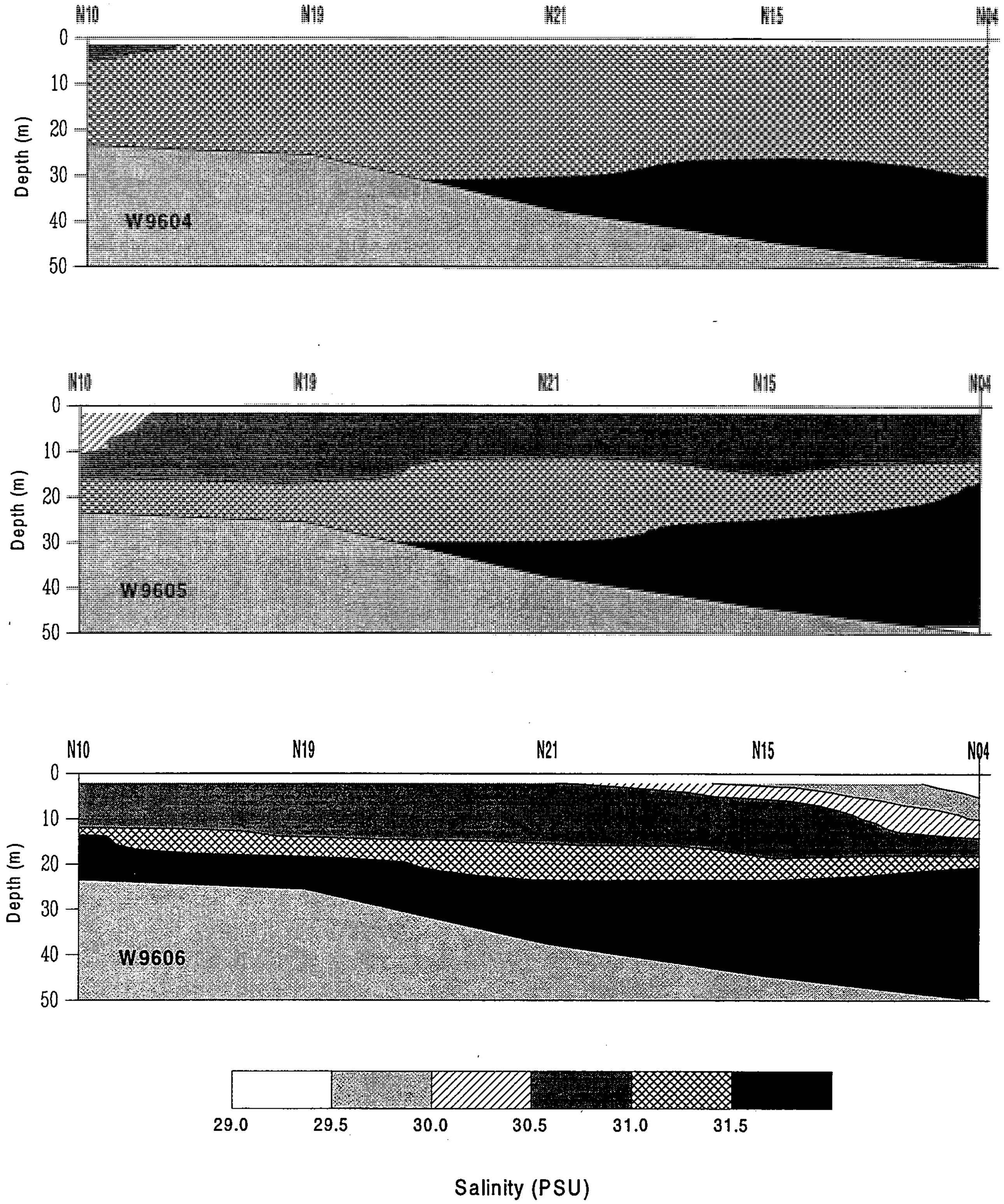


FIGURE 4-15
Salinity (PSU) Contours Along the Nearfield Transect During April-May

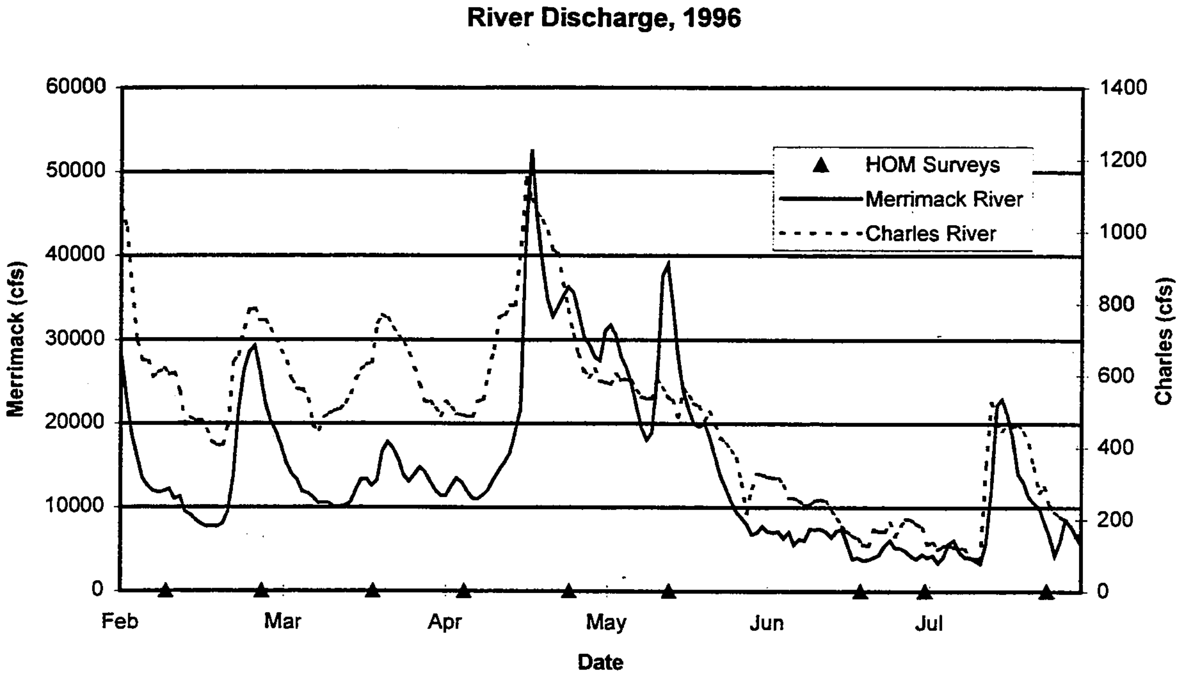


FIGURE 4-16
River Discharge from the Merrimack and Charles Rivers

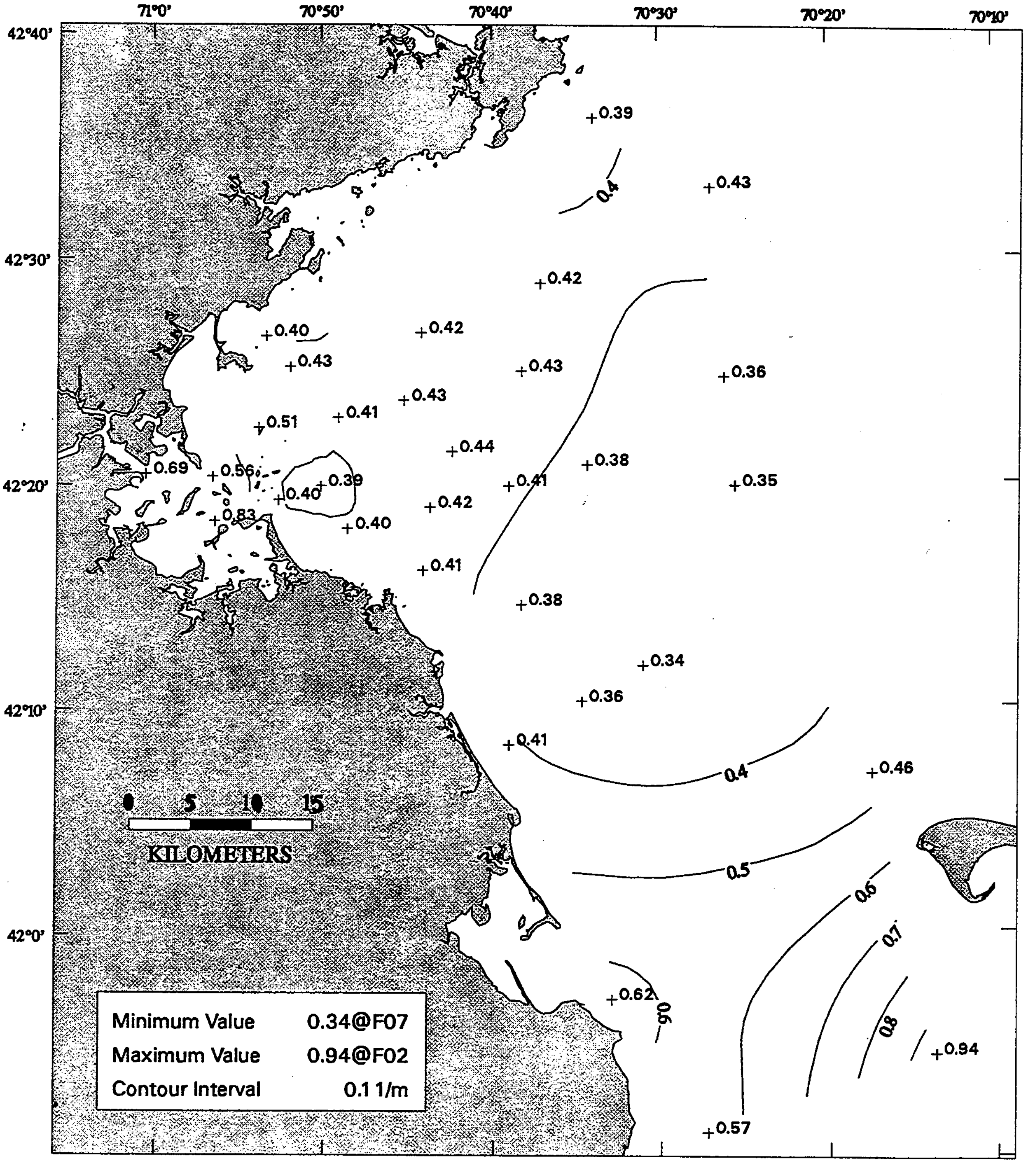


FIGURE 4-17
Surface Water Contour Plot of Beam Attenuation (/m) in Early February (W9601)

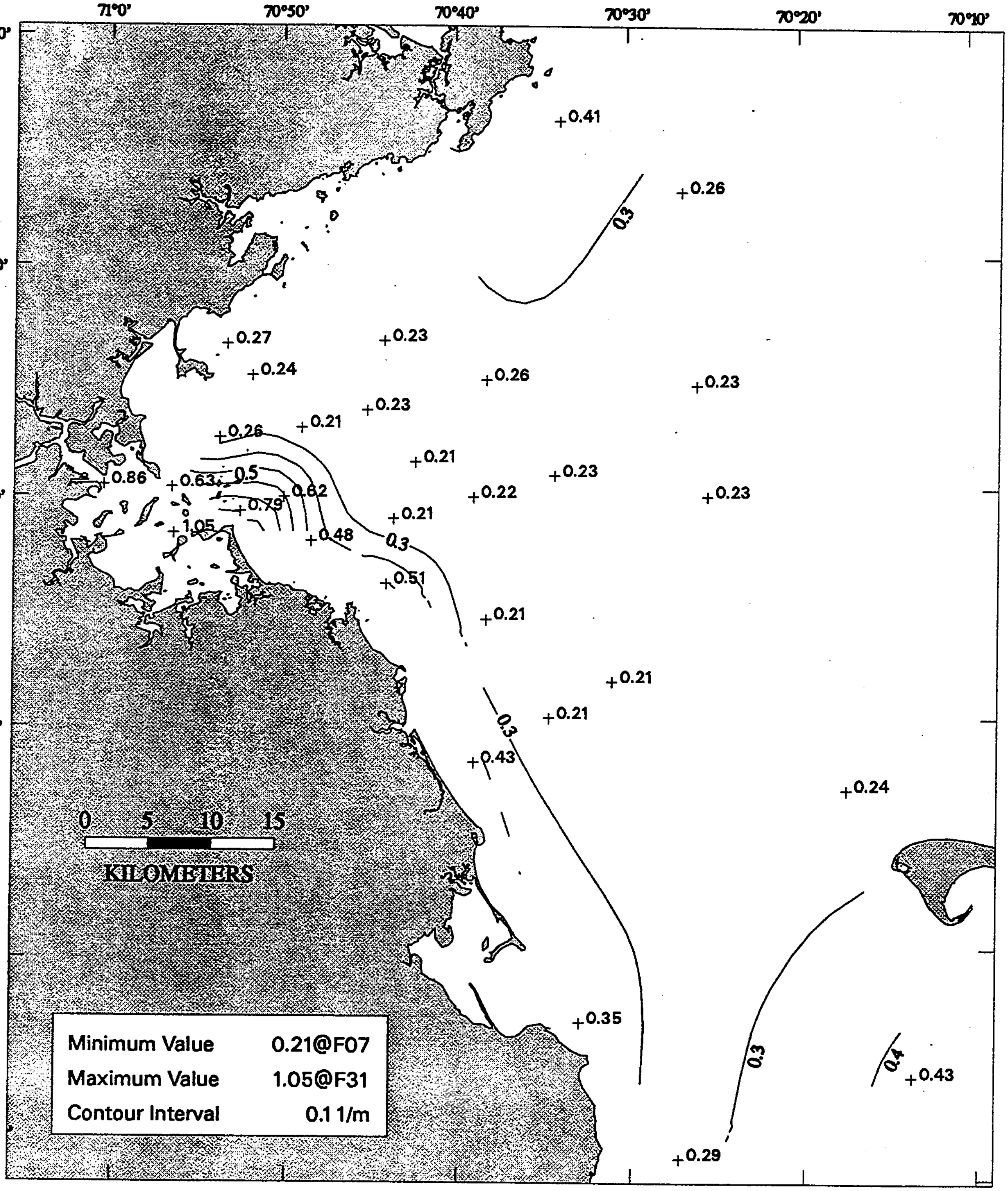
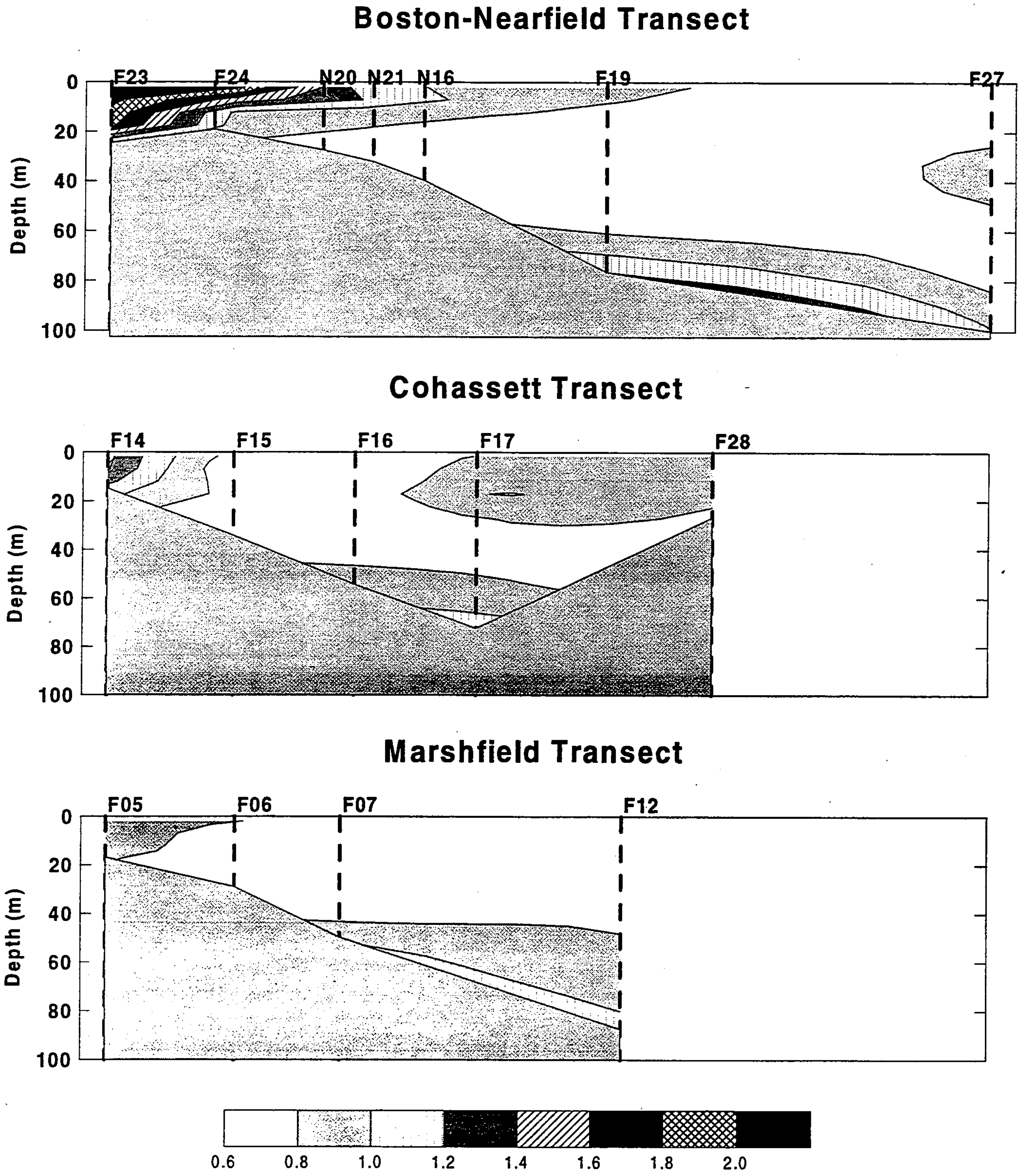


FIGURE 4-18
Surface Water Contour Plot of Beam Attenuation (/m) in Early April (W9604)


Boston-Nearfield Transect

Cohassett Transect

Marshfield Transect

FIGURE 4-19
Beam Attenuation (/m) Contours Along Three Farfield Transects in June (W9607)

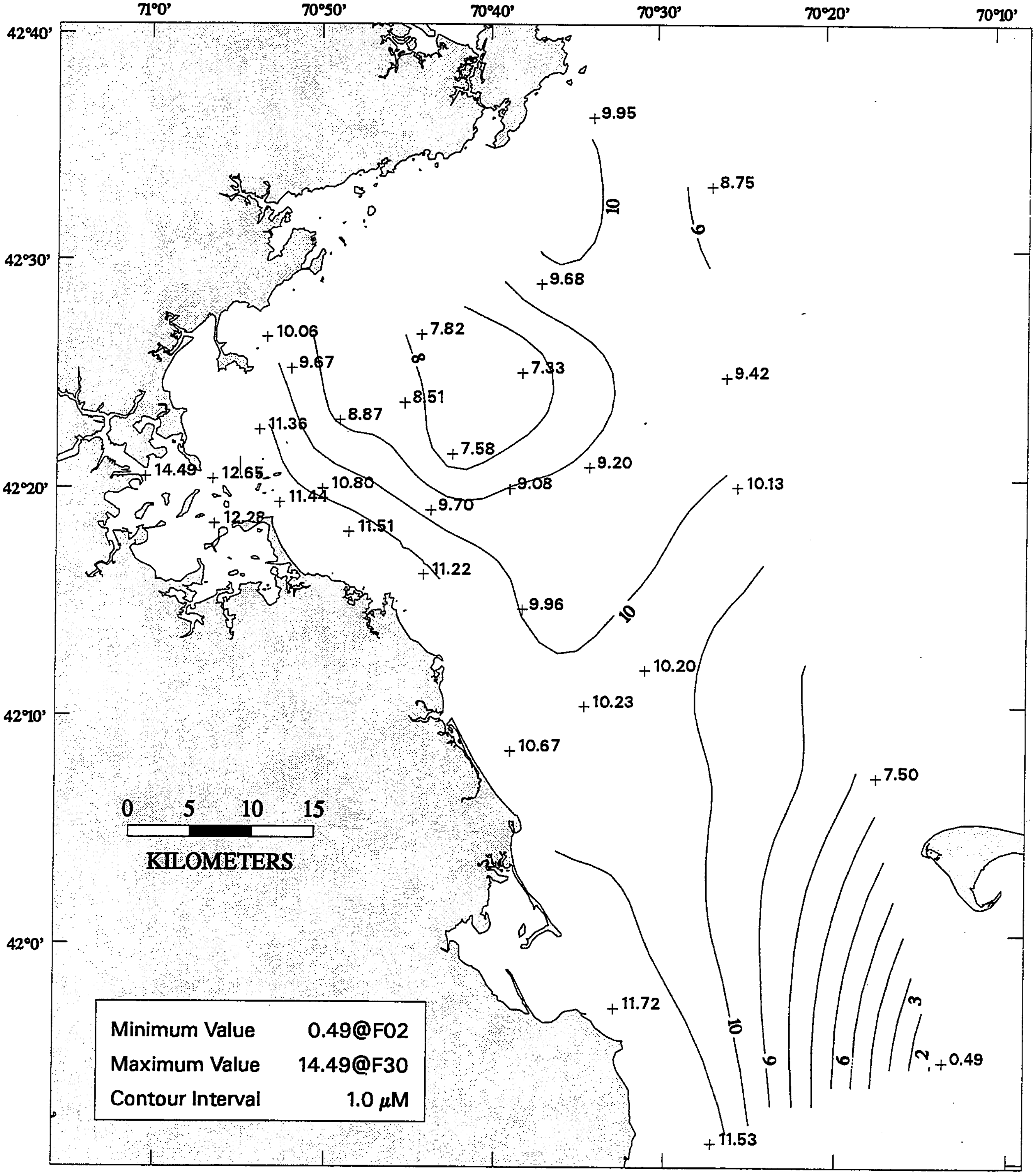


FIGURE 4-20
Surface Water Contour Plot of Nitrate (µM) in Early February (W9601)

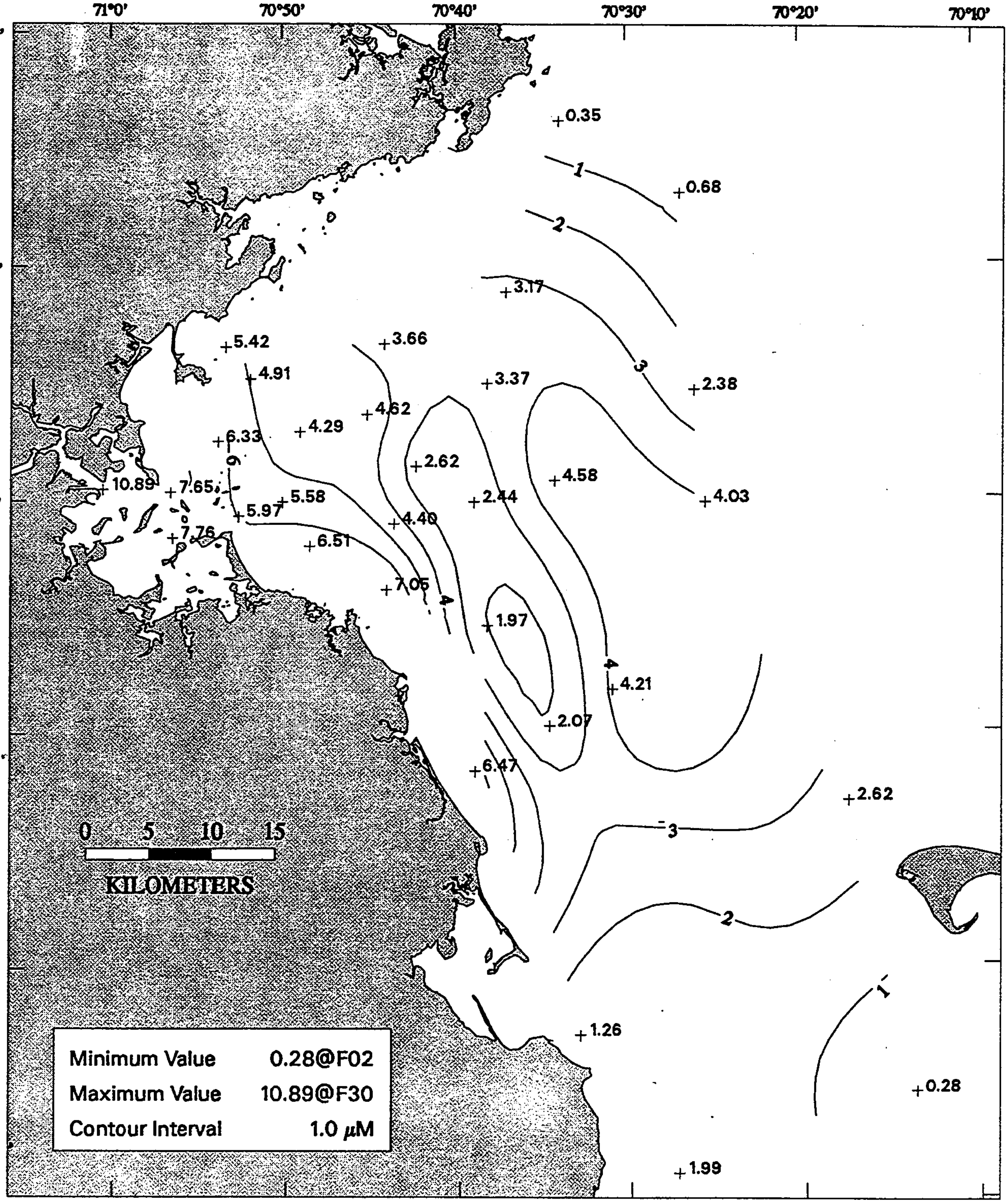


FIGURE 4-21
Surface Water Contour Plot of Nitrate (μM) in Late February (W9602)

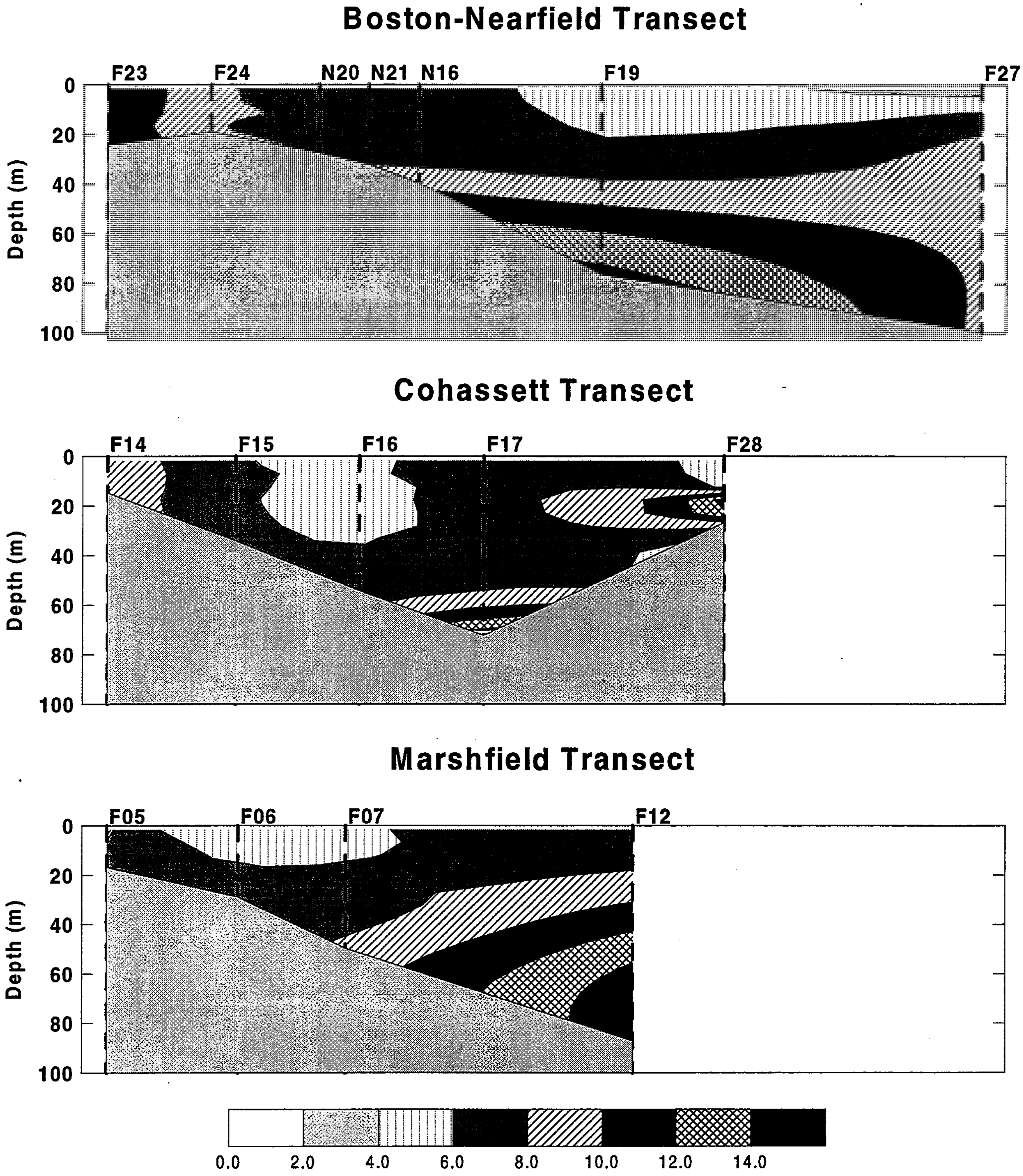
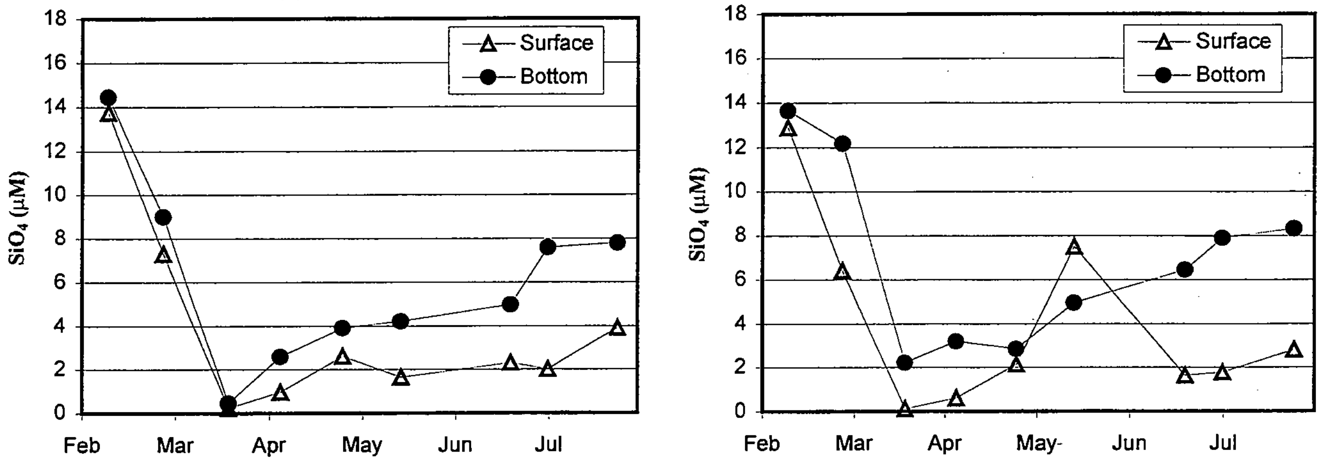
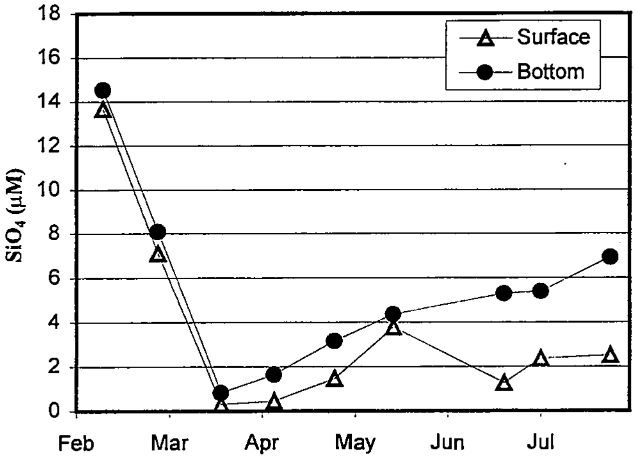


FIGURE 4-22
Silicate Concentration (μM) Contours Along Three Farfield Transects in Late February (W9601)

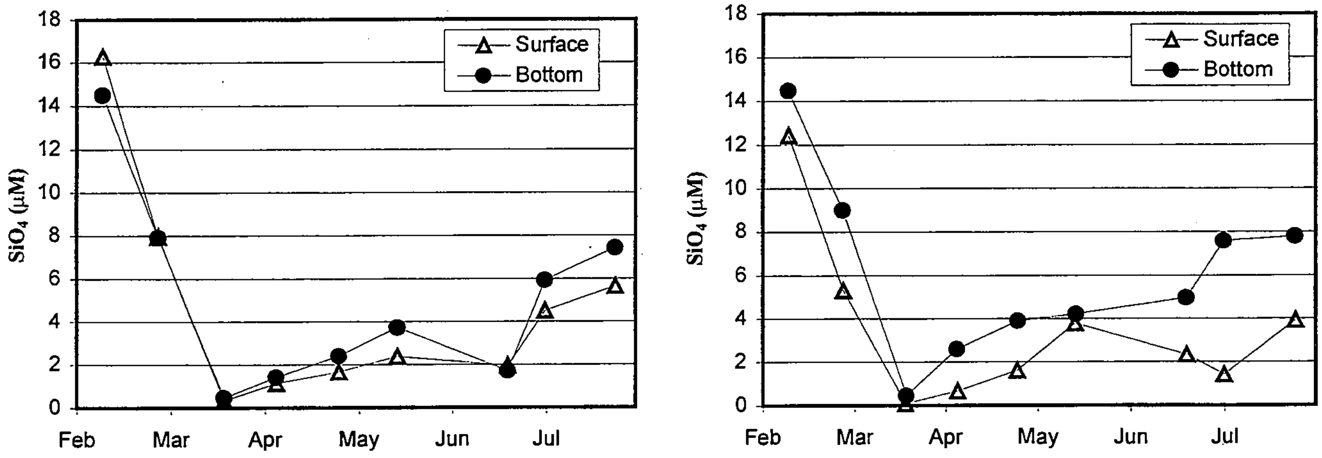


(a) Station N01

(b) Station N04



(c) Station N21



(d) Station N10

(e) Station N07

FIGURE 4-23

Time-Series of Surface and Bottom Water Silicate Concentration at Five Nearfield Stations

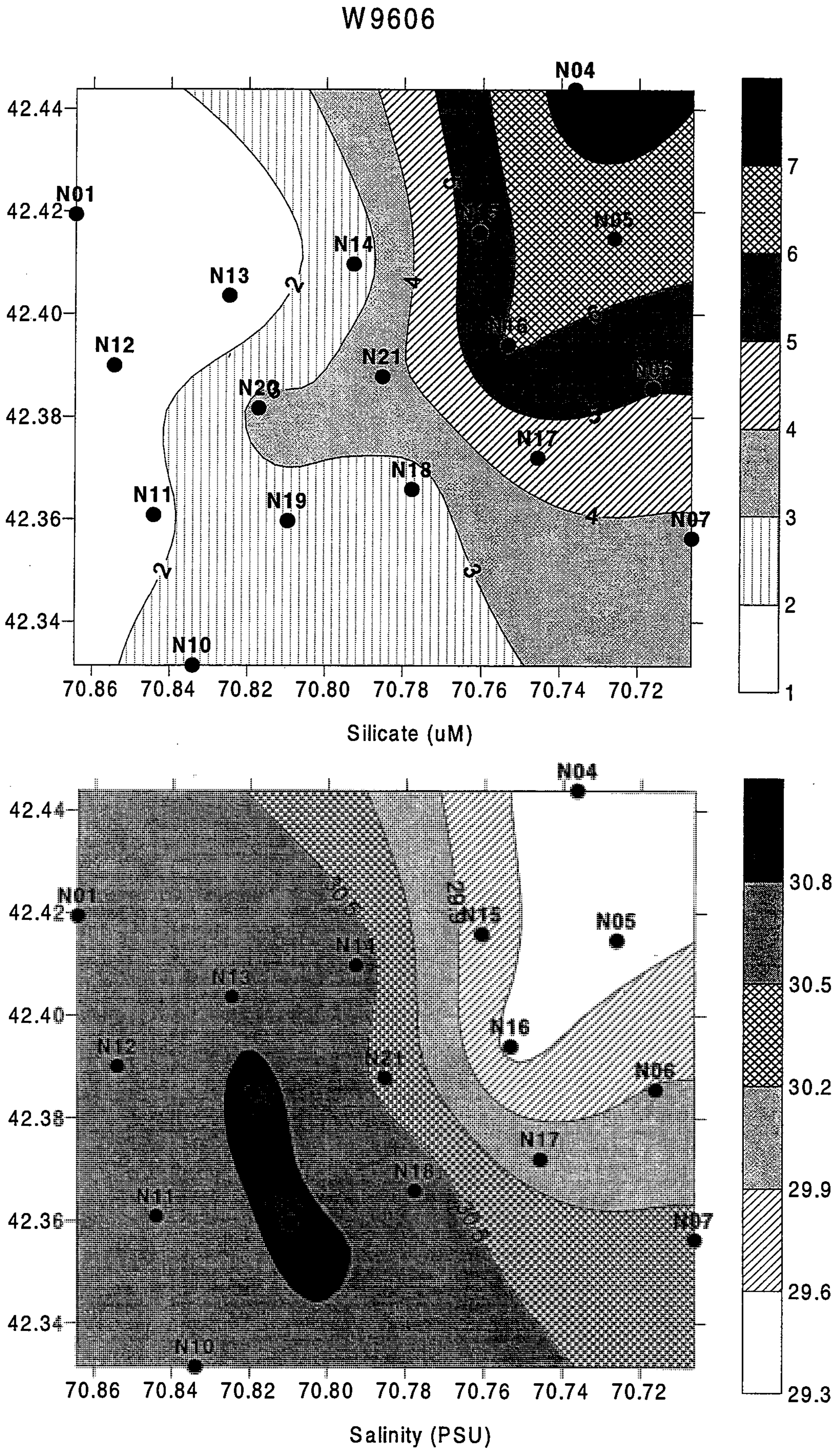


FIGURE 4-24

Surface Water Distribution of Silicate (top) and Salinity in the Nearfield in May

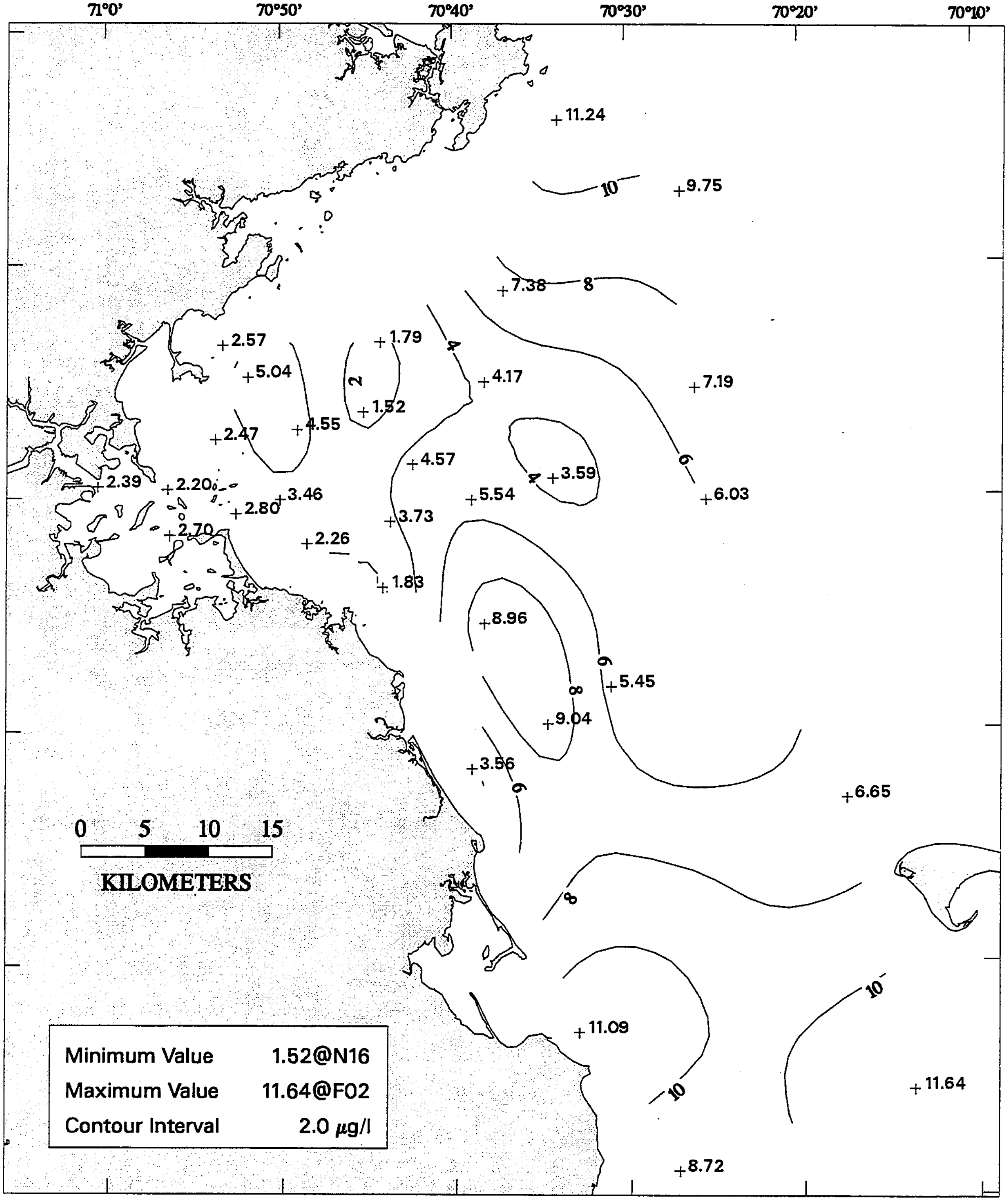


FIGURE 4-25

Surface Water Contour Plot of Chlorophyll *a* (µg/L) in Late February (W9602)

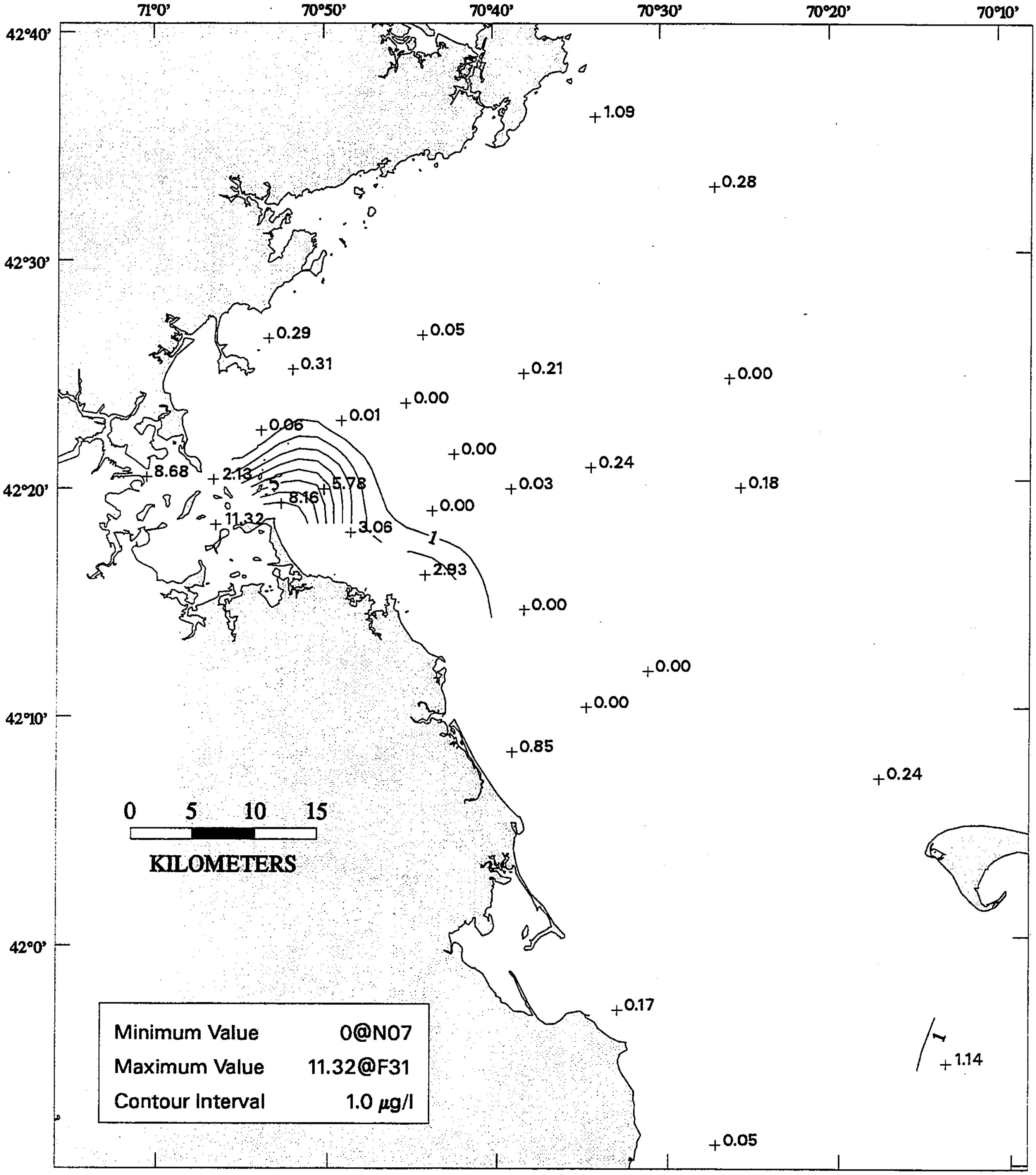
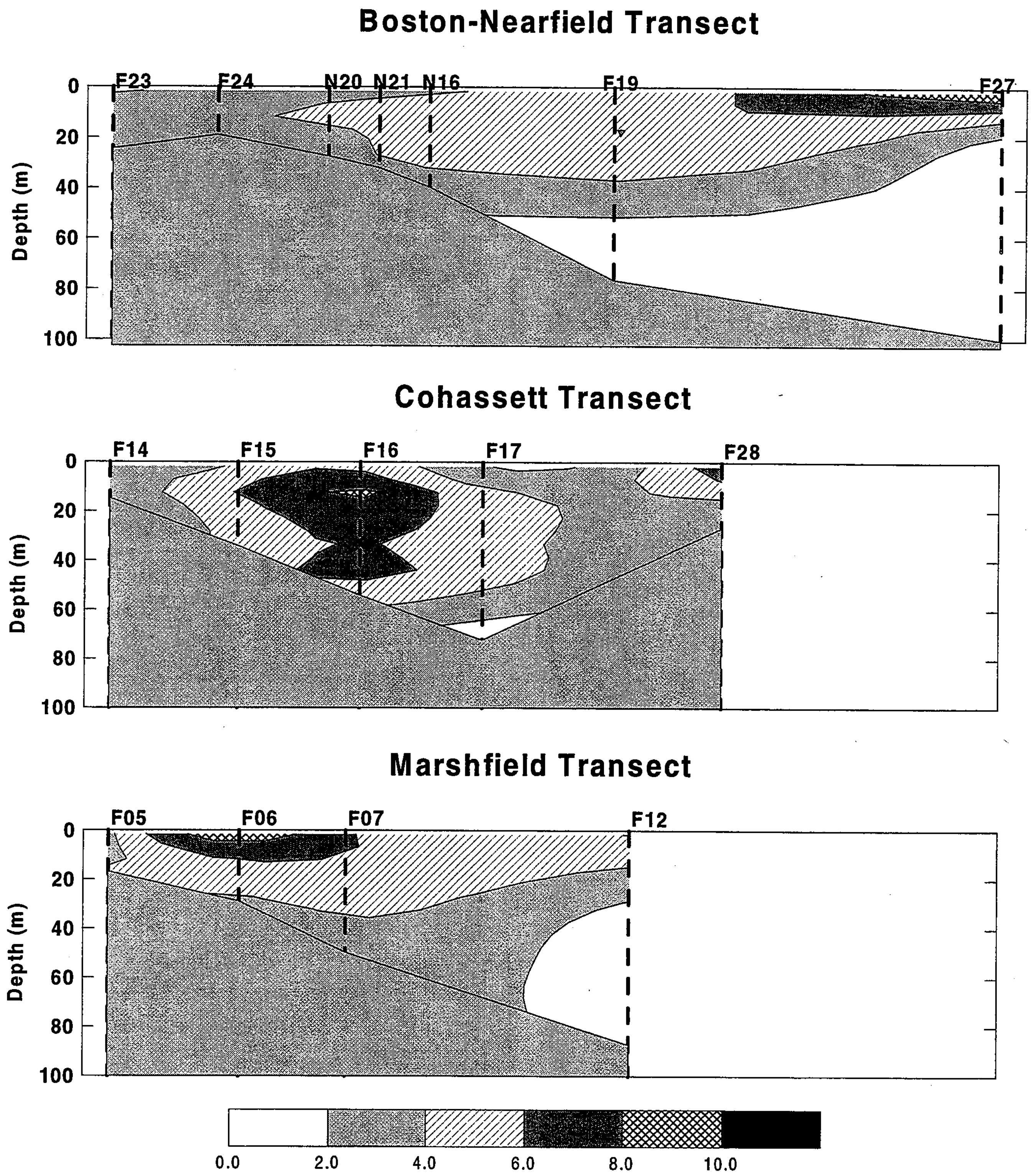


FIGURE 4-26
Surface Water Contour Plot of Chlorophyll *a* (µg/L) in Early April (W9604)


Boston-Nearfield Transect

Cohassett Transect

Marshfield Transect

FIGURE 4-27
Chlorophyll *a* (µg/L) Contours Along Three Farfield Transects in Late February (W9602)

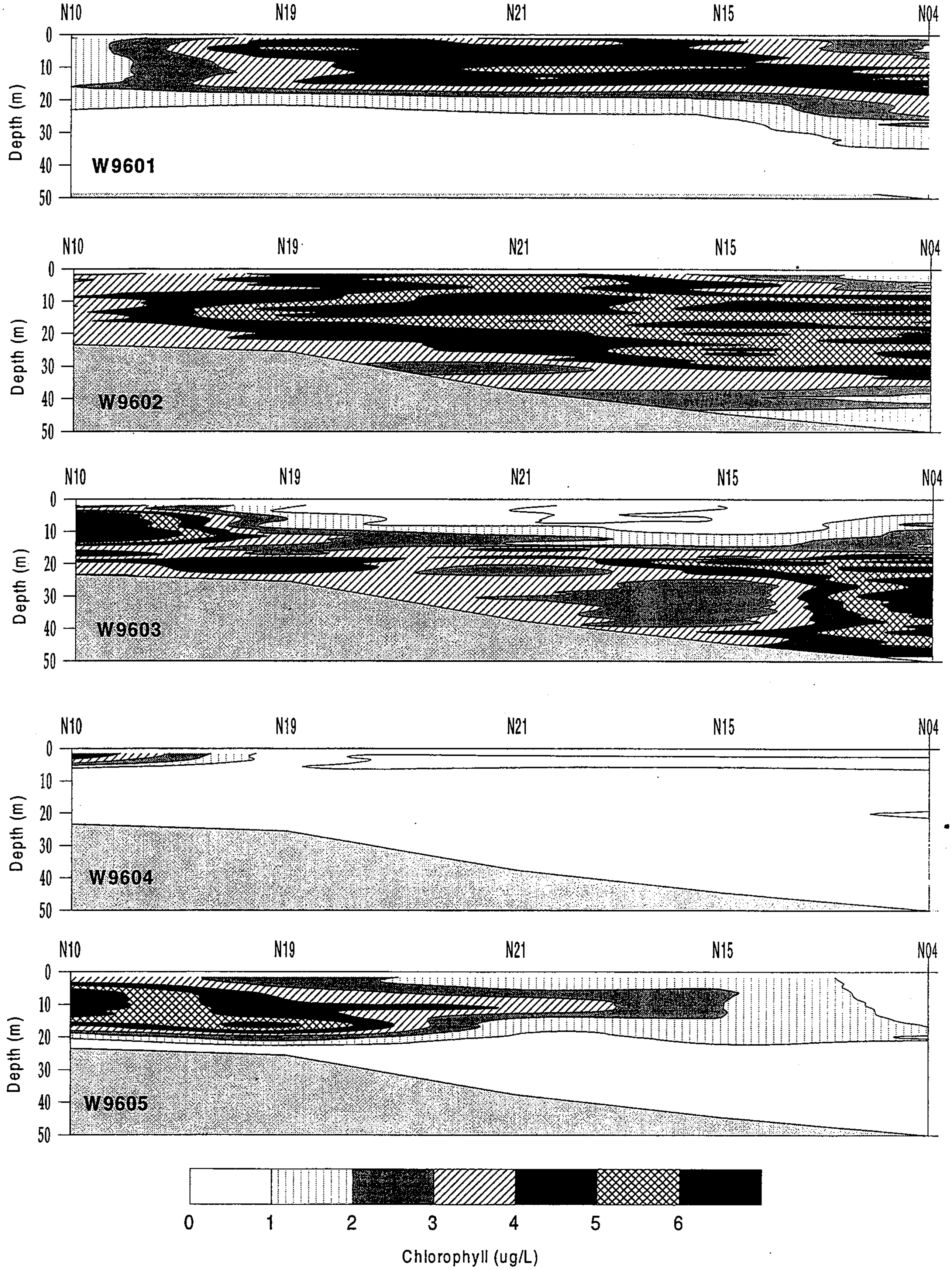


FIGURE 4-28

Chlorophyll *a* (µg/L) Contours Along the Nearfield Transect During the First Five Nearfield Surveys

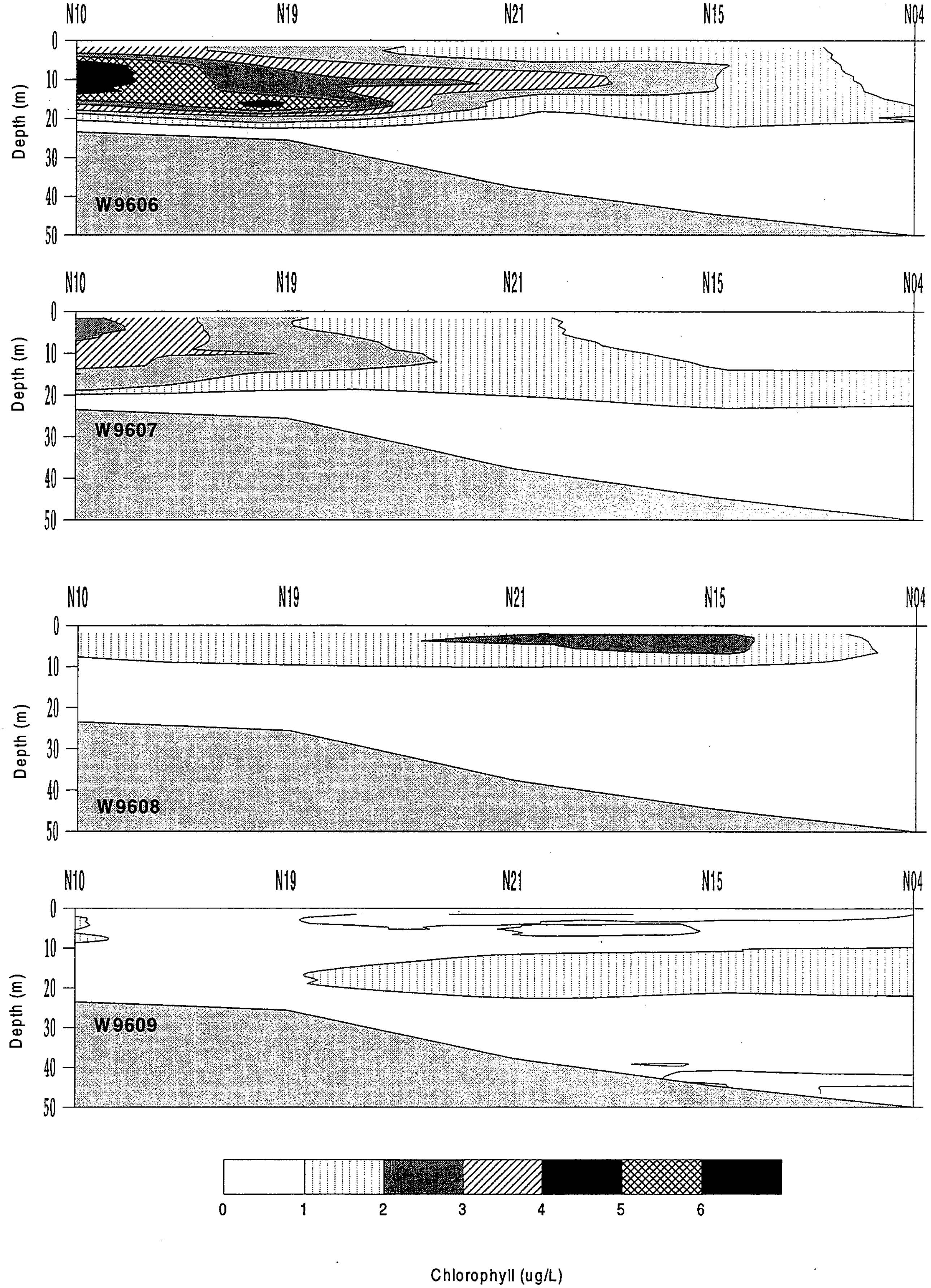
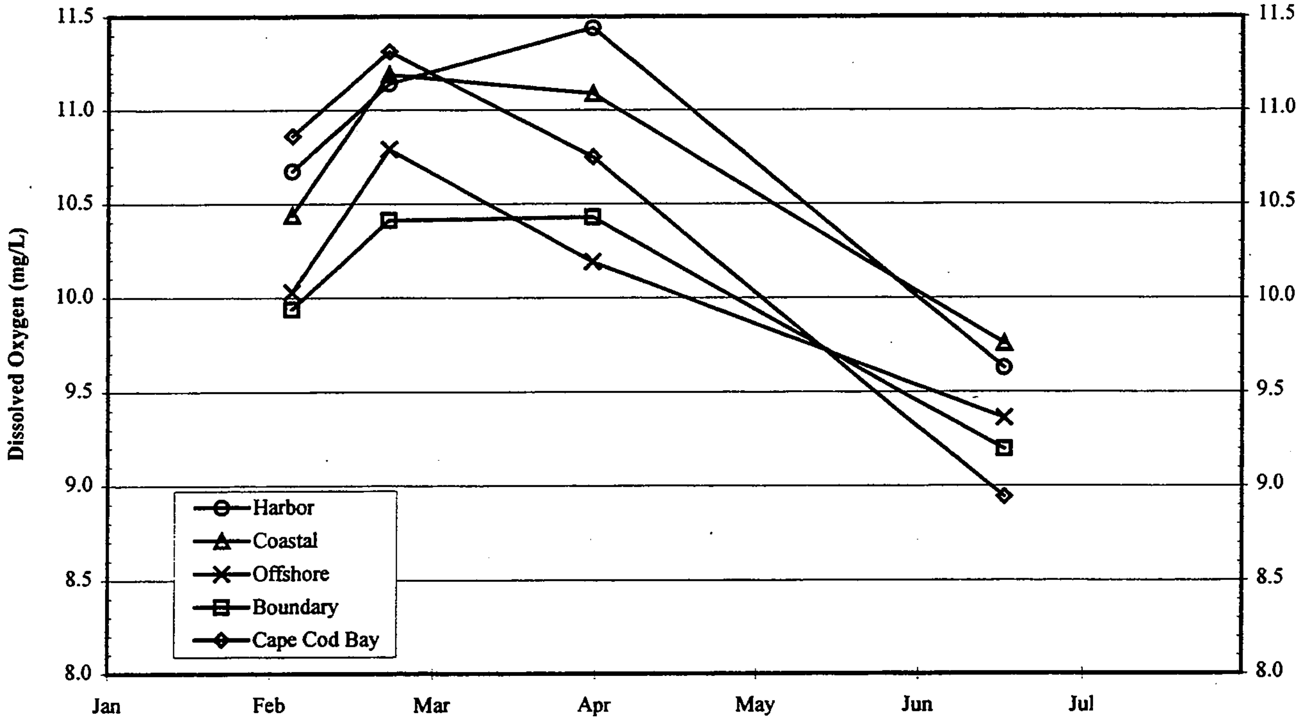


FIGURE 4-29
Chlorophyll *a* (µg/L) Contours Along the Nearfield Transect During the Final Four Nearfield Surveys

(a) Dissolved Oxygen Concentration



(b) Dissolved Oxygen Percent Saturation

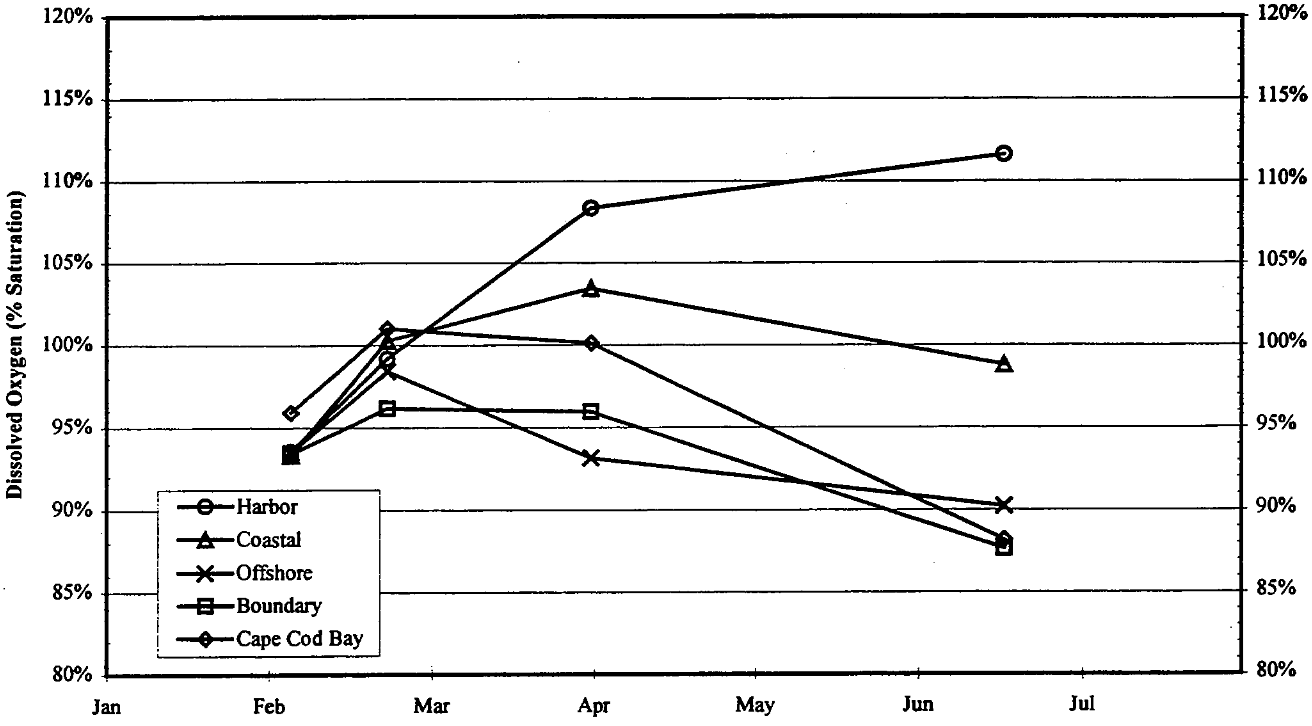


FIGURE 4-30

Time-Series of Average Bottom Water Dissolved Oxygen Concentration (mg/L) and Saturation (%) in the Farfield

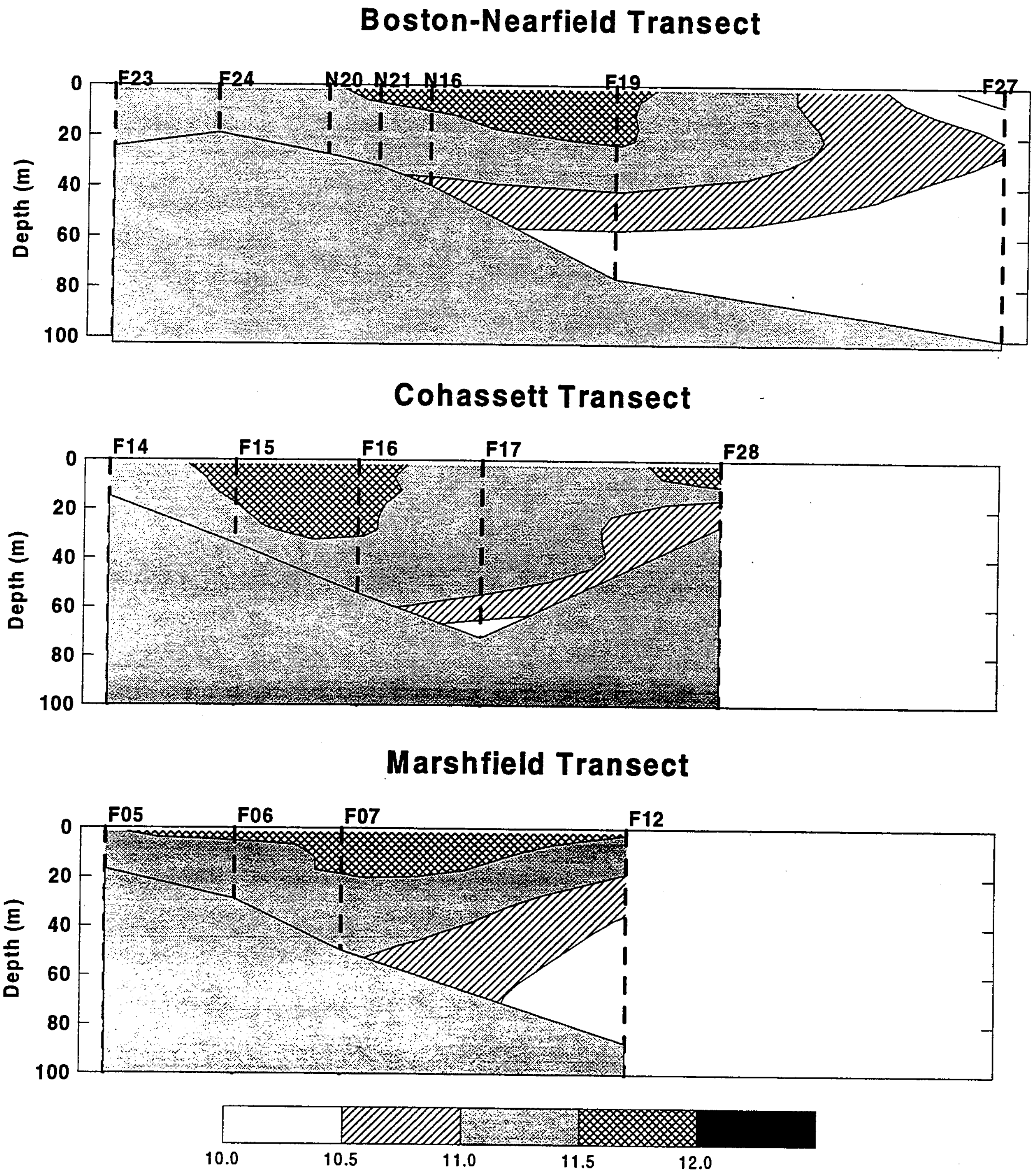
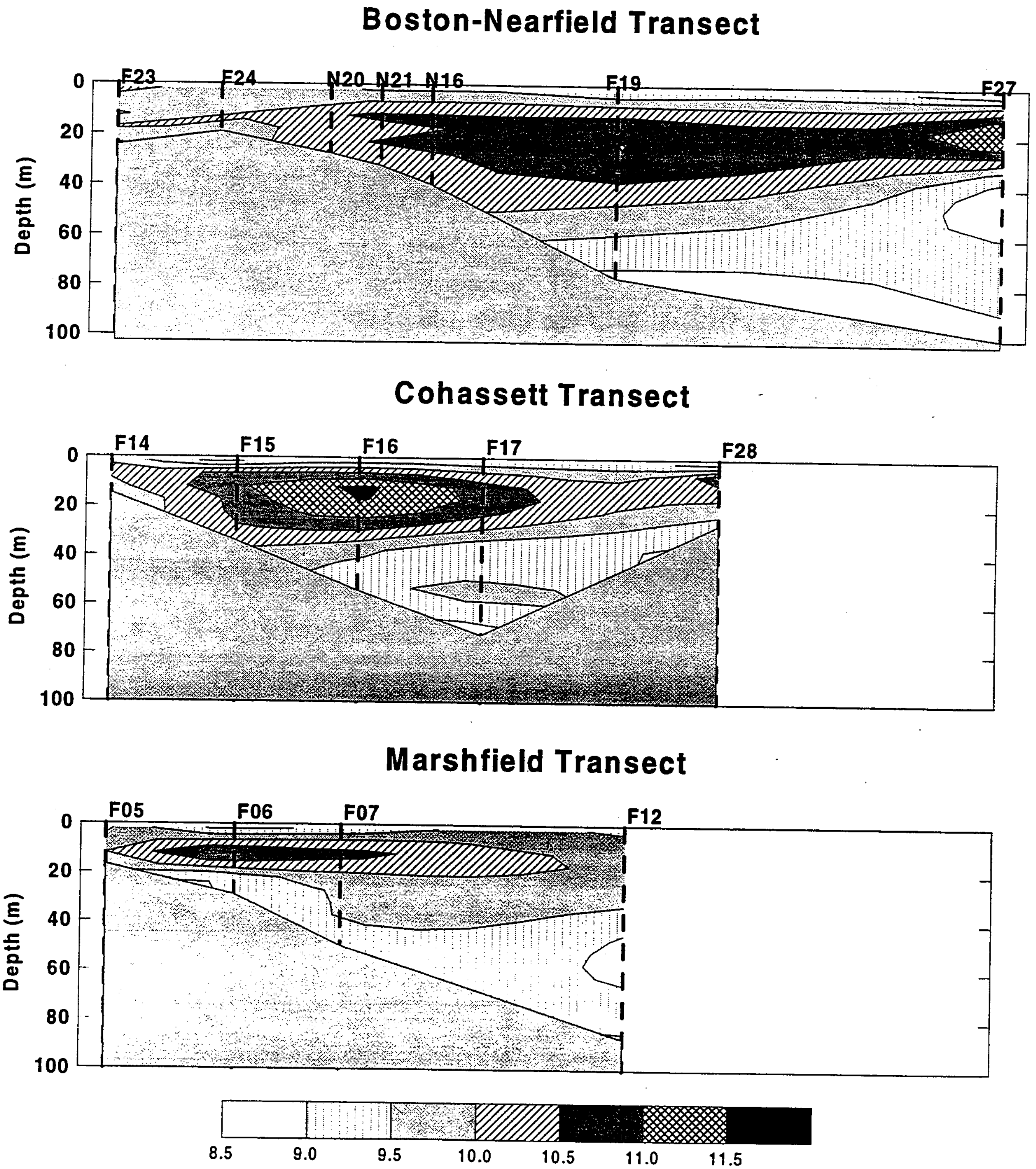


FIGURE 4-31
Dissolved Oxygen Concentration (mg/L) Contours Along Three Farfield Transects in Late February (W9601)

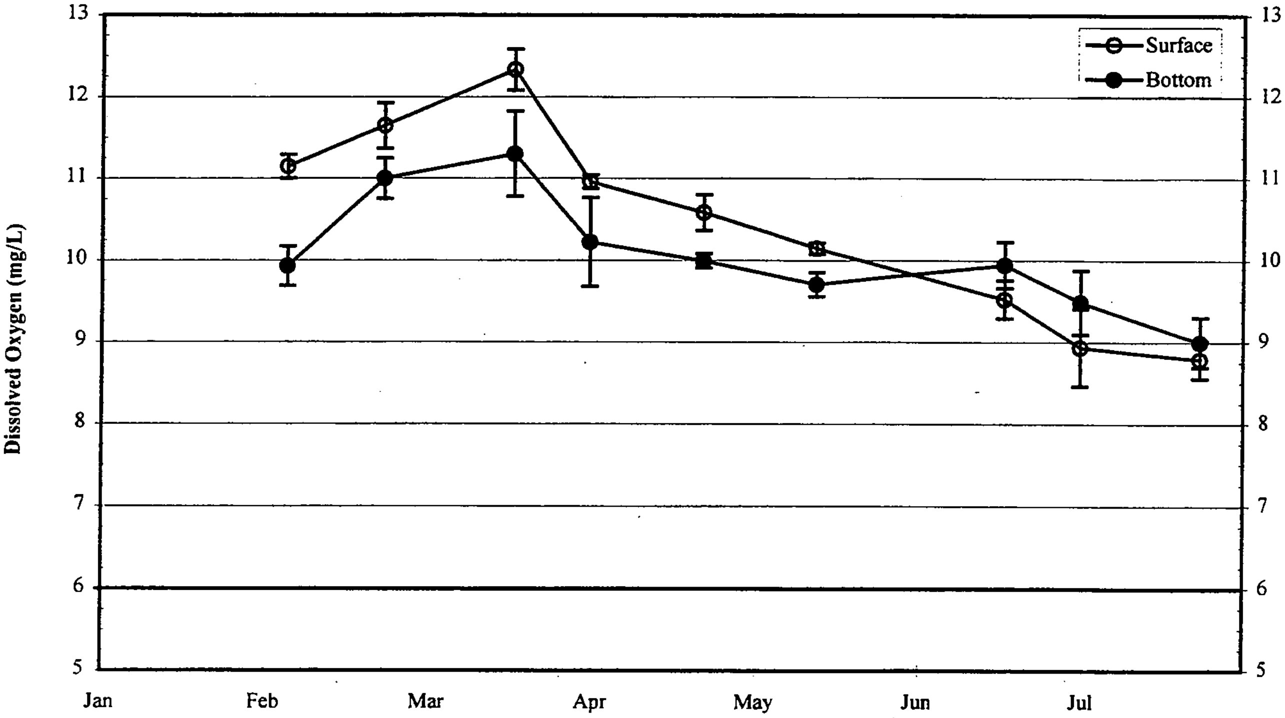


Boston-Nearfield Transect

Cohassett Transect

Marshfield Transect

FIGURE 4-32
Dissolved Oxygen Concentration (mg/L) Contours Along Three Farfield Transects in June (W9607)


(a) Dissolved Oxygen Concentration

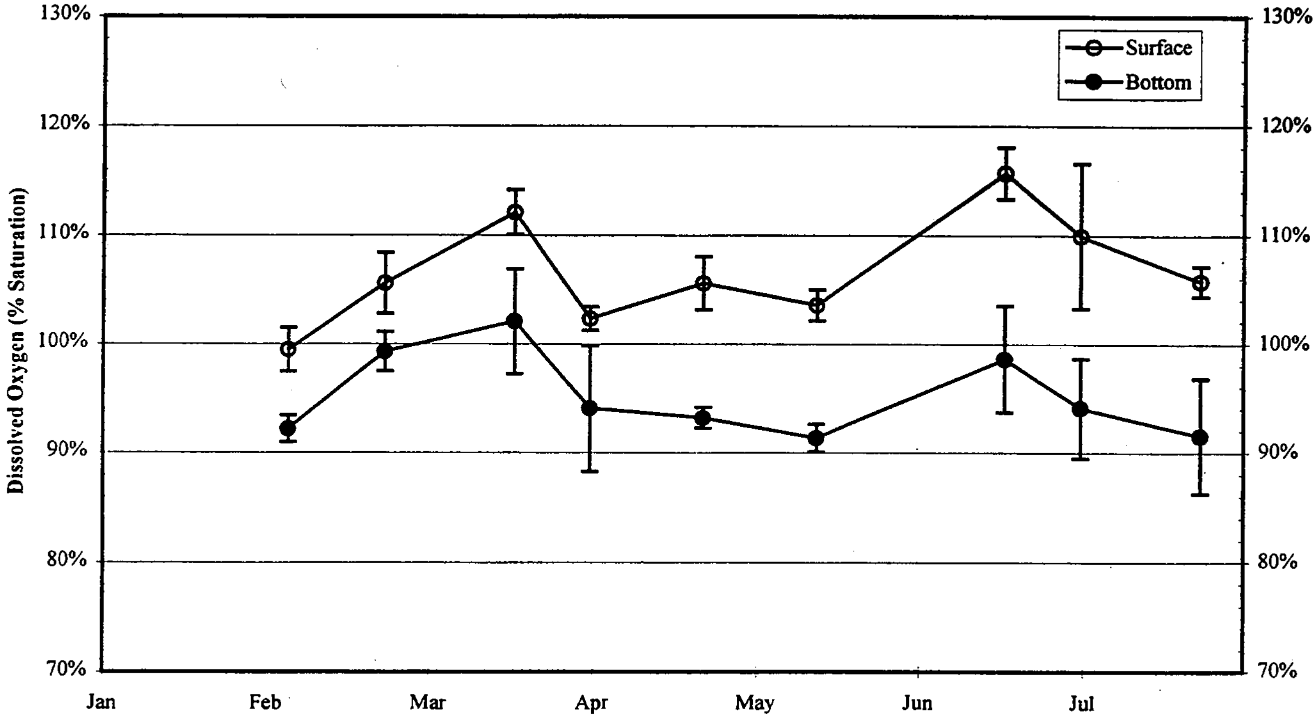

(b) Dissolved Oxygen Percent Saturation

FIGURE 4-33

Time-Series Average of Surface and Bottom Water Dissolved Oxygen Concentration (mg/L) and Saturation (%) Among all Nearfield Stations

5.0 PRODUCTIVITY, RESPIRATION, AND PLANKTON RESULTS

5.1 Productivity

Production measurements were taken at three nearfield stations (N04, N10, N16) and one farfield station (F23), at the entrance to Boston Harbor. All stations were sampled during the four farfield surveys conducted during this semi-annual reporting period; additionally, N04 and N10 were sampled during all nine nearfield surveys during the period. Samples were collected at five depths throughout the euphotic zone. Production was determined by measuring ^{14}C uptake at varying light intensities as summarized below and in Appendix A.

In addition to samples collected from the water column, productivity calculations also utilized light attenuation data from a CTD-mounted 4π sensor, and incident light time-series data from an on-deck 2π irradiance sensor. Upon collection of the productivity samples and addition of ^{14}C-bicarbonate, they were incubated in a temperature-controlled incubator. The resulting photosynthesis versus light intensity (P-I) curves (Figure 5-1 and comprehensively in Appendix E), were used, in combination with ambient light attenuation and incident light data, to calculate hourly production for each sampling depth for determination of daily areal rates of phytoplankton productivity.

For this semi-annual report, areal production ($mgCm^{-2}d^{-1}$) is presented, determined by integrating the measured productivity over the depth interval. In addition, calibrated chlorophyll *a* sensor data were used to normalize daily productivity (provided for each of five water depths) for calculation of chlorophyll-specific production, a measurement of the efficiency of production and physiological status of the phytoplankton population.

5.1.1 Areal Production

Measured areal production during the first semi-annual period was indicative of the different conditions affecting productivity between the harbor (station F23) and harbor-influenced (station N10) regions, and the nearfield, represented by stations N04 and N16. In the nearfield, areal production peaked during the second winter survey in late February (W9602). The spring bloom appeared to be completed by April (W9604), with lower productivity levels typical of nutrient-depleted summer conditions extending into June. In and near the harbor, the seasonal increase in productivity did not diminish concurrently with the more offshore locations, but continued to show high rates of production through July.

In the nearfield, areal production was relatively high (>1,000 $mgCm^{-2}d^{-1}$) during the first regional survey (W9601) at N04 and N16, and then reached semi-annual nearfield maximum concentrations of approximately 3,000 $mgCm^{2}d^{-1}$ during the winter bloom in late February (Figure 5-2). Productivity then declined to the semi-annual minima measured at these stations (<100 $mgCm^{-2}d^{-1}$) in April (W9604). As measured at station N04 during the nearfield surveys, productivity remained relatively low throughout April, May, and June (486-620 $mgCm^{-2}d^{-1}$).

During the first July survey (W9608), productivity results from N04 increased again to 1,833 $mgCm^{-2}d^{-1}$, although chlorophyll was low in the outer nearfield surface water (Figure 4-29). In late July (W9609), areal productivity decreased slightly (1,159 $mgCm^{-2}d^{-1}$). The cause of the observed increase in early July is being examined further, however, it is similar to the July 1995 event which was caused by an influx of subpycnocline nutrients into the euphotic zone.

Boston Harbor data showed a different pattern of productivity relative to the nearfield, and were more consistent with chlorophyll measurements made in the Harbor Studies Program (Section 4.3). As measured at F23 during the four farfield surveys, areal productivity increased from a seasonal low in early February (216 $mgCm^{-2}d^{-1}$), to higher values in April (2,536 $mgCm^{-2}d^{-1}$), to the semi-annual maximum areal productivity value among all of the monitoring stations in June (5,203 $mgCm^{-2}d^{-1}$; Figure 5-2).
Station N10 was sampled during all nine nearfield surveys, with results showing a sawtooth pattern of episodic periods of productivity. As was seen at F23, the semi-annual minimum at N10 (369 $mgCm^{-2}d^{-1}$) occurred in early February (W9601). Areal production increased to 2,771 $mgCm^{-2}d^{-1}$ in March (W9603). Throughout the spring, measurements of areal production shifted between values of approximately 1,000 $mgCm^{-2}d^{-1}$ in early April (W9604) and May (W9606), to a station high value of 5,053 $mgCm^{-2}d^{-1}$ during the harbor spring bloom in late April (W9605), and 4,455 $mgCm^{-2}d^{-1}$ in June (W9607).

5.1.2 Chlorophyll-Specific Production

In order to compare production with chlorophyll concentrations, chlorophyll-specific production (daily production normalized to average chlorophyll concentrations over the water column) values were calculated. The spatial and temporal distribution of production and chlorophyll-specific production on a volumetric basis was summarized by showing contoured production through the first nine surveys of 1996, along with the depths of the samples collected and processed (Figures 5-3 and 5-4).

Daily production during the second survey (W9602) conducted in February was focused in the surface water of the outer nearfield stations N04 and N16 (Figure 5-3), consistent with the winter bloom characterized in the chlorophyll and nutrient data. Chlorophyll-specific production was slightly higher at N04 (Figure 5-4). The summer period in the outer nearfield, especially at N04 (because of the higher temporal resolution), showed that daily production was almost as high as during the early winter bloom. Station N04 had very high chlorophyll-specific production throughout the summer in the upper water column (Figure 5-4), indicative of a physiologically active (but nutrient-deprived) phytoplankton assemblage.

Chlorophyll-specific production is an estimate of the efficiency of photosynthesis. The distribution of chlorophyll-specific production indicates that during the summer, the efficiency of production was high relative to the amount of biomass present (as measured by total chlorophyll *a*) in the outer nearfield. At the outer nearfield station N04, chlorophyll-specific production was almost 500 mgC/mgchl*a*/d during the early July survey (W9608). Despite the low chlorophyll biomass in the water column during the summer, supporting monitoring data contain evidence for high summer productivity. Plankton data from the early July survey, for example, indicated that diatom organic carbon (as measured by estimated carbon equivalence) actually exceeded estimates made during the spring bloom (see Section 5.3, Figure 5-13). Both particulate organic carbon and respiration data also indicated high productivity in the surface water (Section 5.2). The low concentration of chlorophyll in the nearfield water column during the early July survey was likely a result of grazing by the zooplankton population.

The high chlorophyll-specific production may also have been an indication of the onset of a bloom. Available data from the WETLabs spectrophotometer, located at a depth of 6 meters on the USGS mooring near N18, indicated that chlorophyll concentrations tripled during the week following survey W9608 (Figure 5-5a). The localized diatom bloom captured at the surface of N04 during W9608 (Section 5.3) may have been responsible for the surface chlorophyll maximum shown in Figure 4-29 for W9608. The WETLabs data would also suggest that the surface bloom developed throughout the surface mixed layer since the week-long peak in concentration was also documented in the 13.5 meter sensor (Figure 5-5b). This sequence is reminiscent of productivity measurements taken during 1995 which indicated the onset of a bloom between survey dates (Cibik *et al*, 1996). The WETLabs data also documented a brief but strong increase in chlorophyll concentrations concurrent with the June survey (W9607), consistent with the increase in productivity seen at N16 and N10 during that period.

At stations F23 and the harbor-influenced station N10, daily production increased early, then remained relatively high throughout the semi-annual period (Figure 5-3). Chlorophyll-specific production showed continuous increase throughout the period. During the summer at station N10, chlorophyll-specific production was approximately 300 mgC/mgchl*a*/d for all three summer surveys (Figure 5-4). Because the harbor was vertically well-mixed and nutrient replete throughout the summer, productivity continued to increase through the summer with increasing light levels.

5.2 Respiration

Respiration was measured at the same three nearfield stations (N04, N10, and N16) and one harbor station (F23) as productivity, as well as at farfield station F19, in Stellwagen Basin (Figure 1-2). All stations were sampled during the four farfield surveys; additionally, N04 and N10 were sampled during all nine nearfield surveys during the first semi-annual period of 1996. Measurements were made on samples collected at three depths (surface, mid-water, and bottom). Samples were incubated without light and at *in situ* temperatures. Bottom water respiration measurements were also obtained at station F19 during the first three benthic flux surveys (March, May, and July). These data will be presented in the annual water column synthesis report.

Both respiration (in units of $\mu MO_2/hr$) and carbon-specific respiration ($\mu MO_2/\mu MC/hr$) rates at the three sampled depths are presented here. Carbon-specific respiration was calculated by normalizing respiration rates to the total measured particulate organic carbon (POC) at each respiration depth. Carbon-specific respiration provides an indicator of how biologically available (labile) the POC substrate material is for microbial breakdown.

5.2.1 Water Column Respiration

Respiration rates during the winter and spring surveys (W9601-W9606) in 1996 were <0.15 $\mu MO_2/hr$ for all of the stations and depths measured (Figure 5-6). Generally a similarity of respiration rate in a well-mixed water column is expected because respiration is a temperature-dependent reaction, and also the lack of a pycnocline allows unrestricted flux of particulate organic carbon (POC) to the bottom waters. During the winter and spring of 1996, however, there was a slight difference between surface and bottom water respiration at several stations, likely due to a slight lag in delivery of POC to bottom water even during well-mixed conditions. At the Stellwagen Basin station F19, for example, the surface water was slightly higher, especially during the second February survey (W9602), indicating an effect from the late winter bloom on surface water respiration rates (Figure 5-6).

In the outer nearfield (stations N04, N16), a slight difference between surface and bottom water respiration rates was present throughout winter and spring, except during the third nearfield survey in March (W9603) at N04. During this survey, bottom and surface water respiration rates were equal. This is a result of increased respiration of sinking plankton from the late winter bloom, as discussed further below (Section 5.2.2). By the following survey in early April (W9604), the difference in surface and bottom water respiration began to be controlled by differential water temperature and the onset of stratification. It should be noted that respiration during the colder mixed periods temporally lags production. Respiration shows less temporal fluctuation than photosynthesis due to the less variable nature of its temperature - dependent rate (as opposed to the more variable light-dependent photosynthesis), and the buffering effect of detrital carbon.

Surface and bottom water respiration remained low until the first summer survey in June (W9607), when the surface water respiration increased by a factor of 2-3 at all stations except at F23, where rates increased by a factor of 6. The high surface water respiration indicated a source of respirable carbon, which potentially could have been supported by the observed production, despite the relatively low chlorophyll concentrations seen in the samples. However, elevated concentrations (peaking around 6 µg/L) were evident in the WETLabs sensor results (Figure 5-5), suggesting that a localized bloom may have occurred. The present outfall in Boston Harbor also provides a source of respirable carbon to F23 and N10. The zooplankton directly contribute to respiration through grazing by producing available substrate in the form of fecal material. The particulate organic carbon (POC) data are consistent with these results, and are further discussed in terms of carbon-specific respiration below (Section 5.2.2).

The final semi-annual survey in late July (W9609) showed a drop in surface water respiration (and carbon-specific respiration, Section 5.2.2), consistent with the observed decrease in productivity.

5.2.2 Carbon-Specific Respiration

Carbon-specific respiration normalizes microbial activity for variations in the size of the carbon pool. Differences in carbon-specific respiration result from variations in the quality of the available organic matter or from environmental conditions such as temperature. Sources of organic carbon which are more easily oxidized (i.e., recently produced phytoplankton) will result in higher carbon-specific respiration. Stratification produces lower carbon-specific respiration in bottom water due the lower water temperature and to the typically lower substrate quality caused by partial degradation during sinking.

POC results were plotted for the same stations and depths as respiration measurements (Figure 5-7). The highest semi-annual POC value measured at station N04 was actually in the bottom water during the March (W9603) survey (36 μM), which when integrated with the chlorophyll data indicates that this was a result of the sinking of the late winter bloom (Section 4.3). Respiration rates at N04 were equal in the surface, mid-, and bottom water, with the bottom water rate being the highest of the semi-annual period (Section 5.2.1). The carbon-specific respiration rate for bottom water was low, however (Figure 5-8), indicating that decomposition of the winter bloom was occurring during sinking.

POC results did not always correlate with chlorophyll results. For example, the early April combined farfield/nearfield survey (W9604) yielded the highest surface water POC concentrations for the semi-annual period at stations F23 (56 μM), N16 (36 μM), and N04 (29 μM). The fact that chlorophyll was low in the outer nearfield during the April survey makes interpretation of the source of POC to the surface water more difficult. The POC at F23 may have been related to the beginning of the harbor bloom in April. Carbon-specific respiration at these stations during early April, however, indicates that the source material was of low quality (Figure 5-8). It appears that the POC in surface water during this period was associated with degraded bloom material or possibly advected POC from coastal sources.

In June (W9607), a peak of POC in the surface water at station N10 (40 μM) was consistent with harbor-influenced chlorophyll production. Carbon-specific respiration was high at both F23 and N10, suggesting the presence of fresh POC production. Evidence for productivity at nearfield station N04 in early July (W9608) was corroborated by a peak in POC concentration and evidence of a diatom bloom (Section 5.3) in the surface water, as well as increased respiration and a relatively high carbon-specific respiration rate. The cumulative evidence suggests that, at nearfield station N04, early July was a productive period despite the lack of chlorophyll measured in the water column. It thus appears from these results that both the outer and inner nearfield are driven primarily by *in situ* processes, with the inner nearfield occasionally showing additional periodic coastal influence.

5.3 Plankton Results

The 1996 HOM Program included analysis of the plankton community in Boston Harbor, Massachusetts Bay, and Cape Cod Bay during 11 nearfield and six combined farfield surveys conducted from February to December. Two stations (N04 and N10) were occupied in the nearfield surveys, while an additional ten locations were sampled during the combined events (Figure 5-9). During 1996, station N16 continued to be sampled during the farfield segment of the combined events in lieu of a station revisit at one of the two nearfield stations. In this report, the first half of the 1996 plankton record is presented (surveys W9601 to W9609), including four of the six annual combined sampling events (W9601, W9602, W9604, and W9607). Comprehensive tabulations of results are available in periodic Plankton Data Reports.

Whole water and screened phytoplankton samples were collected at the surface and at mid-depth, with the latter often selected to coincide with the presence of a sub-surface chlorophyll maximum (as determined by *in vivo* fluorometry). Zooplankton samples were collected at each station by oblique tow. Details regarding sampling and analysis can be found in the Combined Work Plan/QAPP for water column monitoring (Bowen *et al.*, 1997). Quantitative taxonomic analyses and carbon equivalence estimates were made for the plankton communities using species-specific carbon data from the literature.

In this section, the plankton data are presented through an assessment of their seasonal and regional characteristics. Total abundance, relative abundance of major groups, and estimated carbon equivalence are presented for each plankton community. Nuisance algae issues are also addressed. Appendix F-1 tabulates dominant phytoplankton species (>5% of total abundance) for whole water surface samples, along with the associated cell densities and percent abundance. Appendix F-2 provides similar information for the mid-depth samples. Appendix G-1 and G-2 includes information for screened phytoplankton results, while Appendix H presents zooplankton results.

5.3.1 Phytoplankton

5.3.1.1 Seasonal Trends in Total Phytoplankton Abundance

Total phytoplankton abundance in nearfield whole water surface samples (averaged results) increased through early March (survey W9603, Figure 5-10a). Average nearfield densities diminished by late March (W9604), however, peak average surface densities for the reporting period occurred during mid-April (W9605). After the onset of stratification (late April), averaged nearfield densities stayed relatively low until a secondary peak occurred in late June (W9608). Patterns were similar in the mid-depth samples (Figure 5-10b), although the mid-depth peak seen during W9605 did not exceed that reported from W9603.

Cape Cod Bay had the highest regional densities in the first two combined events, both at the surface and mid-depth (Figure 5-10a and 5-10b). Samples from the harbor and coastal areas had the highest densities during the third combined event (late March, W9604). During the June combined event (W9607), harbor and coastal samples again were highest at the surface, but peak densities were noted in the mid-depth samples from the boundary and Cape Cod Bay samples.

5.3.1.2 Nearfield Phytoplankton Community Structure

Phytoplankton abundance and community composition at the three nearfield stations were plotted for surface (Figure 5-11) and mid-depth (Figure 5-12). Note that station N16 was only sampled during the four combined surveys conducted during the reporting period. Overall densities at station N10 were notably higher than N16 or N04, particularly in the surface samples. While the late winter/spring bloom appeared to have diminished by early April at the more seaward stations, it continued to increase in magnitude at N10 (as well as in the harbor and coastal waters, see following section) through April. Dominant phytoplankton groups during the bloom were microflagellates and centric diatoms.

The centric diatom *Thalassiosira* spp. dominated the nearfield early in the bloom (10 to 50 percent of total abundance through the first three surveys, Appendix F-1). Peak densities of around 600,000 cells/L were reported during W9603 at N10. *Chaetoceros* spp. co-dominated during late February and March (W9602 and W9603), and became the dominant centric diatom at the inshore station N10 through mid-May (W9606). Peak densities of *Chaetoceros* reached approximately 2 million cells/L during April (W9605), comprising 60 percent of total abundance (Figure 5-10, Appendix F-1). Mid-depth samples from N10 showed a similar pattern (Figure 5-11), but densities were less than that reported from the surface.

Once the centric diatom bloom ceased, microflagellates were the numerically dominant plankton group (Figures 5-11 and 5-12). Cryptophyte species were co-dominant in the nearfield once stratification set up, reaching densities of around 300,000 cells/L. A localized surface bloom of the centric diatom *Rhizosolenia fragilissima* occurred at N04 during the beginning of July (Figure 5-11c). Surface densities reached 900,000 cells/L, as compared with typical results of <50,000 cells/L during June and July (Lemieux, 1996a).

Plots of estimated phytoplankton carbon also demonstrate the delayed development of the spring bloom at the inshore station N10 (Figures and 5-13 and 5-14). However, with the development of the harbor and coastal bloom during March and April (see following section), carbon at station N10 typically exceeded other nearfield carbon estimates throughout the reporting period. The one exception to this pattern was the surface bloom of *R. fragilissima* at N04 in early July (Figure 5-13c). *Chaetoceros* and *Thalassiosira* were the dominant carbon producers during the spring bloom. Surface carbon was typically equal to or in excess of mid-depth results, with the one main exception being N04 in March (W9603), where phytoplankton carbon increased at mid-depth but decreased at the surface (Figures 5-13c and 5-14c). This was due to increased densities of *Chaetoceros* in the mid-depth sample (Appendix F-2).

Dominant dinoflagellate species detected in screened sample results included *Ceratium tripos*, *Gonyaulax* and *Protoperidinium* spp. early in the season. Densities were typically less than 1,000 cells/L (Appendix G-1 and G-2). By W9604, *Ceratium longipes* and *Dinophysis norvegica* began to emerge in the dinoflagellate flora of the nearfield, reaching densities of a few thousand cells/L by the end of the reporting period.

5.3.1.3 Regional Phytoplankton Assemblages

Abundance plots from farfield station whole water samples were used to demonstrate the differences in regional successional patterns (Figures 5-15 through 5-18). Nearfield results were included to facilitate regional comparisons. Eastern Cape Cod Bay (station F02) had a fully developed centric diatom bloom by the first survey (Figure 5-15). The bloom was dominated by *Rhizosolenia delicatula*, with densities of around 740,000 cells/L at the surface and 570,000 cells/L at mid-depth. *Chaetoceros* spp. co-dominated at the surface (380,000 cells/L), with *Skeletonema costatum* co-dominant at mid-depth (290,000 cells/L). Also present at both depths was the pennate diatom *Asterionellopsis glacialis* at densities of up to 800,000 cells/L. Outside of Cape Cod Bay, only N04 at the northeast corner of the nearfield, and boundary station F27 had noticeable contributions from centric diatoms during this first survey, predominately composed of *Chaetoceros* and *Thalassiosira*.

By late February (W9602), the diatom component of the phytoplankton assemblage had increased system-wide throughout Massachusetts and Cape Cod Bay (Figure 5-16a), with the dominant taxa consisting of *Chaetoceros* and *Thalassiosira* (Appendix F-1). Samples from mid-depth were similar in taxonomic composition but showed less variability in abundance across the regions (Figure 5-16b). The diatom bloom in eastern Cape Cod Bay had extended westward to station F01, and was also pronounced in surface samples at coastal station F24 and offshore station F06. The bloom continued in eastern Cape Cod Bay (F02), however, the previously dominant taxa (*Rhizosolenia* and *Skeletonema* and *A. glacialis*) had all but disappeared from the assemblage there (Lemieux, 1996b).

Results from the early April combined survey W9604 revealed a well developed centric diatom bloom (*Chaetoceros* and *Thalassiosira*) in the harbor and coastal stations, and almost complete absence of diatoms in Cape Cod Bay and offshore waters (Figure 5-17). Densities of *Chaetoceros* exceeded 4 million cells/L at harbor station F31.

By late June (W9607, Figure 5-18), the harbor and adjacent waters still had a dominant presence of centric diatoms, although *Chaetoceros* had a reduced presence and *Skeletonema costatum* was the dominant taxon. *Chaetoceros* did produce a biomass peak at mid-depth at the boundary station F27 (Figure 5-18b). Small flagellates and cryptophytes dominated the remaining regional results, with a small *Gymnodinium* species present in most samples.

The dinoflagellate flora in the early season farfield samples exhibited similar dominant taxa as those reported for the nearfield stations (*C. tripos*, *Gonyaulax* and *Protoperidinium* spp.). Relatively high densities of several taxa appeared in surface results from the Boundary station F27 by W9604. As with the nearfield, farfield samples from W9607 also revealed succession by *Ceratium longipes* and *Dinophysis norvegica* as the dominant dinoflagellates.

5.3.1.4 Nuisance Algae

Three nuisance algae species have been targeted in the HOM Program: *Alexandrium tamarense*, *Phaeocystis pouchetii*, and *Pseudo-nitzschia multiseries*. The seasonal distribution for each of these species includes the late winter and spring periods covered by this semi-annual report. During 1996, however, none of these species was reported at densities which would cause concern.

A. tamarense was not reported in any samples from the period. Results from monitoring activities conducted by Dr. Don Anderson of Woods Hole Oceanographic Institution which target this species confirmed that very low densities were found for *A. tamarense* in Massachusetts Bay during 1996 (D. Anderson, pers. comm.). There were no instances of shellfish toxicity reported in Massachusetts Bay coastal waters during the reporting period.

Likewise, the late winter and spring of 1996 yielded low densities for *P. pouchetii*. The maximum density reported for this taxon was 179,000 cells/L in a surface screened water sample taken at Boundary station F27 during survey W9604 (Table 3-4; Appendix G-1). All other samples were at least an order of magnitude lower than this maximum reported result. These reported densities were low relative to bloom densities which can reach several million cells/L.

Due to the difficulty in taxonomically separating the toxic diatom *P. multiseries* from the morphologically similar taxon *P. pungens* using light microscopy, the HOM Program conservatively reports their combined abundance as an indicator species. The maximum density of this indicator species (12,000 cells/L) was reported during survey W9602 in the surface sample at harbor station F23 (Table 3-1). A slightly lower peak of 11,000 cells/L was reported in eastern Cape Cod Bay (station F02) during the same survey (Appendix F-1). These results are well below the 100,000 cell/L threshold tentatively being used by the HOM Program based on domoic acid toxicity levels observed in Canadian waters (S. Bates, pers. comm.).

Zooplankton

Seasonal Trends in Total Zooplankton Abundance

Zooplankton densities in the nearfield generally increased through W9604 (early April), with peak densities coinciding with reductions in total phytoplankton abundance at N16 and N04 (Figure 5-19). Initial total abundances during the first survey ranged from around 4,000/m^3 (N10) to close to 20,000 (N04). Peak densities by W9604 reached around 40,000/m^3. Unfortunately, due to sample loss during shipment to the laboratory following survey W9605, zooplankton densities were not reported for the nearfield only survey W9605 in late April. Total densities decreased slightly by the next survey during mid-May.

Total zooplankton abundance peaked at stations N16 and N04 in mid-June (W9607), with maximum densities of around 105,000/m^3 and 192,000/m^3, respectively. Peak abundances of around 50,000/m^3 at station N10 were not reached until the mid-July survey W9609.

Nearfield Zooplankton Community Structure

Zooplankton community composition during the early surveys predominately consisted of copepod adults and copepod nauplii (Figure 5-20), although the more inshore station N10 had a larger contribution from barnacle nauplii and polychaete larvae (Appendix H). Copepods and their nauplii continued to dominate the zooplankton assemblage as the season progressed. These two groups, plus a large occurrence of bivalve larvae (close to 50,000/m^3 at N04) comprised the peaks in abundance observed at stations N16 and N04 in mid-June.

The numerically dominant species among the copepods during the reporting period was *Oithona similis*, with initial densities in February reaching around 5,000/m^3 and peak densities in July of around 15,000/m^3 (Appendix H). Other dominant copepods included *Pseudocalanus newmani*, *Calanus finmarchicus*, and *Temora longicuris*. In terms of estimated biomass, *Calanus finmarchicus* was by far the dominant species, with adults comprising an estimated 6x10^5 µgC/m^3. The next most important contributor of zooplankton biomass was *Pseudocalanus newmani*, with an estimated carbon contribution of around 5x10^4 µgC/m^3.

Regional Zooplankton Assemblages

Regional data for the first combined nearfield/farfield survey (W9601) showed highest zooplankton densities (around 22,000/m^3) in eastern Cape Cod Bay (Figure 5-21). This was the only result which exceeded densities reported in the outer areas of the nearfield. The Cape Cod Bay assemblage was also numerically dominated by copepod adults and nauplii. Other stations were all less than 10,000/m^3, with relatively high densities reported from Coastal station F13 and Offshore station F06. The copepod component was numerically dominated by *Oithona similis* and *Pseudocalanus newmani*, although Cape Cod Bay station F02 had a large numerical contribution from *Centropages hamatus* (Appendix H).

By the late February survey W9602, highest densities reported from farfield stations were found at F06, Cape Cod Bay stations F01 and F02, and Boundary station F27 (Figure 5-22). Maximum densities were lower than the nearfield station N04, and ranged from between 15,000/m^3 to 27,000/m^3. Polychaete larvae had a greater contribution to the total assemblage in coastal stations than that seen in early February, and barnacle larvae were much more important in the harbor and adjacent waters.

During the April combined survey (W9604), the zooplankton assemblage was dominated by copepods and copepod nauplii (Figure 5-23). Maximum densities were reported at the Boundary station F27, where the numerical dominant was *Calanus finmarchicus* copepodites (around 15,000/m^3). The nearfield stations were similar in composition, with *C. finmarchicus* copepodite densities ranging from 7,000 to 8,500 individuals/m^3.

Coastal station F13 had the highest zooplankton abundance outside of the nearfield during the mid-June (W9607) combined survey (Figure 5-24). The assemblage there and at F24 also exhibited the large abundance of bivalve larvae seen at N04 during this period. The Cape Cod Bay assemblage was similar in structure to Offshore station F06.

5.4 Summary of Water Column Biological Events

- Areal production trends differed between the harbor-influenced stations (F23, N10) and the more seaward nearfield stations (N04, N16);

- Major production events among the outer nearfield stations (N04, N16) occurred during the winter bloom in late February (approximately 3,000 mgCm^{-2}d^{-1}), followed by a secondary peak in early July (almost 2,000 mgCm^{-2}d^{-1}) at station N04;

- Productivity in the outer nearfield reached minimum semi-annual values in April following the decline of the late winter/spring bloom, and remained low through June;

- Productivity in the harbor increased linearly throughout the period, whereas productivity was episodic at nearfield station N10, with peaks in March, April, and June;

- In June, areal production reached semi-annual maximum values among all stations at F23 in (5,203 mgCm^{2}d^{1}) and N10 (4,455 mgCm^{-2}d^{-1});

- Elevated chlorophyll-specific production at station N04 in June provided evidence of highly efficient photosynthesis, despite the relative absence of chlorophyll in the water column, which was indicative of a developing bloom;

- Respiration rates during the winter and spring remained <0.15 μMO_2/hr in both surface and bottom water at all stations and water depths measured;

- A slight difference between surface and bottom water respiration rates was generally present throughout winter and spring, except during March at N04, when bottom rates were as high as the surface due to respiration of sinking plankton from the late winter bloom;

- The highest semi-annual POC value measured at station N04 was in the bottom water during March, and carbon-specific respiration data indicated that the POC was of low quality, suggesting that decomposition of the winter bloom was occurring during sinking;

- Surface water respiration increased by a factor of at least 2-3 at all stations in June (W9607), which combined with POC measurements indicated that a bloom may have occurred during the prior survey interval;

- Surface water respiration remained high through survey W9608 at station N04, consistent with the observed diatom production;

- Cape Cod Bay had the highest regional phytoplankton densities during the late winter bloom;

- The dominant phytoplankton taxa during the late February regional bloom were the centric diatoms *Thalassiosira* and *Chaetoceros*;

- Total phytoplankton abundance in the nearfield increased through early March, with *Thalassiosira* dominating early (up to 50 percent of total in first three surveys);

- The late winter phytoplankton bloom diminished in more seaward samples by early April, but continued to develop in the harbor through mid-May;

- *Chaetoceros* became the dominant phytoplankton taxon at the inshore station N10 and the harbor (reaching 2 million cells/L, or up to 60 percent of total);

- After the onset of stratification, nearfield phytoplankton densities stayed relatively low until a secondary peak occurred in late June produced by a mixed assemblage of microflagellates, centric diatoms, cryptophytes, and dinoflagellates;

- The Harbor and adjacent waters retained a strong centric diatom complement through June, although *Chaetoceros* was replaced by *Skeletonema costatum* as the dominant taxon;

- A localized surface bloom of the centric diatom *Rhizosolenia fragilissima* occurred at N04 during the beginning of July, which may have spread throughout the nearfield;

- Nearfield zooplankton densities generally increased through early April (W9604), with the April maxima coinciding with reductions in phytoplankton abundance at N16 and N04;

- Total zooplankton abundance peaked at stations N16 and N04 in mid-June, but did not peak at N10 until mid-July;

- Zooplankton community composition during the early part of the year consisted predominately of copepod adults and nauplii;

- The numerically dominant copepod during the reporting period was *Oithona similis*, with peak densities reported in July;

- *Calanus finmarchicus* was by far the dominant copepod in terms of estimated biomass.

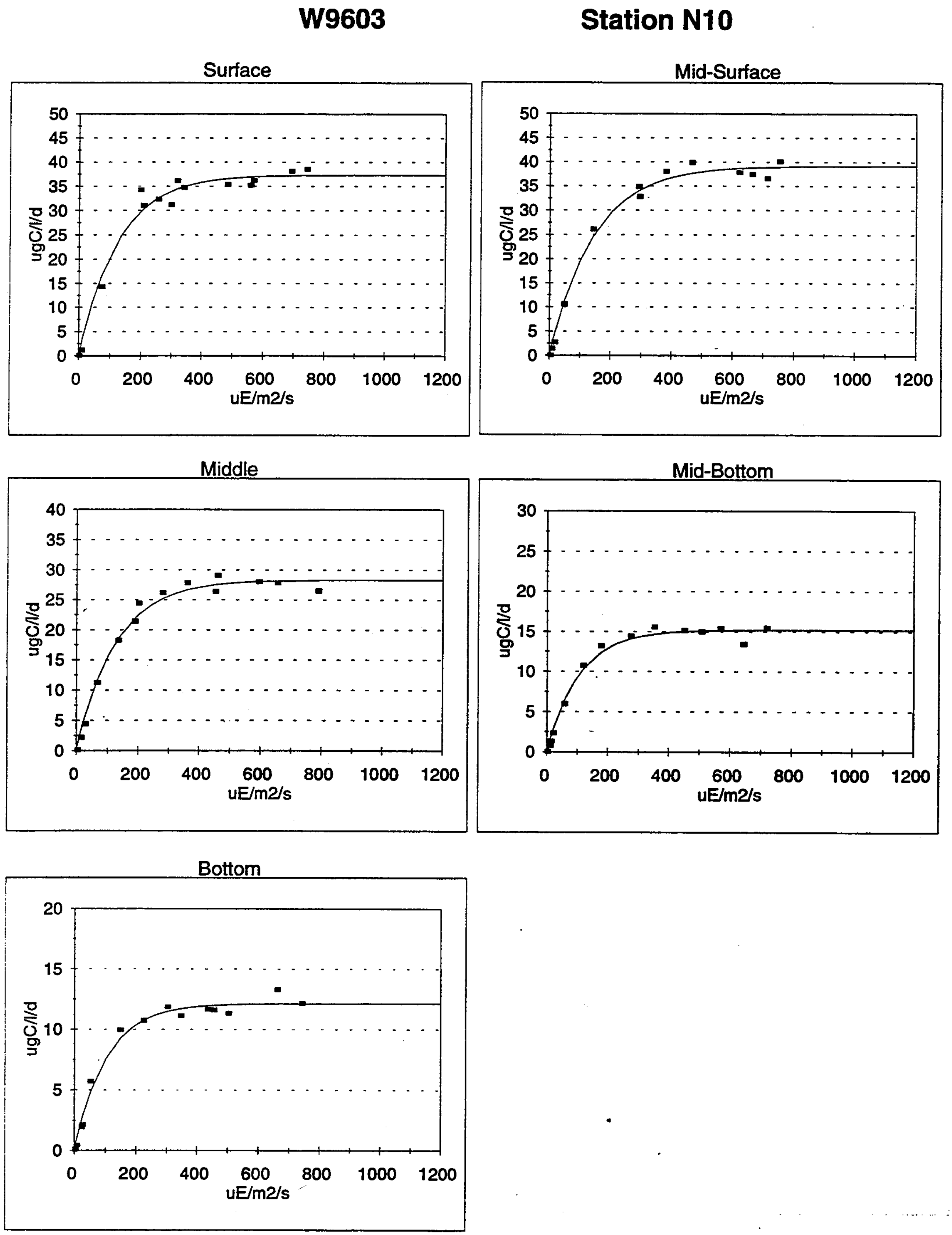
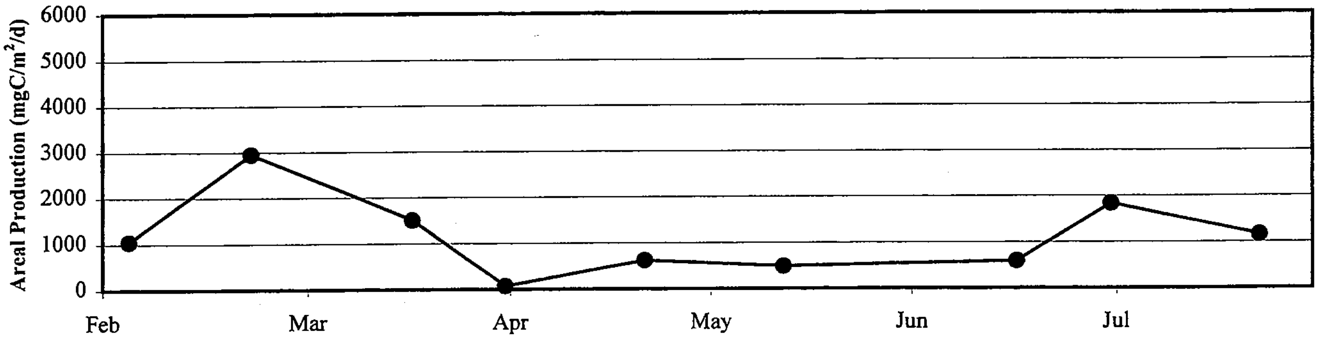
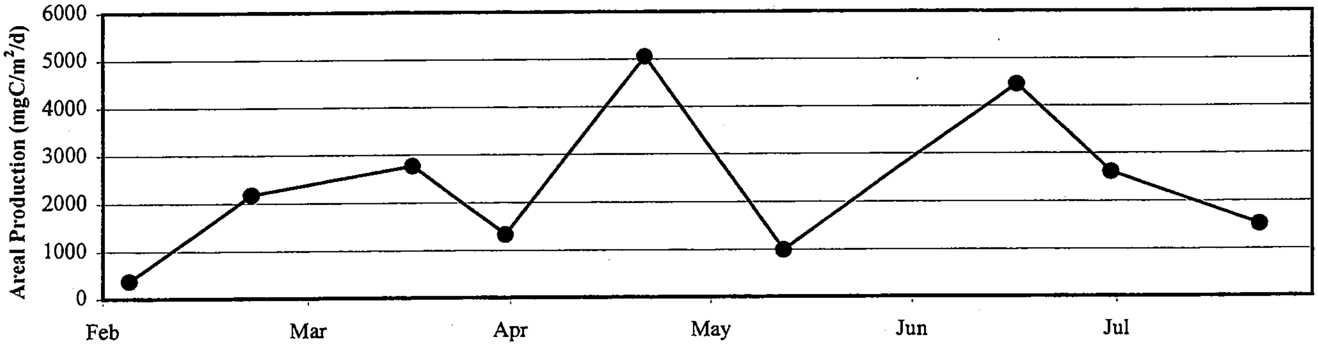


FIGURE 5-1
An Example Photosynthesis-Irradiance Curve from Station N10 Collected in March 1996

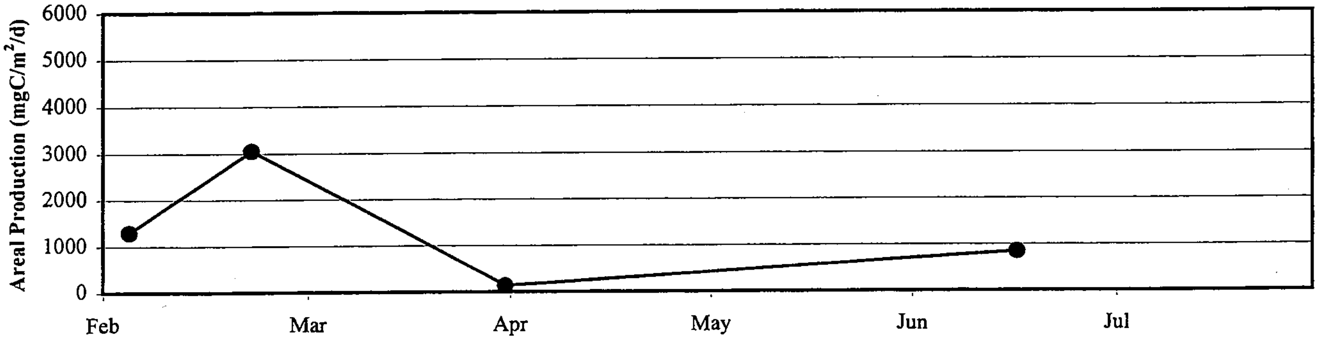
(a) Station N04



(b) Station N10



(c) Station N16



(d) Station F23

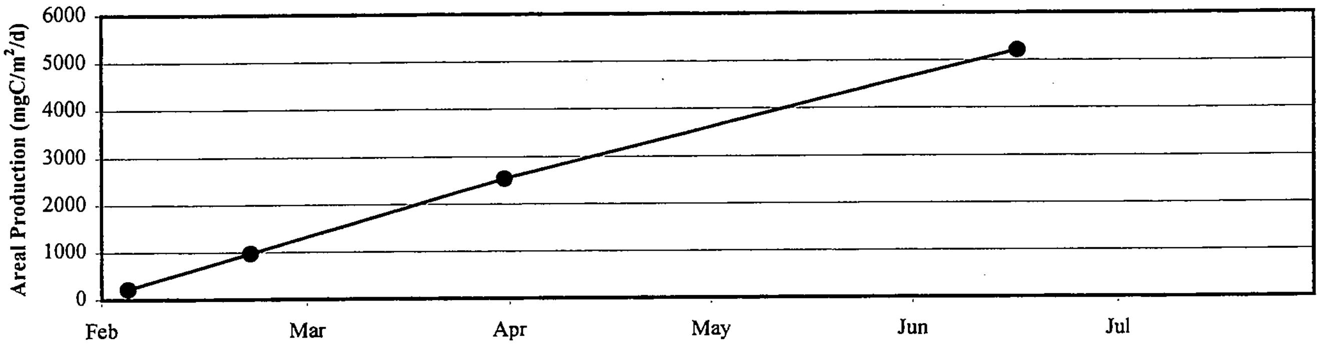


FIGURE 5-2

Time-Series of Areal Production for Productivity/Respiration Stations

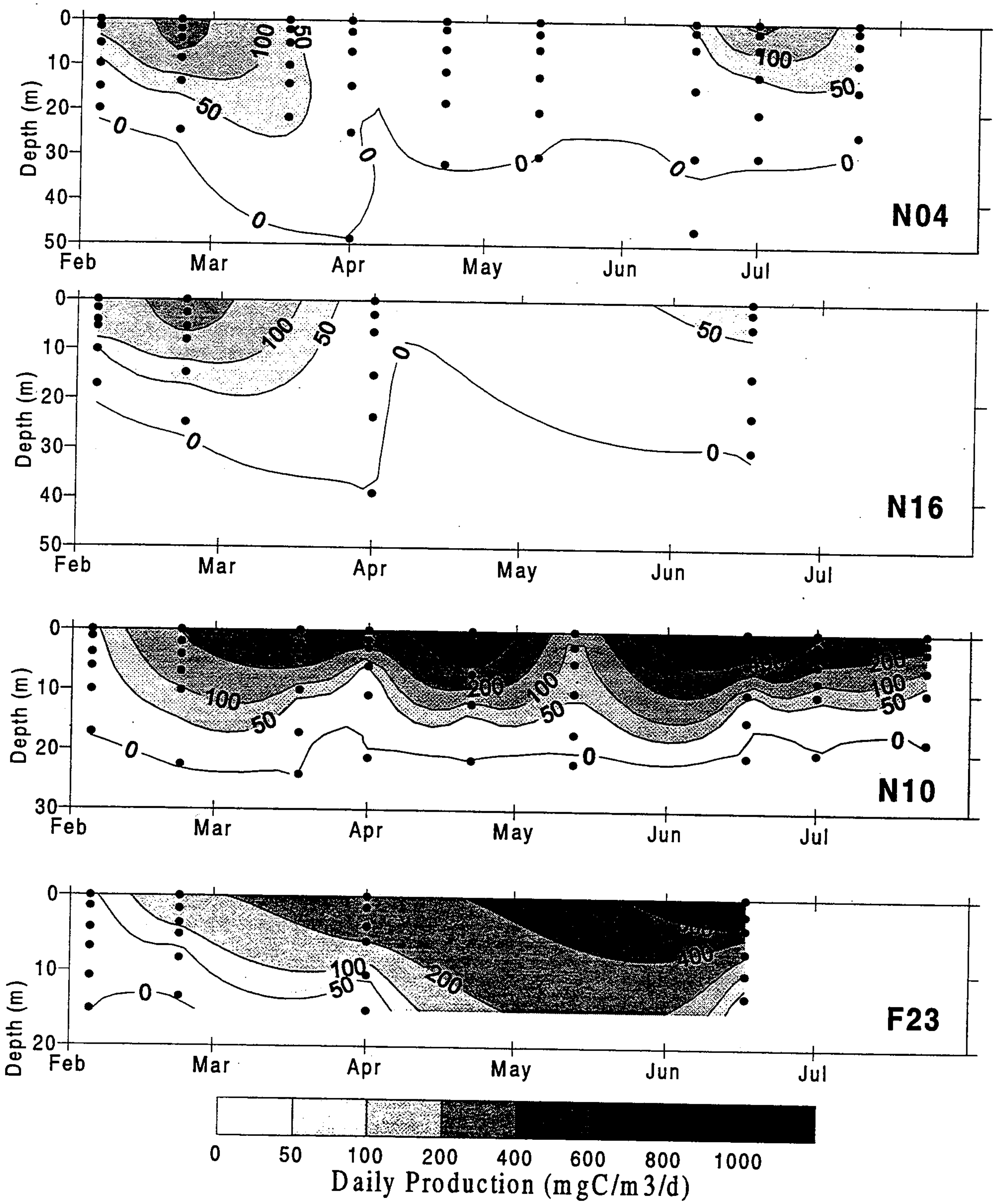


FIGURE 5-3
Time-Series of Contoured Daily Production (mgC/m³/d) at Productivity/Respiration Stations

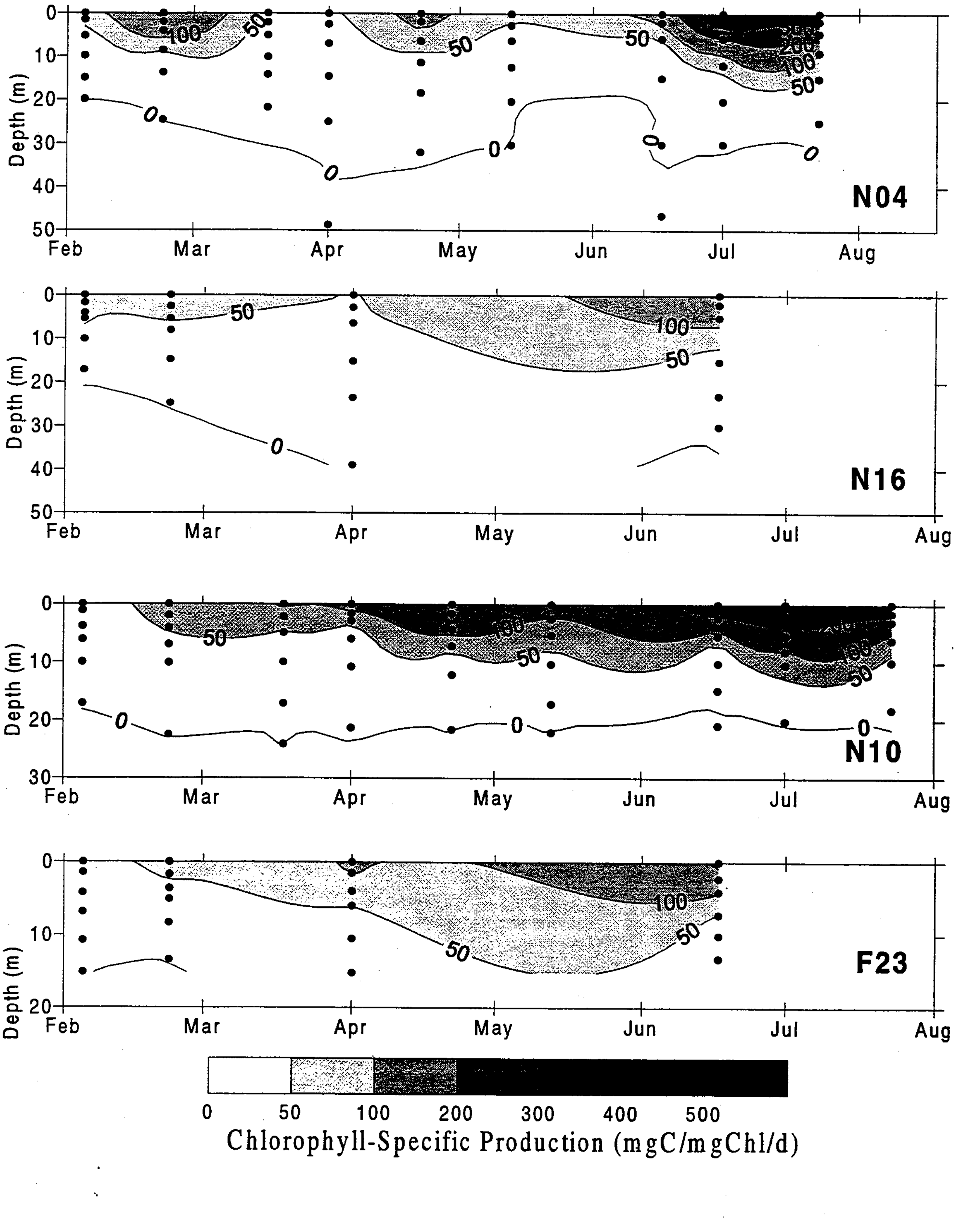
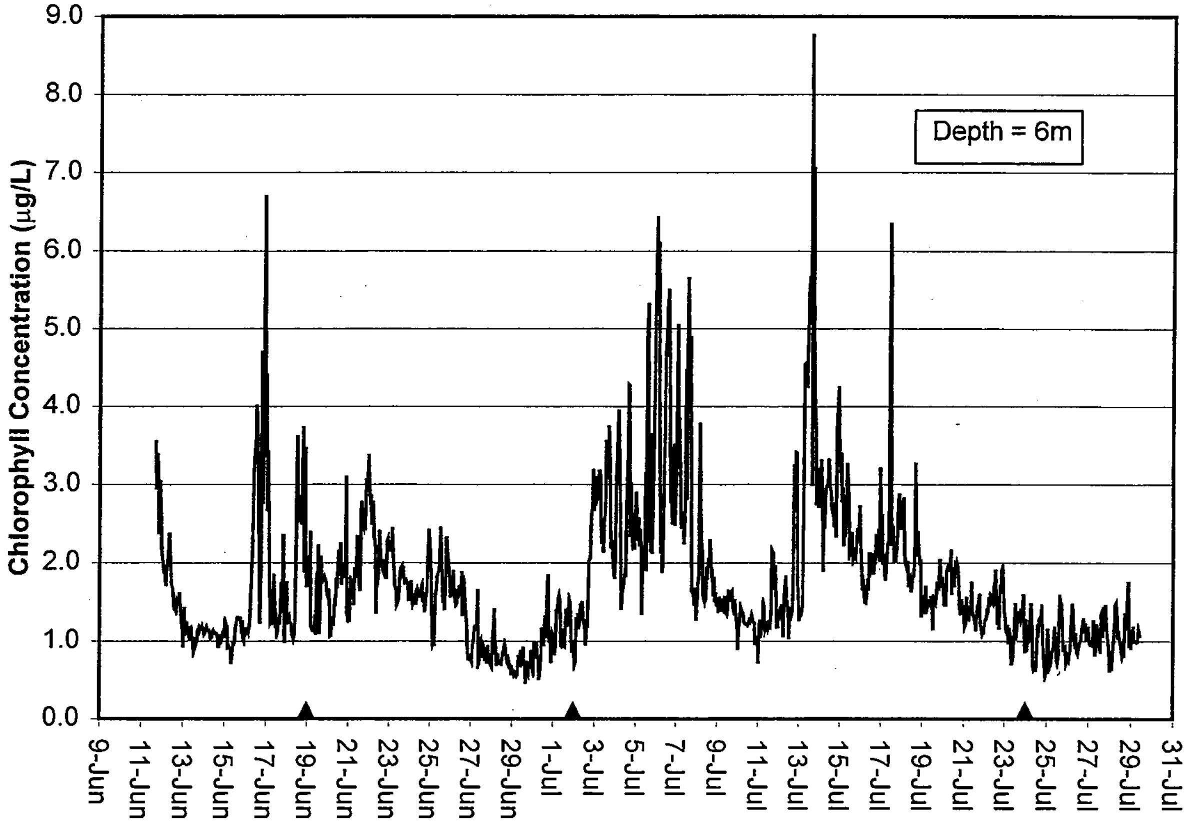


FIGURE 5-4
Time-Series of Contoured Chlorophyll-Specific Production (mgC/mgChl/d) at Productivity/Respiration Stations



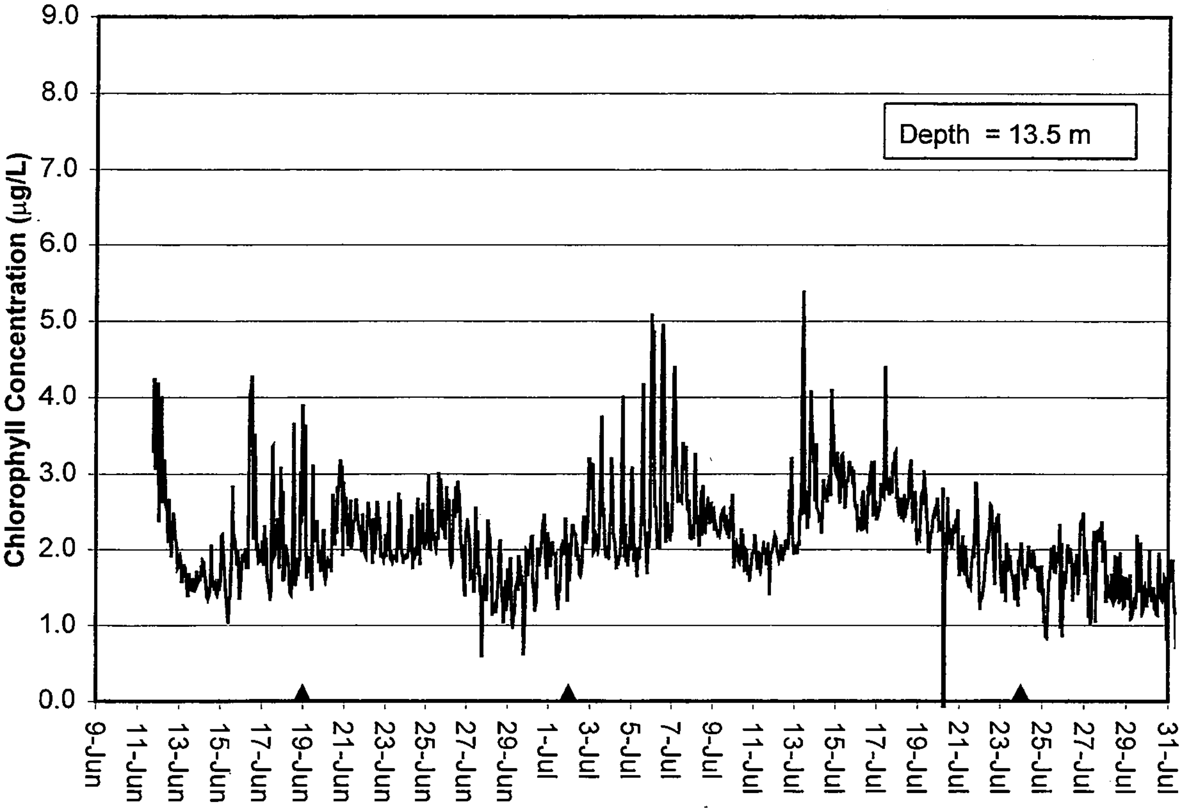
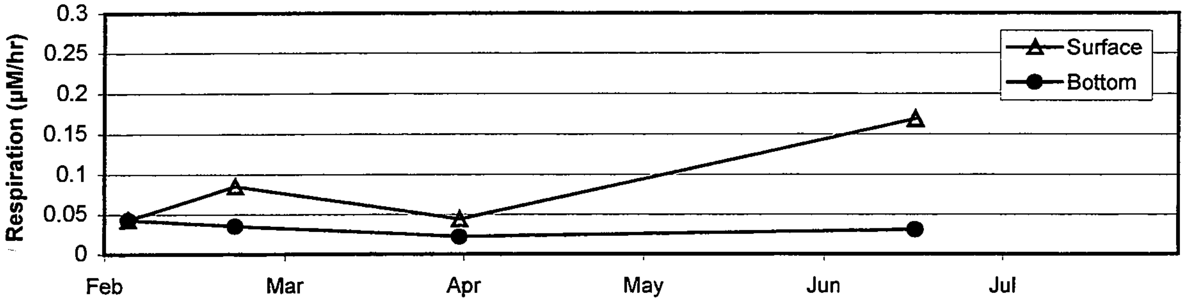


FIGURE 5-5

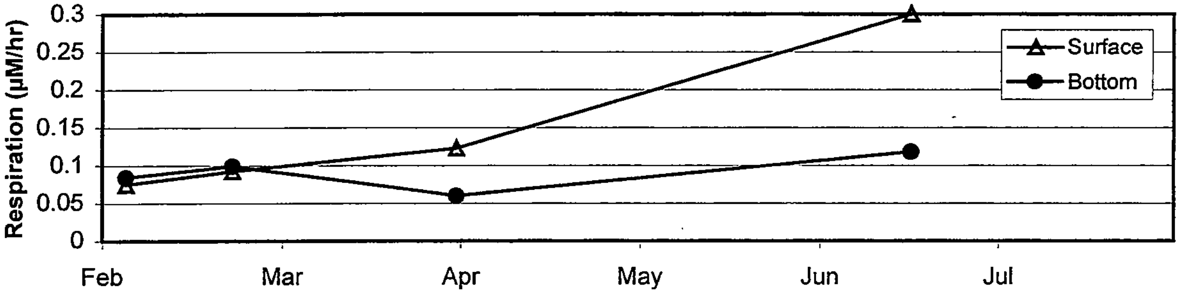
WETLabs Sensor Chlorophyll Results (June 9 - July 31, 1996)

Triangles on x-axis mark survey dates.

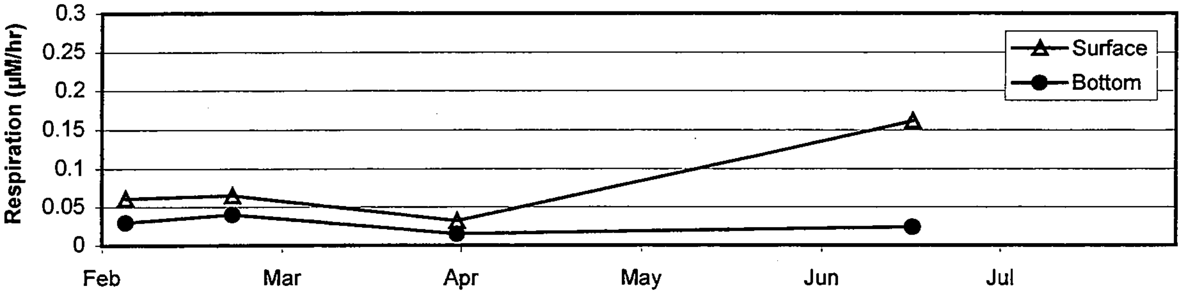
(a) Station F19



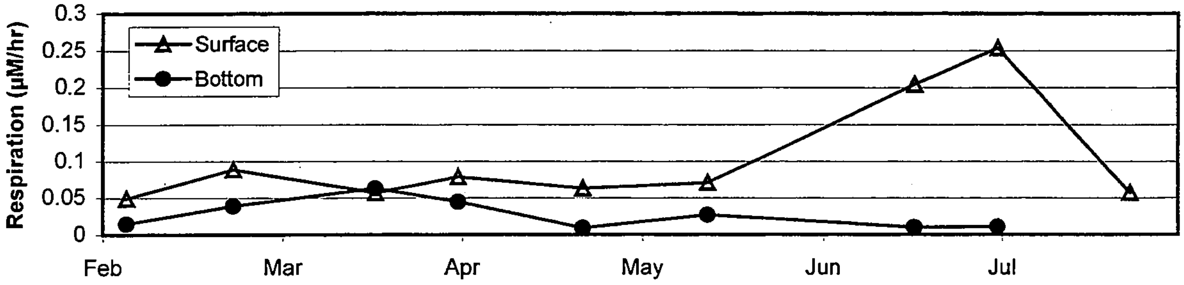
(b) Station F23



(c) Station N16



(d) Station N04



(e) Station N10

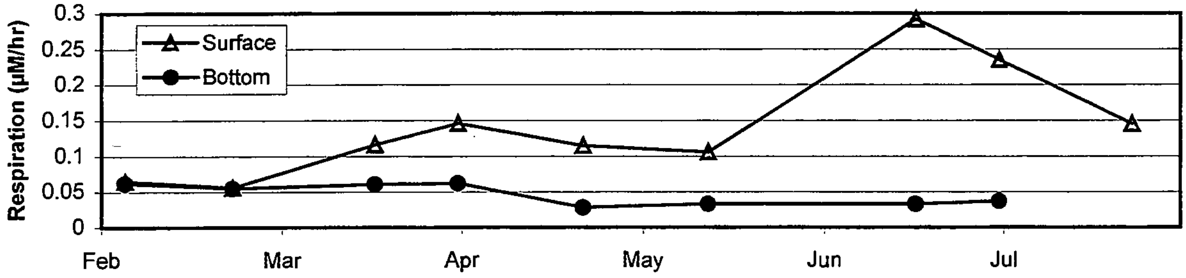
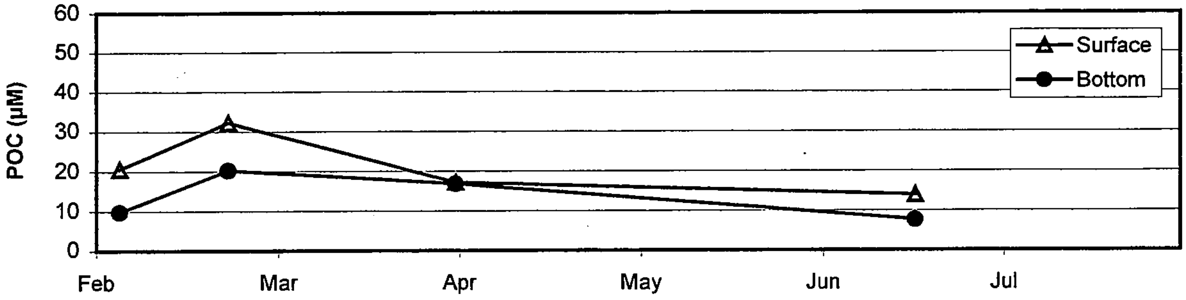
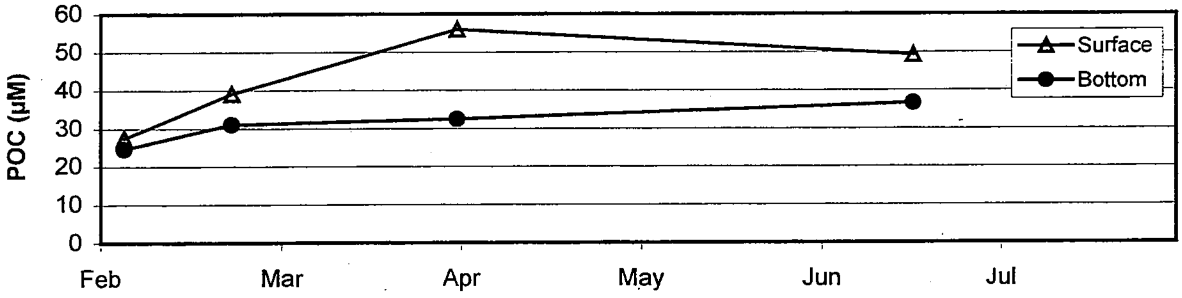


FIGURE 5-6
Time-Series of Water Column Respiration at Productivity/Respiration Stations

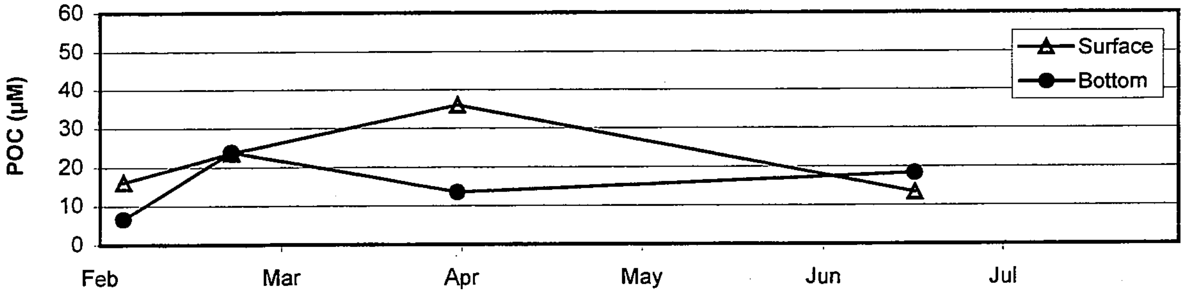
(a) Station F19



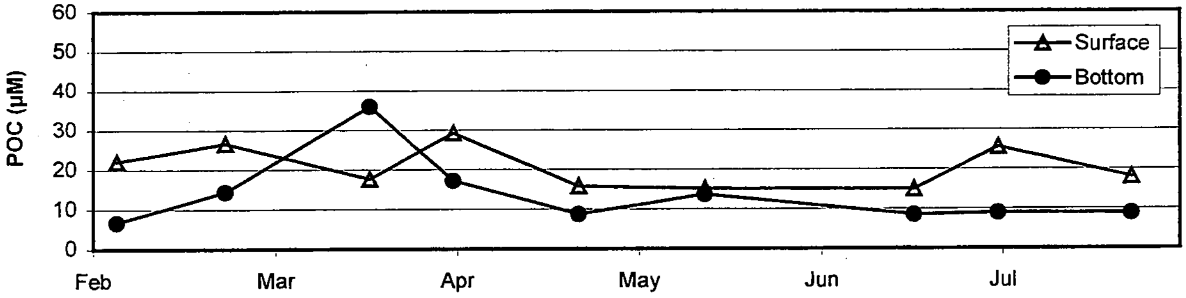
(b) Station F23



(c) Station N16



(d) Station N04



(e) Station N10

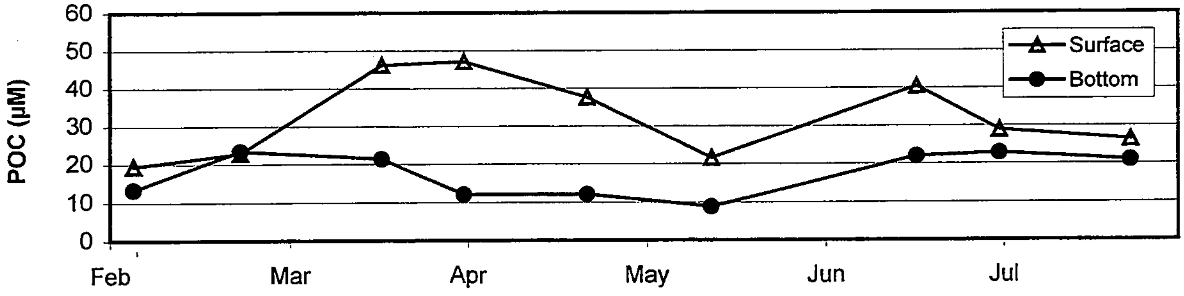
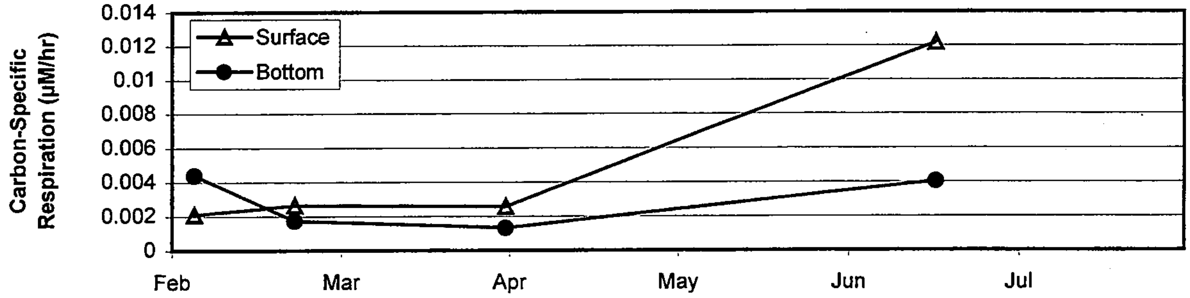


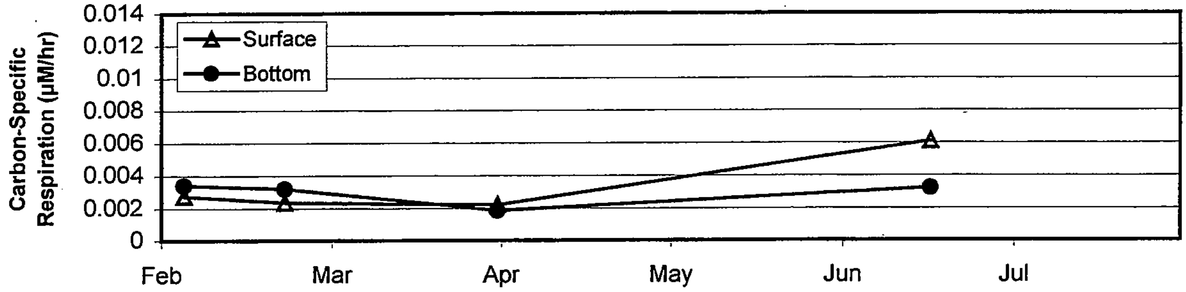
FIGURE 5-7

Time-Series of Particulate Organic Carbon at Productivity/Respiration Stations

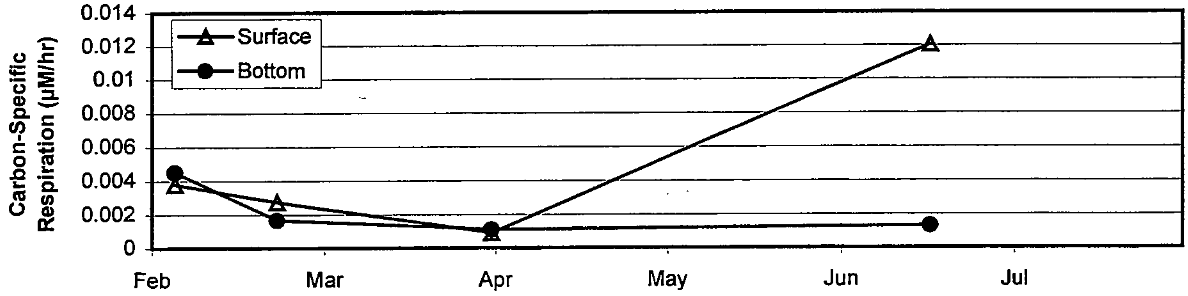
(a) Station F19



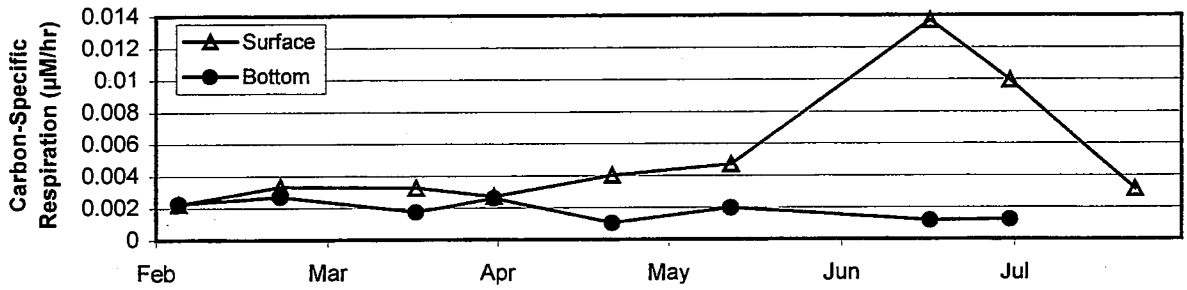
(b) Station F23



(c) Station N16



(d) Station N04



(e) Station N10

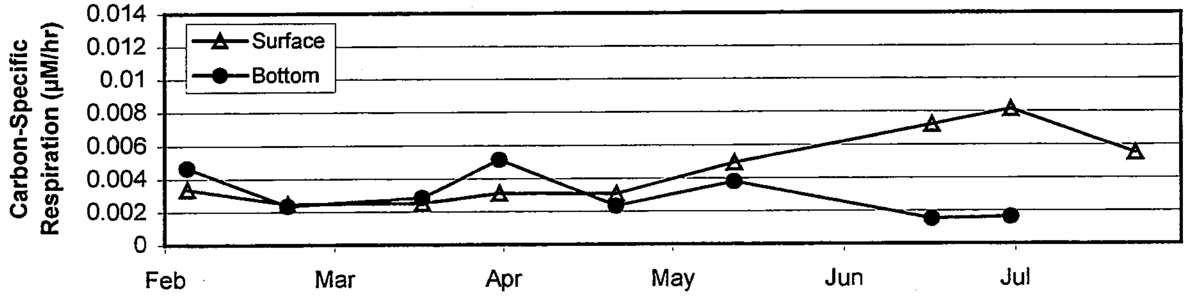


FIGURE 5-8
Time-Series of Carbon-Specific Respiration at Productivity/Respiration Stations

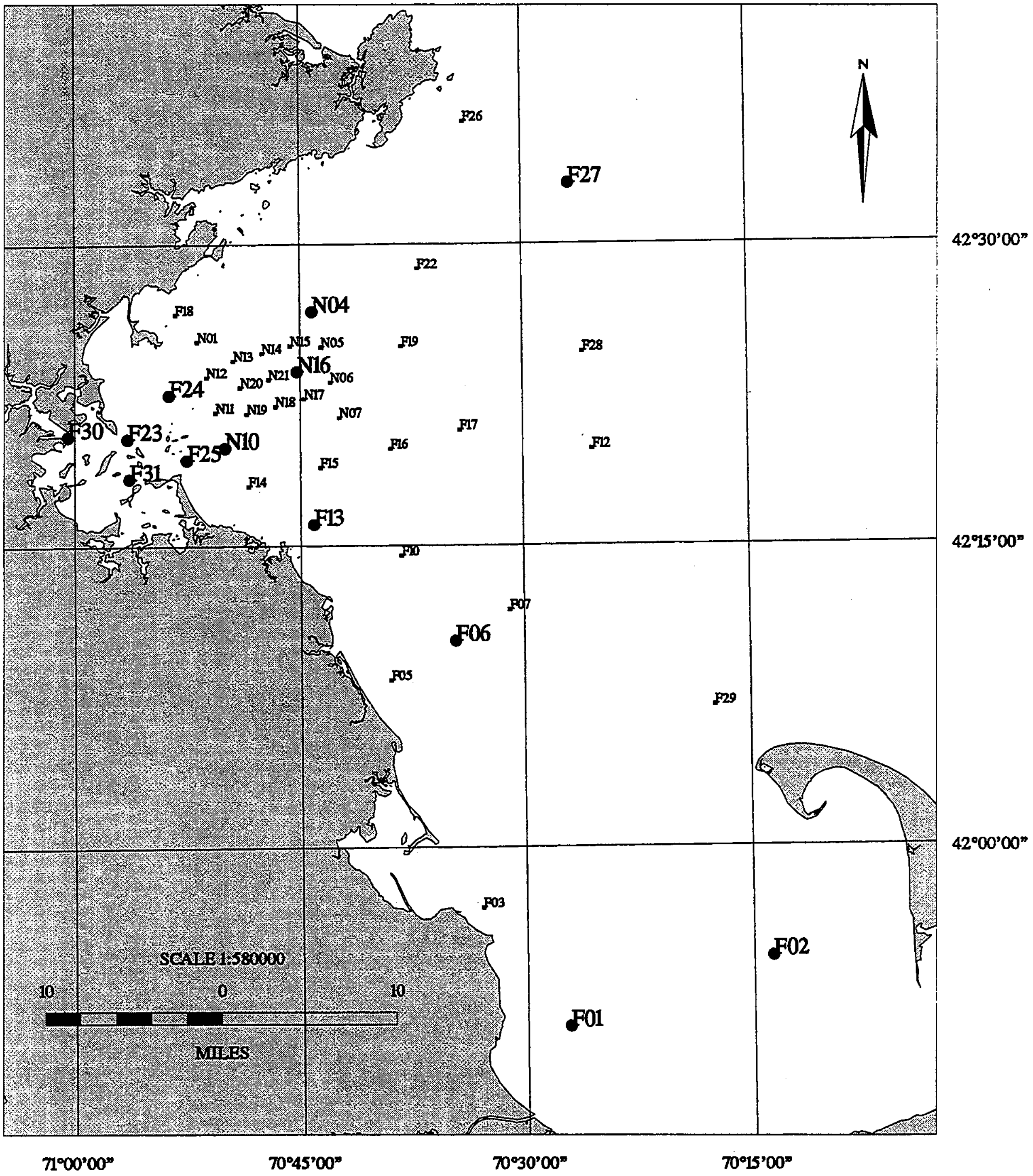


Figure 5-9
1996 Plankton Station Locations (Enlarged Text)

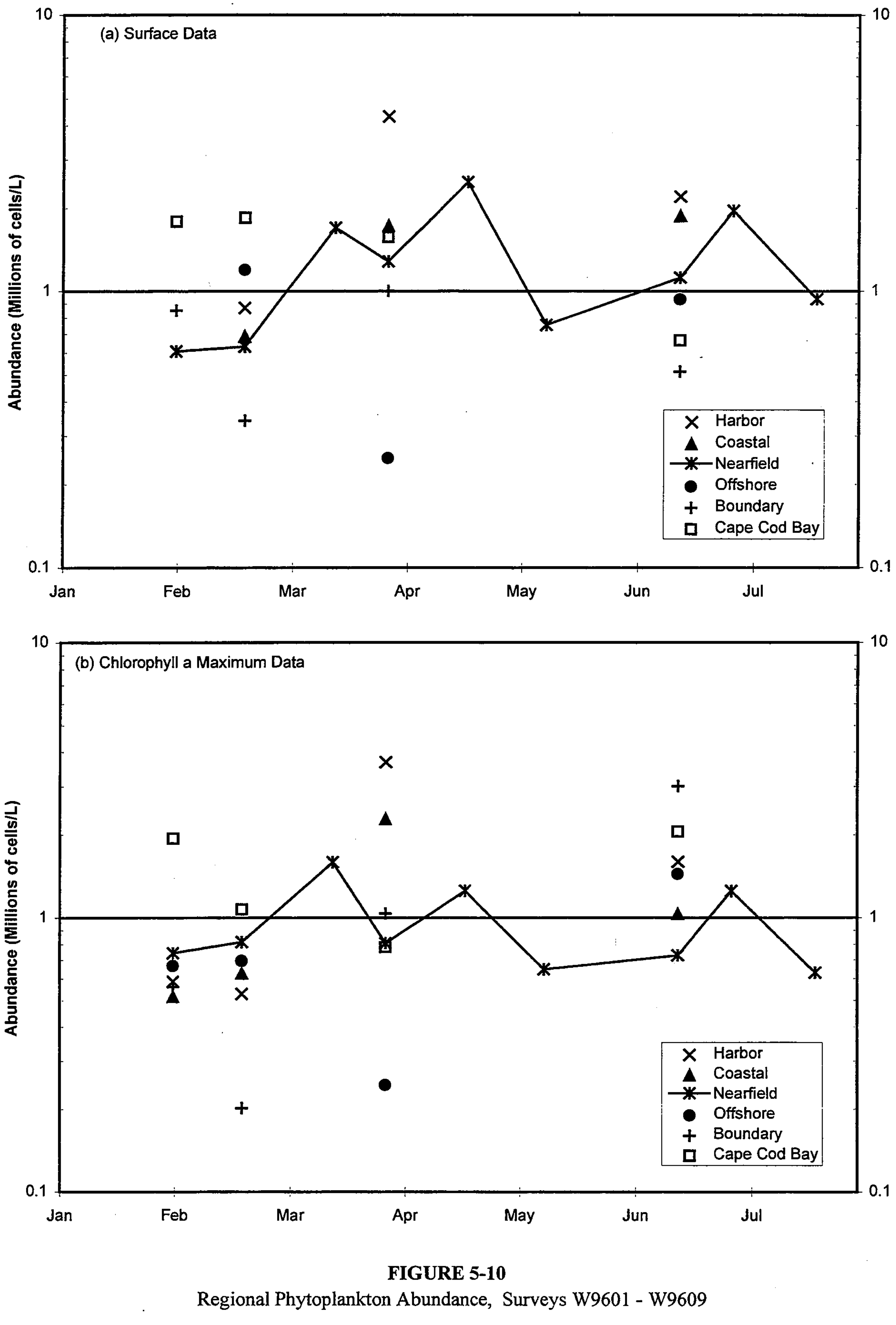


FIGURE 5-10
Regional Phytoplankton Abundance, Surveys W9601 - W9609

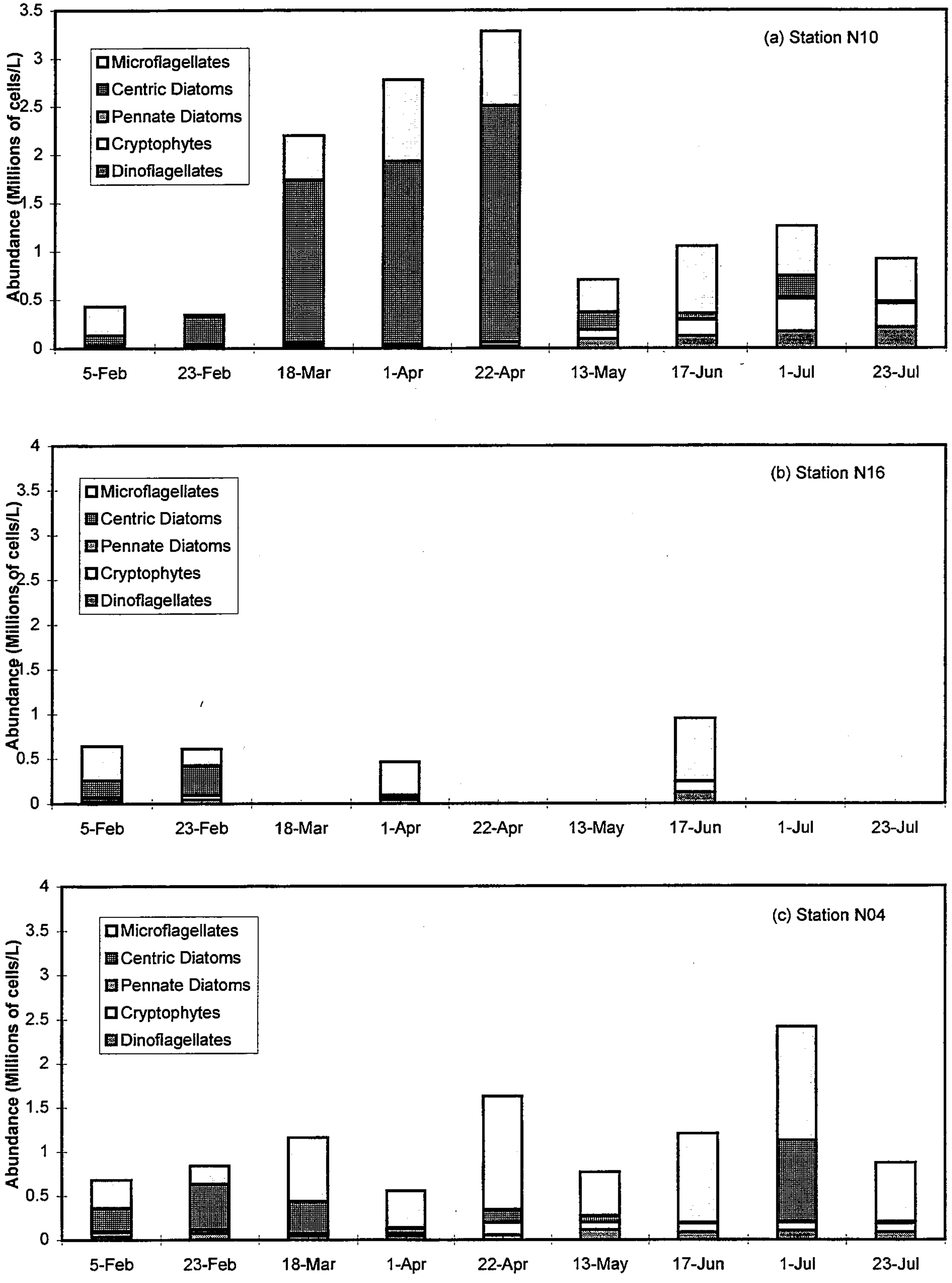


FIGURE 5-11

Phytoplankton Abundance by Major Taxonomic Group, Nearfield Surface Samples

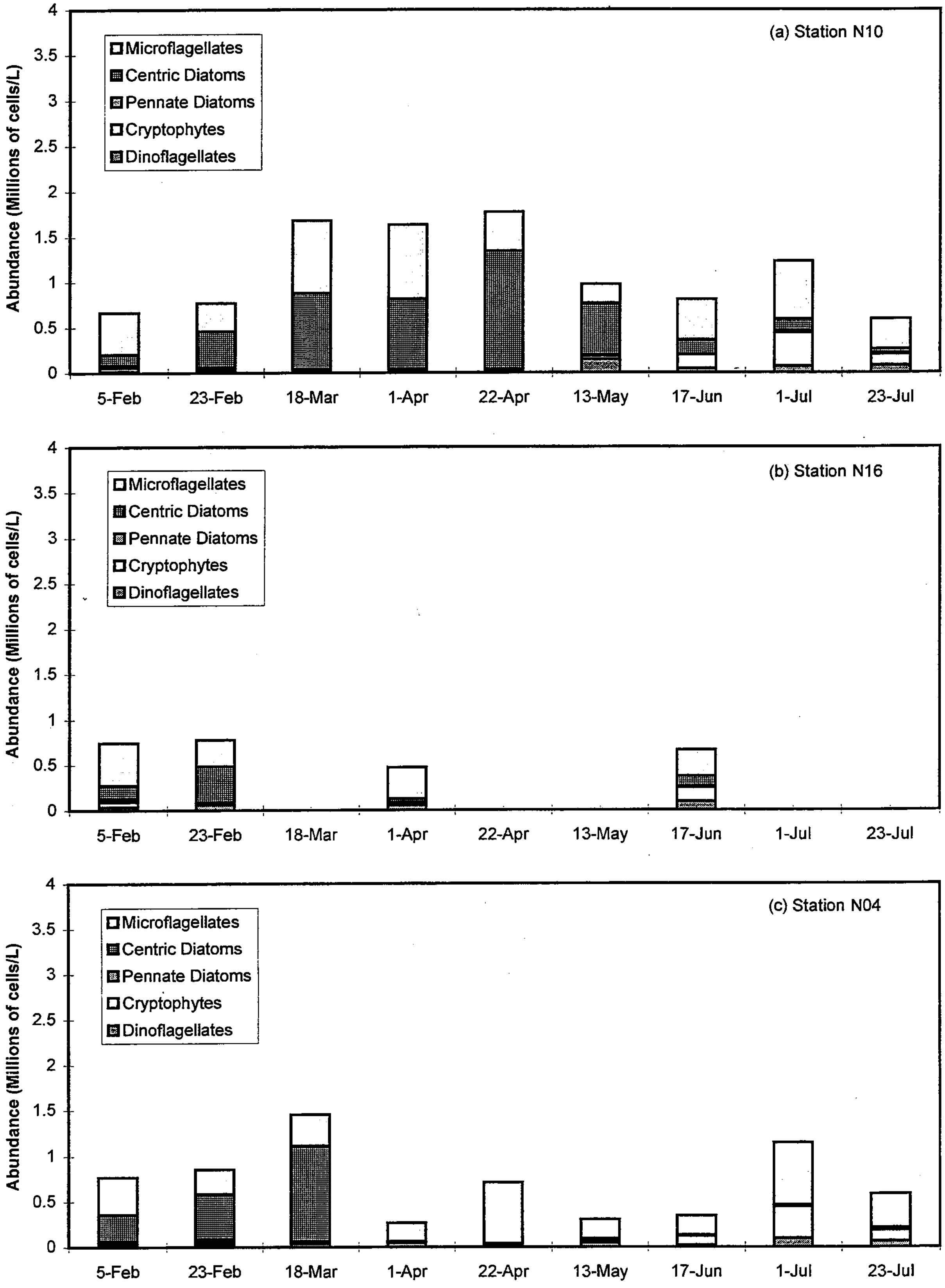


FIGURE 5-12
Phytoplankton Abundance by Major Taxonomic Group, Nearfield Mid-Depth Samples

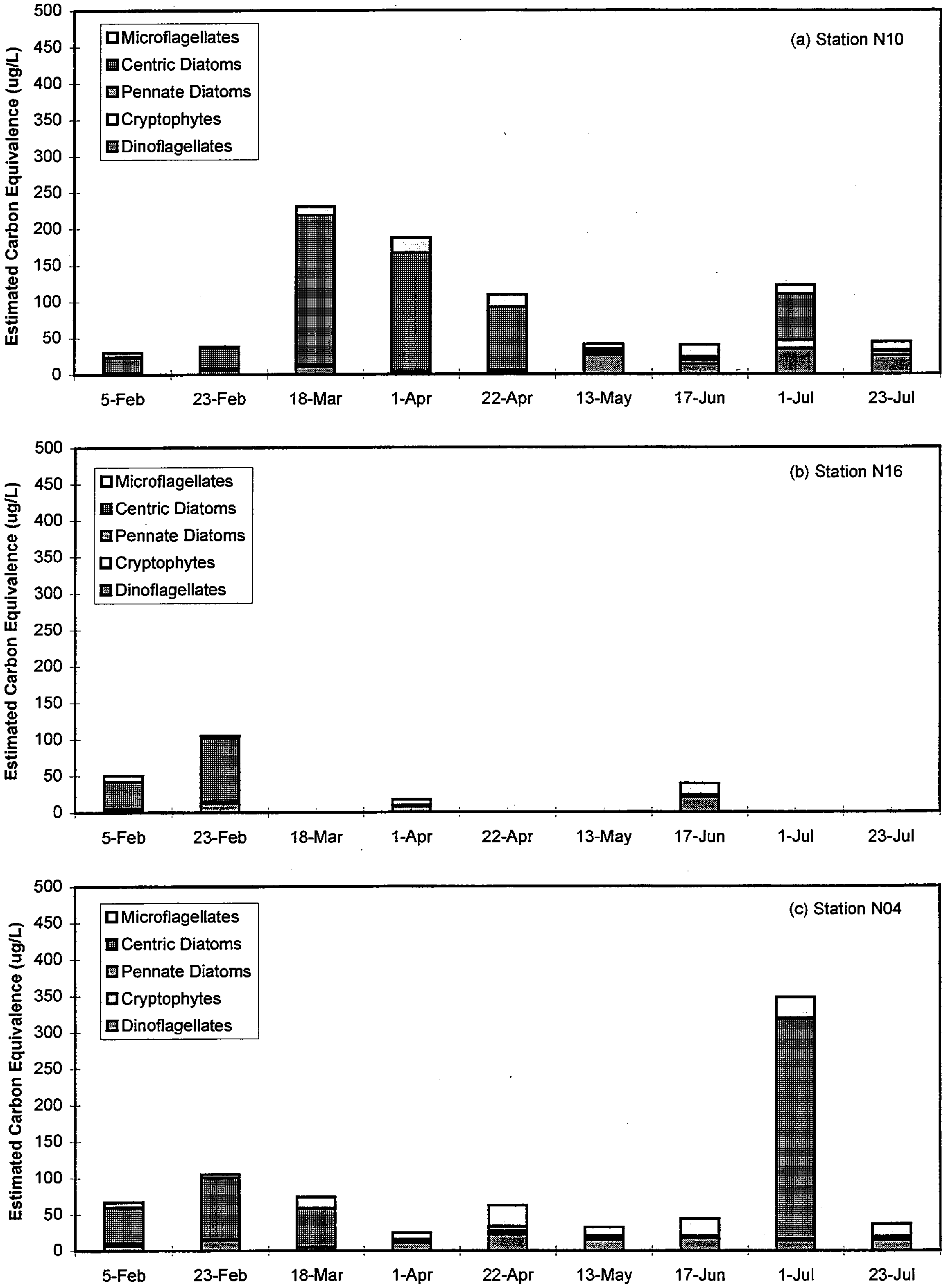


FIGURE 5-13

Phytoplankton Carbon by Major Taxonomic Group, Nearfield Surface Samples

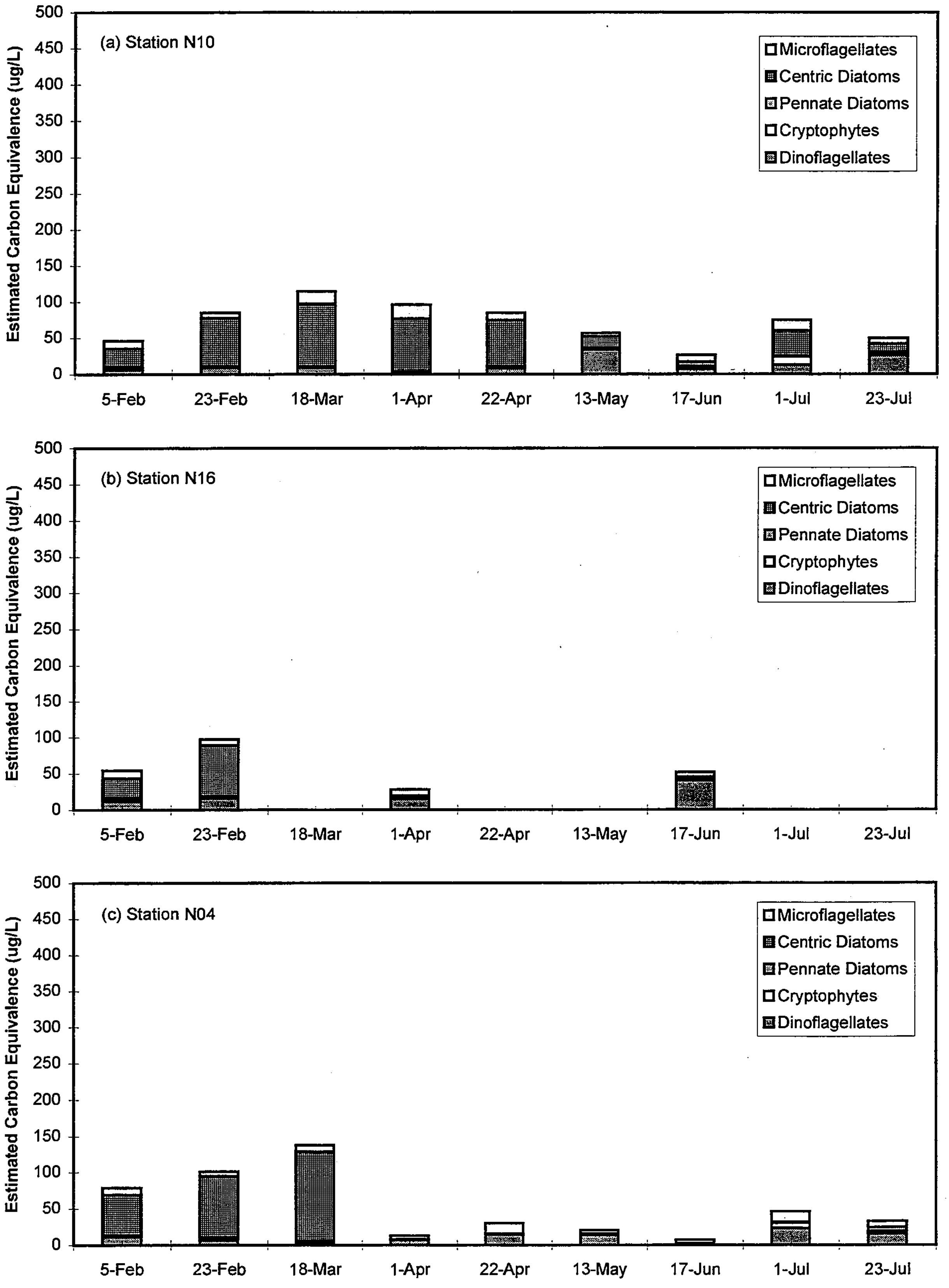


FIGURE 5-14

Phytoplankton Carbon by Major Taxonomic Group, Nearfield Mid-Depth Samples

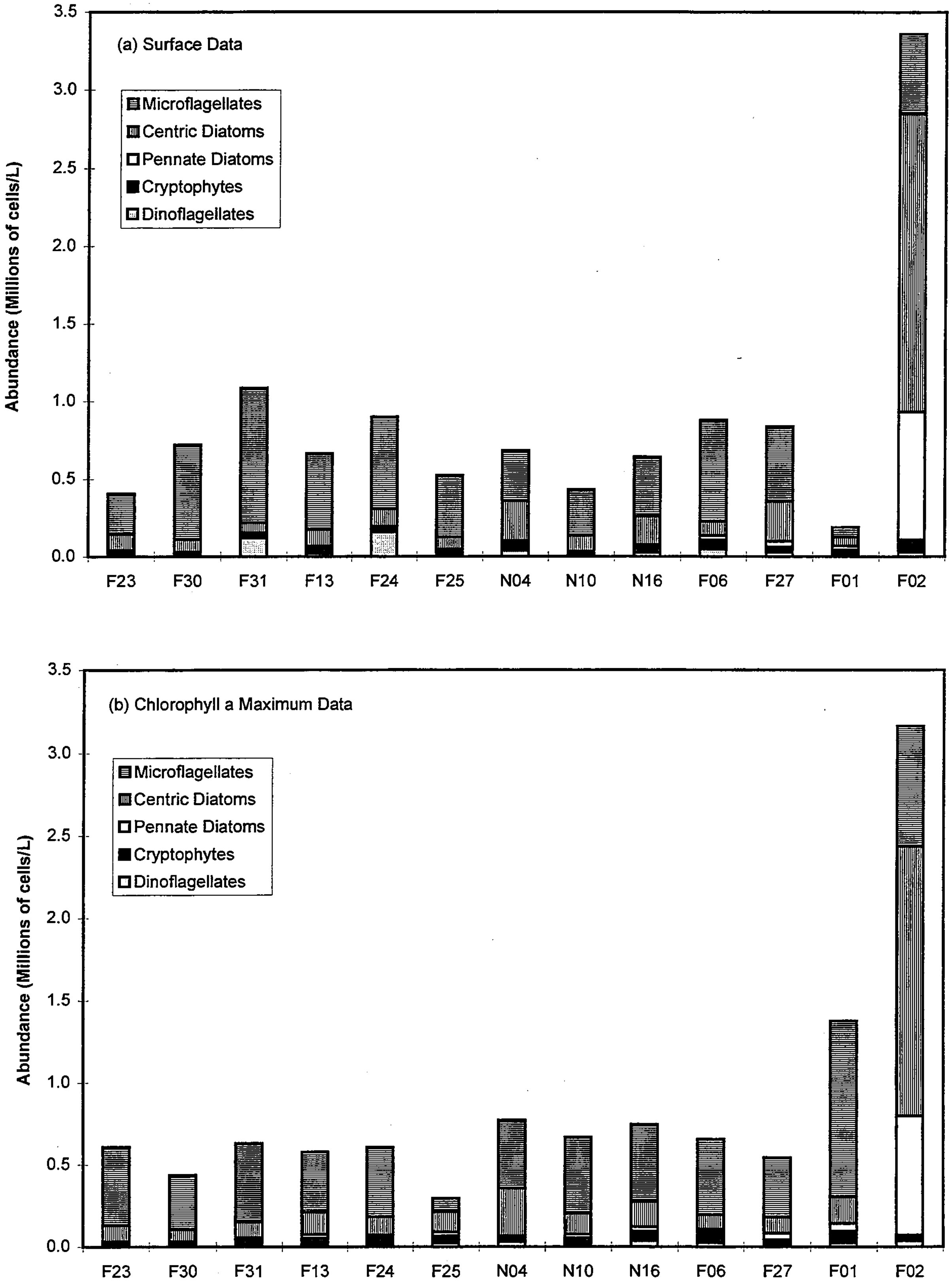


FIGURE 5-15
Phytoplankton Abundance by Major Taxonomic Group -W9601 Farfield Survey Results
February 5 -10, 1996

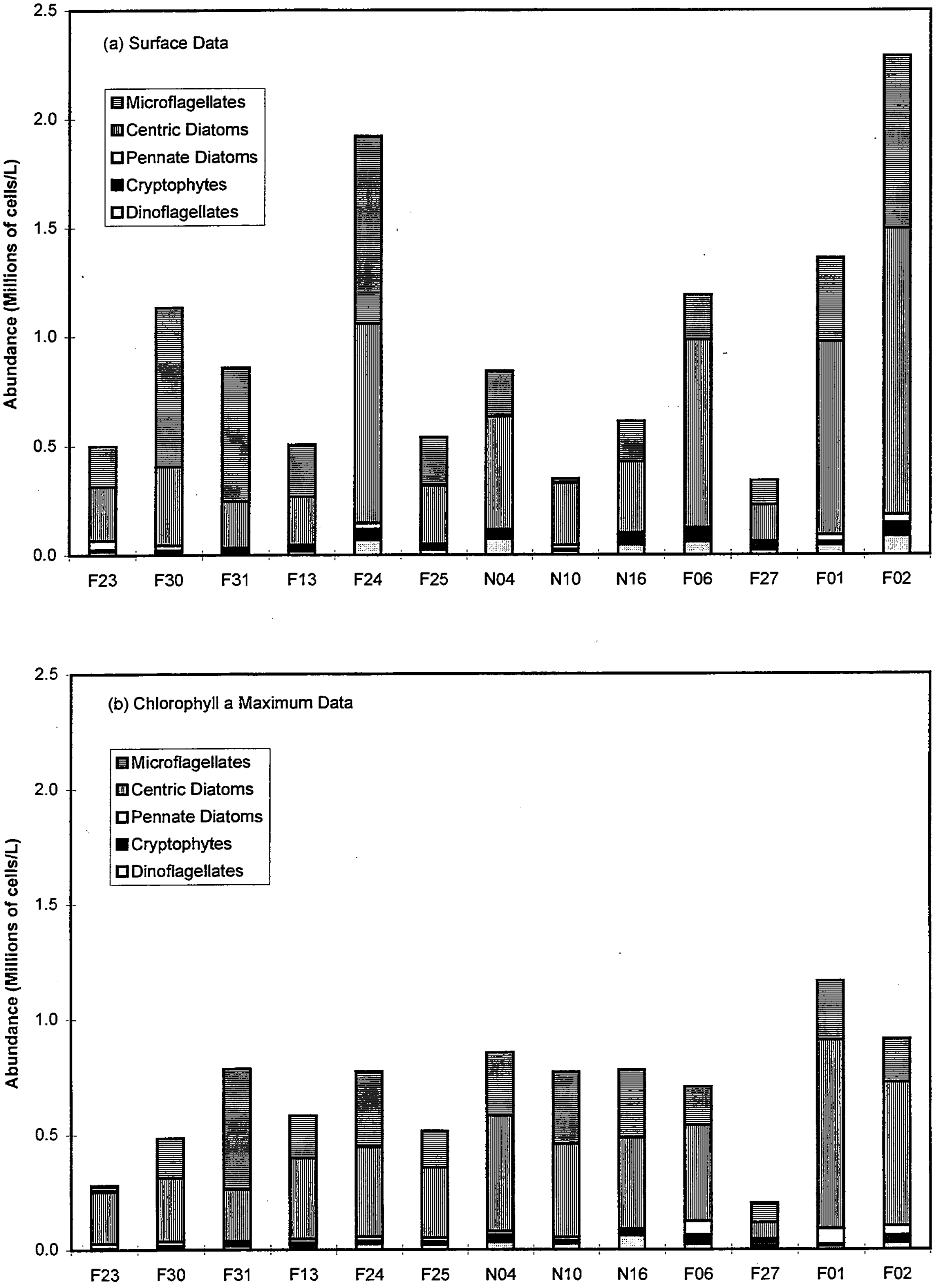


FIGURE 5-16
Phytoplankton Abundance by Major Taxonomic Group - W9602 Farfield Survey Results
February 23 - 28 1996

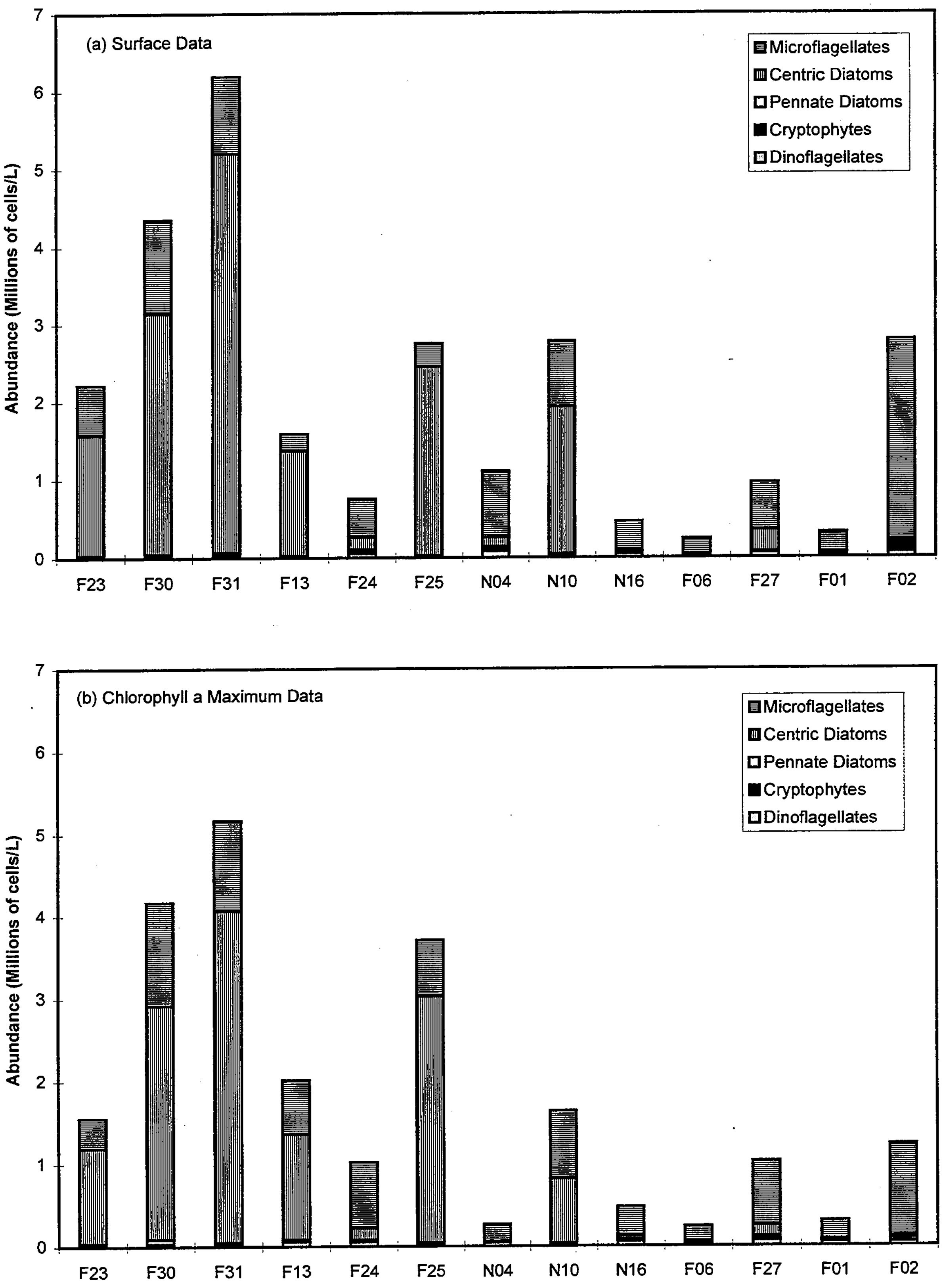


FIGURE 5-17
Phytoplankton Abundance by Major Taxonomic Group - W9604 Farfield Survey Results
April 1- 6, 1996

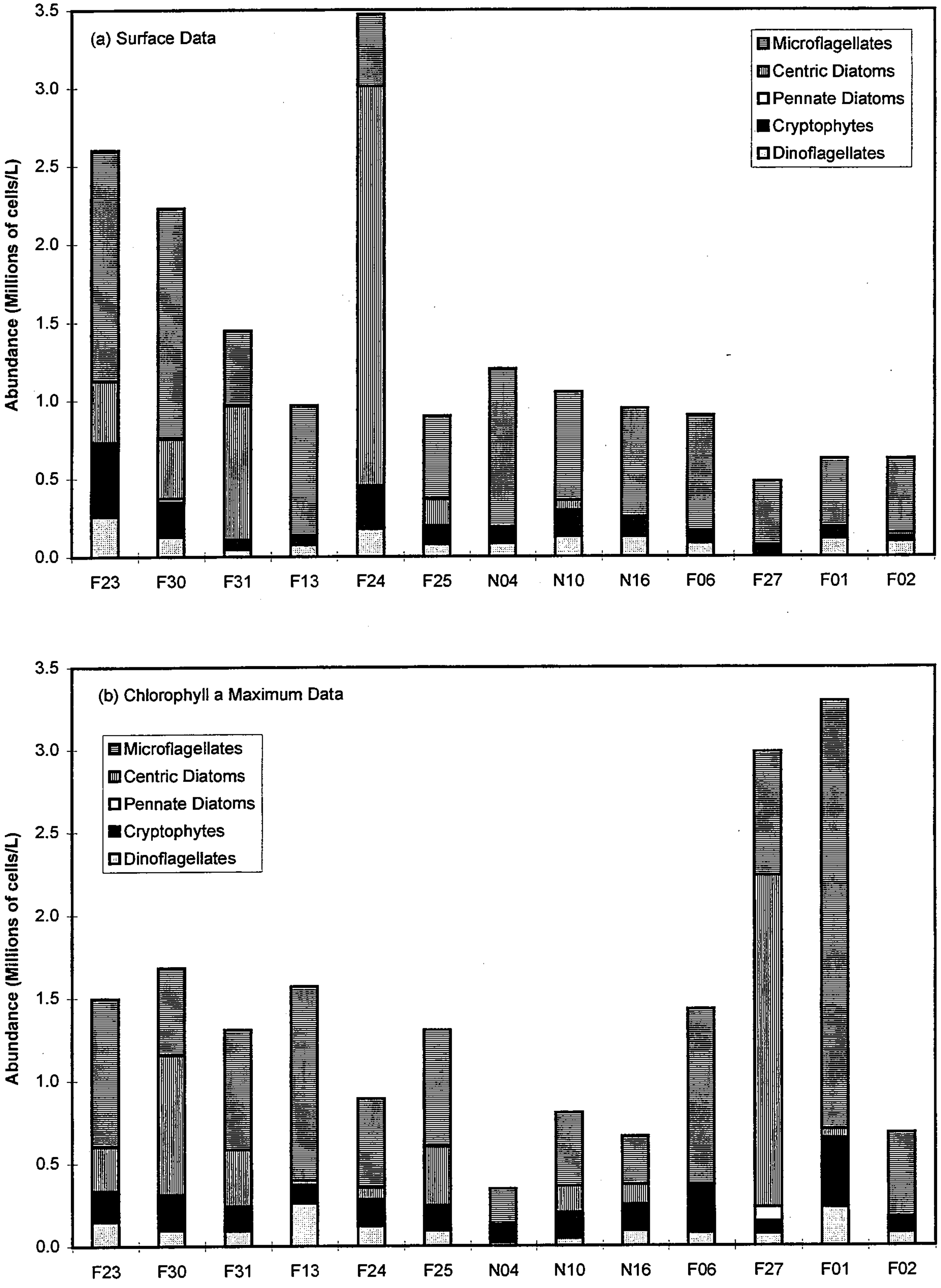


FIGURE 5-18

Phytoplankton Abundance by Major Taxonomic Group -W9607 Farfield Survey Results
June 17 -20 1996

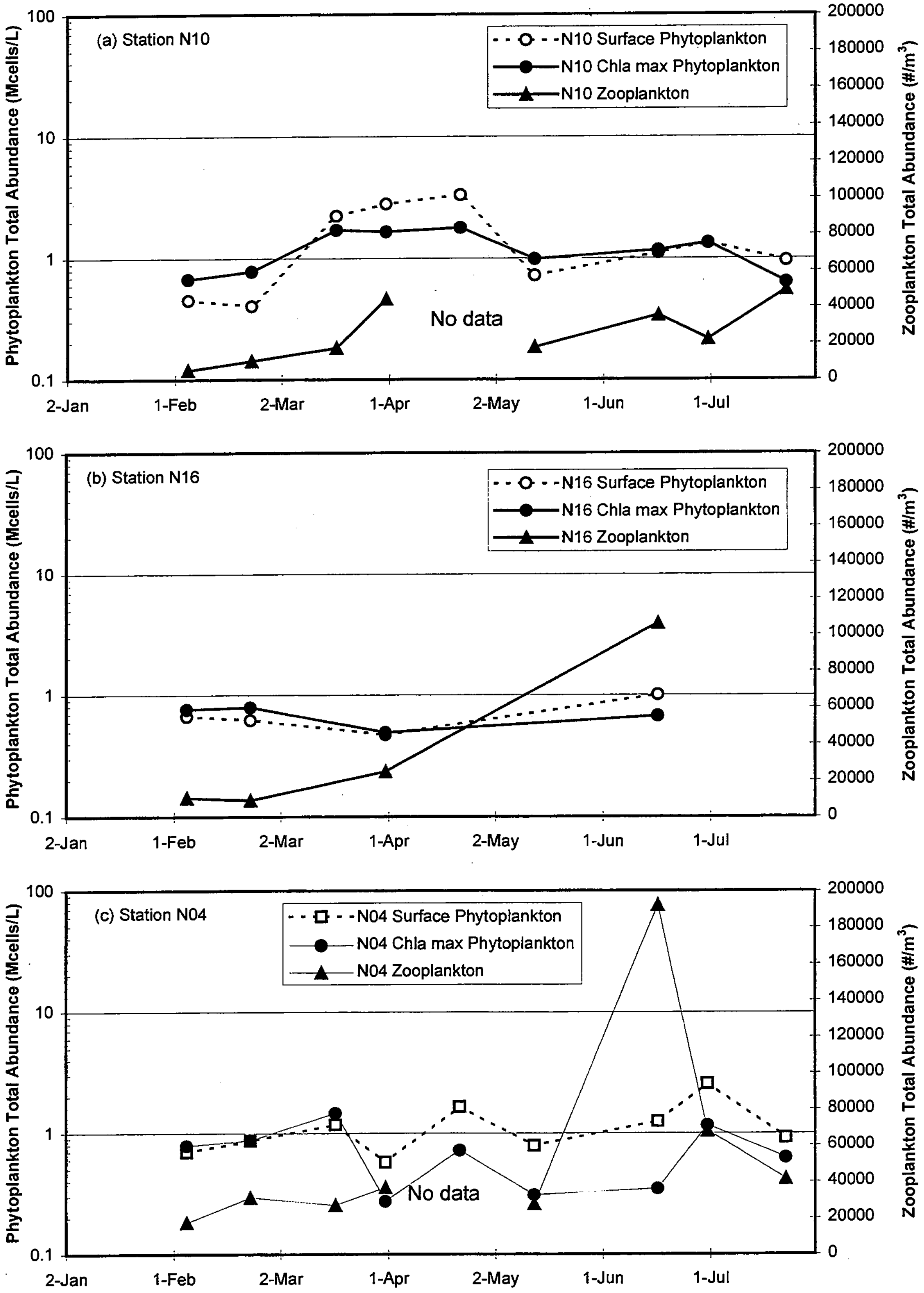


FIGURE 5-19

Nearfield Phytoplankton and Zooplankton Abundance, Surveys W9601 - W9609

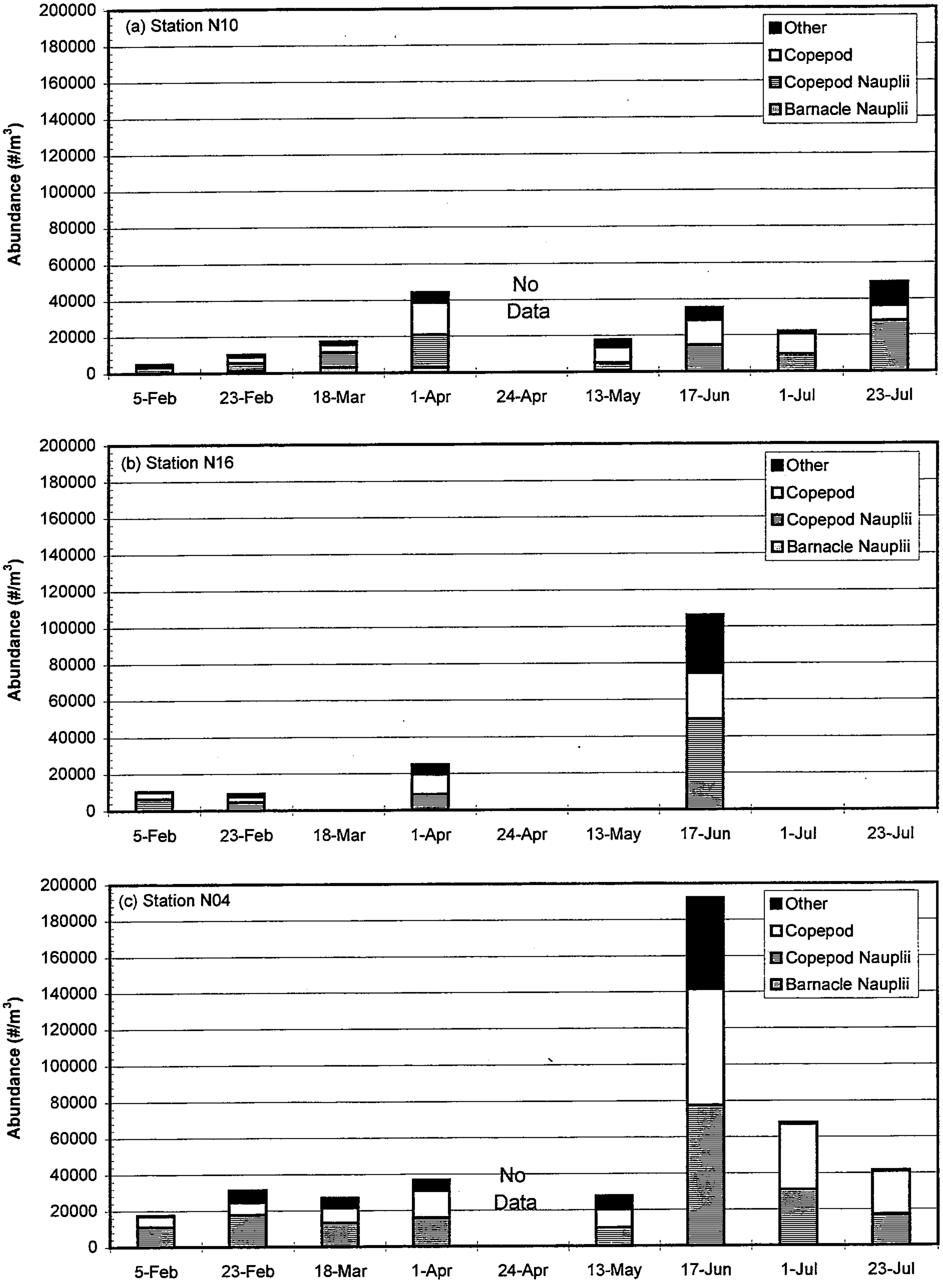


FIGURE 5-20

Nearfield Zooplankton Abundance by Major Taxonoimc Group

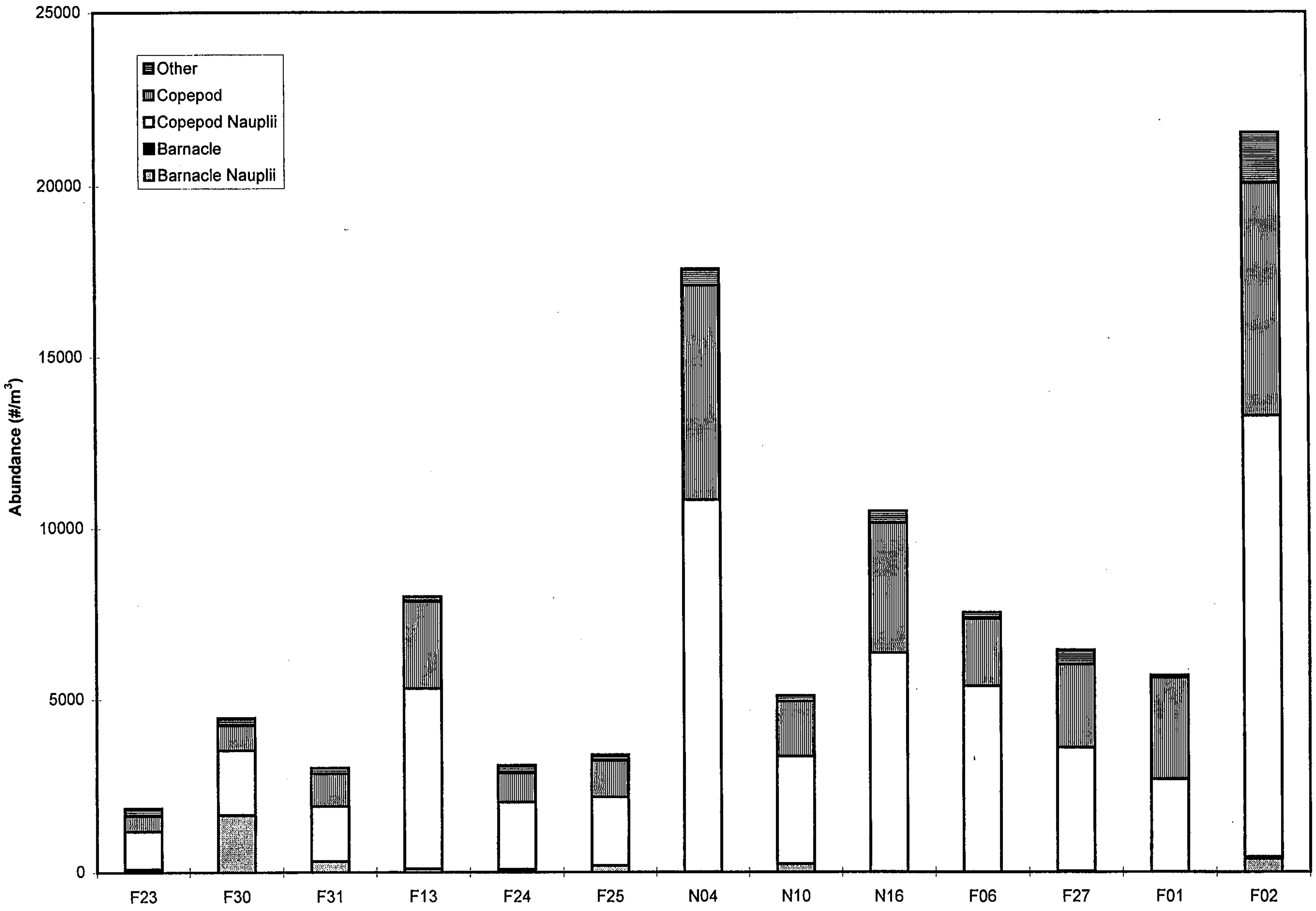


FIGURE 5-21
Zooplankton Abundance by Major Taxonomic Group - W9601 Farfield Survey Results
February 5 -10, 1996

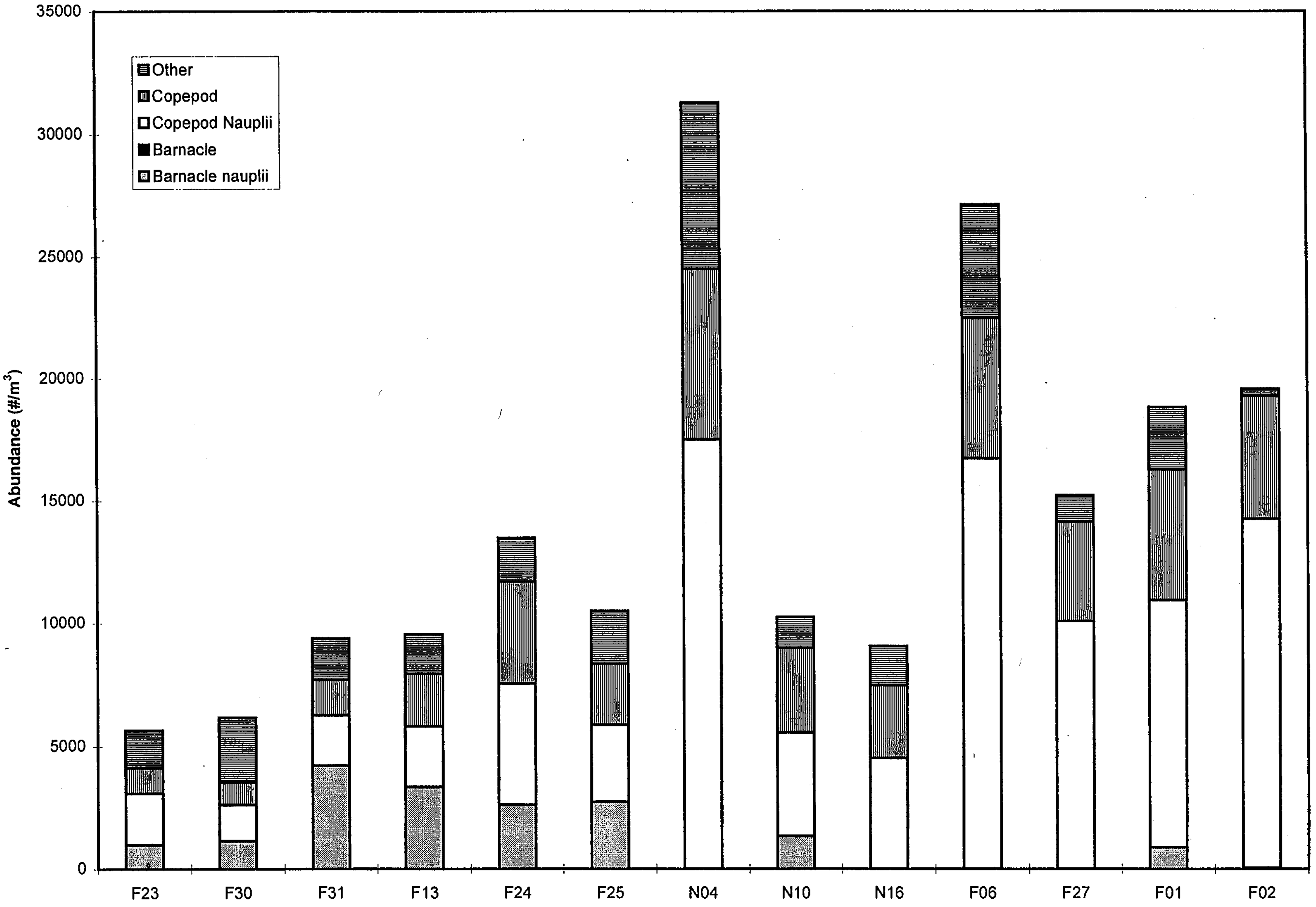


FIGURE 5-22
Zooplankton Abundance by Major Taxonomic Group - W9602 Farfield Survey Results
February 23 -28, 1996

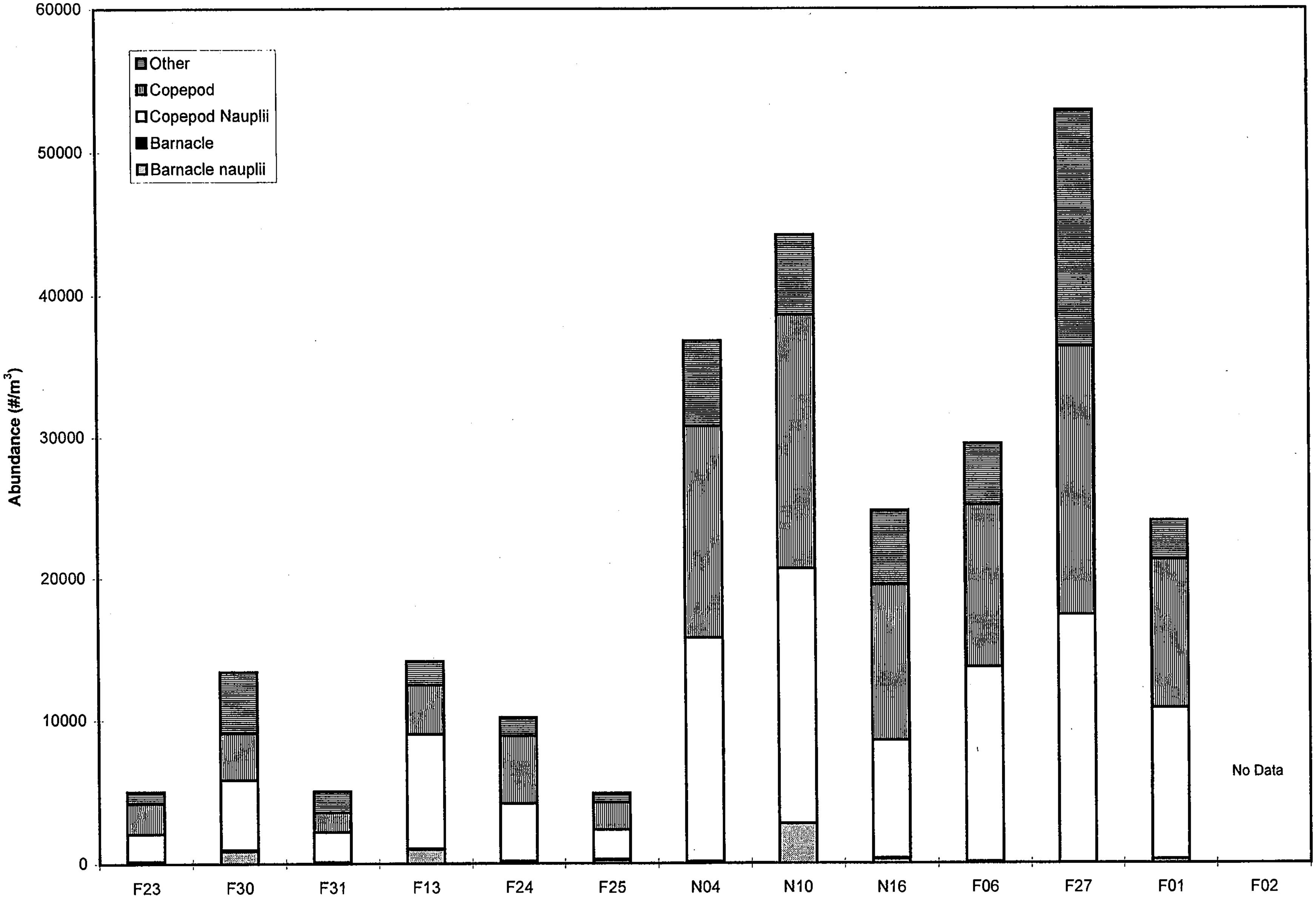


FIGURE 5-23
Zooplankton Abundance by Major Taxonomic Group - W9604 Farfield Survey Results
April 1 -6, 1996

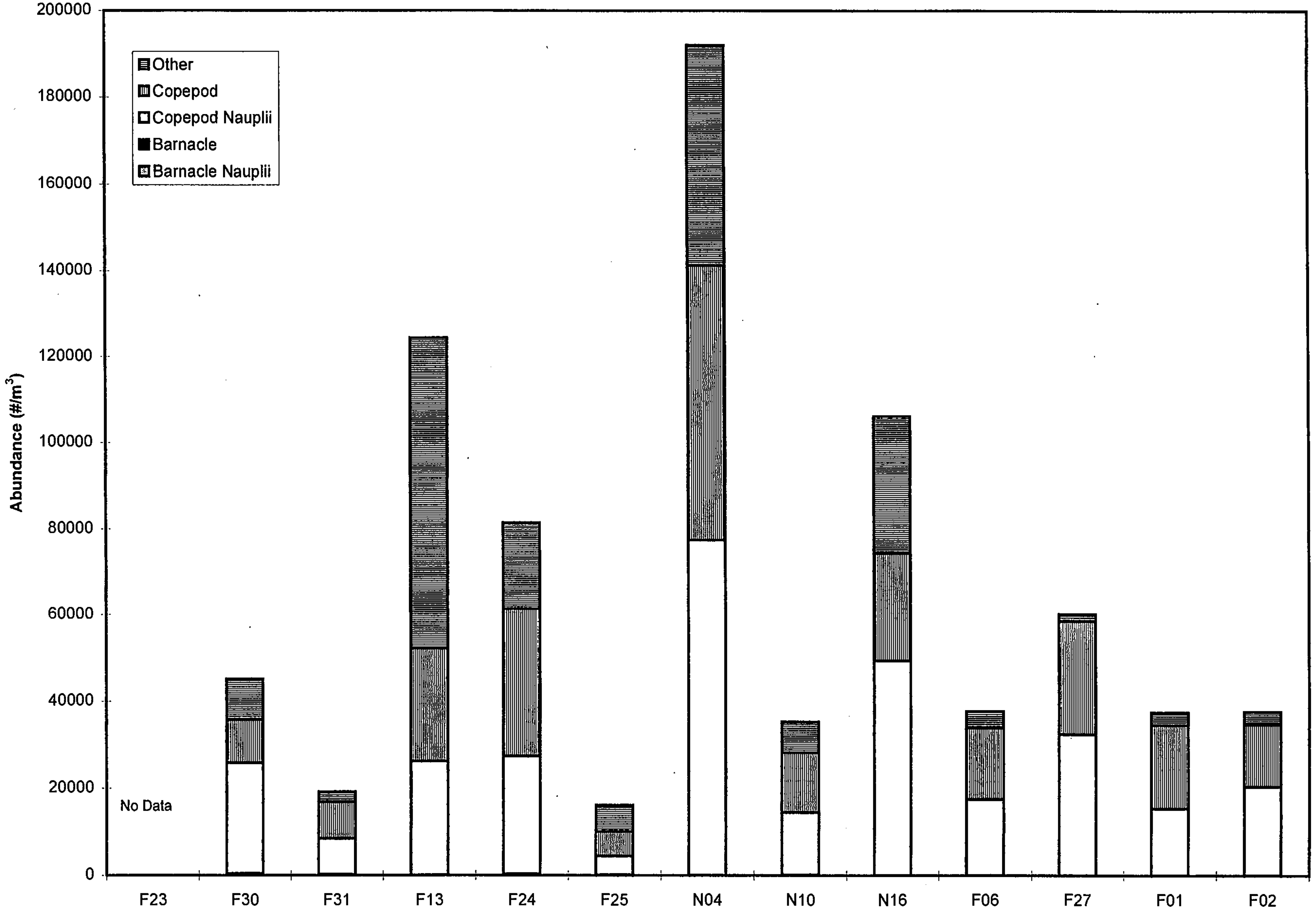


FIGURE 5-24
Zooplankton Abundance by Major Taxonomic Group - W9607 Farfield Survey Results
June 17 -20, 1996

6.0 SUMMARY OF MAJOR WATER COLUMN EVENTS

The purpose of this section is to provide a brief synthesis of some of the regional events supported by both the physical and biological trends in the data. Major events that occurred both regionally and in the nearfield as supported by a variety of data are presented.

A system-wide late winter bloom occurred in the latter part of February, resulting in high chlorophyll concentrations in all regions except Boston Harbor. The bloom was dominated by the centric diatoms *Thalassiosira* and *Chaetoceros*. Nutrient depletion in surface water was consistent with patterns of chlorophyll production. Maximum nutrient depletion in the nearfield water column during the semi-annual period was measured in March following the winter bloom. Local chlorophyll maxima in the surface water were measured in Cape Cod Bay (9-12 µg/L), off the Marshfield area (9 µg/L), in the nearfield (5 µg/L), and at the northern end of the boundary region (10-22 µg/L). Nearfield sub-surface chlorophyll concentrations were >6 µg/L, with a maximum (10-20 m) located in the central nearfield, while the harbor showed concentrations of <2 µg/L. The highest nearfield surface water DO concentrations were measured during the first three winter surveys related to the late winter bloom, reaching a peak in March. Productivity measurements were consistent with bloom conditions, with the highest values measured at the two outer nearfield productivity/respiration stations (approximately 3,000 $mgCm^{-2}d^{-1}$).

By the third (nearfield only) survey in March (W9603), maximum chlorophyll concentrations were segregated between inner and outer nearfield stations. A harbor-influenced inshore component resulted from the further development of the regional bloom into the harbor and coastal regions. A mid-water (20-40 m) continuation of the late winter bloom was also evident in the outer nearfield, where bottom water respiration (at N04) was as high as in surface water due to increased respiration of the settling organic material. The highest semi-annual POC concentration measured at station N04 was also reported in the bottom water during March. This substrate supported the maximum bottom water respiration rates measured during the period. Both chlorophyll and carbon-specific respiration data indicated that this material was associated with the late winter/spring bloom.

The onset of stratification was developing by mid-April (W9605) in the inner nearfield, but not until mid-May (W9606) in the outer nearfield. Stratification was augmented by calm weather and a persistent surface water salinity decline through April and May, reaching minimum values of <29 PSU. The spring freshet was caused by a water mass intrusion of low salinity water from the Gulf of Maine, potentially related to spring fluvial discharge. The depleted nutrients in the nearfield surface water, which contributed to the collapse of the late winter/spring bloom in the outer nearfield, appeared to be resupplied by this water mass incursion as evidenced in the May survey (W9606) nutrient data. These additional nutrients, particularly the increase in SiO_4 in the surface water (>7 μM), appeared to have resulted in increased diatom productivity. Evidence of this production in the nearfield data included:

- rapid reductions in dissolved SiO_4 concentrations;
- elevated water column DO concentration and percent saturation by the ensuing June survey (W9607);
- increased chlorophyll-specific production in surface water during W9607; and
- peaks in surface water respiration, POC, and carbon-specific respiration during W9607;

Unfortunately, continuous data from the WETLabs instrument were not available prior to June 11. The initial record did suggest a trend of decreasing chlorophyll at the onset of the data, potentially indicating elevated chlorophyll concentrations were present in early June. The data did show a modest increase in chlorophyll coincident with the June survey.

The rate of daily production in surface water at N04 in the subsequent survey (W9608, early July) was as high as during the winter bloom. A localized bloom of the centric diatom *Rhizosolenia fragilissima* was reported at N04 during this survey, with indications from continuous monitoring that it may have developed further during the following week. There was a peak in surface water POC, and chlorophyll-specific production at station N04 provided evidence of efficient photosynthesis, despite the low biomass in the water column. The cumulative evidence suggests that high levels of production were occurring in the nearfield during June and July. The phytoplankton production was apparently being rapidly grazed by zooplankton, whose total abundance peaked in the nearfield during the period, keeping phytoplankton biomass low.

By contrast, the data indicate that productivity in the harbor increased throughout the period, reaching the semi-annual maximum value at station F23 in June (5,203 $mgCm^{-2}d^{-1}$). Although peak production in the inner nearfield coincided with the climax of the late winter/spring bloom in April (station N10, around 5,000 $mgCm^{-2}d^{-1}$), a secondary peak occurred in June as well (4,455 $mgCm^{-2}d^{-1}$). Again, concentrations of chlorophyll were relatively low in the harbor and adjacent stations (3 to 6 μg/L), indicating that grazing was also controlling phytoplankton biomass.

7.0 REFERENCES

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APPENDIX A

Productivity Methods

Methods

Production Analyses by ^{14}C - Field Procedures.

From each of the 5 productivity depths at each productivity station, samples were obtained by filtration through 300 mm Nitex screen (to remove zooplankton) from the Niskin bottles into opaque 1 gal polyethylene bottles. Under subdued green light, sub-samples were transferred by siphon into individual 75 ml acid cleaned polycarbonate bottles. Each bottle was flushed with approximately 250 ml of sample. A total of 16 bottles (14 light bottles, 2 dark bottles) were filled for each depth and incubated in a light and temperature controlled incubator. Light bottles from each depth are incubated at 14 light intensities (250 W tungsten-halogen lamps attenuated with Rosco neutral density filters) and all bottles incubated within 2° C of the *in situ* temperature at each depth for 4-6 hr (actual time was recorded). Single bottles of sample collected from each depth was assayed for background (time-zero) activity.

The 75 ml samples were incubated with 5-10 μCi ^{14}C-bicarbonate (higher activity during winter and spring season) and biological activity terminated by filtration of the entire contents of the bottles through 2.5 cm diameter Whatman GF/F glass fiber filters and immediate contact of the filters with 0.2 ml of a 20% aqueous solution of acetic acid contained in pre-prepared 20 ml glass scintillation vials (vials immediately recapped). For specific activity determination 0.1 ml aliquots of sample were placed in pre-prepared 20 ml scintillation vials containing 0.2 ml of benzethonium hydroxide (approximately 1.0 M solution in methanol; Sigma Chemical Company) to covalently sequester the ^{14}C inorganic carbon (vials immediately recapped). Specific activity was determined from the measured activity and measurements of DIC.

Samples for DIC analysis were collected from the Niskin bottles into 300 ml BOD bottles, following collection procedures used for oxygen analyses. Within 6 hr. of BOD sample collection, duplicate 10 ml samples were injected into 20 ml crimp-sealed serum bottles containing 0.5 ml of a 2N aqueous solution of sulfuric acid for subsequent I.R. analysis (Beckman IR-315 infrared analyzer) of the gaseous phase (5 - 150 ml samples) at the W.H.O.I. laboratory.

During summer months 1995 some of the ^{14}C incubations (W9508-W9513) were incubated on shore in the MWRA laboratory at Deer Island. Samples were collected in opaque bottles and maintained at *in situ* temperature until transport to the lab. The ^{14}C incubations were begun approximately 2 - 3 hr from sample collection and should compare favorably with samples that are incubated aboard the ship.

Production Analyses by ^{14}C - Laboratory Procedures.

Sample processing. Upon arrival to the W.H.O.I. laboratory scintillation cocktail (10 ml Scintiverse II) were added to the scintillation vials containing the specific activity samples and analyzed using a Packard Tricarb 4000 liquid scintillation counter which possesses automated routines for quench correction. Vials containing acidified filters were opened and placed in a ventilator in the hood for overnight to allow the filters to dry and excess ^{14}C carbon dioxide dissipate. The vials containing the filters were analyzed by scintillation spectroscopy as described above.

Calculation of Primary production. Volume specific primary production was calculated using equations similar to that of Strickland and Parsons (1972) as follows:

$$P(i) = \frac{1.05(DPM(i) - DPM(blk))}{V_s A_{sp} T}$$

$$P(d) = \frac{1.05(DPM(d) - DPM(blk))}{V_s A_{sp} T}$$

$$A_{sp} = \frac{DPM(sa) - DPM(back)}{V_{sa} DIC}$$

where:

P(i) = primary production rate at light intensity i, (µgC $l^{-1}h^{-1}$ or mgC $m^{-3}h^{-1}$)
P(d) = dark production, (µgC $l^{-1}h^{-1}$ or mgC $m^{-3}h^{-1}$)
A_{sp} = specific activity (DPM/µgC)
DPM(i) = dpm in sample incubated at light intensity i
DPM(blk) = dpm in zero time blank (sample filtered immediately after addition of tracer)
DPM(d) = dpm in dark incubated sample
DPM(back) = background dpm in vial containing only scintillation cocktail
V_s = volume of incubated sample (l)
T = incubation time (h)
V_{sa} = volume counted of specific activity sample (ml)
DIC = concentration of dissolved inorganic carbon (µg/ml)

P-I curves. For each of the 5 depths for each photosynthesis station a P-I curve was obtained from the data P(I) = P(i)-P(d) vs. the irradiance (I, µE $m^{-2}s^{-1}$) that the incubating sample is exposed. The P-I curves were fit via one of two possible models, depending upon whether or not significant photoinhibition occurs. In cases where photoinhibition is evident the model of Platt et al. (1980) was fit (SAAM II, 1994) to obtain the theoretical maximum production, and terms for light-dependent rise in production and degree of photoinhibition:

$$P(I) = P_{sb}''(1 - e^{-a})e^{-b}$$

$$P\max'' = P_{sb}''[a''/(a'' + \beta'')][\beta''/(a'' + \beta'')]^{\beta''/}$$ (Lohrenz et al., 1994)

where:

P(I) = primary production at irradiance I, corrected for dark fixation (P(i)-P(d))
P_{sb}"= theoretical maximum production without photoinhibition
a = α"I/Psb", and α"is the initial slope the light-dependent rise in production

b = β"I/Psb", and β"is a term relaying the degree of photoinhibition
P_{max}"= light saturated maximum production

If it is not possible to converge upon a solution the model of Webb et al. (1974) was similarly fit to obtain the maximum production and the term for light-dependent rise in production:

$$P(I) = P_{\max}"\left(1 - e^{-a'}\right)$$

where:

P(I) = primary production at irradiance I corrected for dark fixation (P(i)-P(d))
P_{max}"= light saturated maximum production
a' = α"I/Pmax", and α"is the initial slope the light-dependent rise in production

Nearly all P-I curves obtained did not show evidence of photoinhibition and were fit according to the Webb model.

Light vs. depth profiles. To obtain a numerical representation of the light field throughout the water column bin averaged CTD light profiles (0.5 m intervals) was fit (SAAM II, 1994) to an empirical sum of exponentials equation of the form:

$$I_Z = A_1 e^{-a_1 Z} + A_2 e^{-a_2 Z}$$

which is an expansion of the standard irradiance vs. depth equation:

$$I_Z = I_0 e^{-kZ}$$

where:

I_Z = light irradiance at depth Z
I_0 = incident irradiance (Z=0)
k = extinction coefficient
A_1, A_2 = factors relating to incident irradiance ($I_0 = A_1+A_2$)
a_1, a_2 = coefficients relating to the extinction coefficient ($k = a_1+a_2$)

The expanded equation was used as pigment absorption and other factors usually resulted in significant deviation from the idealized standard irradiance vs. depth equation. The best fit profiles were used to compute percent light attenuation for each of the sampling depths.

Daily incident light field. During normal CTD hydrocasts the incident light field was routinely measured via a deck light sensor at high temporal resolution. The average incident light intensity was determined for each of the CTD casts to provide, over the course of the photoperiod (12 hr period centered upon solar noon), a reasonably well resolved irradiance time series consisting of 12-17 data points. A 48 point time series (every 15 min.) of incident was obtained from these data by linear interpolation.

Calculation of daily primary production. Given the best fit parameters (Pmax", α", β") of the P-I curves obtained for each of the 5 sampling depths, percent *in situ* light attenuation at each depth determined from the sum of exponential fits of the *in situ* light field, and the photoperiod incident light (I_0) time series it was possible to compute daily volumetric production for each depth. To do this at a given depth, hourly production was determined for the *in situ* light intensity computed for each 15 min. interval of the photoperiod, using the appropriate P-I parameters and *in situ* irradiance computed from the percent attenuation and incident irradiance. Daily production (μgC $l^{-1}d^{-1}$) was obtained by integration of the determined activity throughout the 12 hr photoperiod. An advantage of this approach is that seasonal changes in photoperiod length are automatically incorporated into the integral computation. For example, during winter months computed early morning and late afternoon production contributes minimally to whole day production, whereas during summer months the relative contribution during these hours is more significant. The investigator does not have to decide which factor to employ when converting hourly production to daily production. The primary assumption for the approach is that the P-I relationship obtained at the time of sample procurement (towards the middle of the photoperiod) is representative of the majority of production occurring during the photoperiod.

Calculation of daily areal production. Areal production (mgC $m^{-2}d^{-1}$) was obtained by trapezoidal integration of daily volumetric production vs. depth from the sea surface down to the 0.5% light level. The P-I factors from the uppermost sampling depth (approximately 1.2 - 2.7 m, depending upon weather state) were used to compute the contribution of the portion of the water column between the sea surface interface and uppermost sampling depth to areal production (rather than to assume that the activity in the uppermost sample is representative of that section of the water column, which is not always the case).

Calculation of chlorophyll-specific parameters. Chlorophyll-specific measures of the various parameters were determined by dividing by the appropriate chlorophyll term obtained from independent measurements:

$$a = \frac{a"}{[chla]}$$

$$P\max = \frac{P\max"}{[chla]}$$

where:

α = chlorophyll-a-specific initial slope of light-dependent production $[(gC(gchla)^{-1}h^{-1}(\mu Em^{-2}s^{-1})^{-1}]$

Pmax = light saturated chlorophyll-specific production $[gC(gchla)^{-1}h^{-1}]$

APPENDIX B

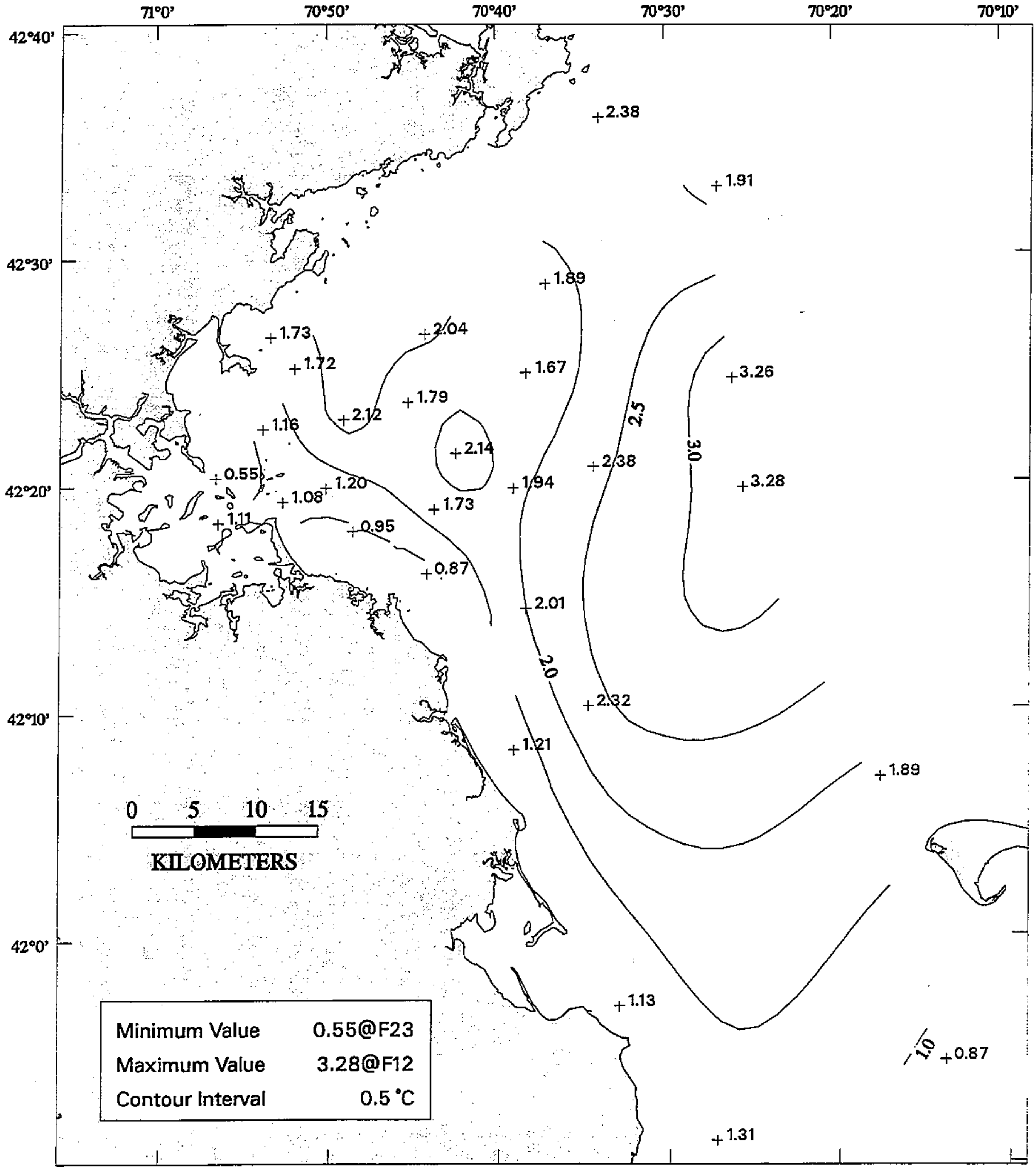
Surface Contour Plots - Farfield Surveys

All contour plots were created using data from the surface bottle sample (A). Each plot is labelled on the bottom right with the survey number ("9601"), and parameter as listed below. The minimum and maximum value, and the station where the value was measured, is provided for each plot, as well as the contour interval and parameter units.

Appendix B: Table of Contents

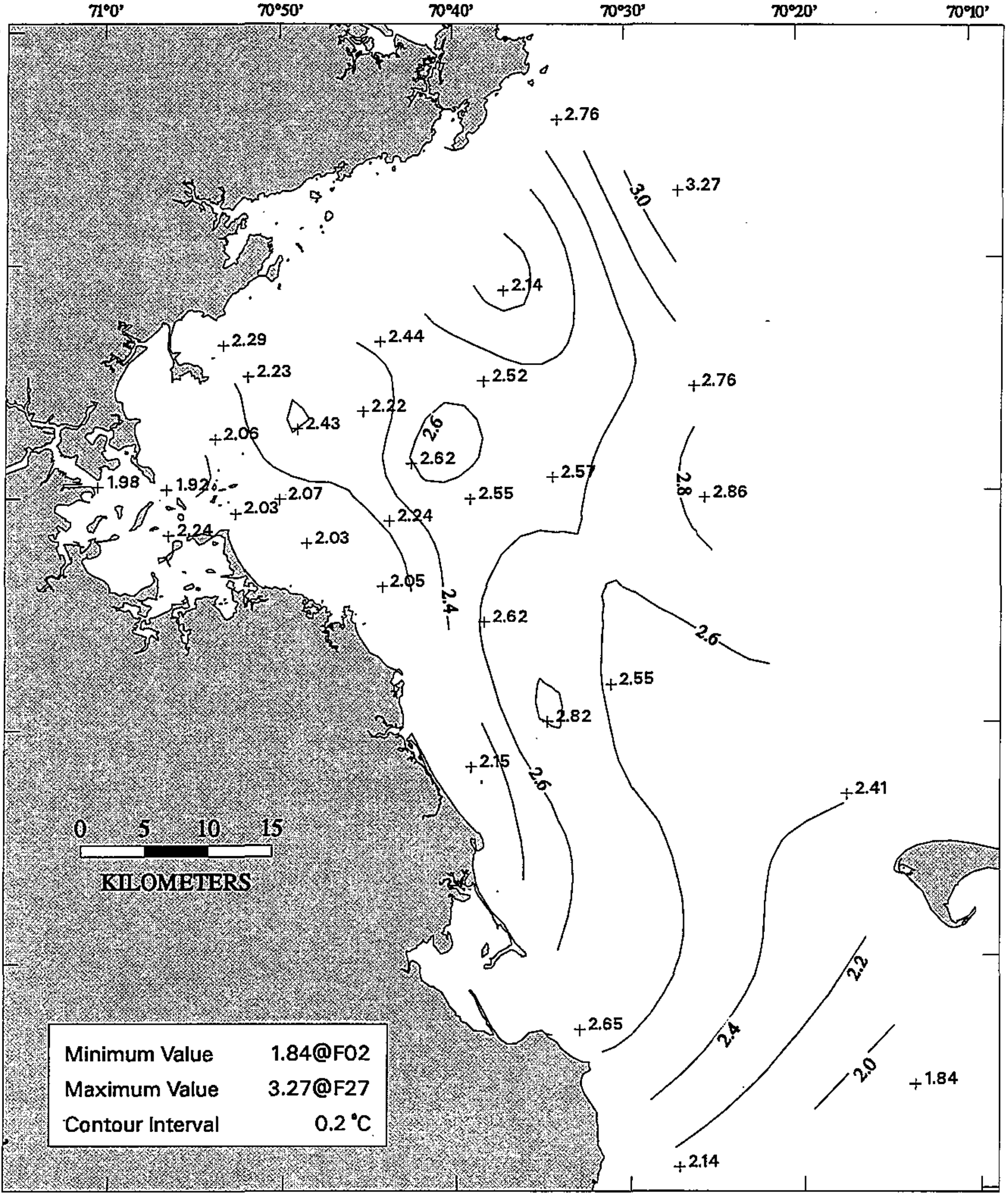
Parameter Name	Map Parameter Name	Units
Temperature	temp_lin	°C
Salinity	sal_lin	PSU
Transmissivity (beam attenuation)	tran_lin	/m
Nitrate (NO_3)	no3_lin	µM
Phosphate (PO_4)	po4_lin	µM
Silicate (SiO_4)	sio4_lin	µM
Dissolved Inorganic Nitrogen (DIN*)	din_lin	µM
Chlorophyll *a*	fluo_lin	µg/L

*$NO_3 + NO_2 + NH_4$

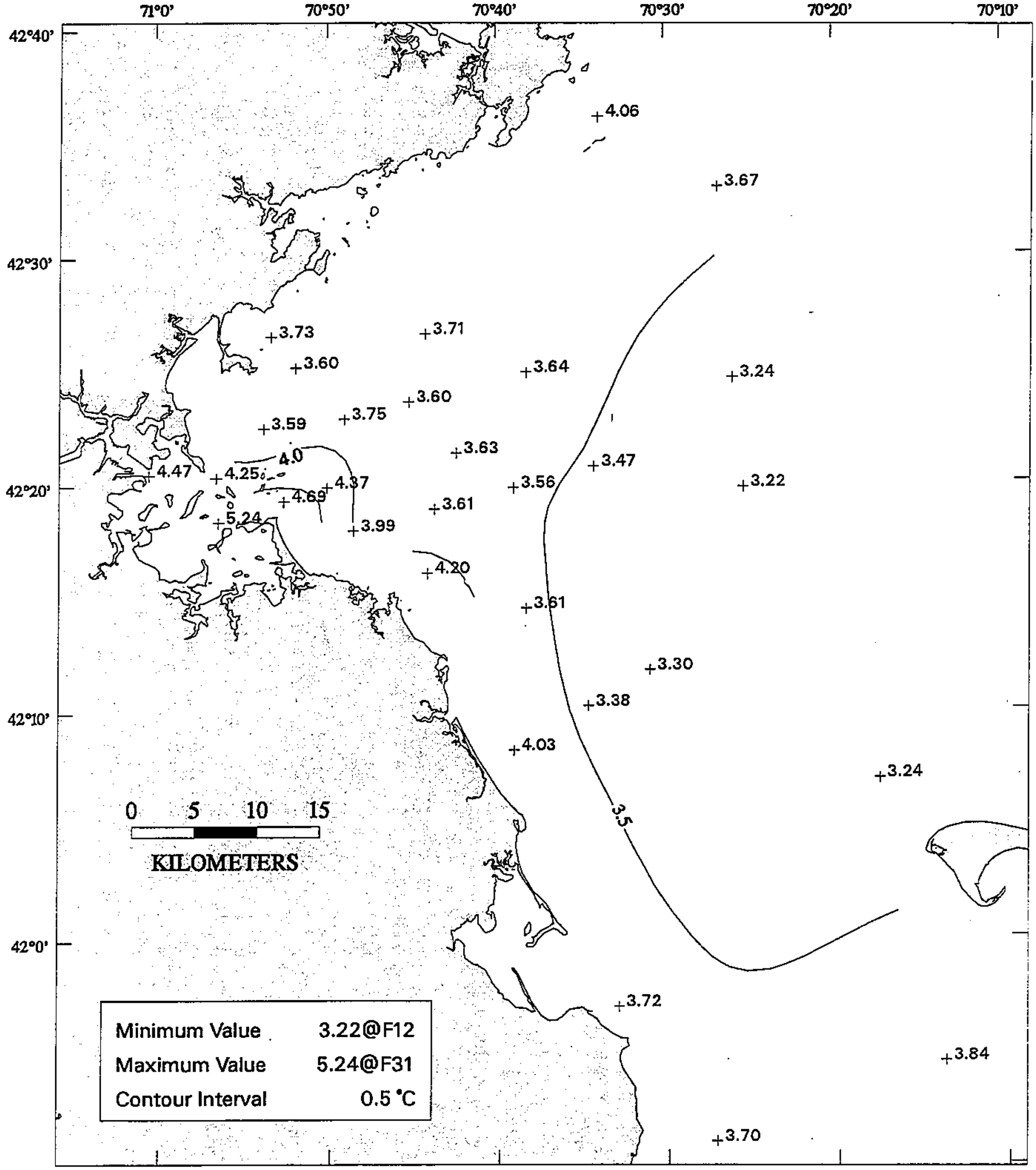


Minimum Value	0.55@F23
Maximum Value	3.28@F12
Contour Interval	0.5 °C

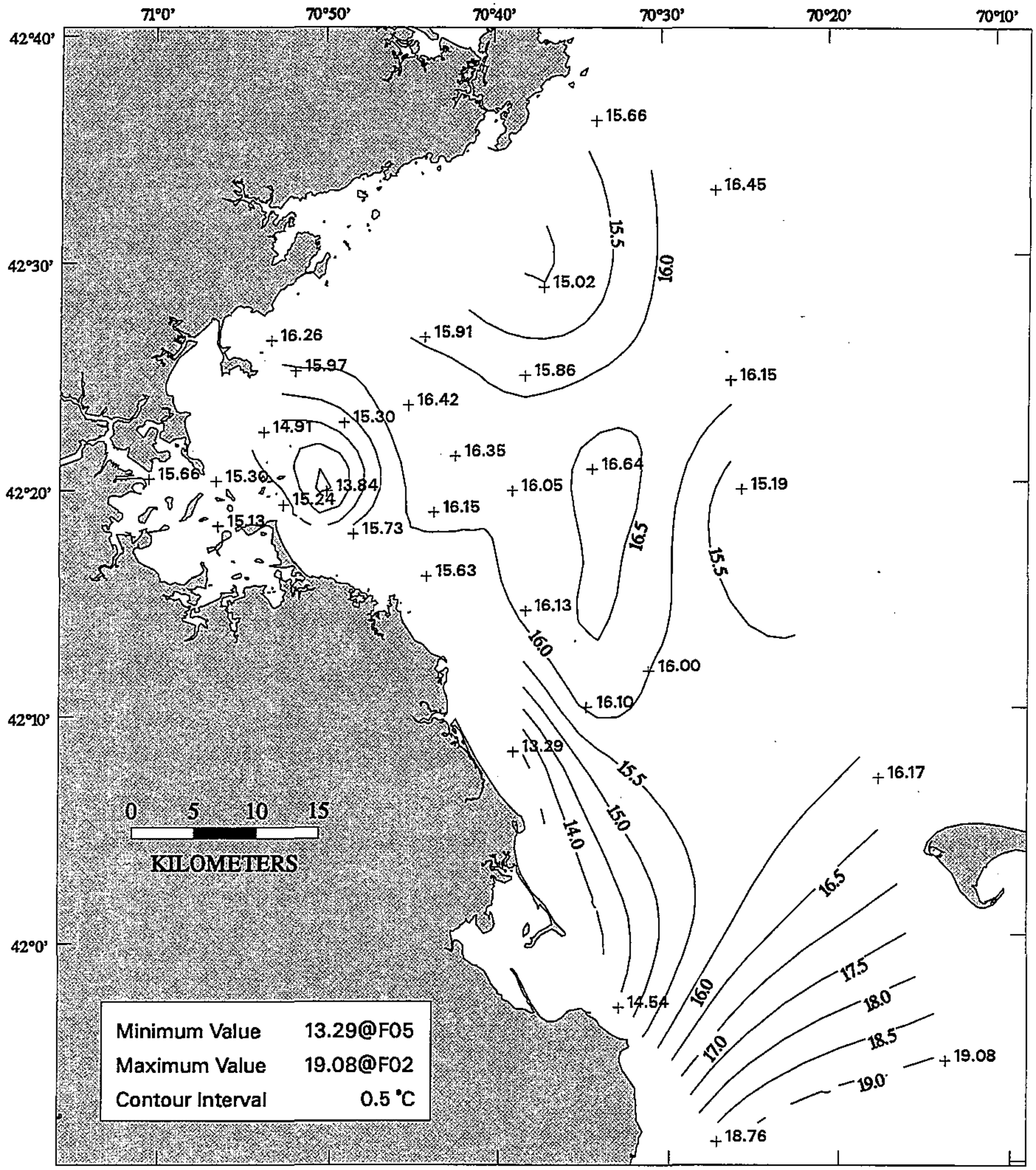
9601temp_lin
TEMP



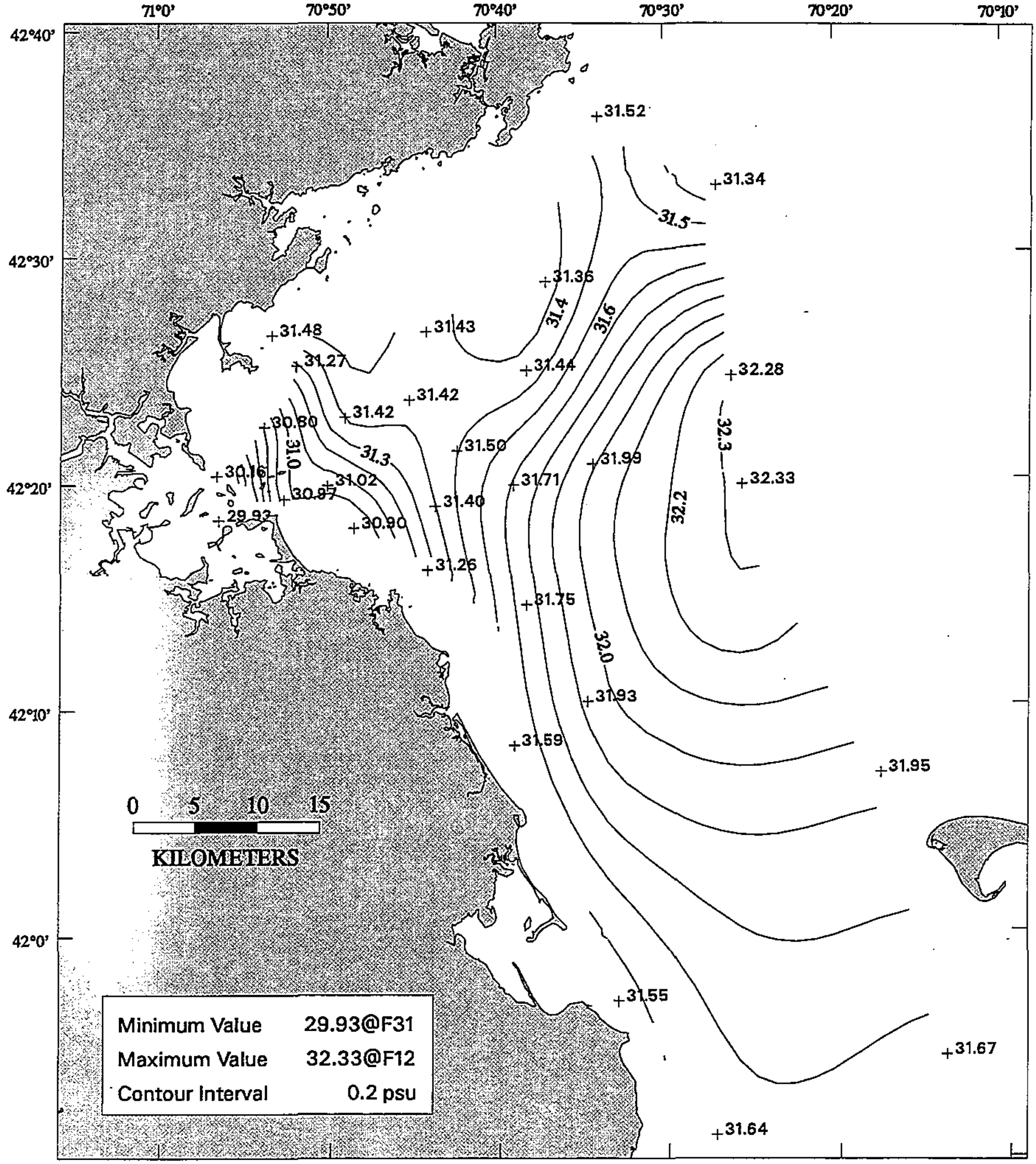
9602temp_lin
TEMP



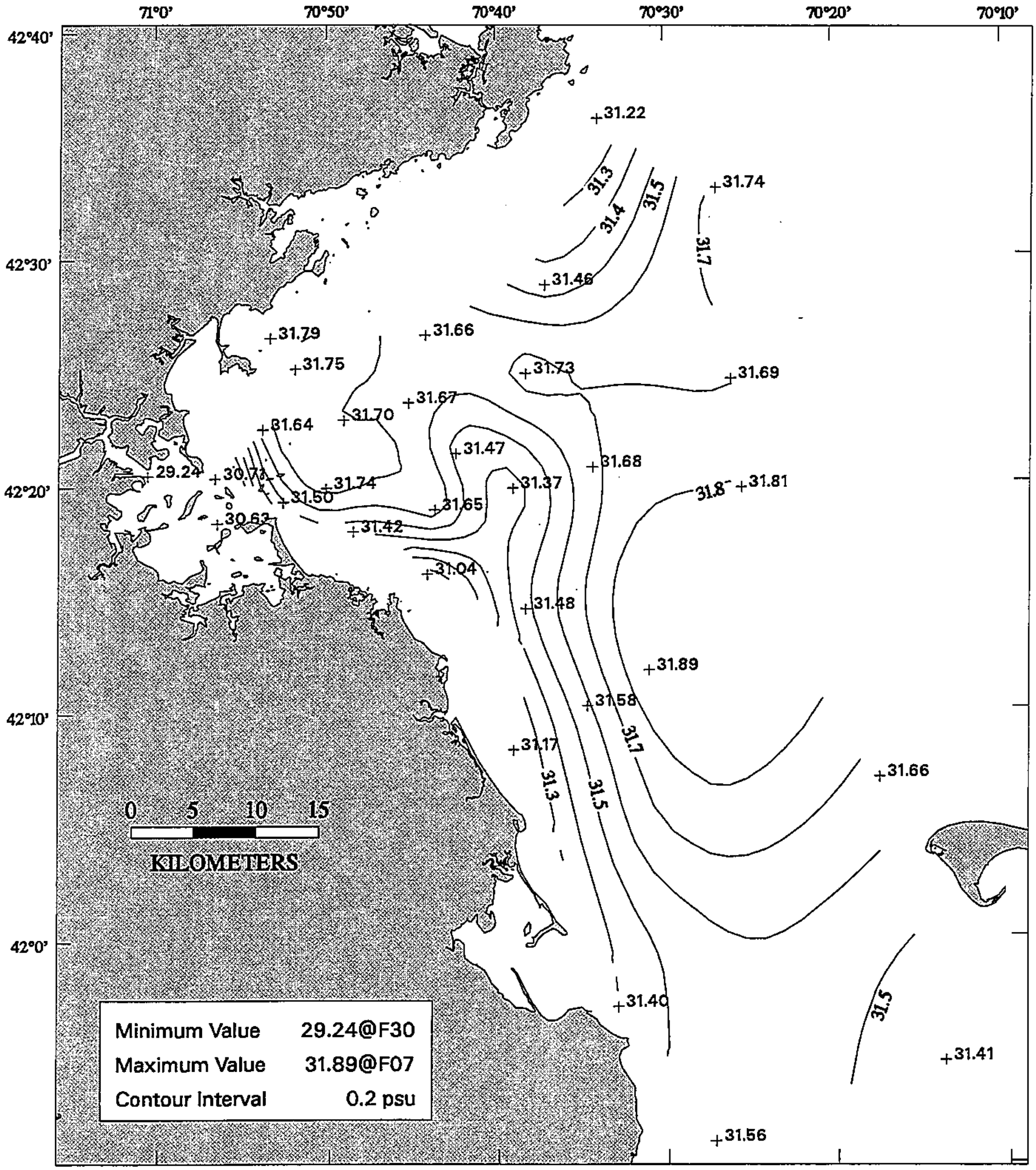
9604temp_lin
TEMP



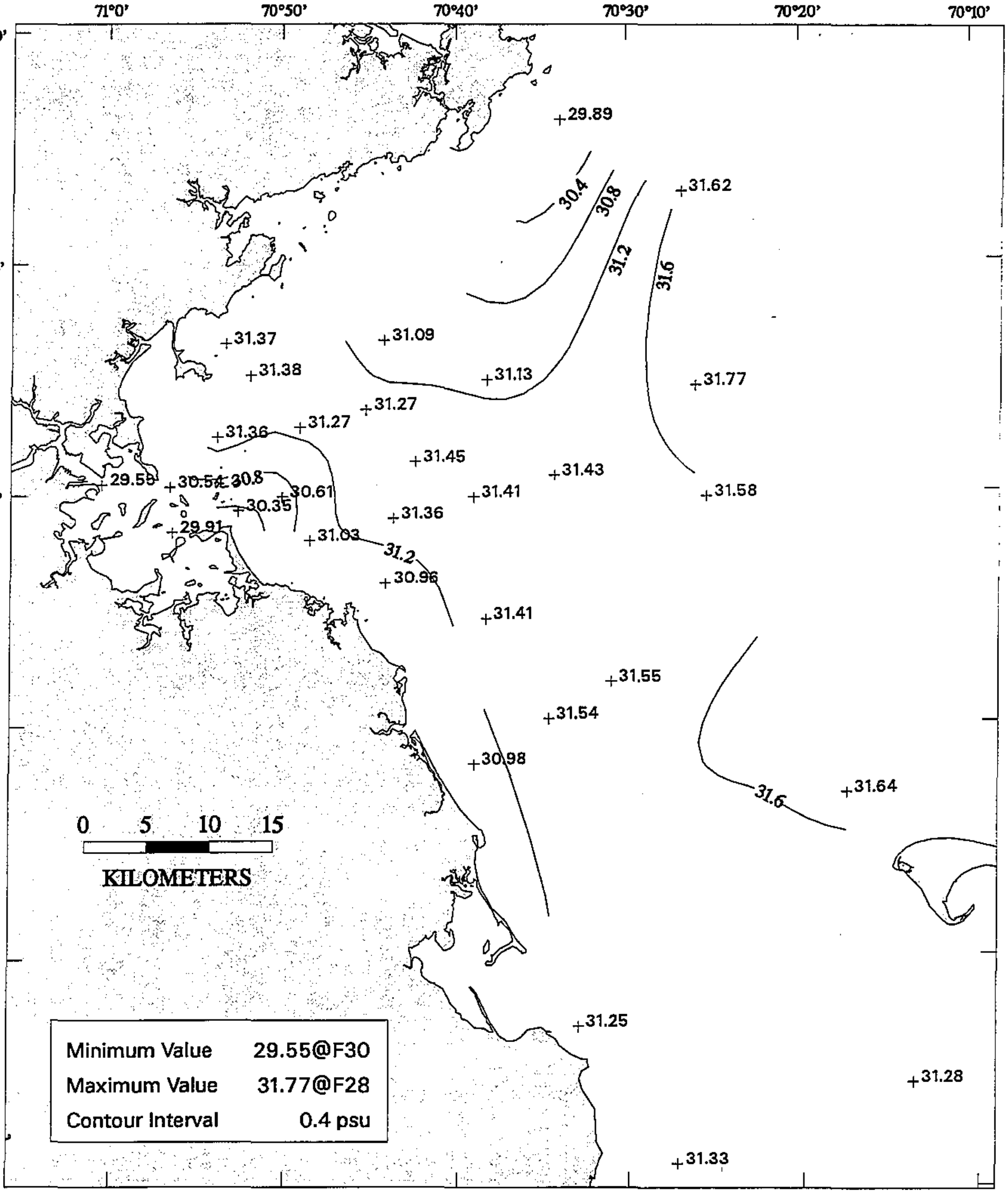
9607temp_lin
TEMP



9601sal_lin
SAL

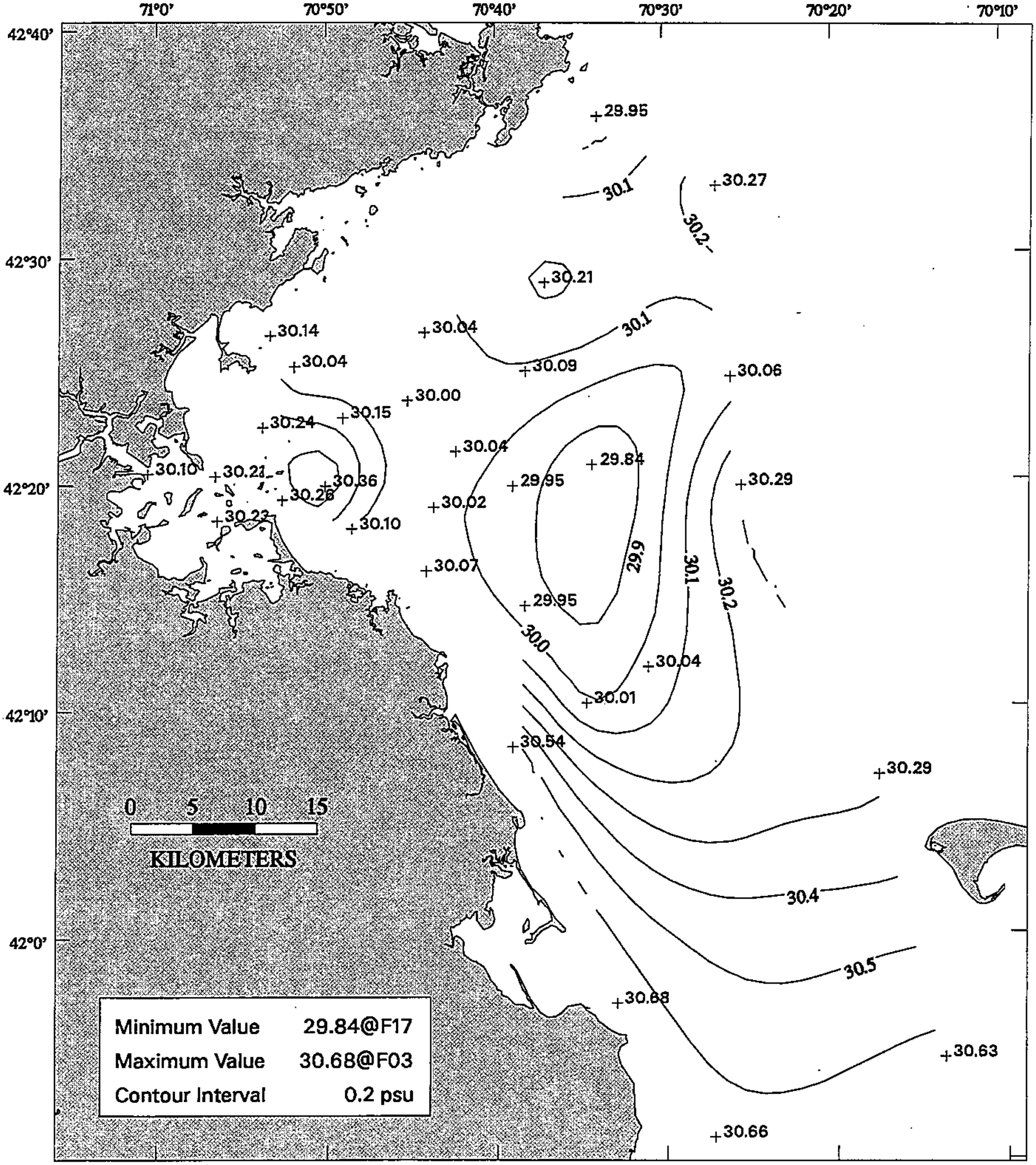


9602sal_lin
SAL

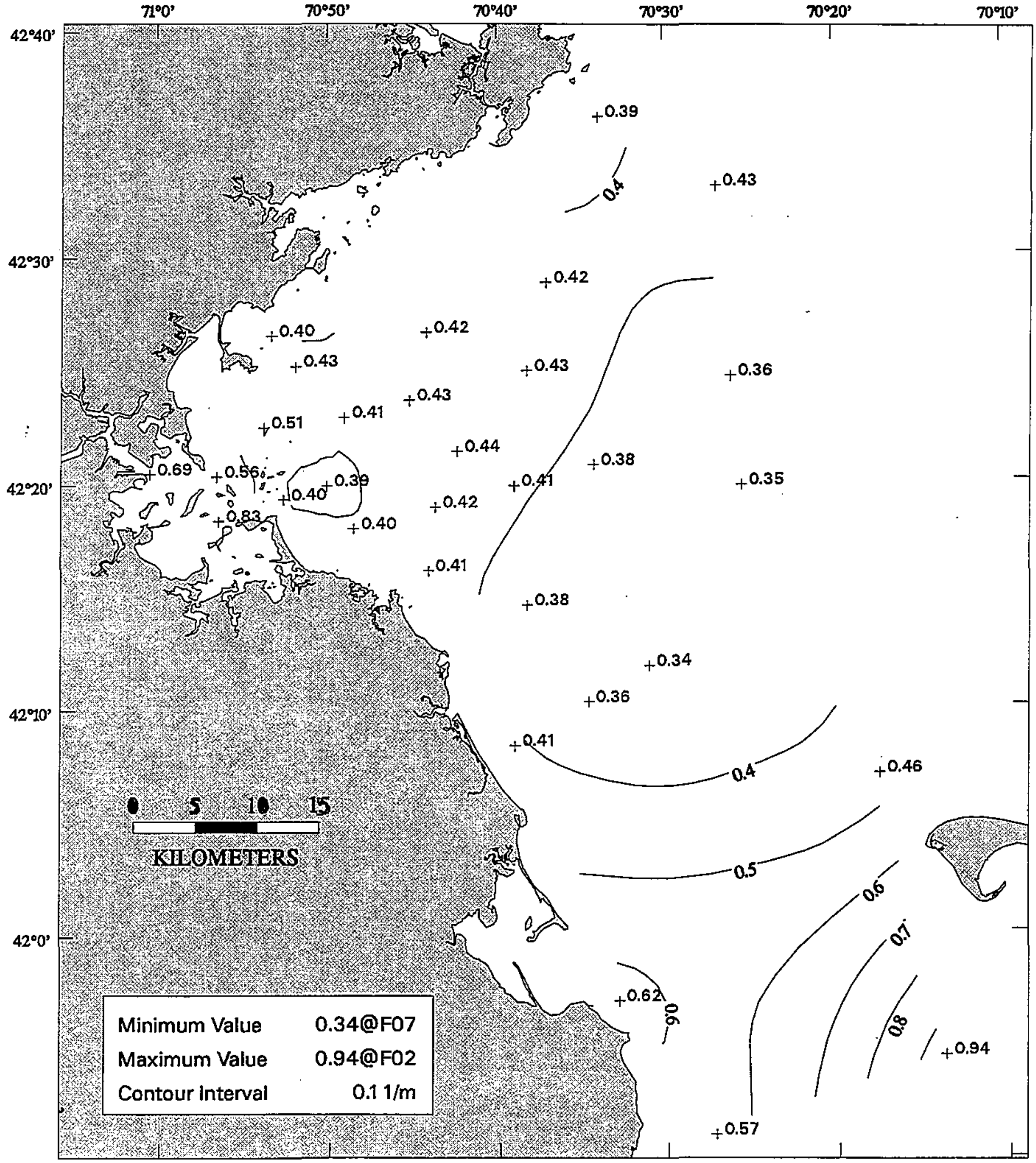


Minimum Value	29.55@F30
Maximum Value	31.77@F28
Contour Interval	0.4 psu

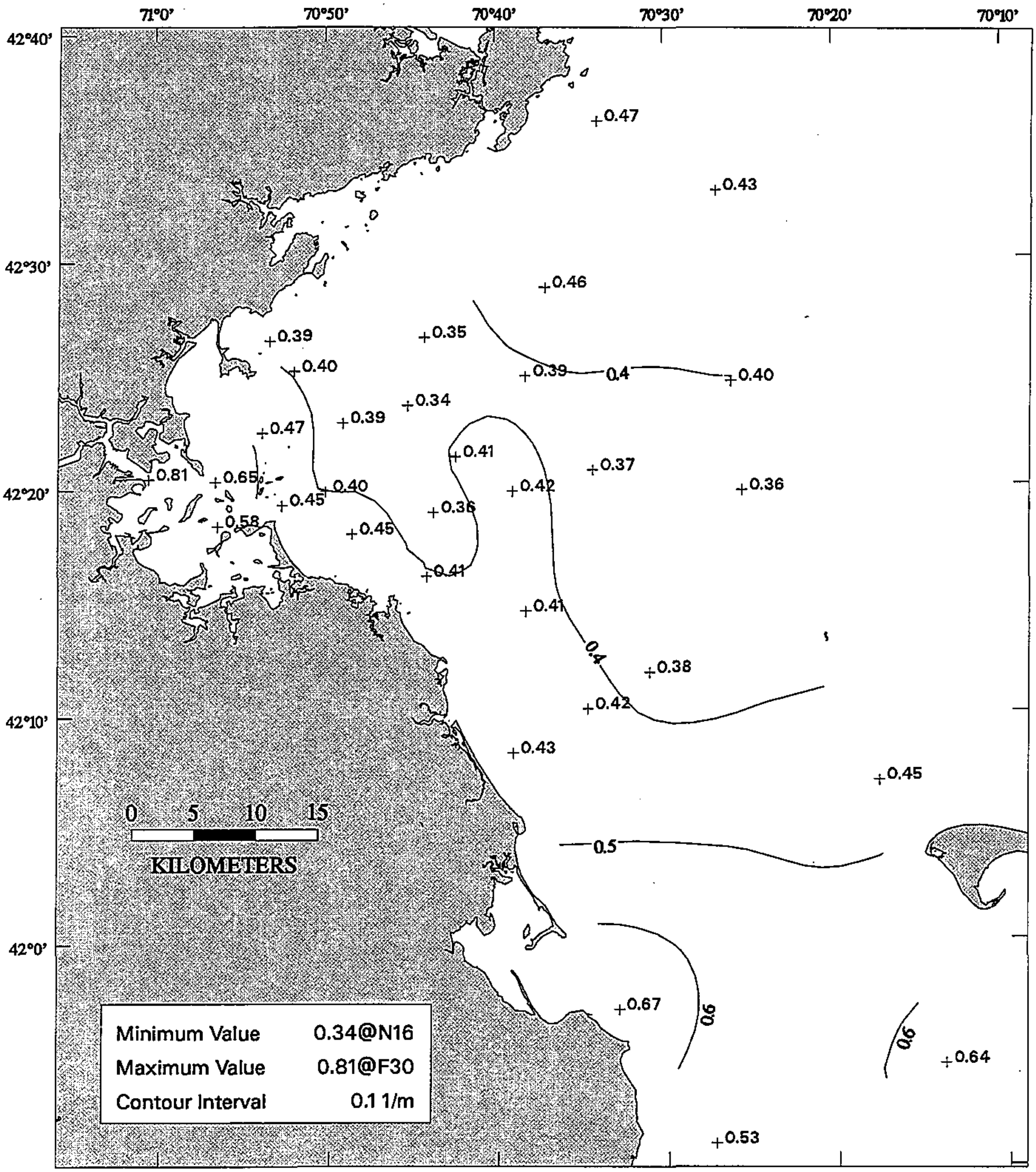
9604sal_lin
SAL



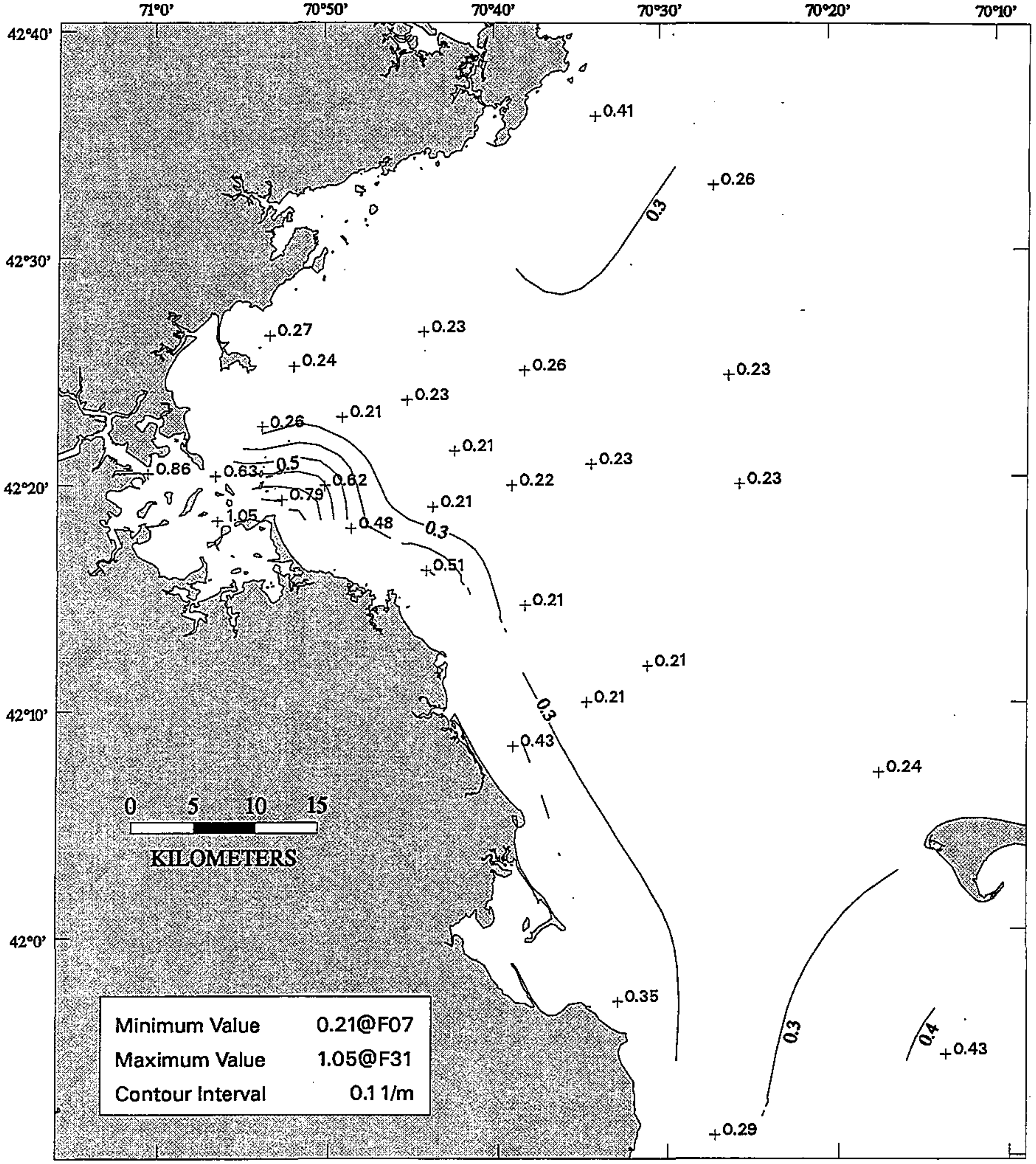
9607sal_lin
SAL



9601tran_lin
TRAN

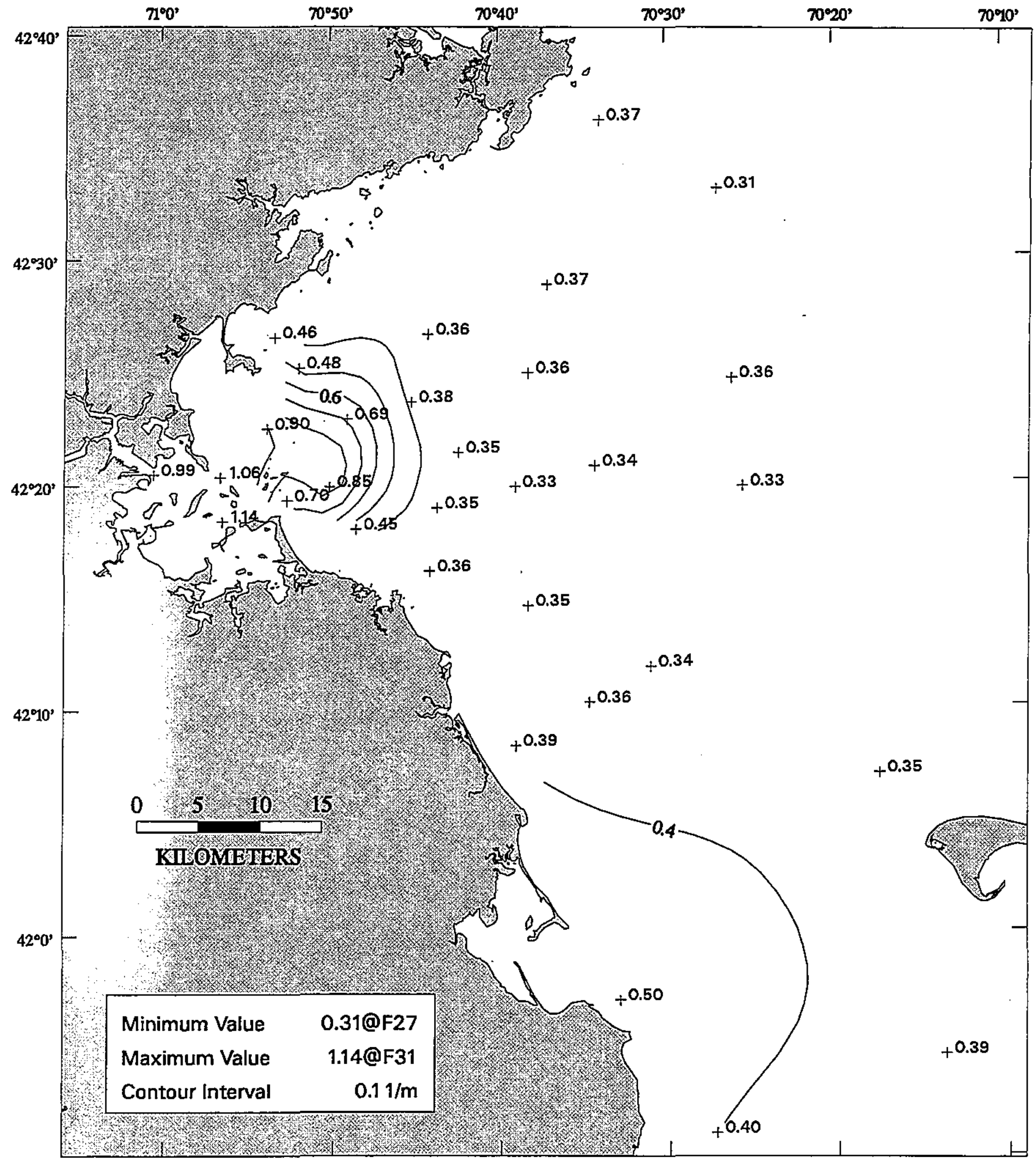


9602tran_lin
TRAN

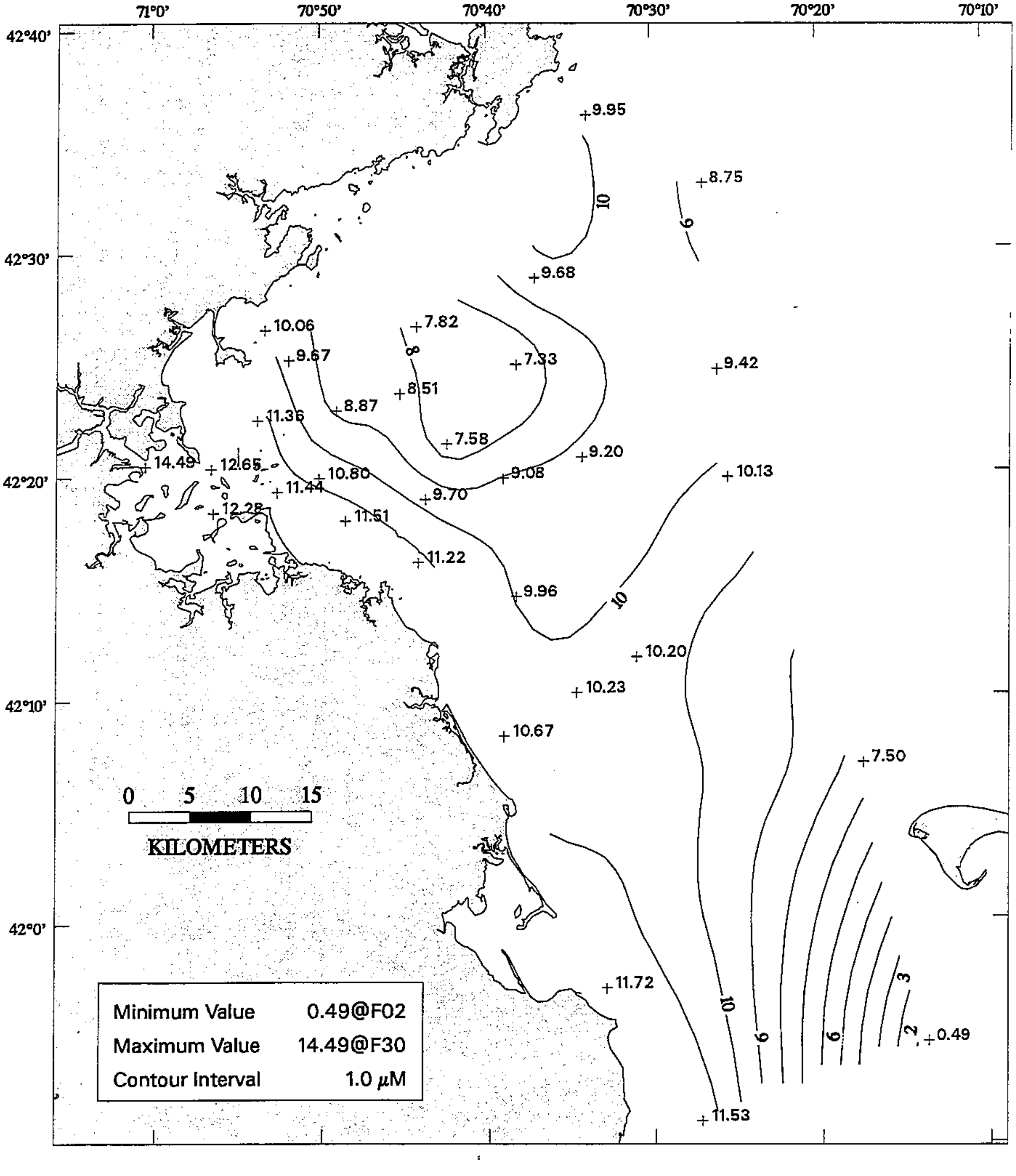


Minimum Value	0.21@F07
Maximum Value	1.05@F31
Contour Interval	0.1 1/m

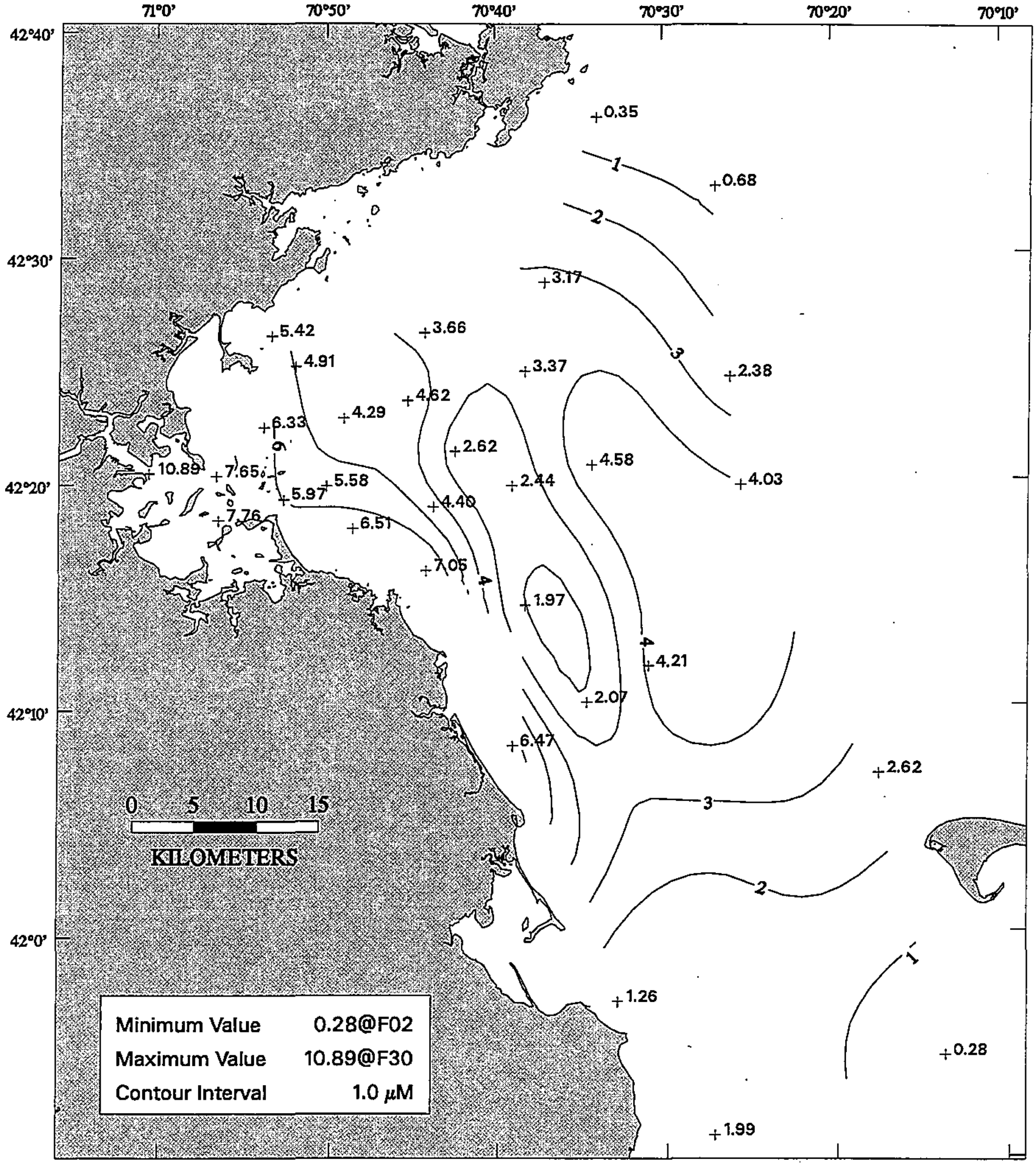
9604tran_lin
TRAN



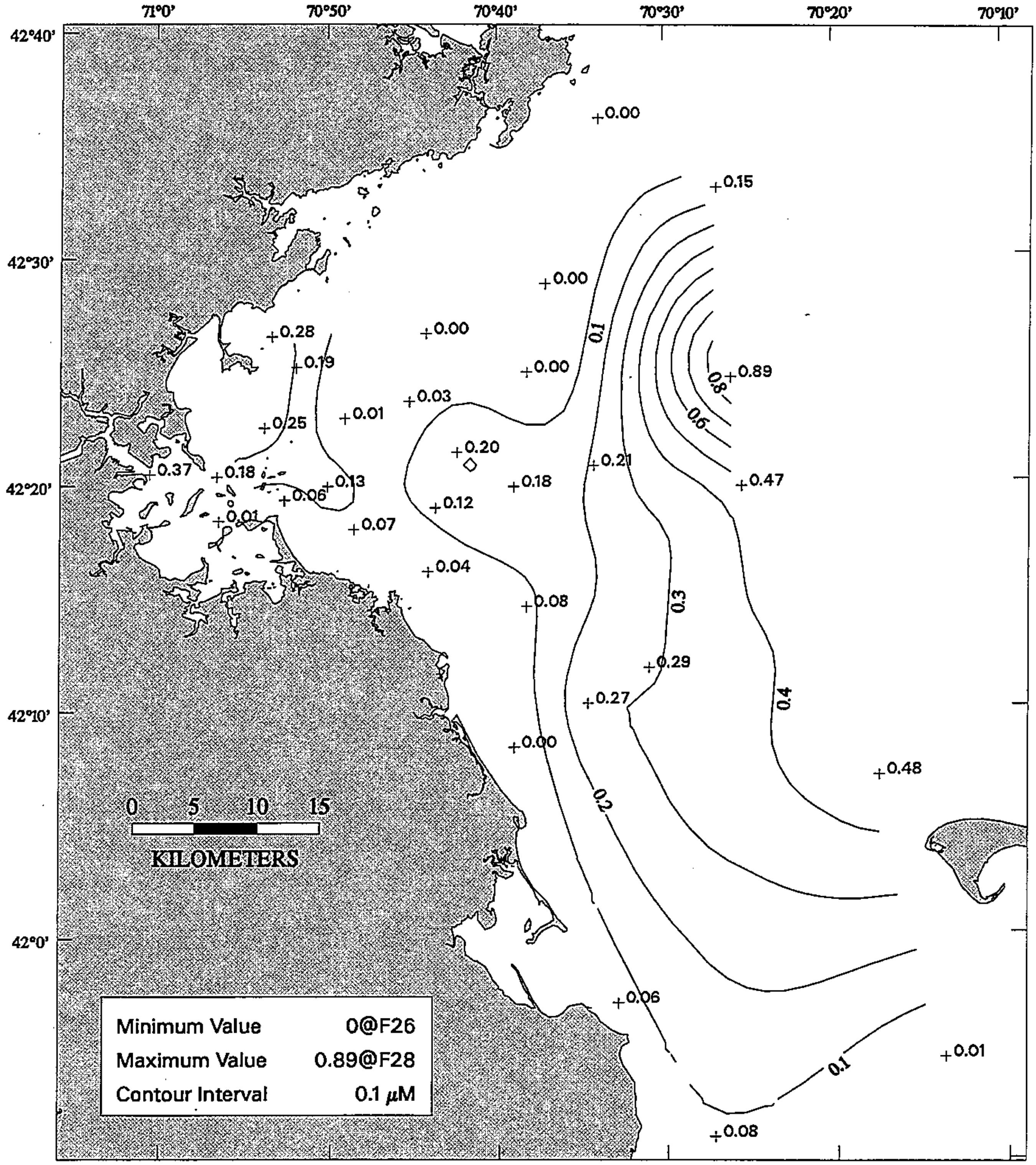
9607tran_lin
TRAN



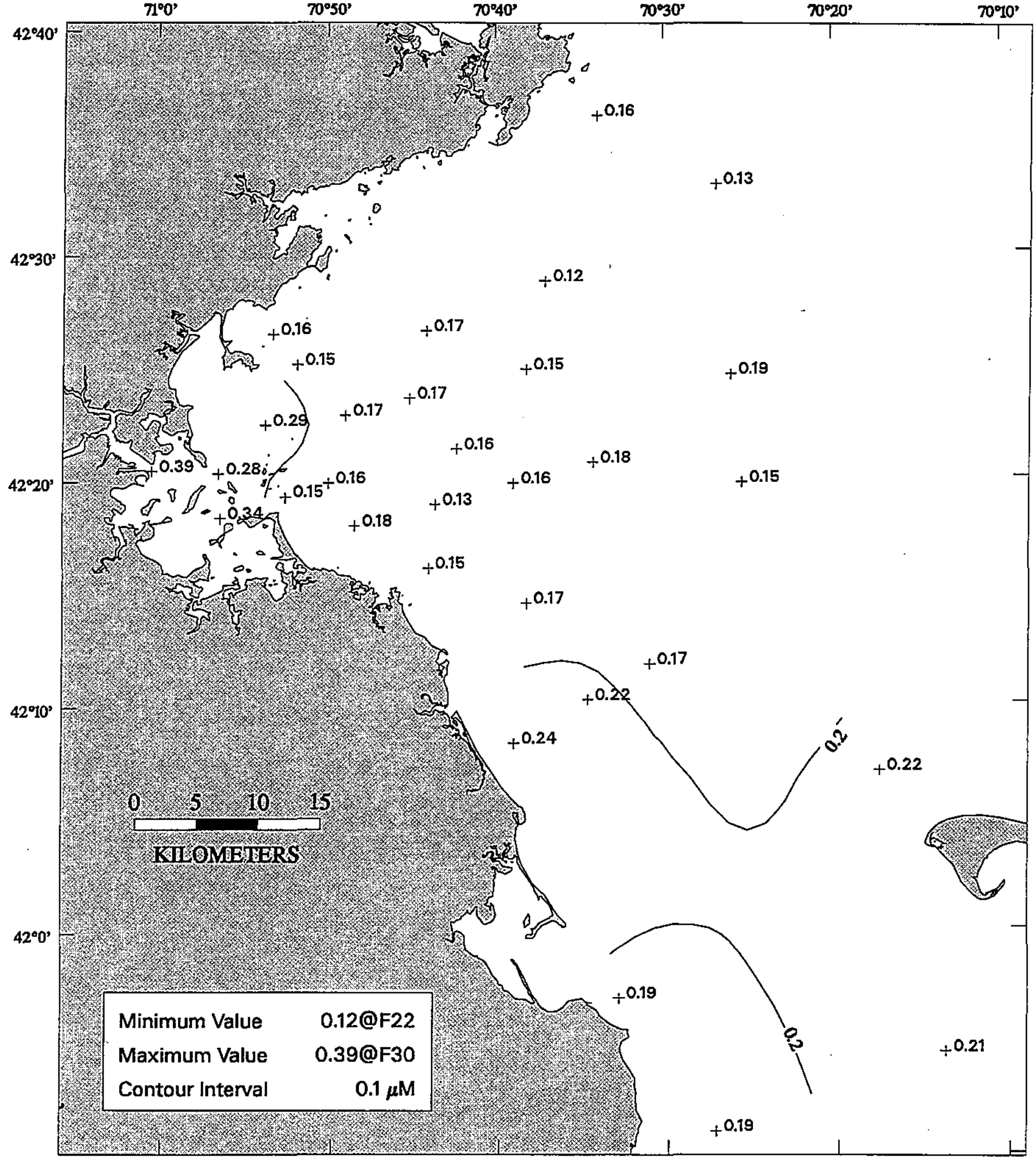
9601no3_lin
NO3



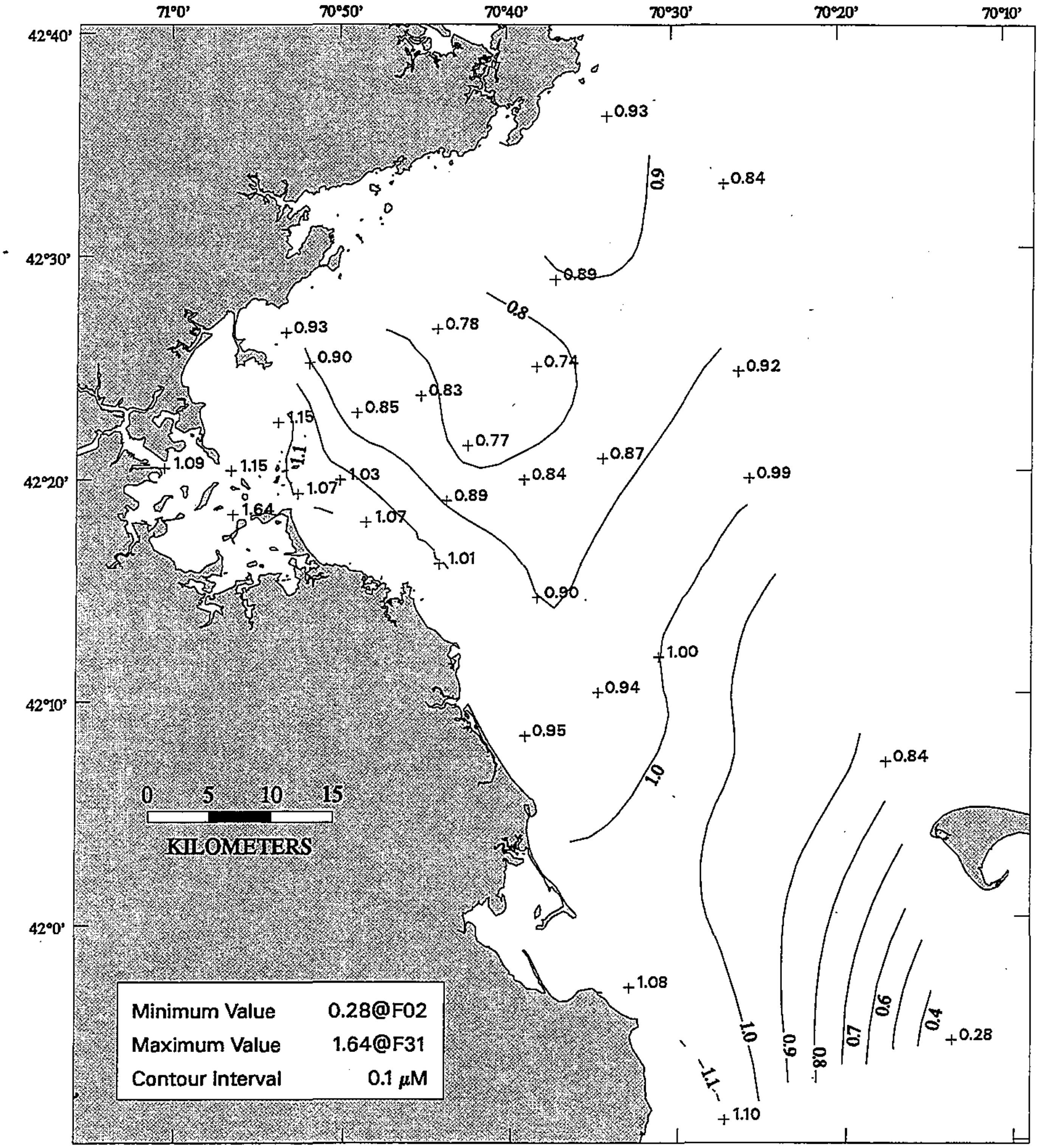
9602no3_lin
NO3



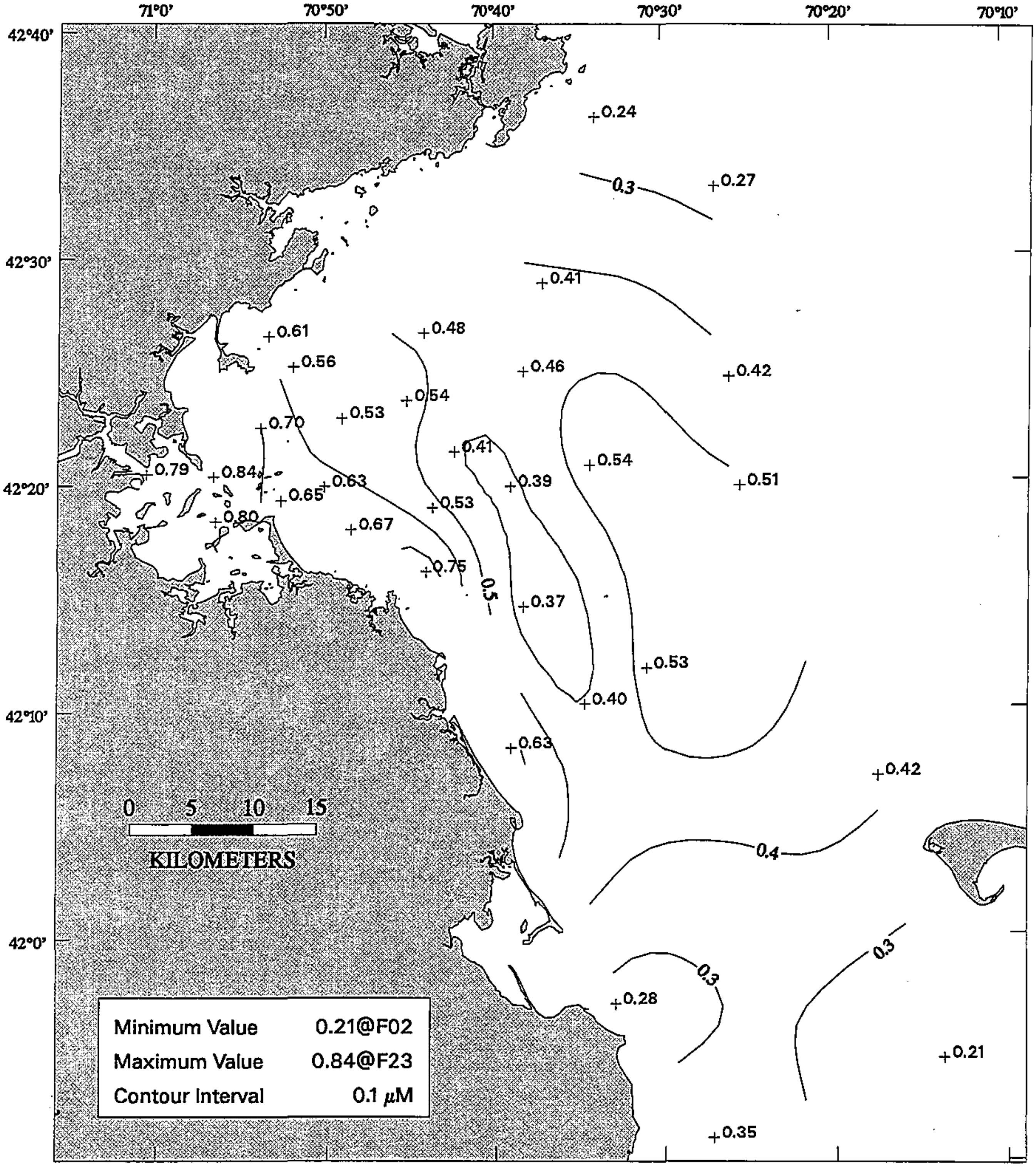
9604no3_lin
NO3



9607no3_lin
NO3

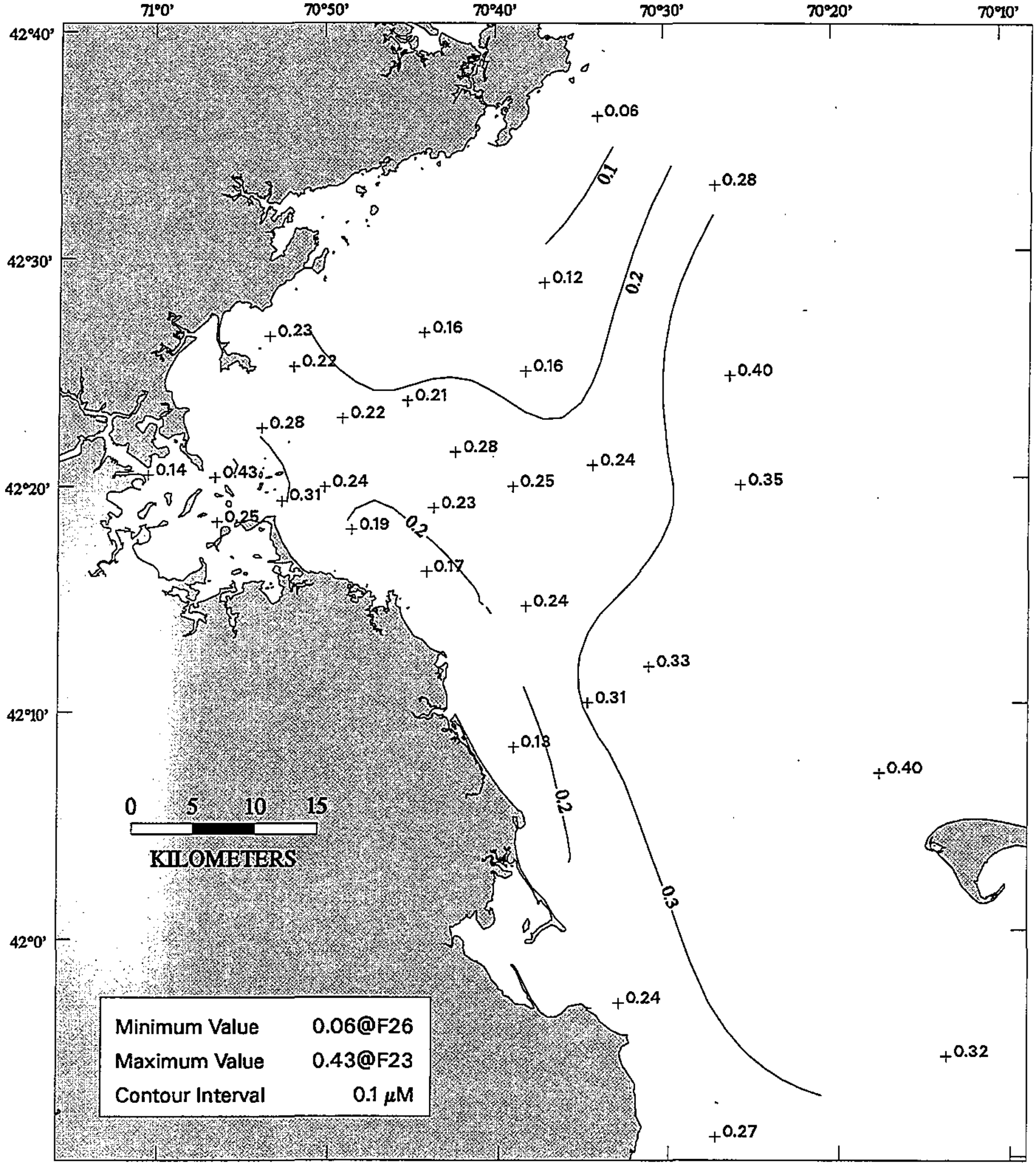


9601po4_lin
PO4

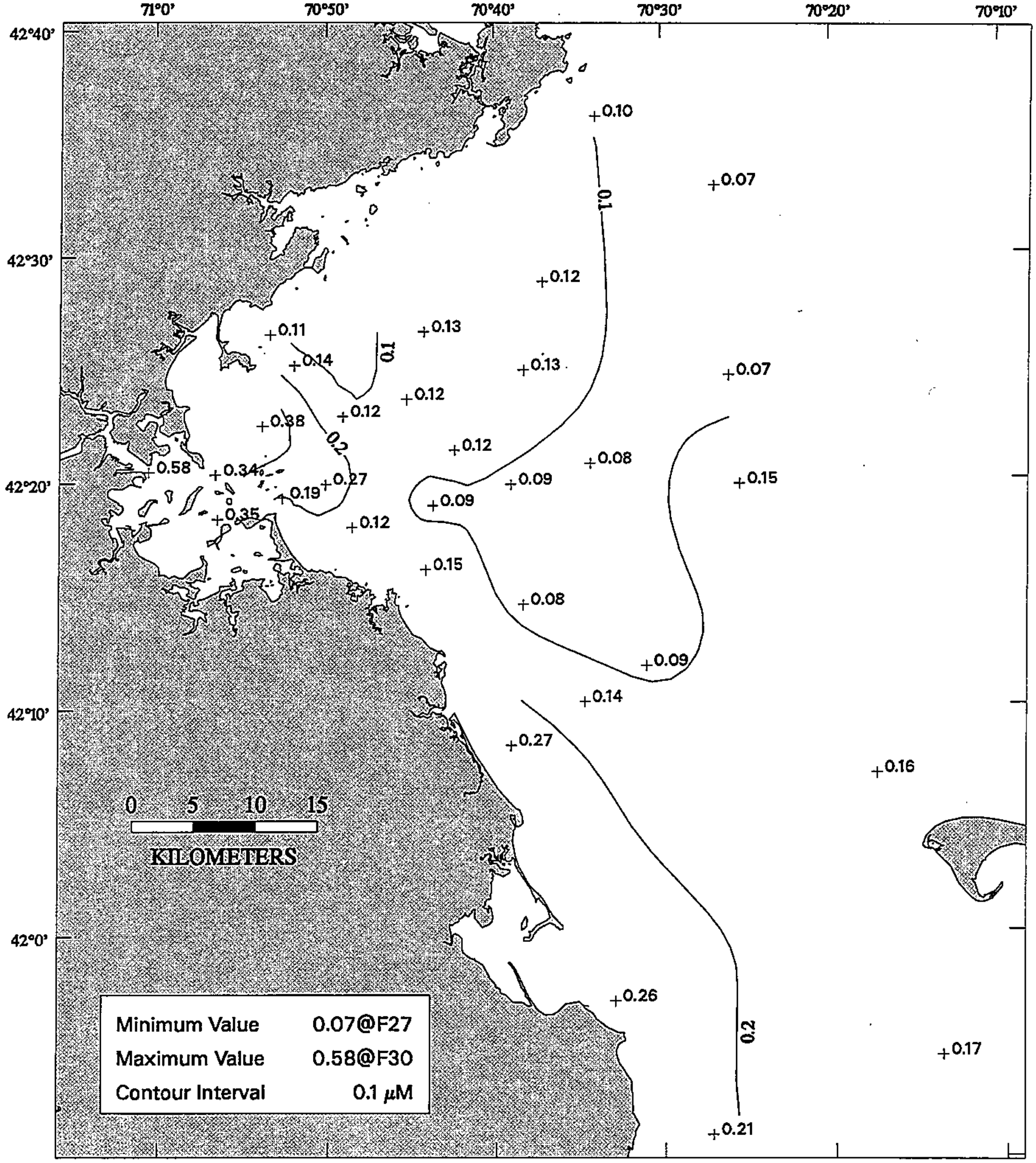


Minimum Value	0.21@F02
Maximum Value	0.84@F23
Contour Interval	0.1 μM

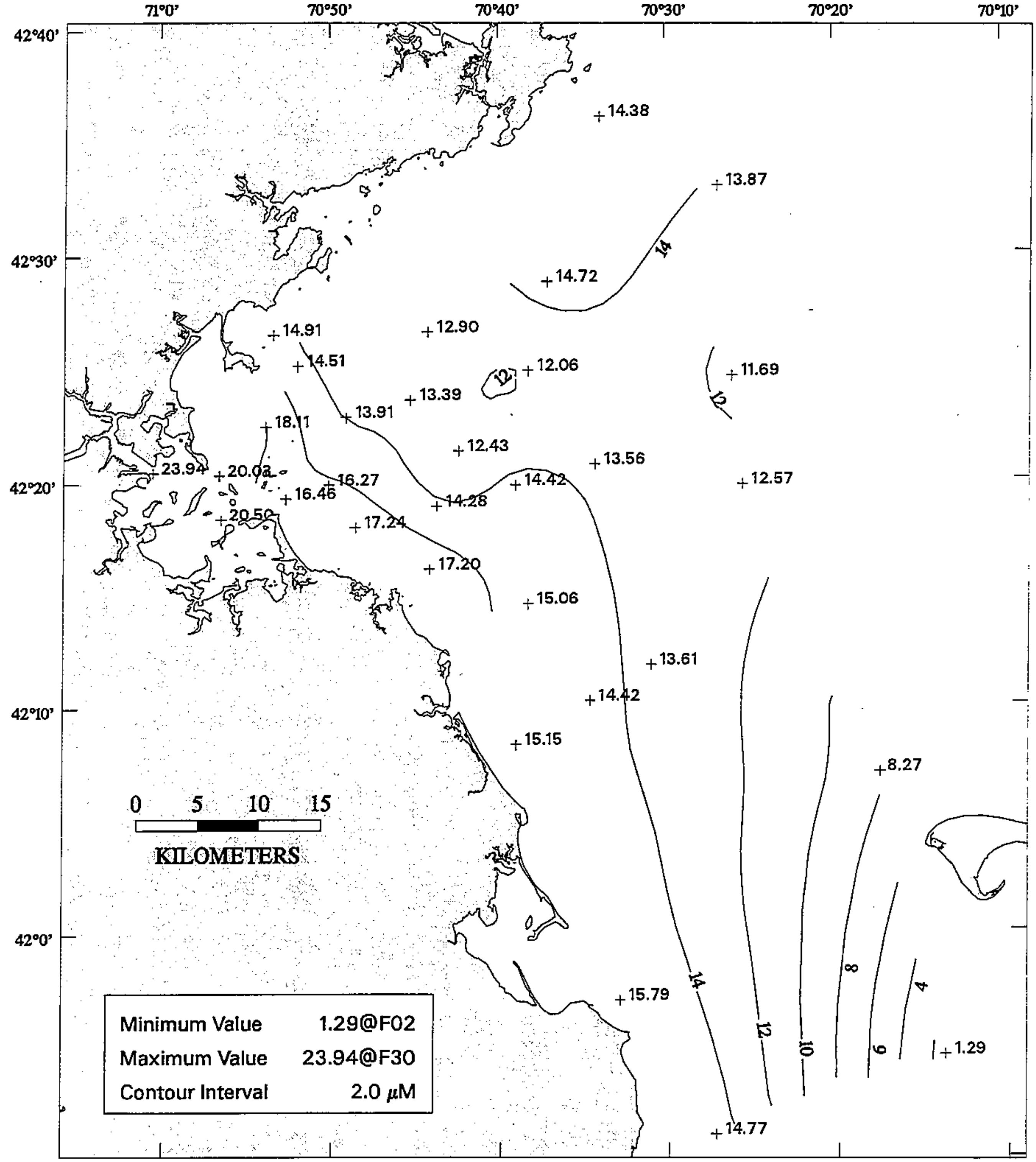
9602po4_lin
PO4



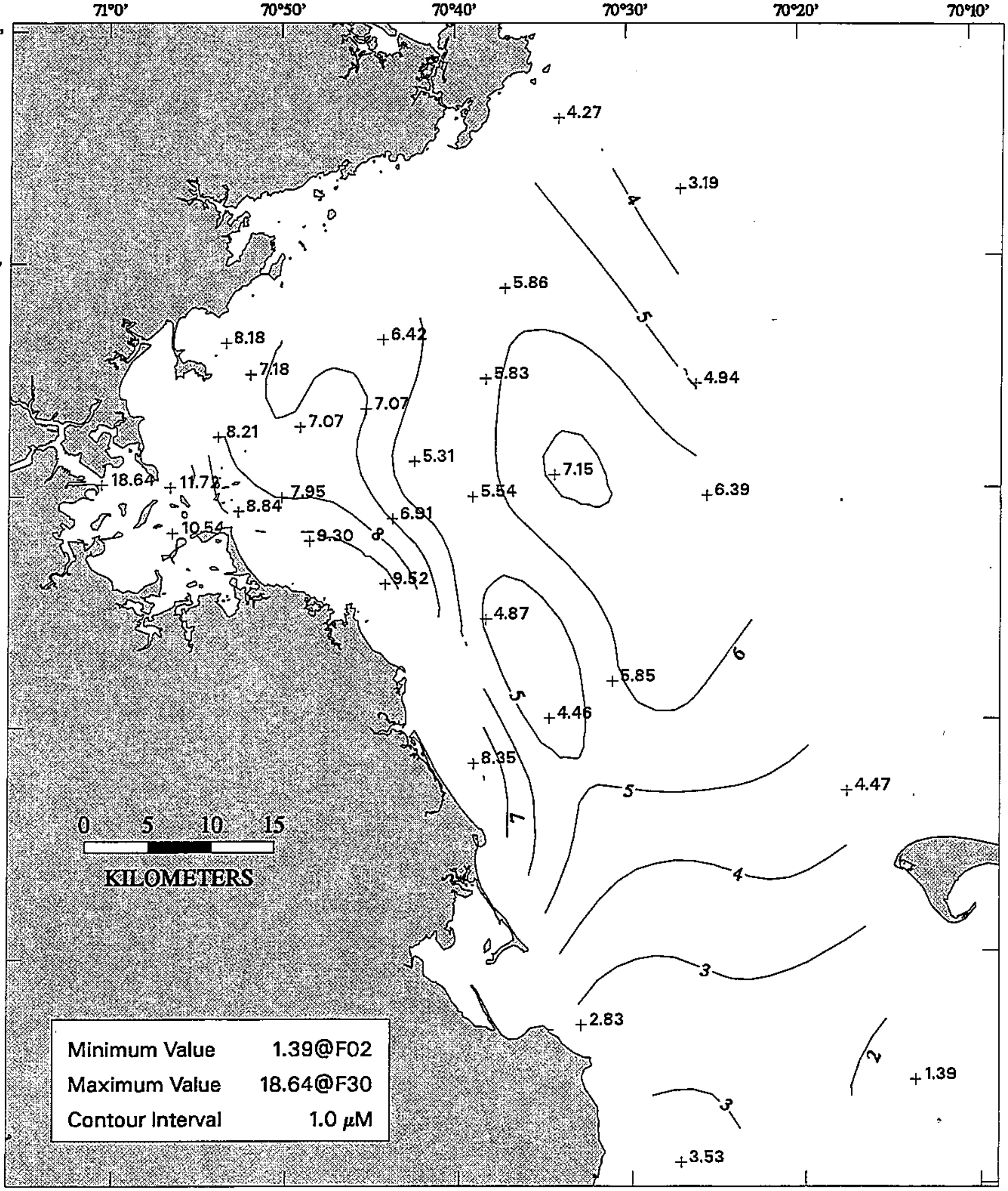
9604po4_lin
PO4



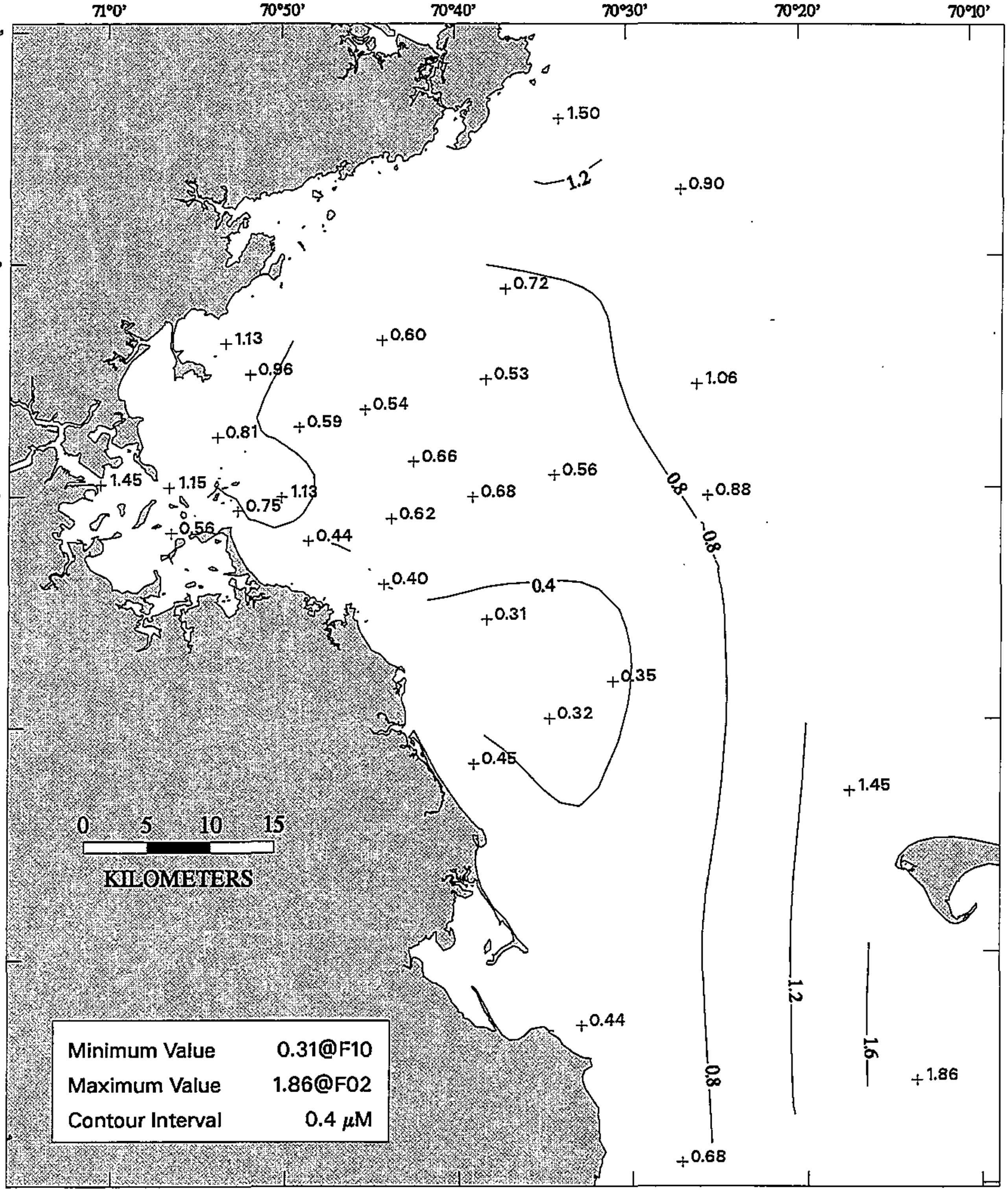
9607po4_lin
PO4



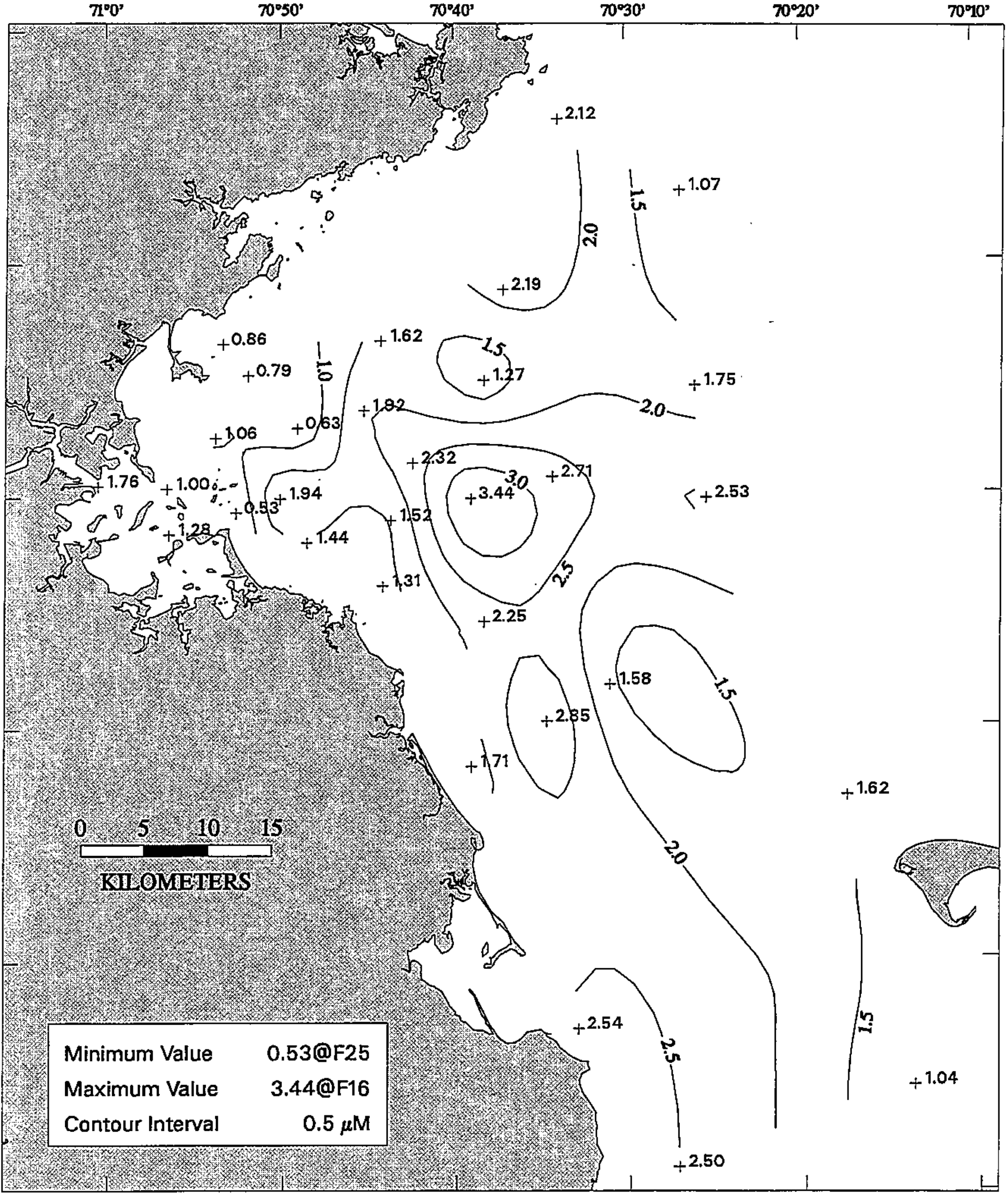
9601sio4_lin
SIO4



9602sio4_lin
SIO4

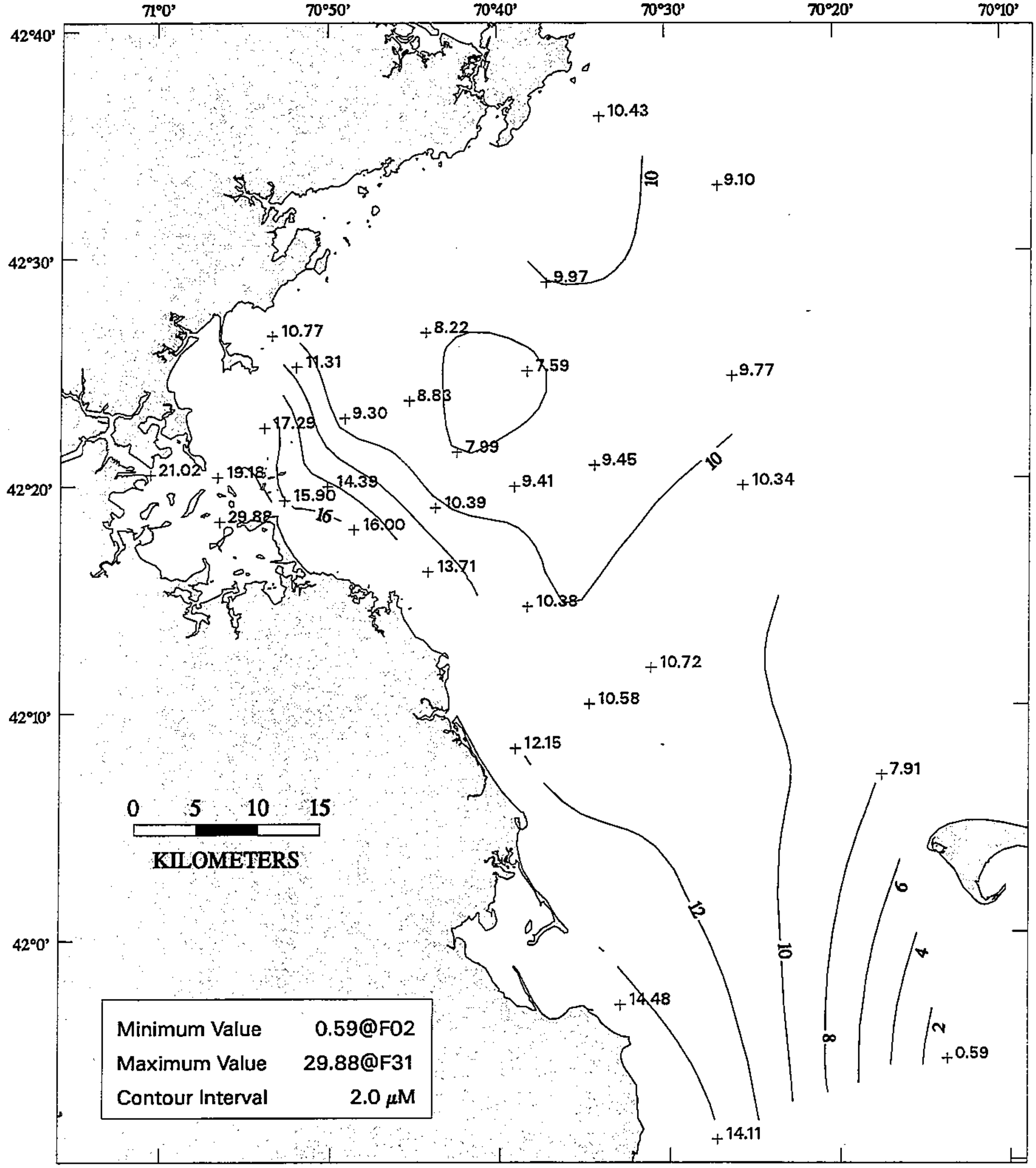


9604sio4_lin
SIO4

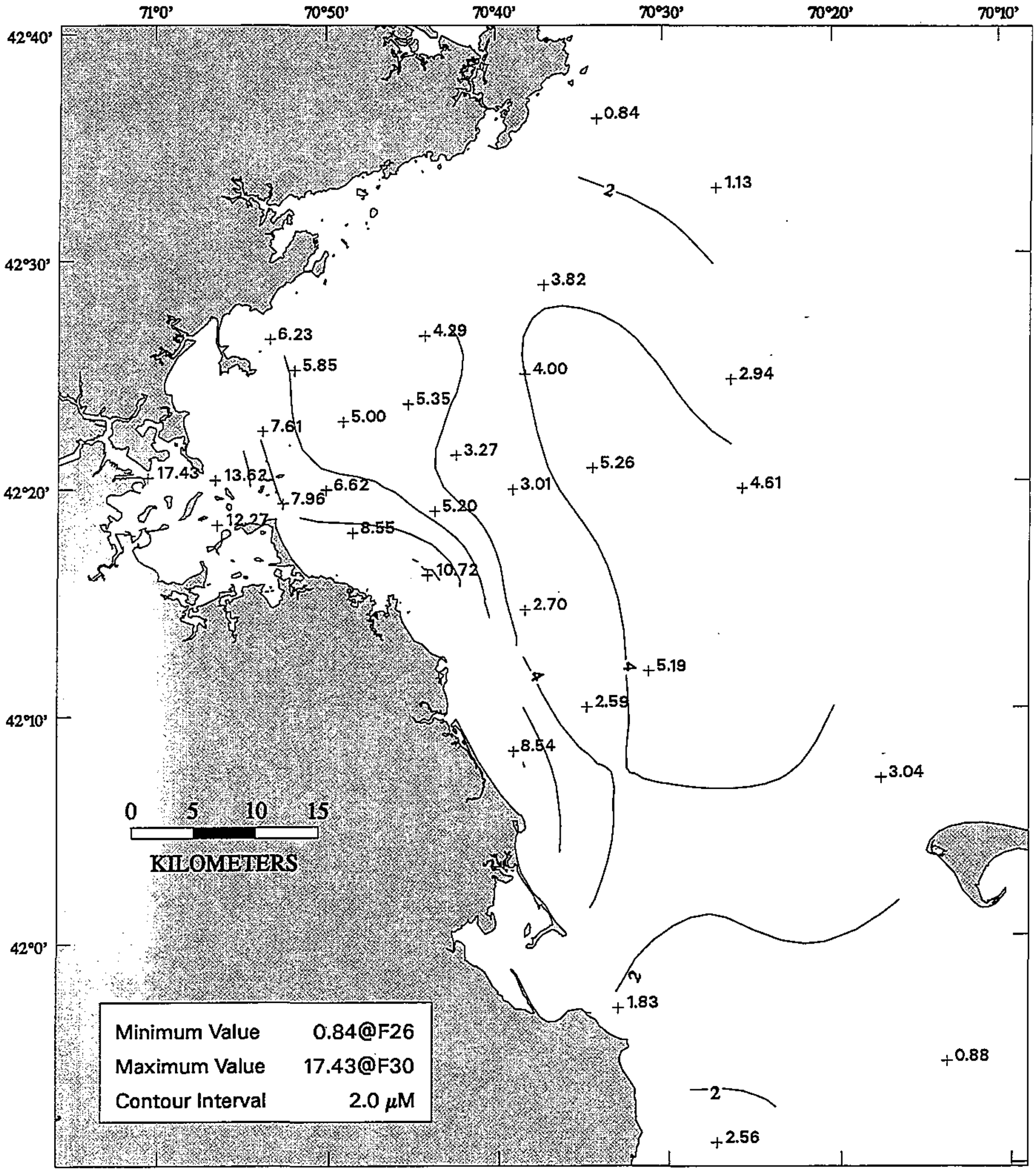


Minimum Value	0.53@F25
Maximum Value	3.44@F16
Contour Interval	0.5 μM

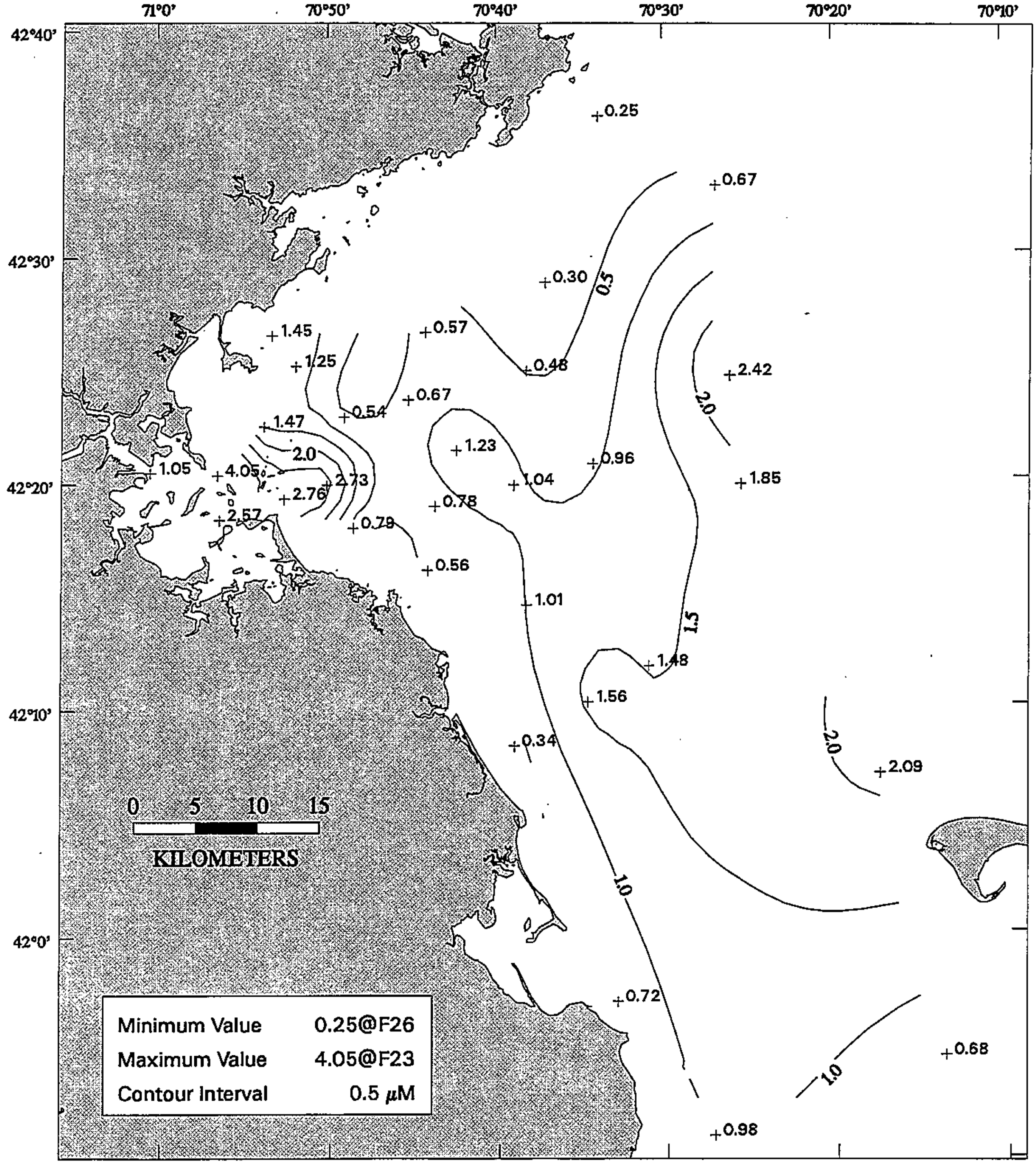
9607sio4_lin
SIO4



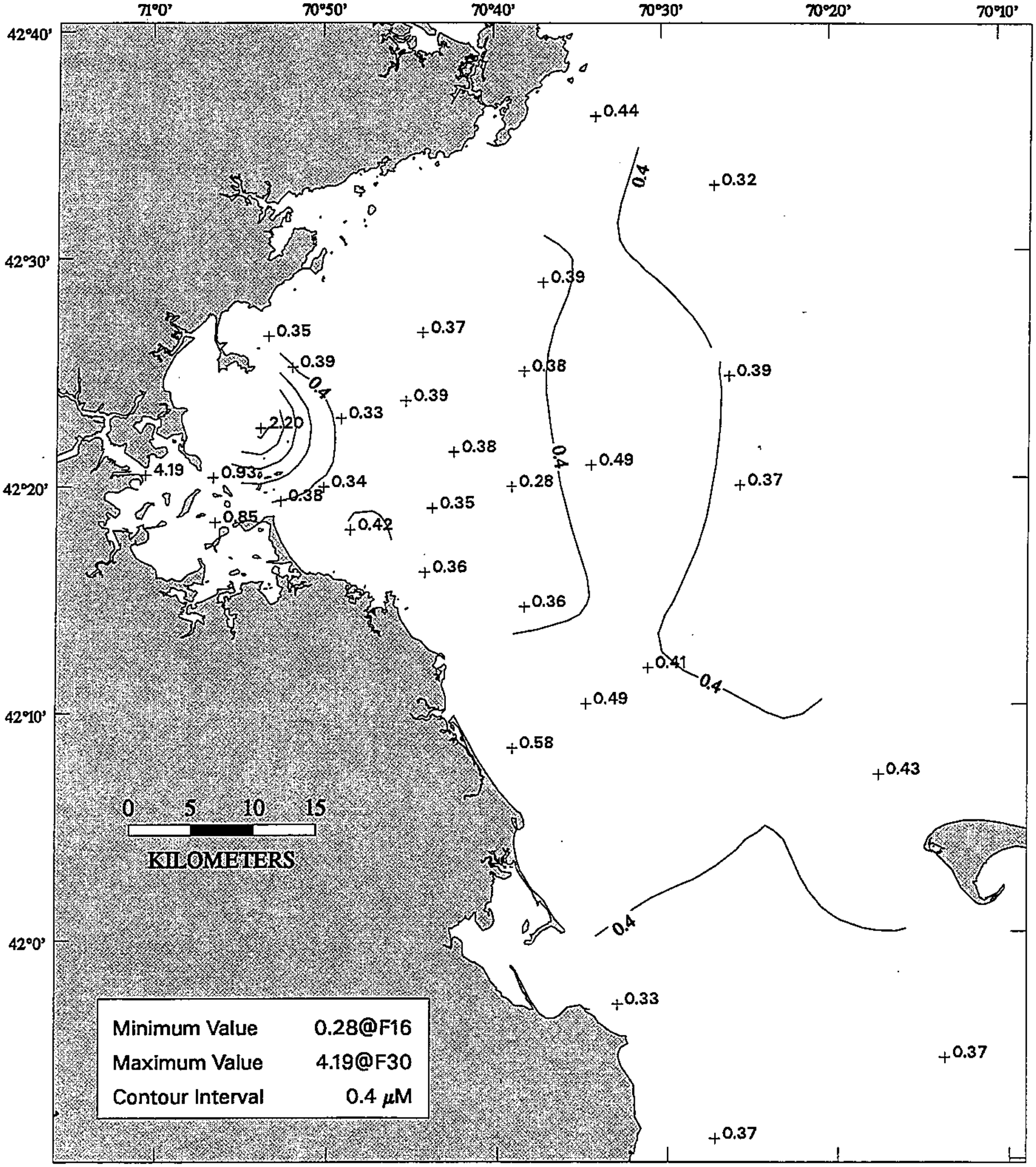
9601din_lin
DIN



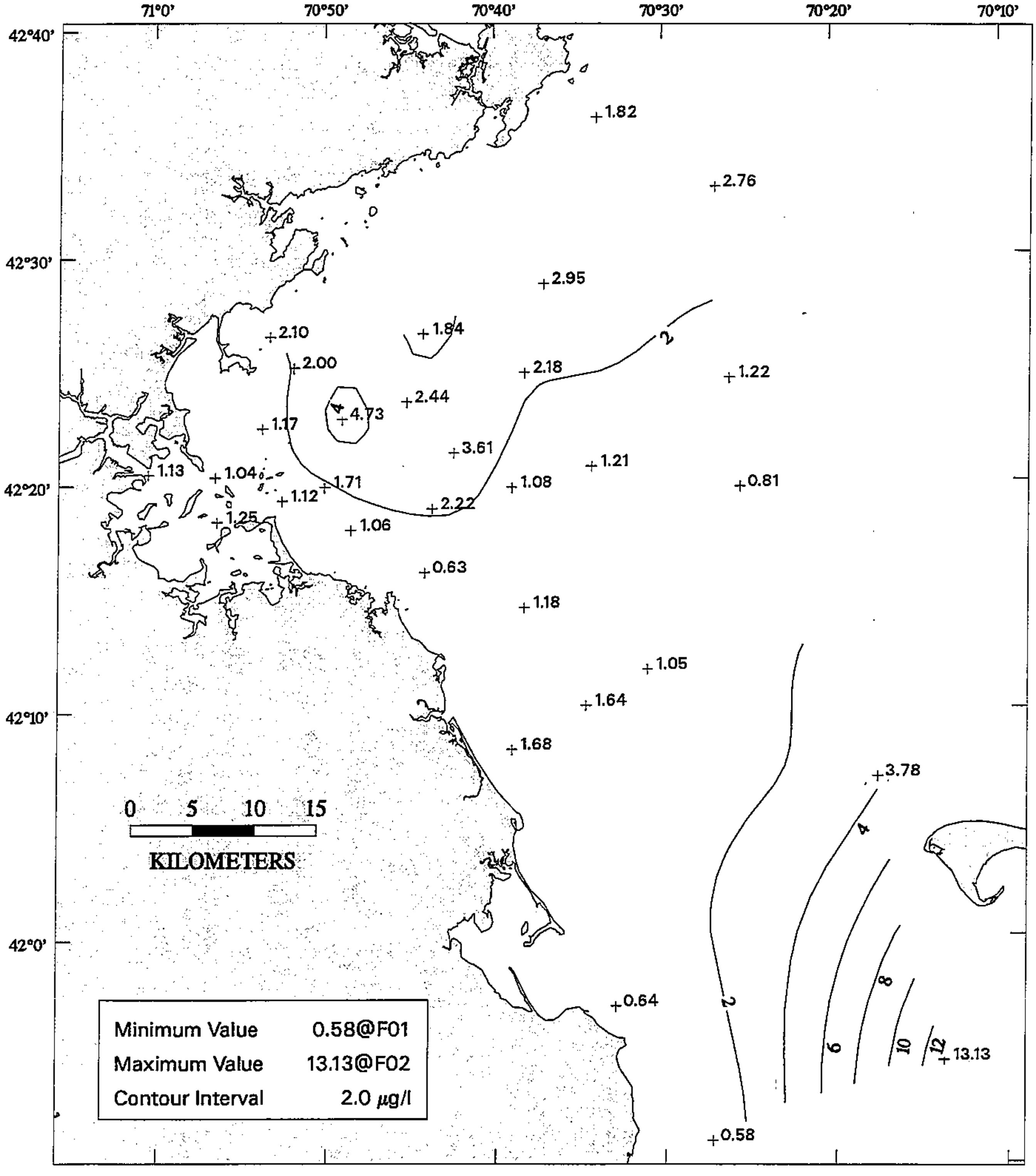
9602din_lin
DIN



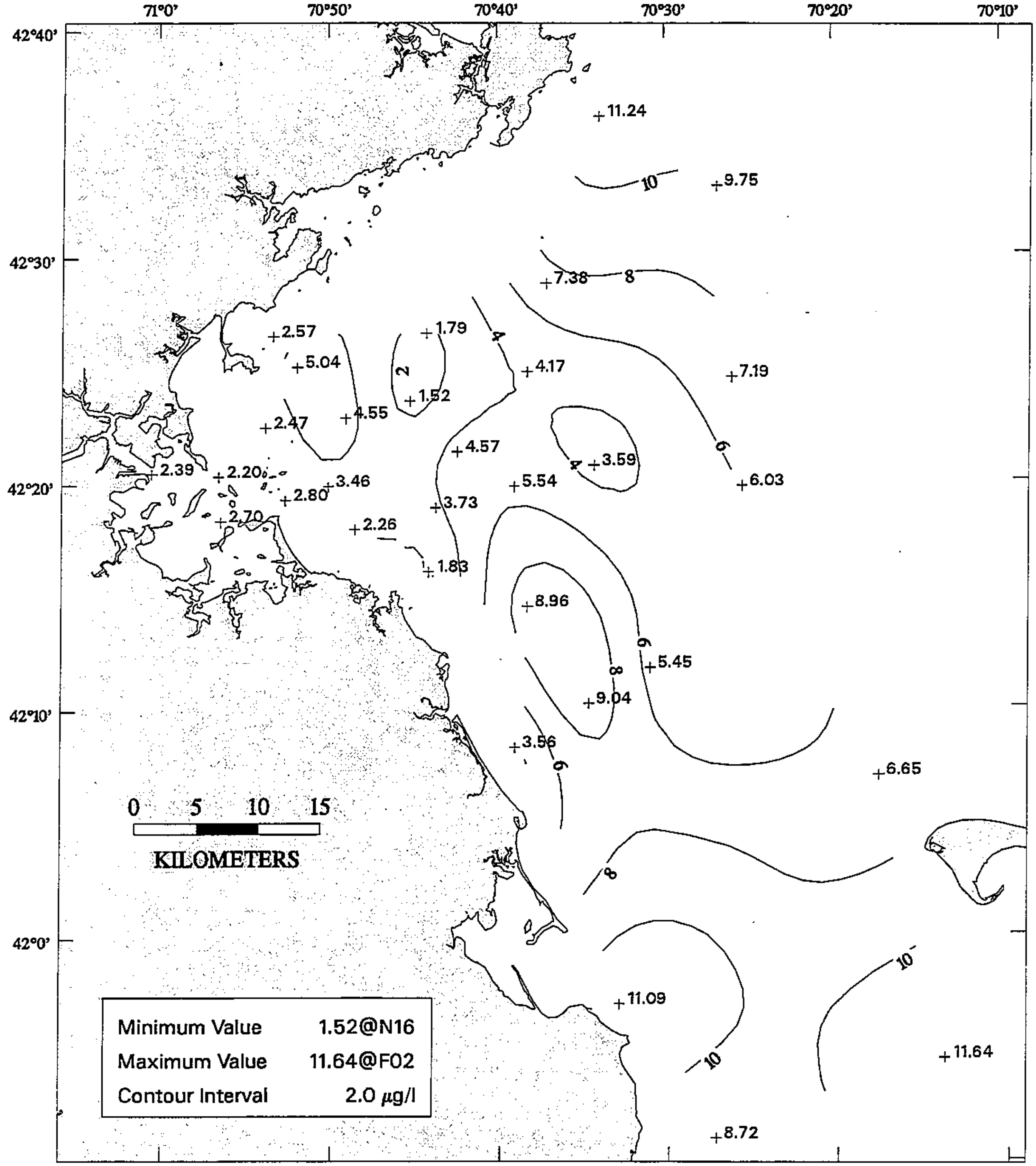
9604din_lin
DIN



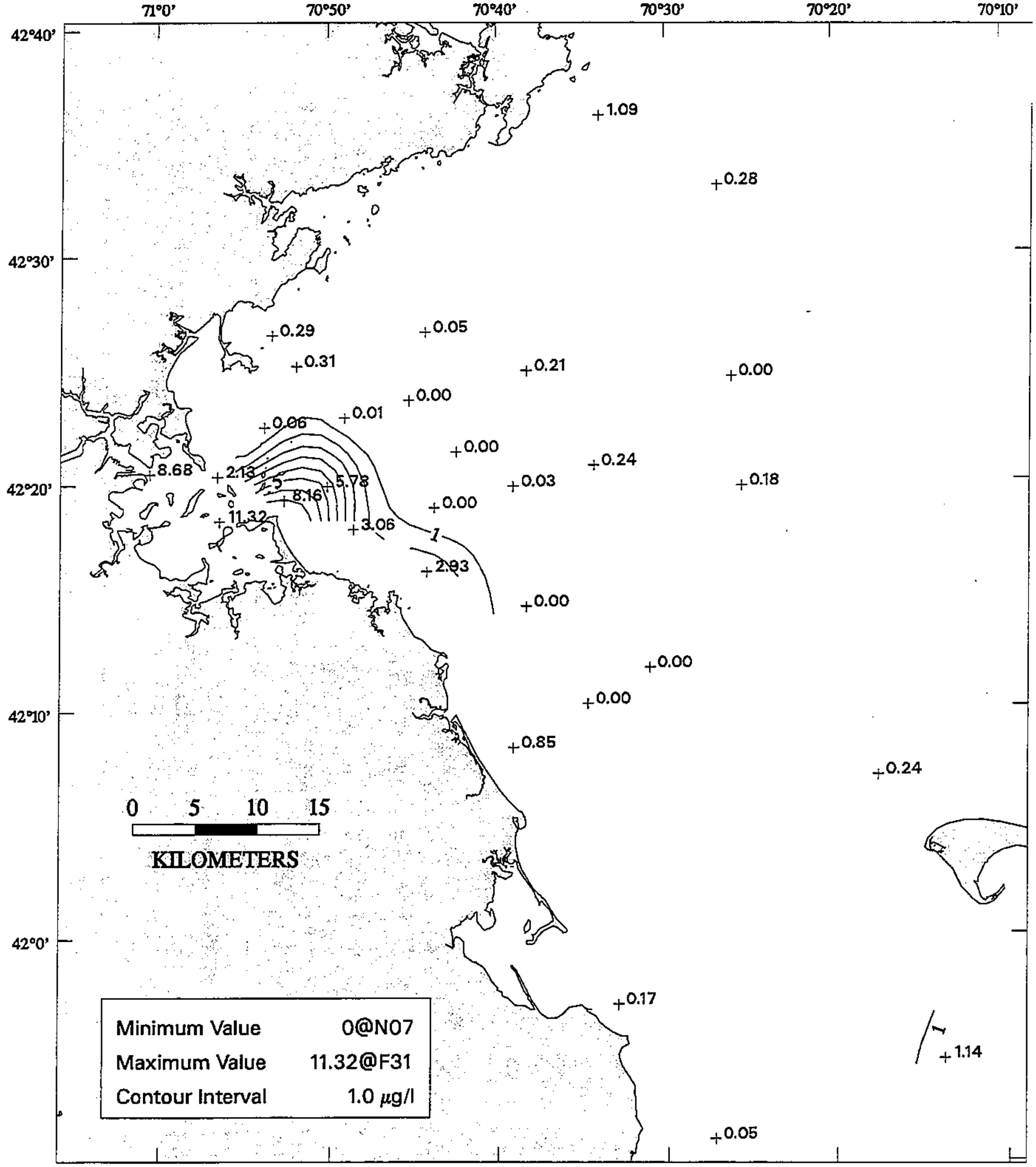
9607din_lin
DIN



9601fluo_lin
FLUO

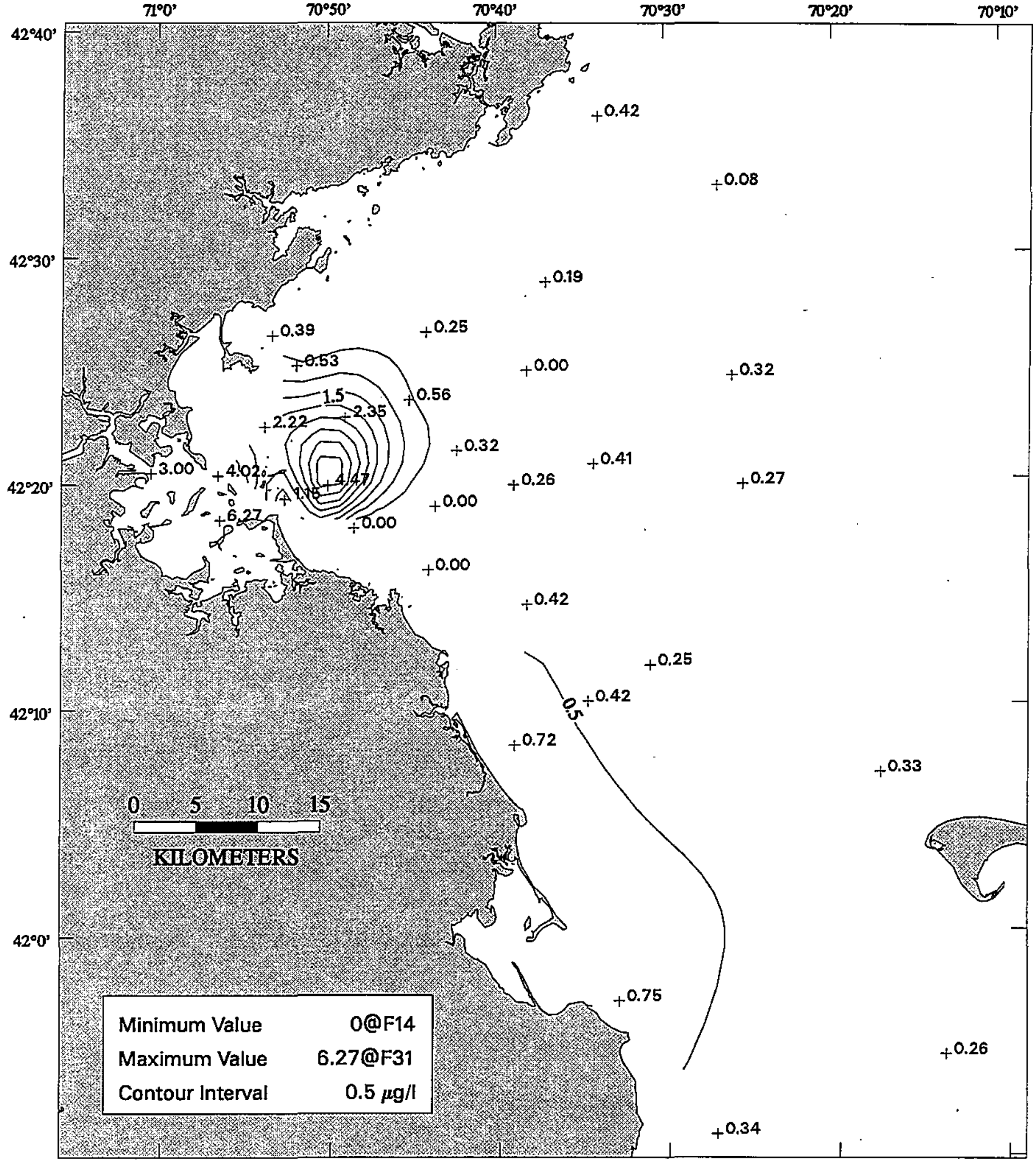


9602fluo_lin
FLUO



Minimum Value	0@N07
Maximum Value	11.32@F31
Contour Interval	1.0 μg/l

9604fluo_lin
FLUO



9607fluo_lin
FLUO

APPENDIX C

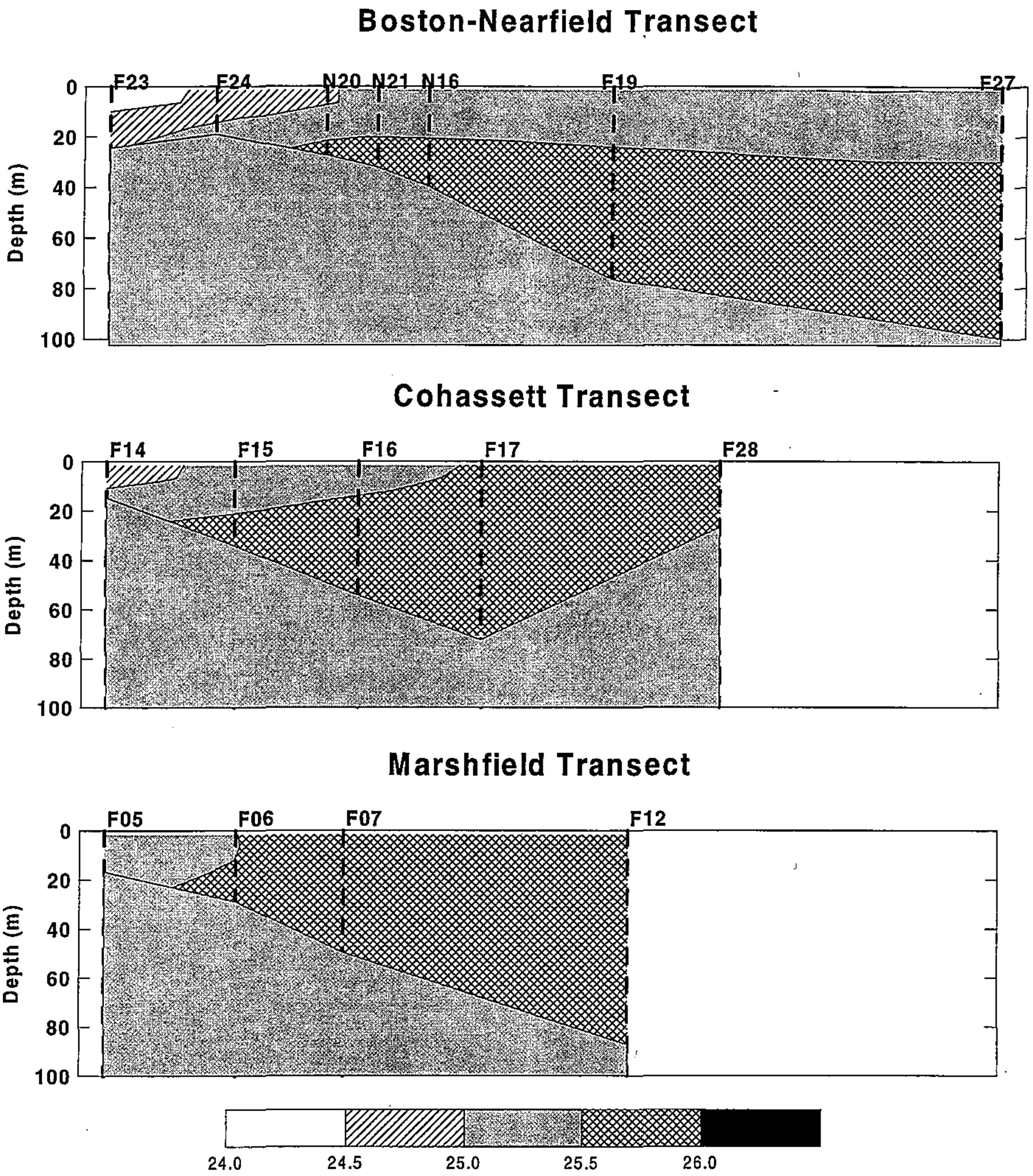
Transect Plots

Data were contoured relative to water depth and distance between stations as shown on the transects (Figure 1-3, text). Relative distances between stations and water depth at each station is shown on the transect. Water depth is labelled with negative values in meters, with zero depth at the sea surface, and shaded. Three transects (Boston-Nearfield, Cohasset, and Marshfield) are provided on each plot, as well as shaded contour levels on the scale bar at the bottom of the plot. Contour units are as noted on the table below. Each plot is labelled on the bottom right with the parameter as listed below, and the survey number ("9601").

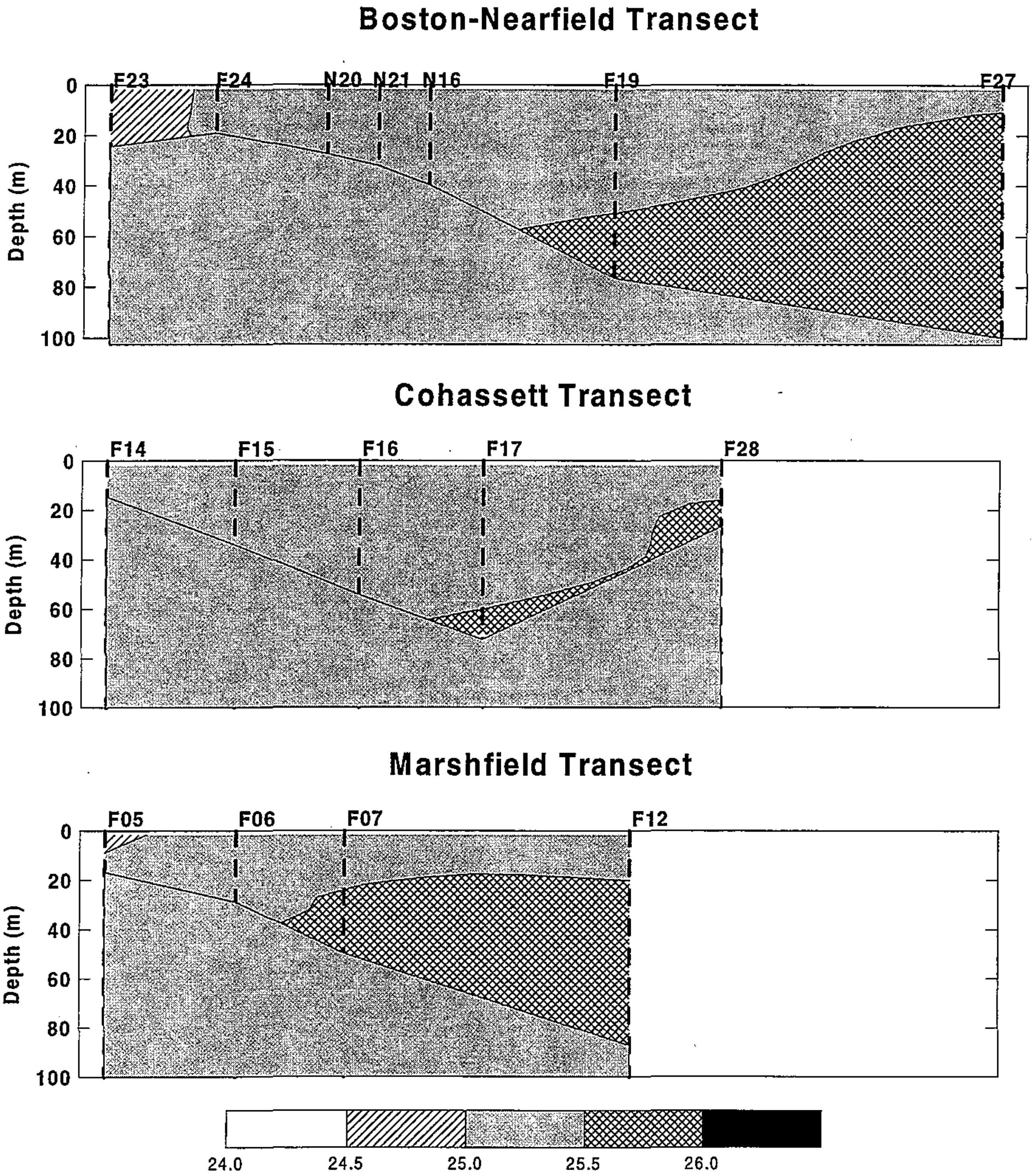
Appendix C: Table of Contents

Parameter Name	Units
Sigma-T (σ_t)	n/a
Temperature	°C
Salinity	PSU
Beam Attenuation	/m
Nitrate + Nitrite	µM
Phosphate (PO_4)	µM
Silicate (SiO_4)	µM
Ammonium (NH_4	µM
Fluorescence (clophylla)	µg/L
Dissolved Oxygen	mg/L

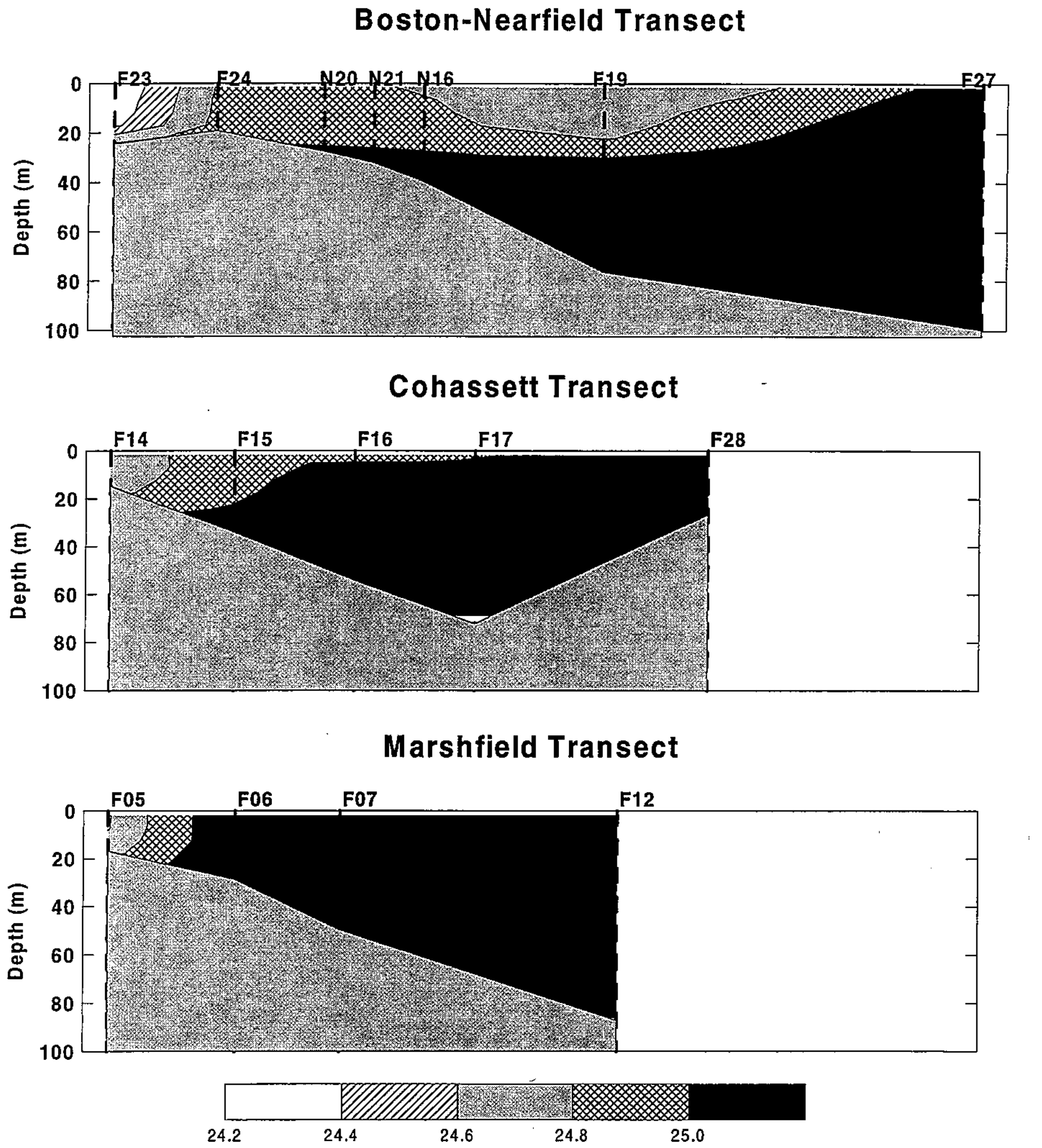
*$NO_3 + NO_2 + NH_4$



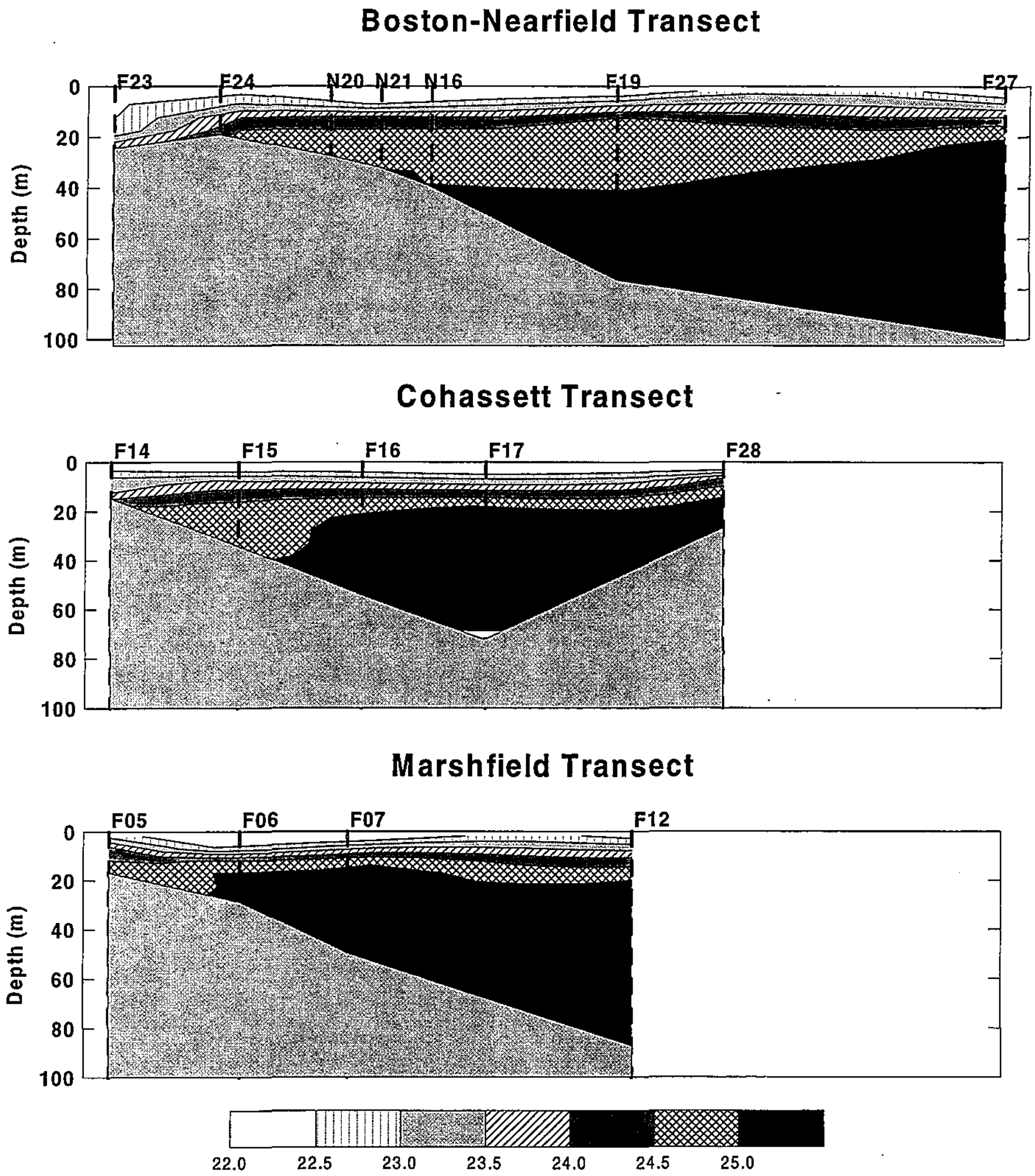
Parameter: Sigma-T
Survey: 9601



Parameter: Sigma-T
Survey: 9602



Parameter: Sigma-T
Survey: 9604

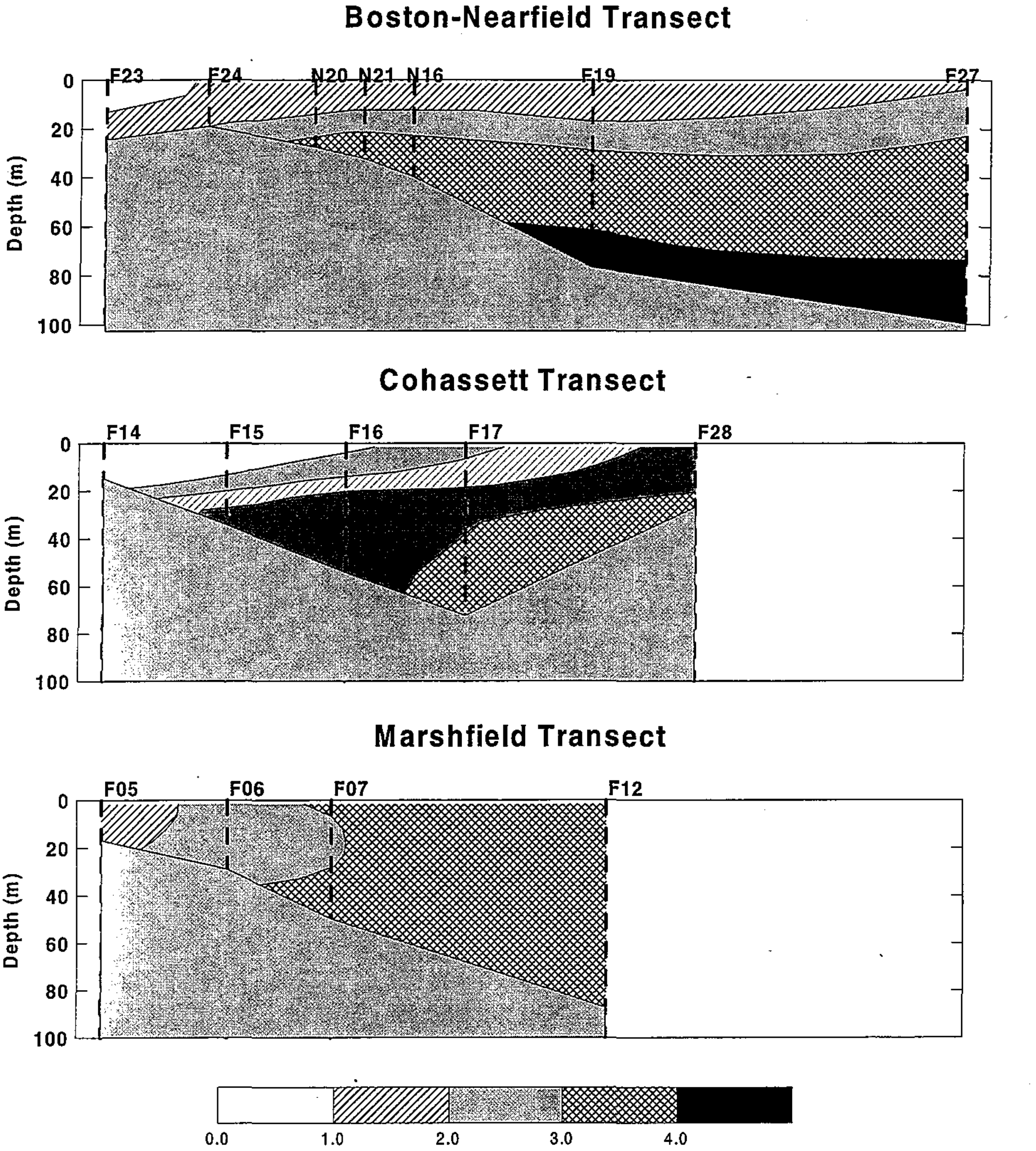


Boston-Nearfield Transect

Cohassett Transect

Marshfield Transect

Parameter: Sigma-T
Survey: 9607

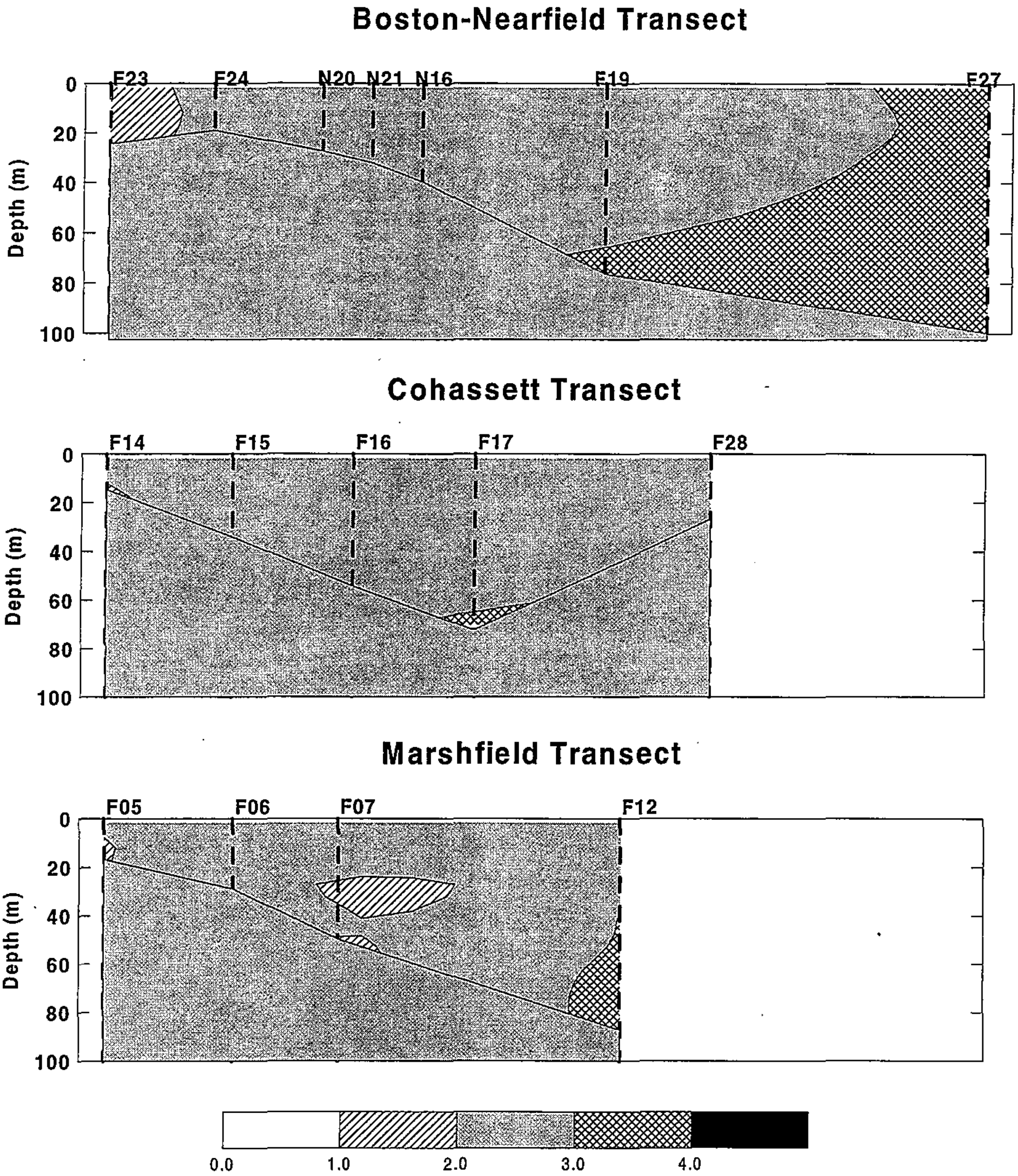


Boston-Nearfield Transect

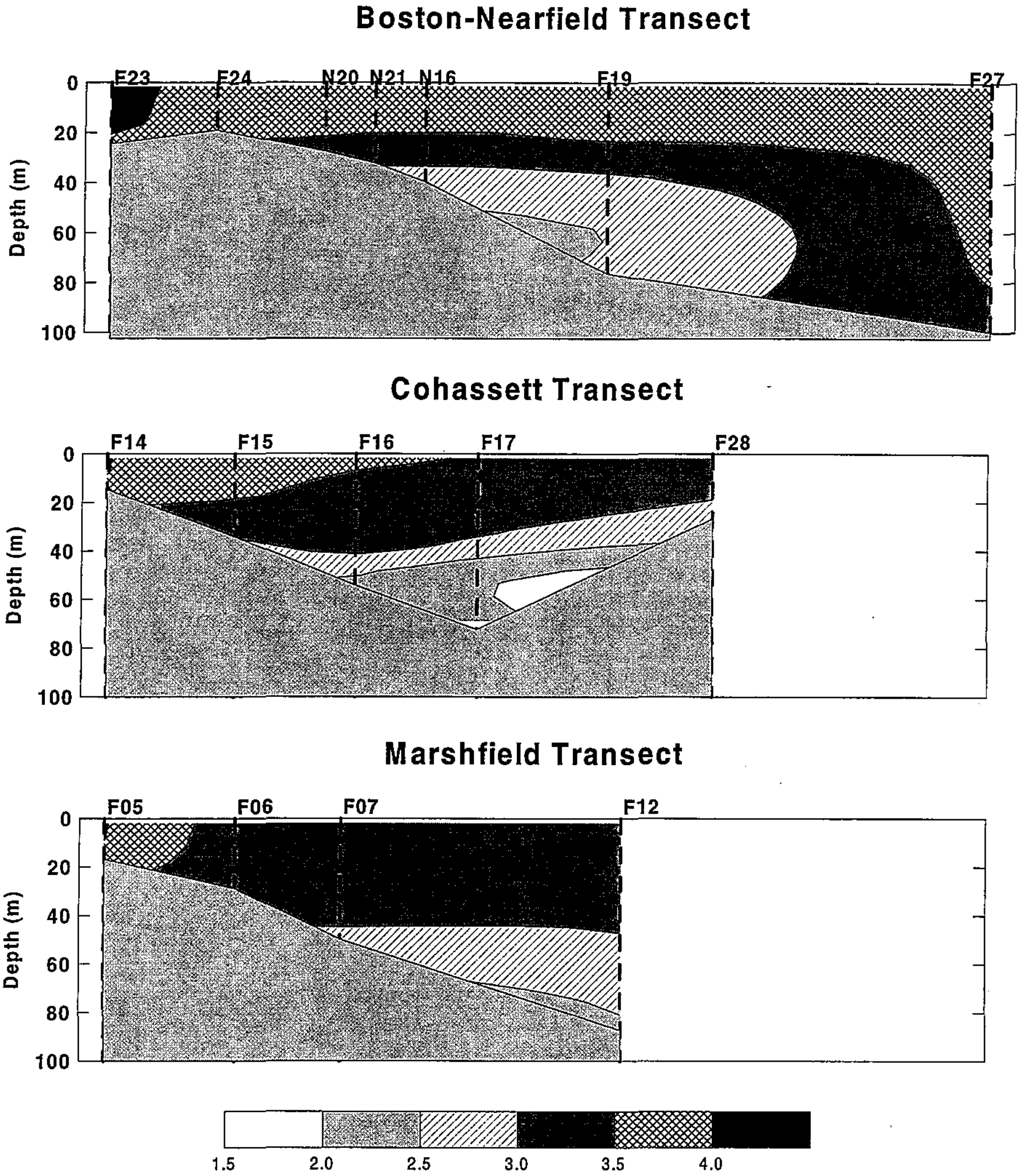
Cohassett Transect

Marshfield Transect

Parameter: Temperature
Survey: 9601



Parameter: Temperature
Survey: 9602

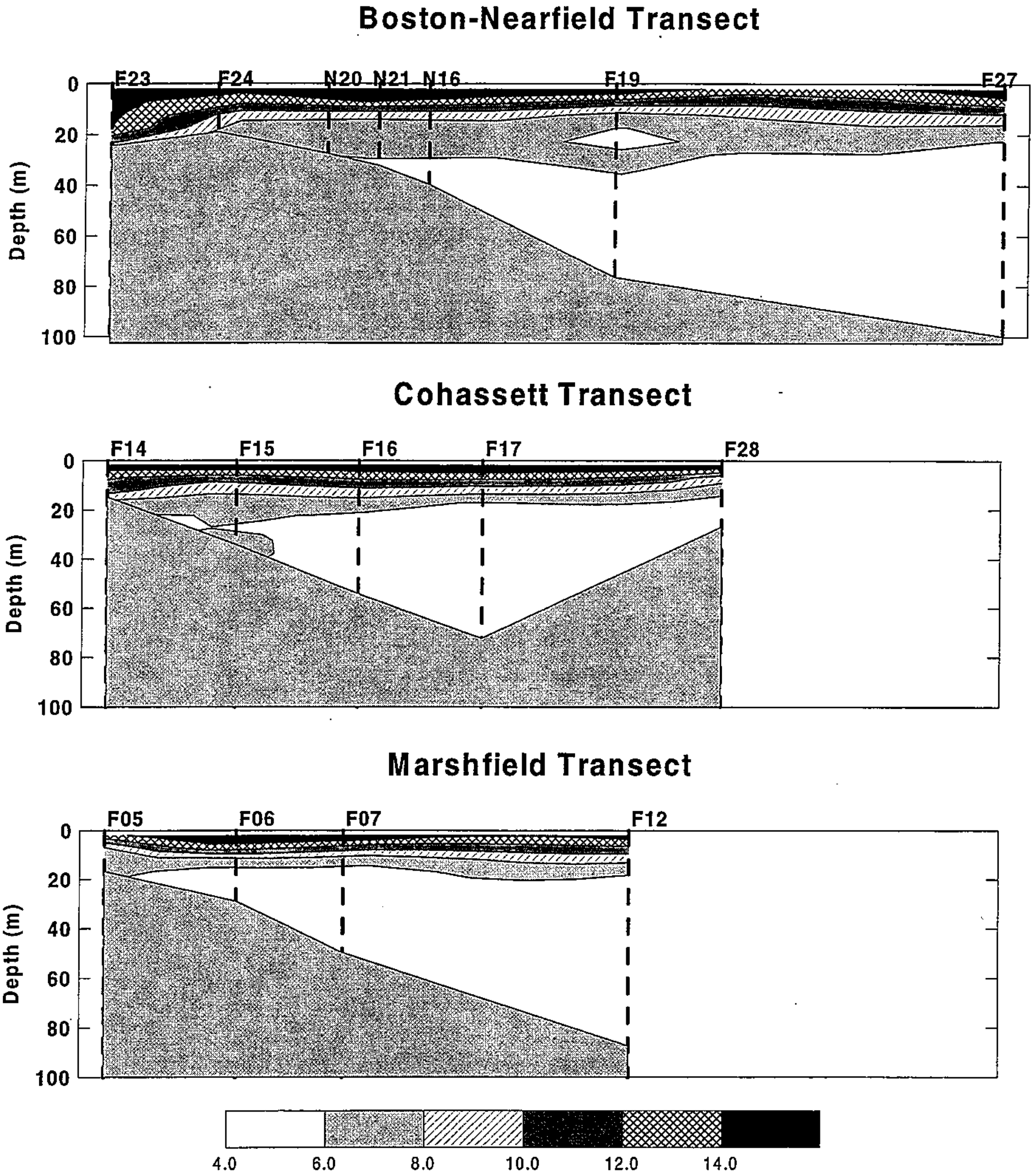


Boston-Nearfield Transect

Cohassett Transect

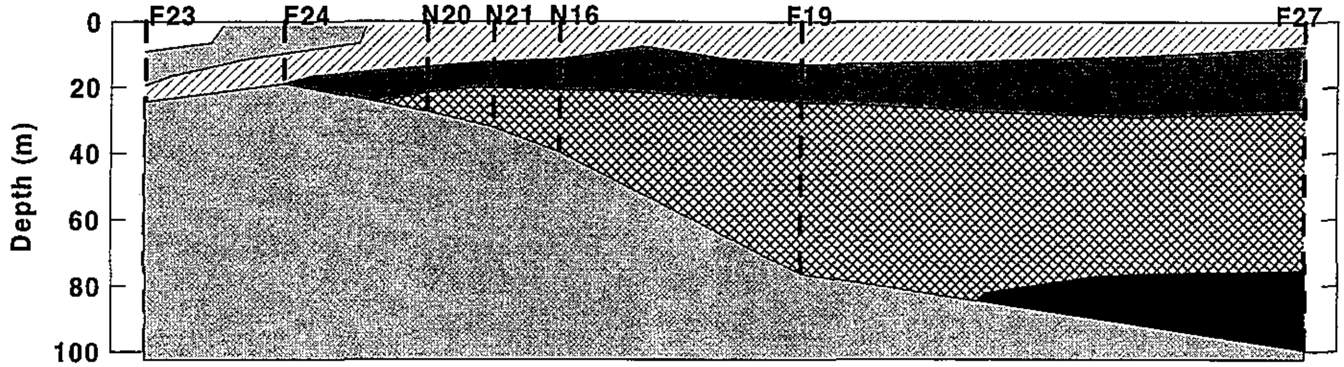
Marshfield Transect

Parameter: Temperature
Survey: 9604

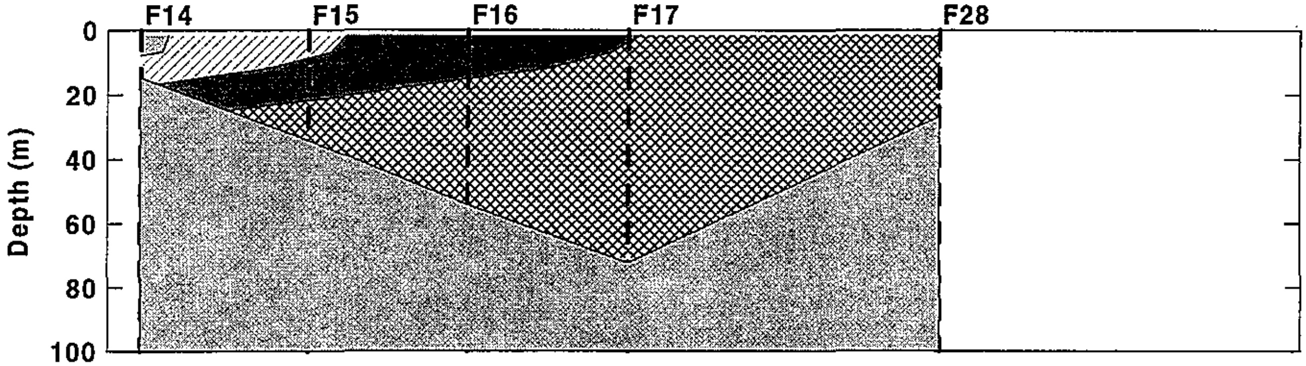


Parameter: Temperature
Survey: 9607

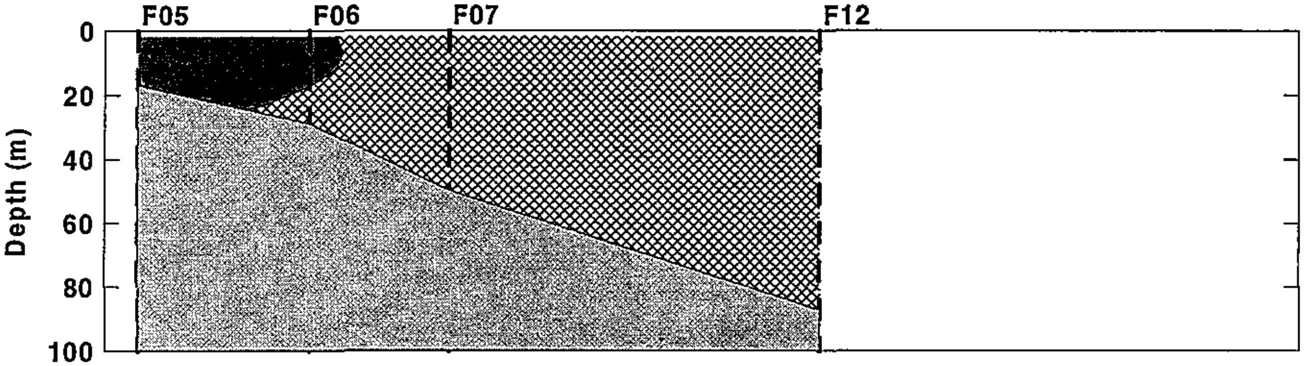
Boston-Nearfield Transect

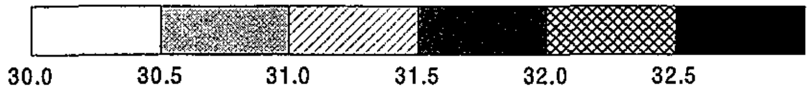


Cohassett Transect

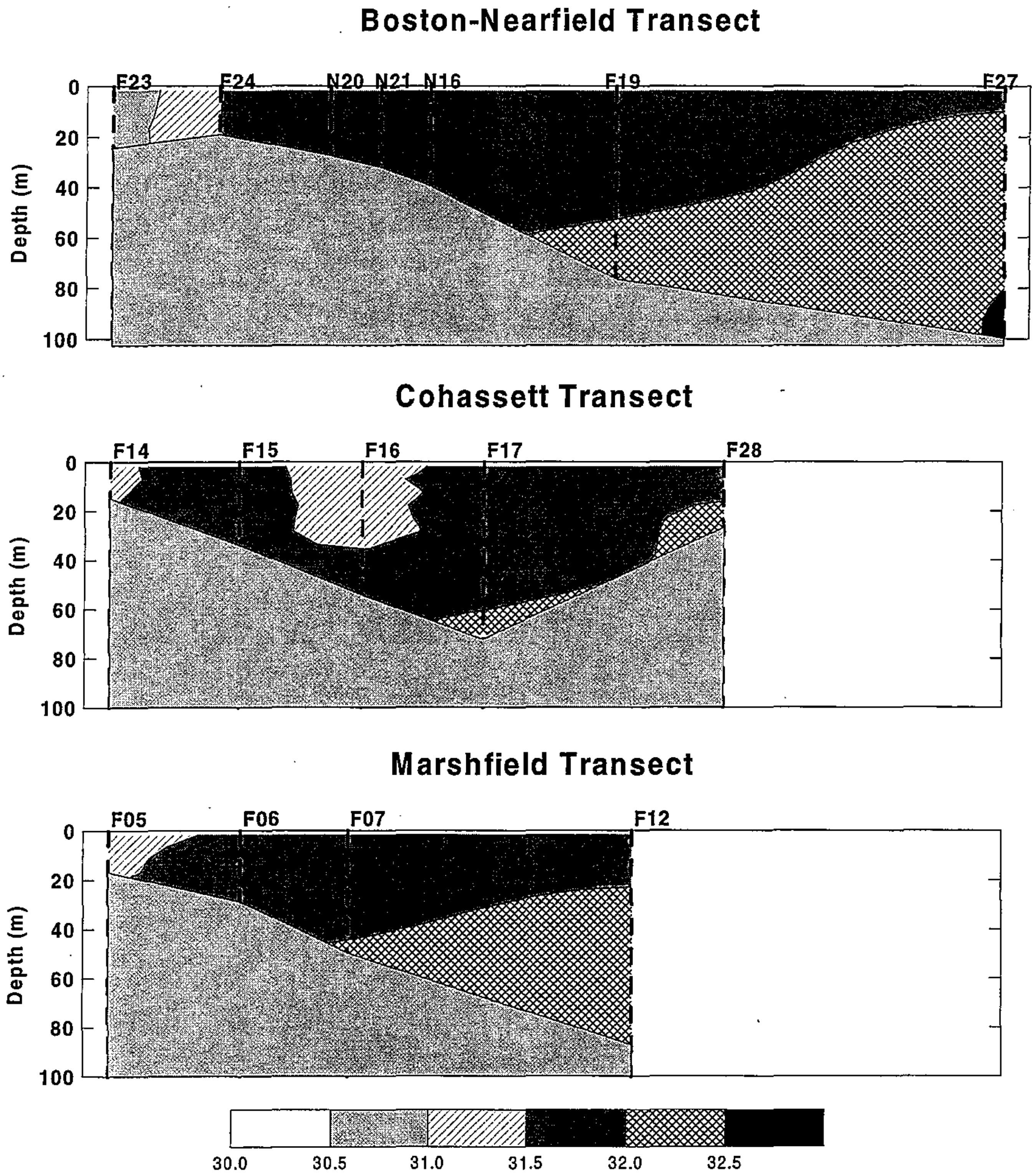


Marshfield Transect





Parameter: Salinity
Survey: 9601

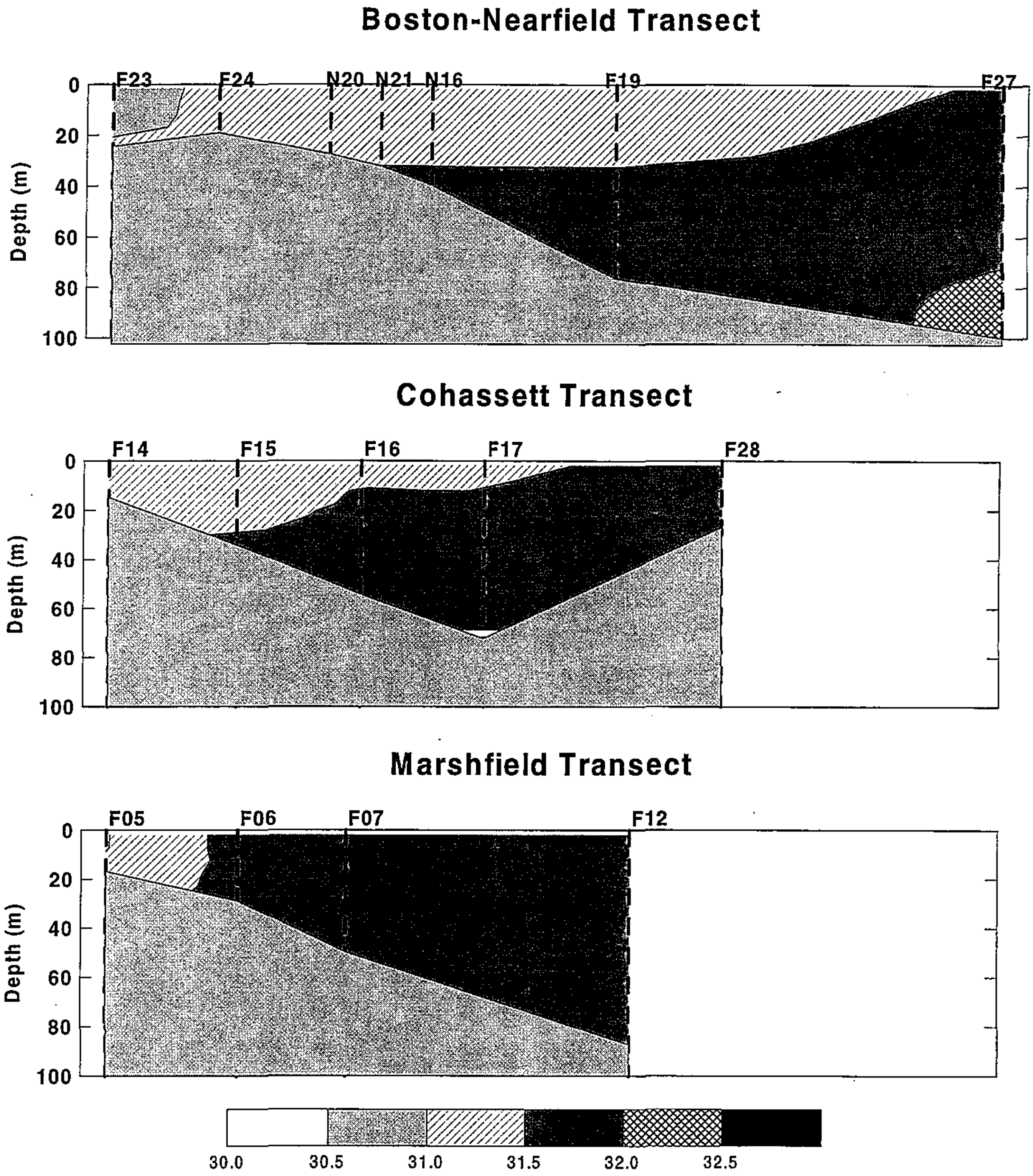


Boston-Nearfield Transect

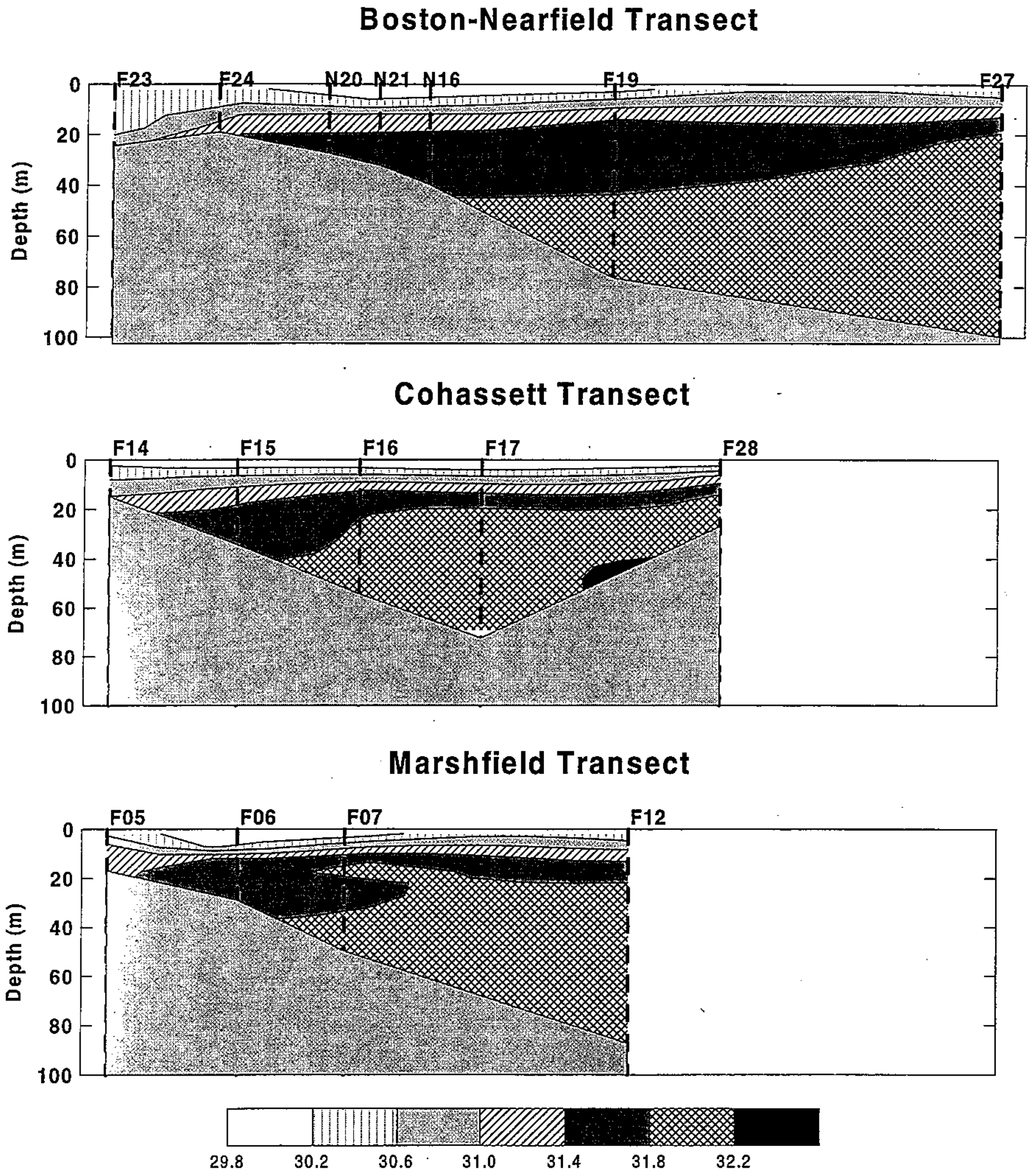
Cohassett Transect

Marshfield Transect

Parameter: Salinity
Survey: 9602



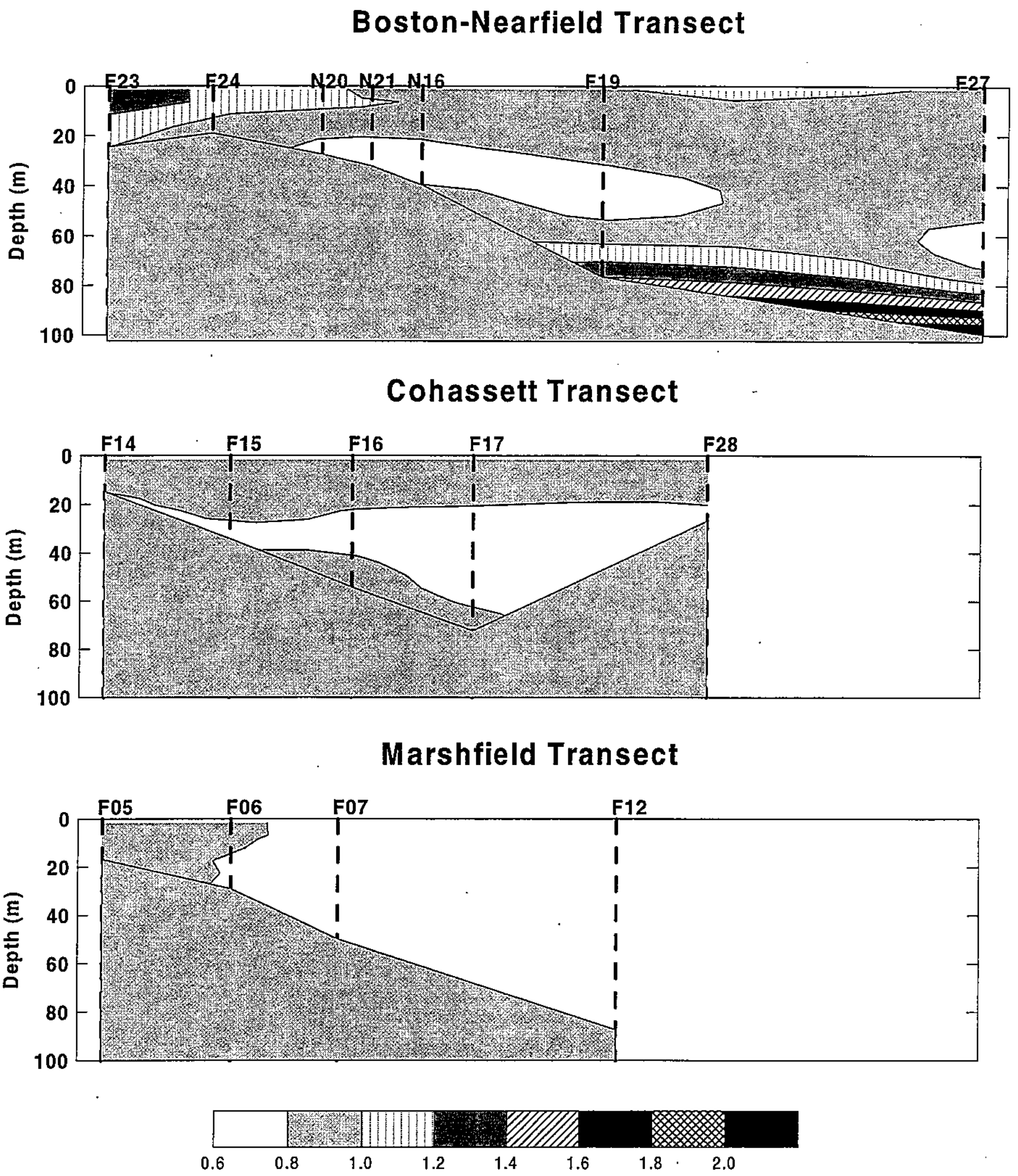
Parameter: Salinity
Survey: 9604


Boston-Nearfield Transect

Cohassett Transect

Marshfield Transect

Parameter: Salinity
Survey: 9607

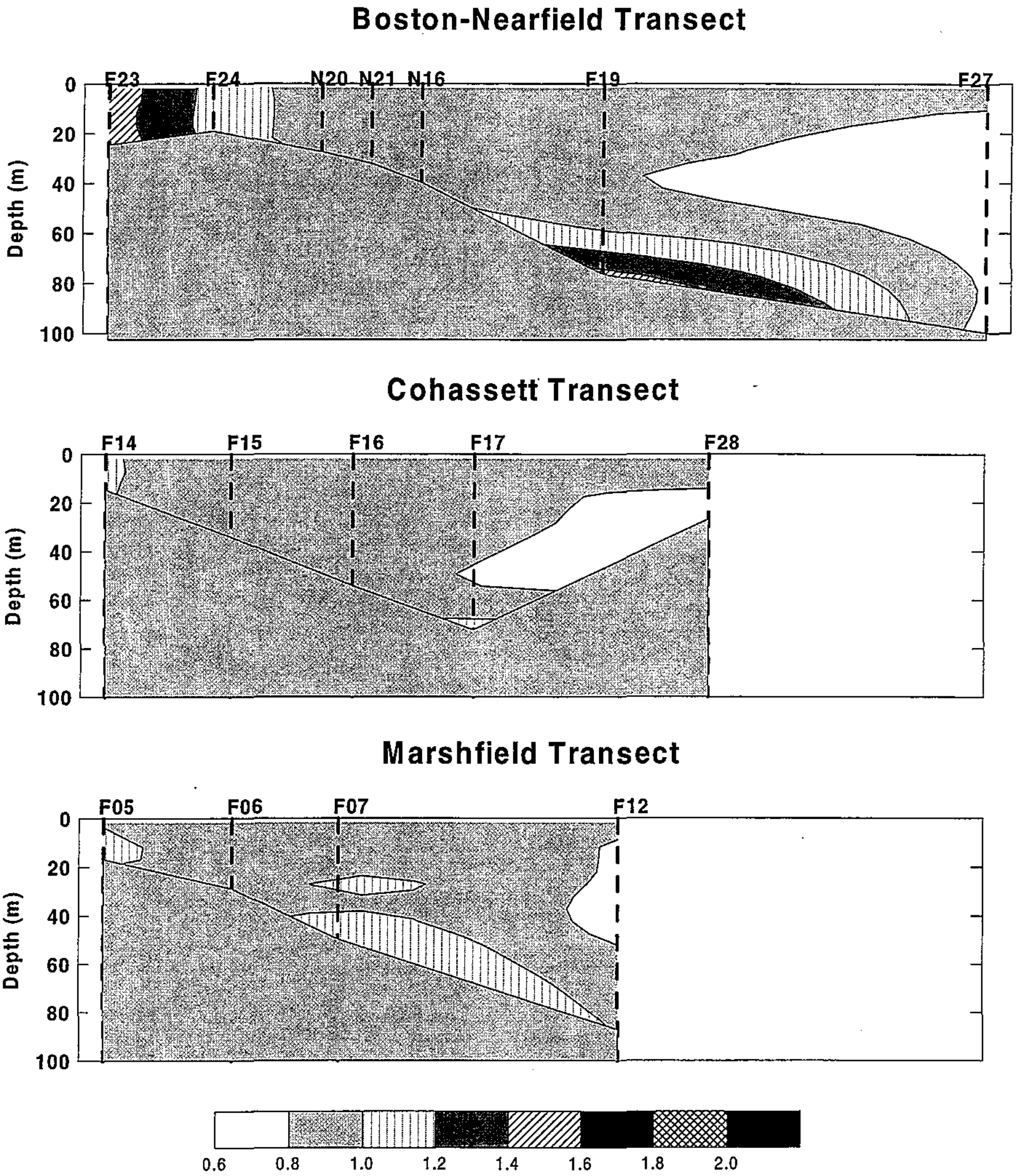


Boston-Nearfield Transect

Cohassett Transect

Marshfield Transect

Parameter: Beam Attenuation
Survey: 9601

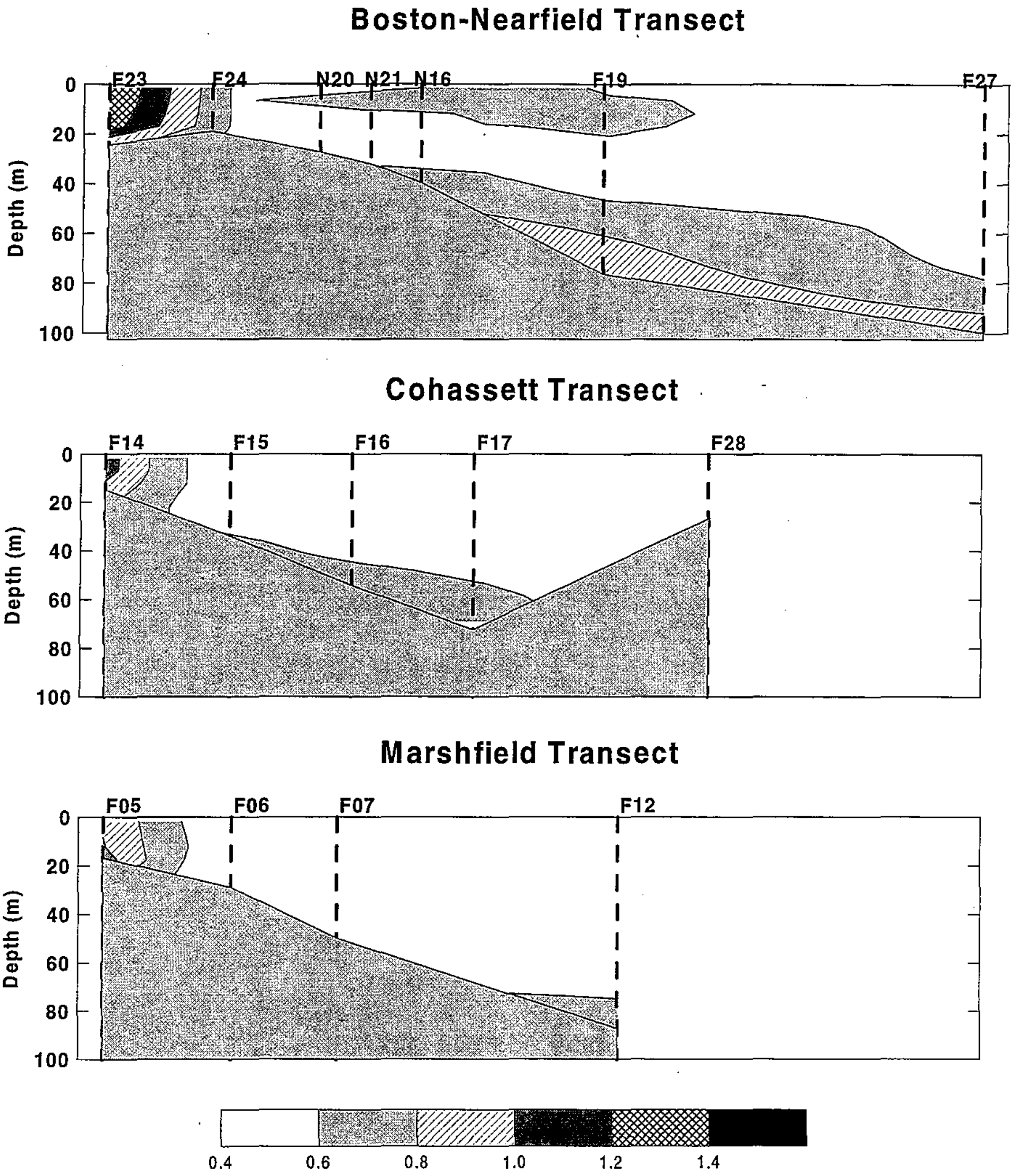


Boston-Nearfield Transect

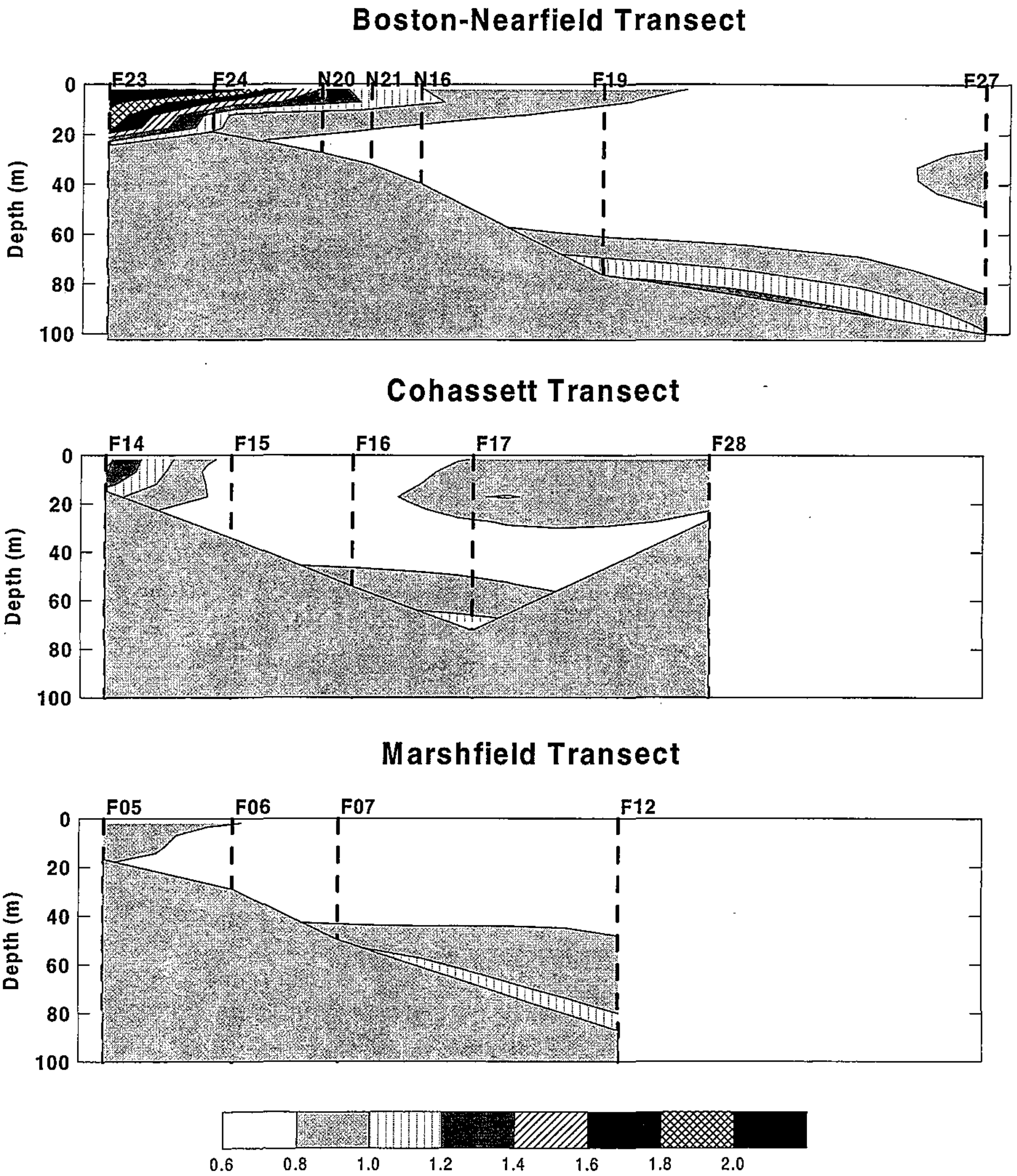
Cohassett Transect

Marshfield Transect

Parameter: Beam Attenuation
Survey: 9602



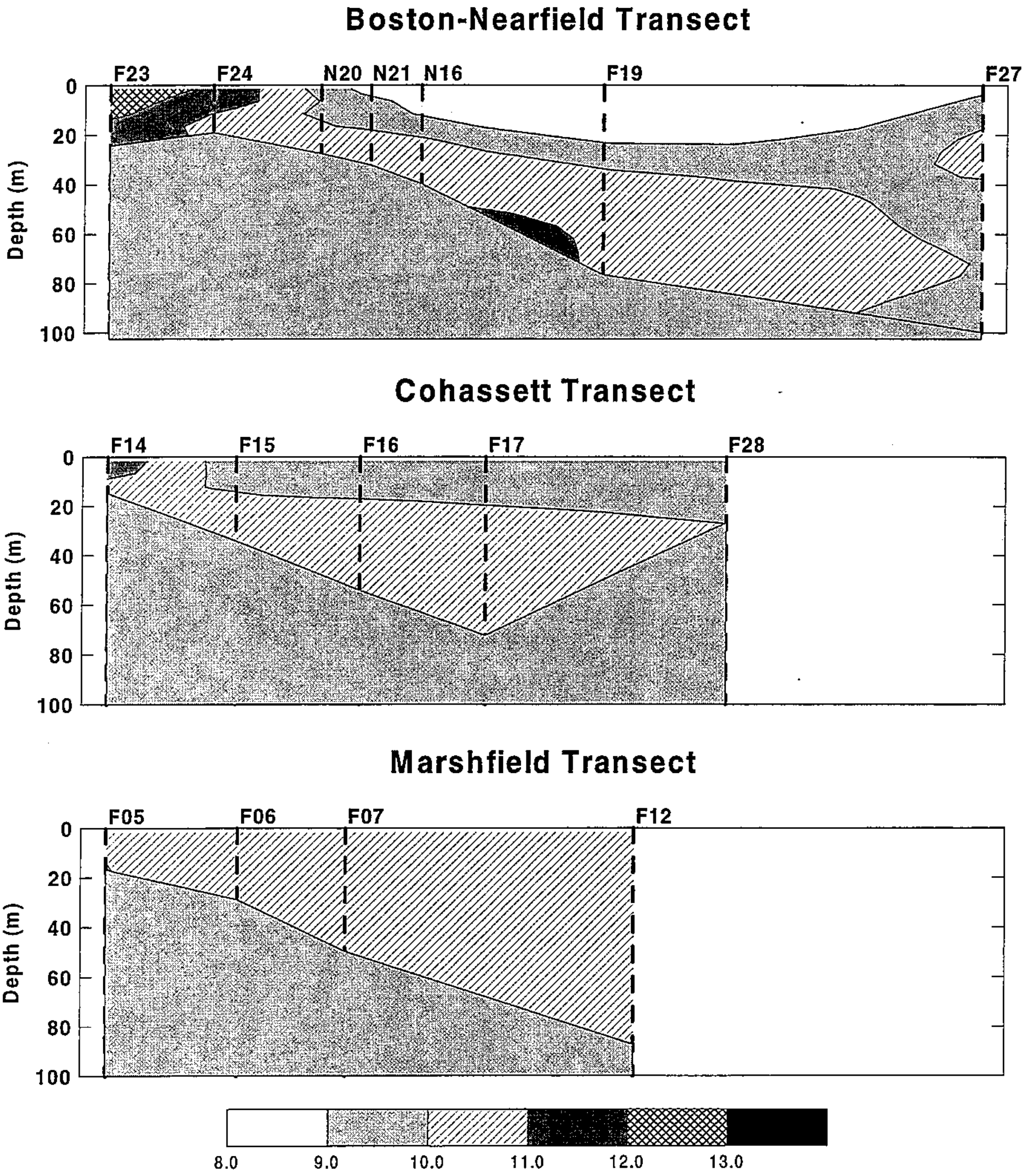
Parameter: Beam Attenuation
Survey: 9604


Boston-Nearfield Transect

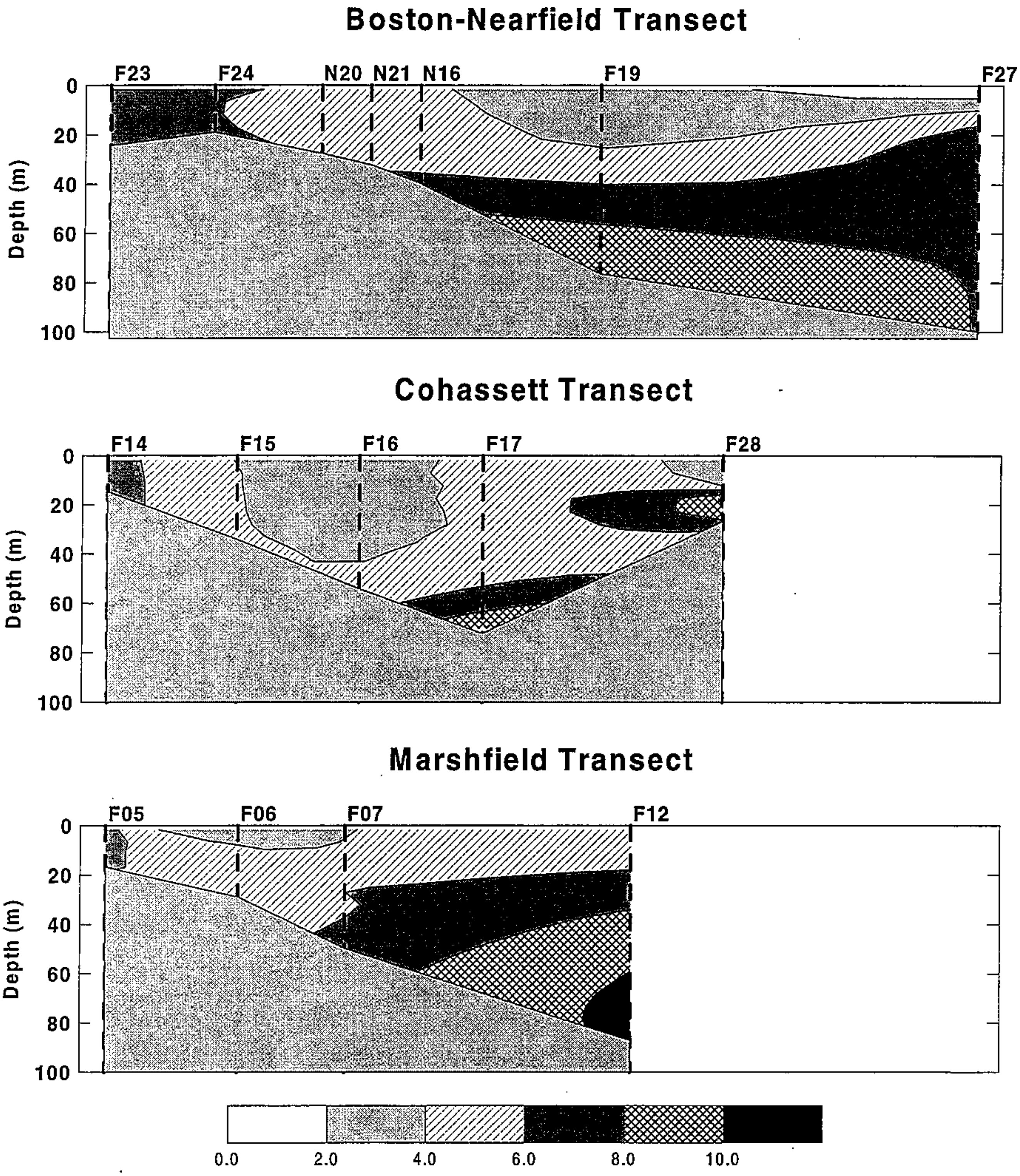
Cohassett Transect

Marshfield Transect

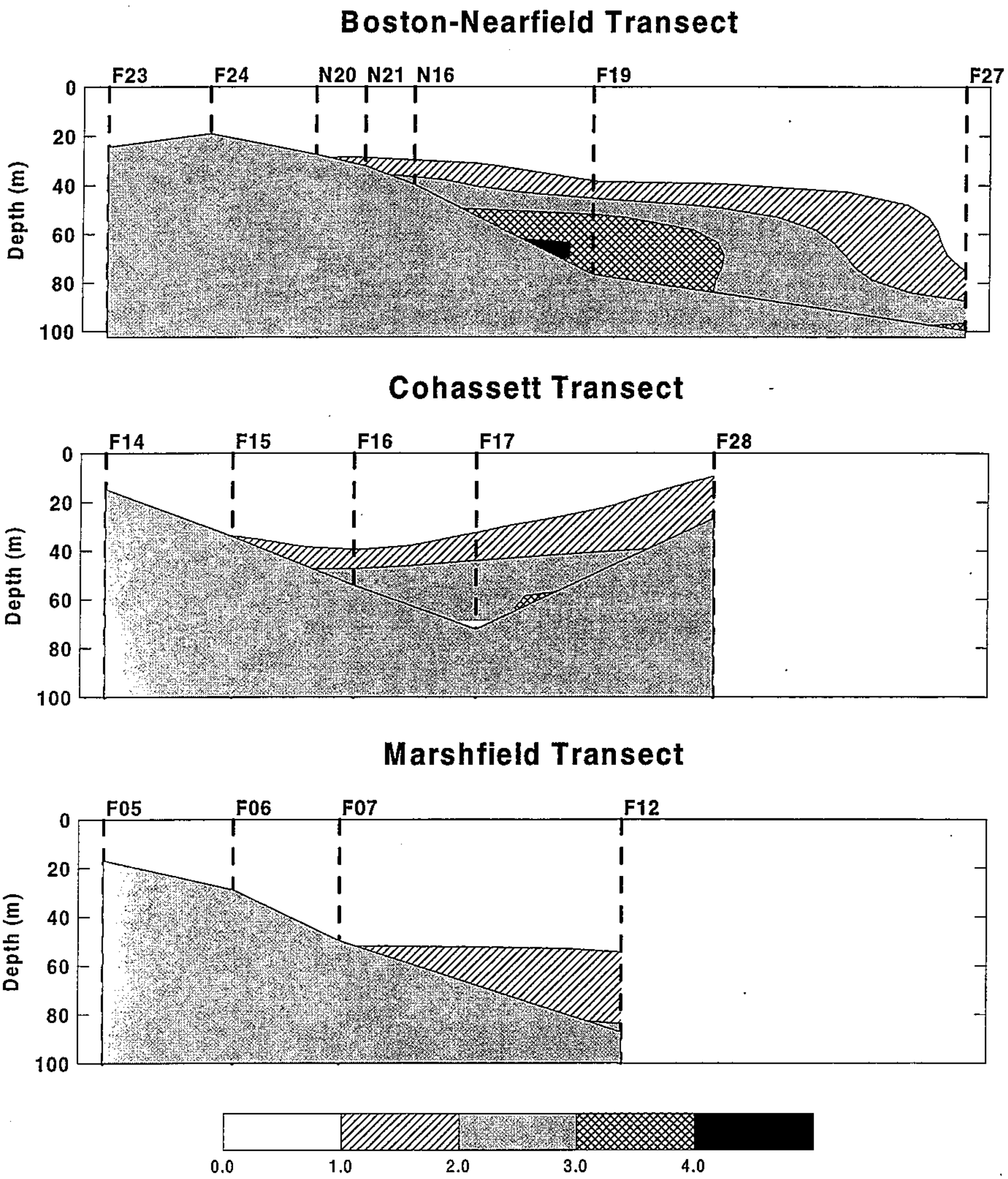
Parameter: Beam Attenuation
Survey: 9607



Parameter: Nitrite+Nitrate
Survey: 9601



Parameter: Nitrite+Nitrate
Survey: 9602

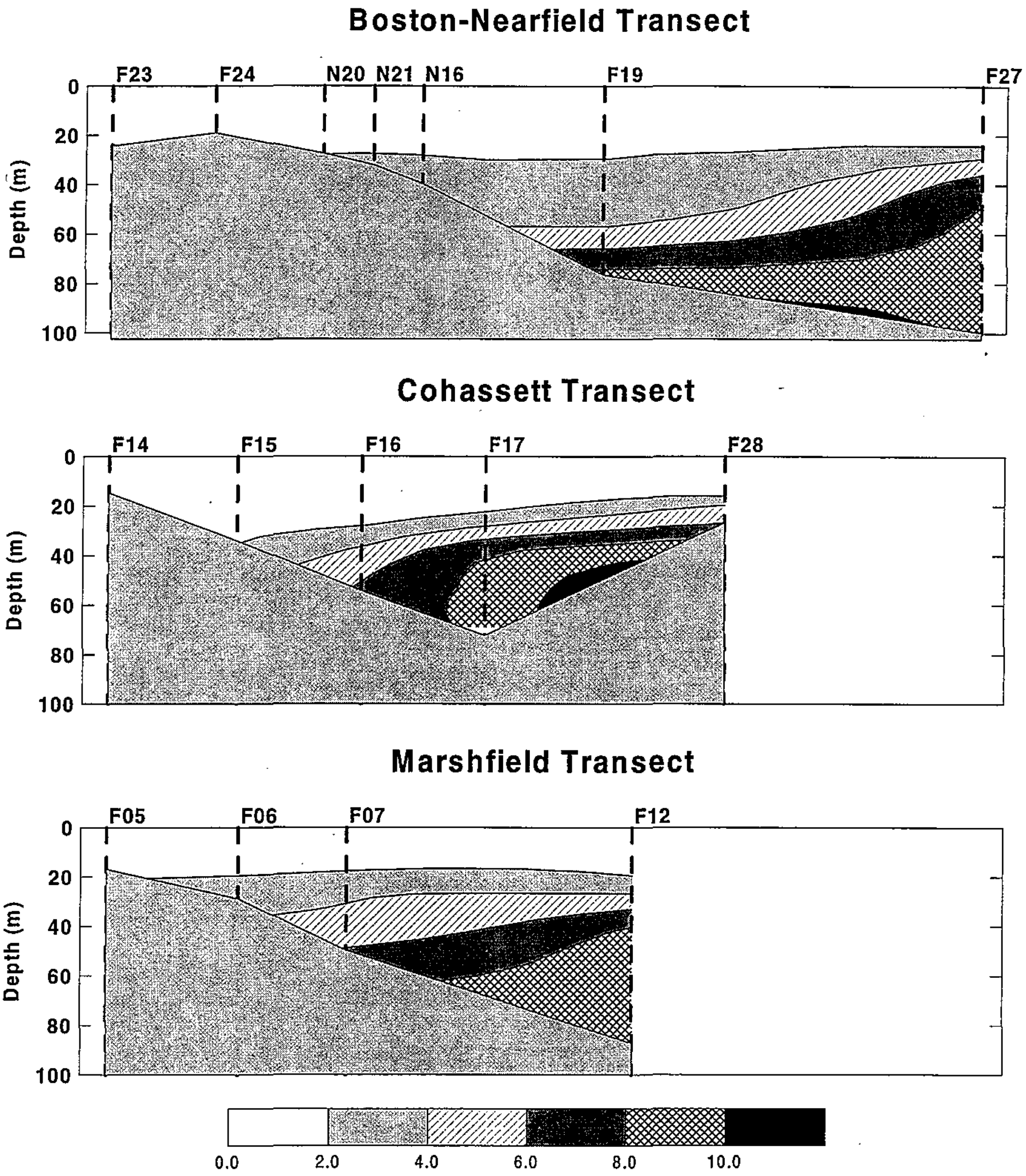


Boston-Nearfield Transect

Cohassett Transect

Marshfield Transect

Parameter: Nitrite+Nitrate
Survey: 9604

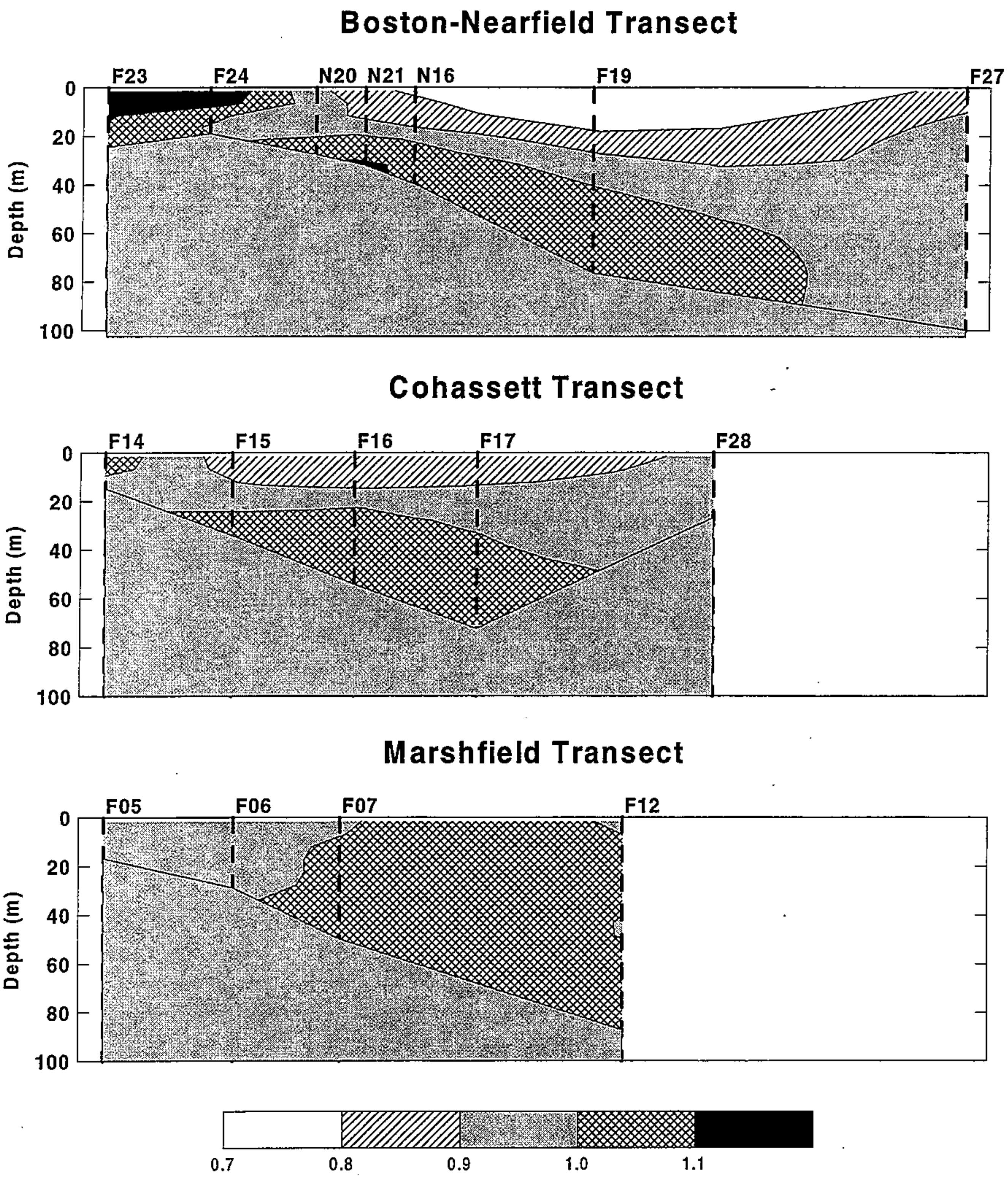


Boston-Nearfield Transect

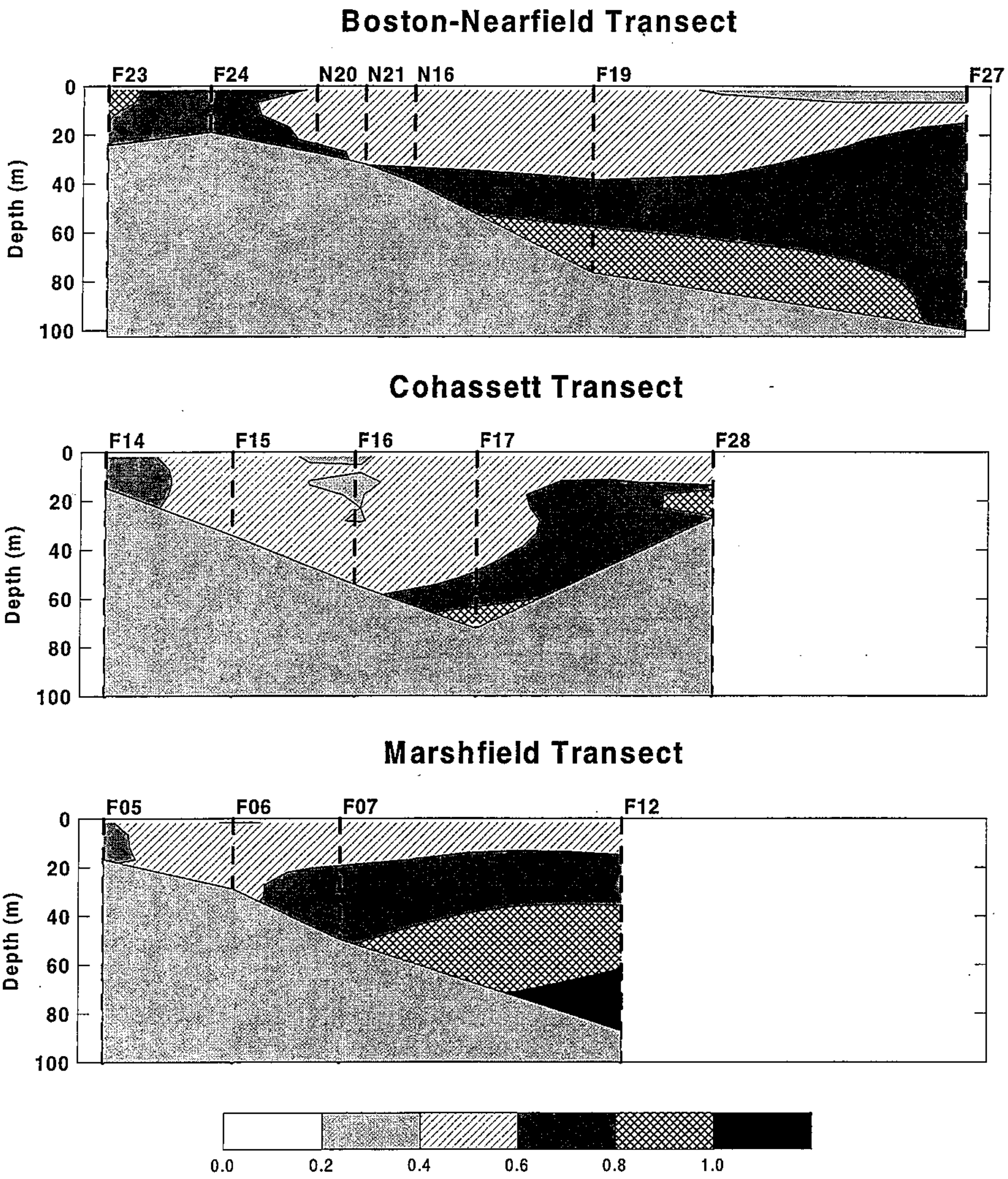
Cohassett Transect

Marshfield Transect

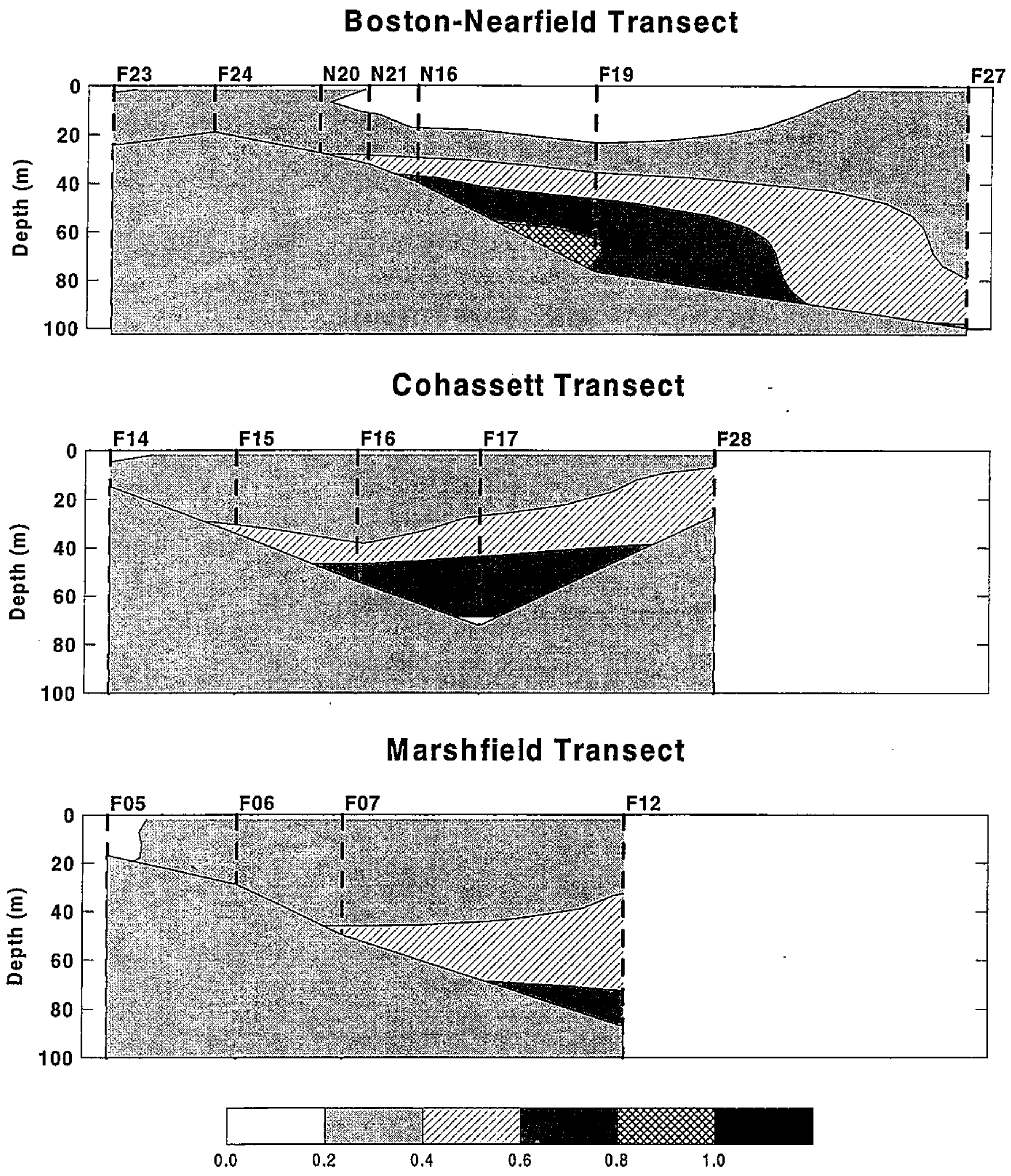
Parameter: Nitrite+Nitrate
Survey: 9607



Parameter: Phosphate
Survey: 9601



Parameter: Phosphate
Survey: 9602

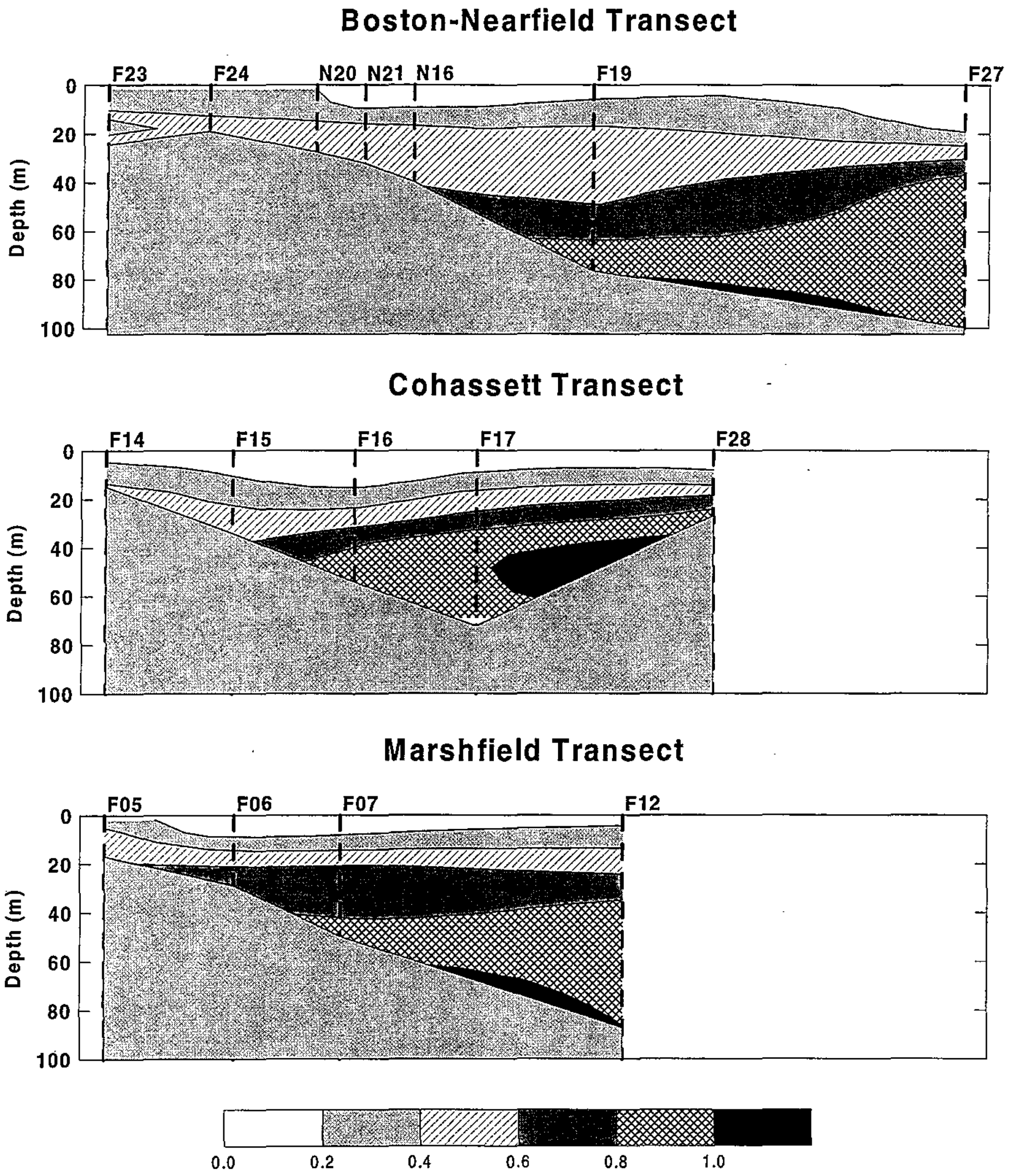


Boston-Nearfield Transect

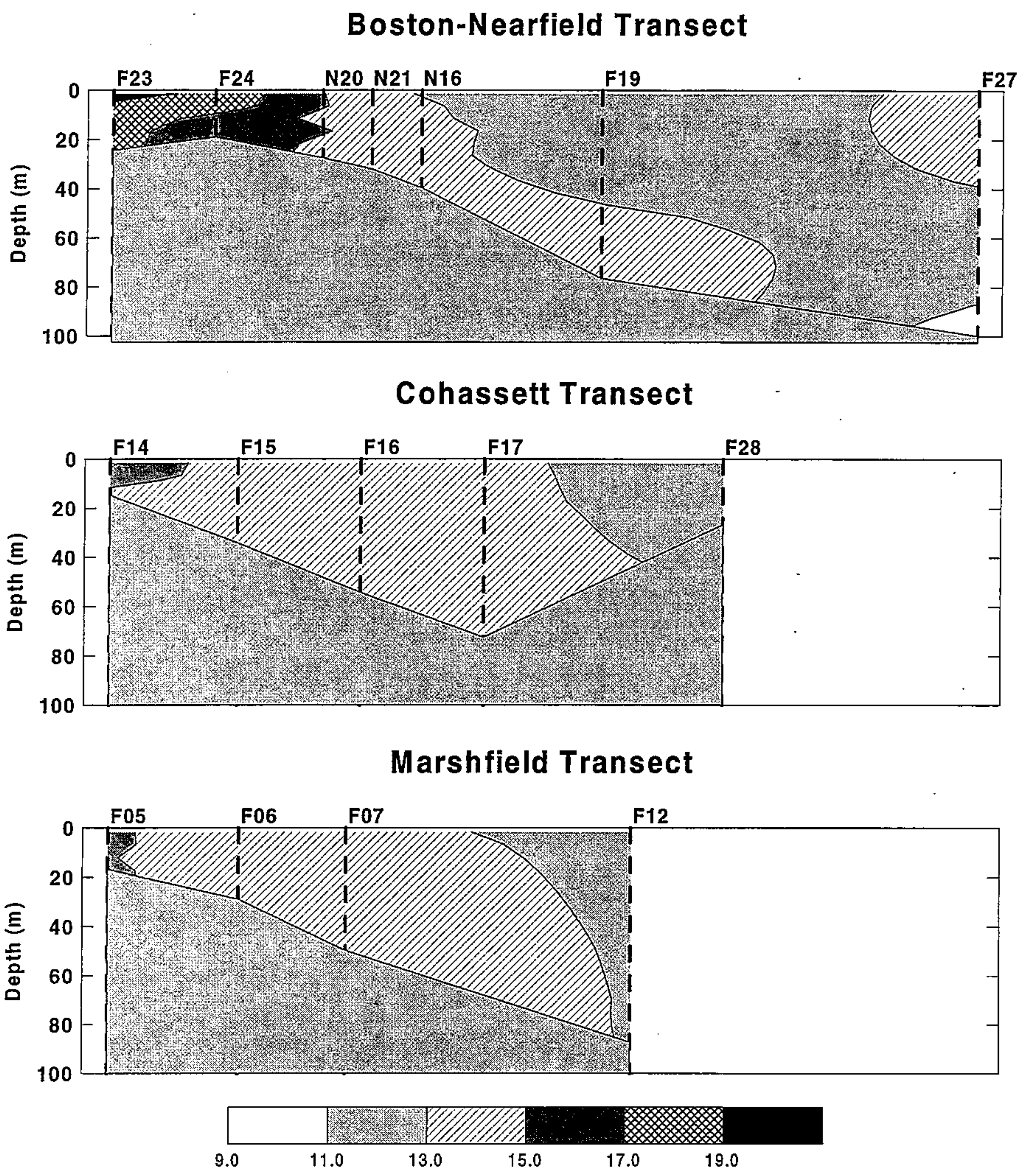
Cohassett Transect

Marshfield Transect

Parameter: Phosphate
Survey: 9604



Parameter: Phosphate
Survey: 9607



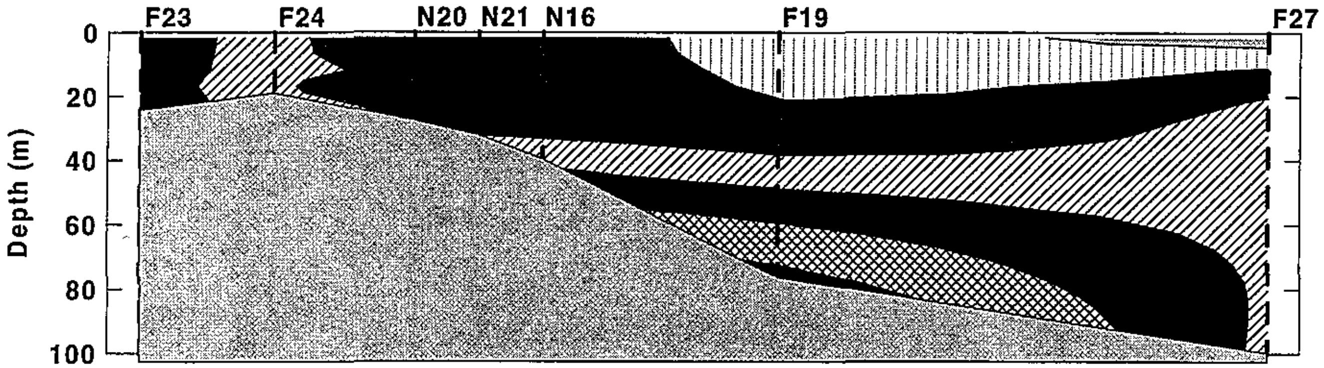
Boston-Nearfield Transect

Cohassett Transect

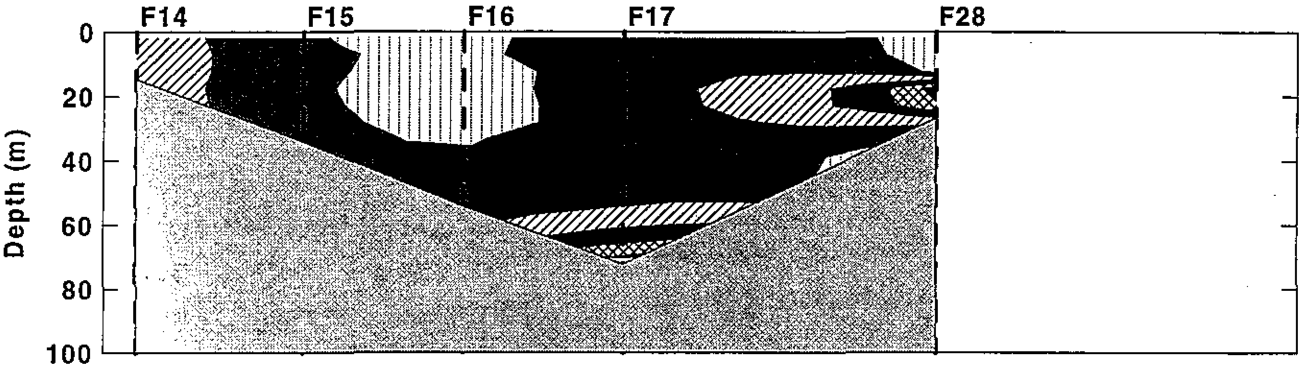
Marshfield Transect

Parameter: Silicate
Survey: 9601

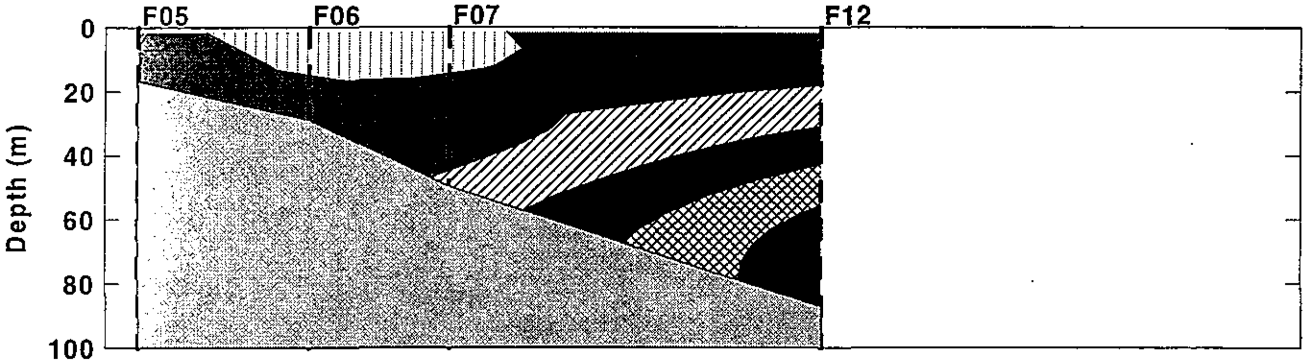
Boston-Nearfield Transect



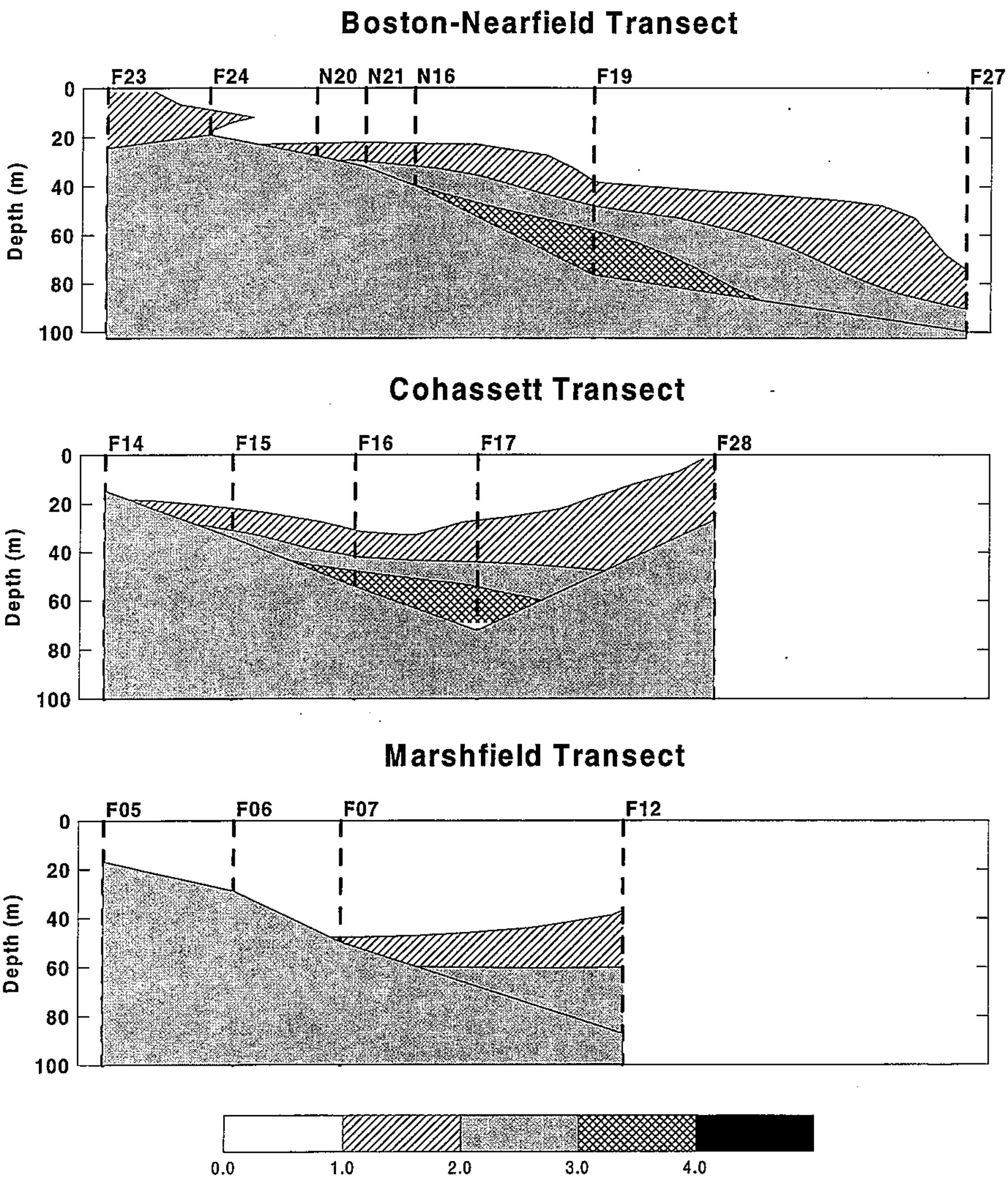
Cohassett Transect



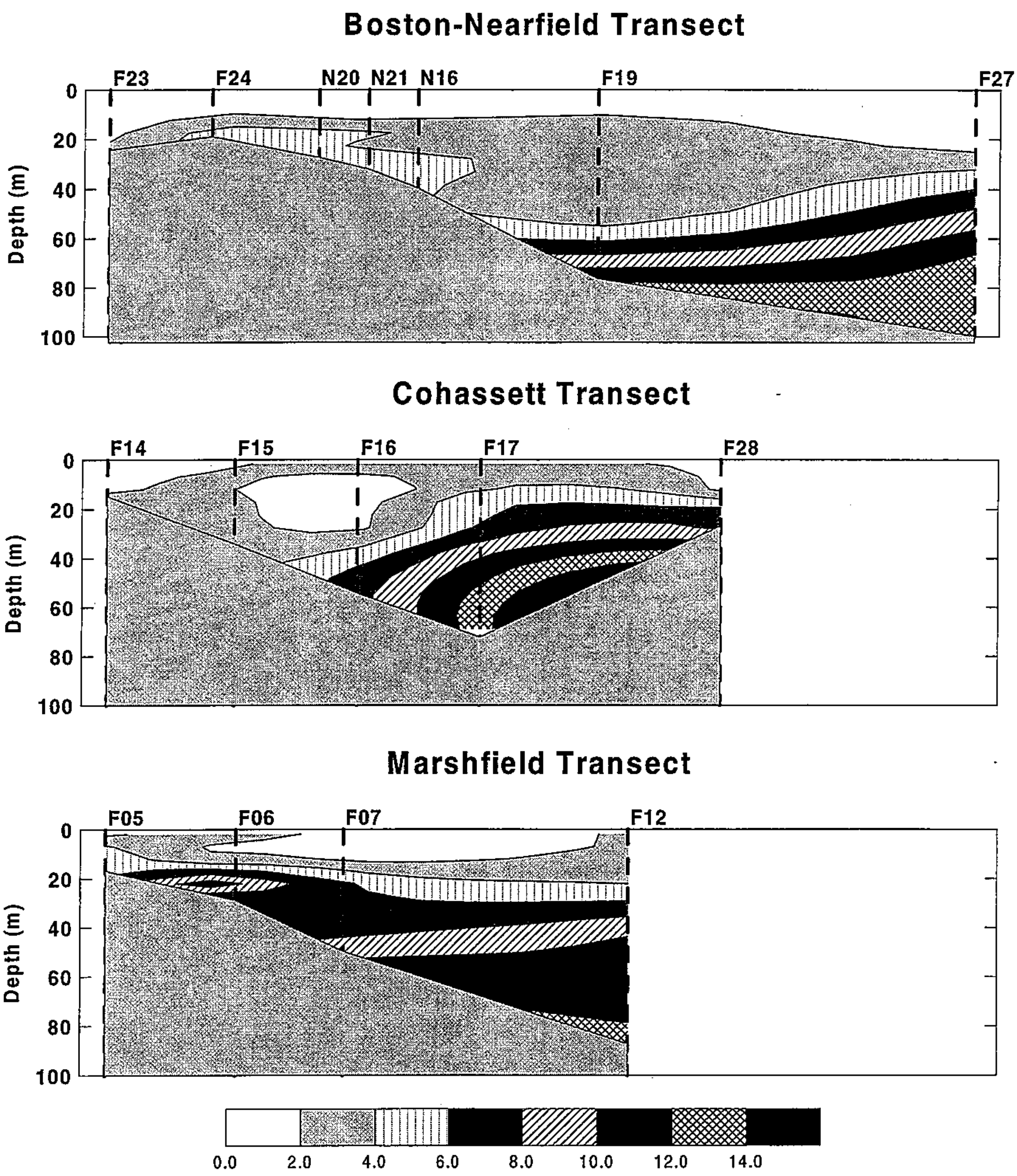
Marshfield Transect



Parameter: Silicate
Survey: 9602



Parameter: Silicate
Survey: 9604

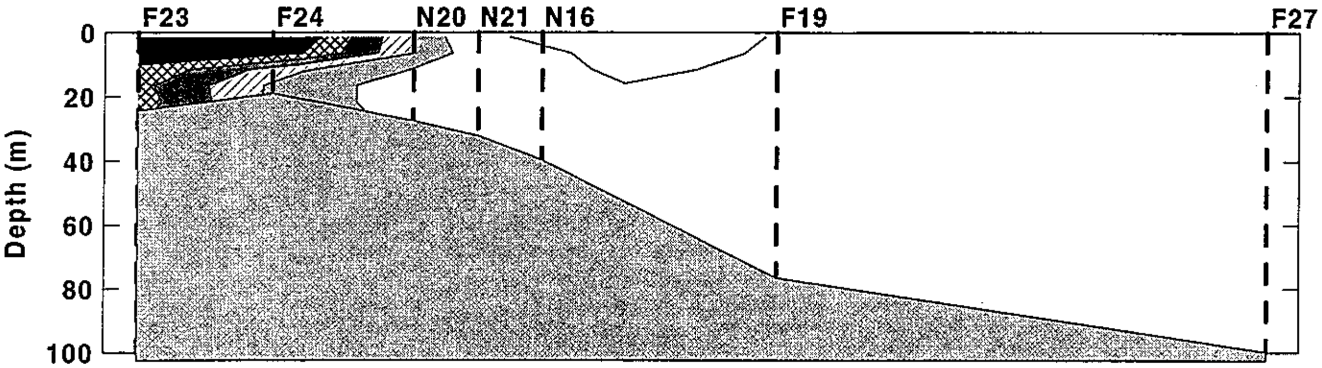

Boston-Nearfield Transect

Cohassett Transect

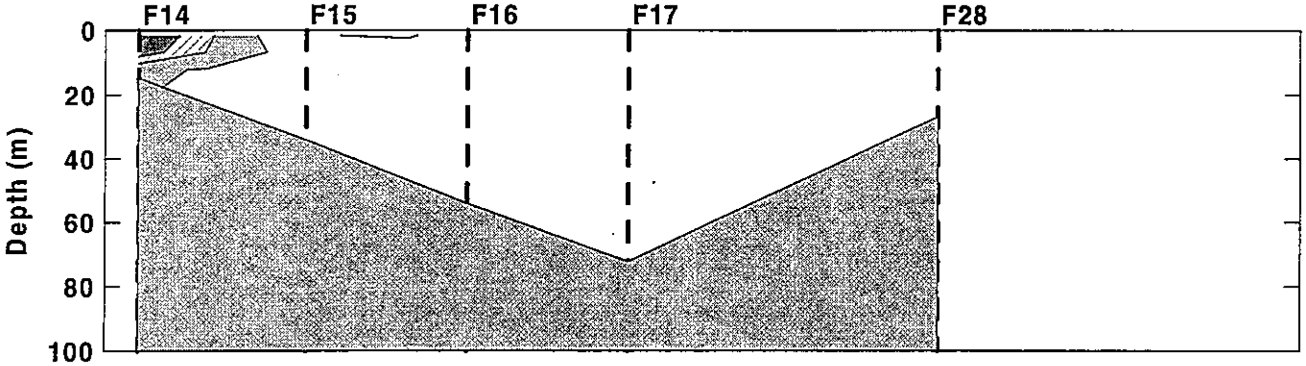
Marshfield Transect

Parameter: Silicate
Survey: 9607

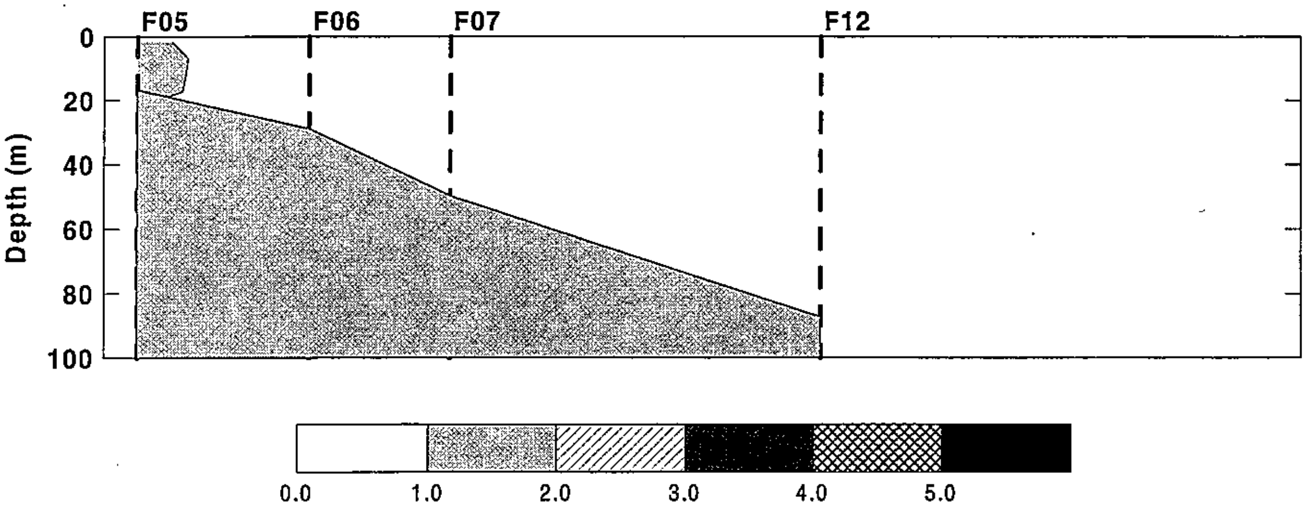
Boston-Nearfield Transect



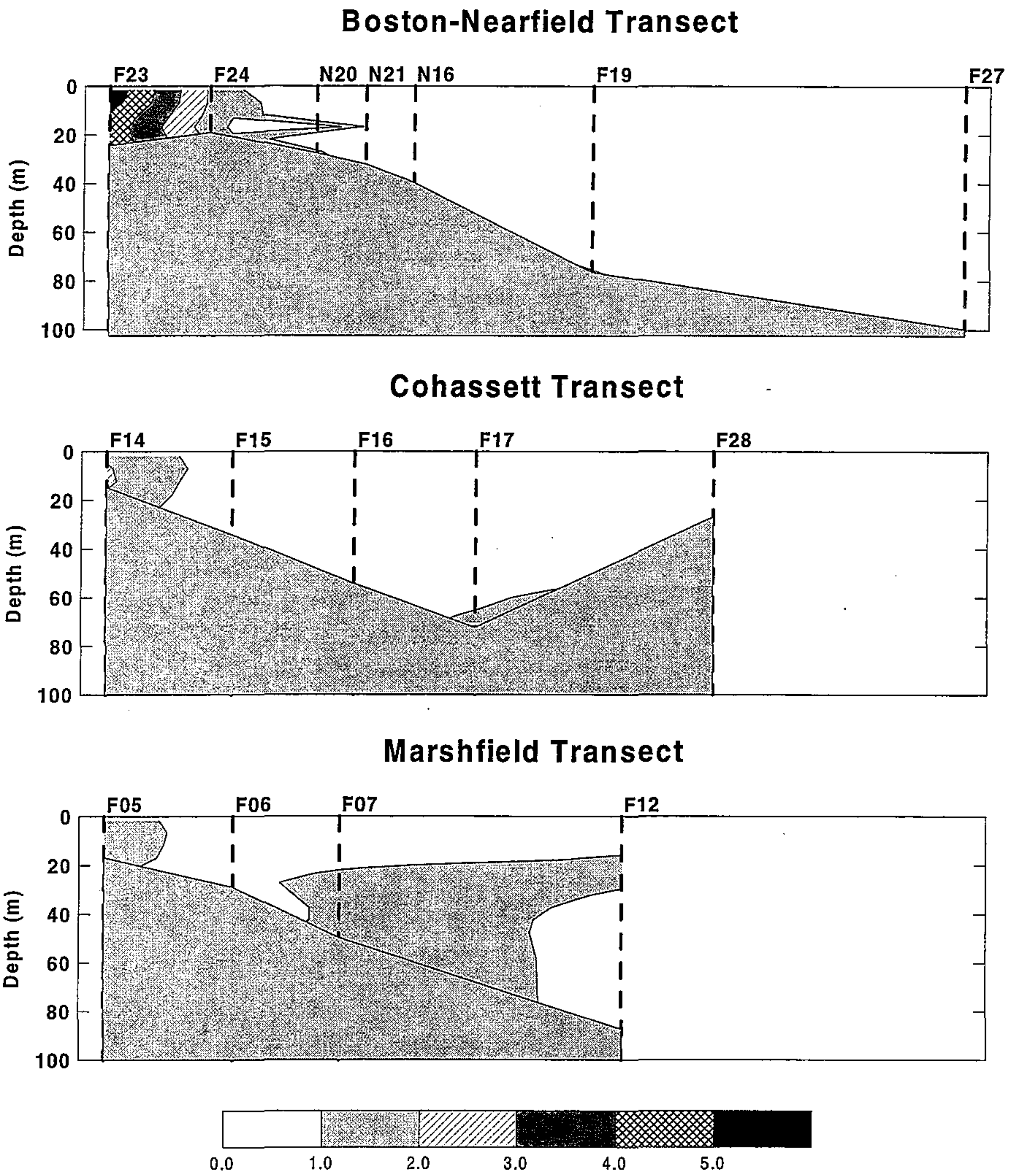
Cohassett Transect



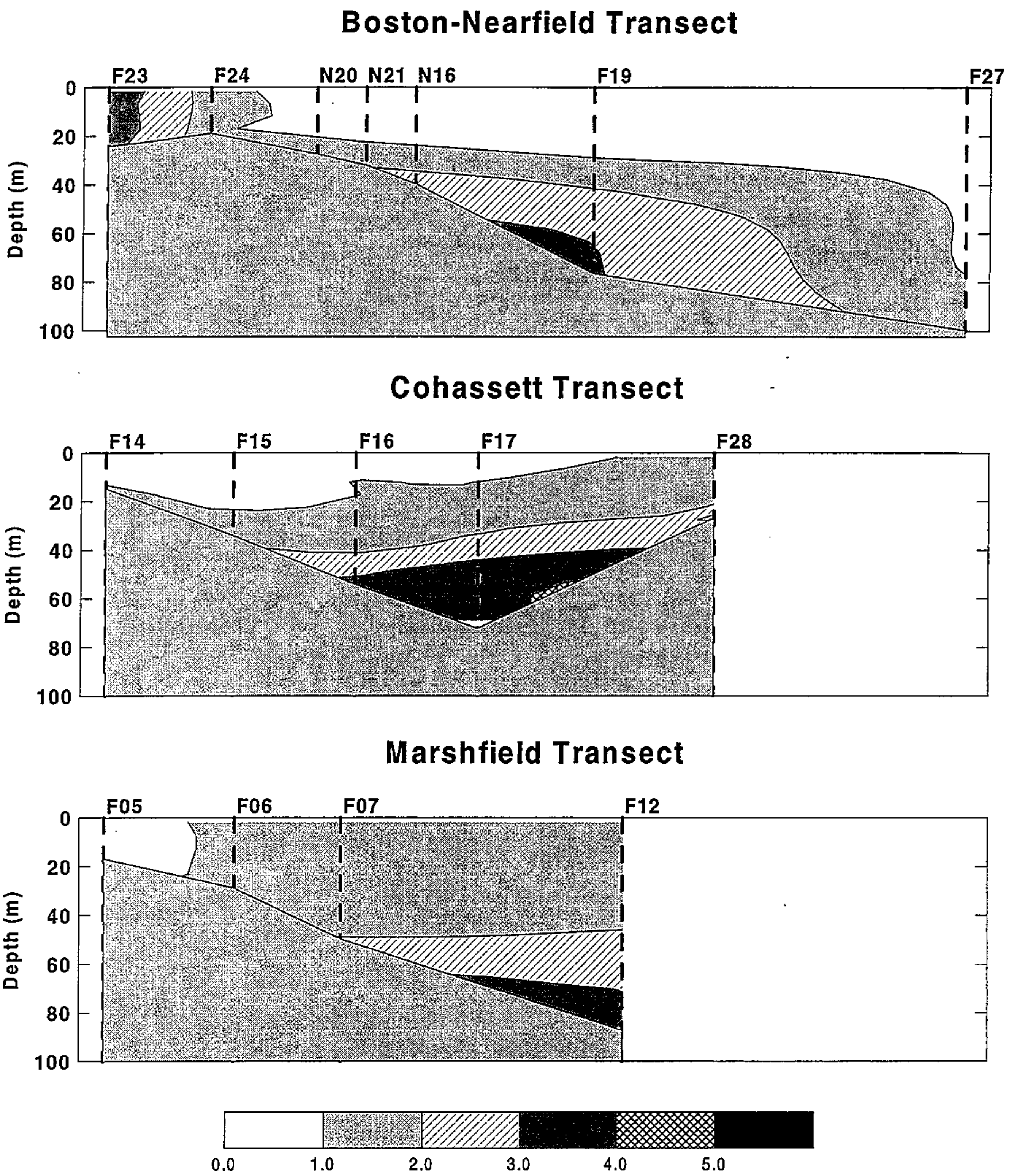
Marshfield Transect



Parameter: Ammonium
Survey: 9601



Parameter: Ammonium
Survey: 9602

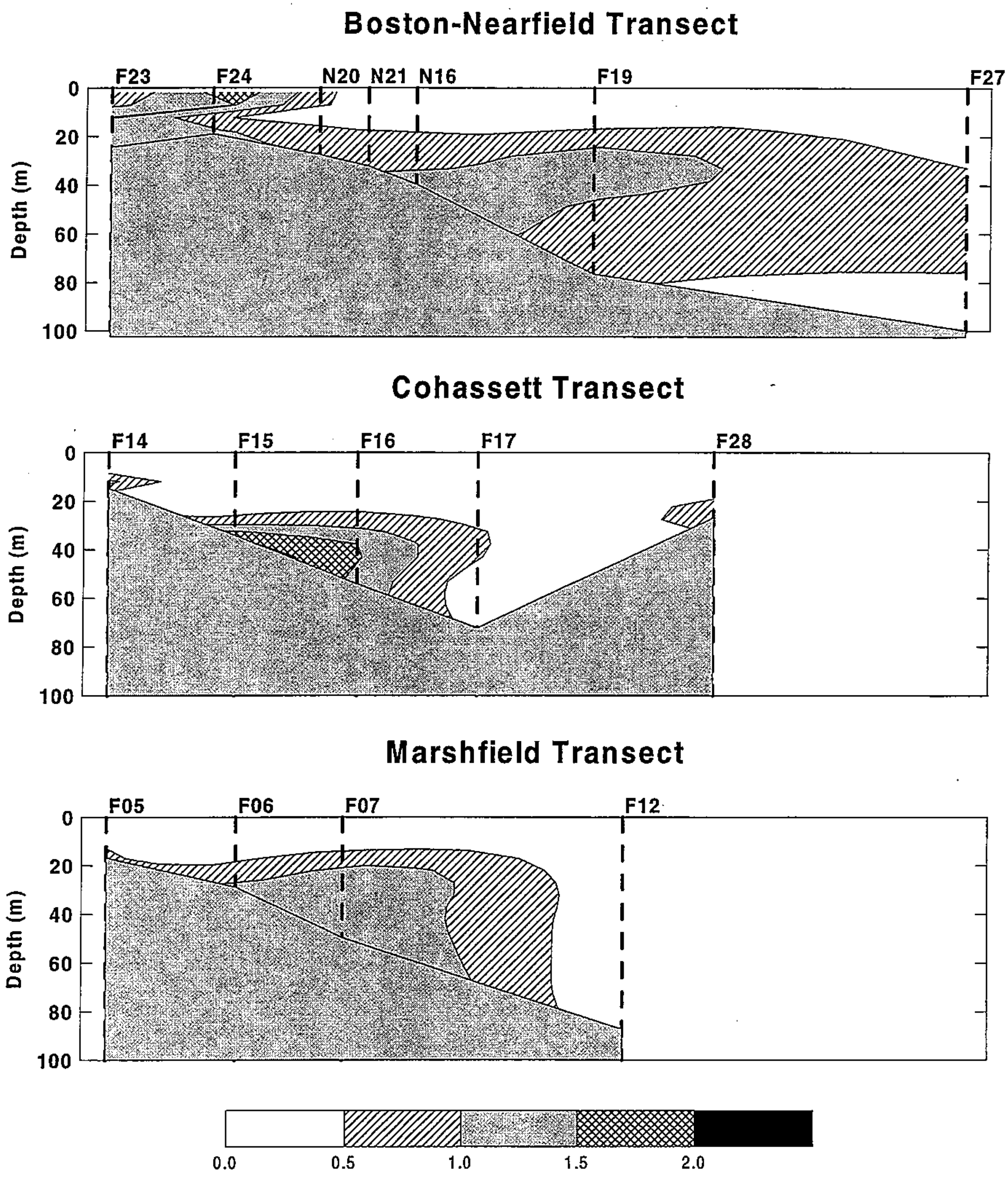


Boston-Nearfield Transect

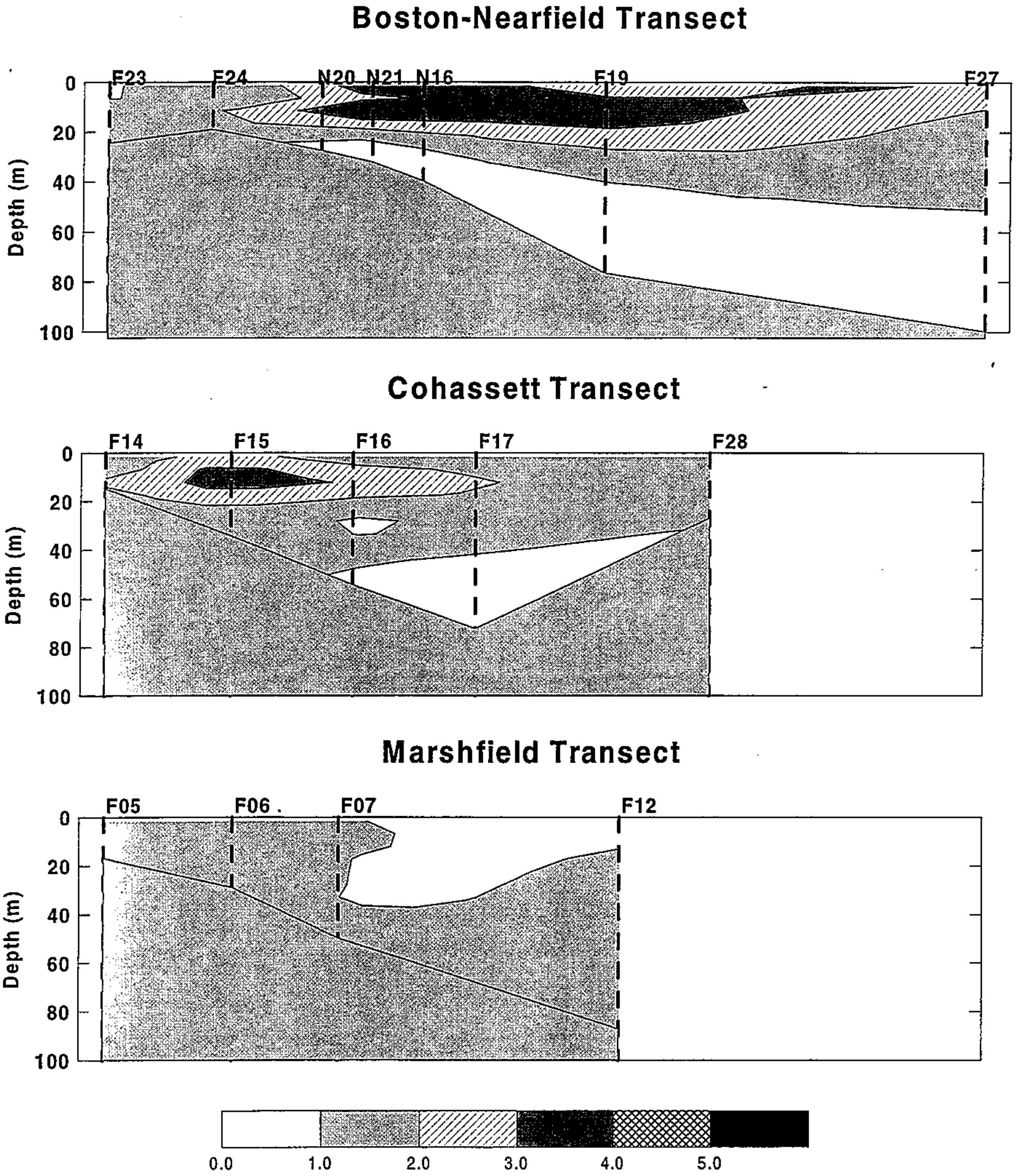
Cohassett Transect

Marshfield Transect

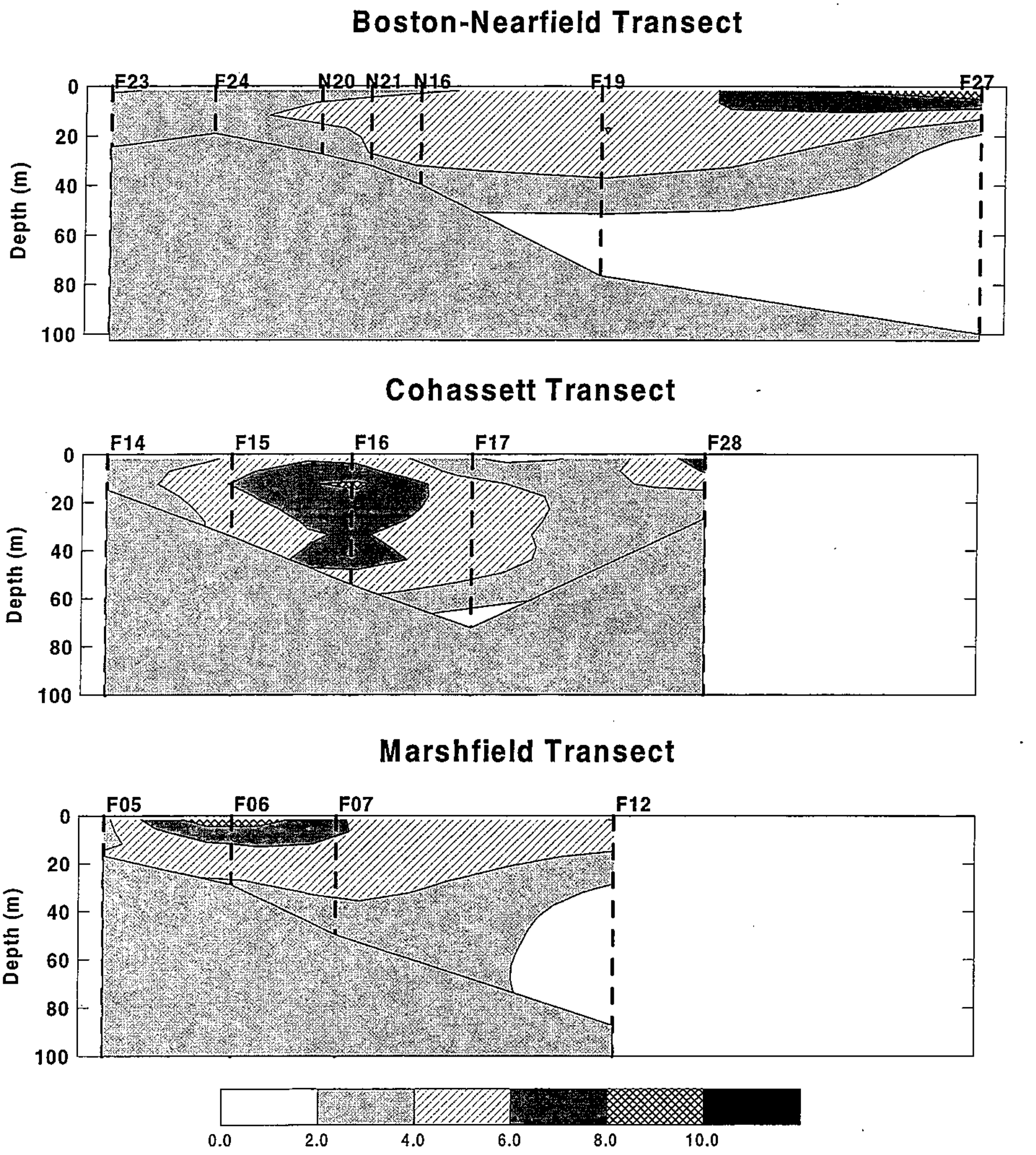
Parameter: Ammonium
Survey: 9604



Parameter: Ammonium
Survey: 9607



Parameter: Fluorescence
Survey: 9601

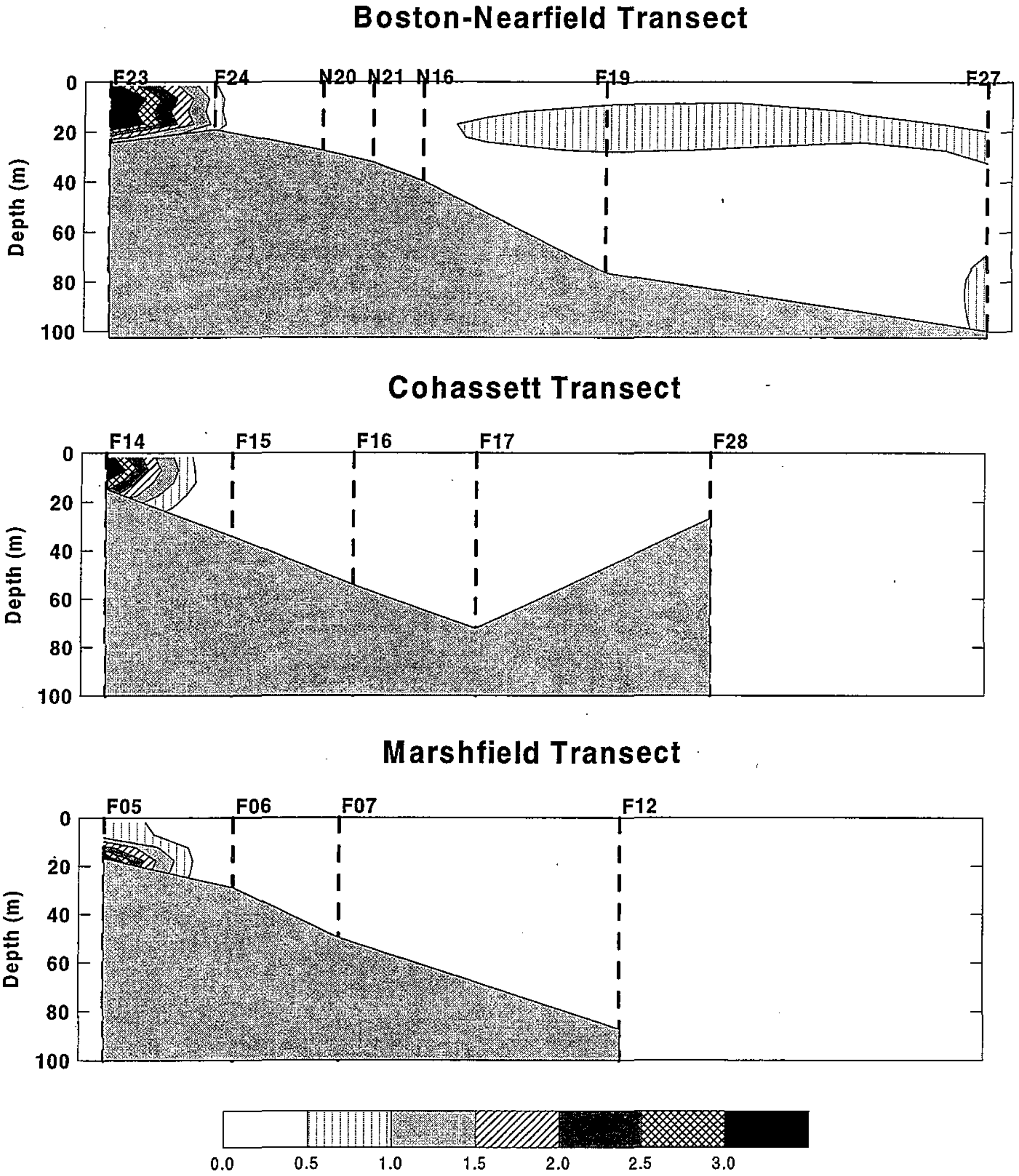


Boston-Nearfield Transect

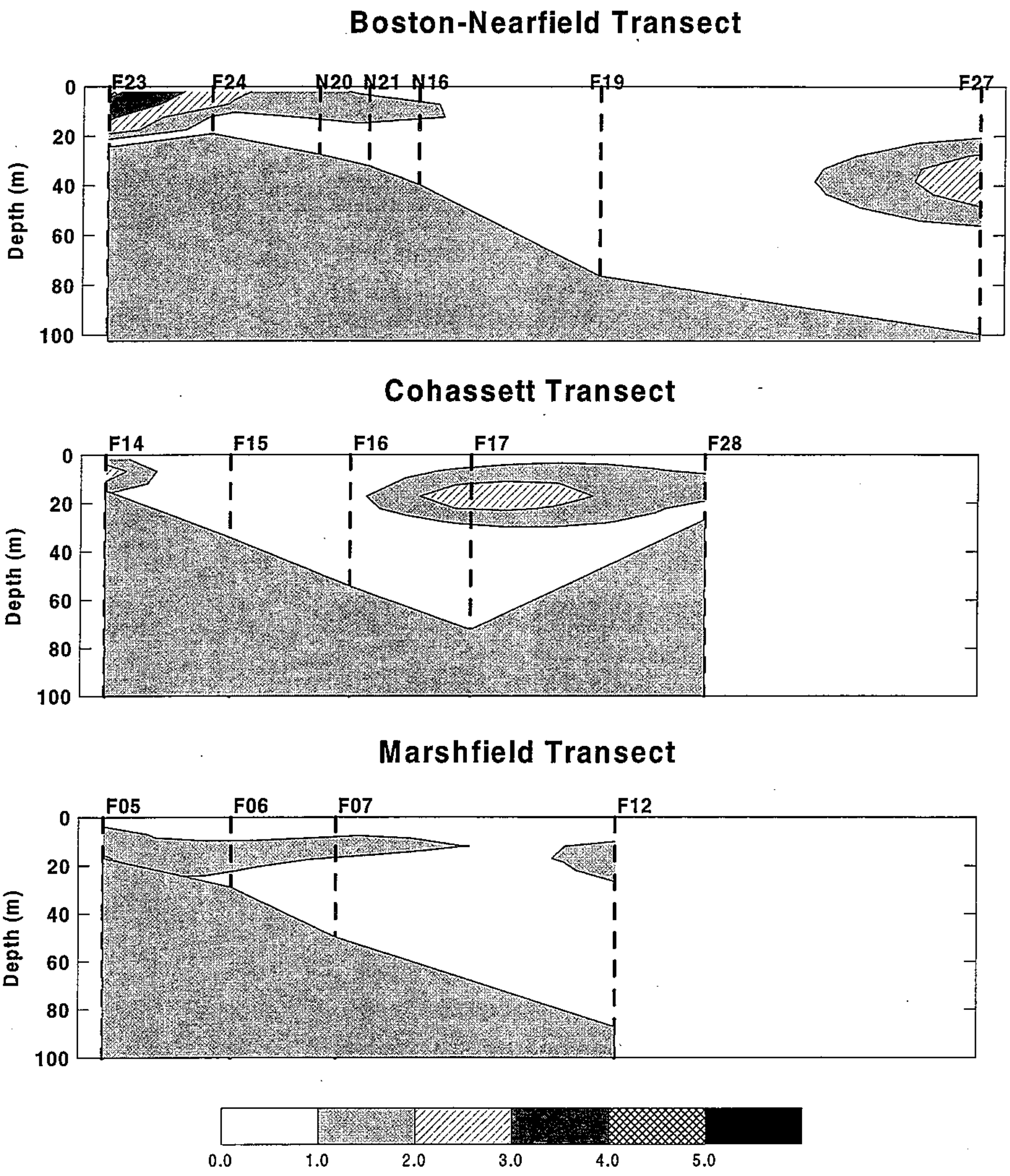
Cohassett Transect

Marshfield Transect

Parameter: Fluorescence
Survey: 9602



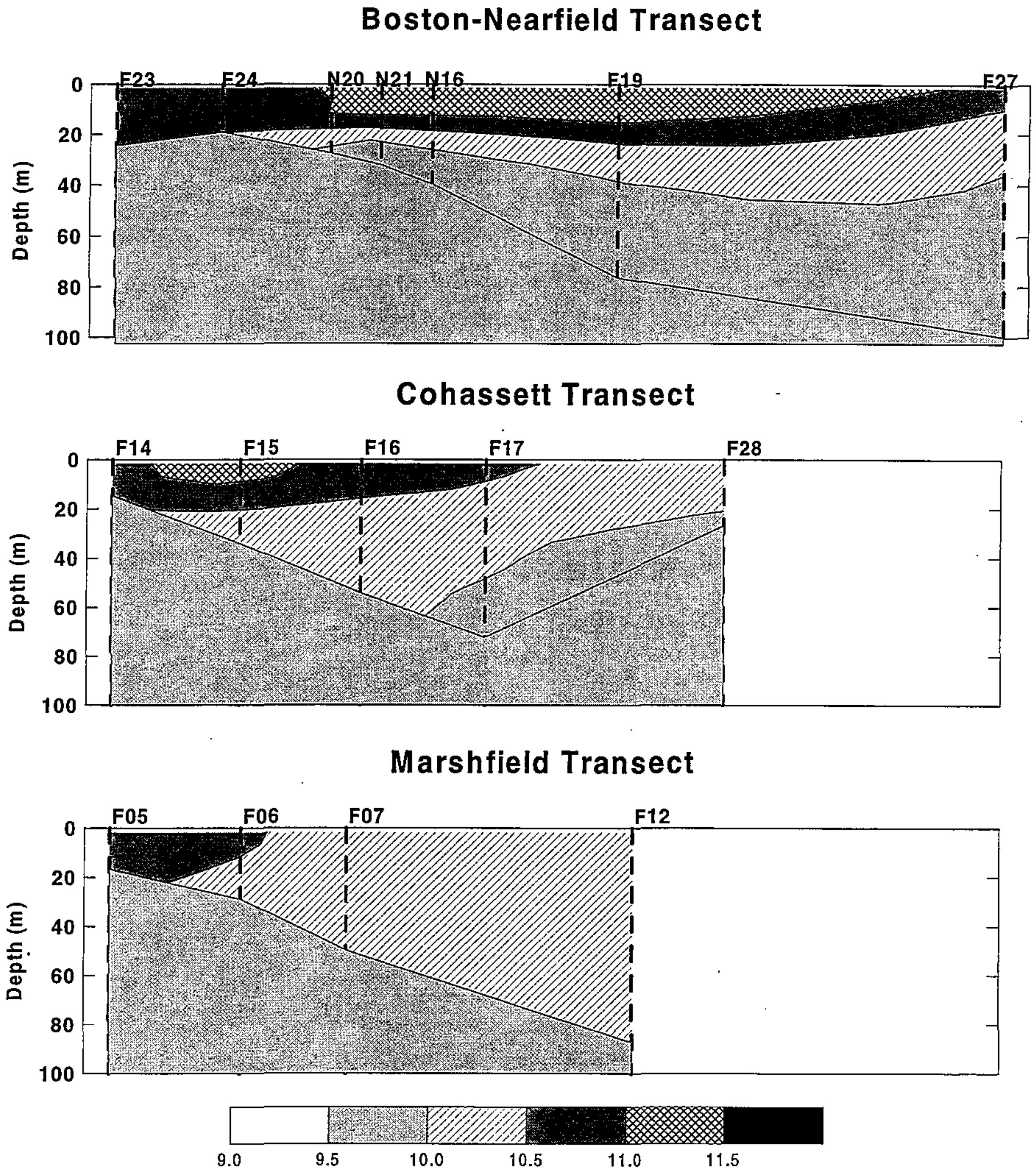
Parameter: Fluorescence
Survey: 9604


Boston-Nearfield Transect

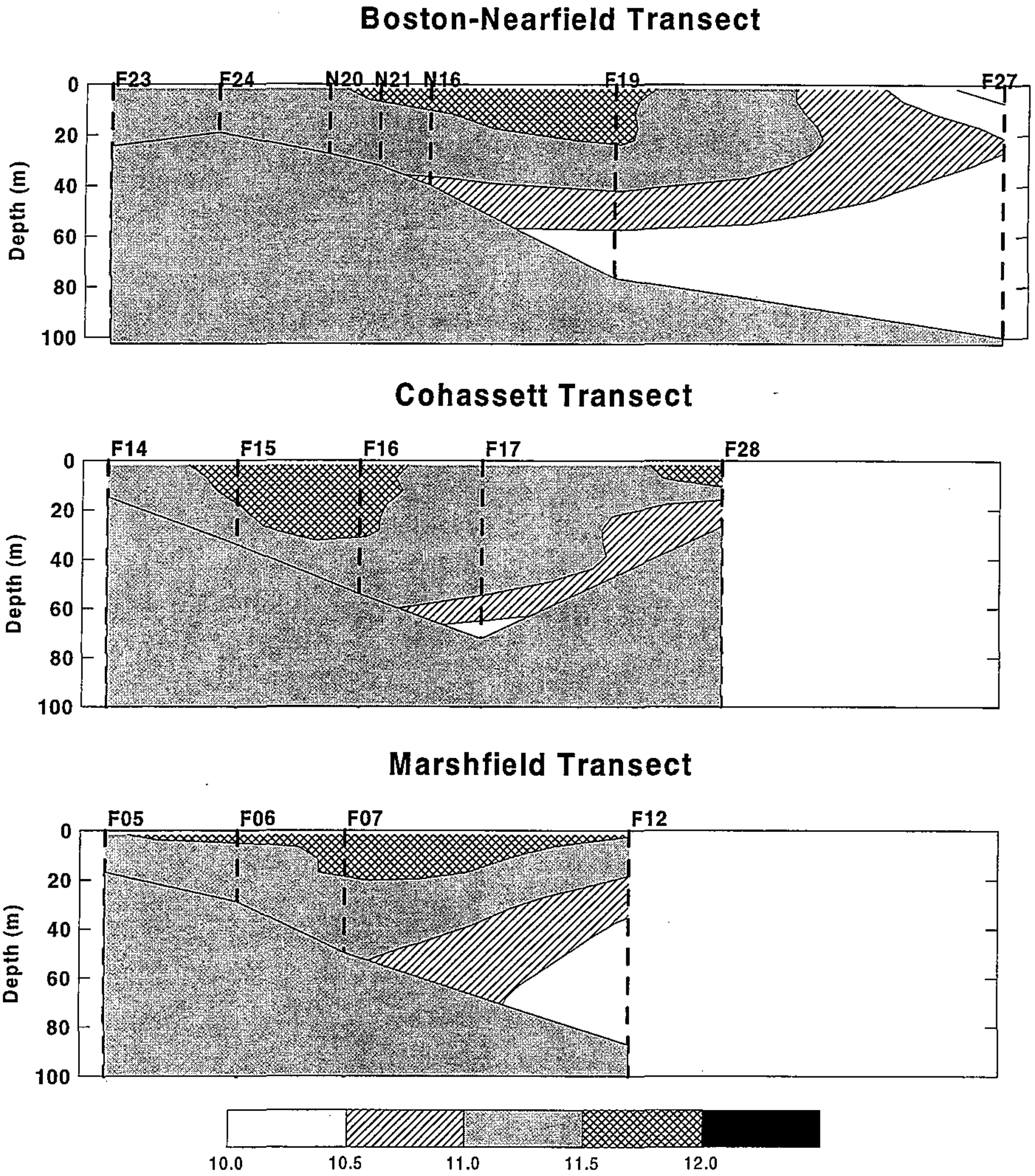
Cohassett Transect

Marshfield Transect

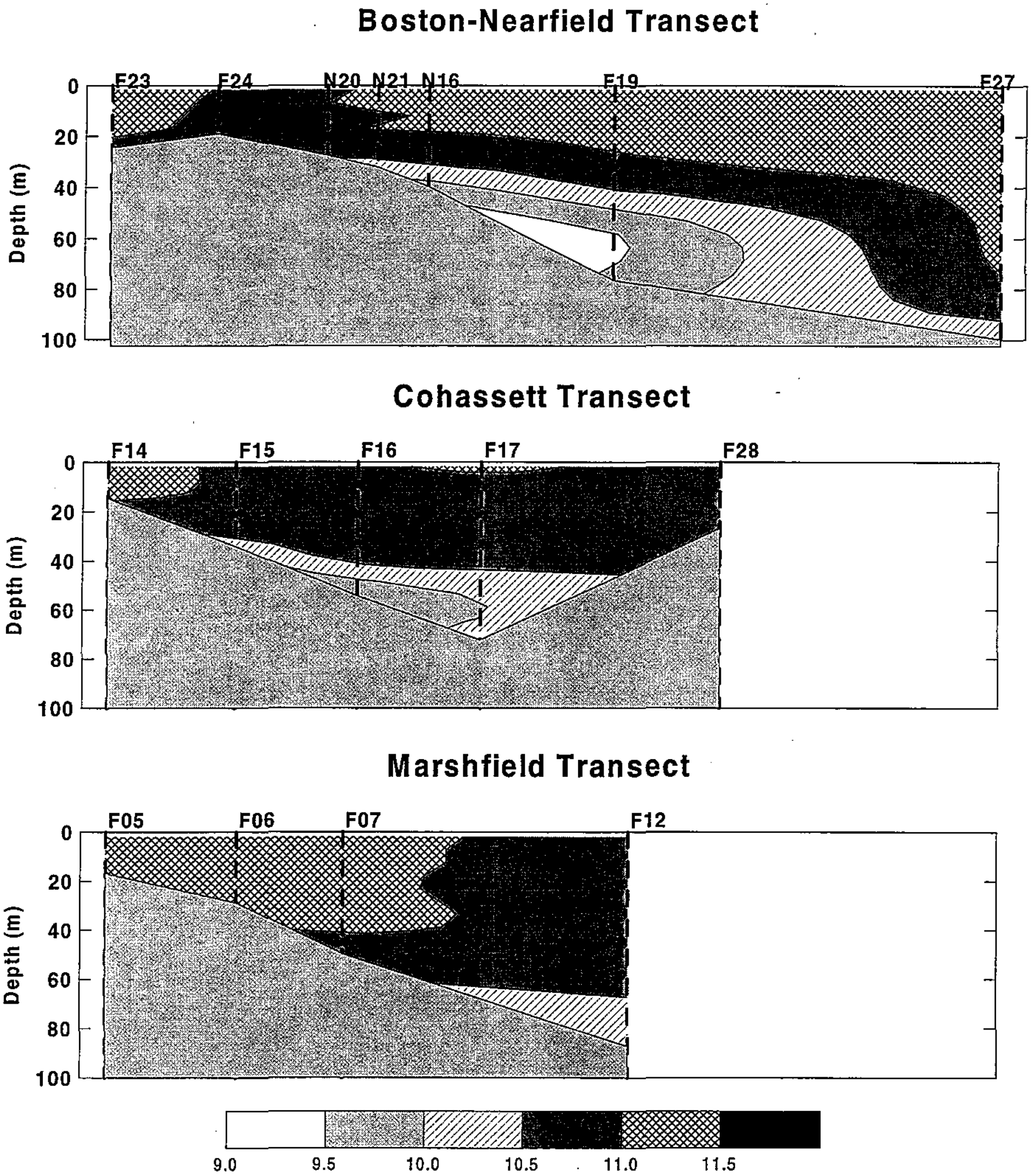
Parameter: Fluorescence
Survey: 9607



Parameter: Dissolved Oxygen (mg/L)
Survey: 9601



Parameter: Dissolved Oxygen (mg/L)
Survey: 9602

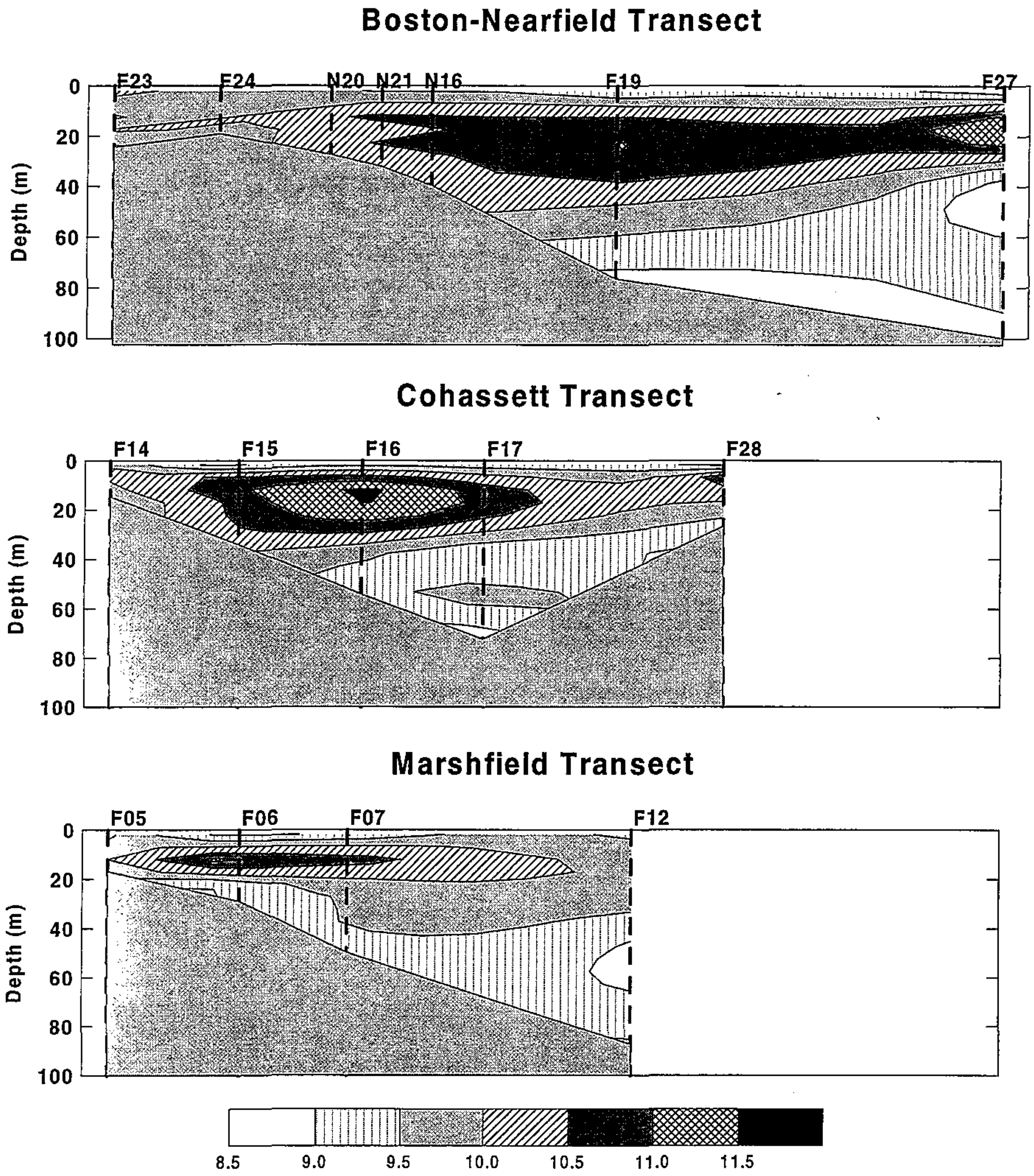


Boston-Nearfield Transect

Cohassett Transect

Marshfield Transect

Parameter: Dissolved Oxygen (mg/L)
Survey: 9604



Parameter: Dissolved Oxygen (mg/L)
Survey: 9607

APPENDIX D

Nutrient Scatter Plots

Scatter plots are included for every survey conducted during the semi-annual period. Each plot includes all stations and all depths. The plots are organized by type of plot, and then by survey. Combined nearfield/farfield surveys show the regions with different symbols, including Boundary, Cape Cod Bay, Coastal, Boston Harbor, Nearfield, and Offshore. Available plots are summarized in the text.

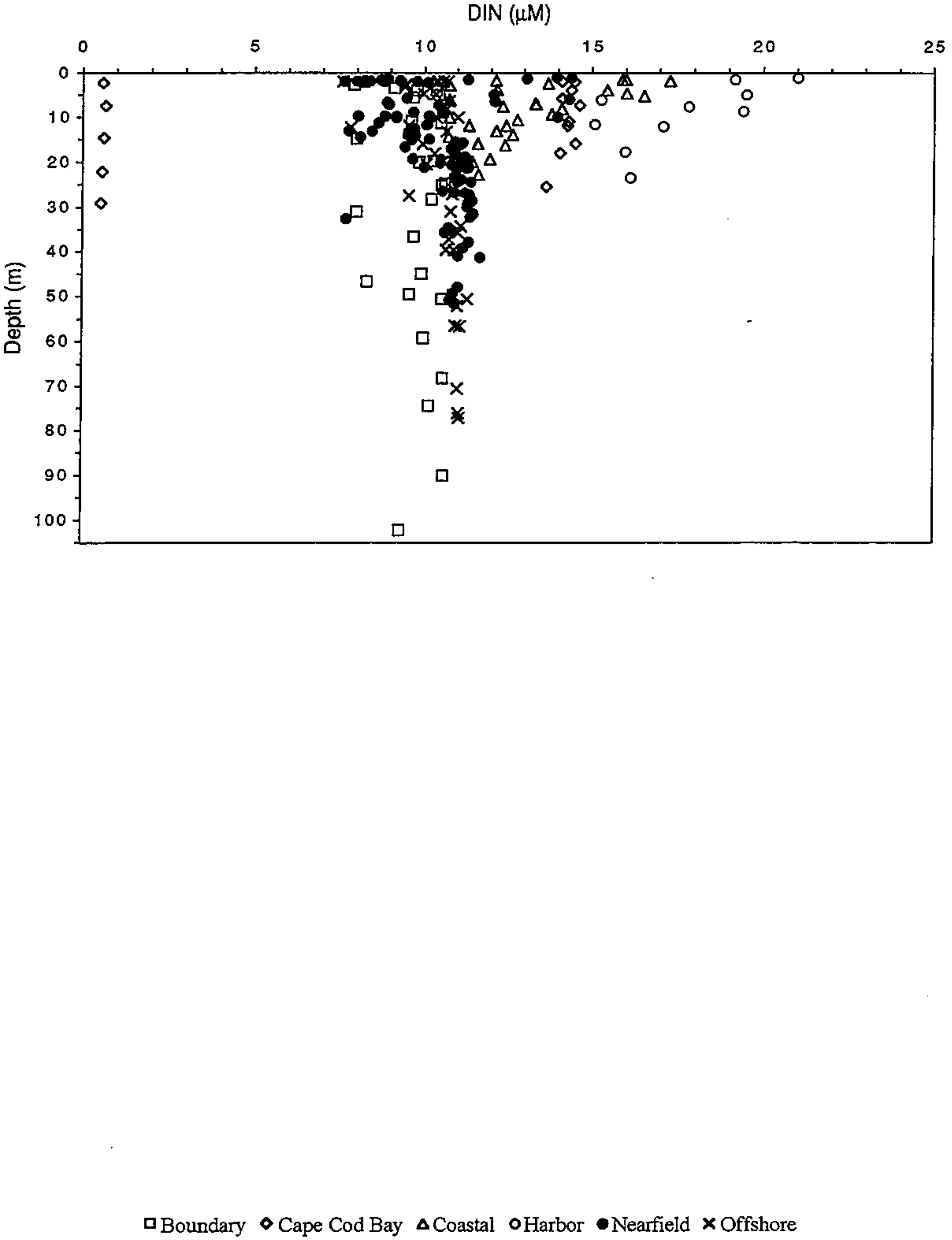


FIGURE 4-1

Depth vs. nutrient plots for farfield survey W9601, (Feb 96).

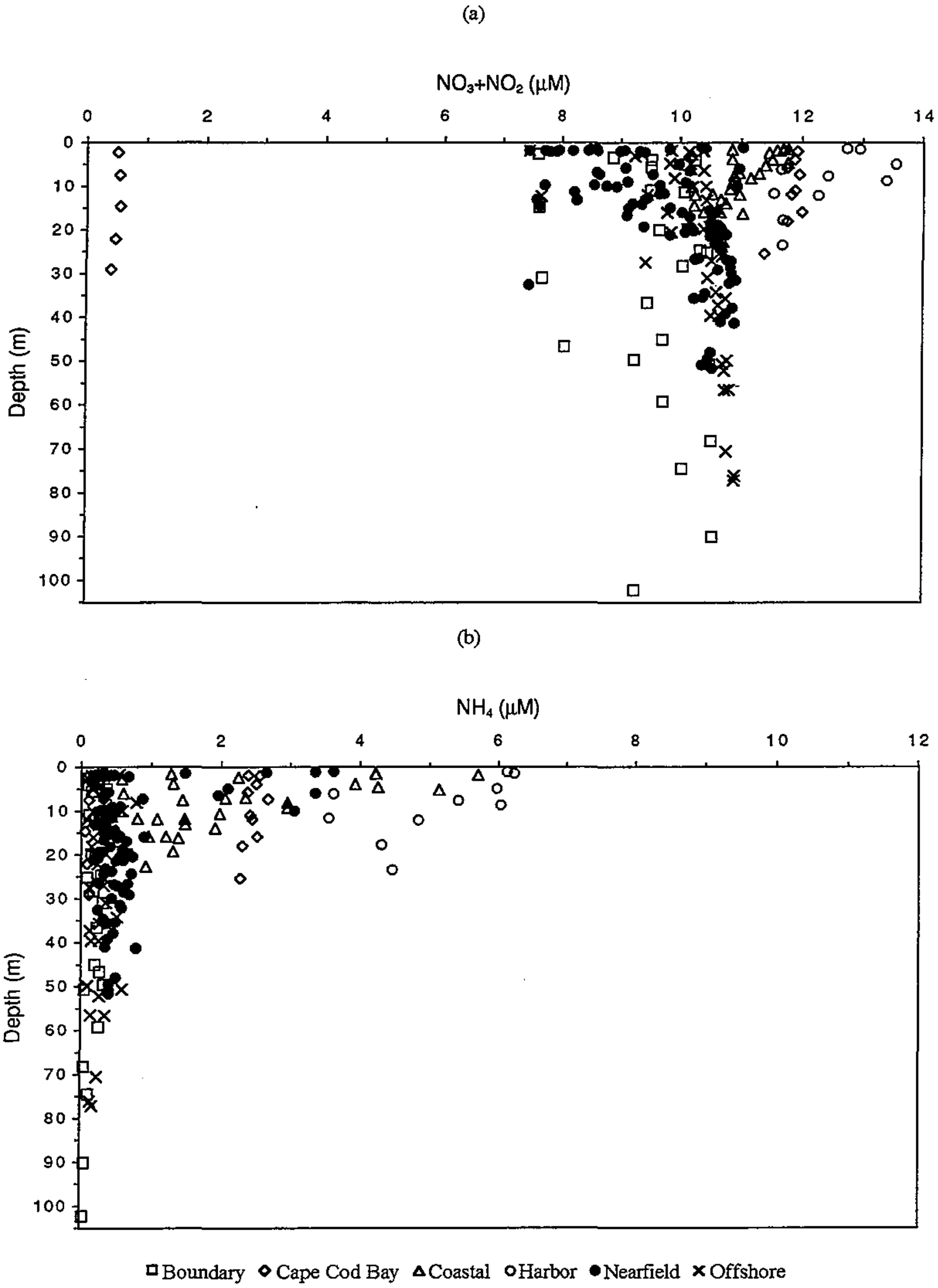


FIGURE 4-2

Depth vs. nutrient plots for farfield survey W9601, (Feb 96).

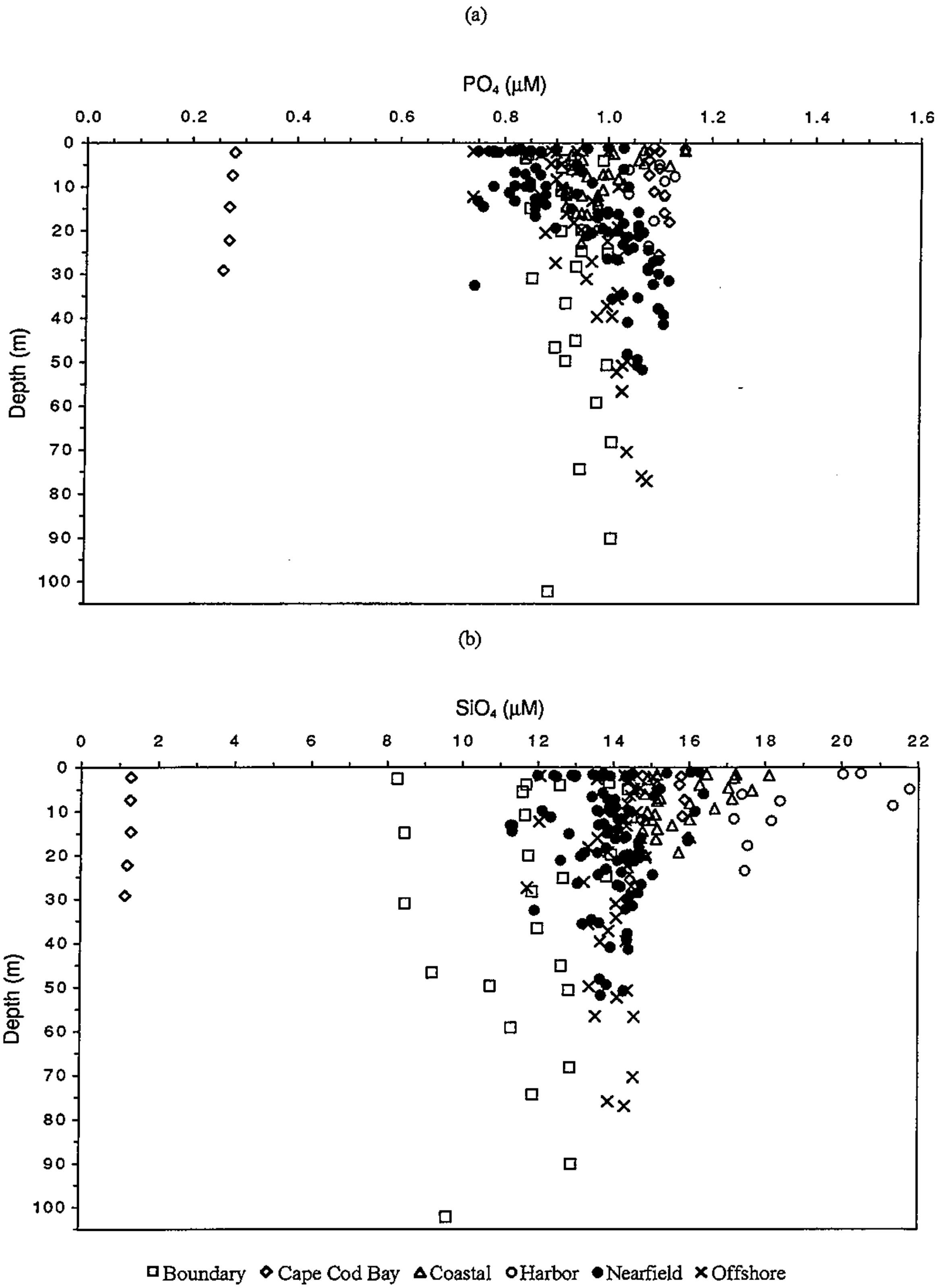


FIGURE 4-3
Depth vs. nutrient plots for farfield survey W9601, (Feb 96).

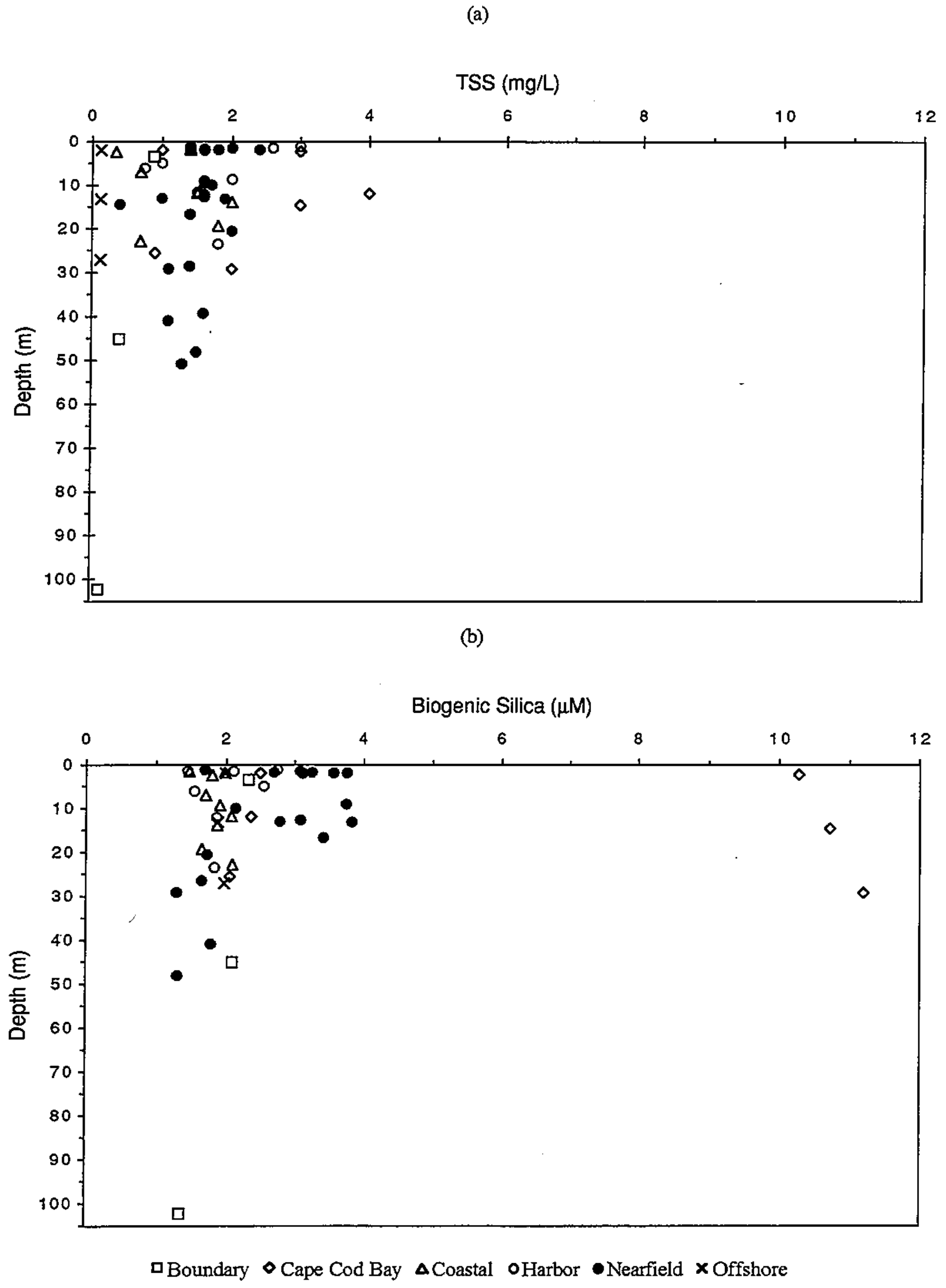


FIGURE 4-4
Depth vs. nutrient plots for farfield survey W9601, (Feb 96).

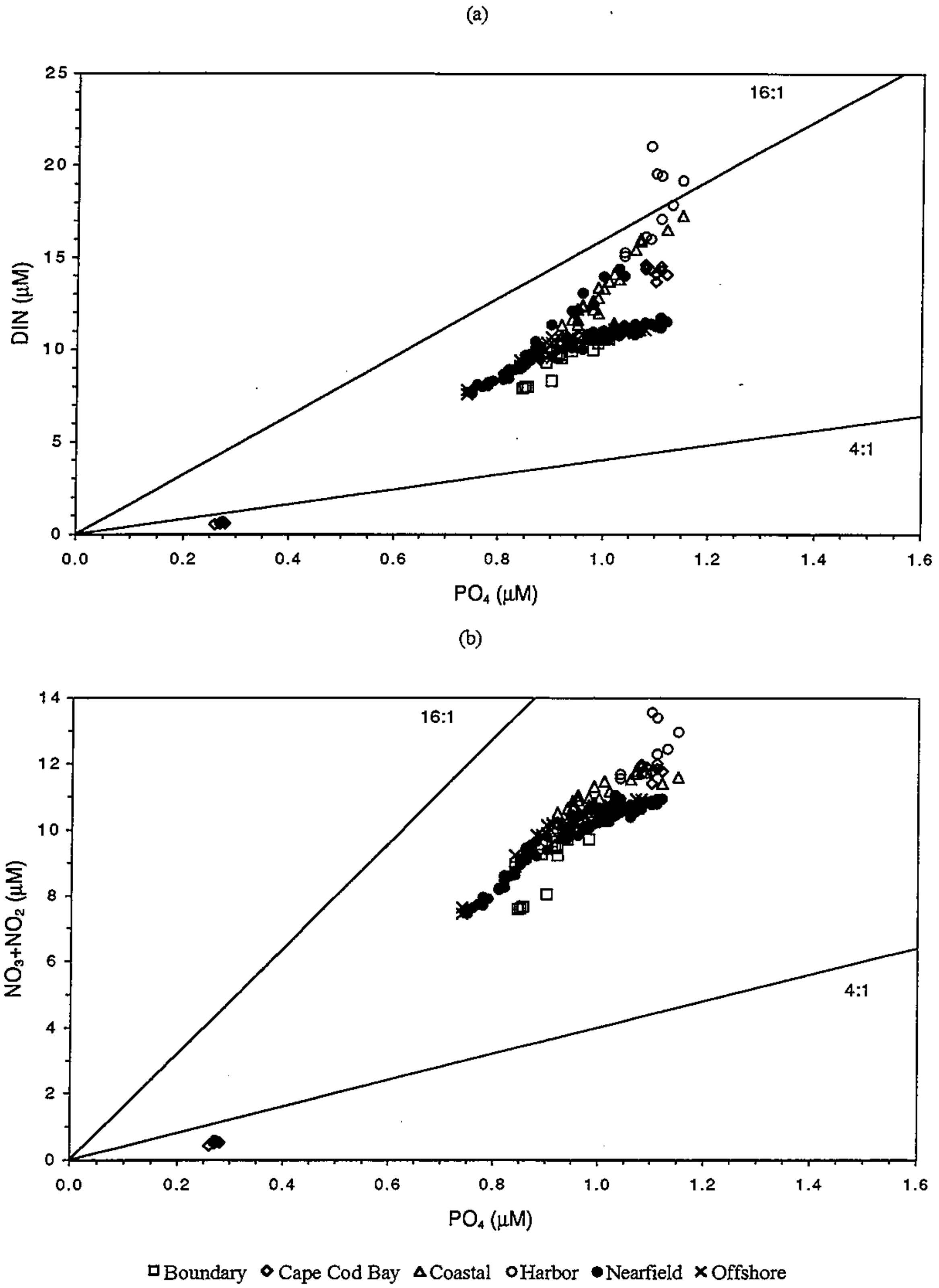


FIGURE 4-5

Nutrient vs. nutrient plots for farfield survey W9601, (Feb 96).

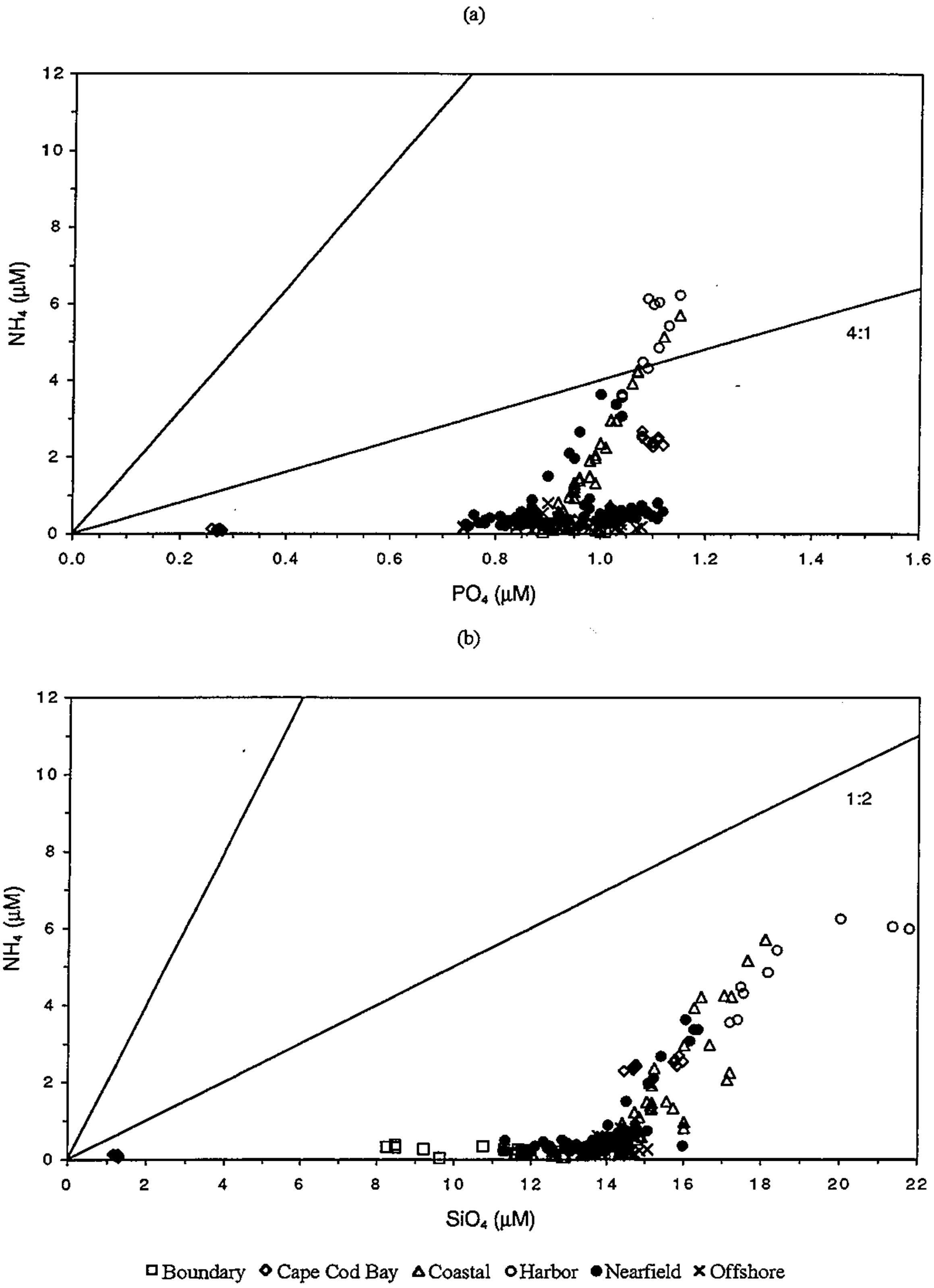


FIGURE 4-6

Nutrient vs. nutrient plots for farfield survey W9601, (Feb 96).

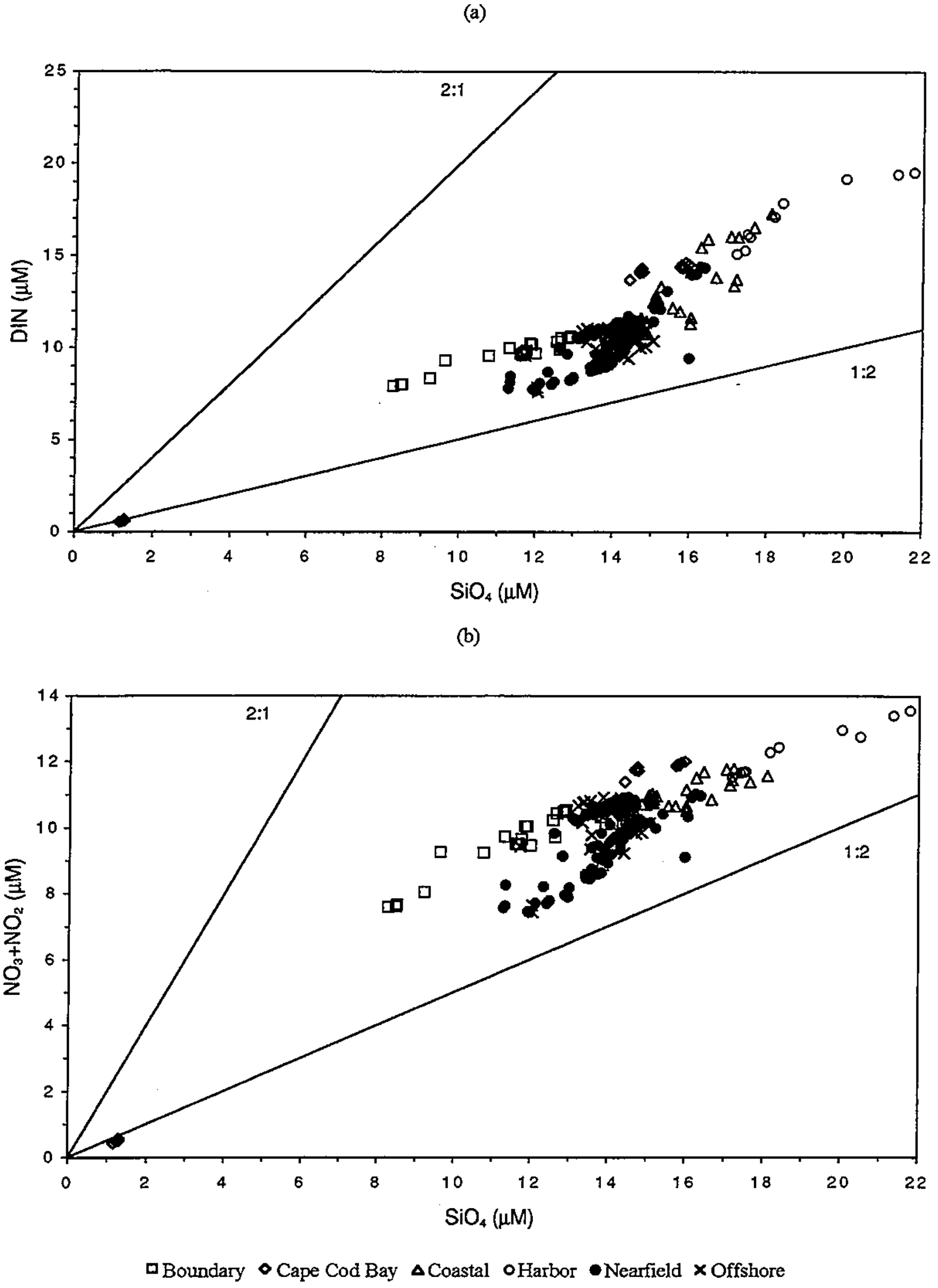


FIGURE 4-7

Nutrient vs. nutrient plots for farfield survey W9601, (Feb 96).

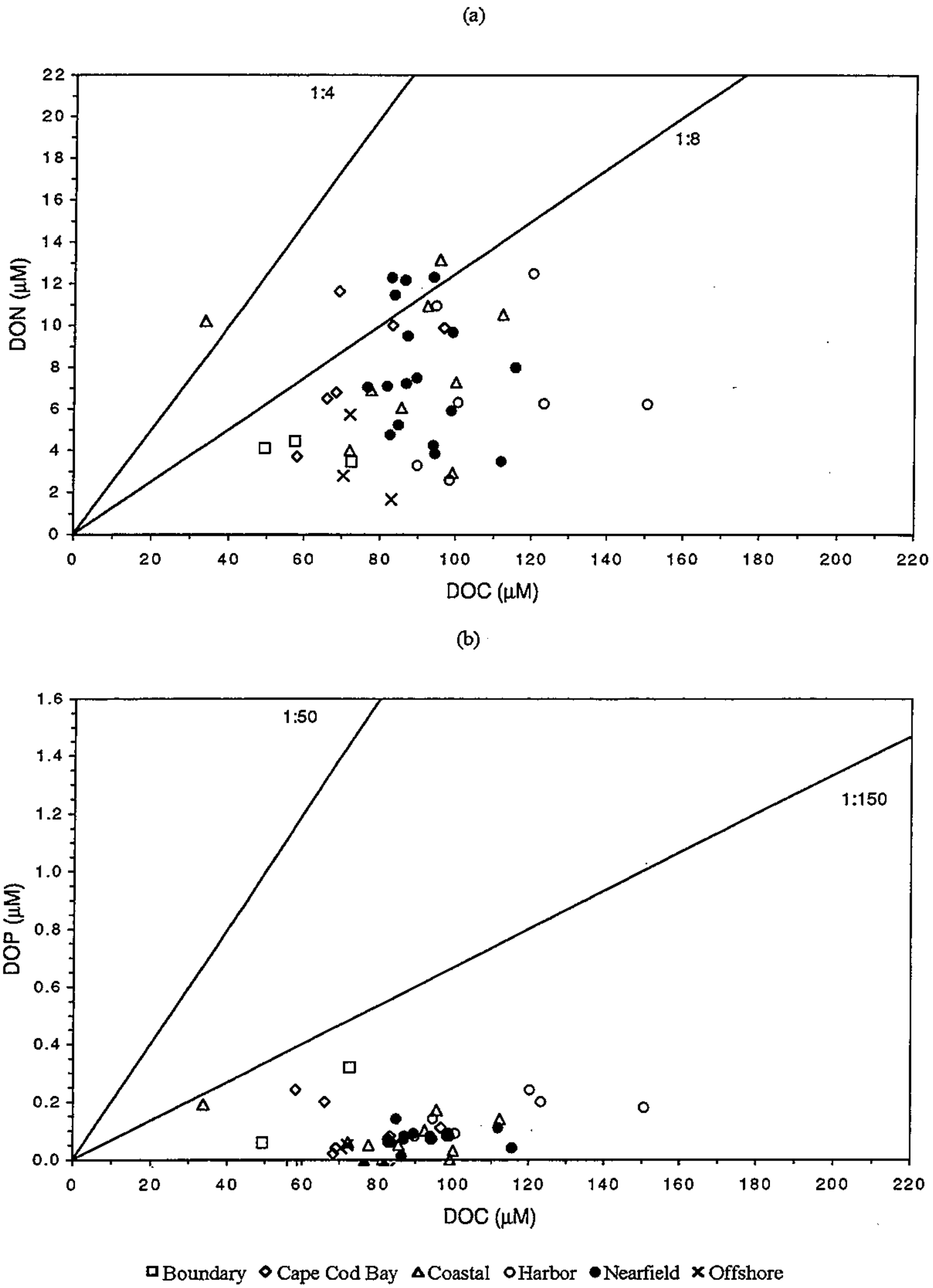


FIGURE 4-8
Nutrient vs. nutrient plots for farfield survey W9601, (Feb 96).

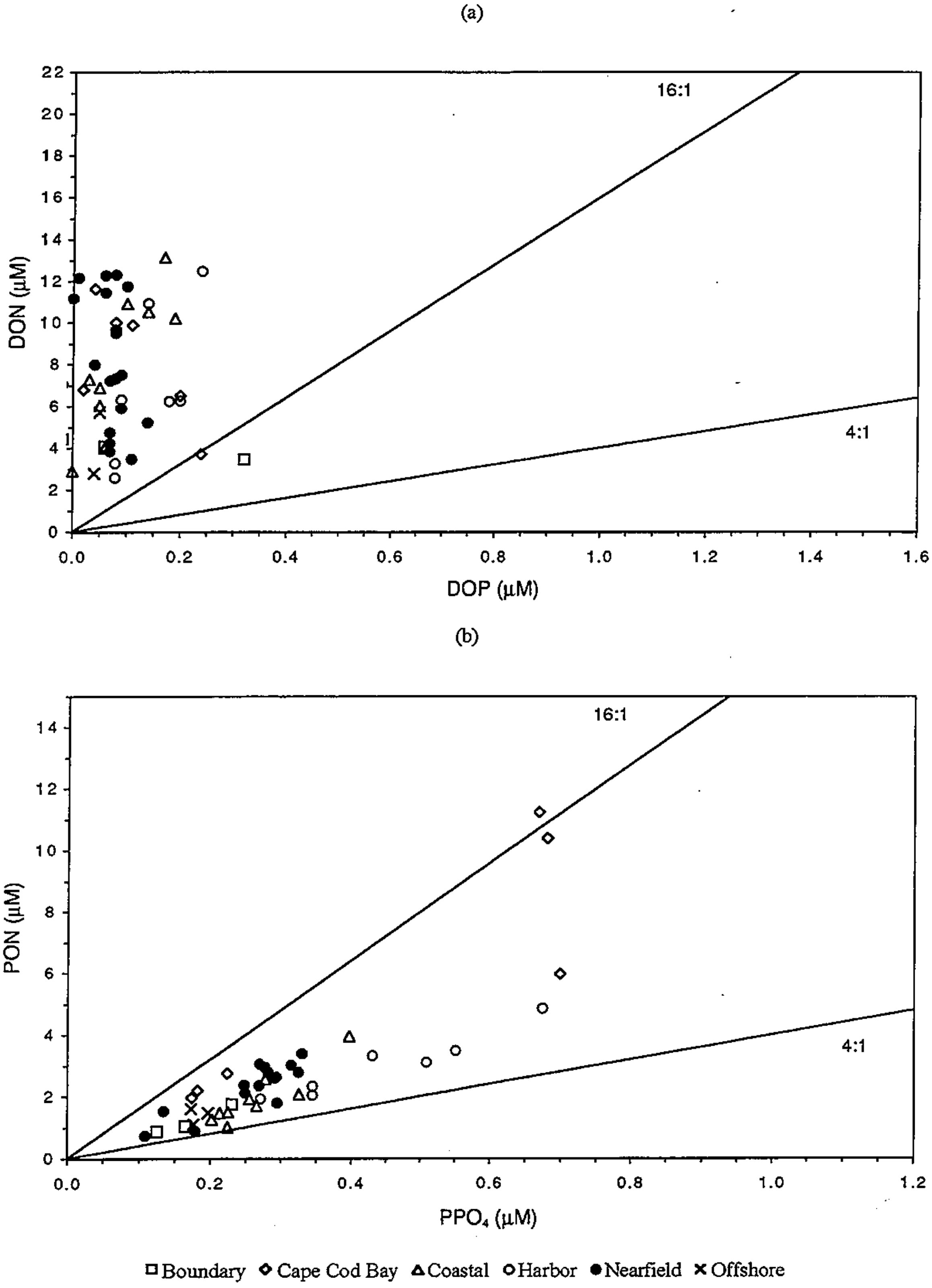


FIGURE 4-9

Nutrient vs. nutrient plots for farfield survey W9601, (Feb 96).

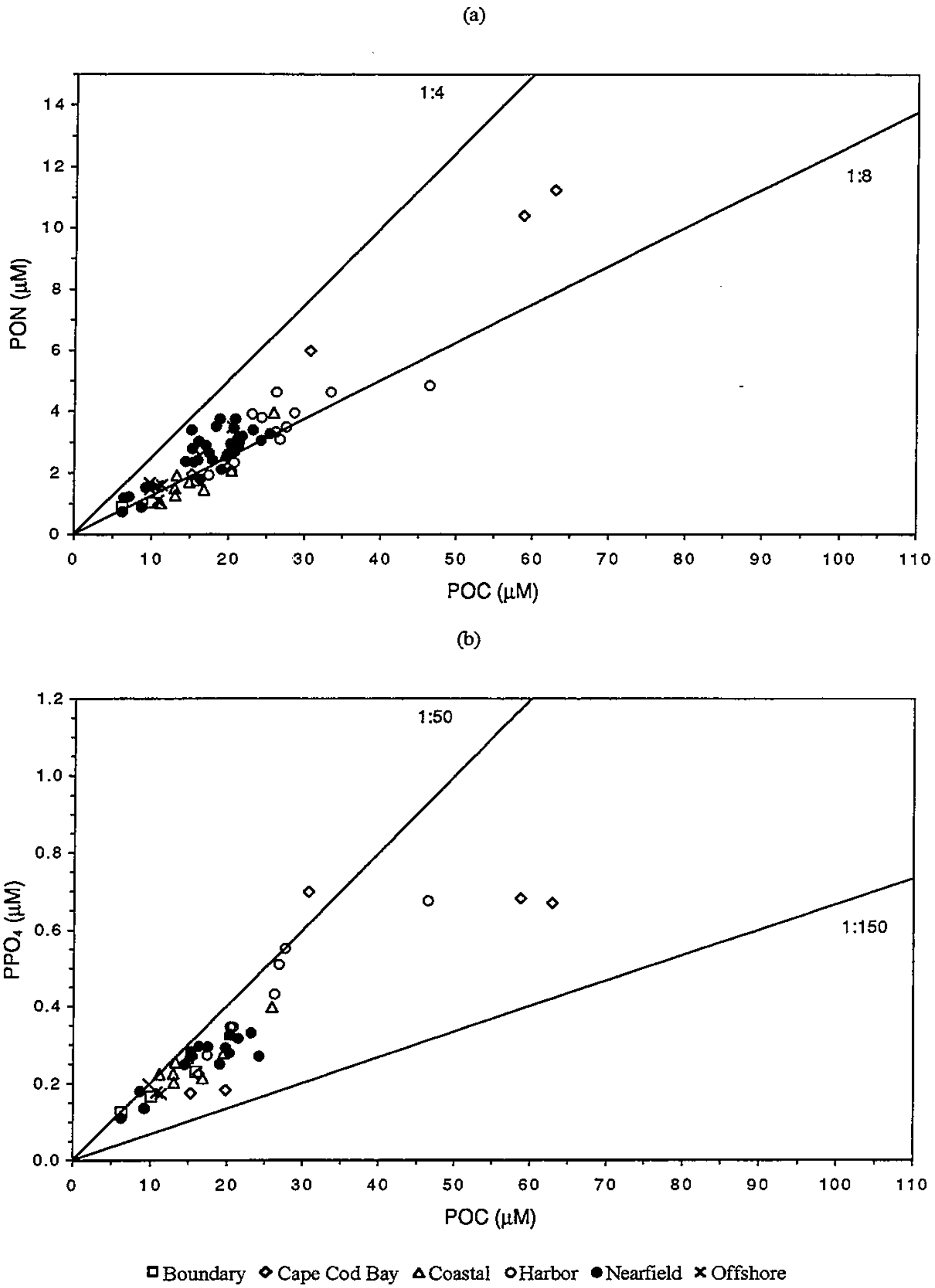


FIGURE 4-10

Nutrient vs. nutrient plots for farfield survey W9601, (Feb 96).

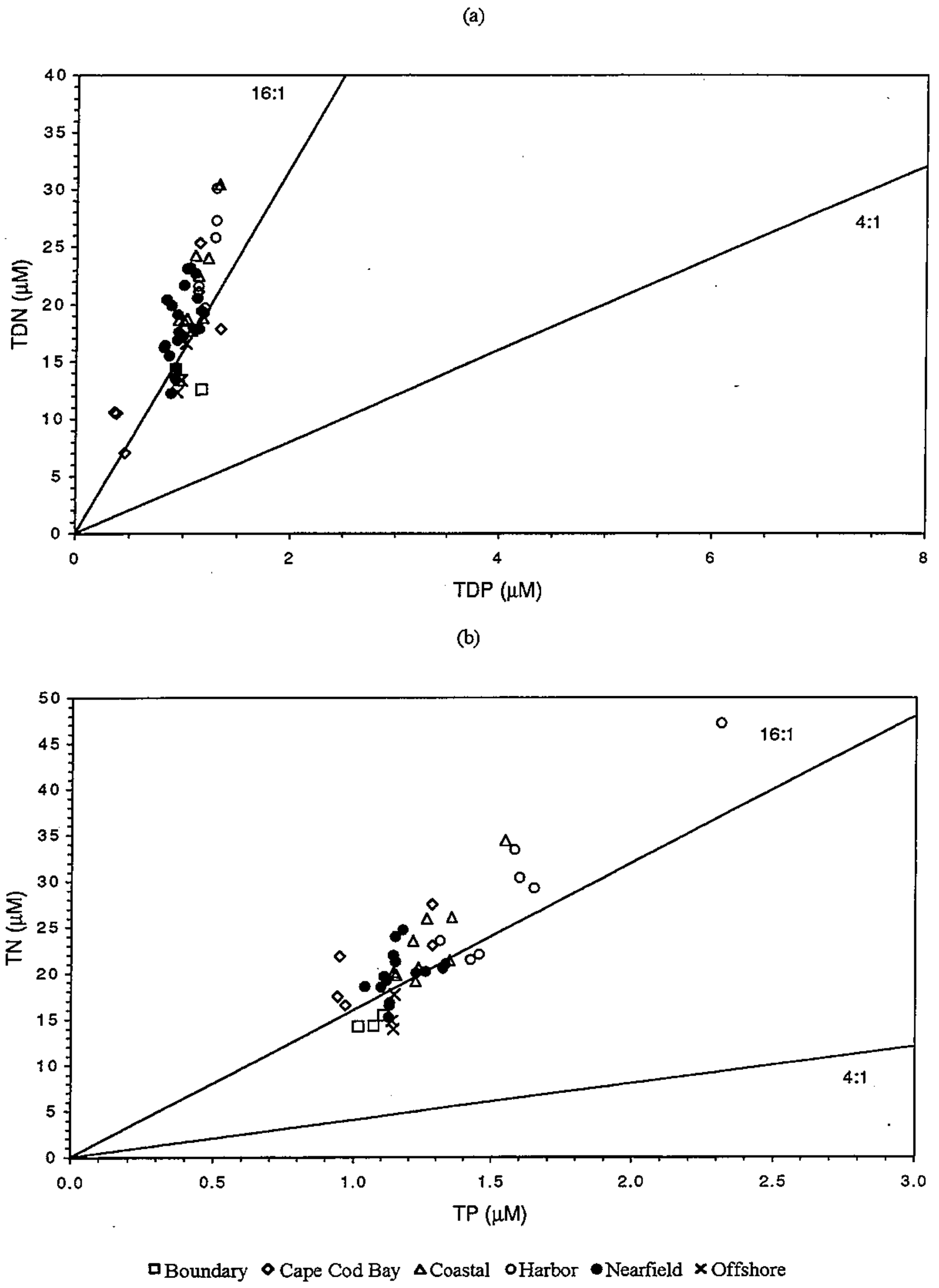


FIGURE 4-11
Nutrient vs. nutrient plots for farfield survey W9601, (Feb 96).

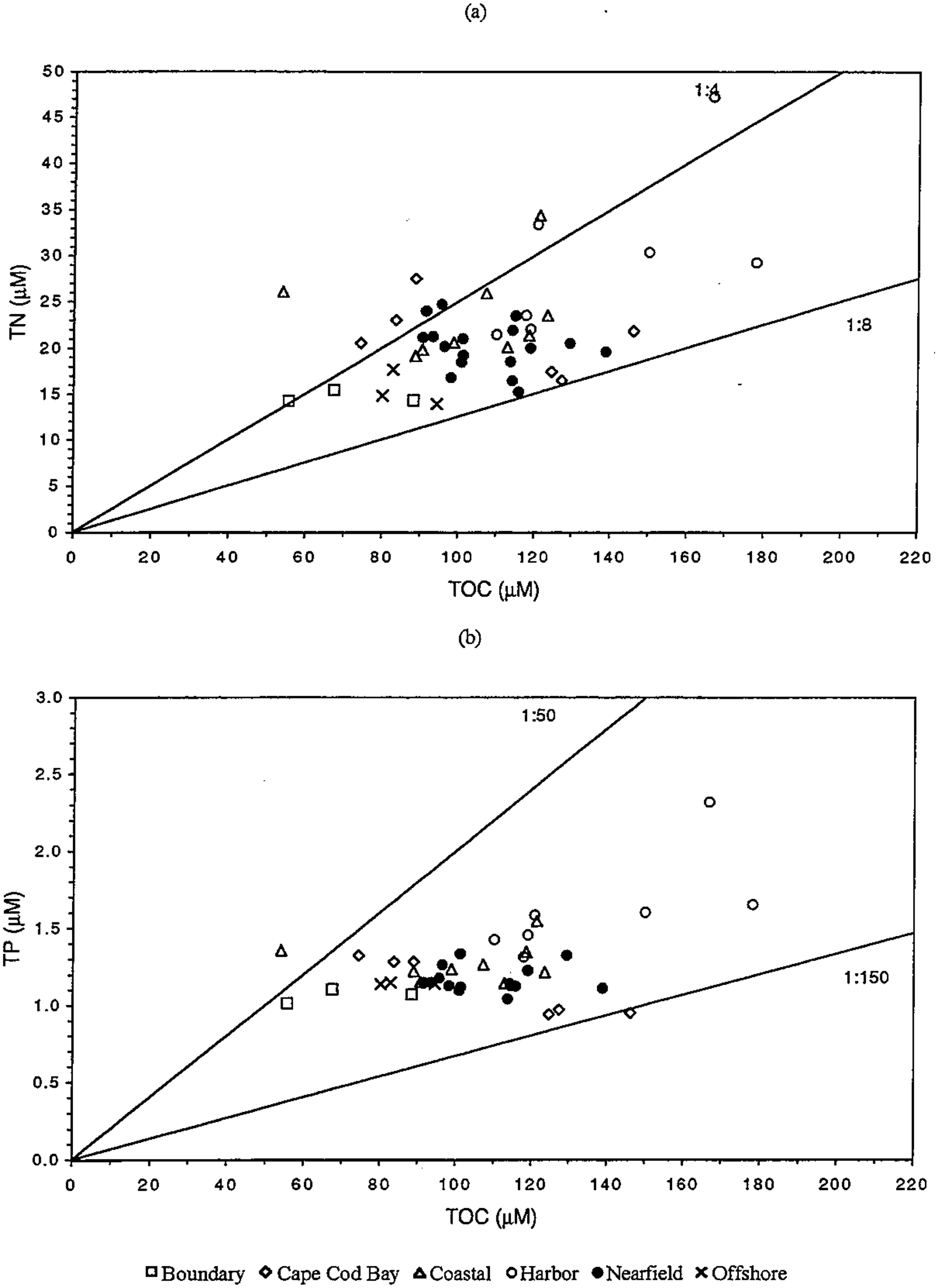


FIGURE 4-12
Nutrient vs. nutrient plots for farfield survey W9601, (Feb 96).

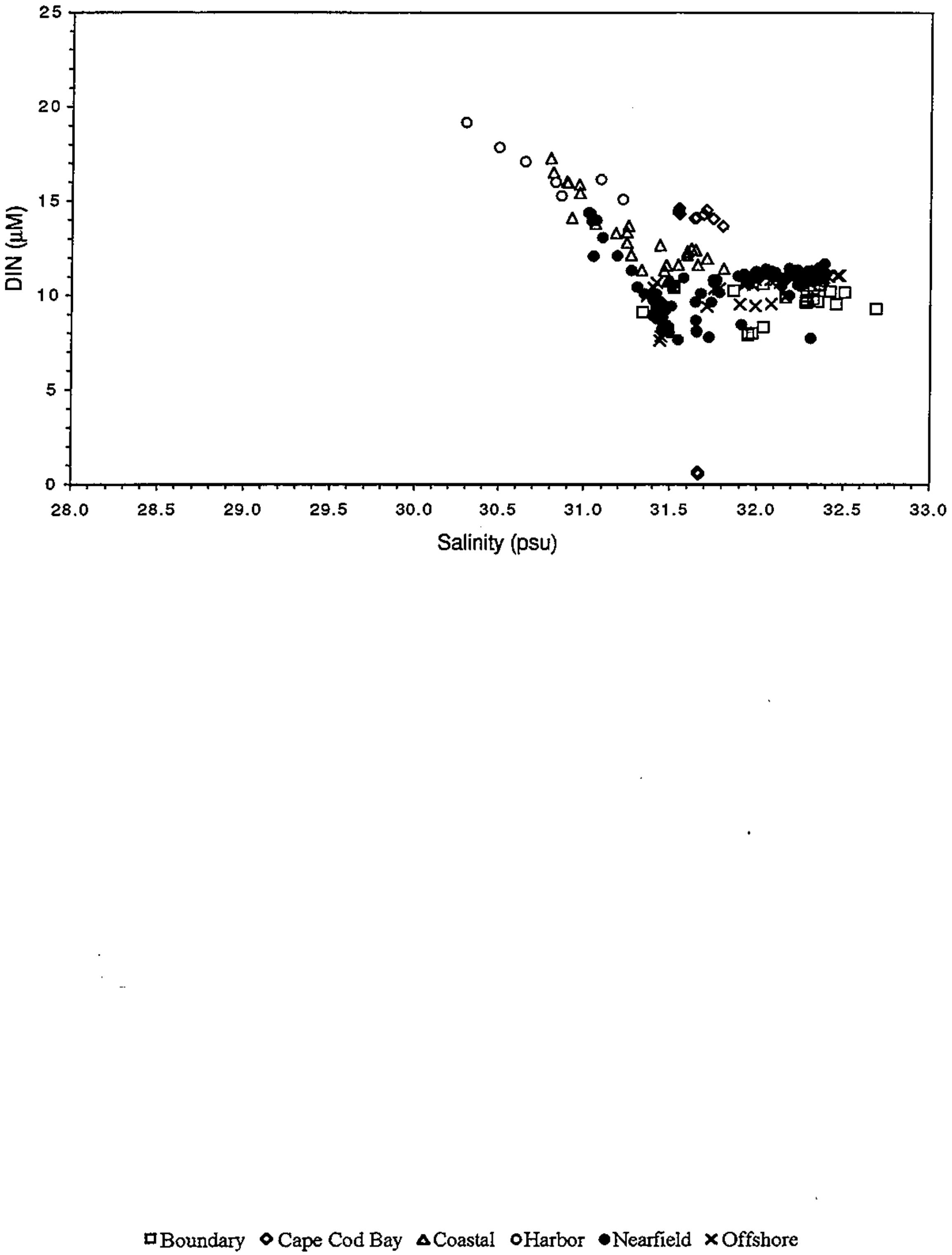


FIGURE 4-13

Nutrient vs. salinity plots for farfield survey W9601, (Feb 96).

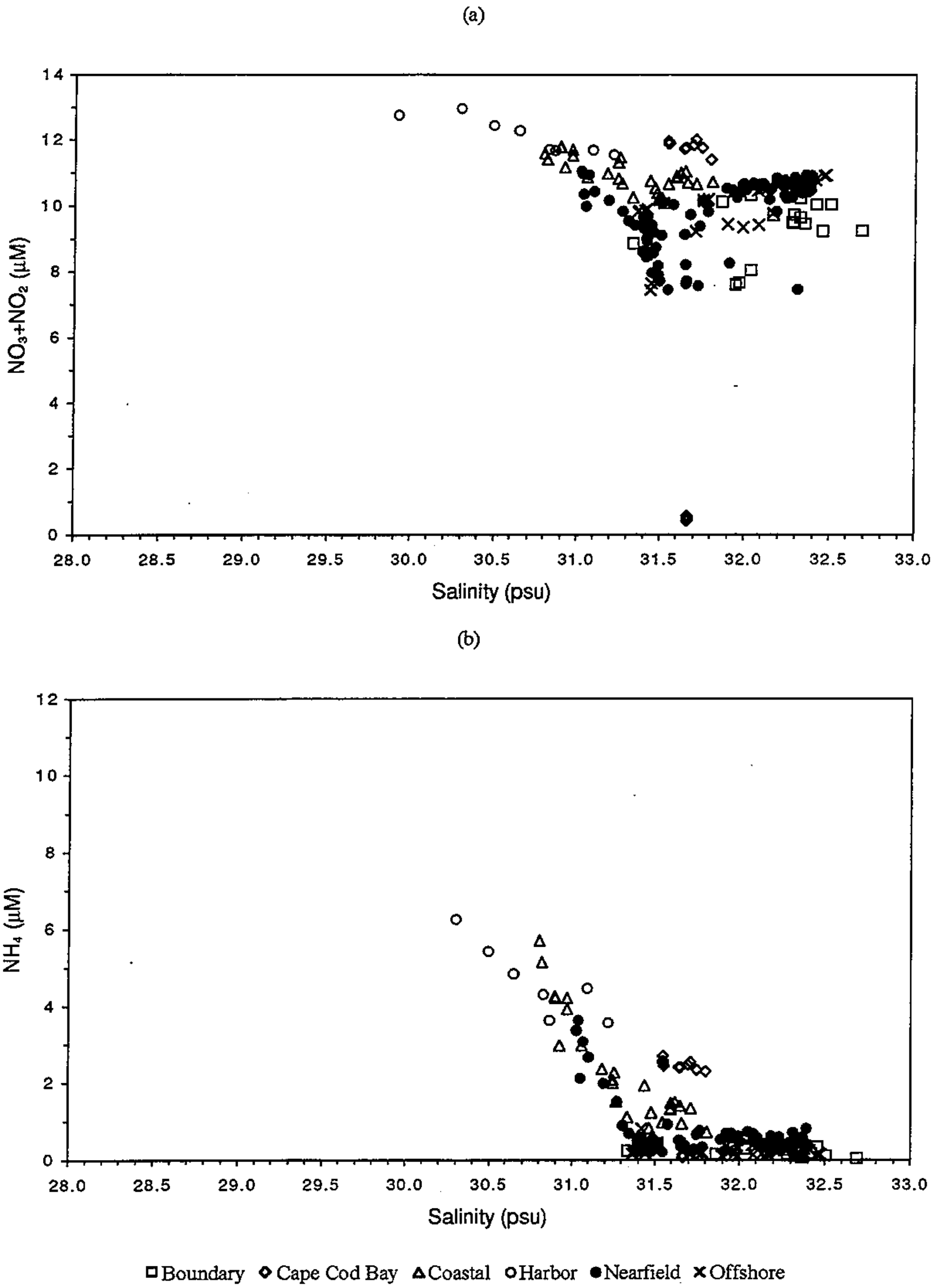


FIGURE 4-14

Nutrient vs. salinity plots for farfield survey W9601, (Feb 96).

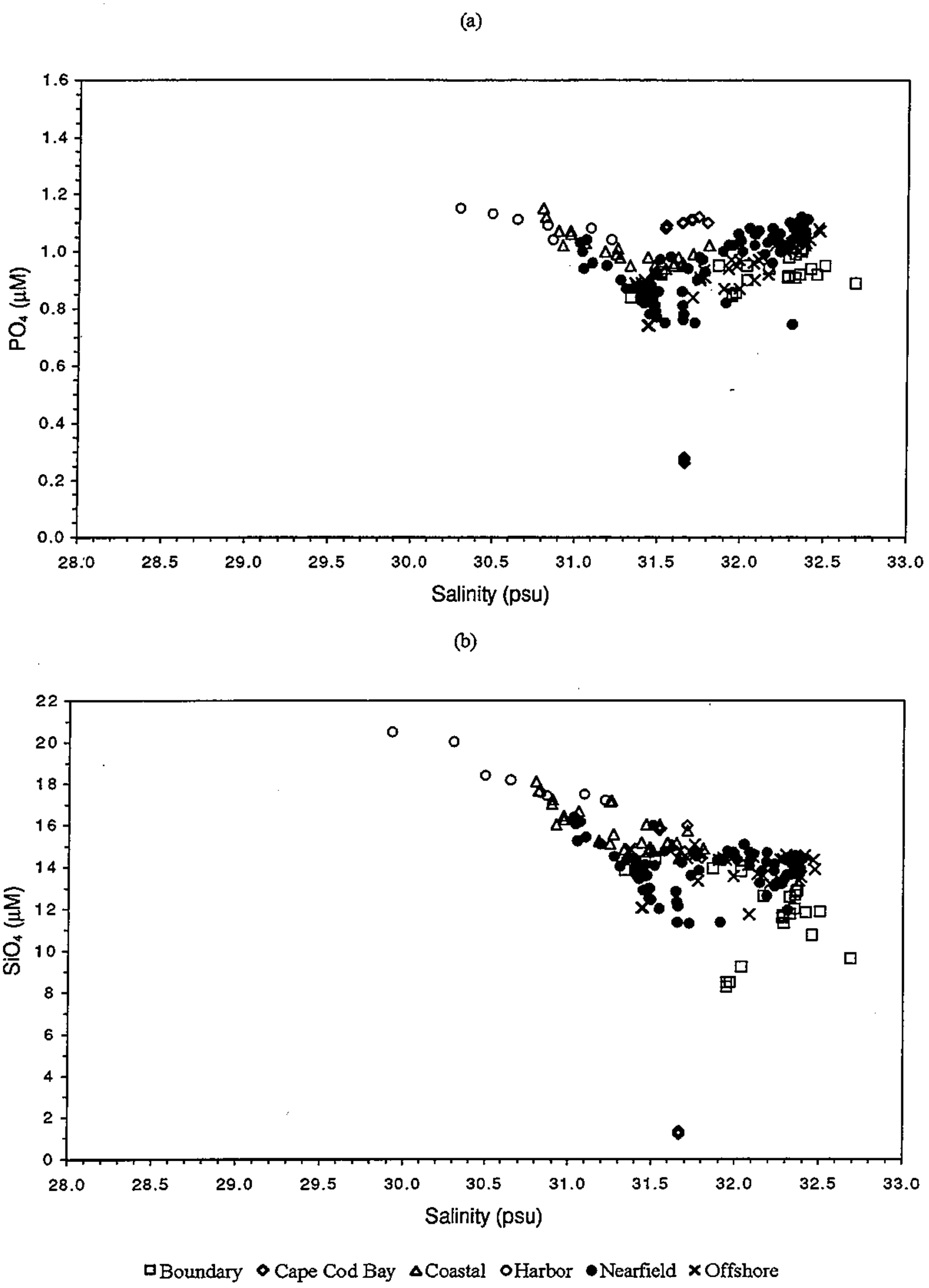


FIGURE 4-15

Nutrient vs. salinity plots for farfield survey W9601, (Feb 96).

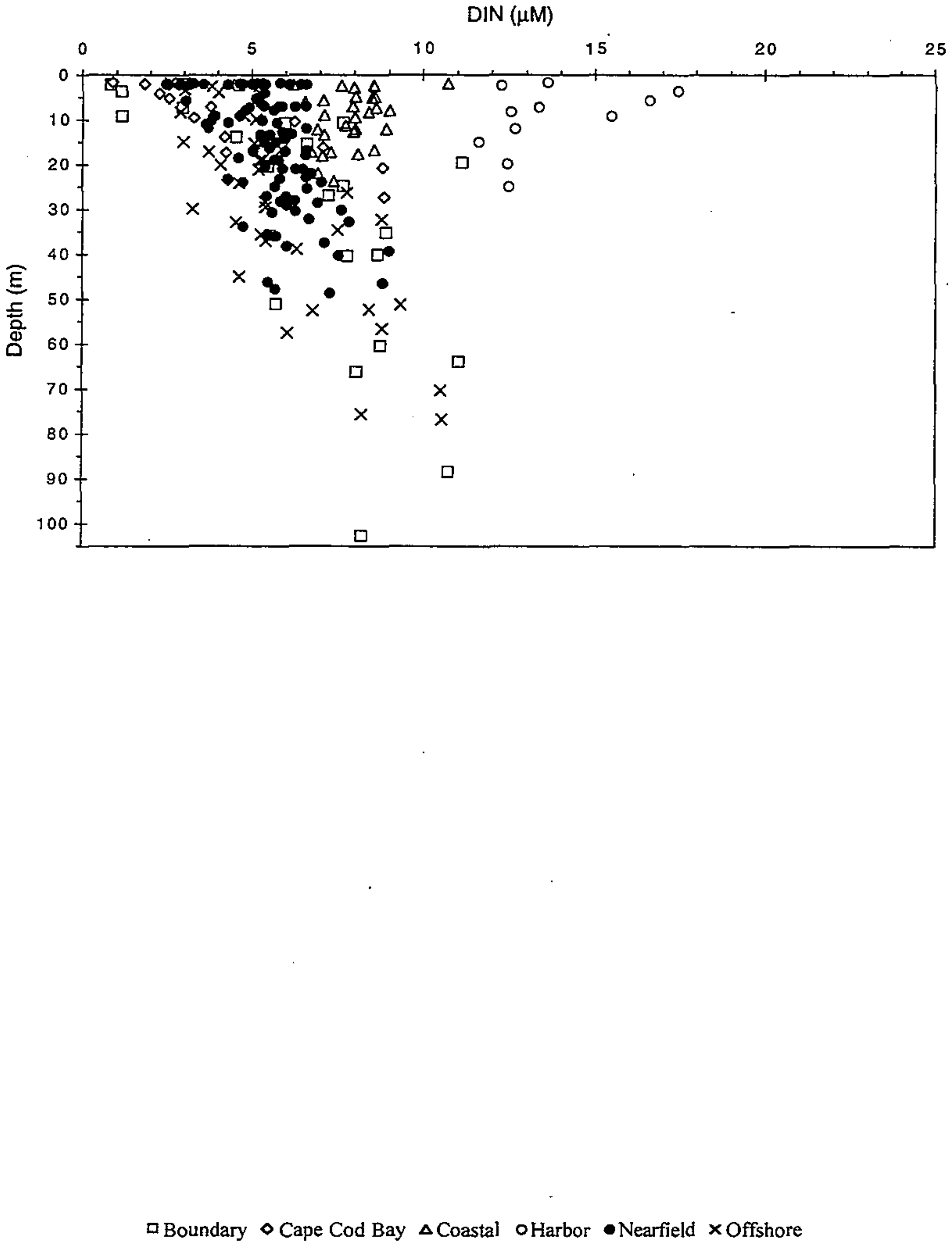


FIGURE 4-16
Depth vs. nutrient plots for farfield survey W9602, (Feb 96).

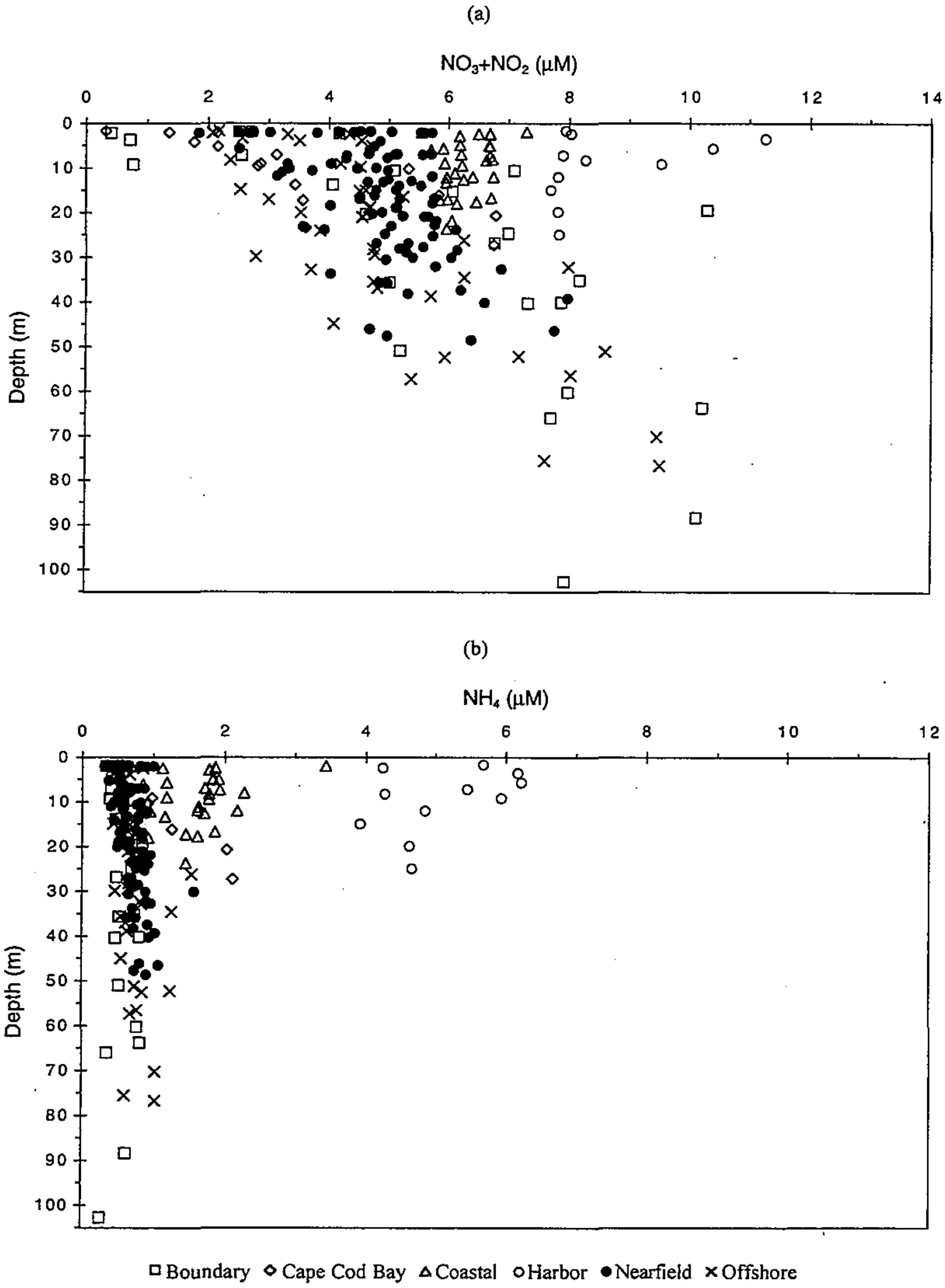


FIGURE 4-17
Depth vs. nutrient plots for farfield survey W9602, (Feb 96).

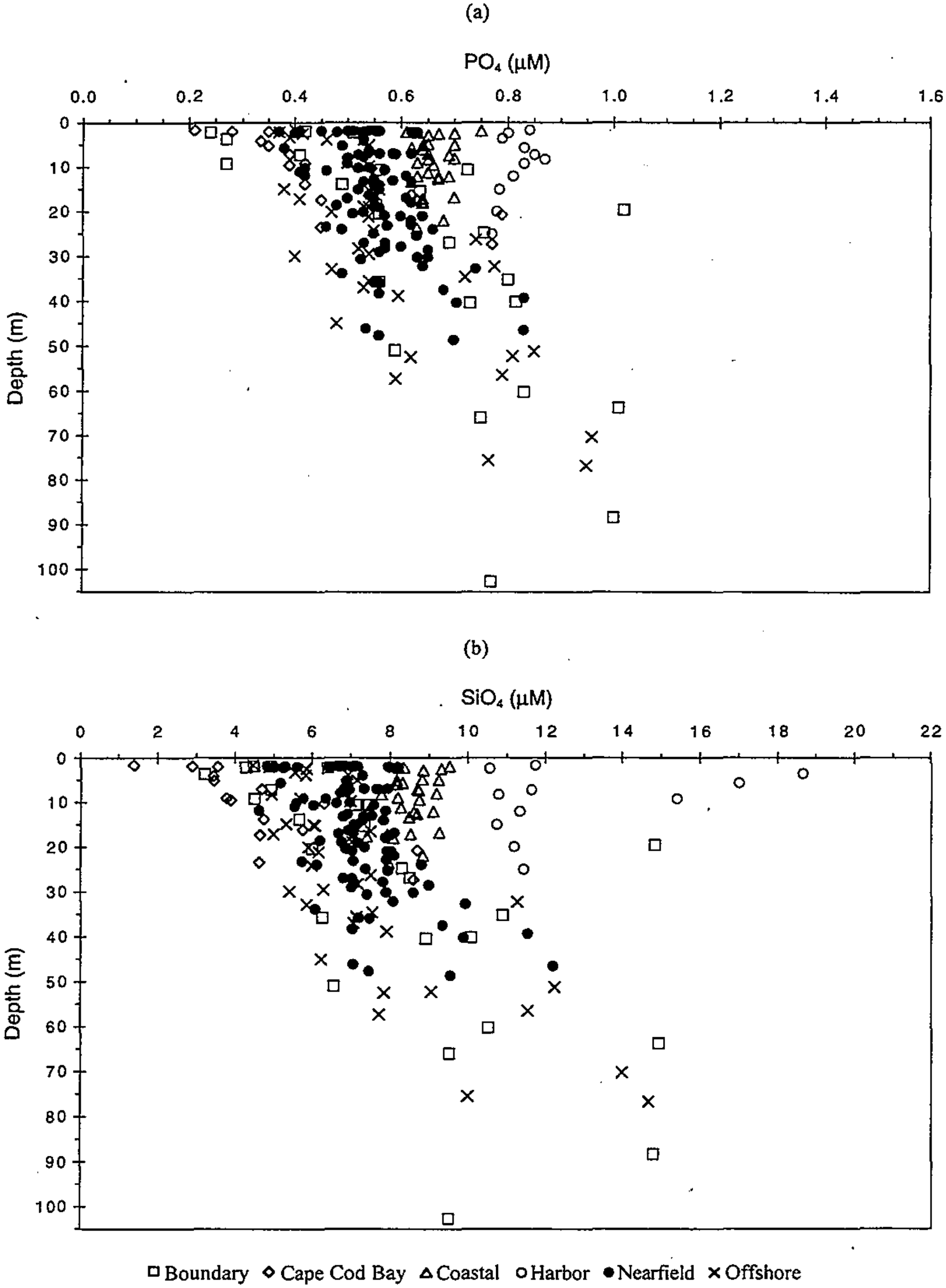


FIGURE 4-18
Depth vs. nutrient plots for farfield survey W9602, (Feb 96).

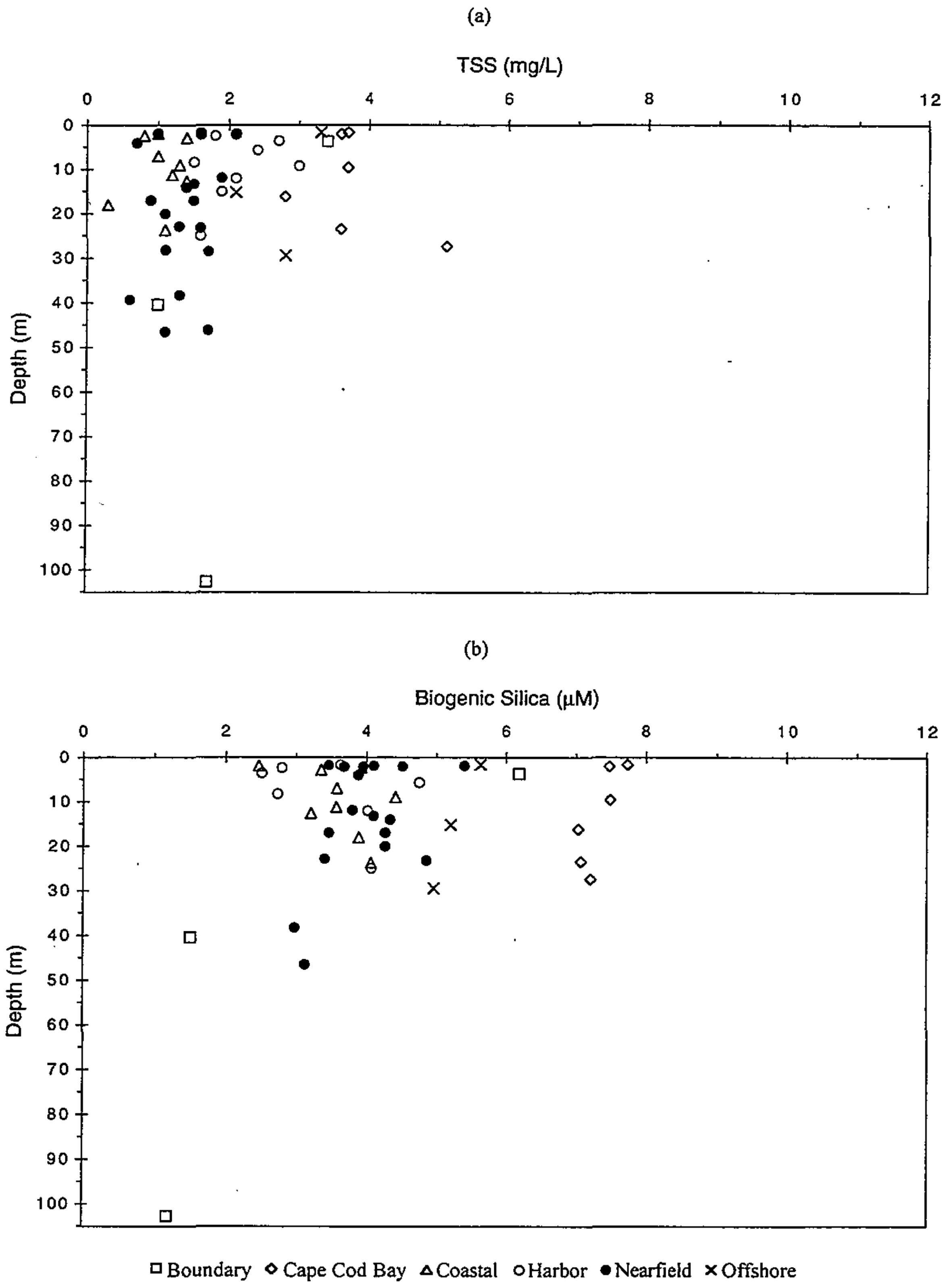


FIGURE 4-19
Depth vs. nutrient plots for farfield survey W9602, (Feb 96).

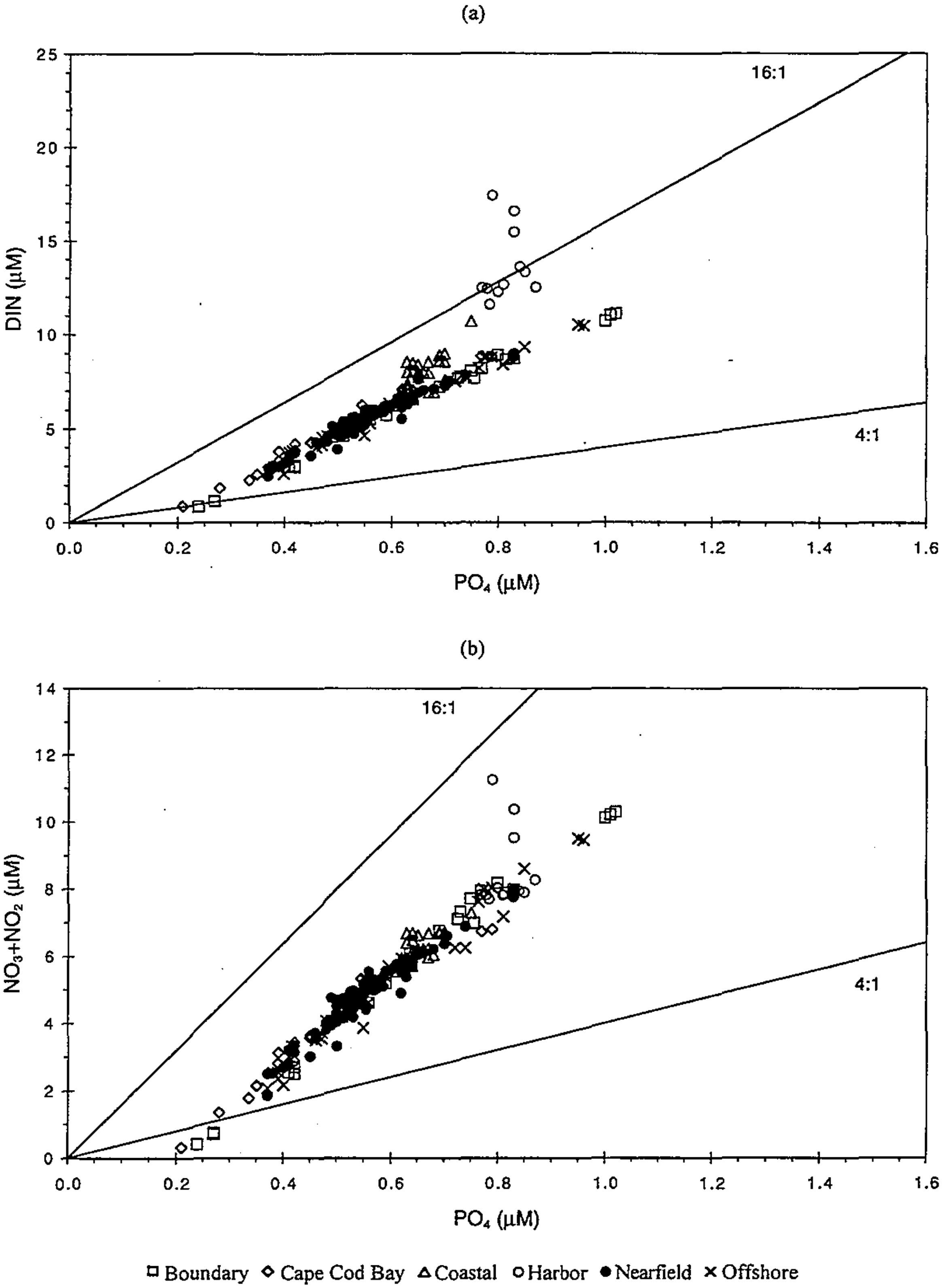


FIGURE 4-20
Nutrient vs. nutrient plots for farfield survey W9602, (Feb 96).

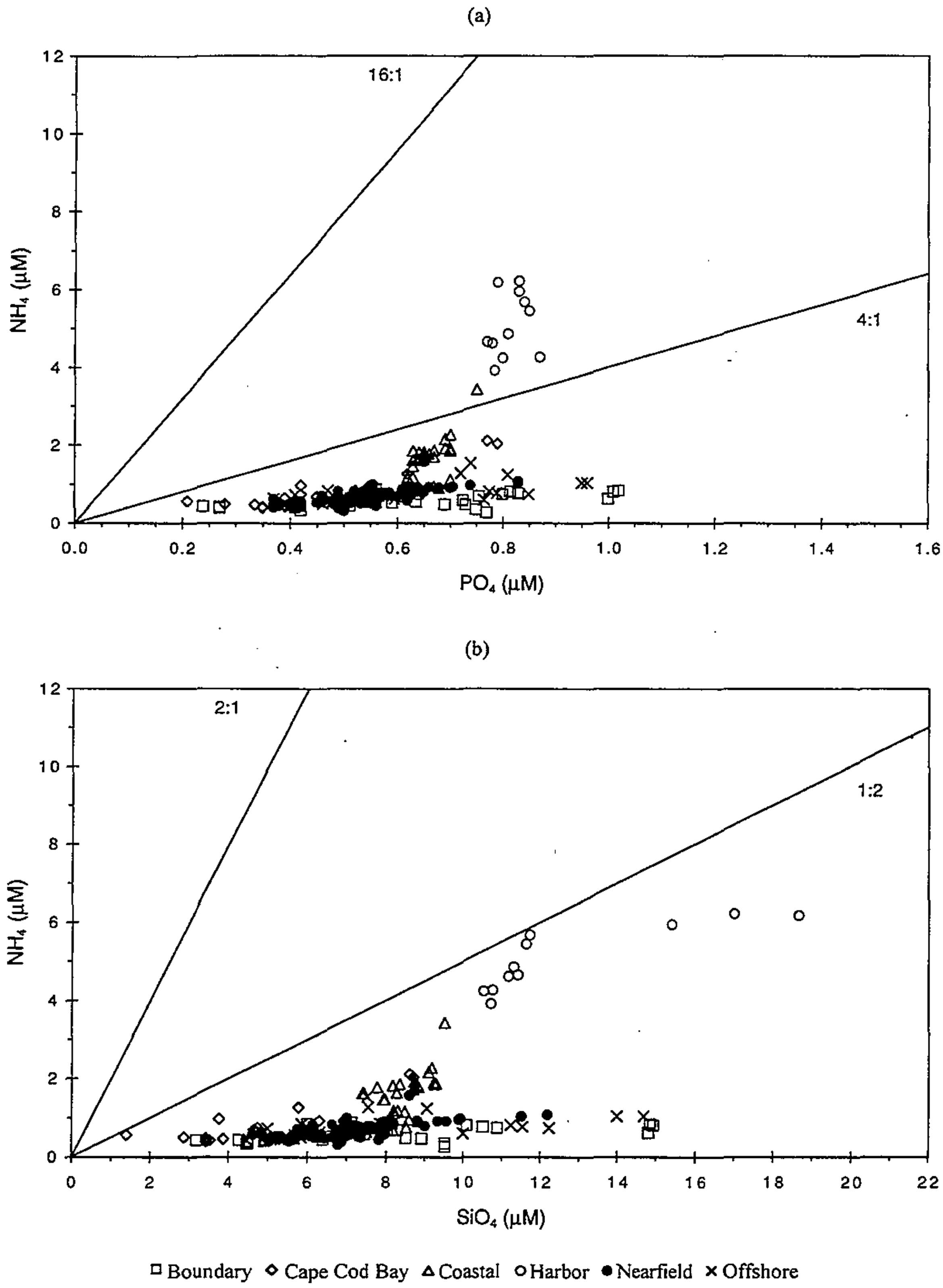


FIGURE 4-21
Nutrient vs. nutrient plots for farfield survey W9602, (Feb 96).

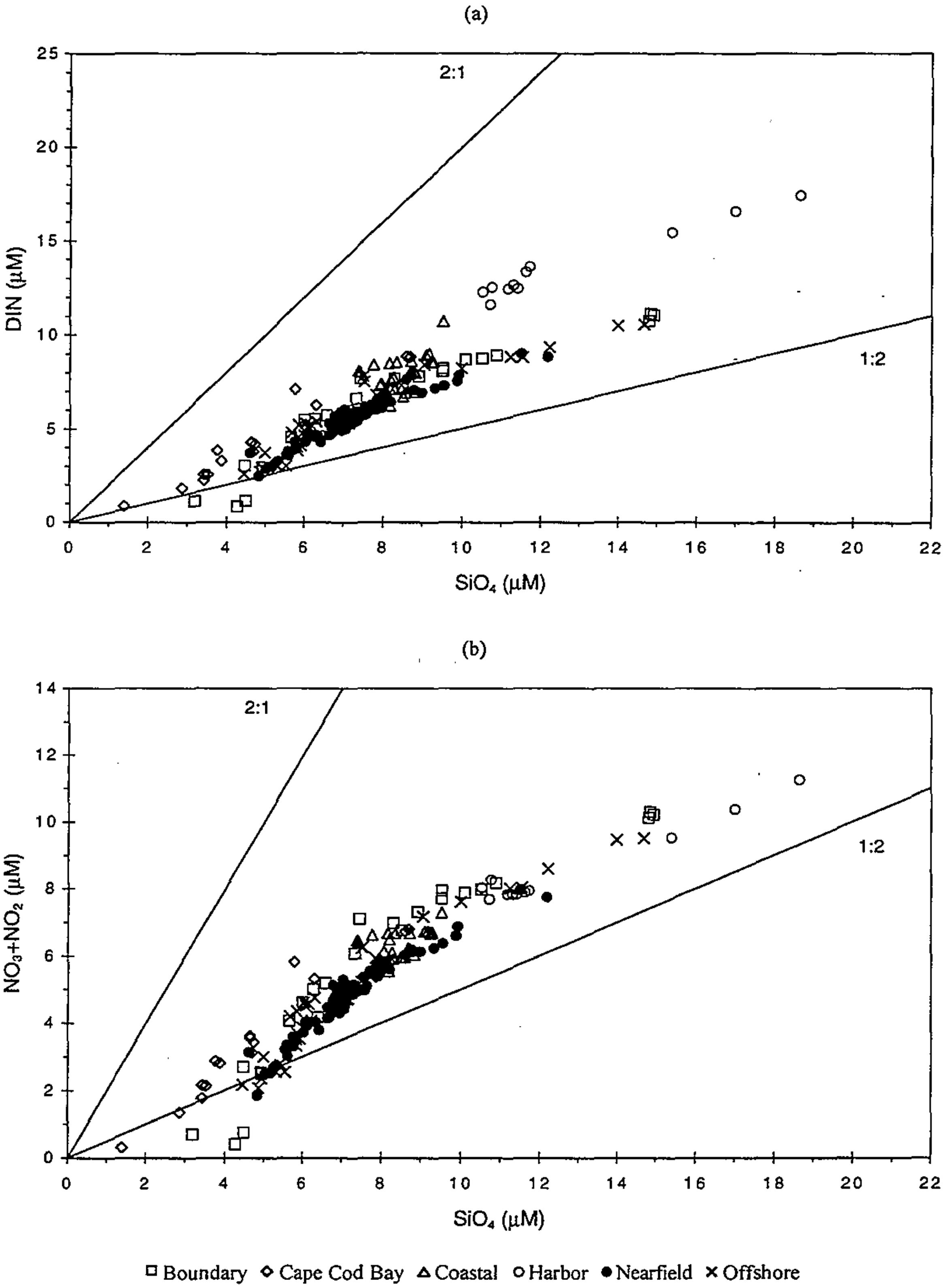


FIGURE 4-22

Nutrient vs. nutrient plots for farfield survey W9602, (Feb 96).

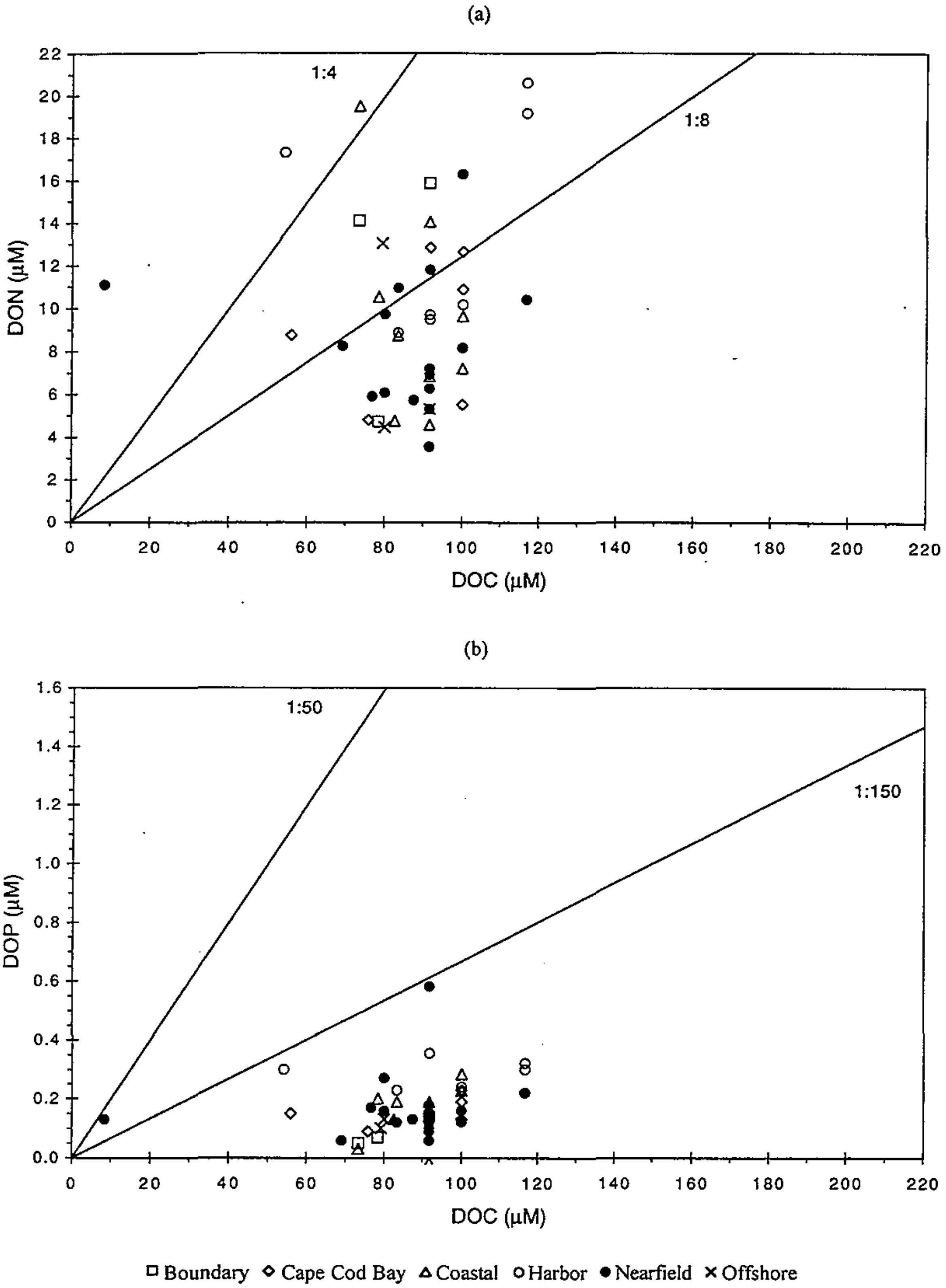
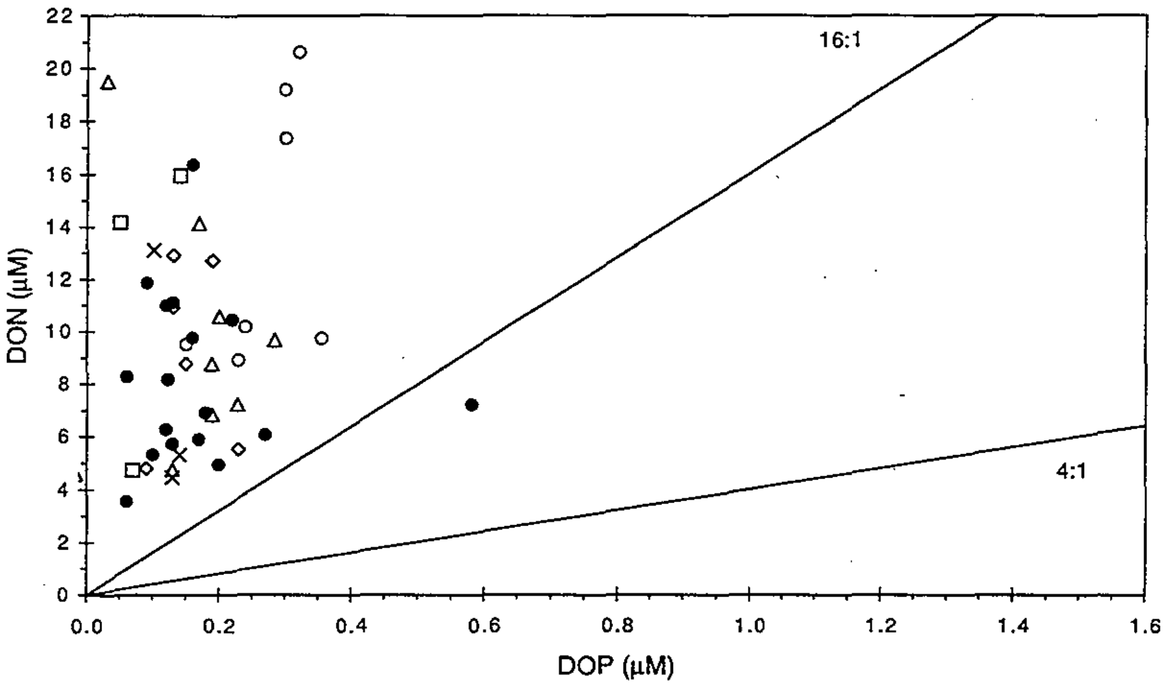


FIGURE 4-23

Nutrient vs. nutrient plots for farfield survey W9602, (Feb 96).

(a)



(b)

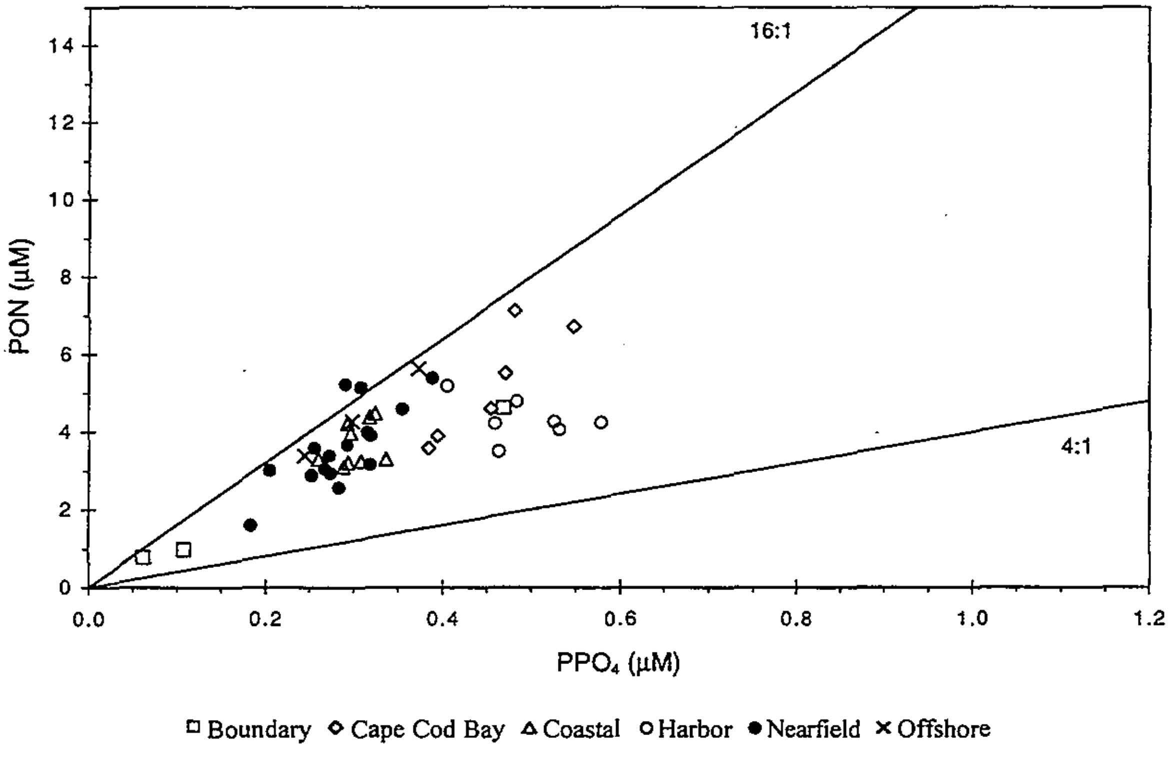


FIGURE 4-24
Nutrient vs. nutrient plots for farfield survey W9602, (Feb 96).

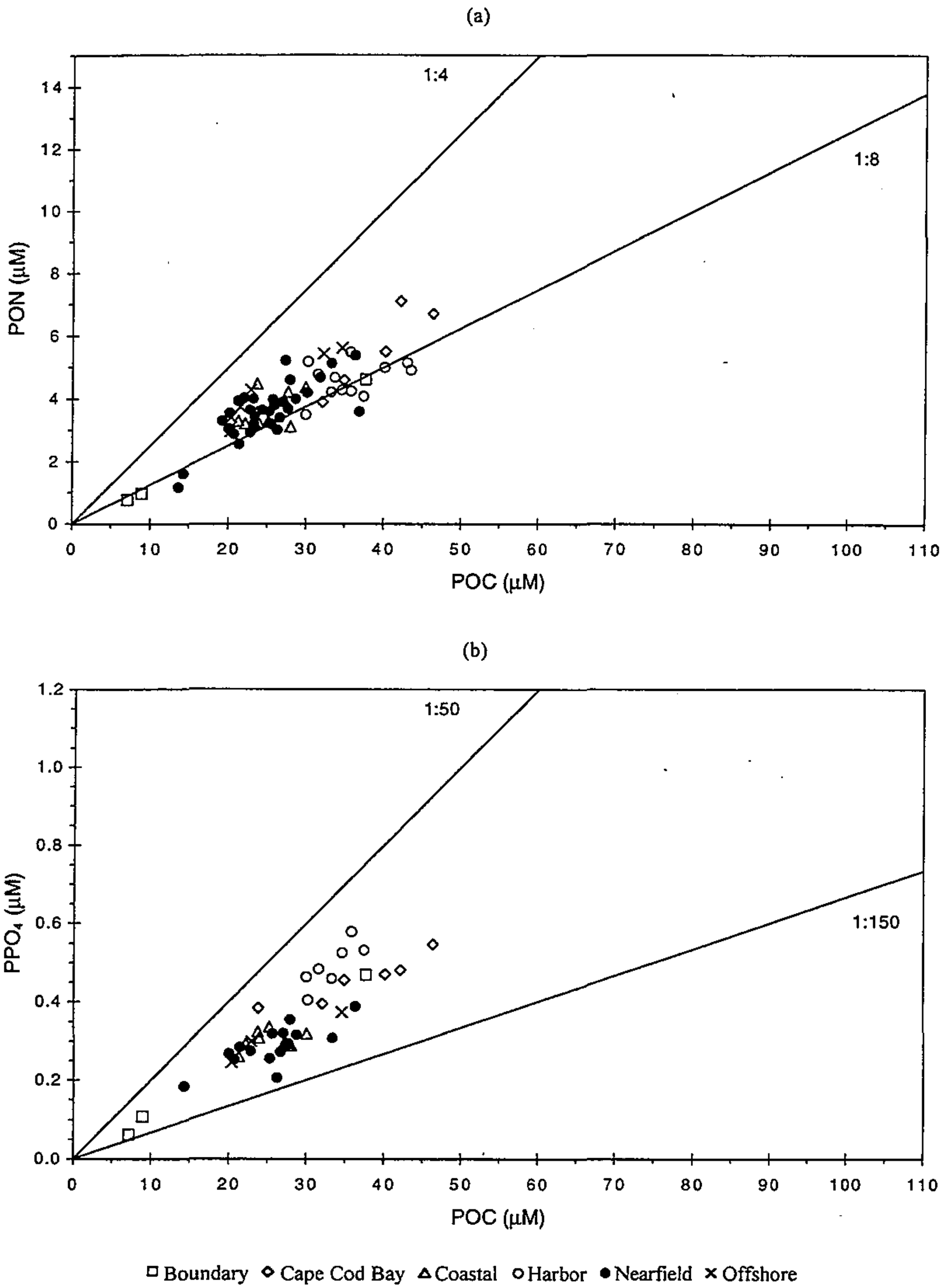


FIGURE 4-25
Nutrient vs. nutrient plots for farfield survey W9602, (Feb 96).

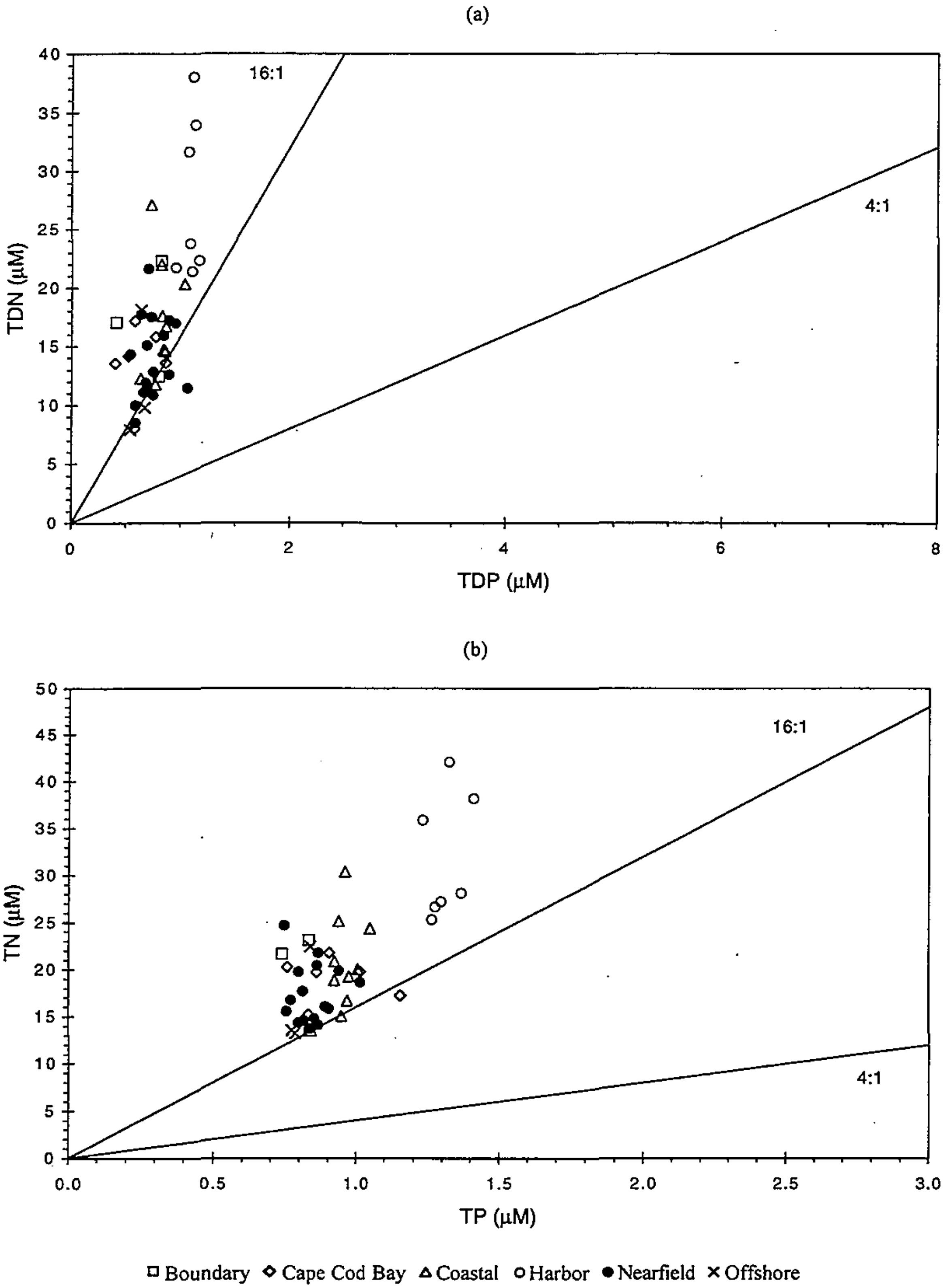


FIGURE 4-26
Nutrient vs. nutrient plots for farfield survey W9602, (Feb 96).

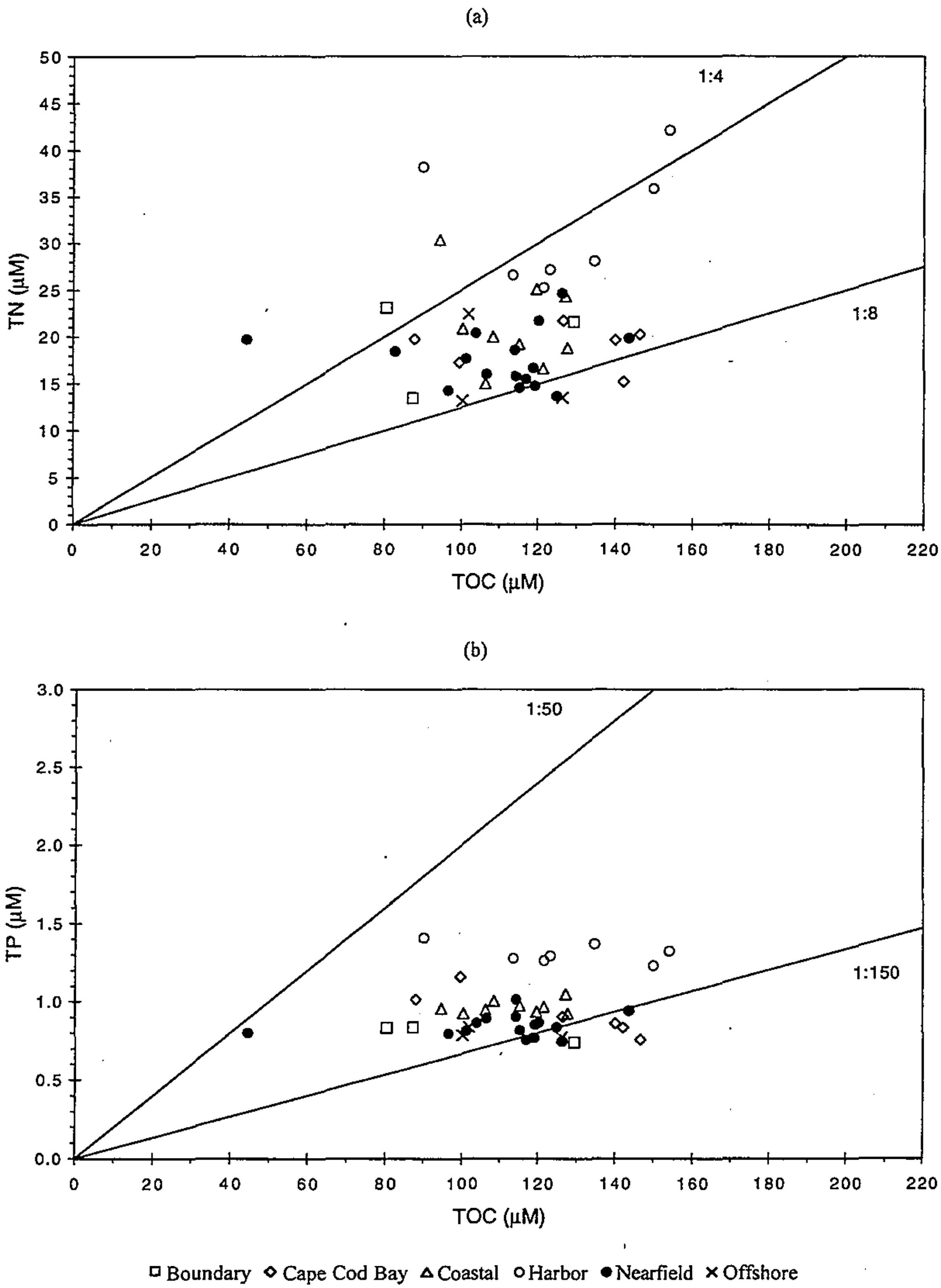
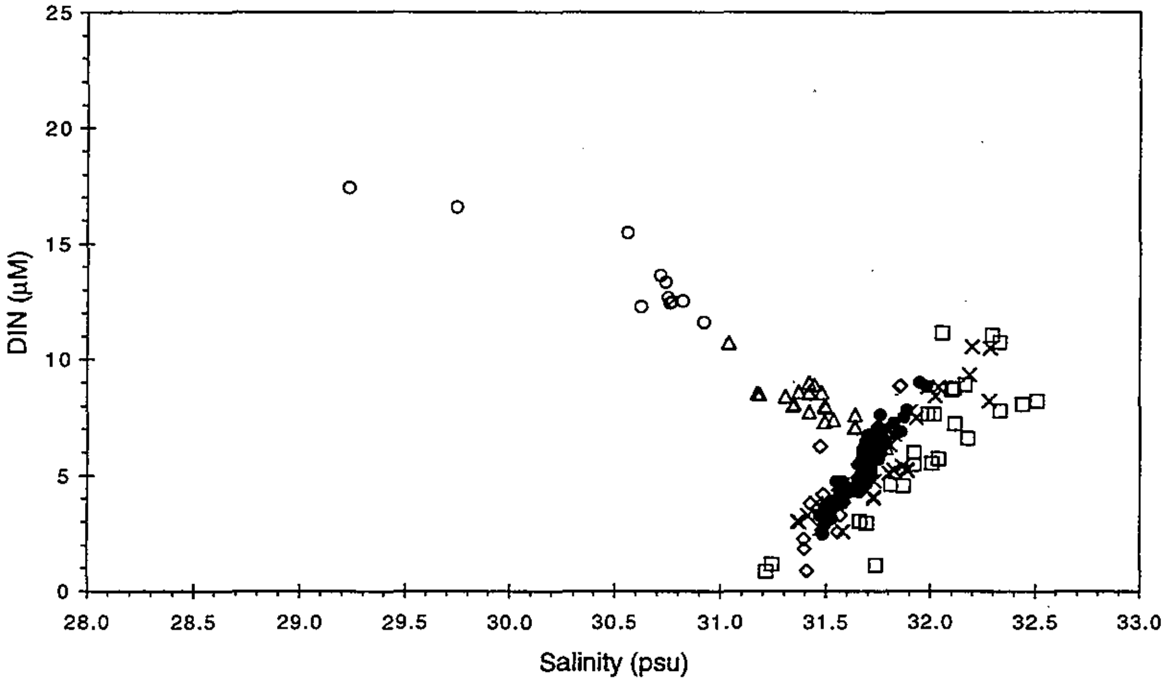


FIGURE 4-27
Nutrient vs. nutrient plots for farfield survey W9602, (Feb 96).



□ Boundary ◇ Cape Cod Bay △ Coastal ○ Harbor ● Nearfield × Offshore

FIGURE 4-28
Nutrient vs. salinity plots for farfield survey W9602, (Feb 96).

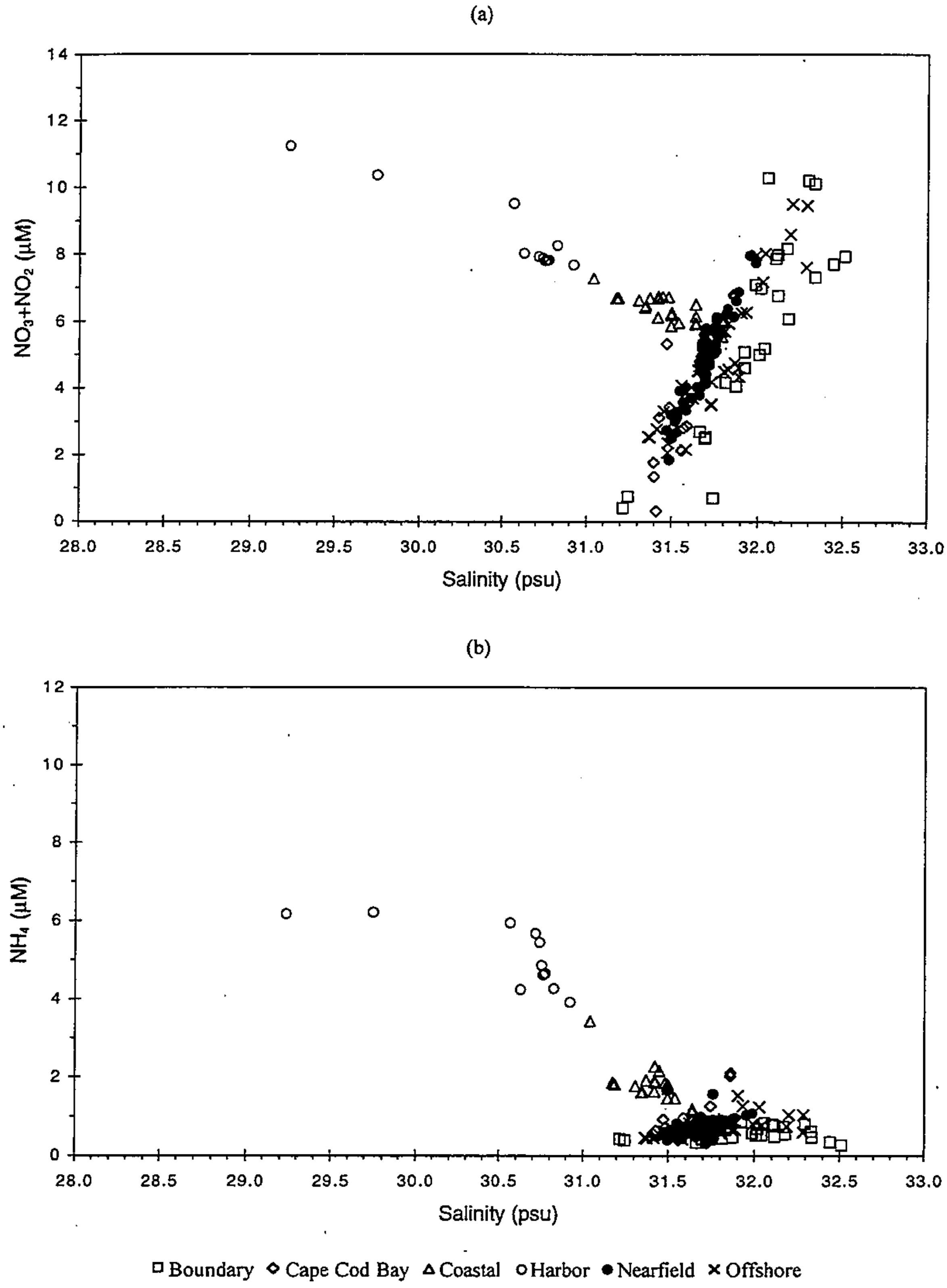


FIGURE 4-29

Nutrient vs. salinity plots for farfield survey W9602, (Feb 96).

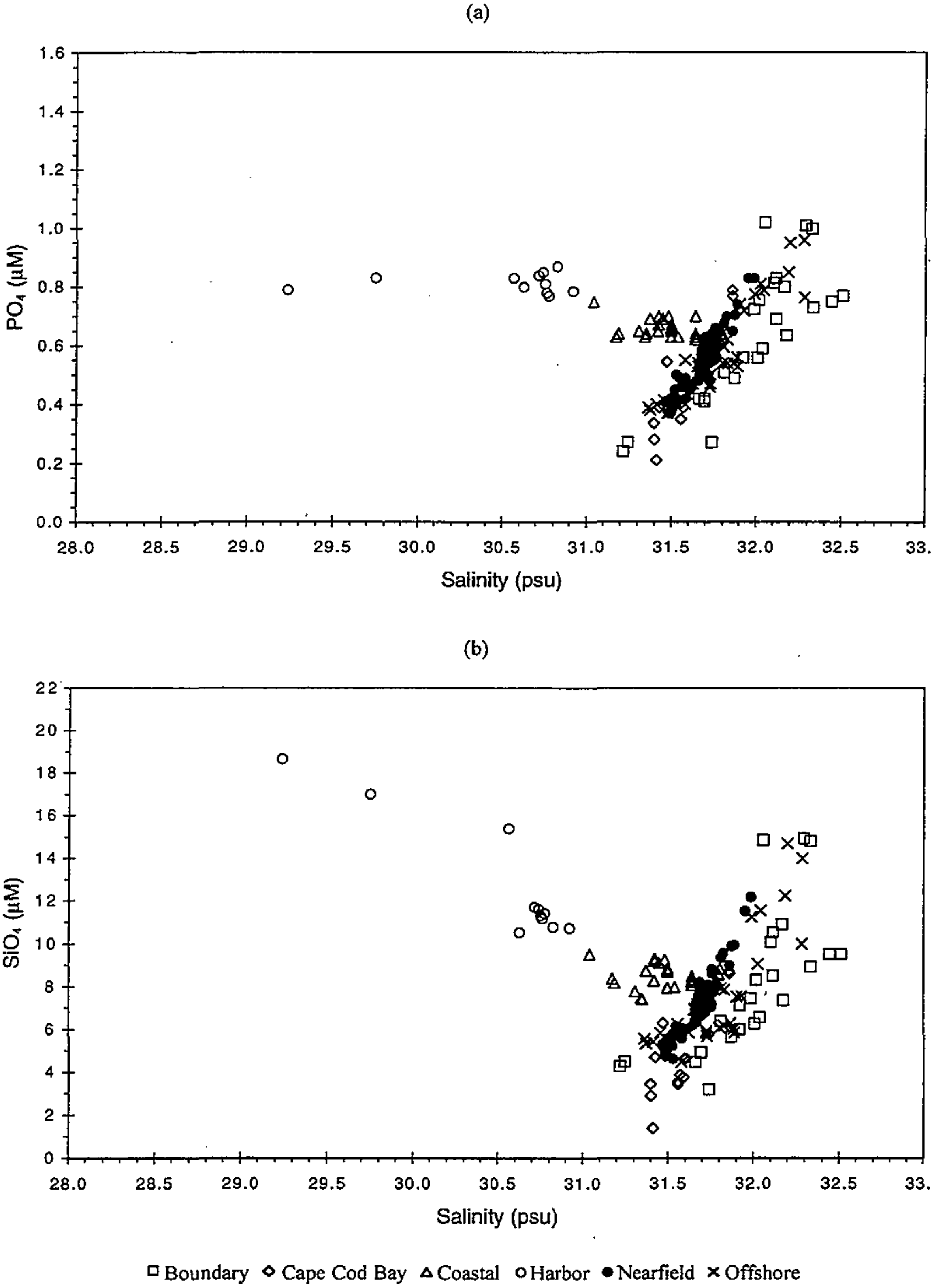


FIGURE 4-30

Nutrient vs. salinity plots for farfield survey W9602, (Feb 96).

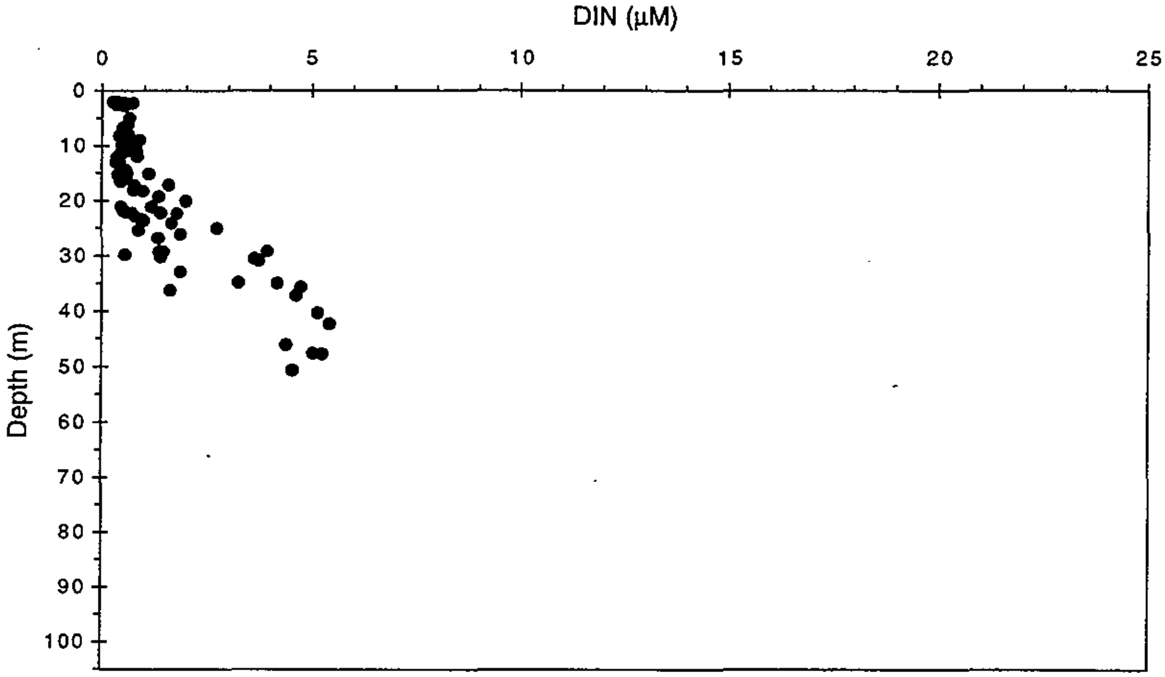


FIGURE 4-31
Depth vs. nutrient plots for nearfield survey W9603, (Mar 96).

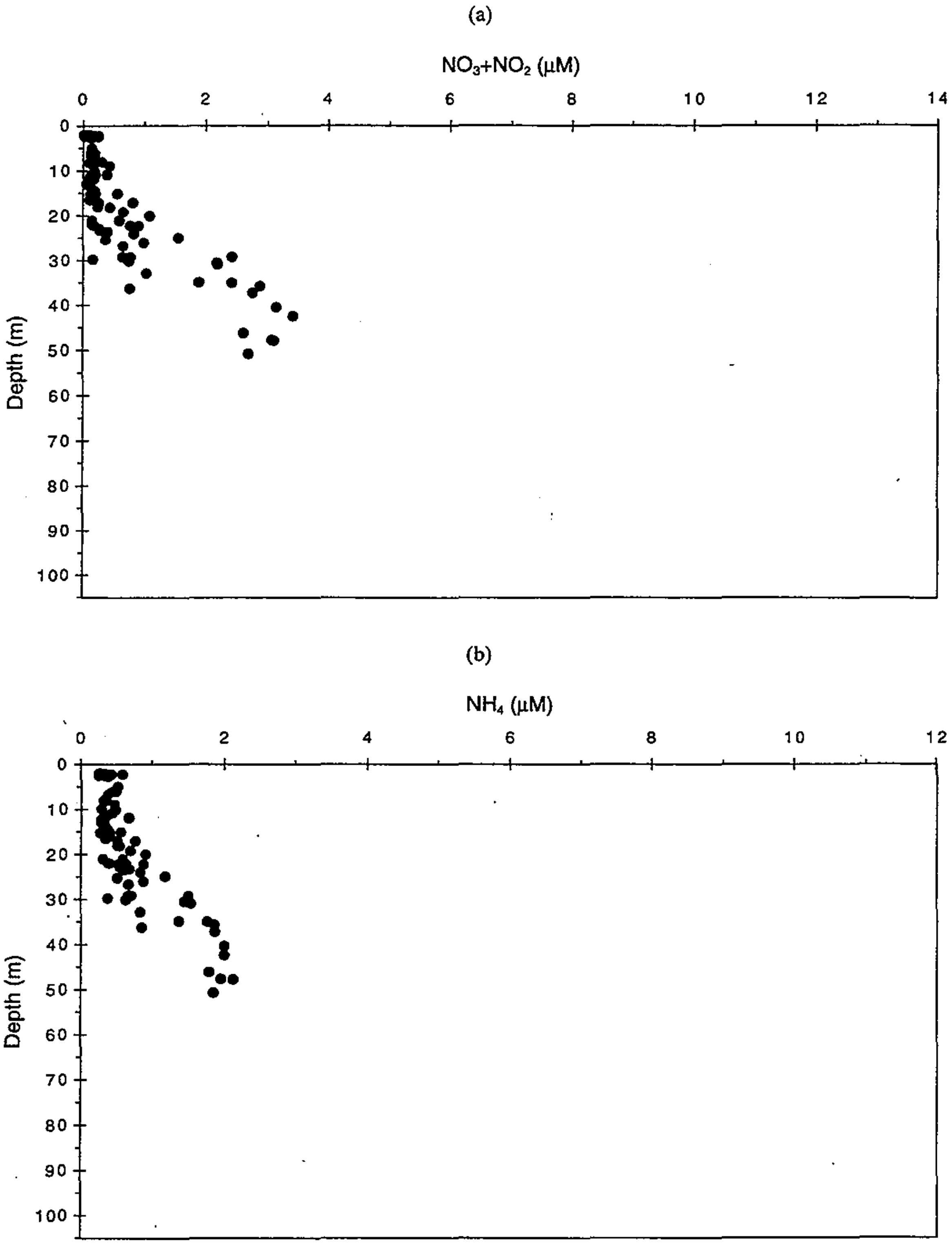


FIGURE 4-32
Depth vs. nutrient plots for nearfield survey W9603, (Mar 96).

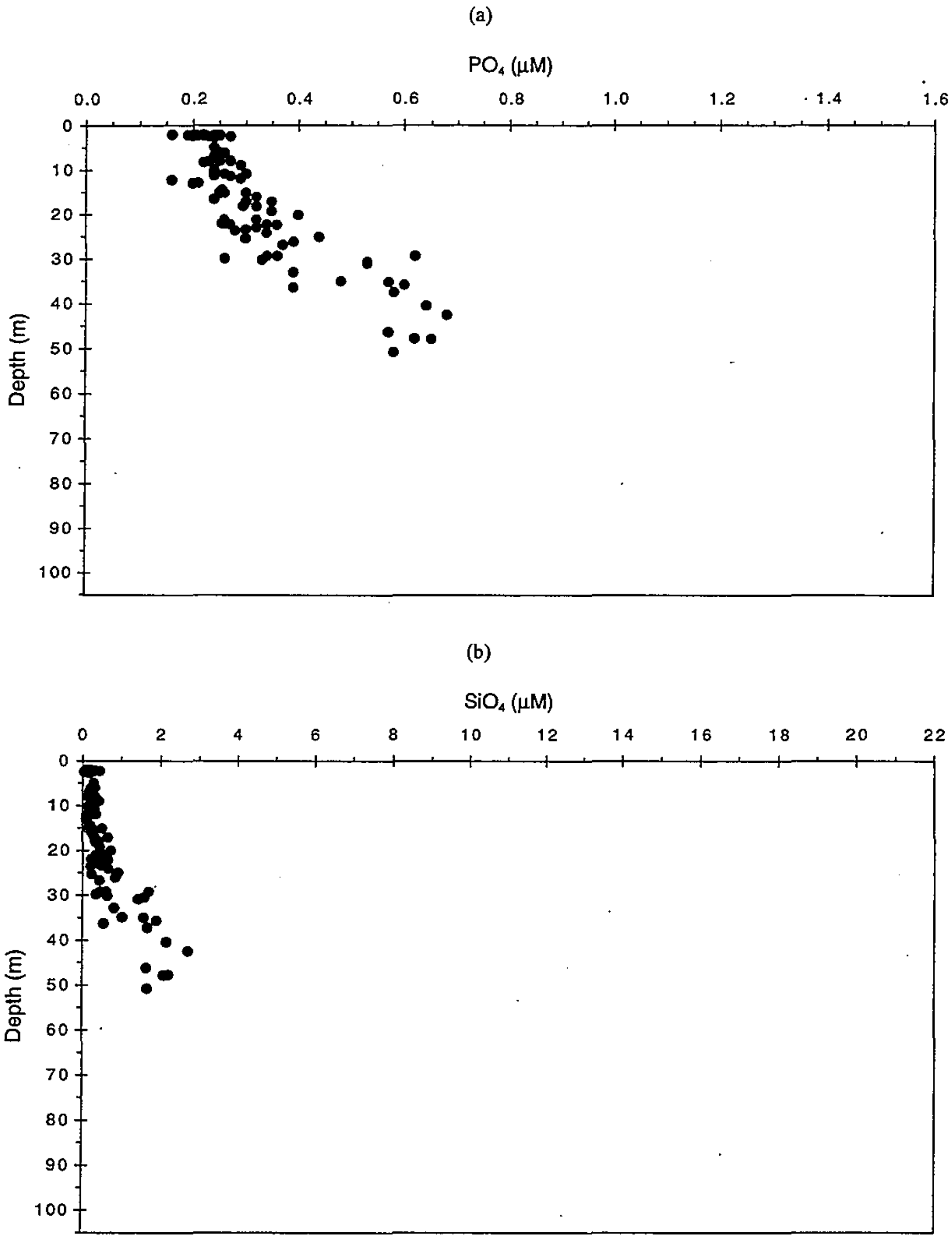


FIGURE 4-33
Depth vs. nutrient plots for nearfield survey W9603, (Mar 96).

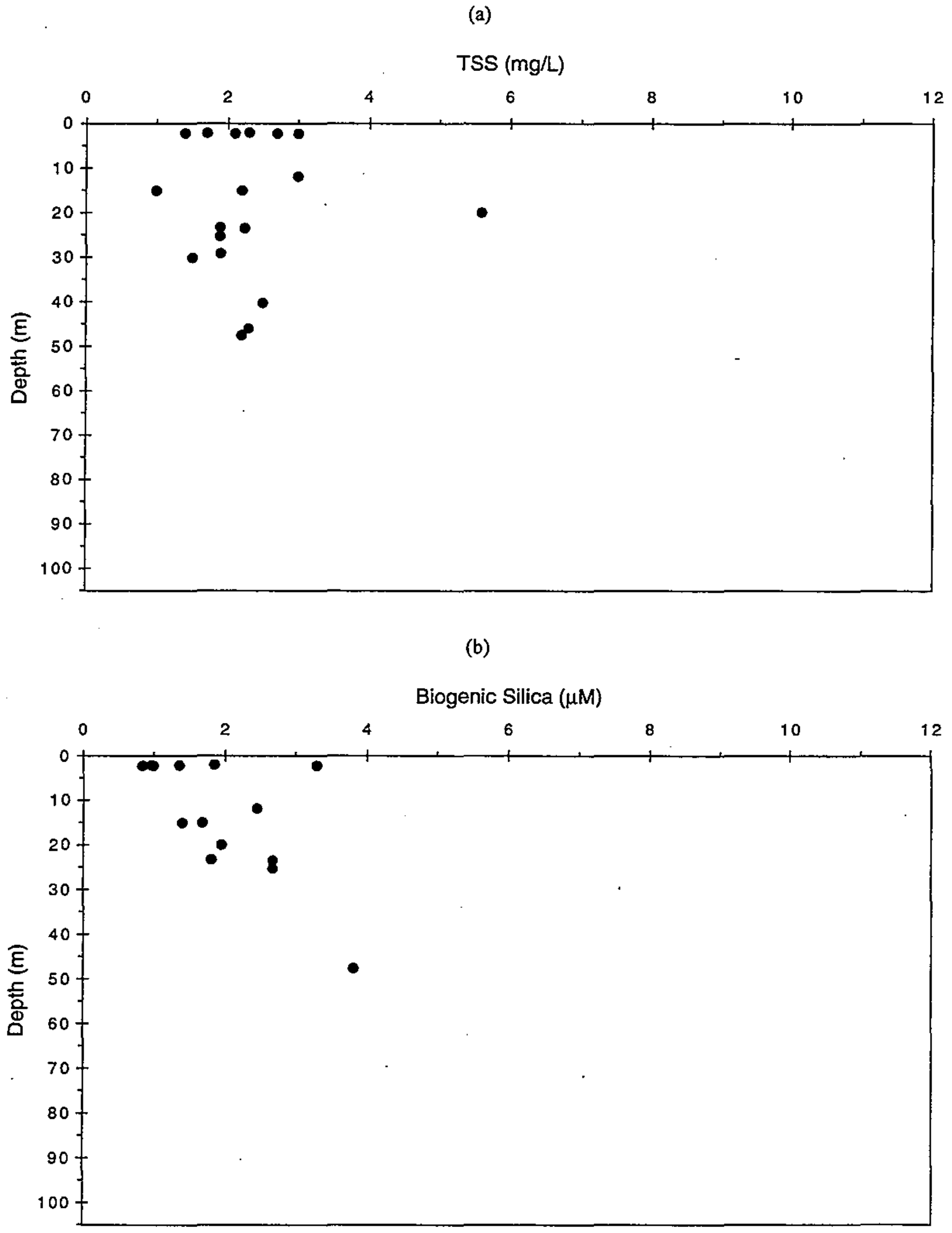


FIGURE 4-34
Depth vs. nutrient plots for nearfield survey W9603, (Mar 96).

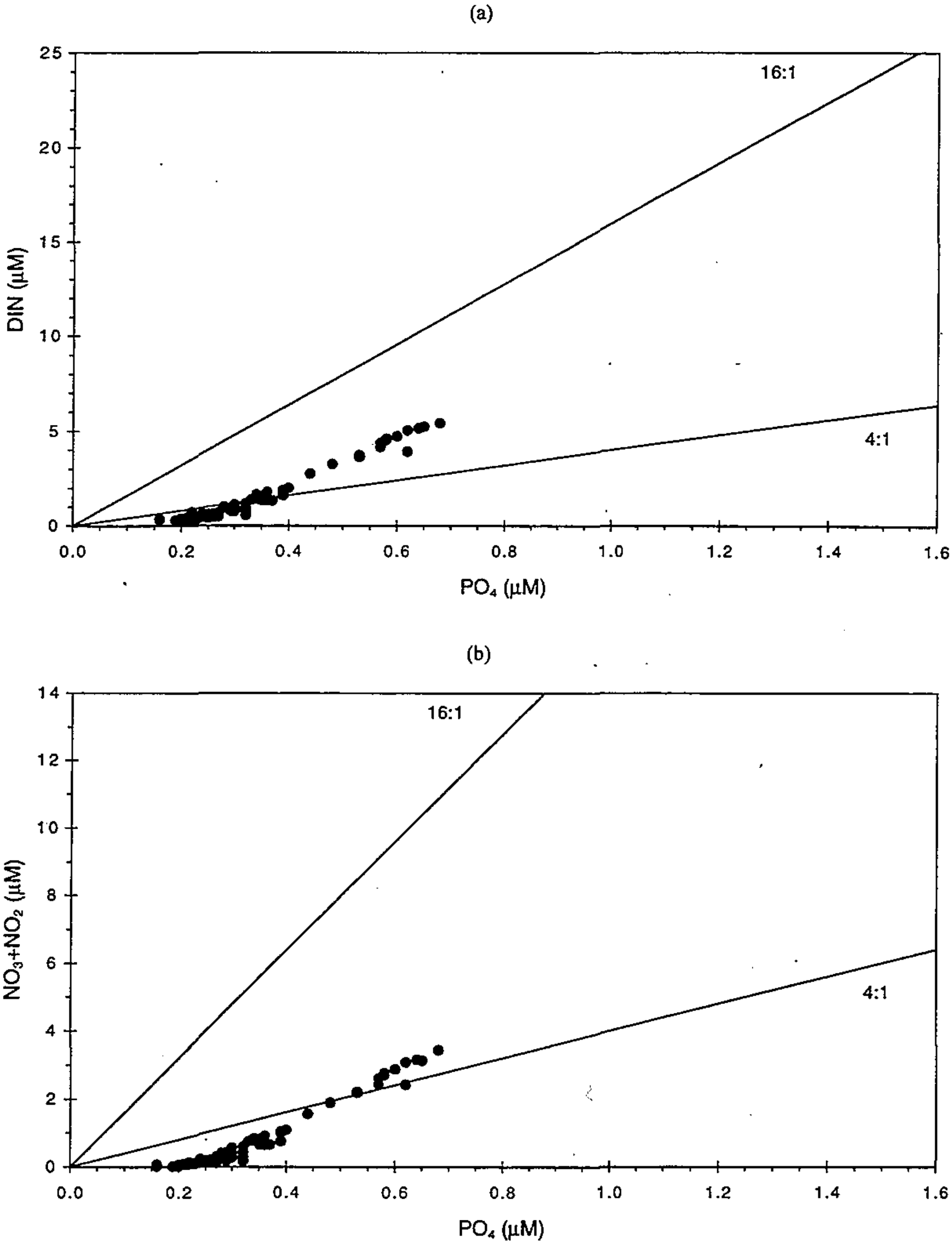


FIGURE 4-35
Nutrient vs. nutrient plots for nearfield survey W9603, (Mar 96).

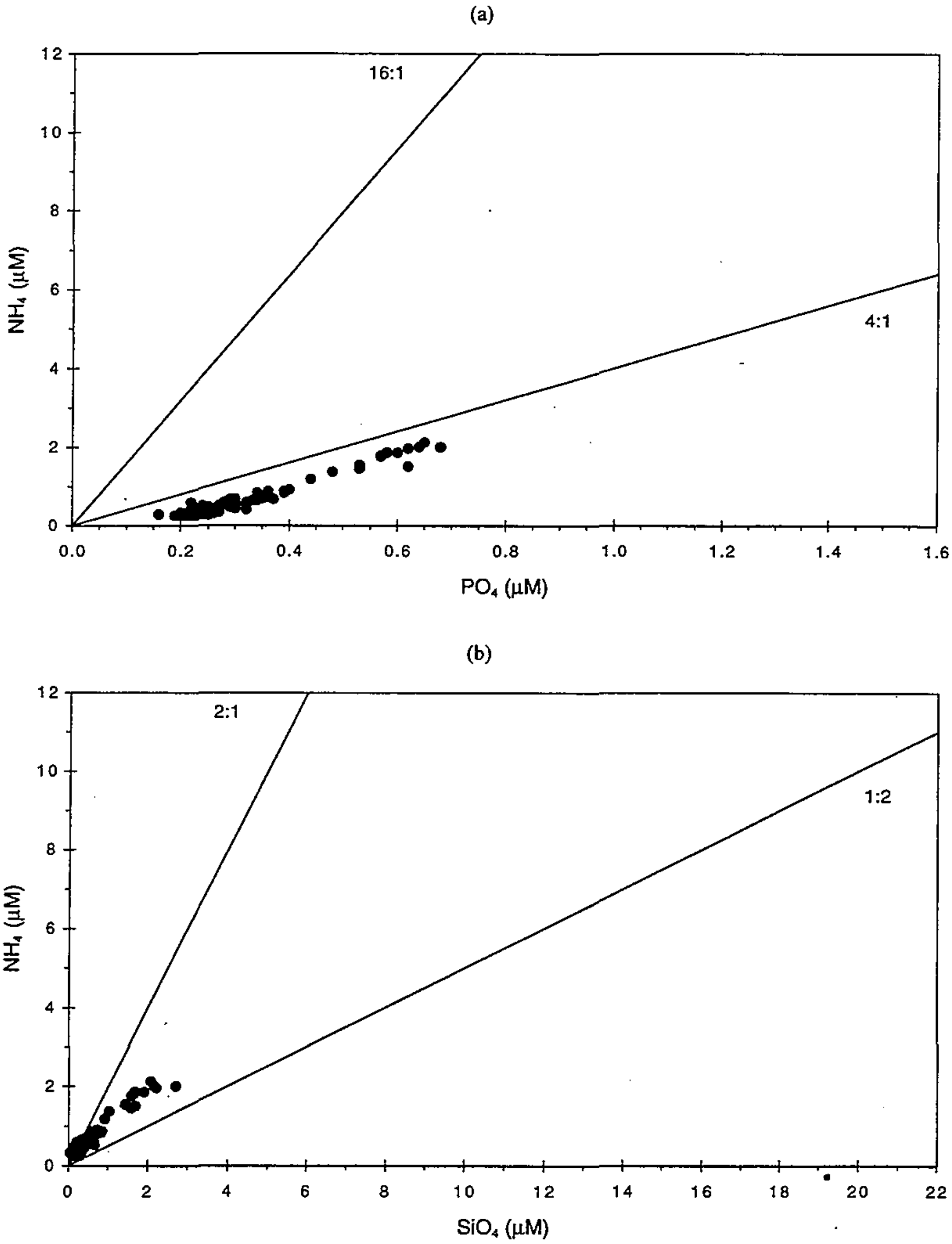


FIGURE 4-36
Nutrient vs. nutrient plots for nearfield survey W9603, (Mar 96).

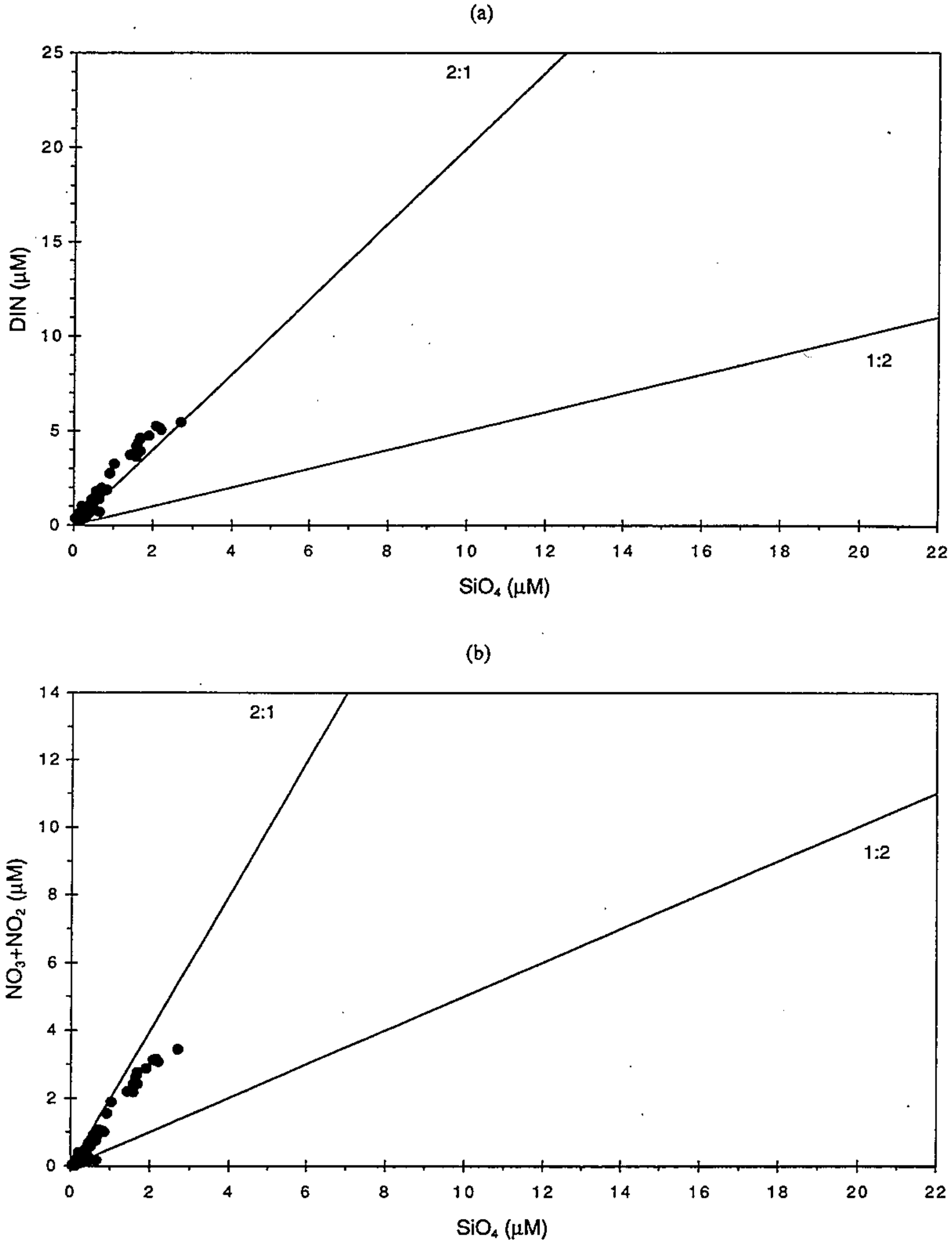


FIGURE 4-37
Nutrient vs. nutrient plots for nearfield survey W9603, (Mar 96).

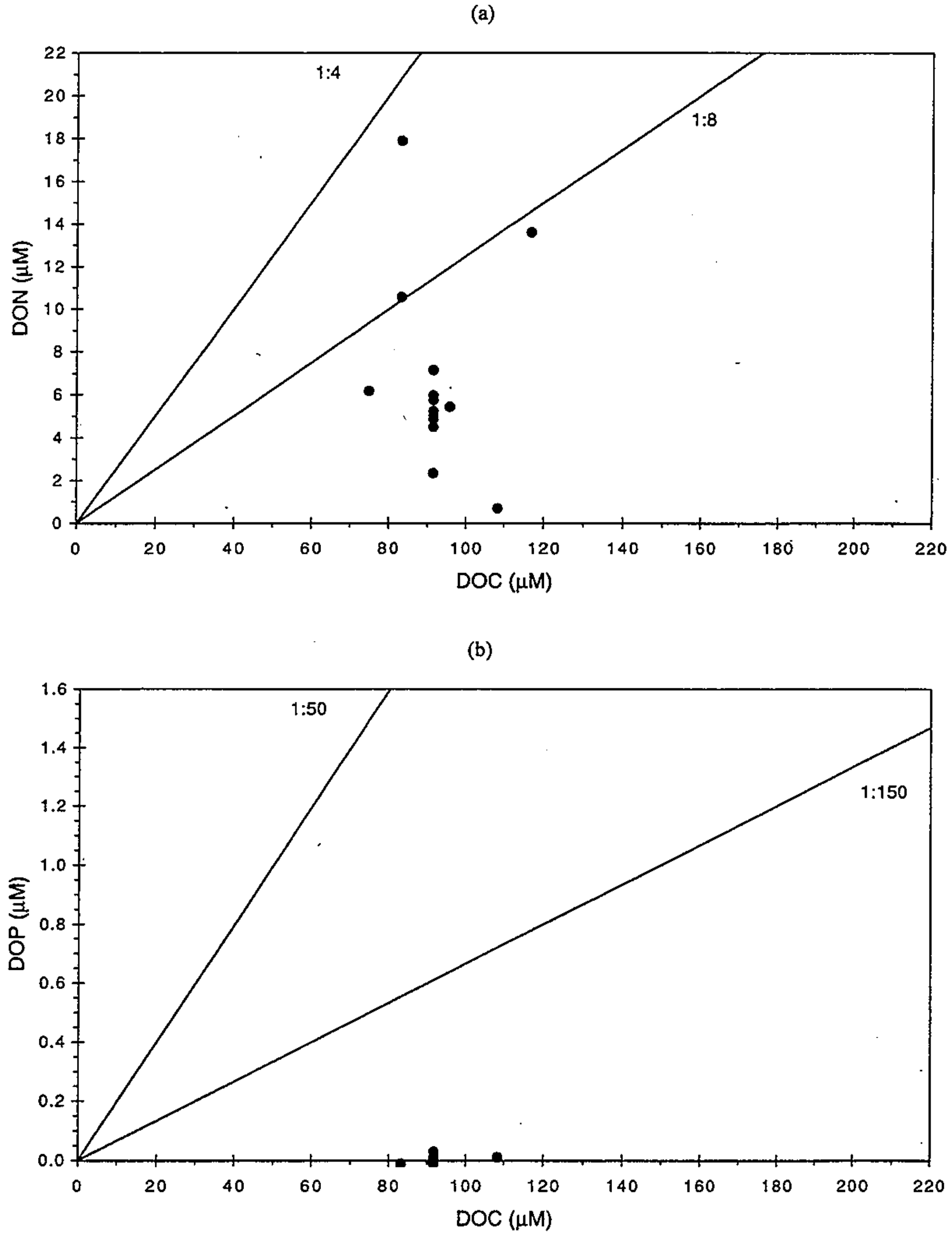


FIGURE 4-38
Nutrient vs. nutrient plots for nearfield survey W9603, (Mar 96).

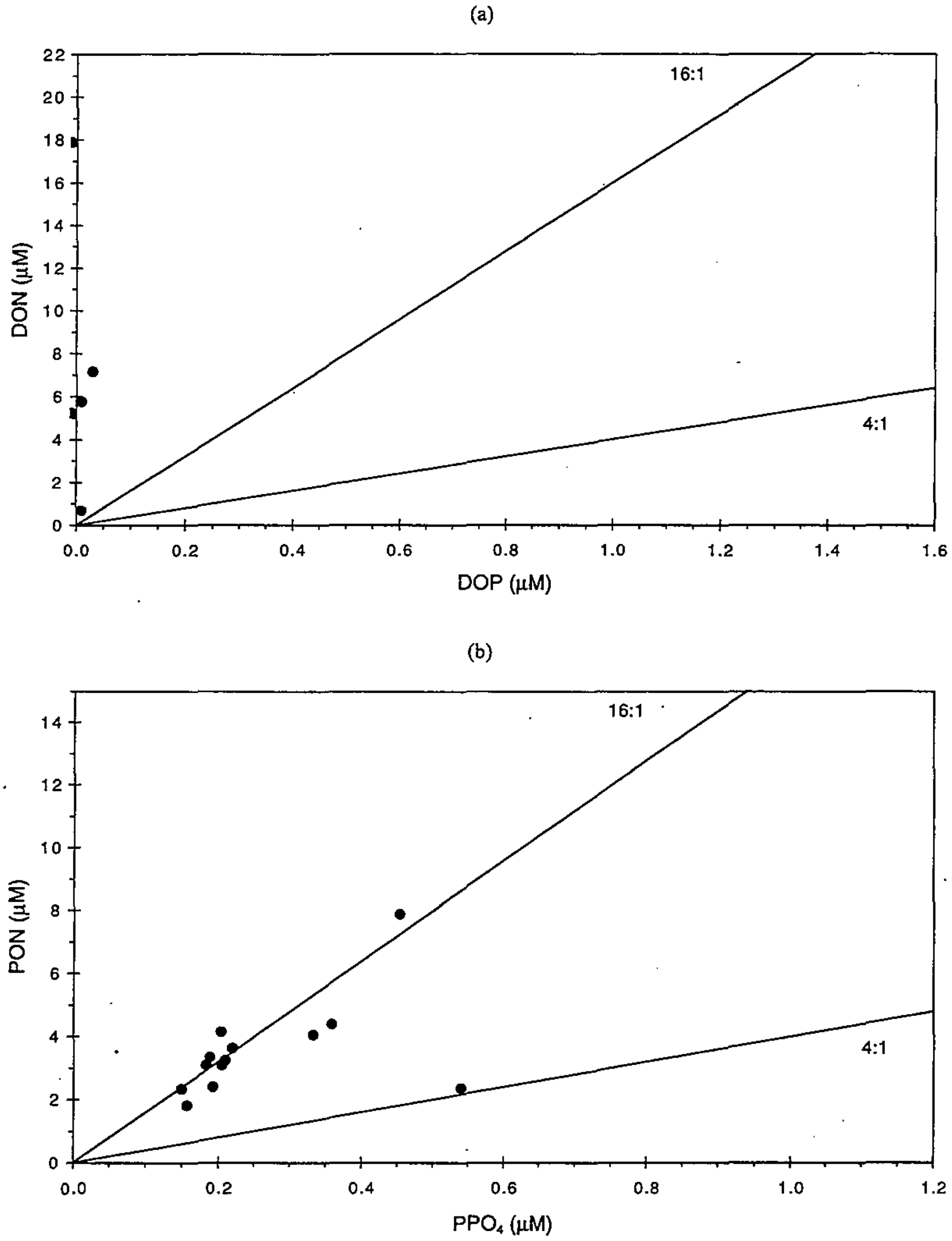


FIGURE 4-39
Nutrient vs. nutrient plots for nearfield survey W9603, (Mar 96).

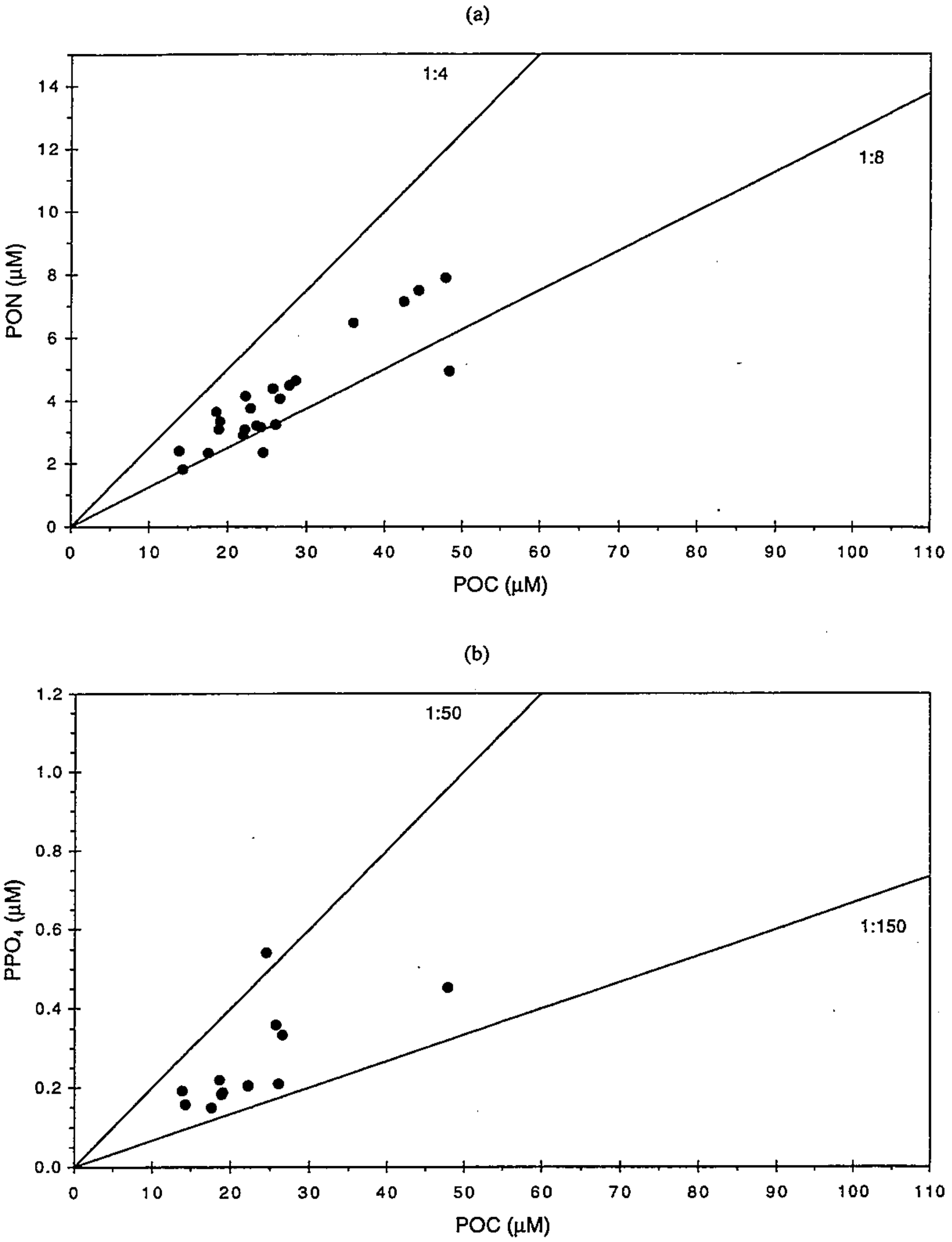


FIGURE 4-40

Nutrient vs. nutrient plots for nearfield survey W9603, (Mar 96).

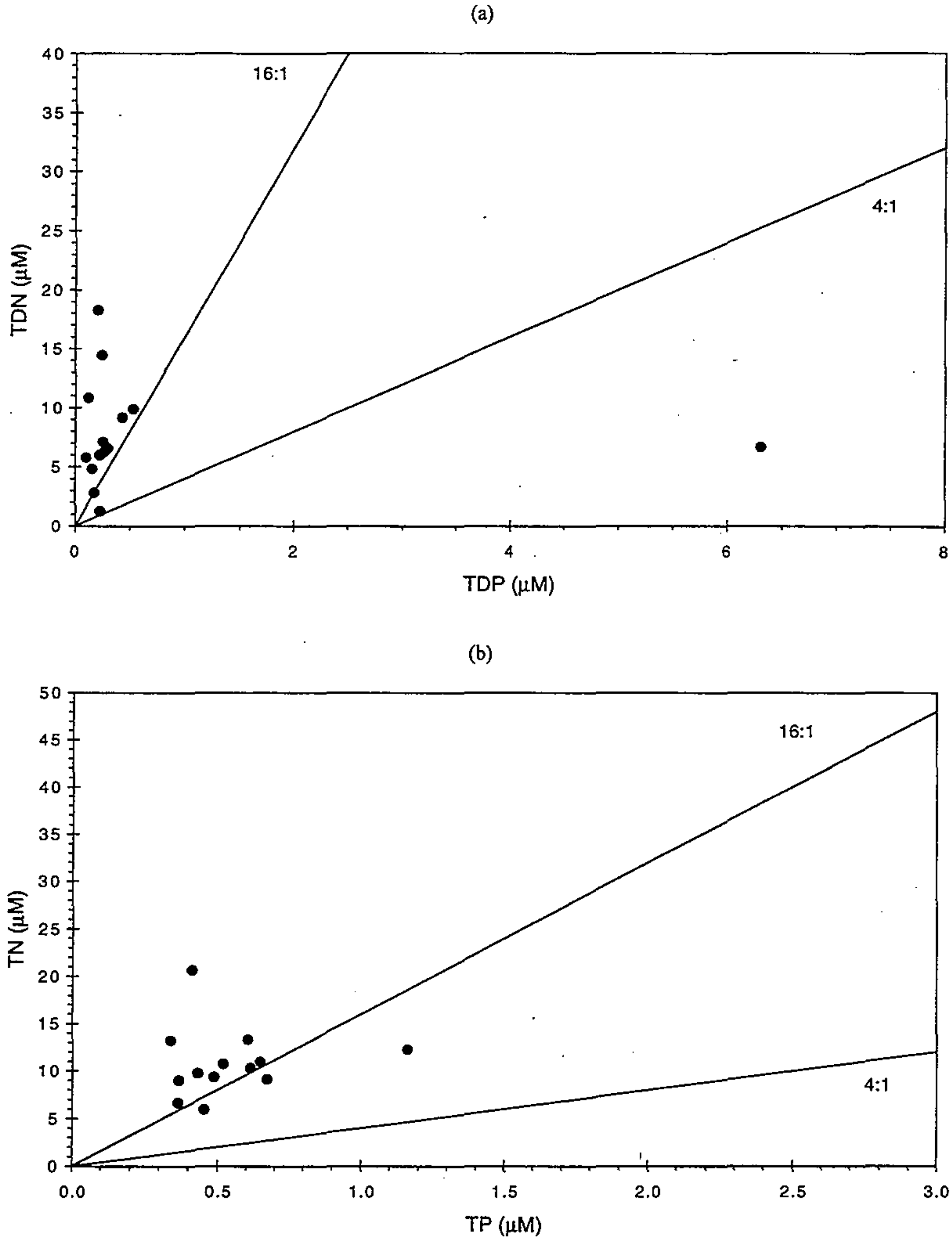
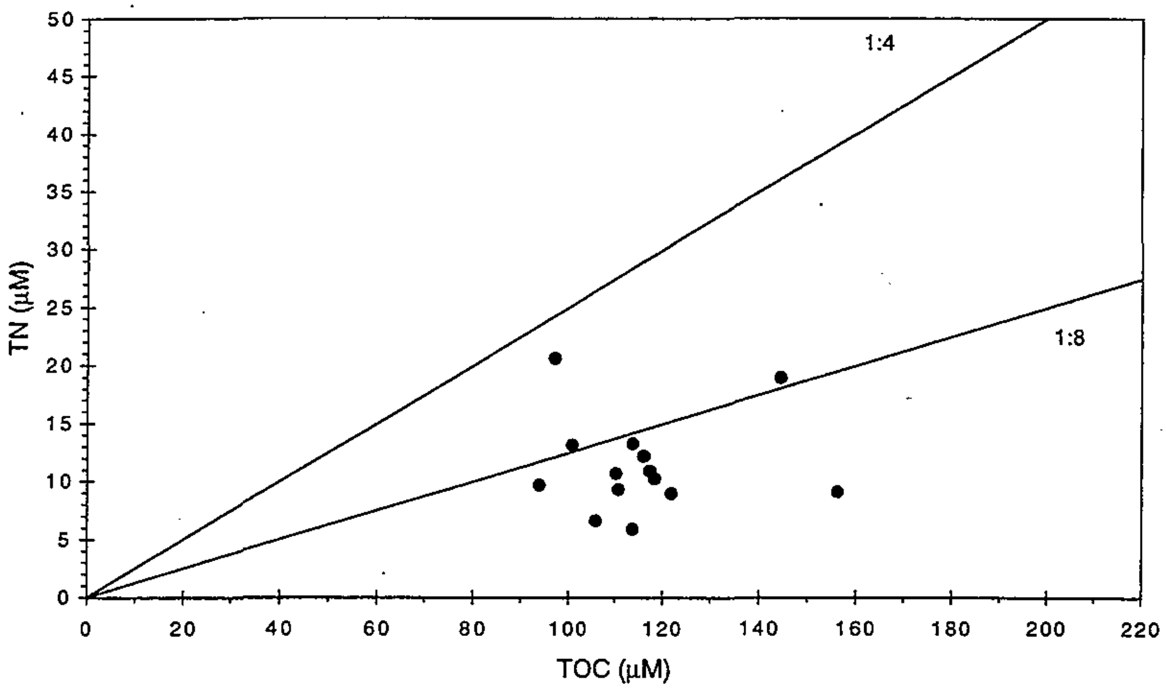


FIGURE 4-41
Nutrient vs. nutrient plots for nearfield survey W9603, (Mar 96).

(a)



(b)

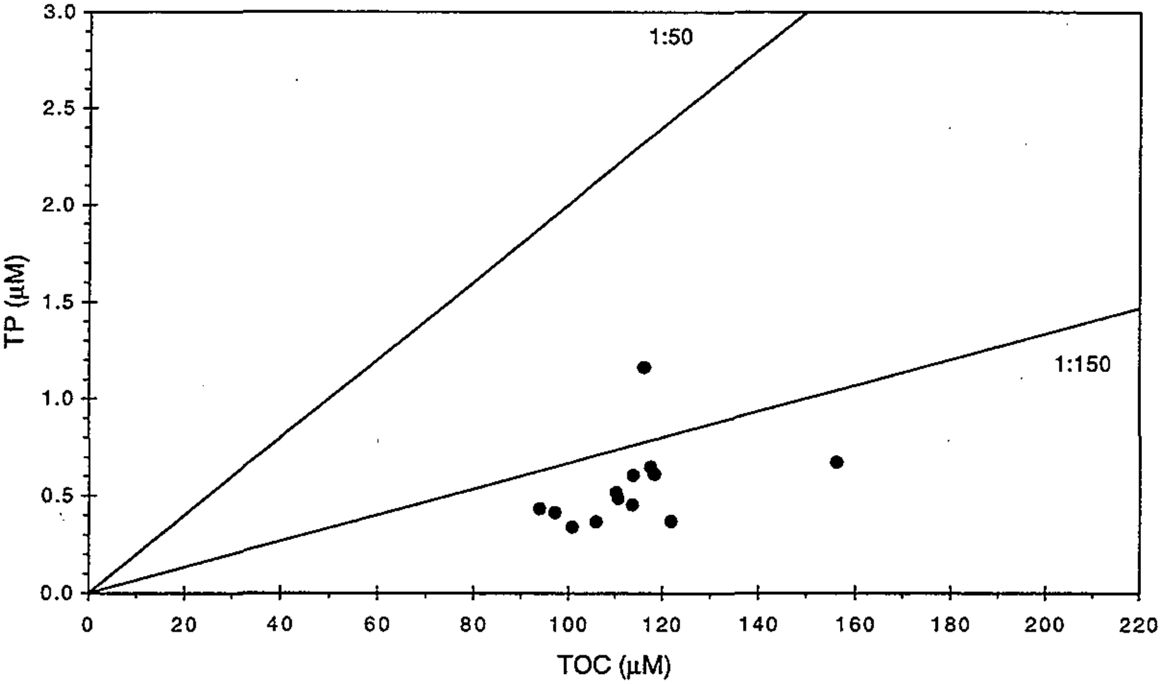


FIGURE 4-42
Nutrient vs. nutrient plots for nearfield survey W9603, (Mar 96).

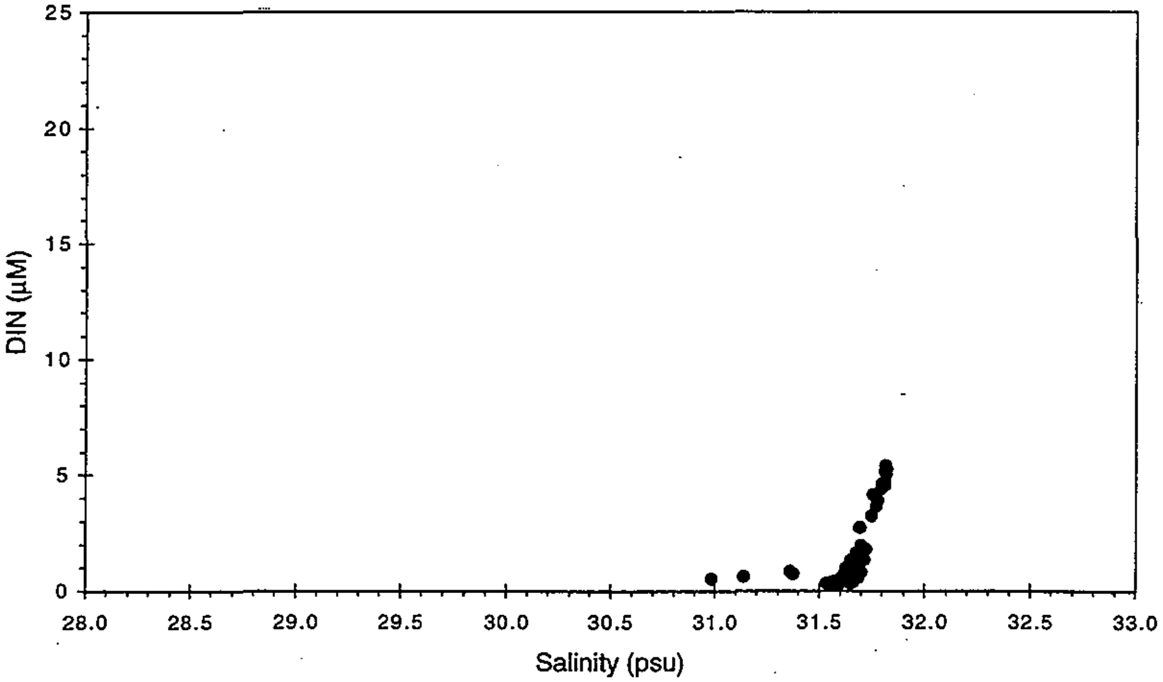


FIGURE 4-43
Nutrient vs. salinity plots for nearfield survey W9603, (Mar 96).

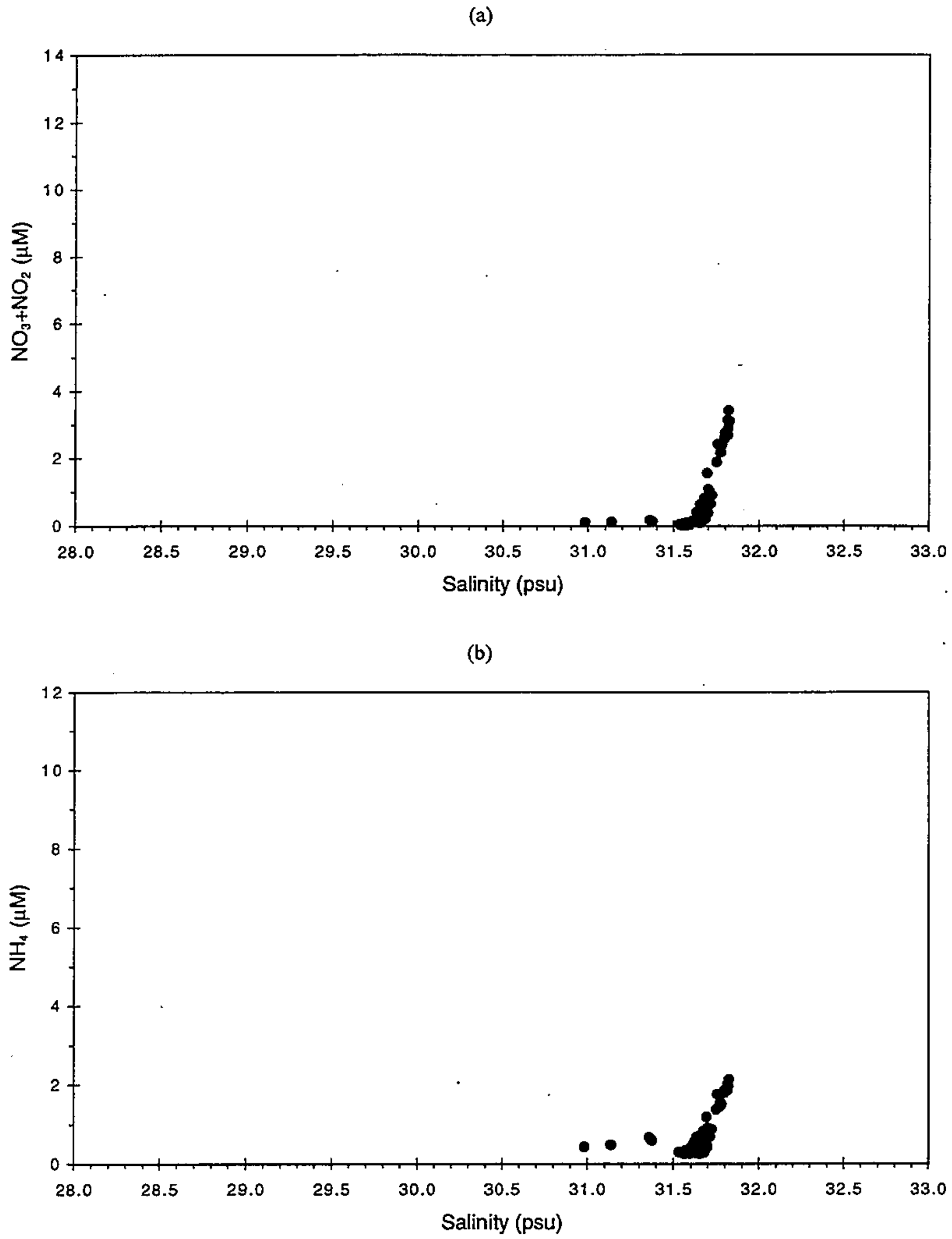


FIGURE 4-44
Nutrient vs. salinity plots for nearfield survey W9603, (Mar 96).

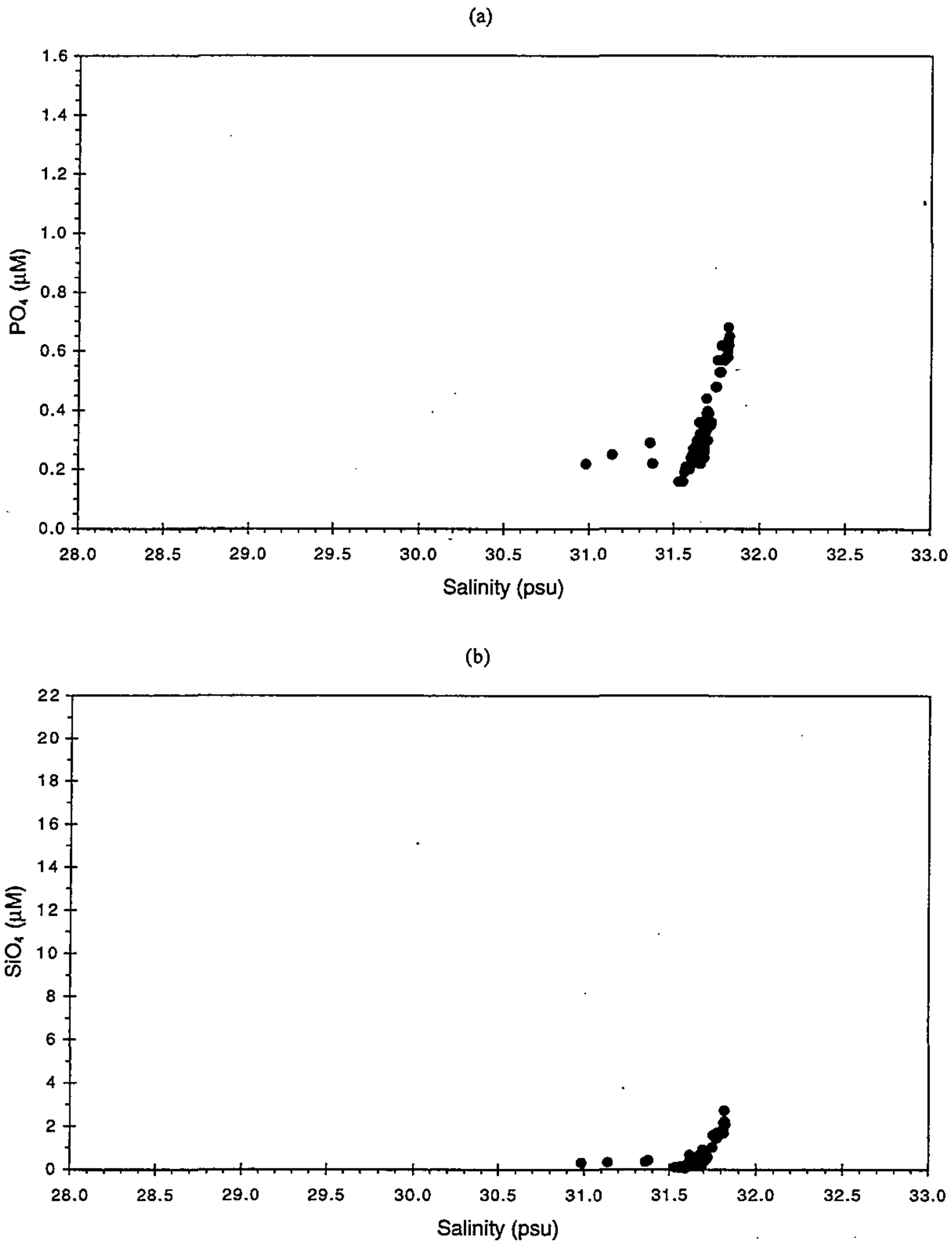


FIGURE 4-45
Nutrient vs. salinity plots for nearfield survey W9603, (Mar 96).

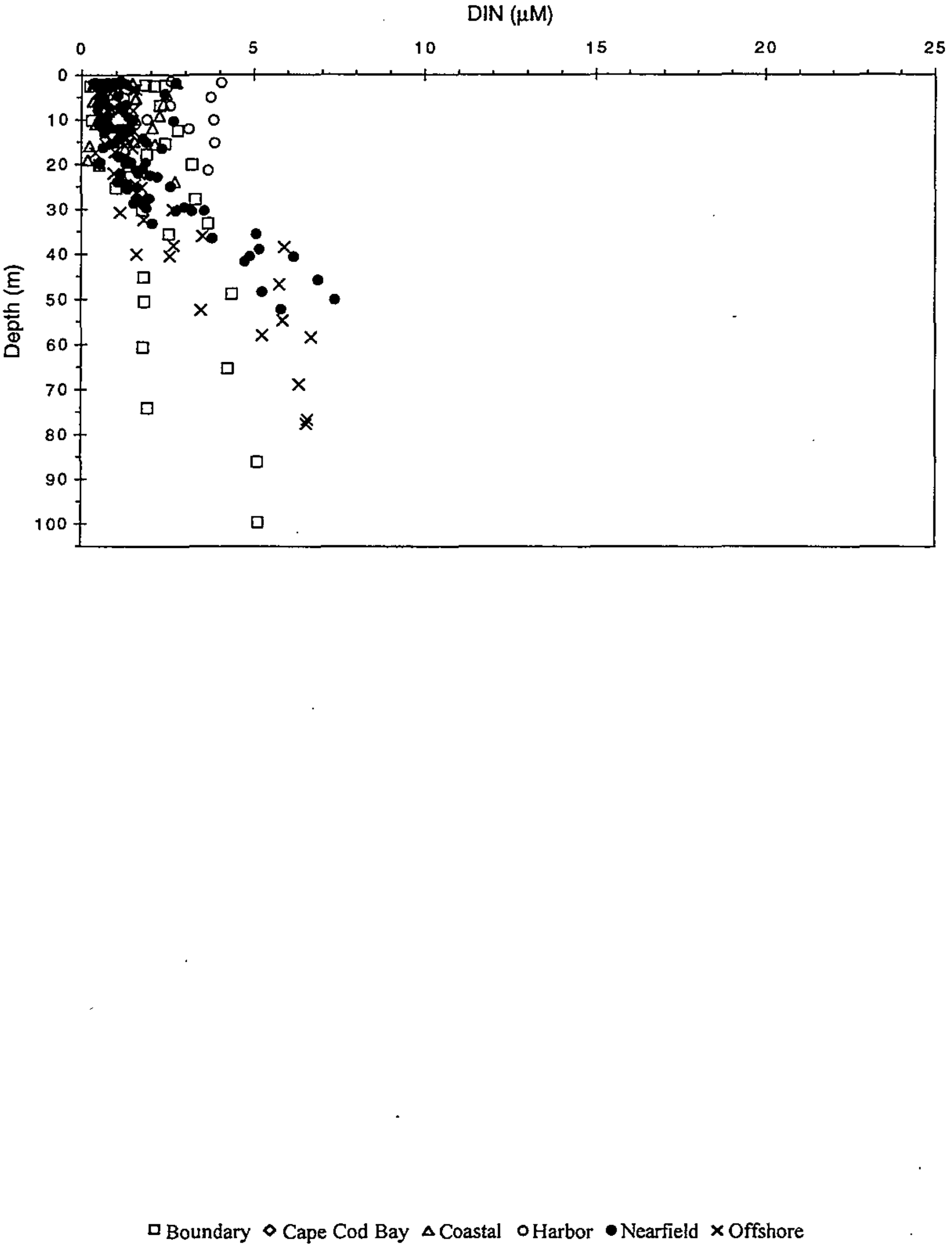


FIGURE 4-46
Depth vs. nutrient plots for farfield survey W9604, (Apr 96).

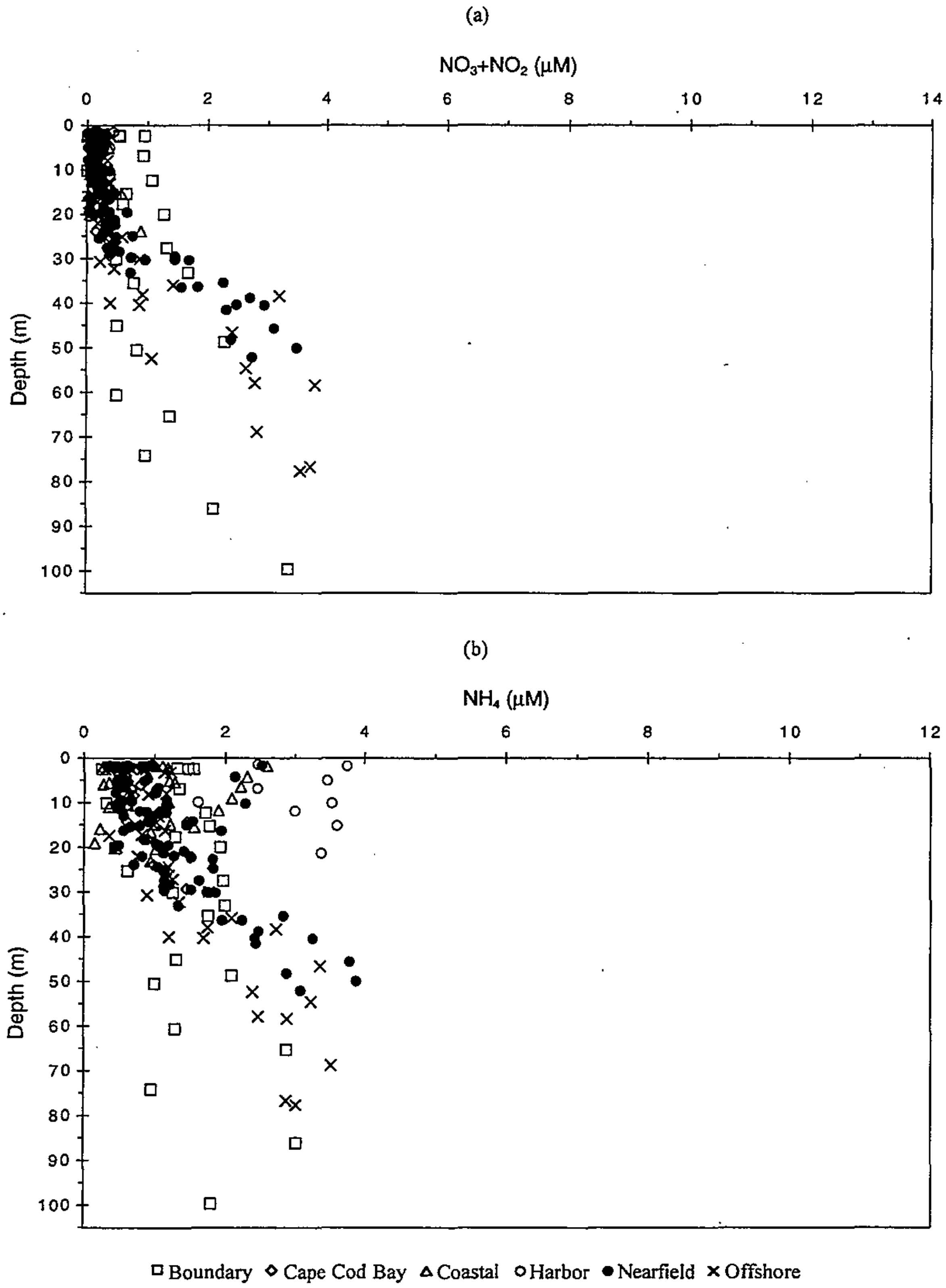


FIGURE 4-47
Depth vs. nutrient plots for farfield survey W9604, (Apr 96).

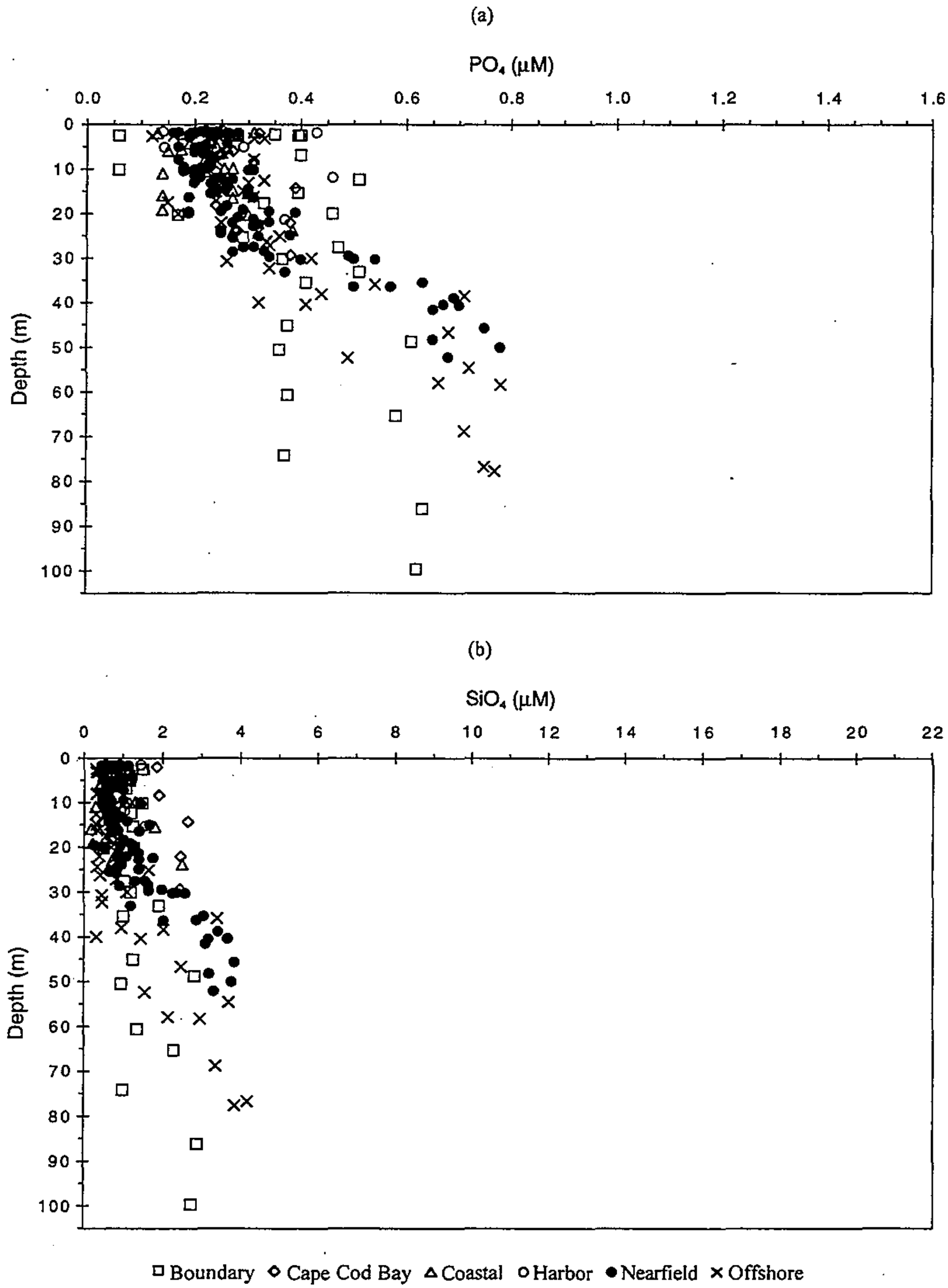


FIGURE 4-48
Depth vs. nutrient plots for farfield survey W9604, (Apr 96).

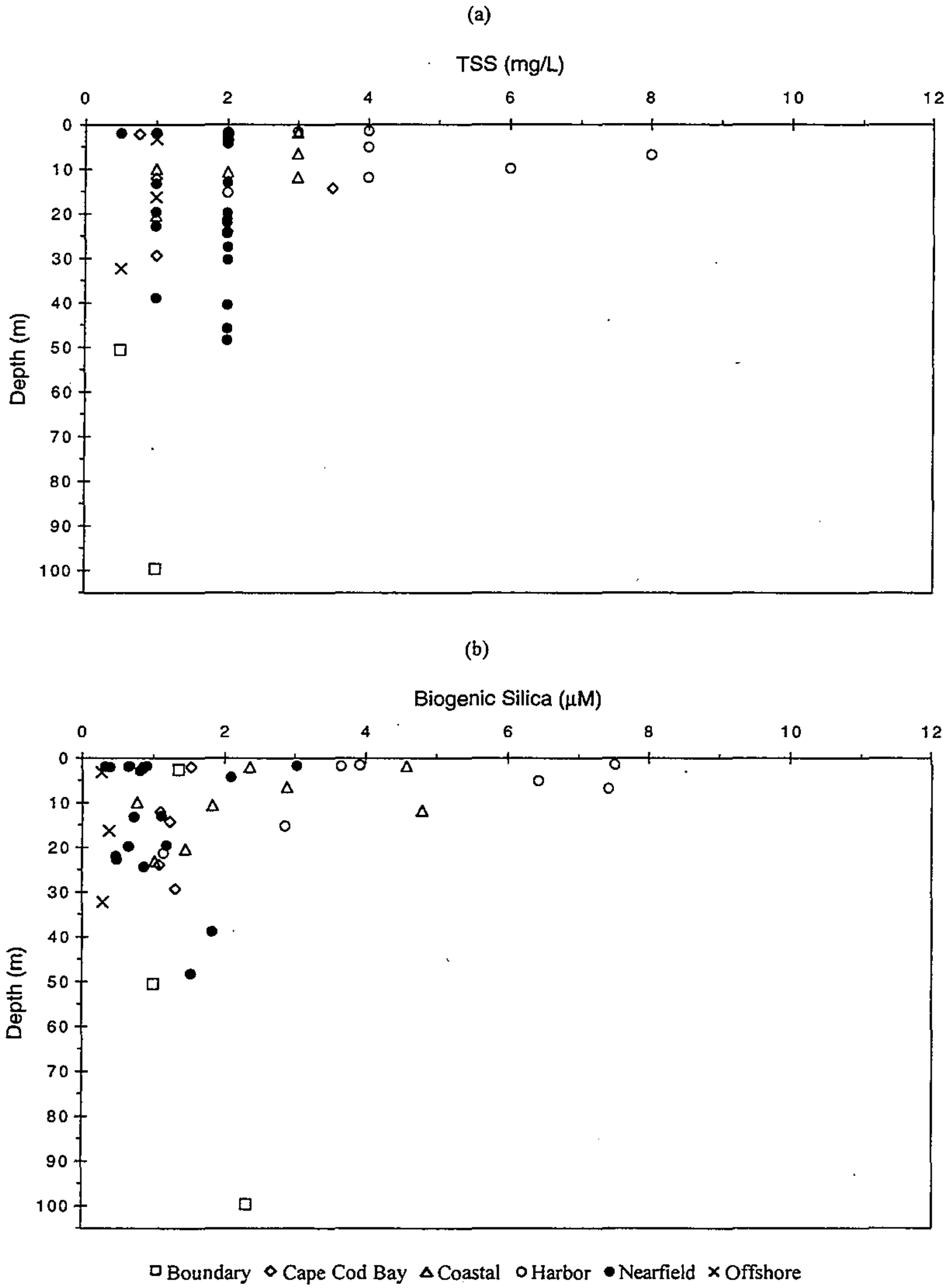


FIGURE 4-49
Depth vs. nutrient plots for farfield survey W9604, (Apr 96).

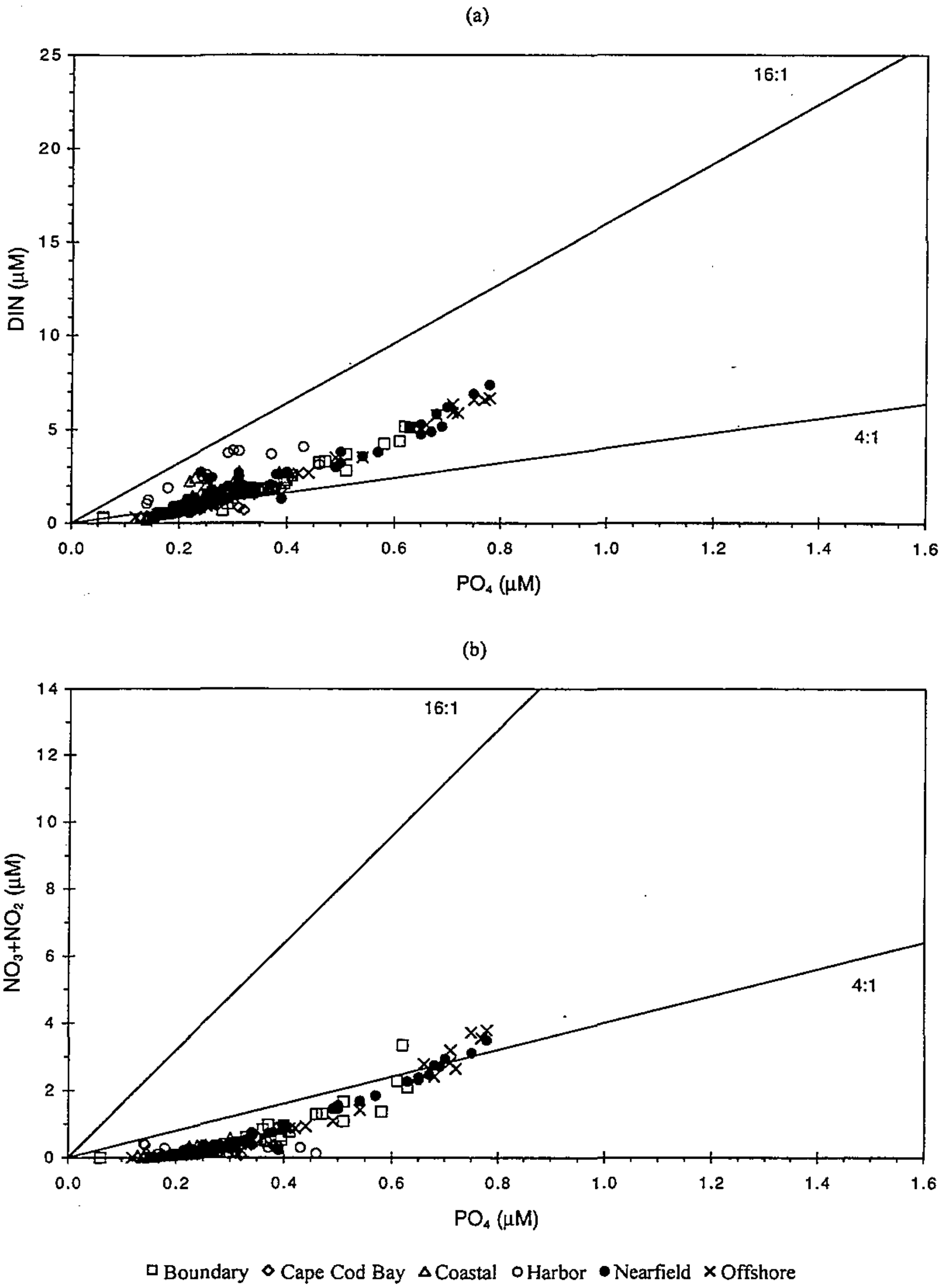


FIGURE 4-50
Nutrient vs. nutrient plots for farfield survey W9604, (Apr 96).

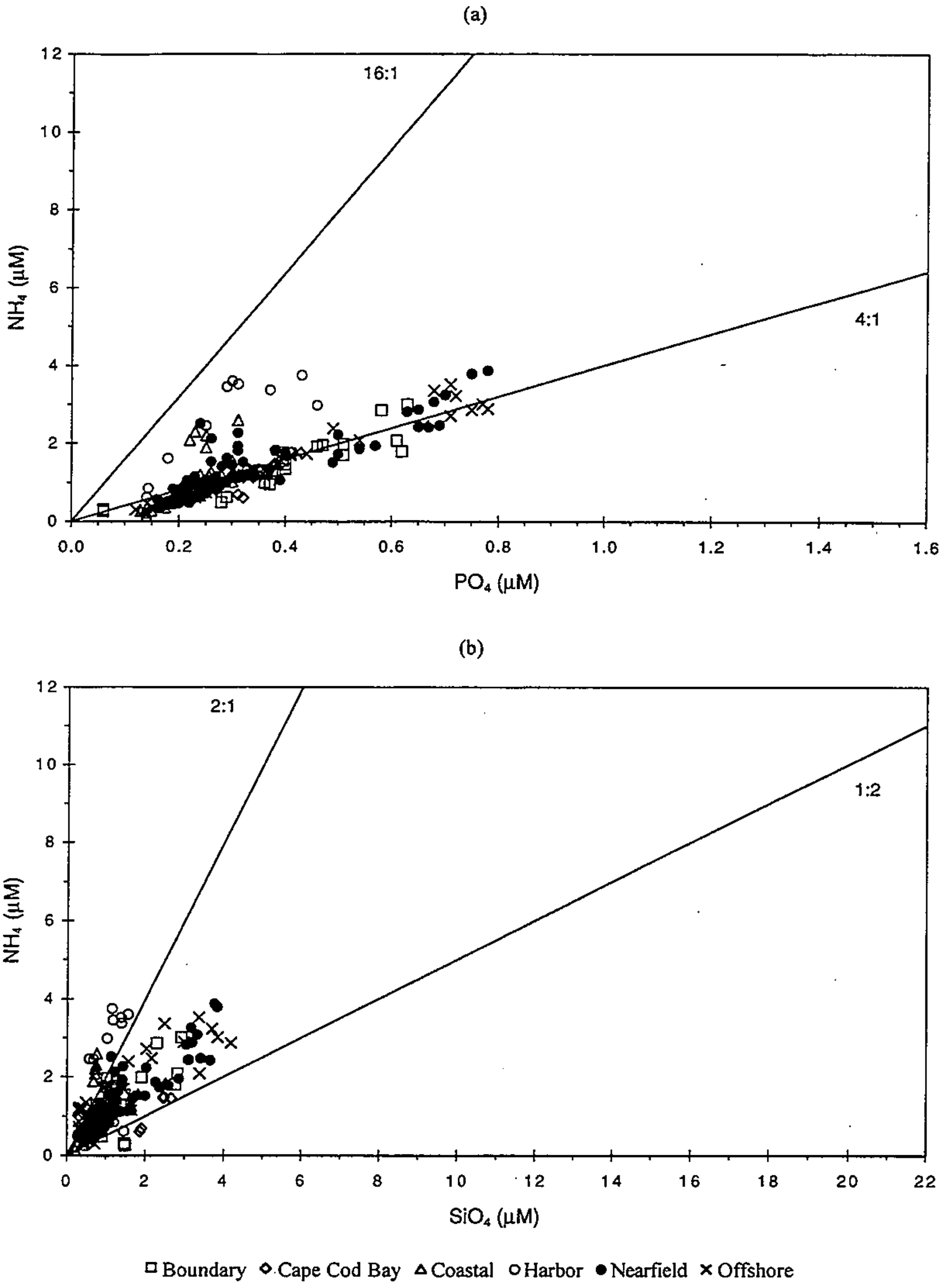


FIGURE 4-51
Nutrient vs. nutrient plots for farfield survey W9604, (Apr 96).

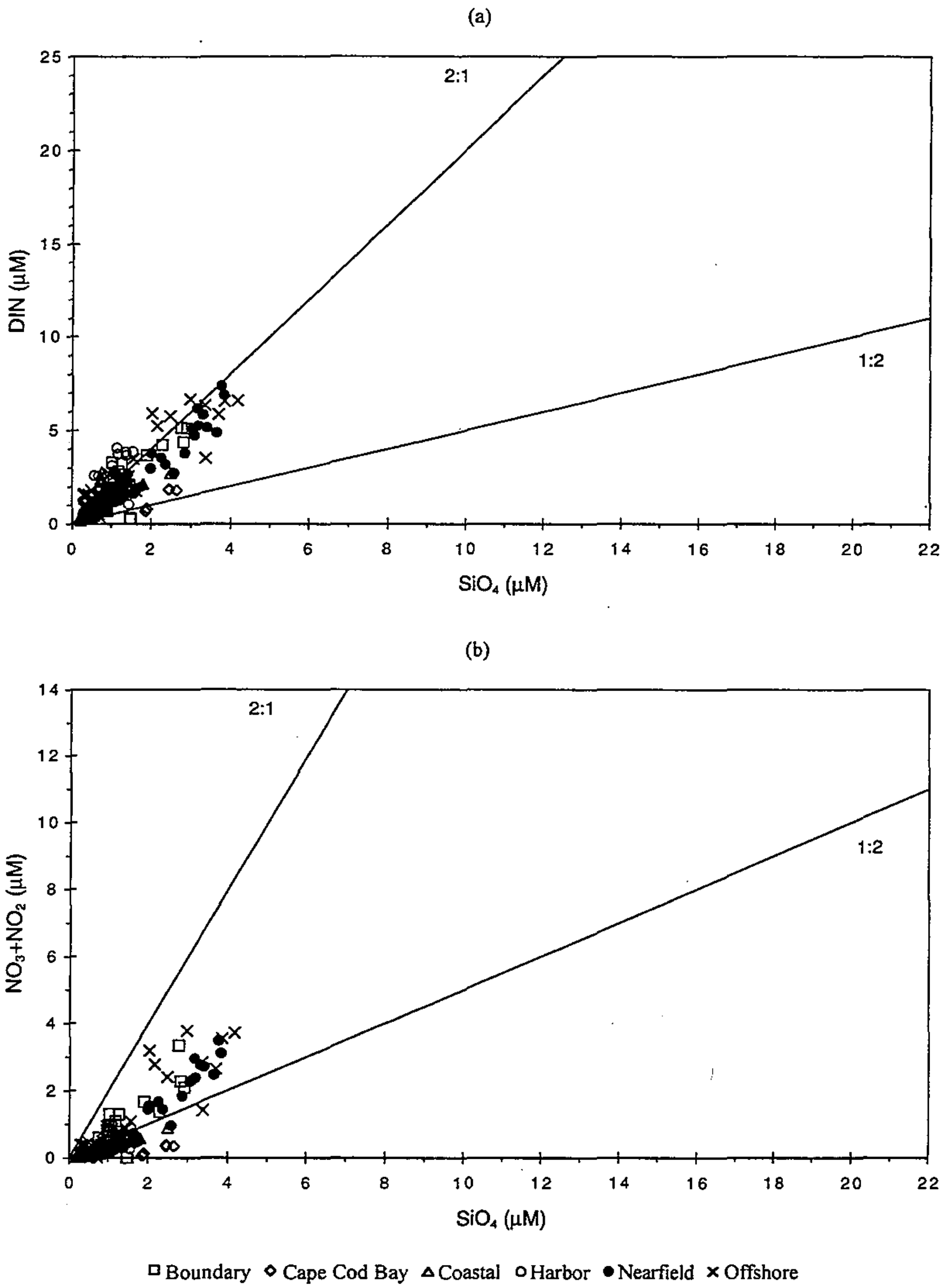


FIGURE 4-52
Nutrient vs. nutrient plots for farfield survey W9604, (Apr 96).

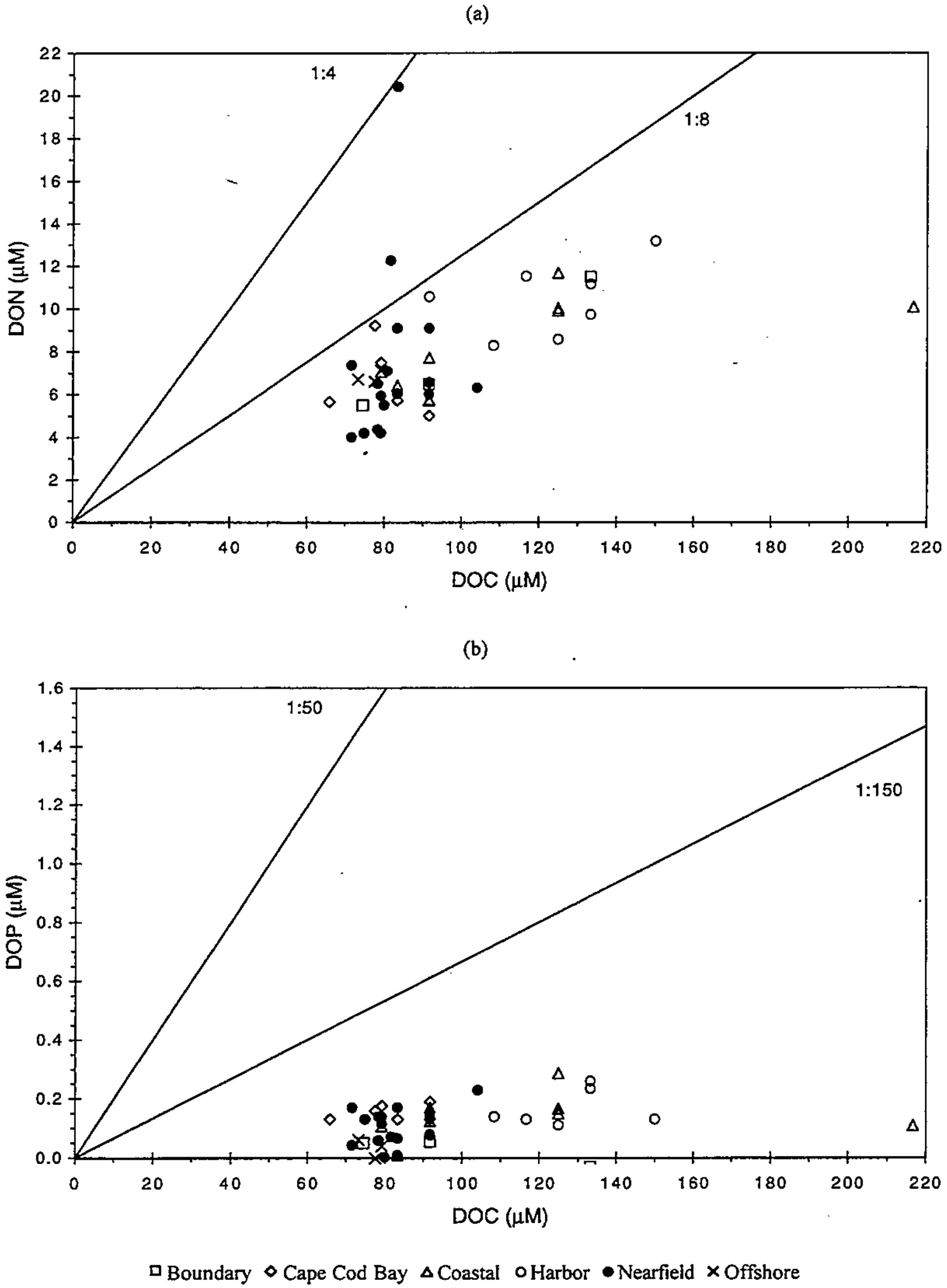


FIGURE 4-53
Nutrient vs. nutrient plots for farfield survey W9604, (Apr 96).

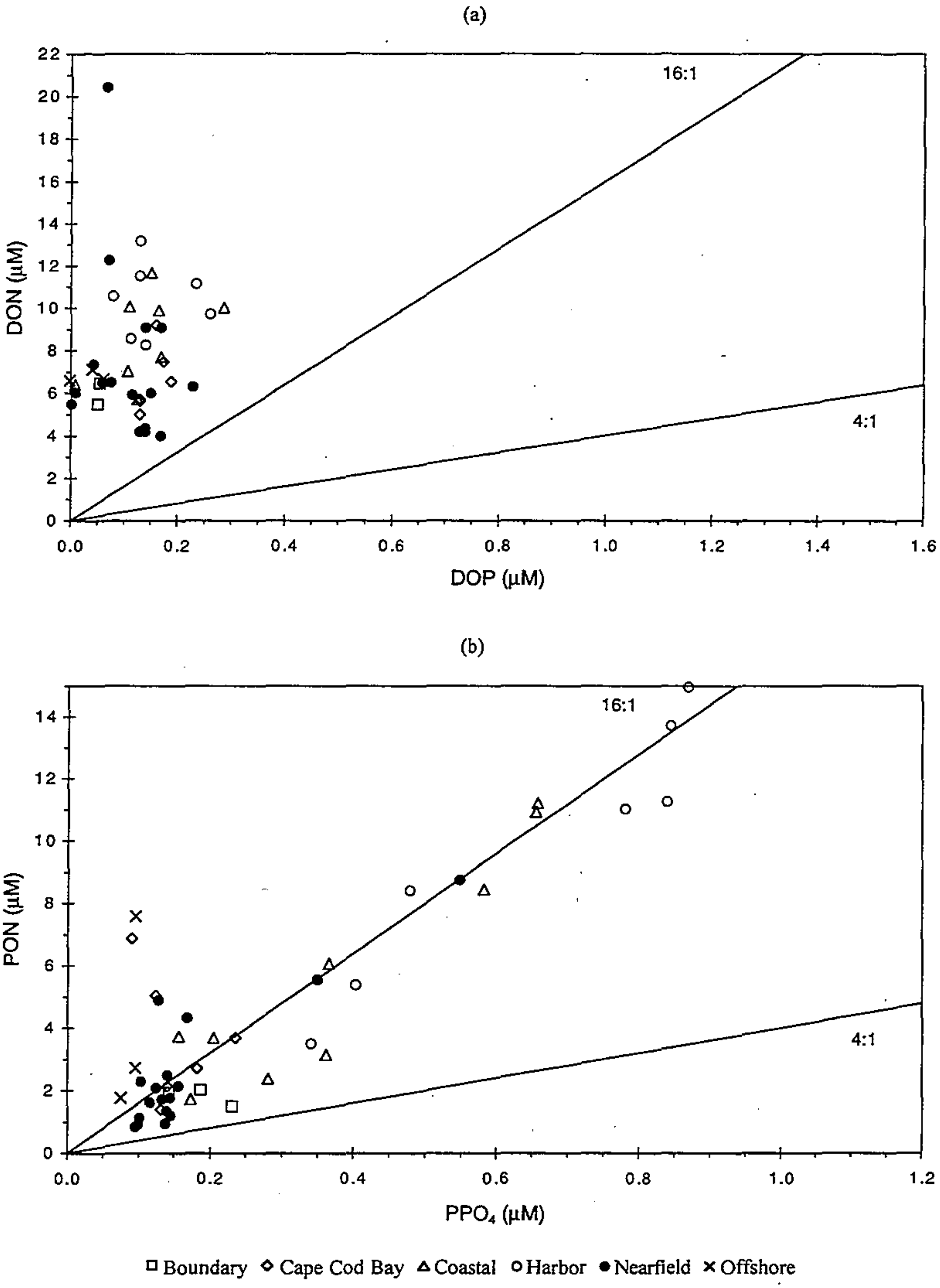


FIGURE 4-54

Nutrient vs. nutrient plots for farfield survey W9604, (Apr 96).

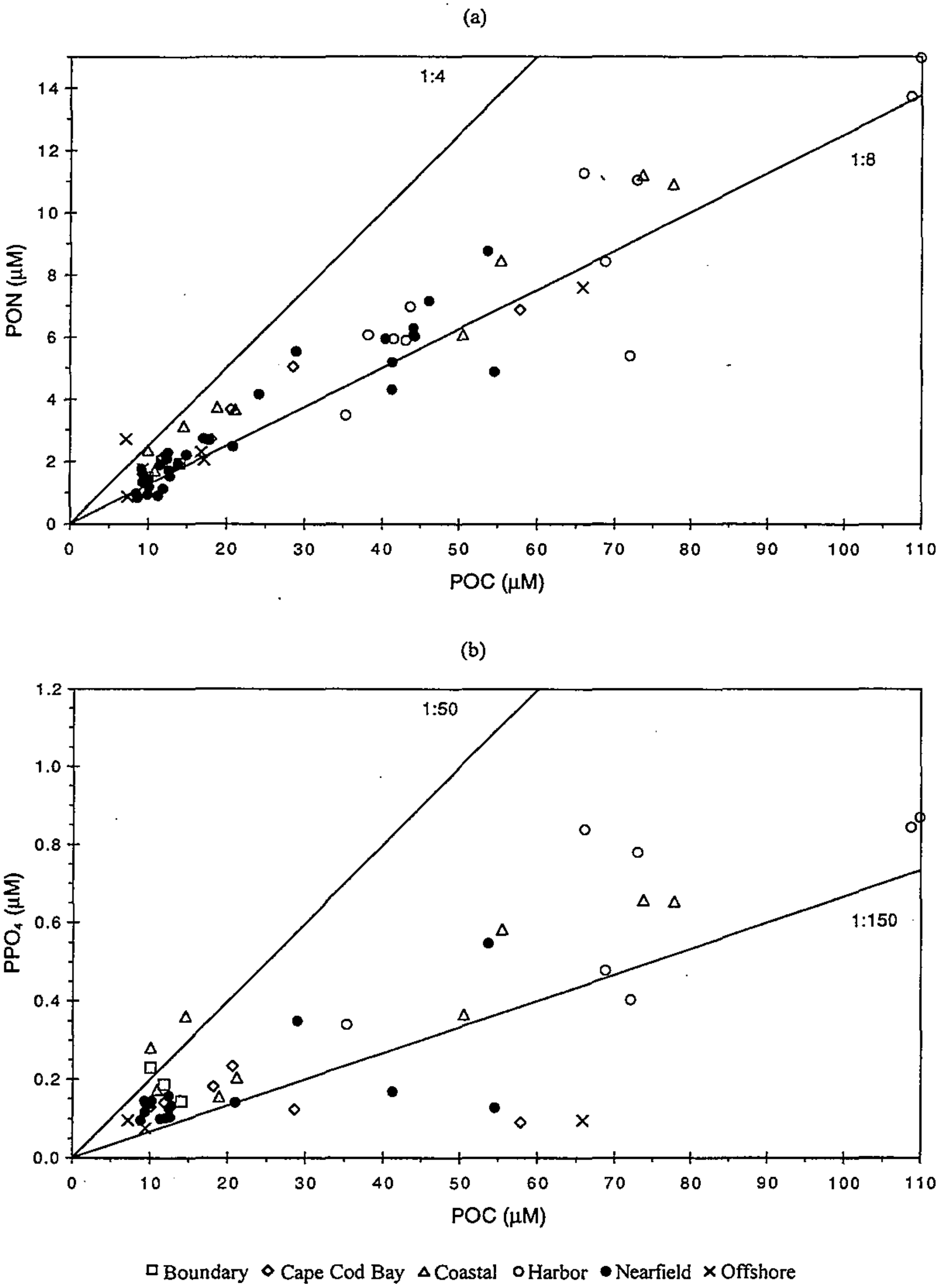


FIGURE 4-55
Nutrient vs. nutrient plots for farfield survey W9604, (Apr 96).

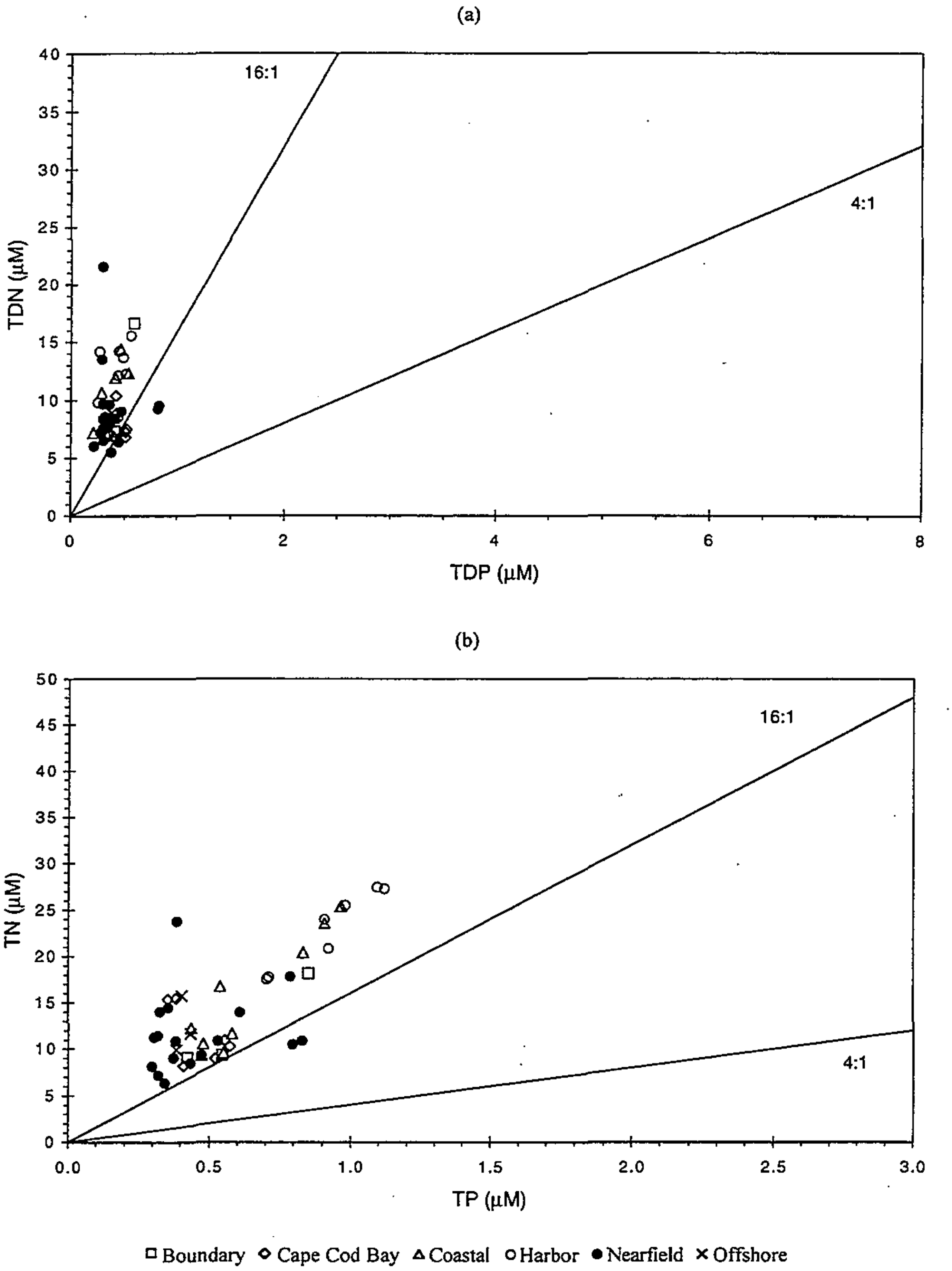


FIGURE 4-56
Nutrient vs. nutrient plots for farfield survey W9604, (Apr 96).

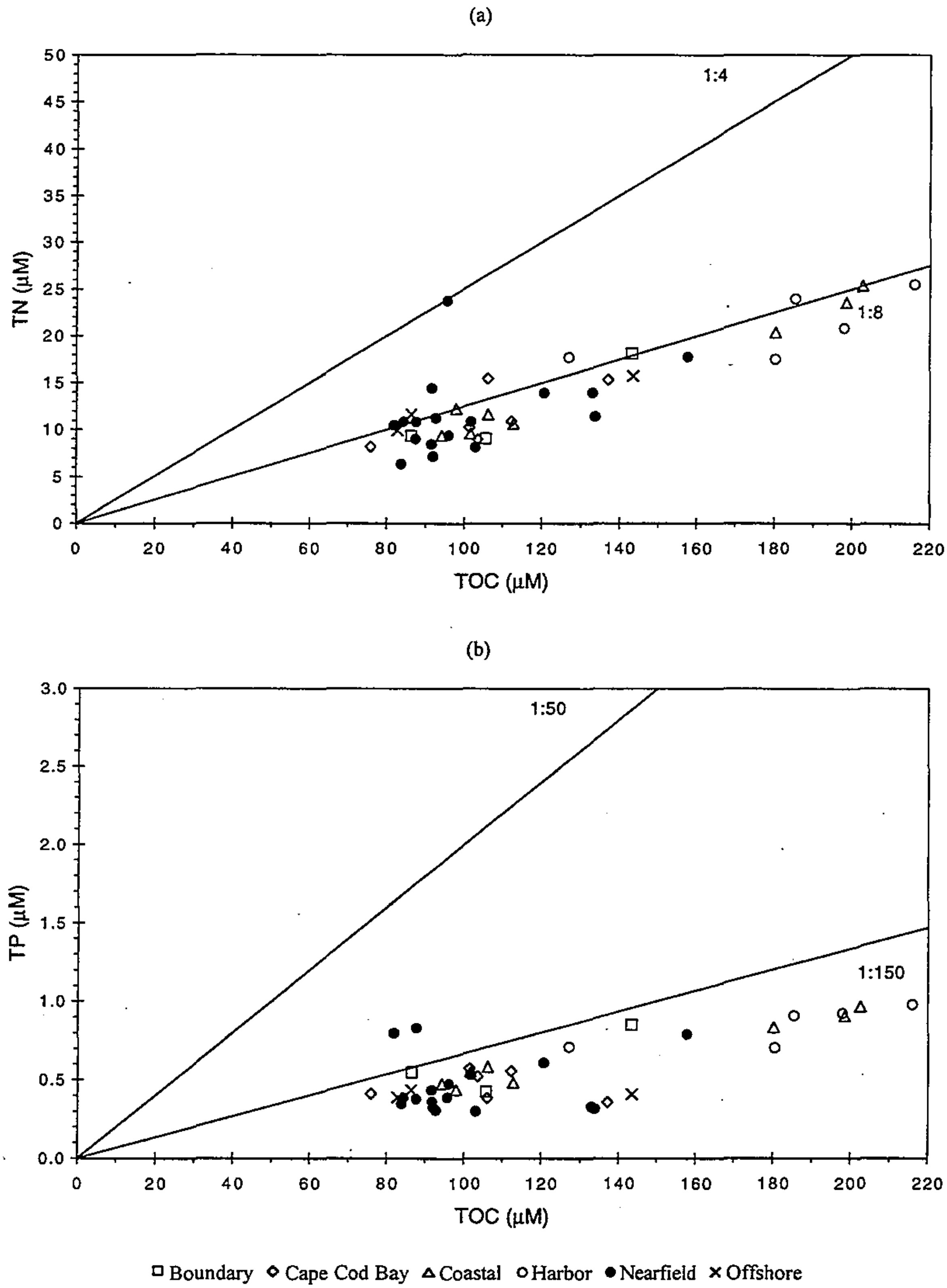


FIGURE 4-57
Nutrient vs. nutrient plots for farfield survey W9604, (Apr 96).

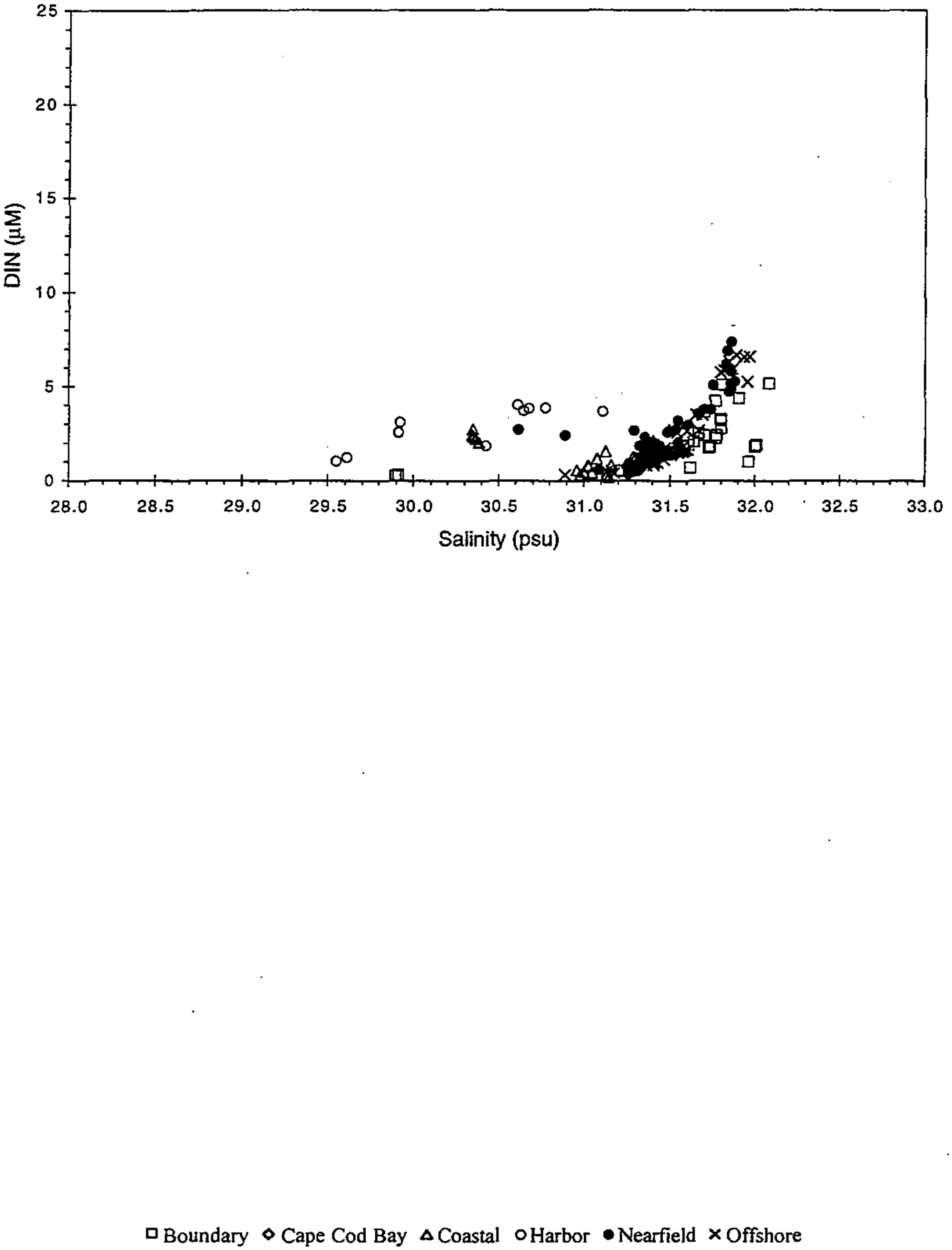


FIGURE 4-58
Nutrient vs. salinity plots for farfield survey W9604, (Apr 96).

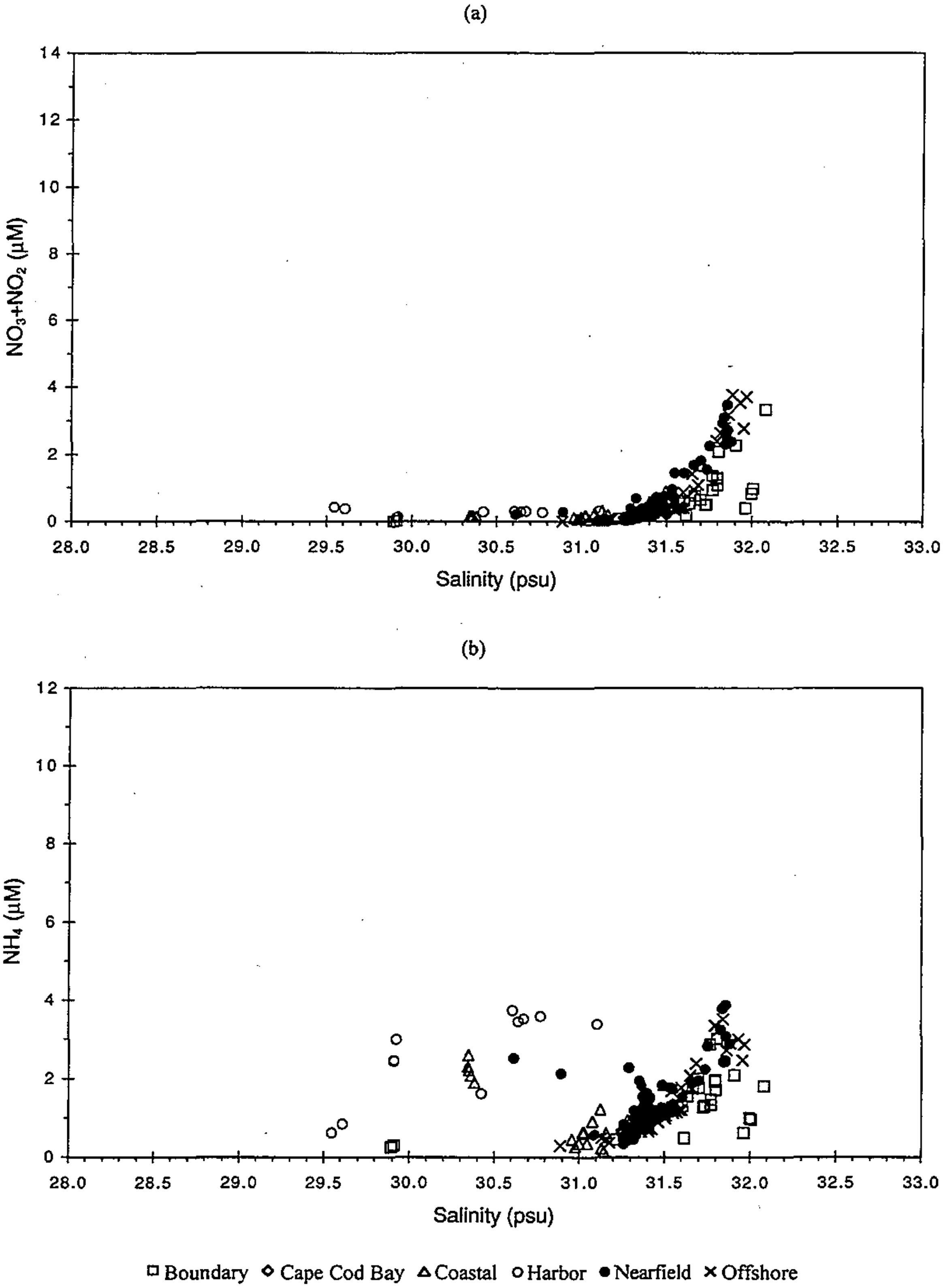


FIGURE 4-59
Nutrient vs. salinity plots for farfield survey W9604, (Apr 96).

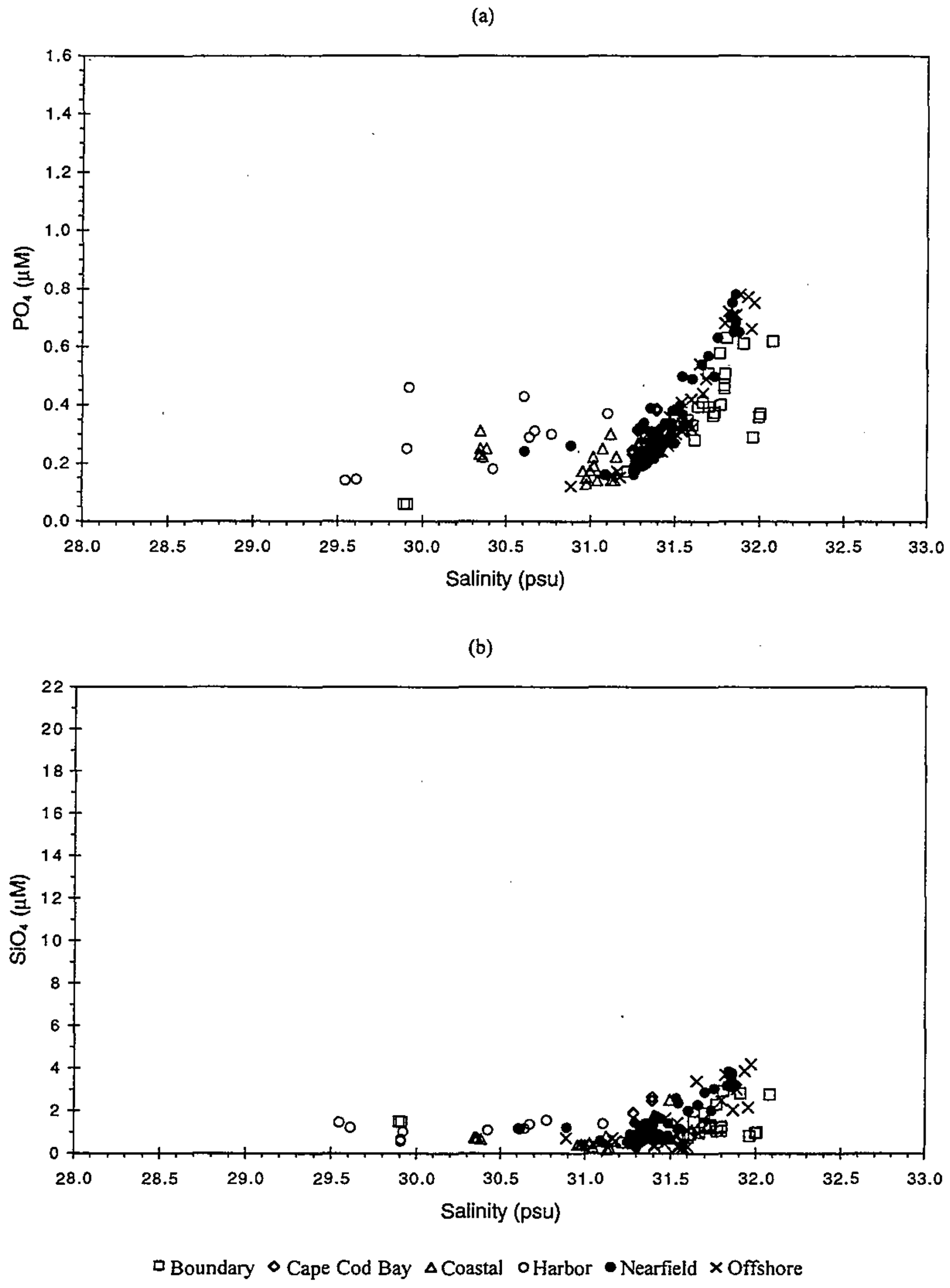


FIGURE 4-60

Nutrient vs. salinity plots for farfield survey W9604, (Apr 96).

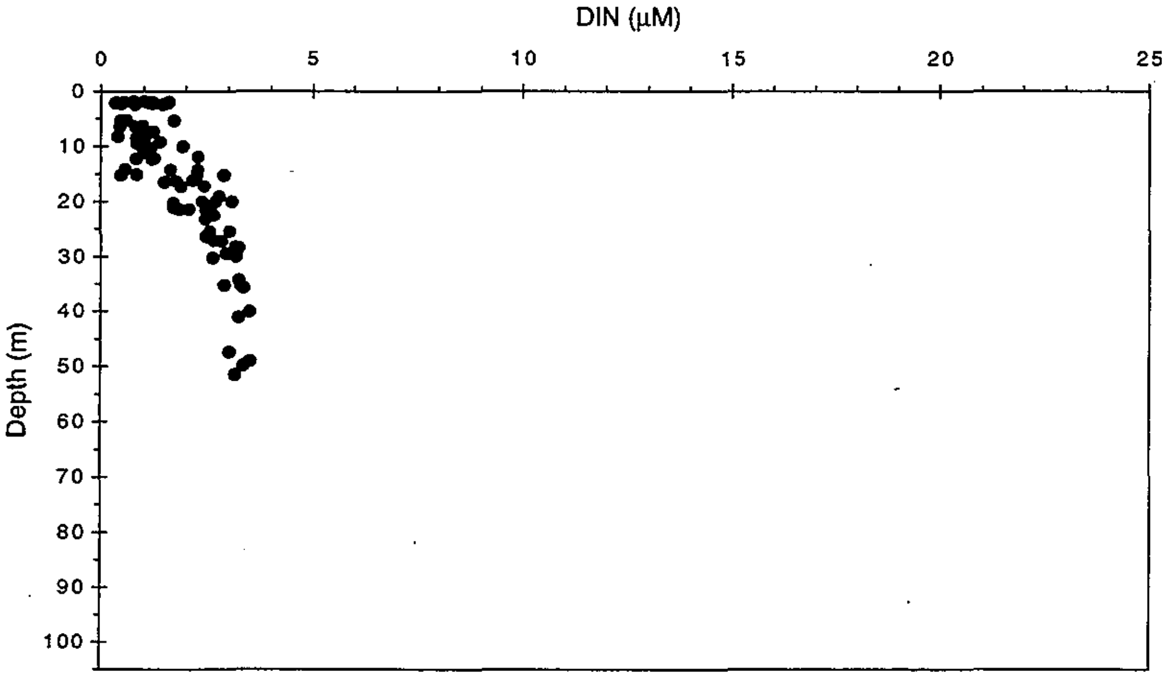
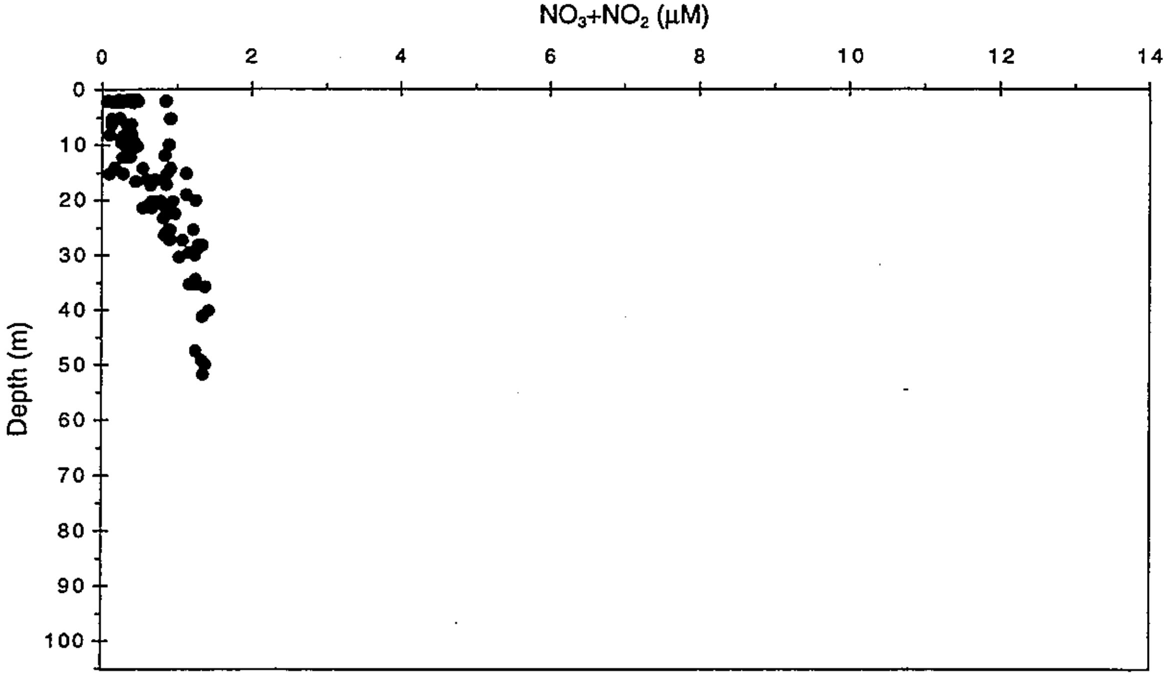


FIGURE 4-61
Depth vs. nutrient plots for nearfield survey W9605, (Apr 96).

(a)



(b)

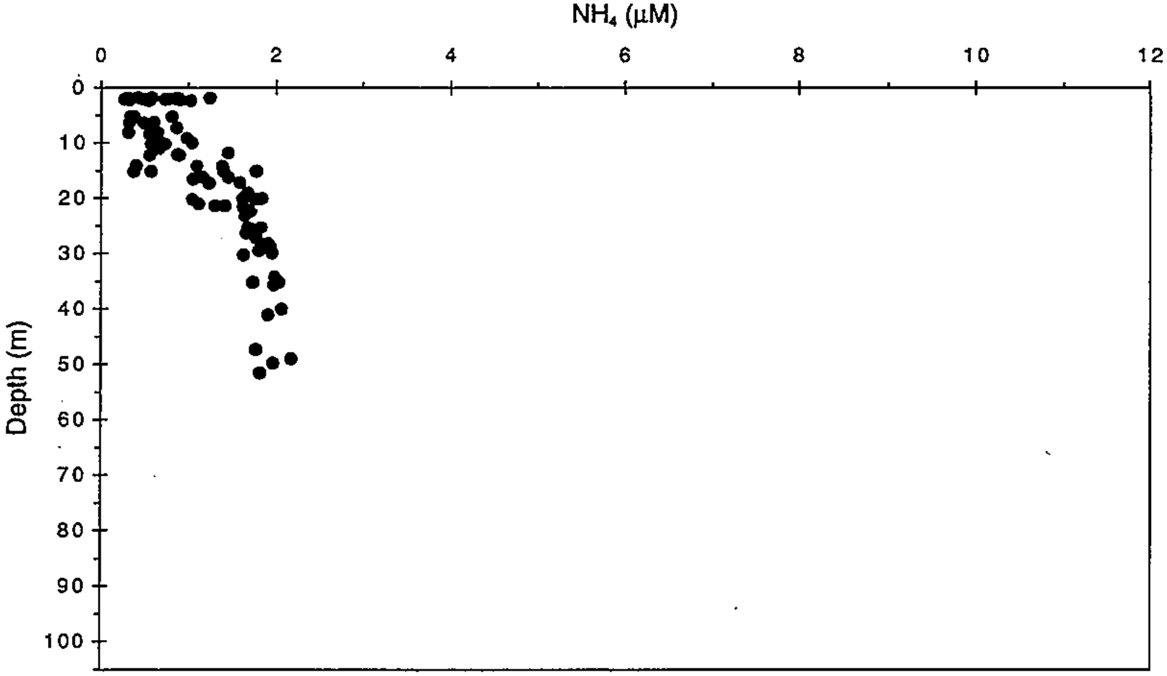


FIGURE 4-62
Depth vs. nutrient plots for nearfield survey W9605, (Apr 96).

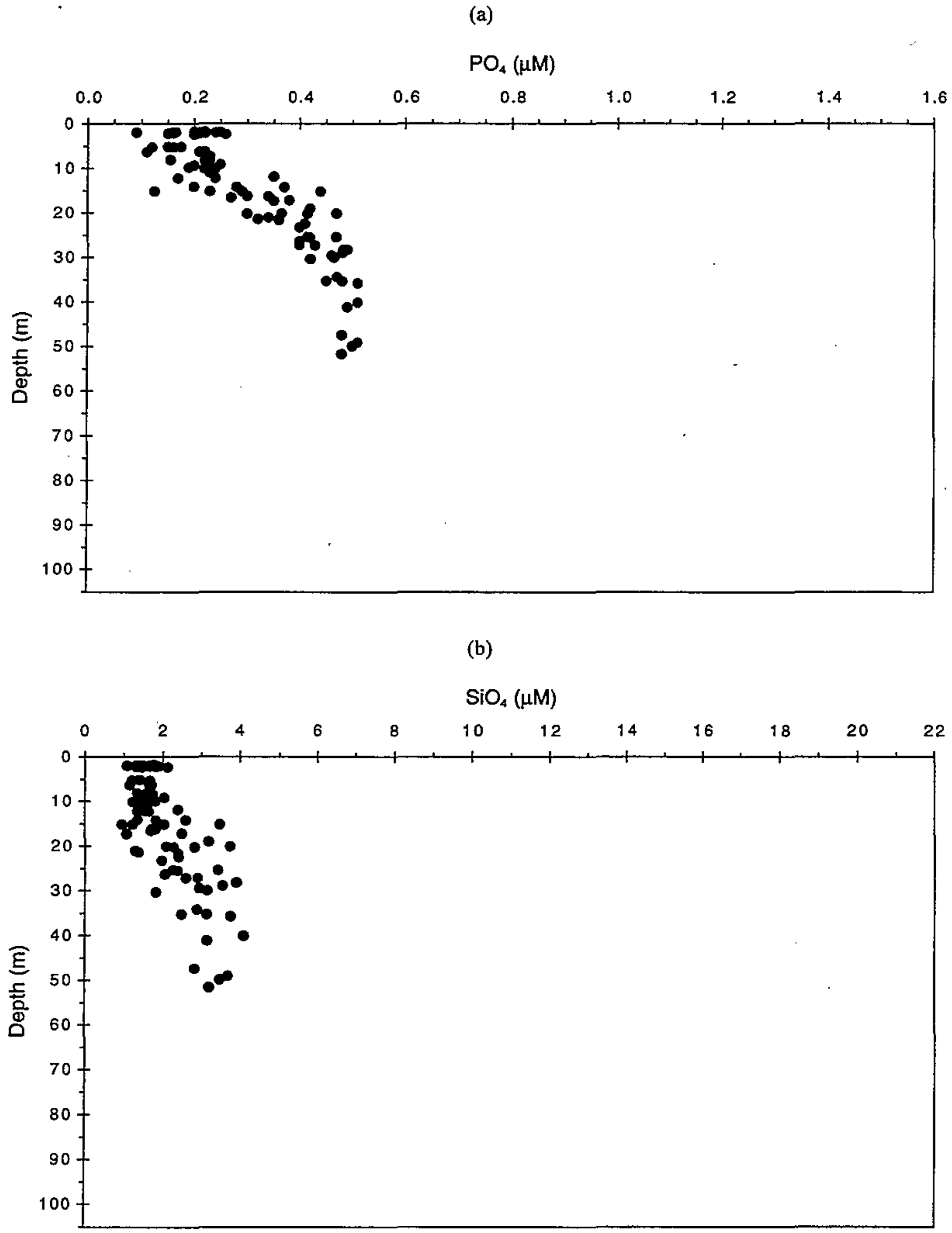


FIGURE 4-63
Depth vs. nutrient plots for nearfield survey W9605, (Apr 96).

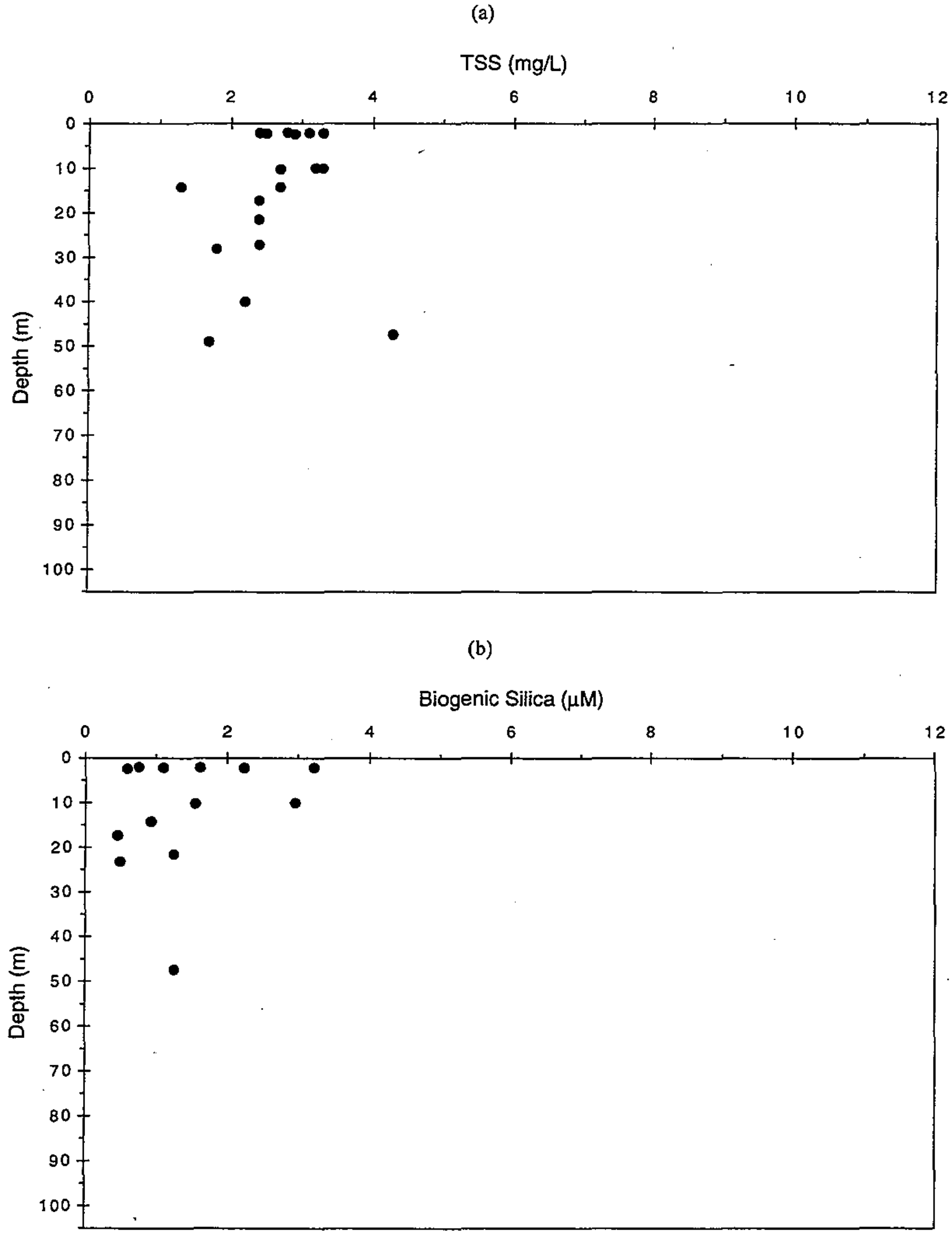


FIGURE 4-64

Depth vs. nutrient plots for nearfield survey W9605, (Apr 96).

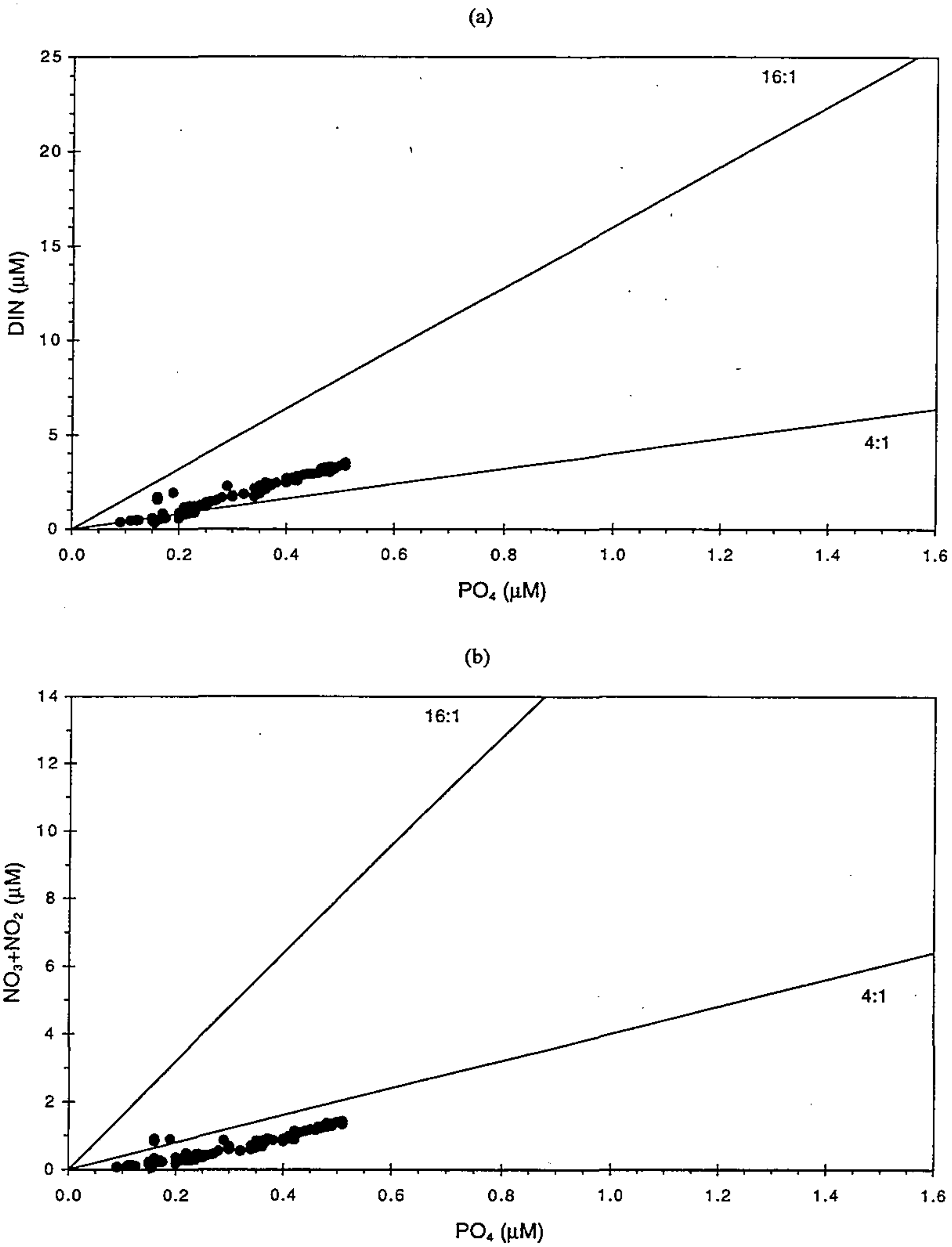


FIGURE 4-65

Nutrient vs. nutrient plots for nearfield survey W9605, (Apr 96).

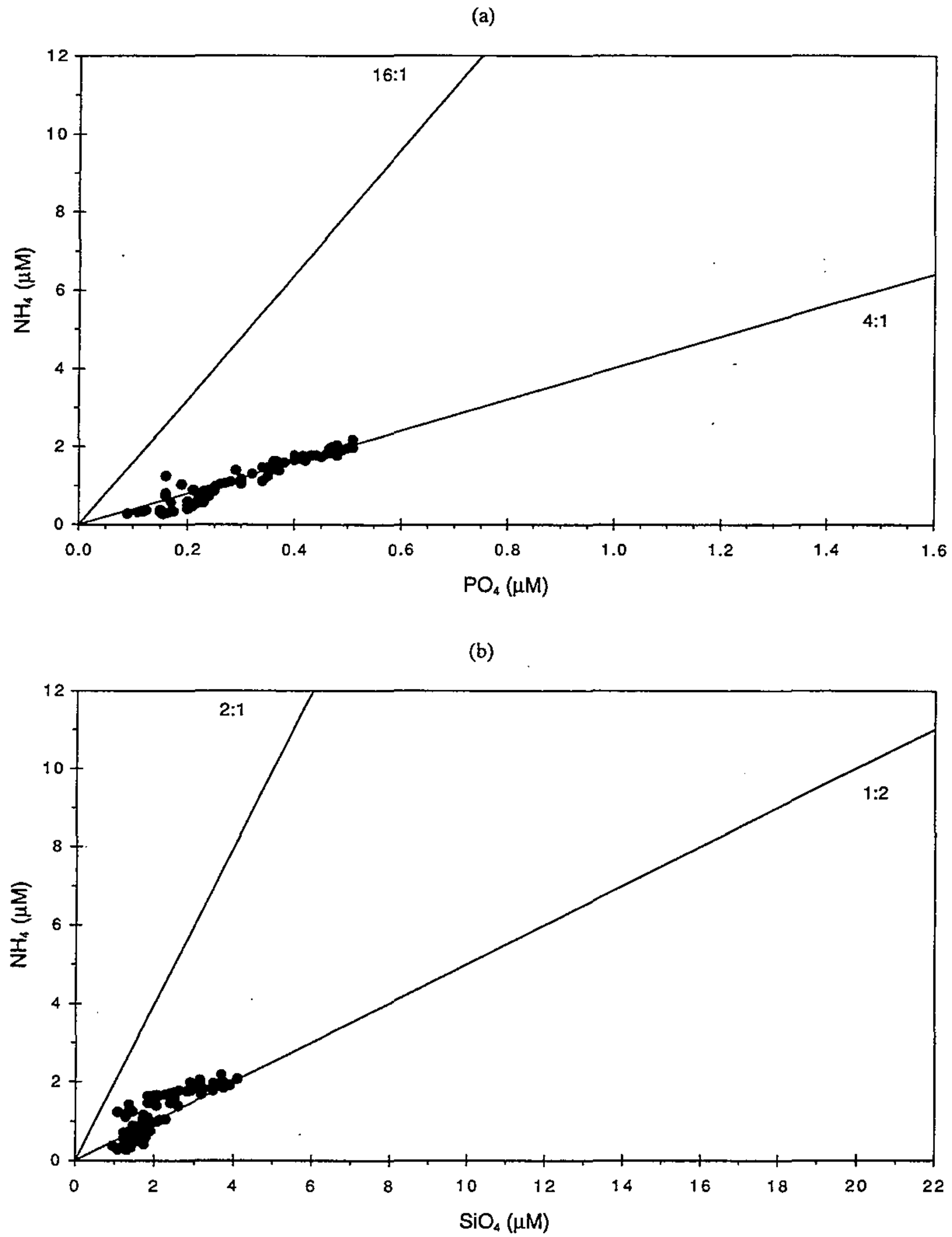


FIGURE 4-66
Nutrient vs. nutrient plots for nearfield survey W9605, (Apr 96).

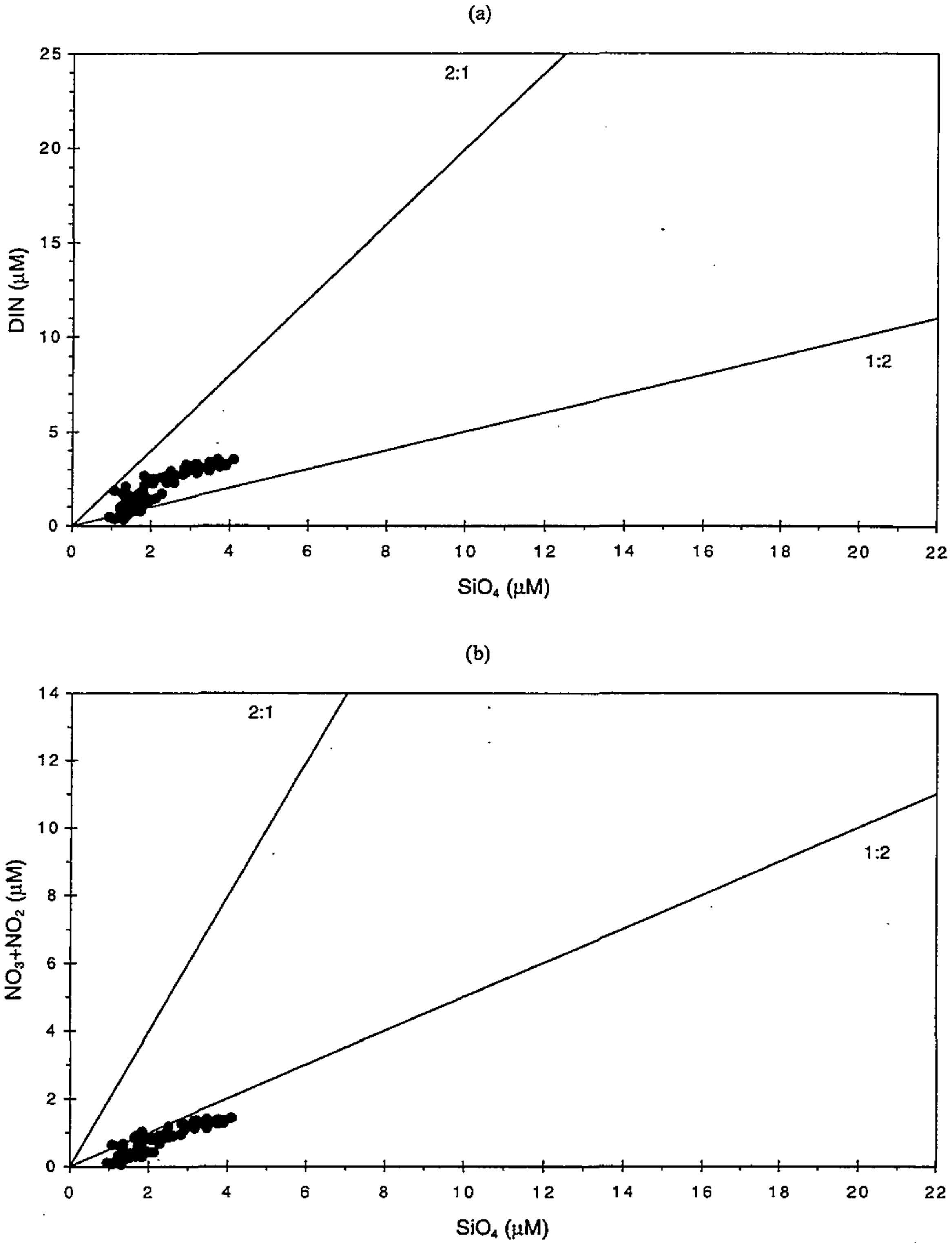
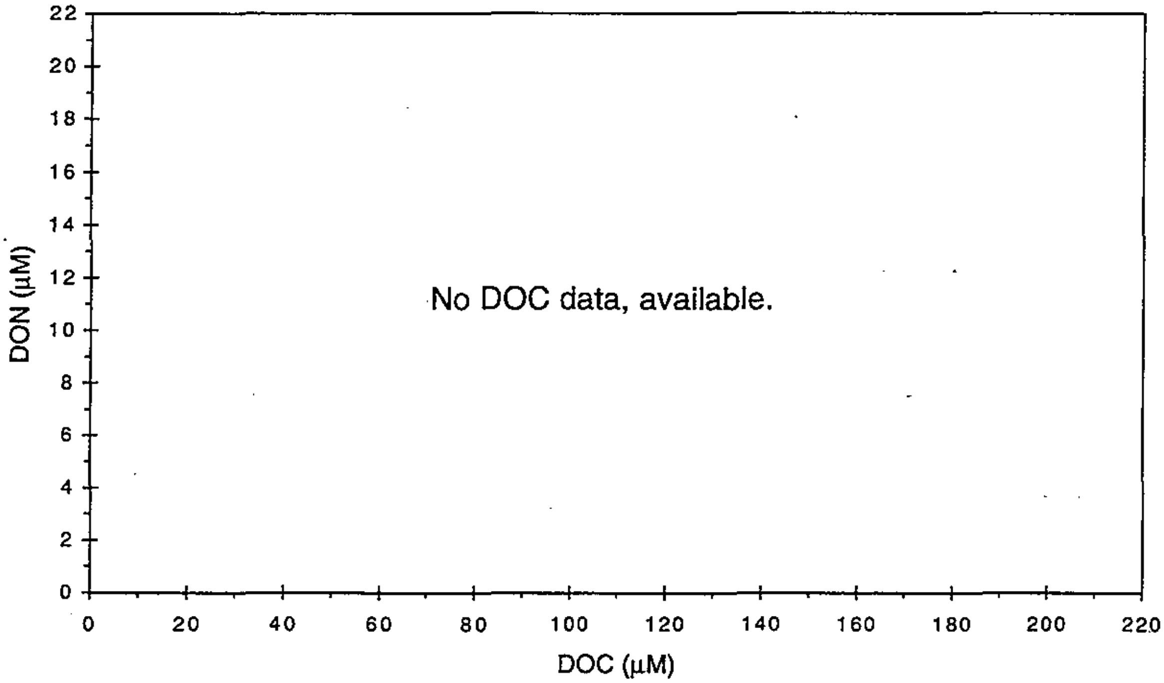


FIGURE 4-67
Nutrient vs. nutrient plots for nearfield survey W9605, (Apr 96).

(a)



(b)

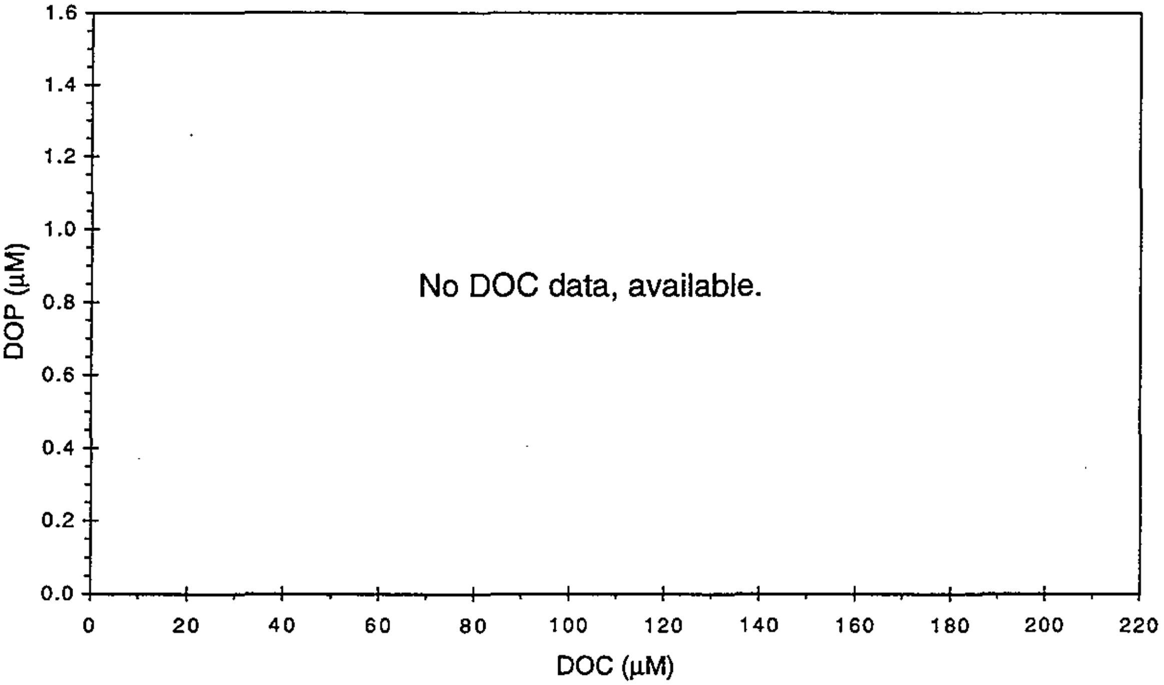


FIGURE 4-68
Nutrient vs. nutrient plots for nearfield survey W9605, (Apr 96).

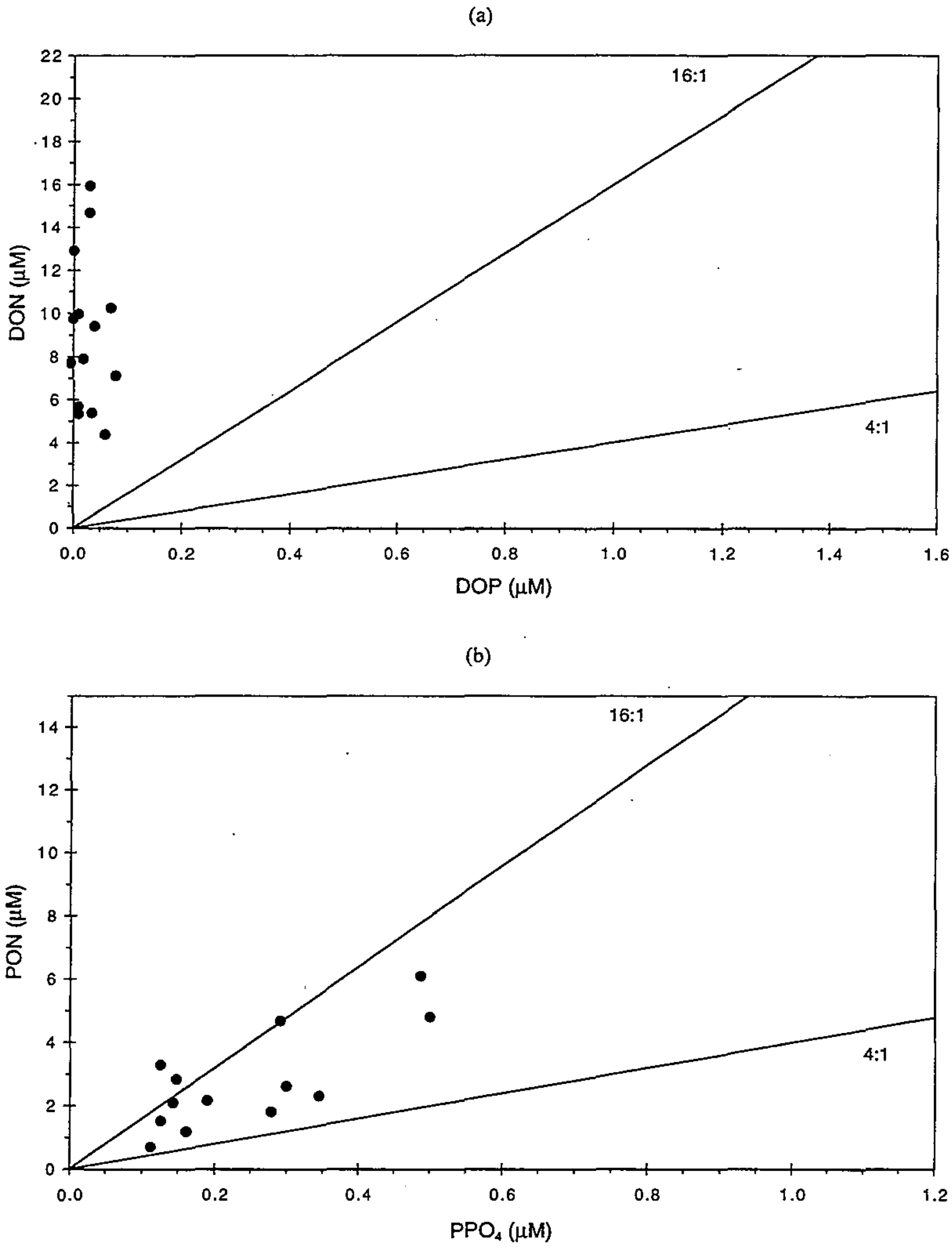


FIGURE 4-69
Nutrient vs. nutrient plots for nearfield survey W9605, (Apr 96).

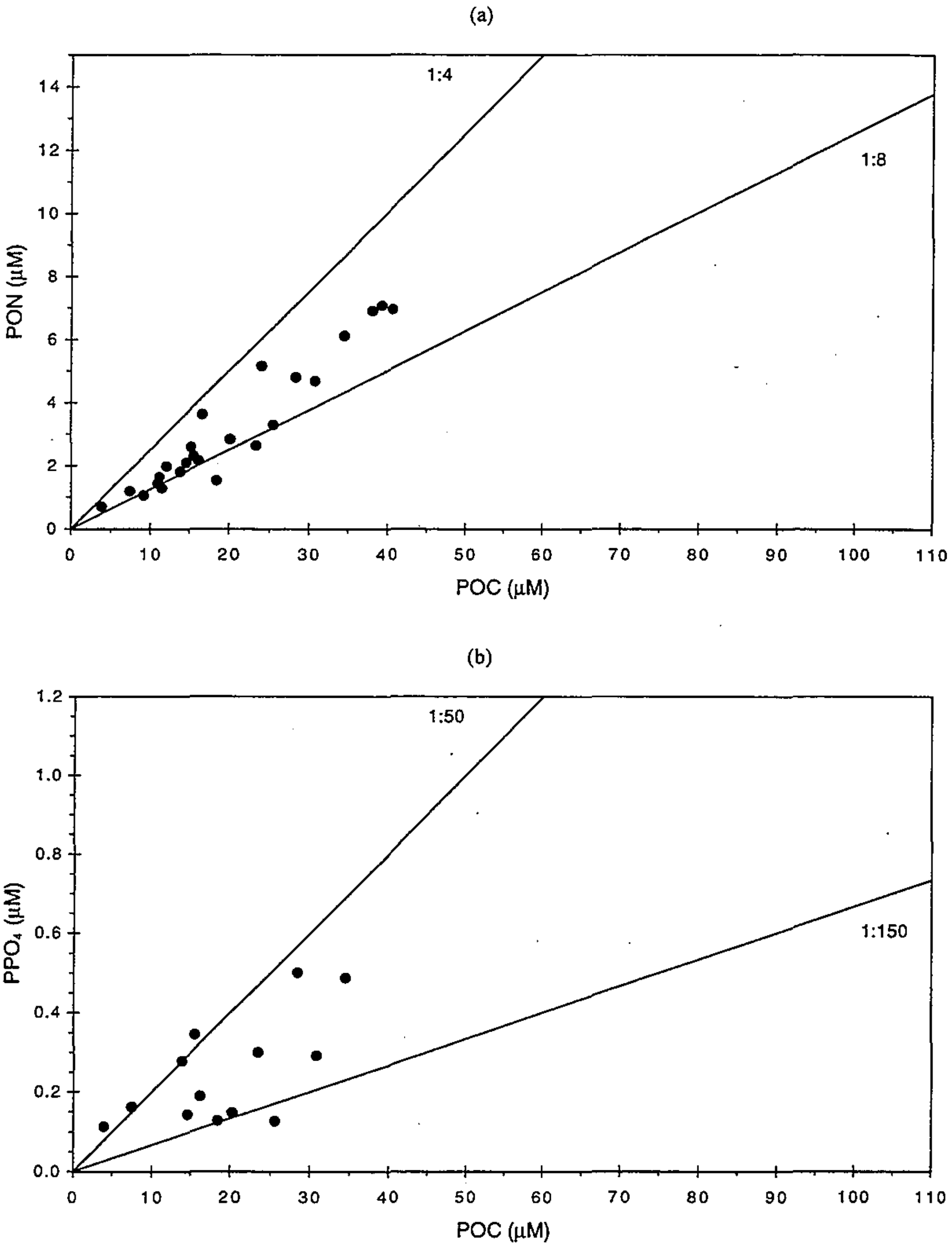


FIGURE 4-70
Nutrient vs. nutrient plots for nearfield survey W9605, (Apr 96).

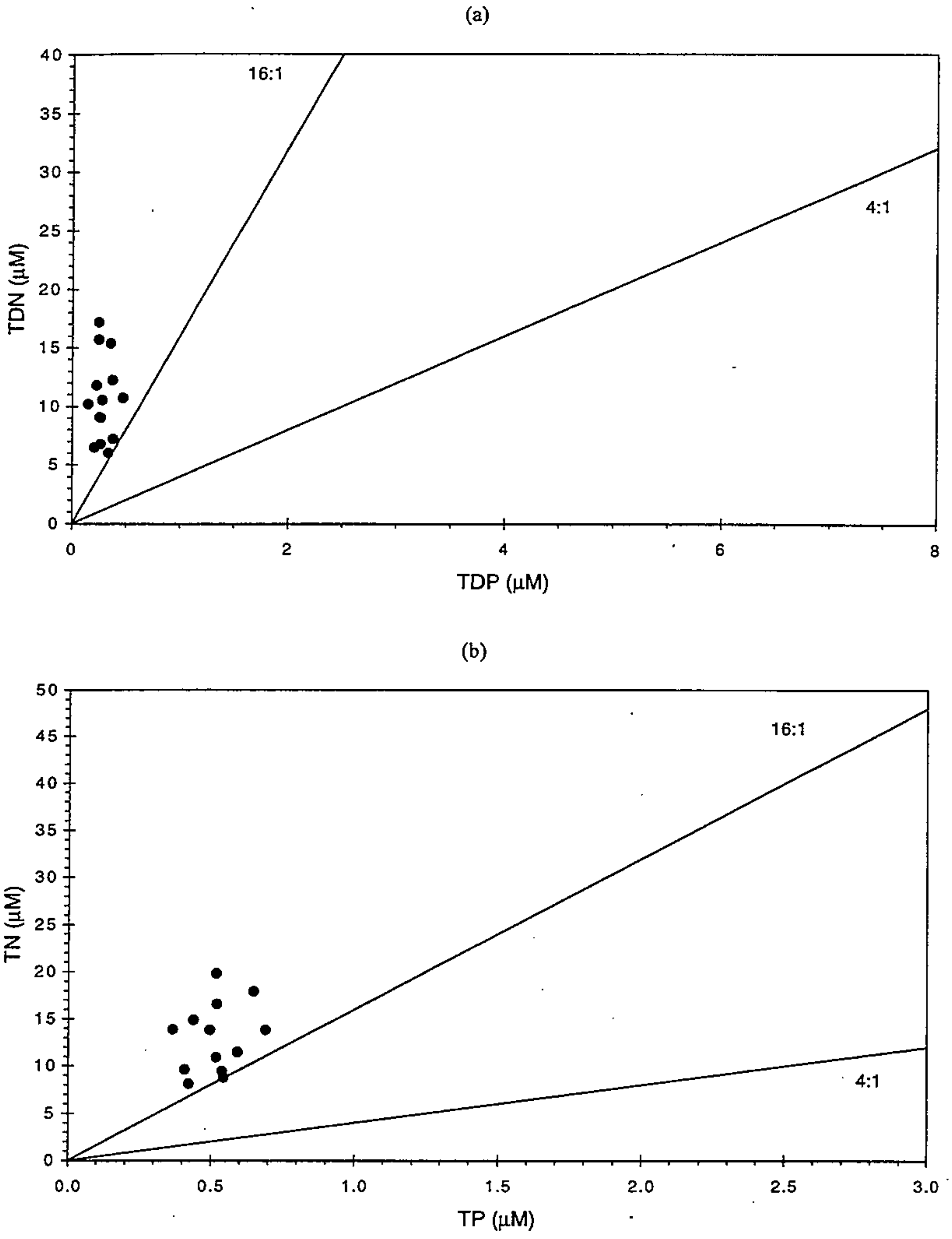


FIGURE 4-71

Nutrient vs. nutrient plots for nearfield survey W9605, (Apr 96).

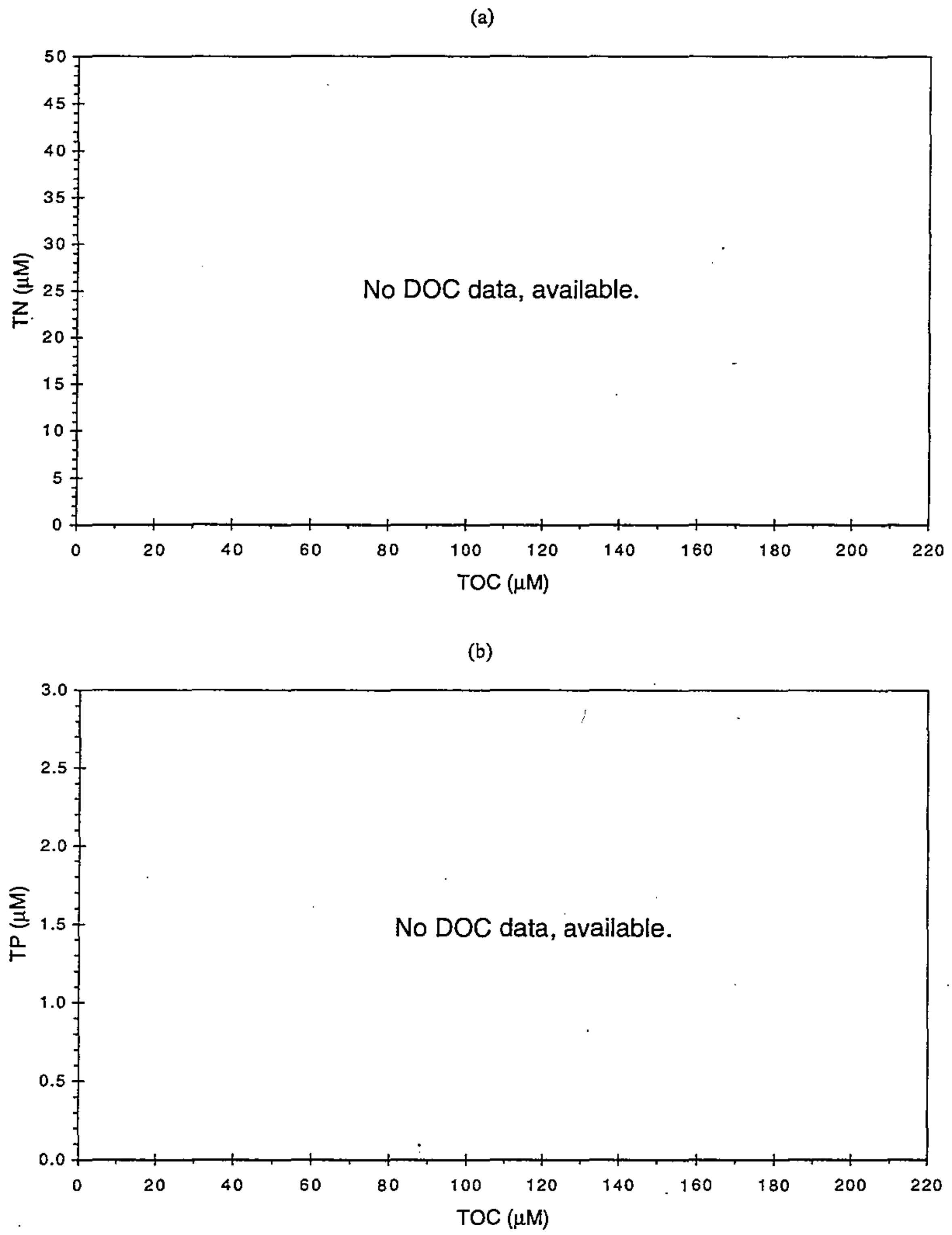


FIGURE 4-72
Nutrient vs. nutrient plots for nearfield survey W9605, (Apr 96).

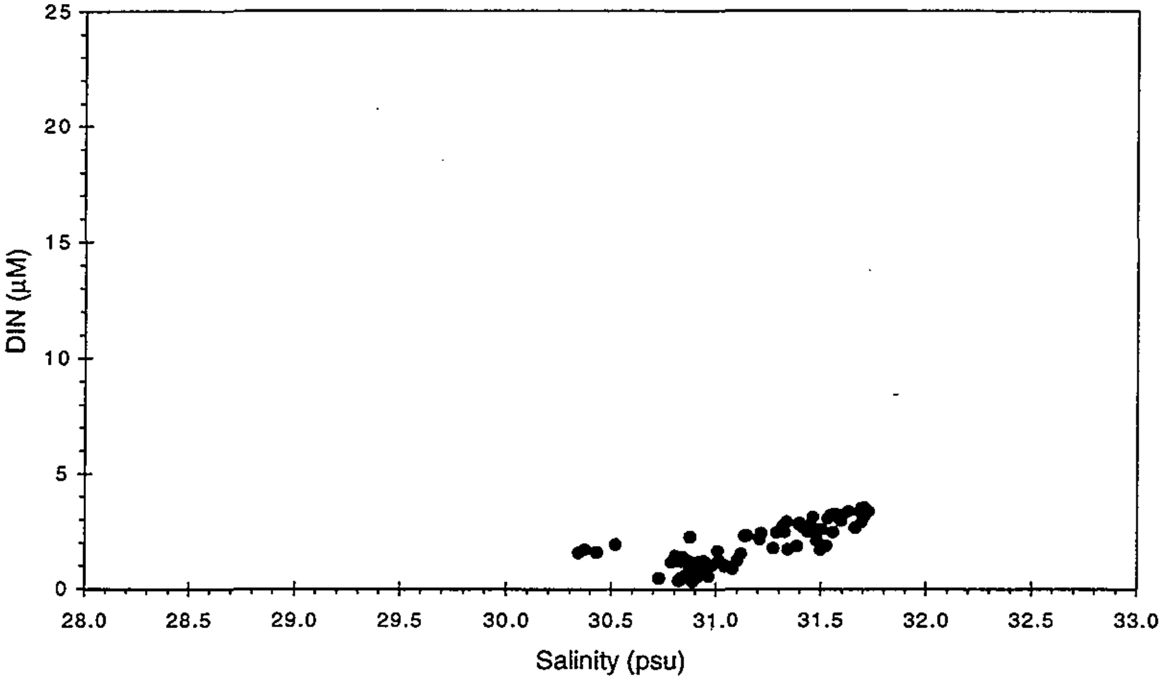


FIGURE 4-73
Nutrient vs. salinity plots for nearfield survey W9605, (Apr 96).

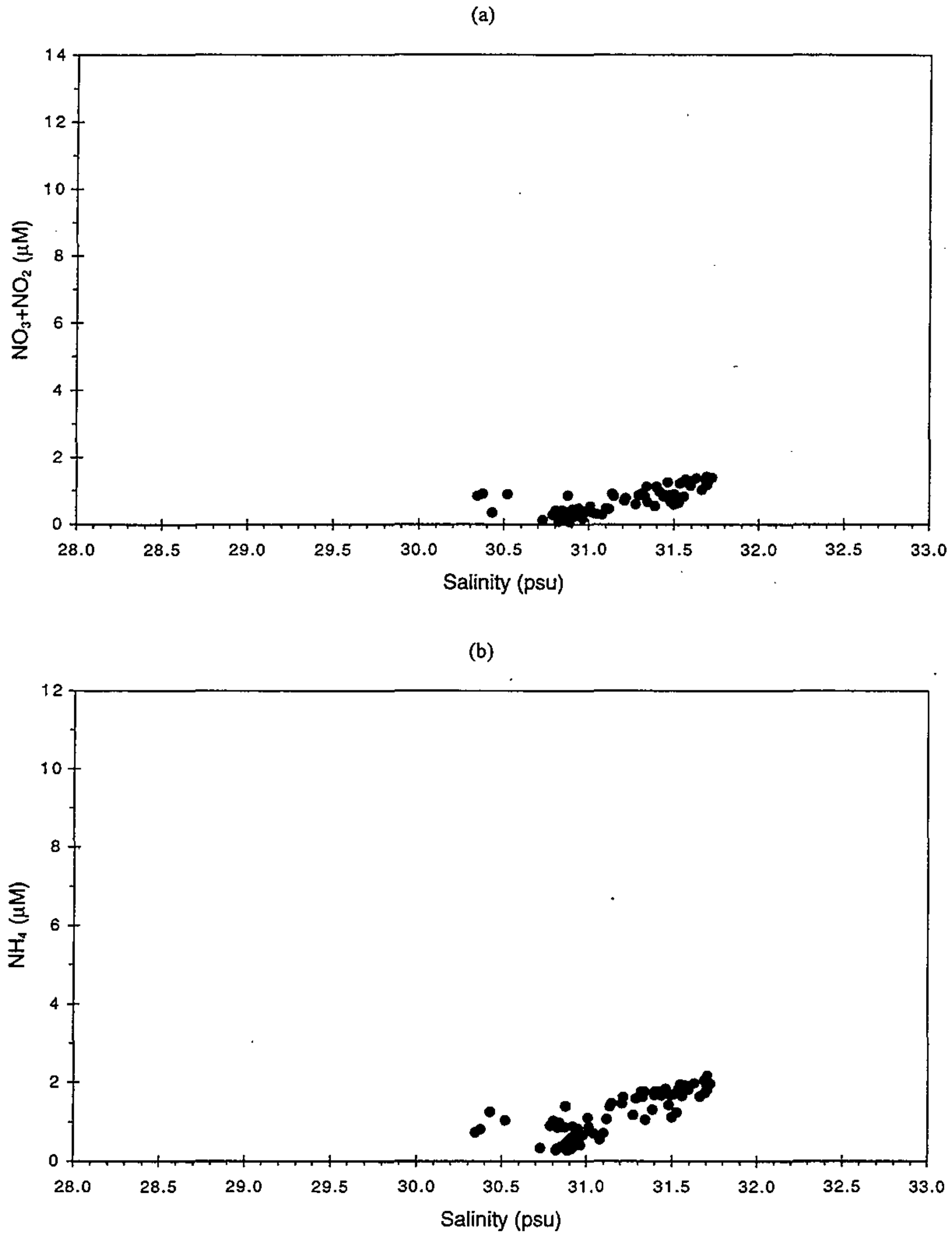


FIGURE 4-74
Nutrient vs. salinity plots for nearfield survey W9605, (Apr 96).

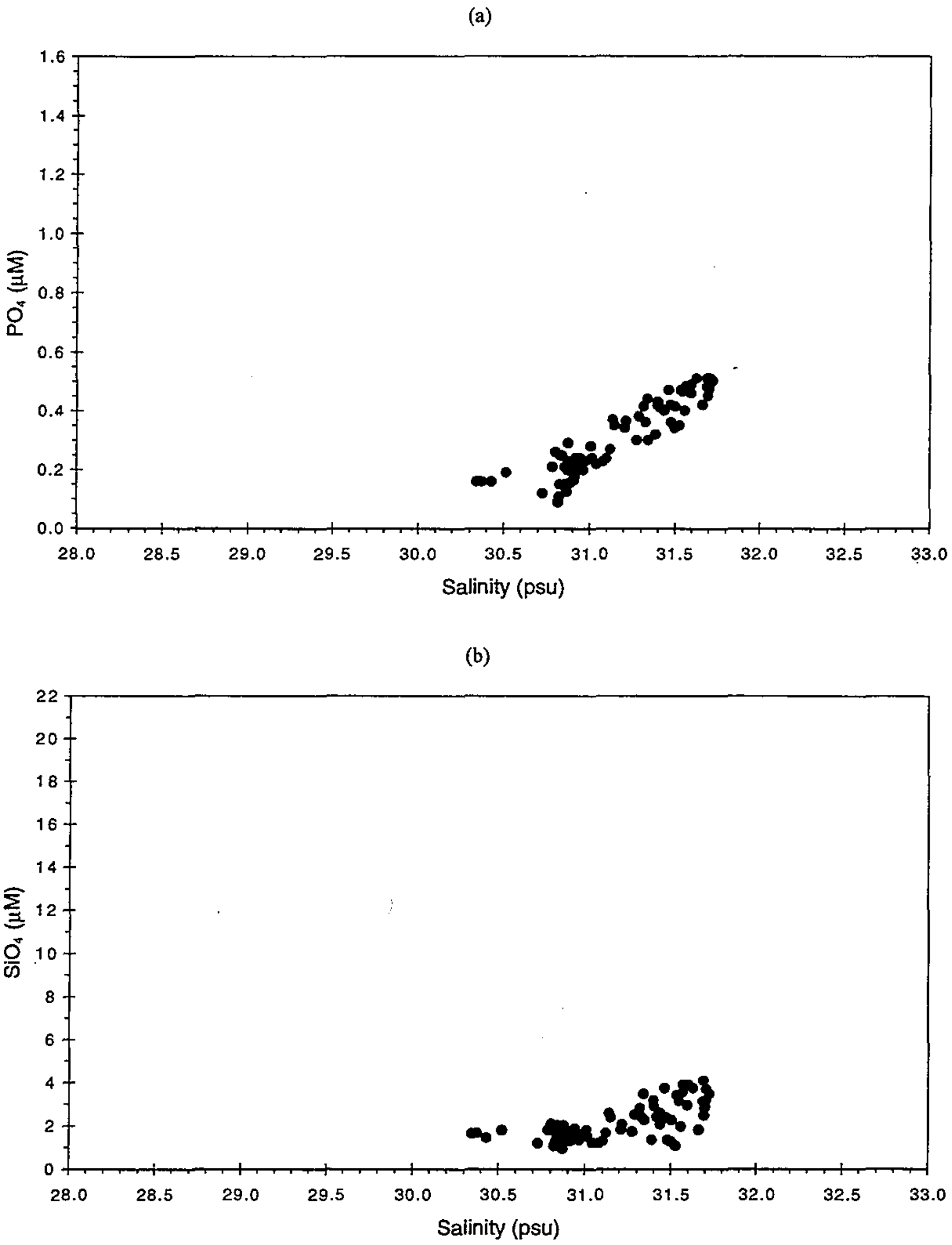


FIGURE 4-75
Nutrient vs. salinity plots for nearfield survey W9605, (Apr 96).

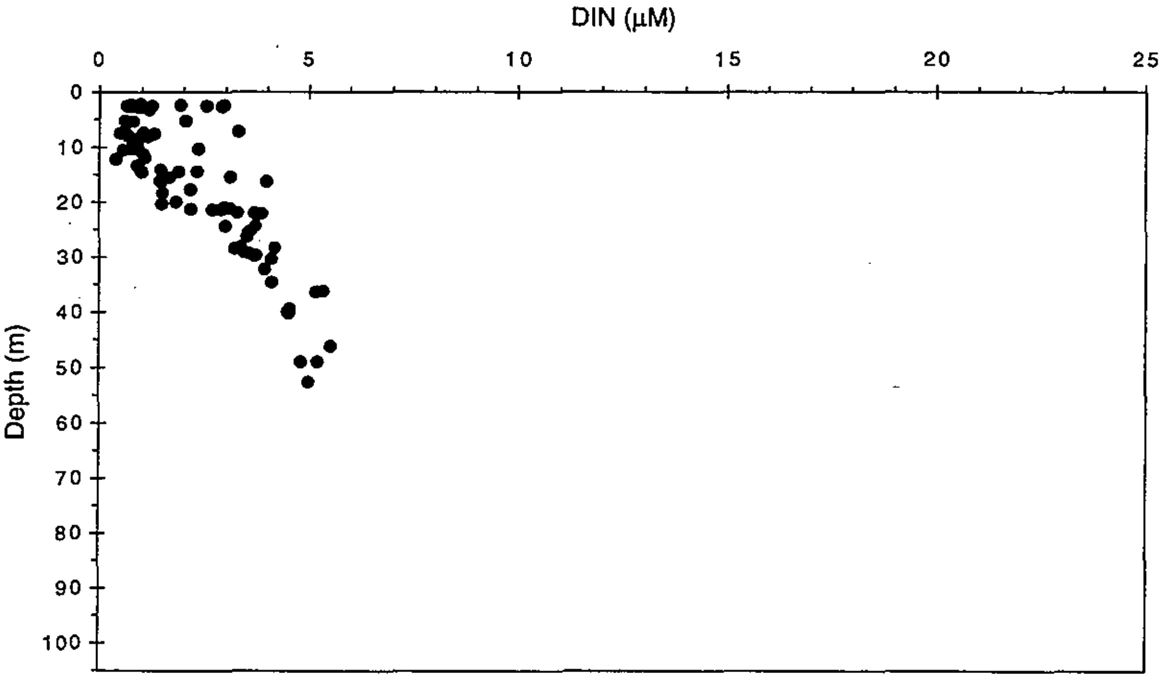
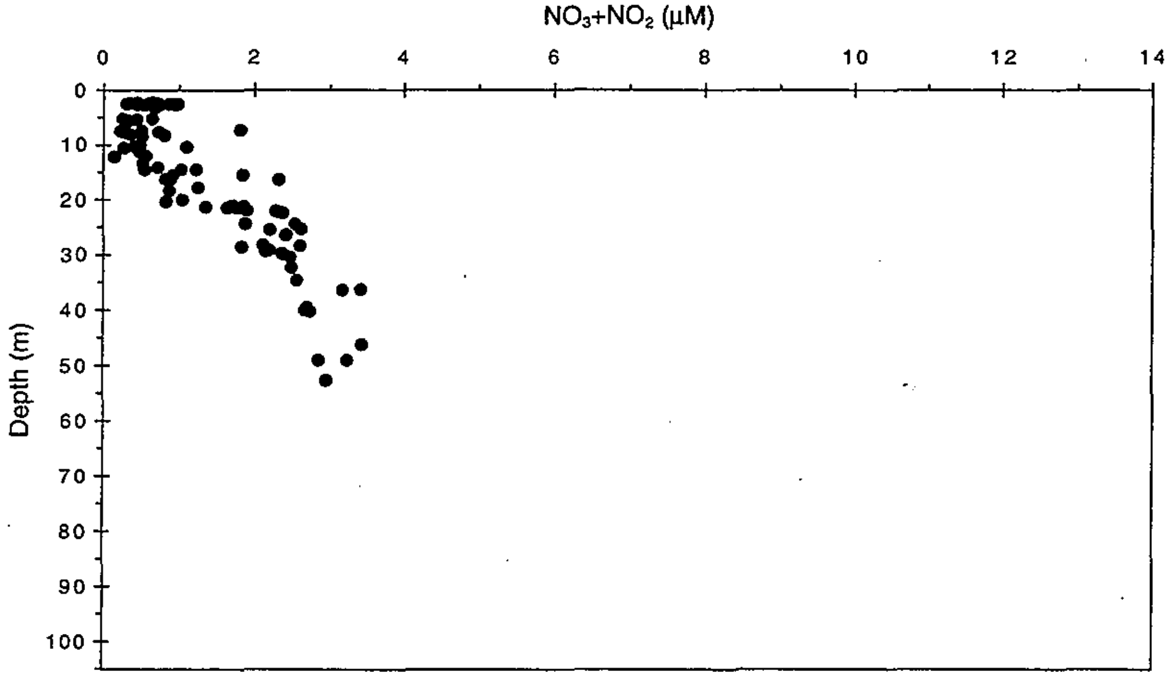


FIGURE 4-76
Depth vs. nutrient plots for nearfield survey W9606, (May 96).

(a)



(b)

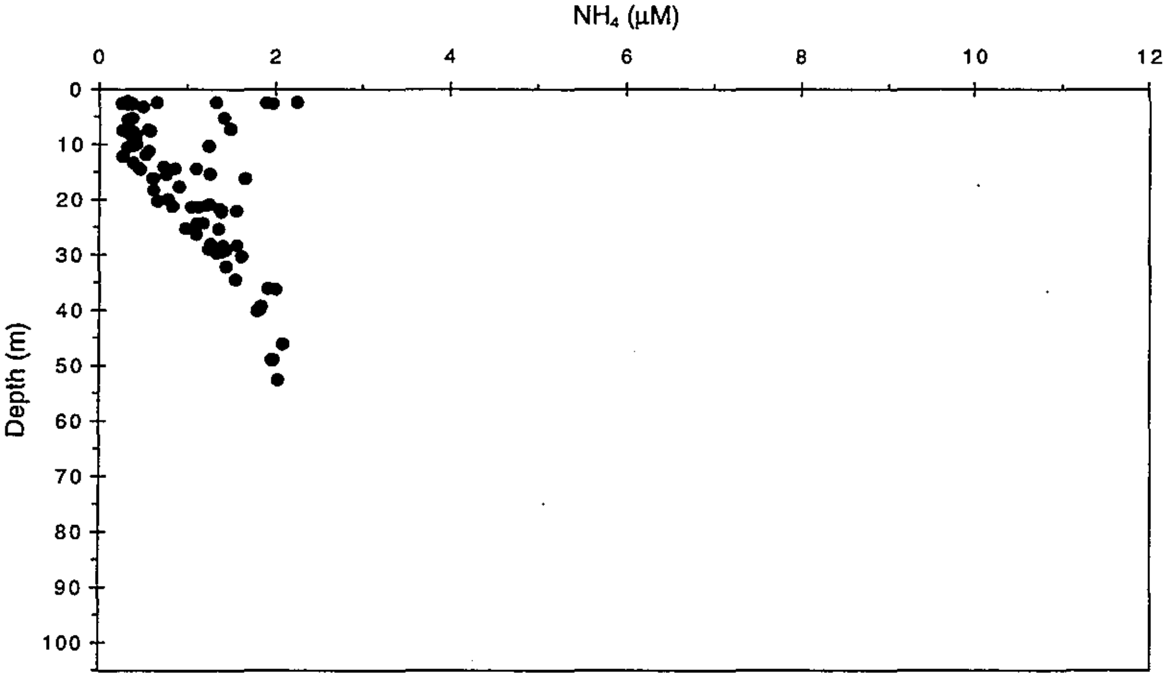


FIGURE 4-77
Depth vs. nutrient plots for nearfield survey W9606, (May 96).

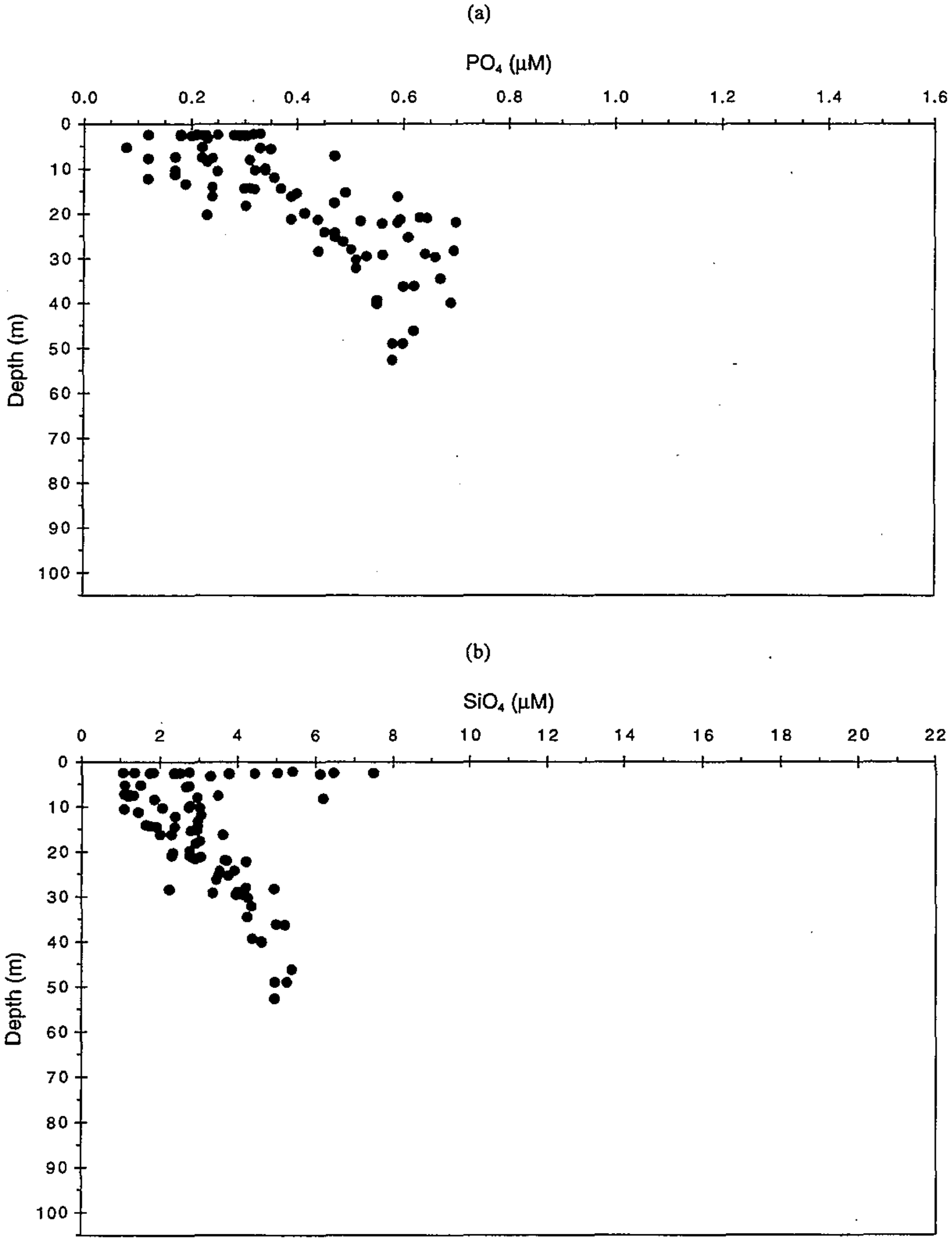
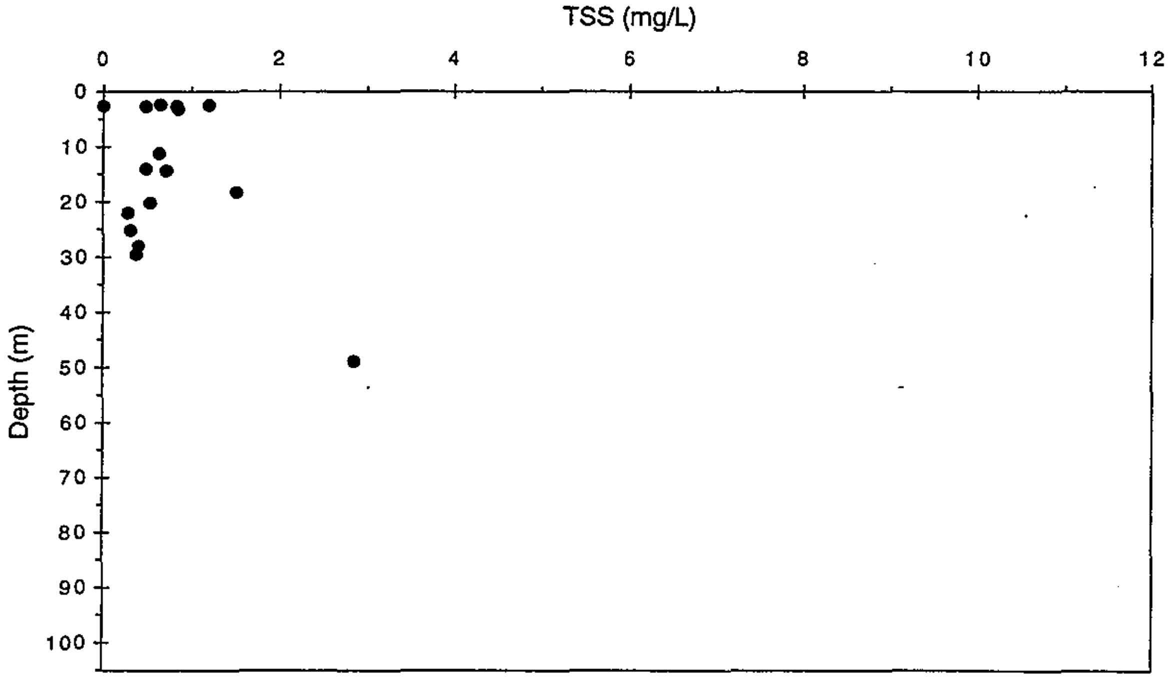


FIGURE 4-78
Depth vs. nutrient plots for nearfield survey W9606, (May 96).

(a)



(b)

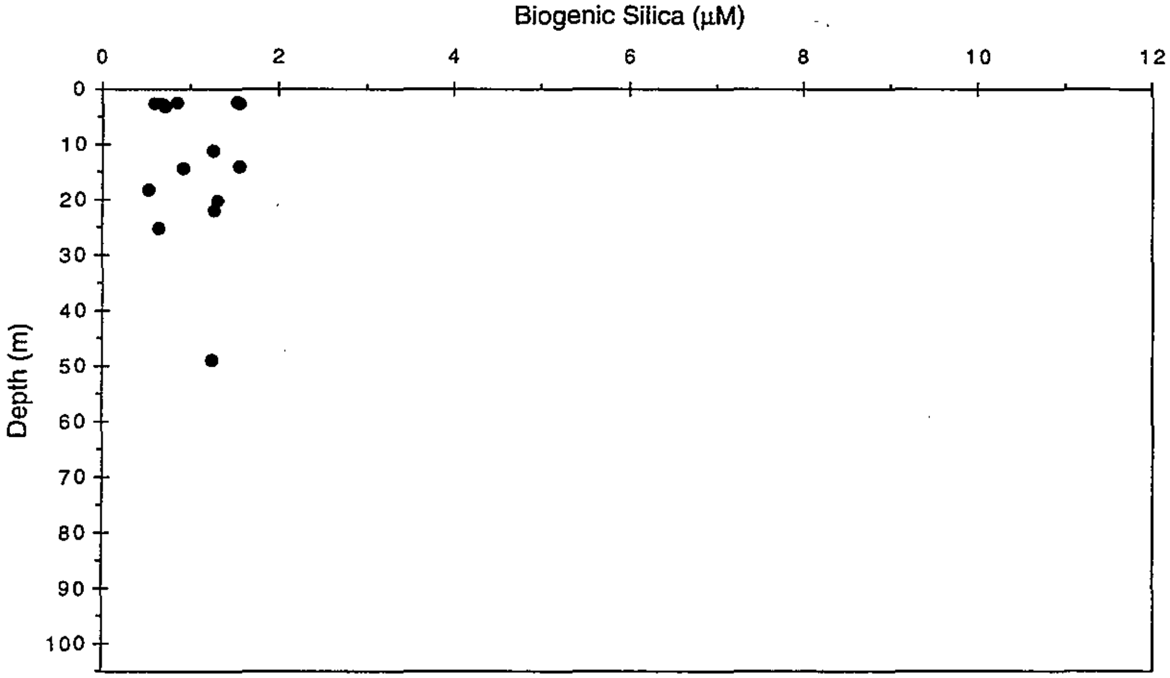


FIGURE 4-79
Depth vs. nutrient plots for nearfield survey W9606, (May 96).

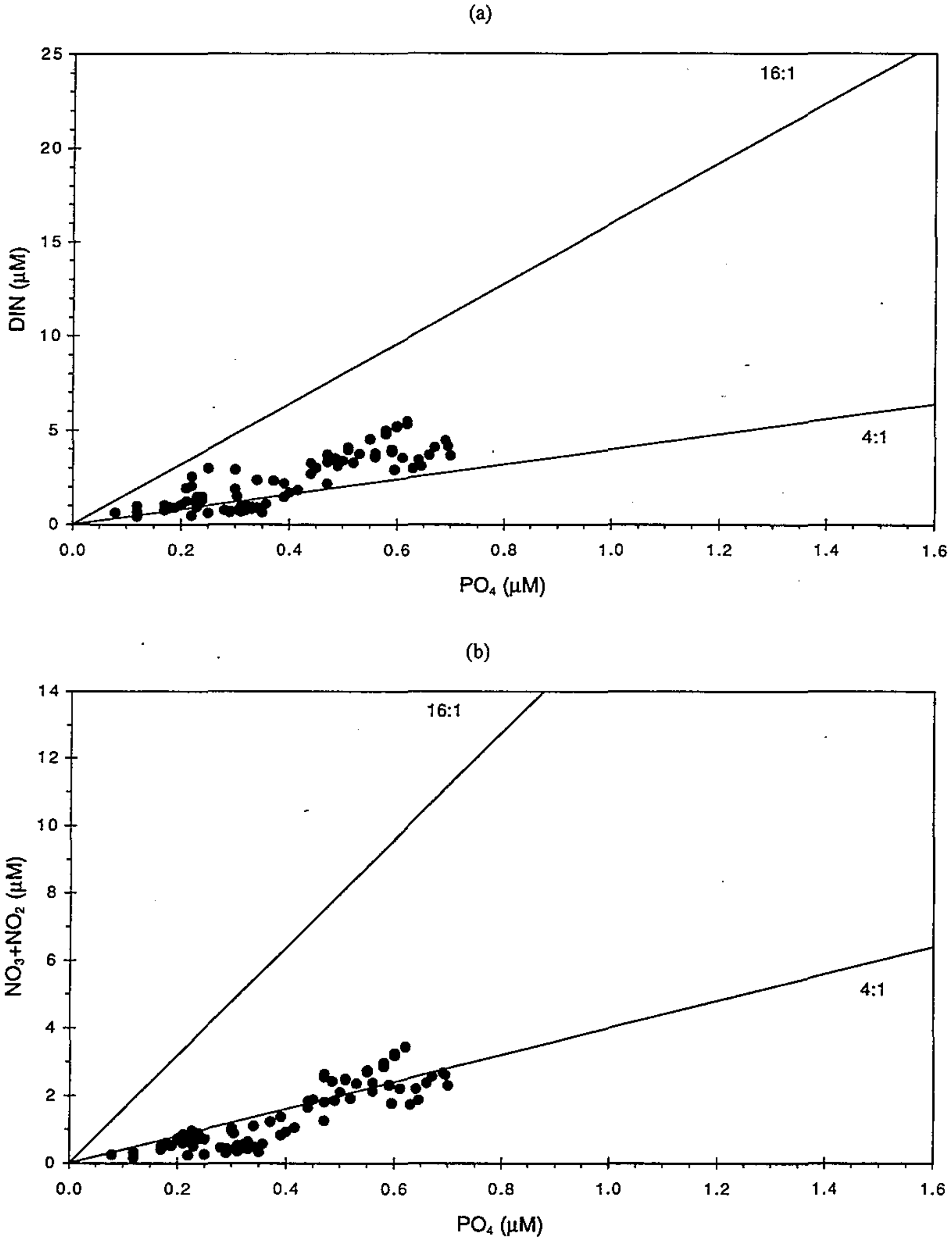


FIGURE 4-80
Nutrient vs. nutrient plots for nearfield survey W9606, (May 96).

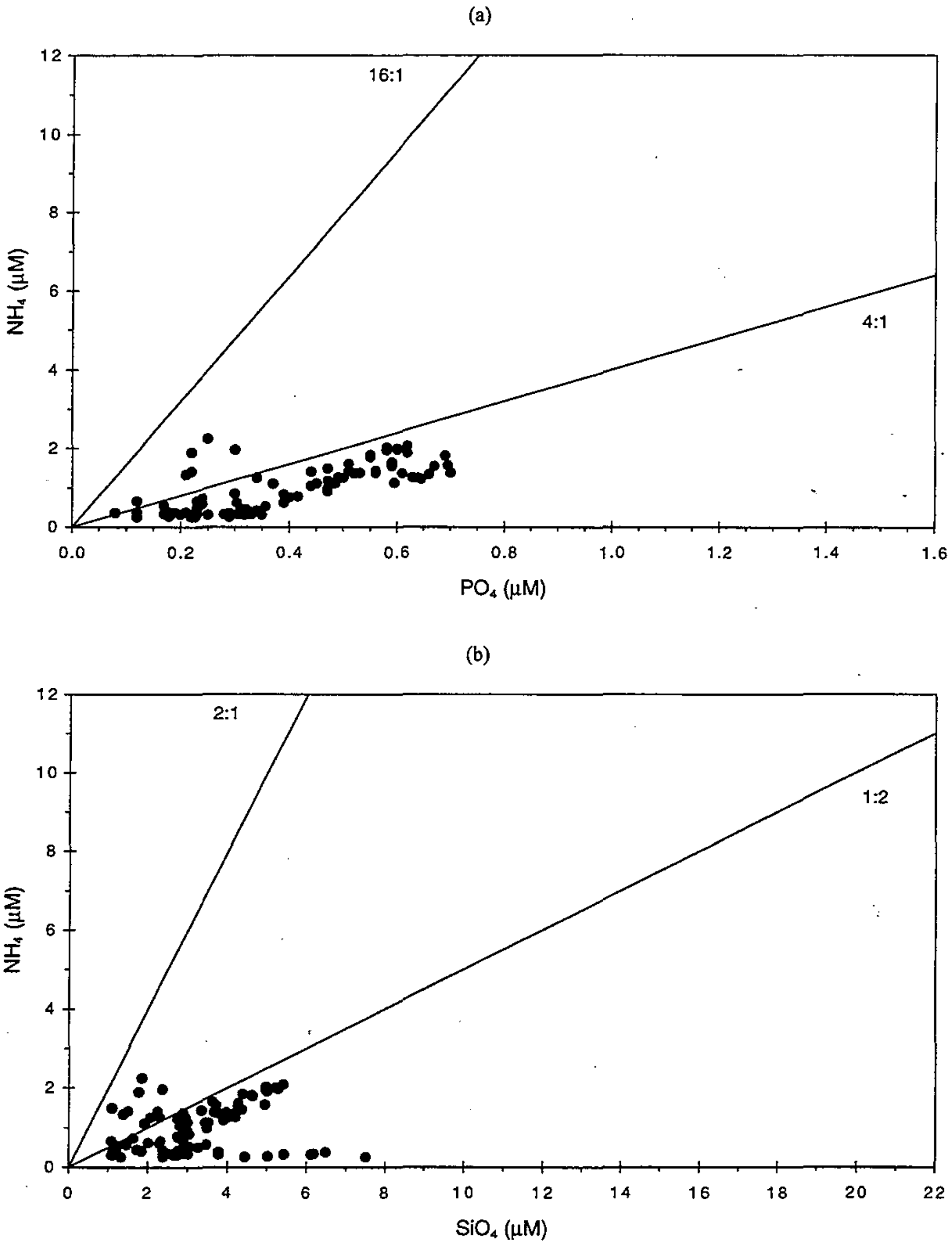
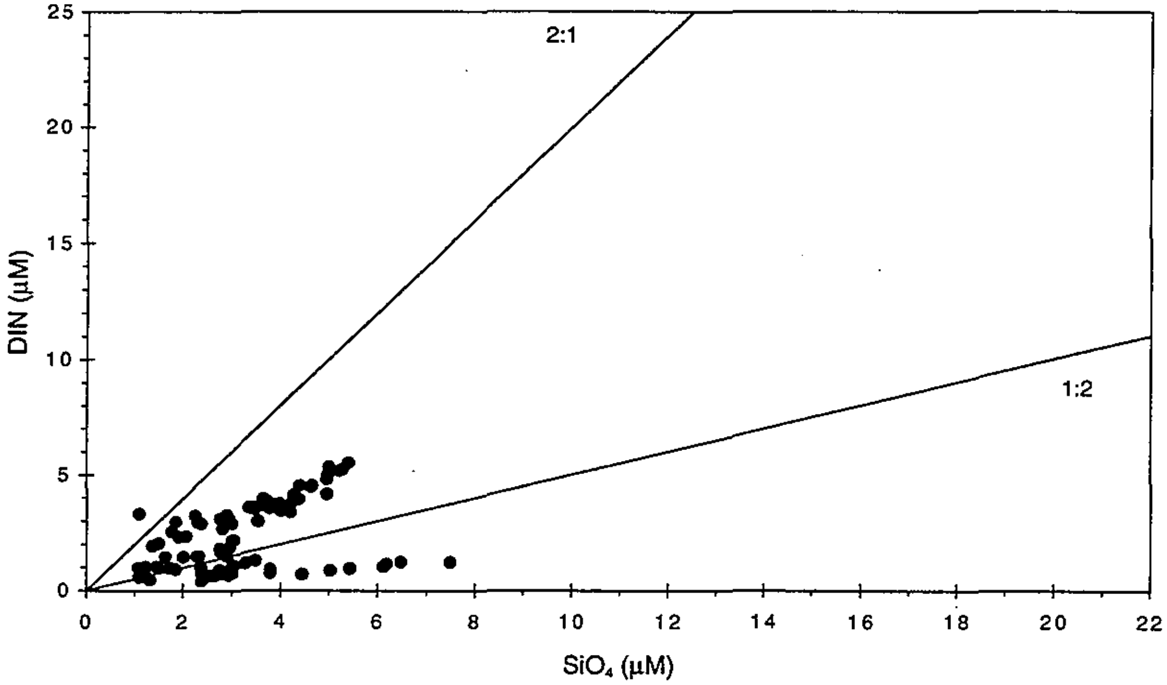


FIGURE 4-81
Nutrient vs. nutrient plots for nearfield survey W9606, (May 96).

(a)



(b)

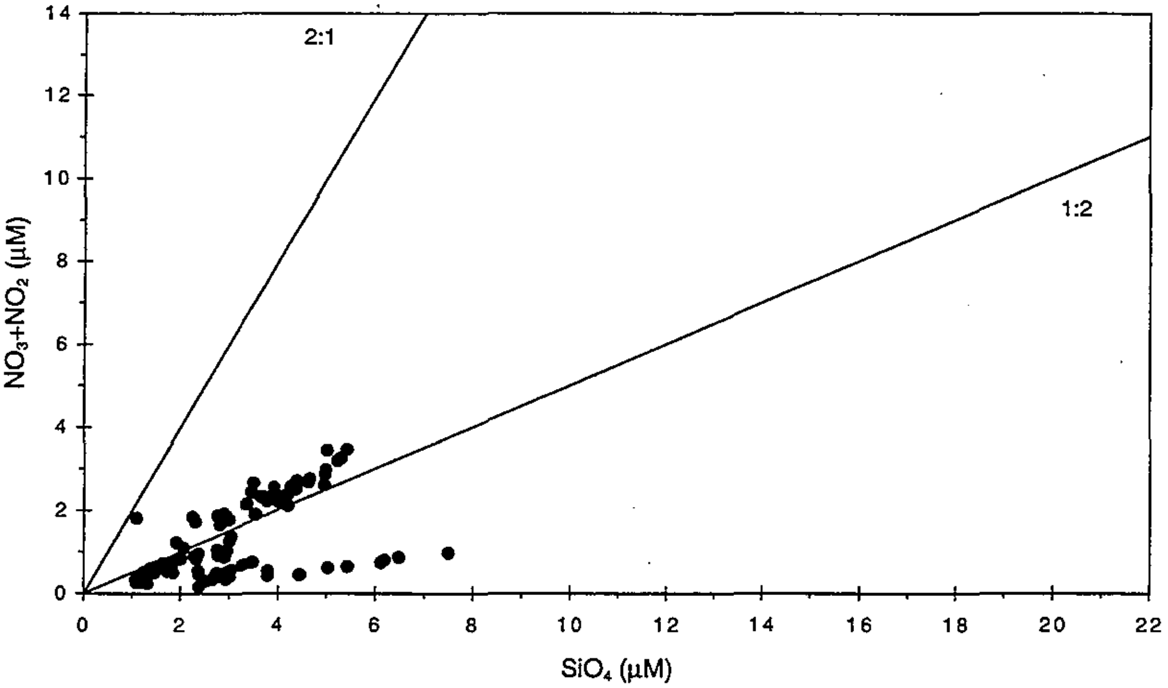
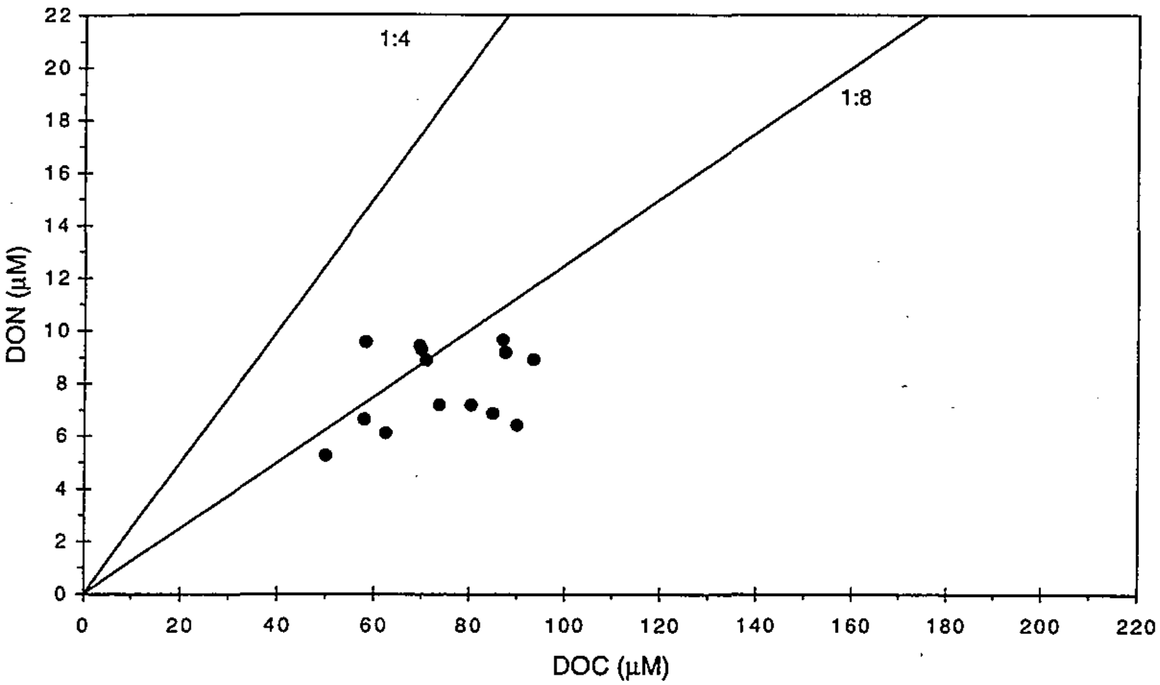


FIGURE 4-82
Nutrient vs. nutrient plots for nearfield survey W9606, (May 96).

(a)



(b)

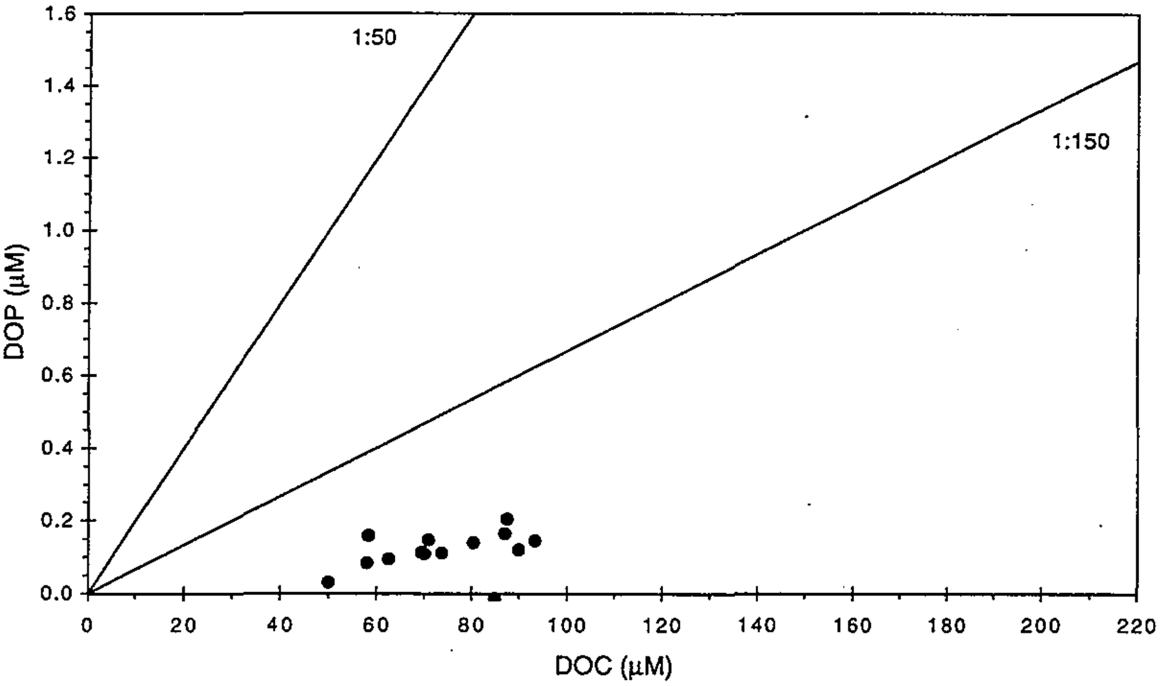
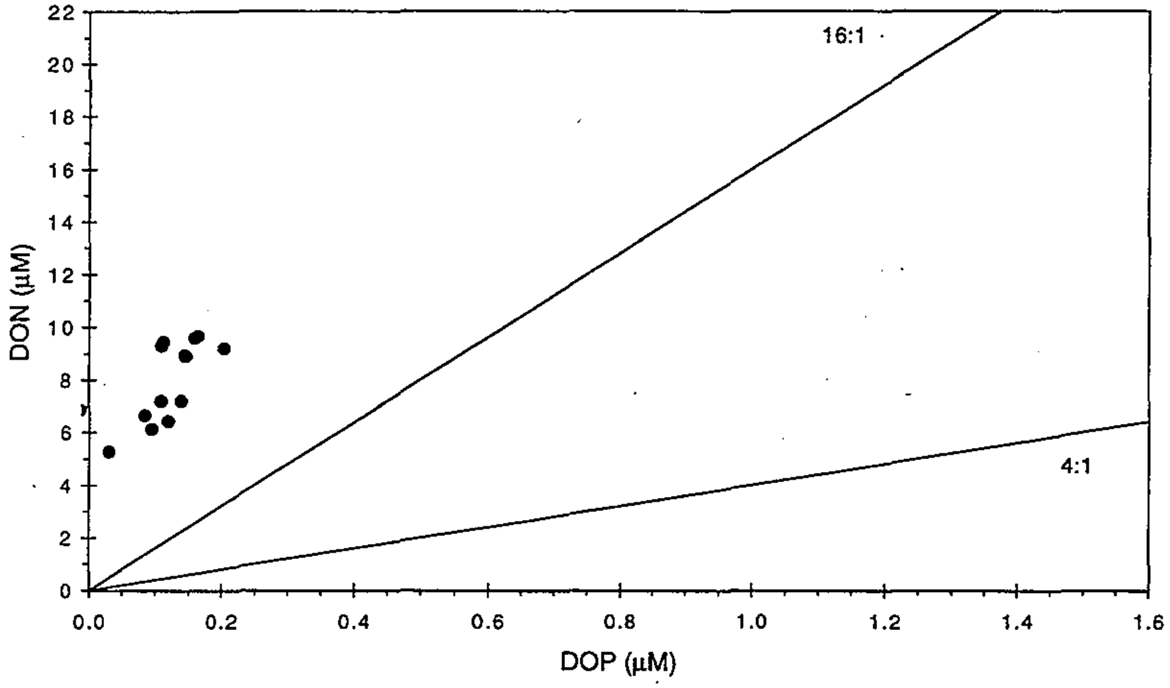


FIGURE 4-83
Nutrient vs. nutrient plots for nearfield survey W9606, (May 96).

(a)



(b)

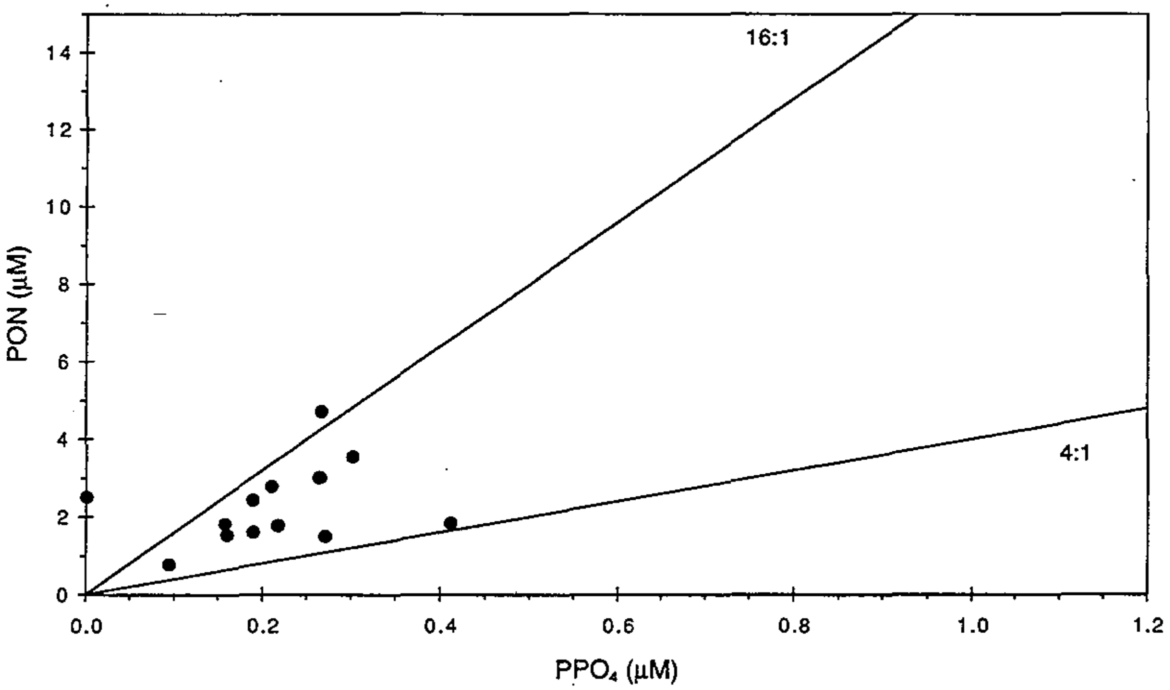
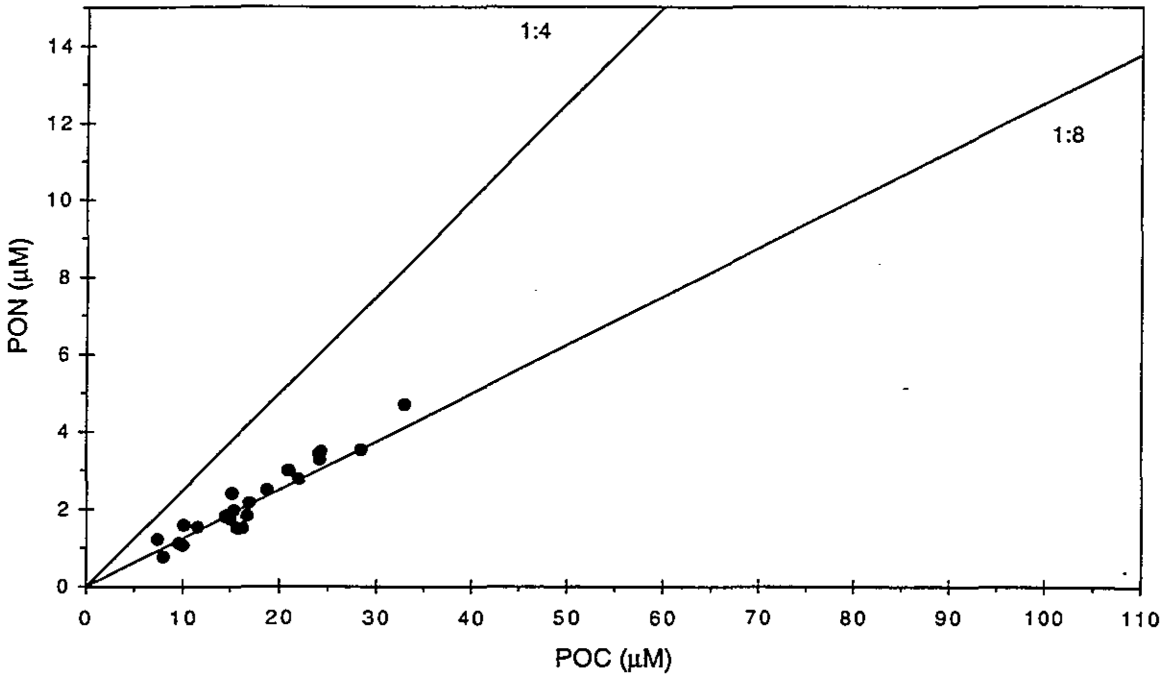


FIGURE 4-84
Nutrient vs. nutrient plots for nearfield survey W9606, (May 96).

(a)



(b)

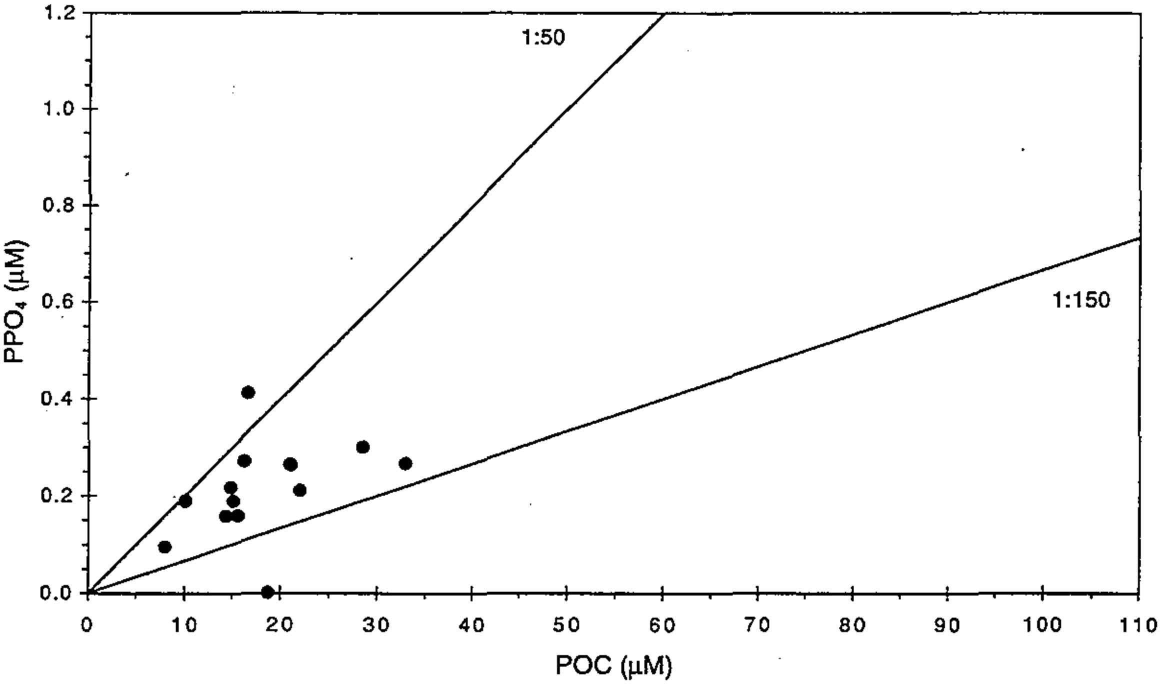


FIGURE 4-85

Nutrient vs. nutrient plots for nearfield survey W9606, (May 96).

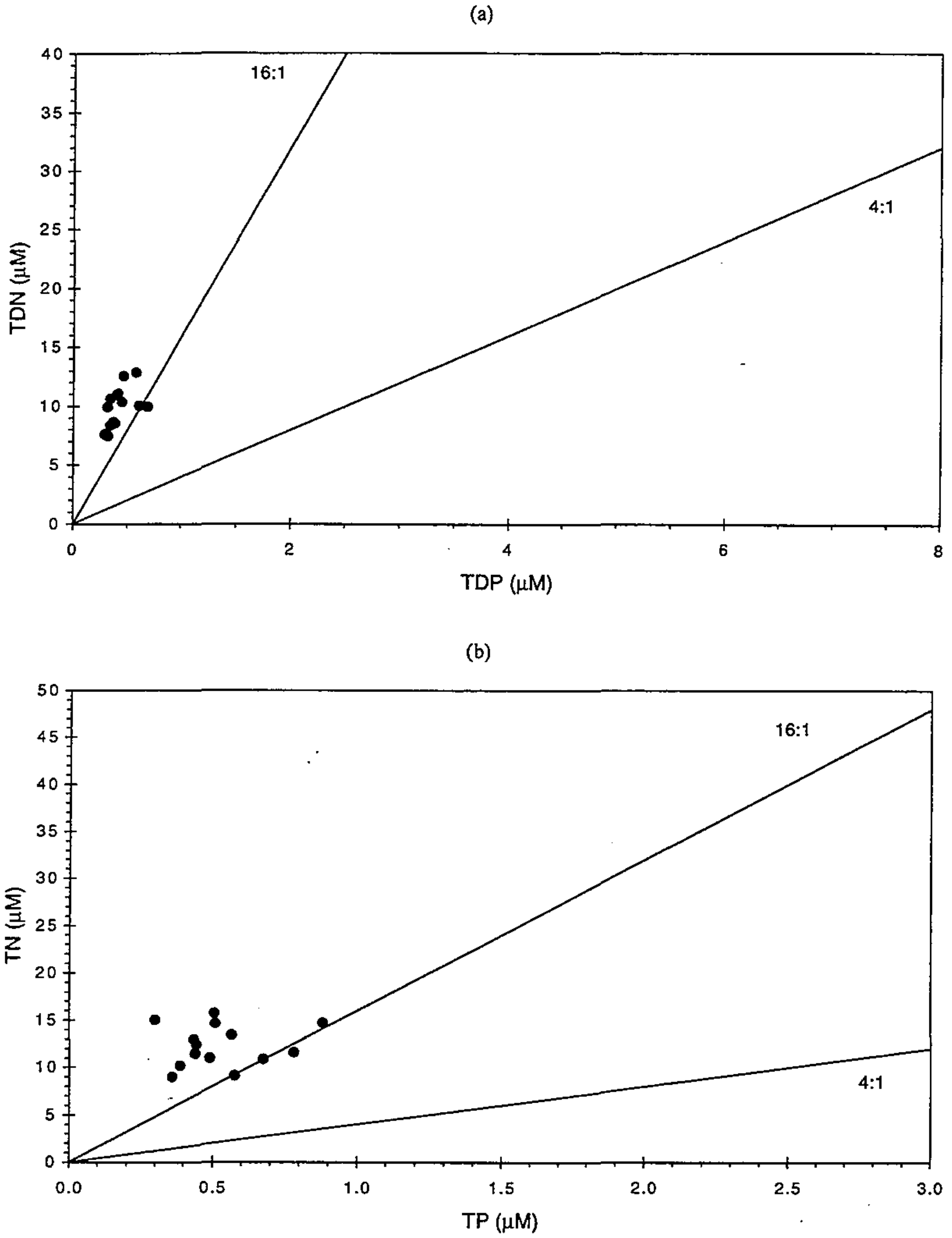


FIGURE 4-86
Nutrient vs. nutrient plots for nearfield survey W9606, (May 96).

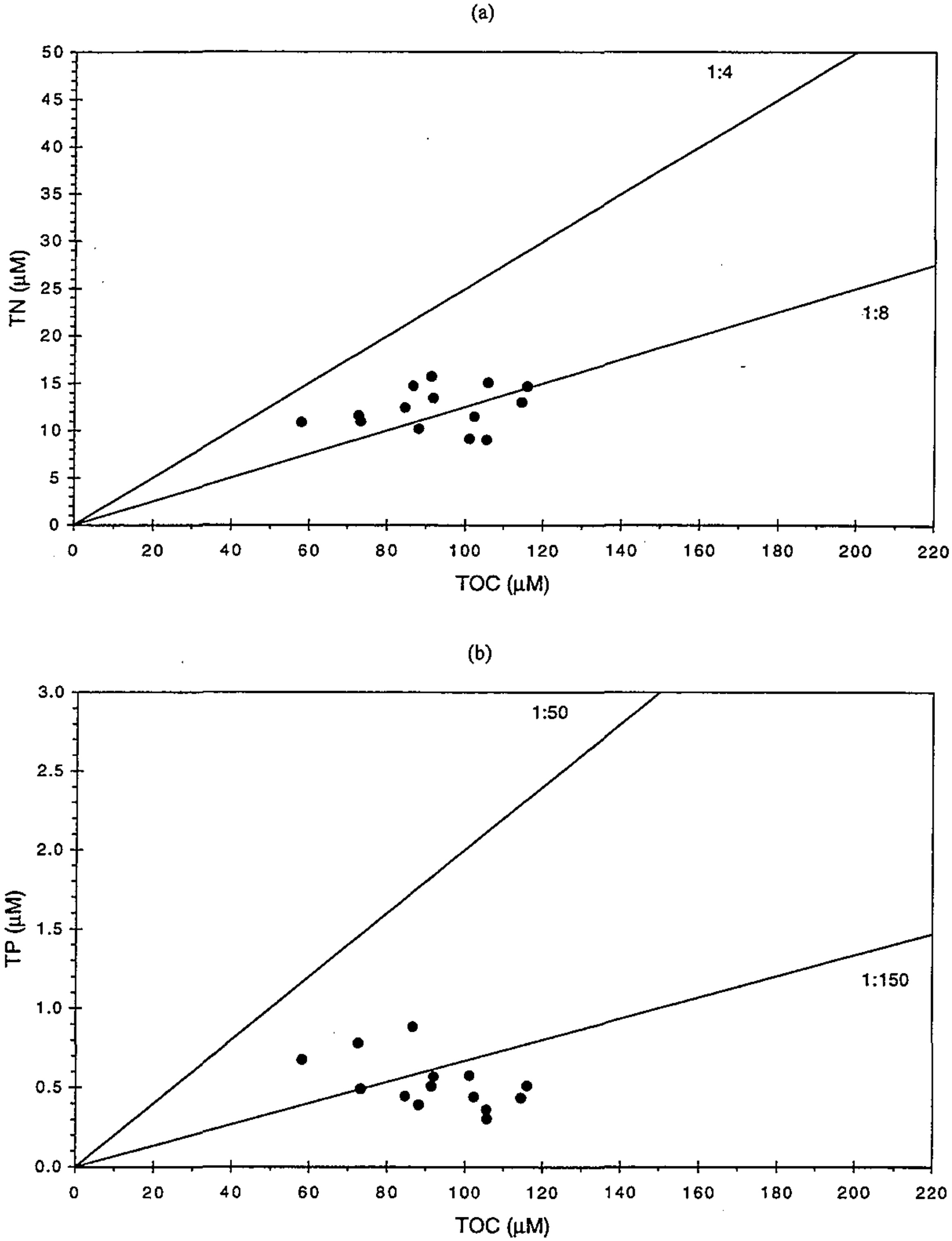


FIGURE 4-87
Nutrient vs. nutrient plots for nearfield survey W9606, (May 96).

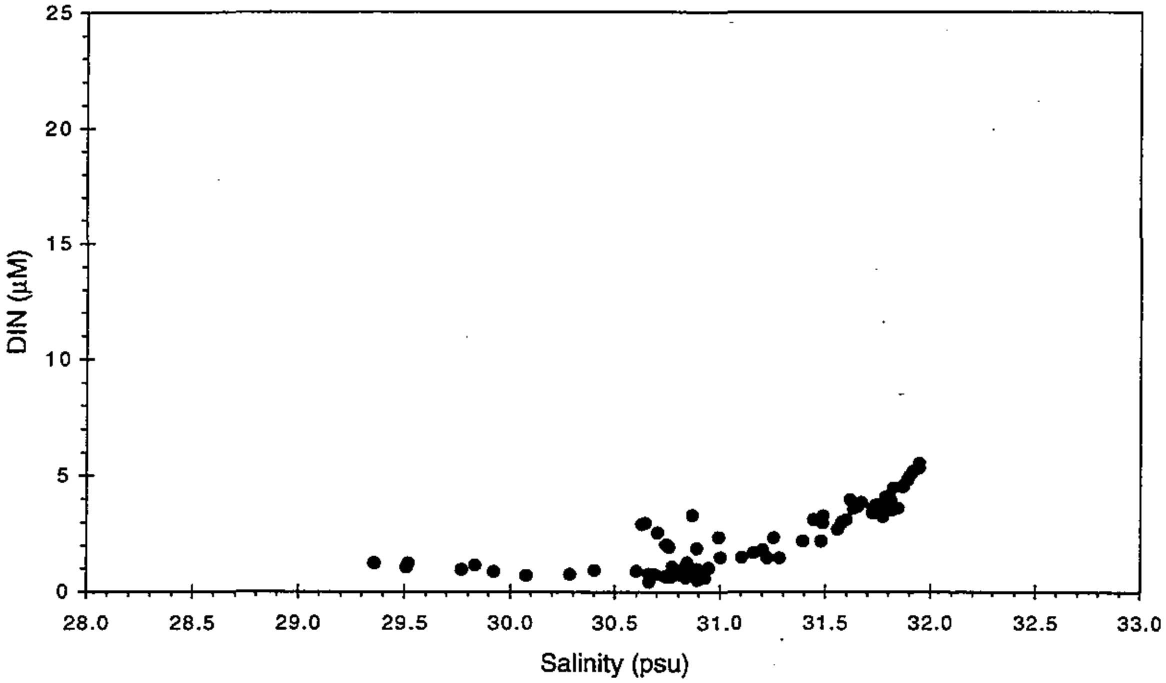


FIGURE 4-88
Nutrient vs. salinity plots for nearfield survey W9606, (May 96).

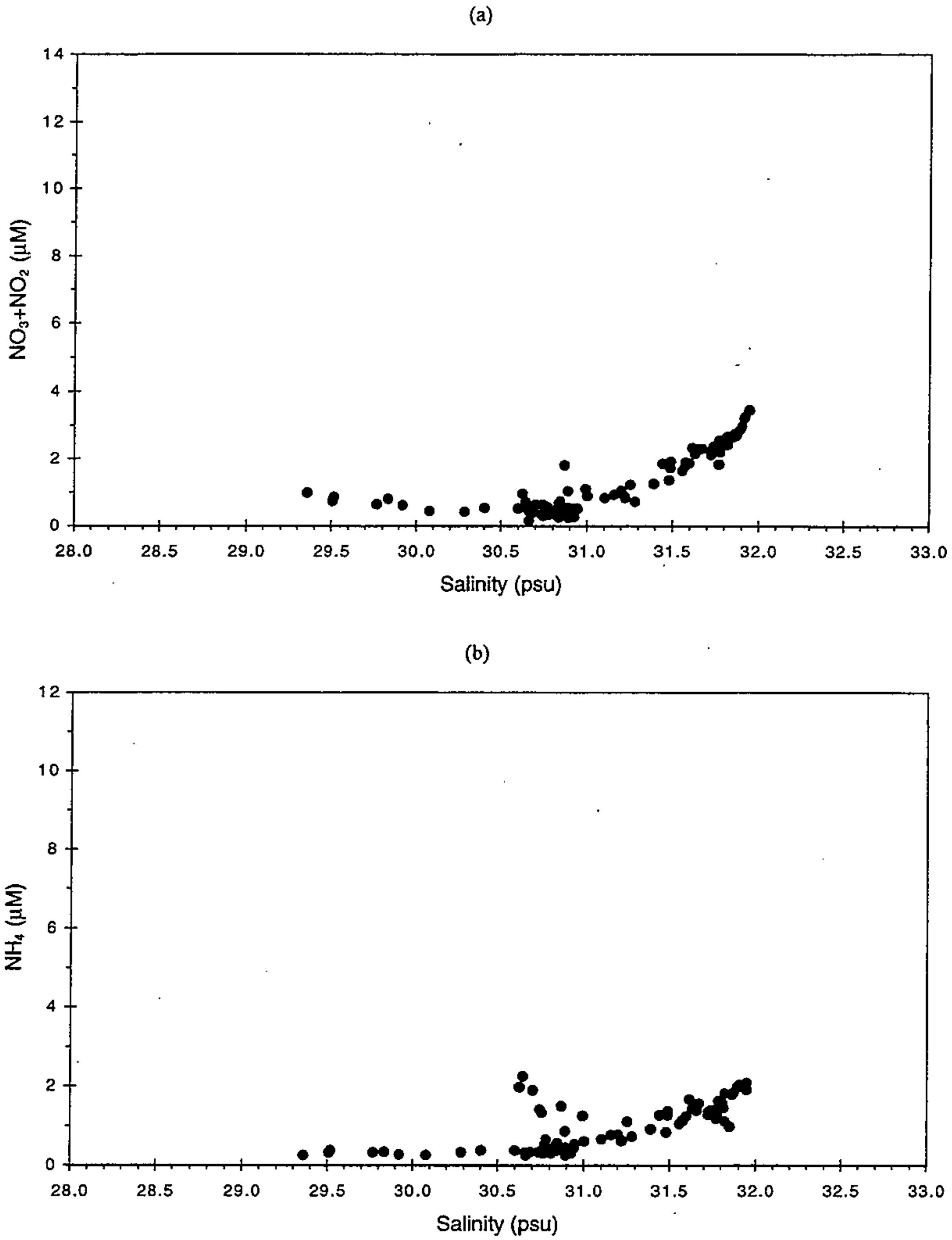
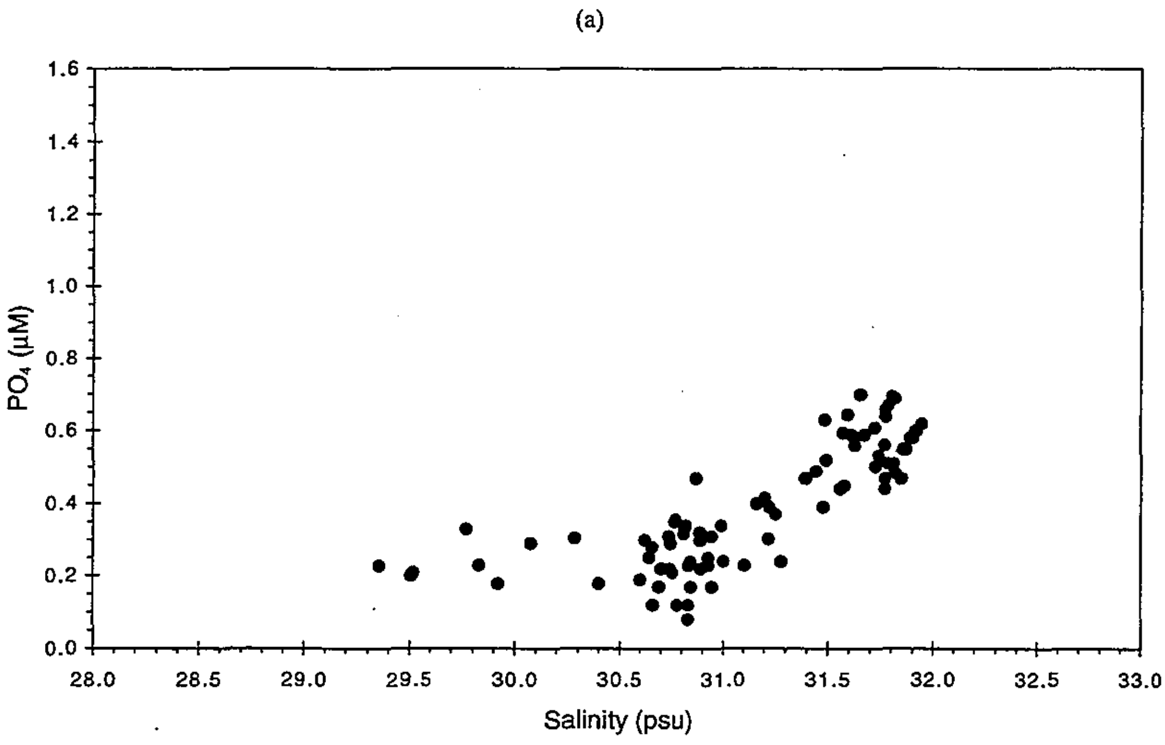


FIGURE 4-89
Nutrient vs. salinity plots for nearfield survey W9606, (May 96).



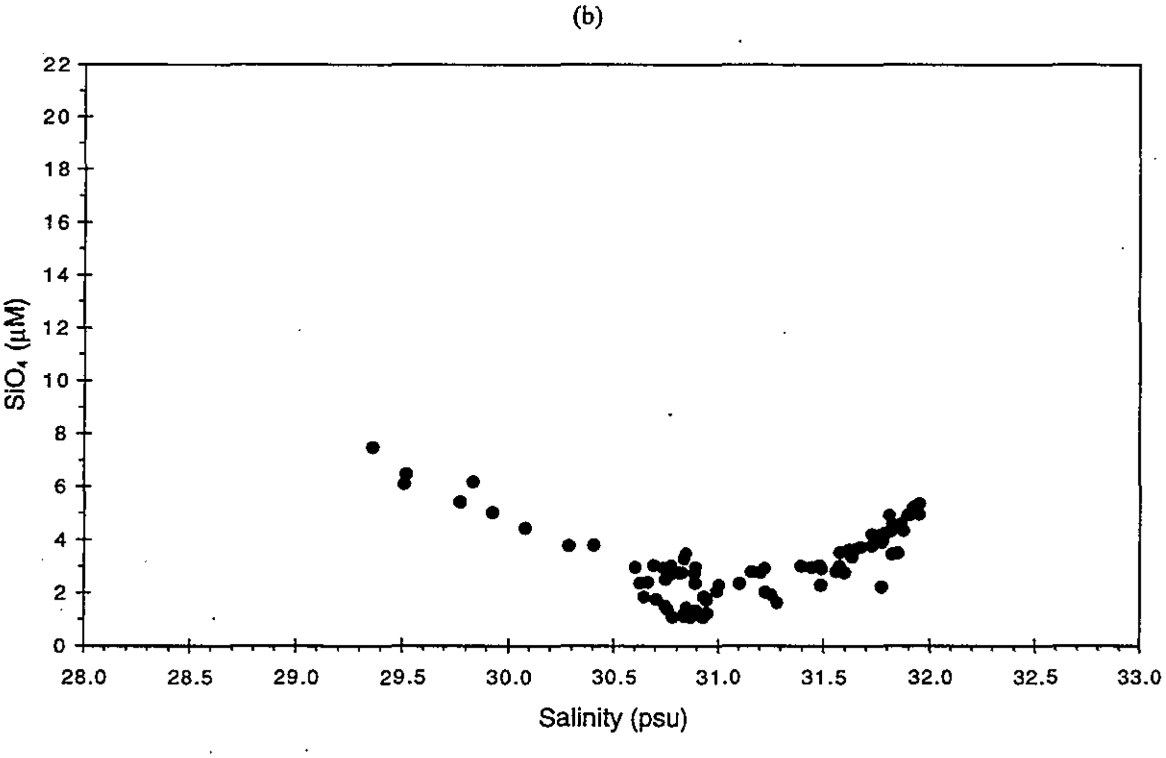
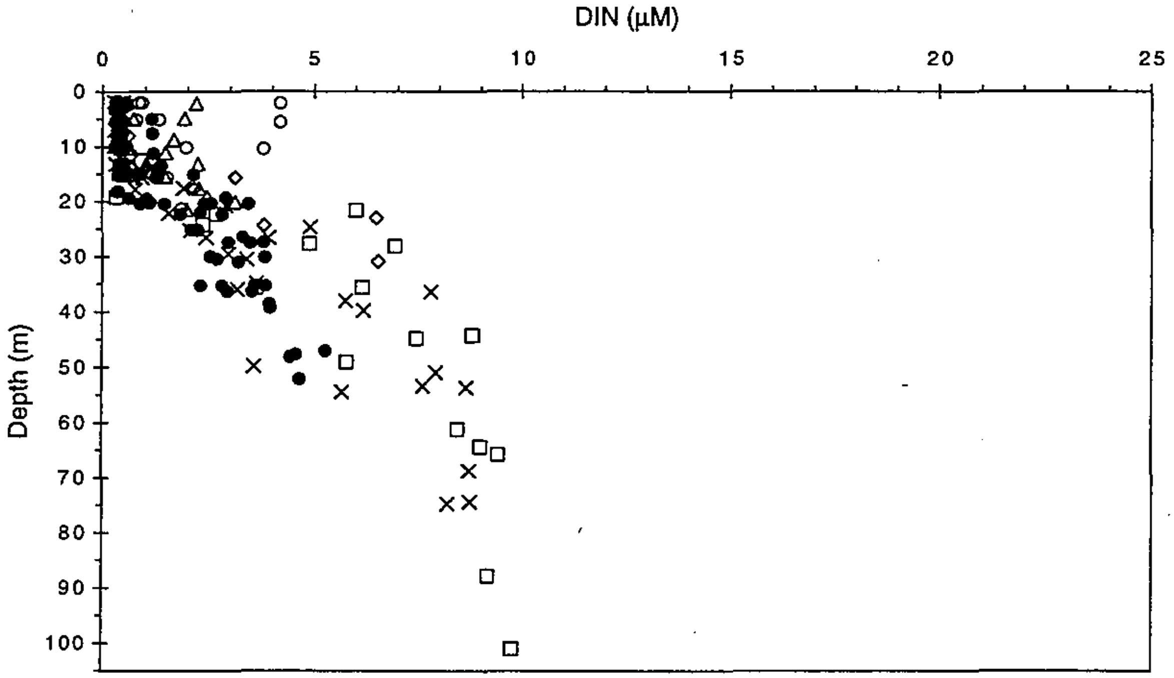


FIGURE 4-90

Nutrient vs. salinity plots for nearfield survey W9606, (May 96).



□ Boundary ◇ Cape Cod Bay △ Coastal ○ Harbor ● Nearfield × Offshore

FIGURE 4-91
Depth vs. nutrient plots for farfield survey W9607, (Jun 96).

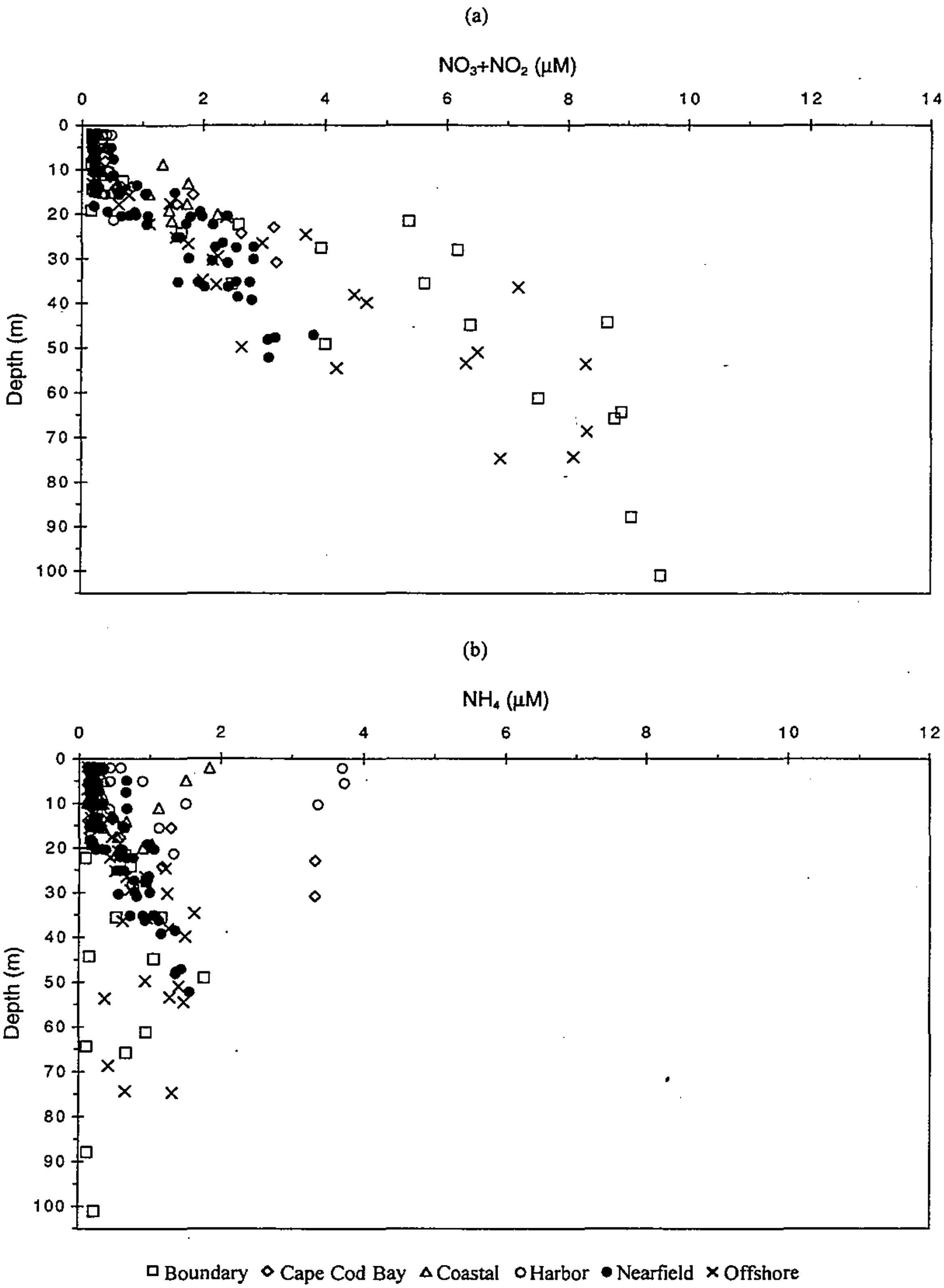


FIGURE 4-92
Depth vs. nutrient plots for farfield survey W9607, (Jun 96).

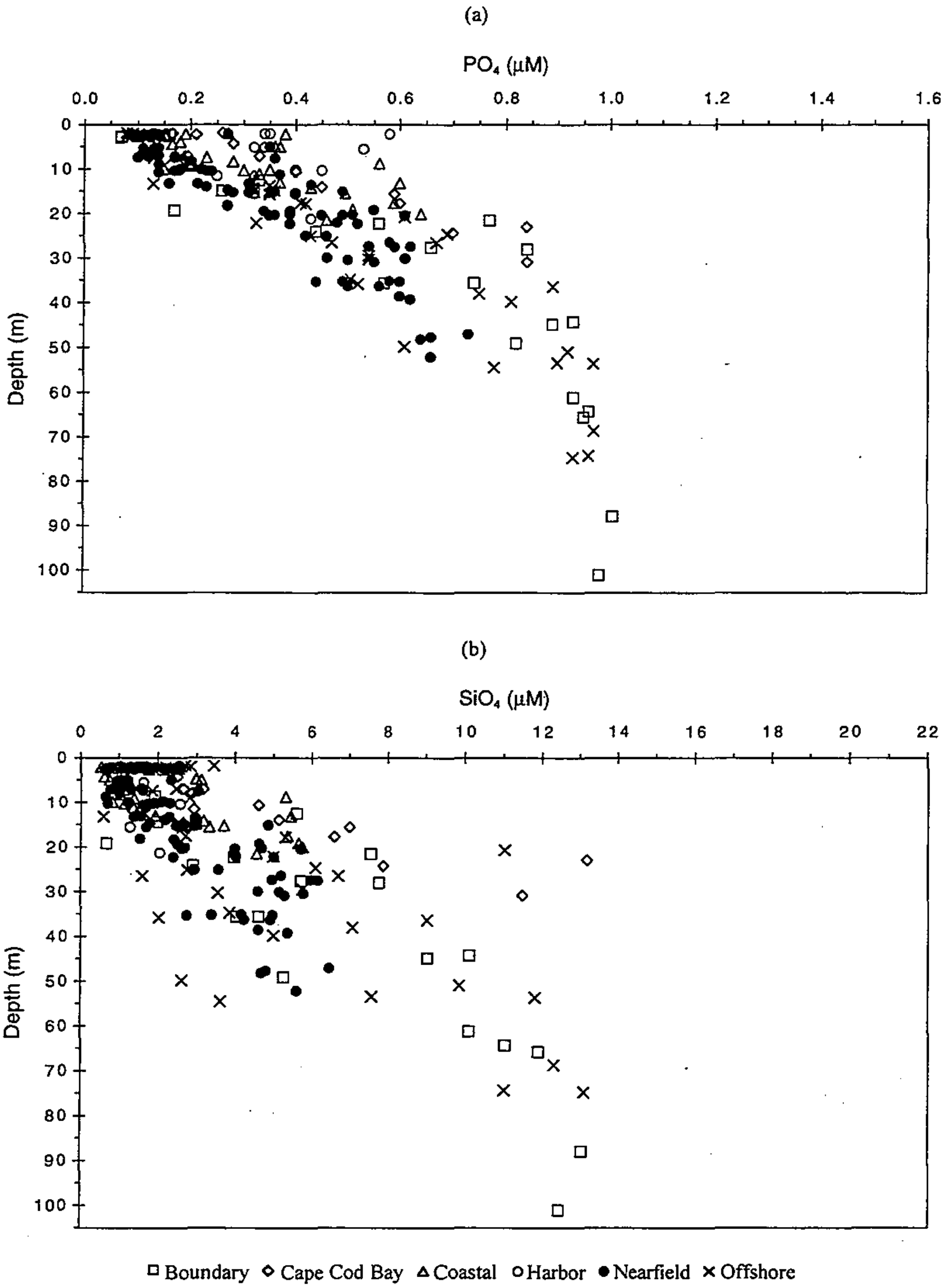


FIGURE 4-93
Depth vs. nutrient plots for farfield survey W9607, (Jun 96).

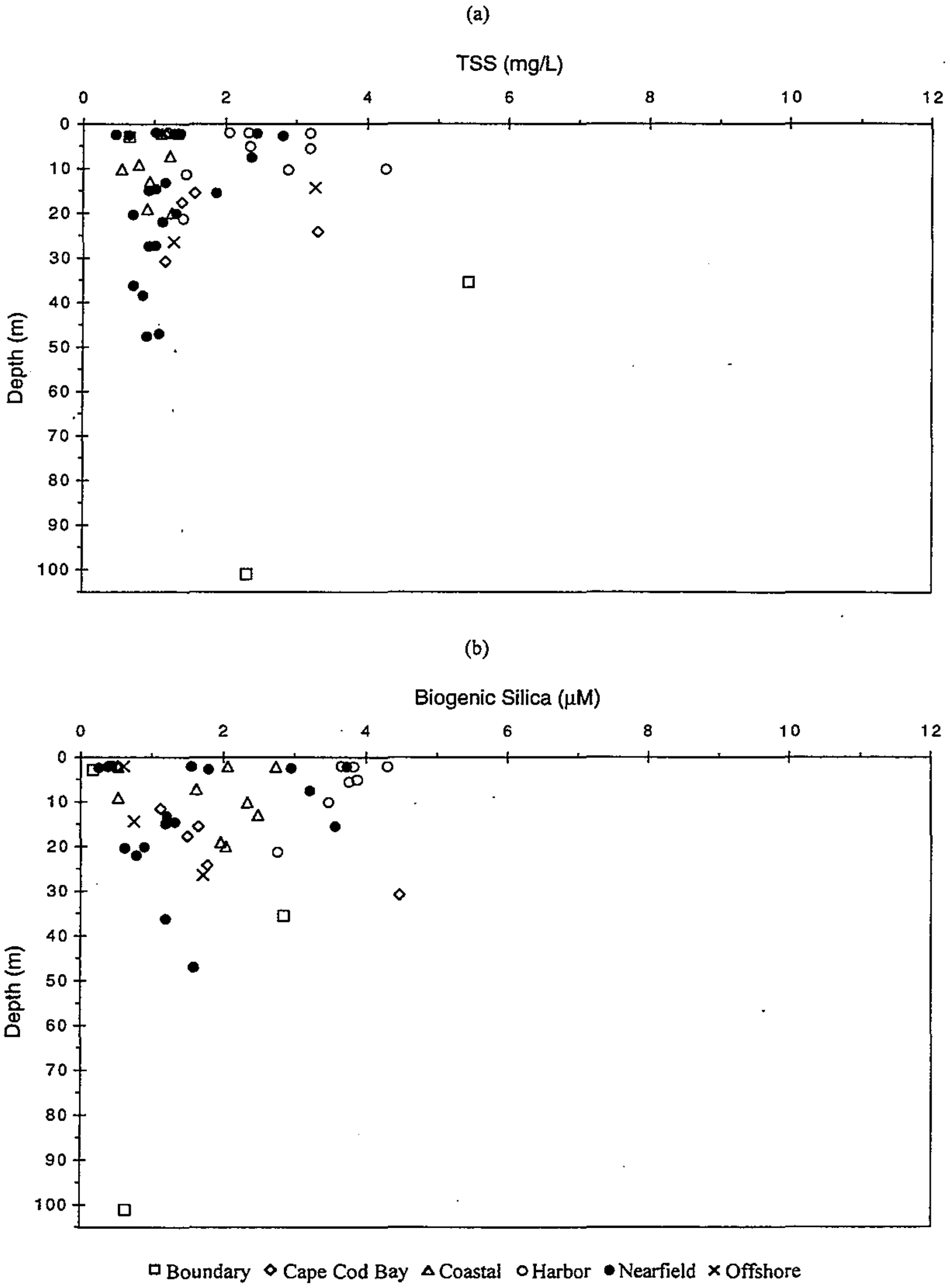


FIGURE 4-94
Depth vs. nutrient plots for farfield survey W9607, (Jun 96).

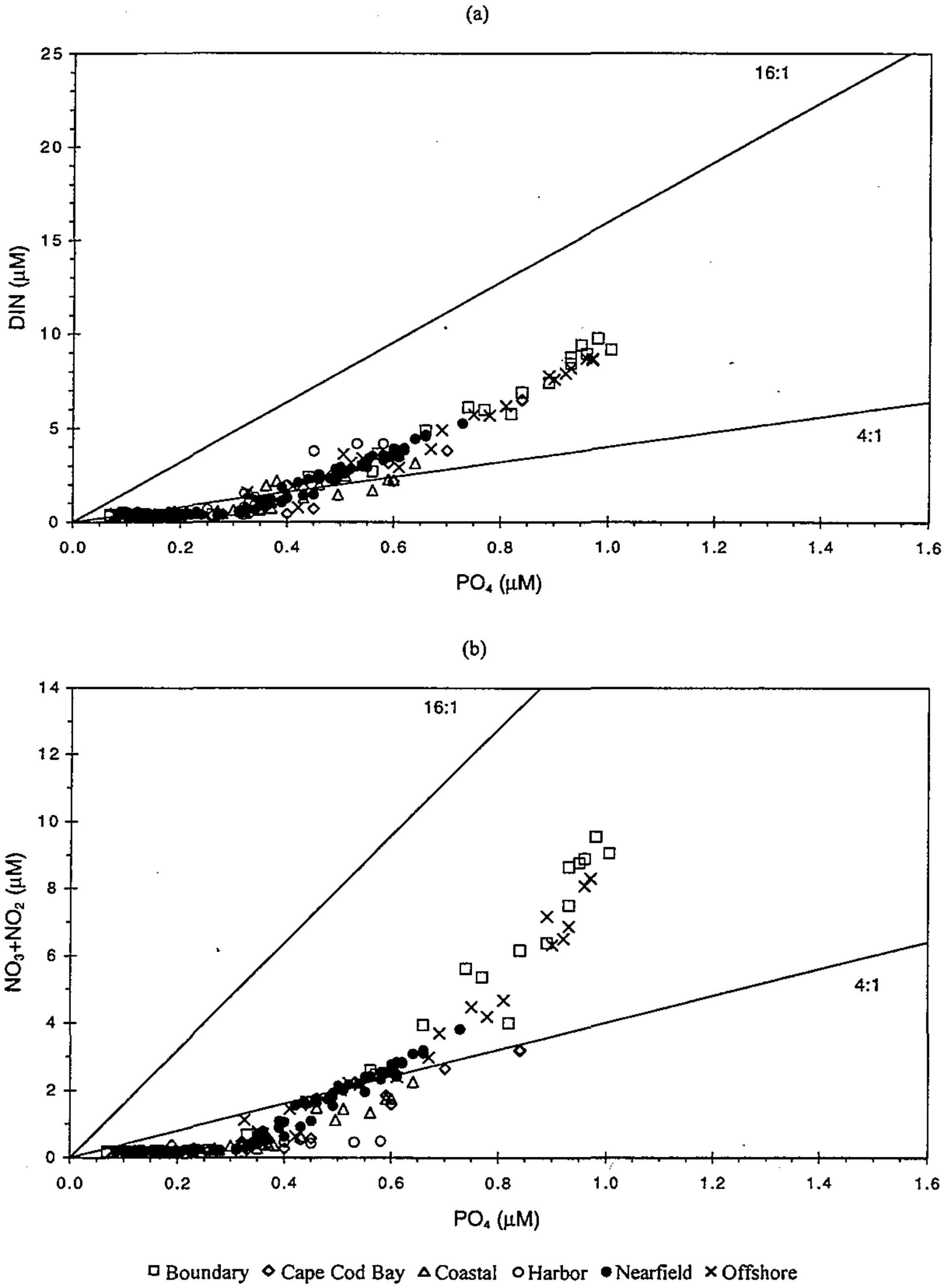


FIGURE 4-95
Nutrient vs. nutrient plots for farfield survey W9607, (Jun 96).

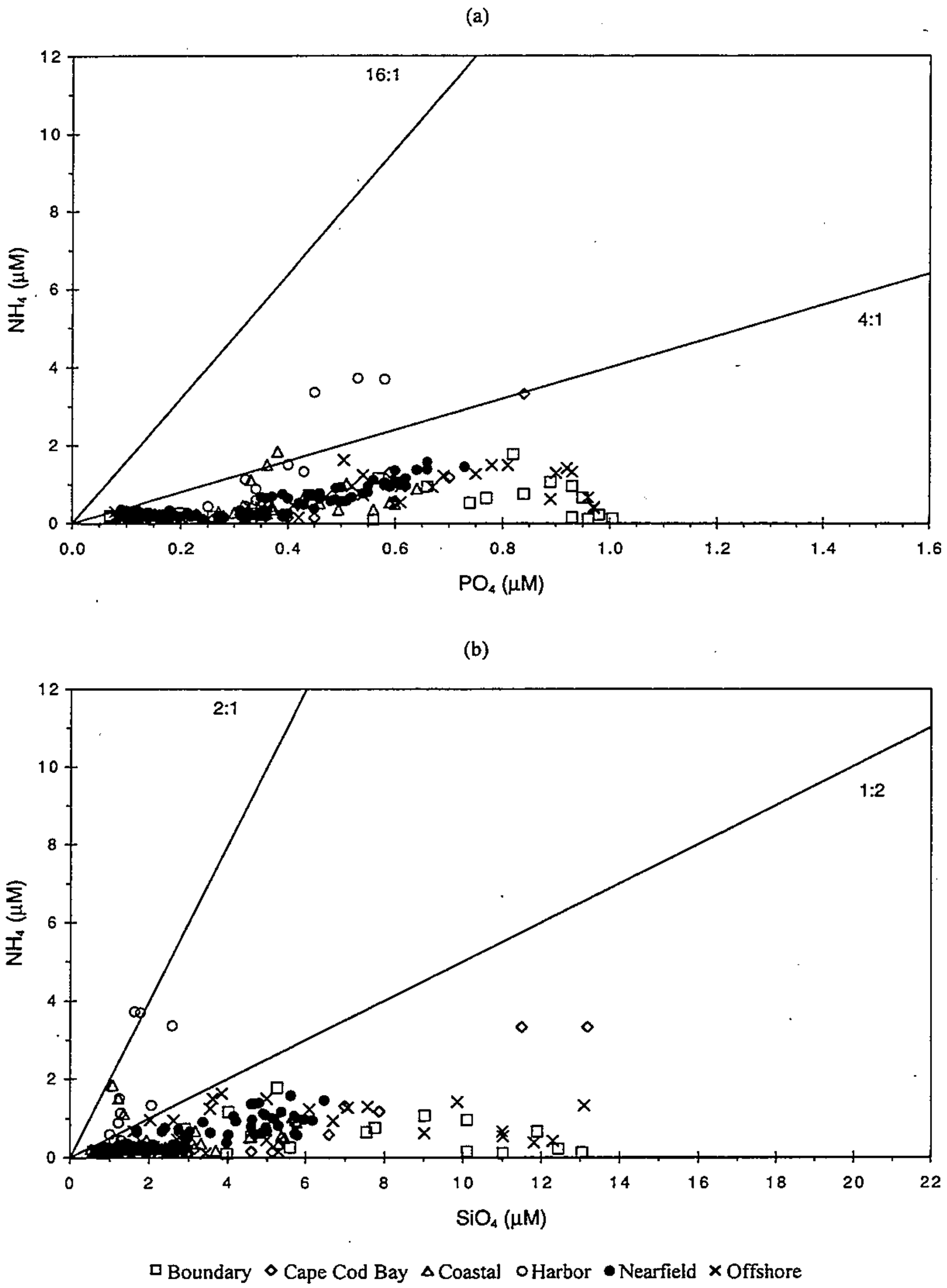


FIGURE 4-96

Nutrient vs. nutrient plots for farfield survey W9607, (Jun 96).

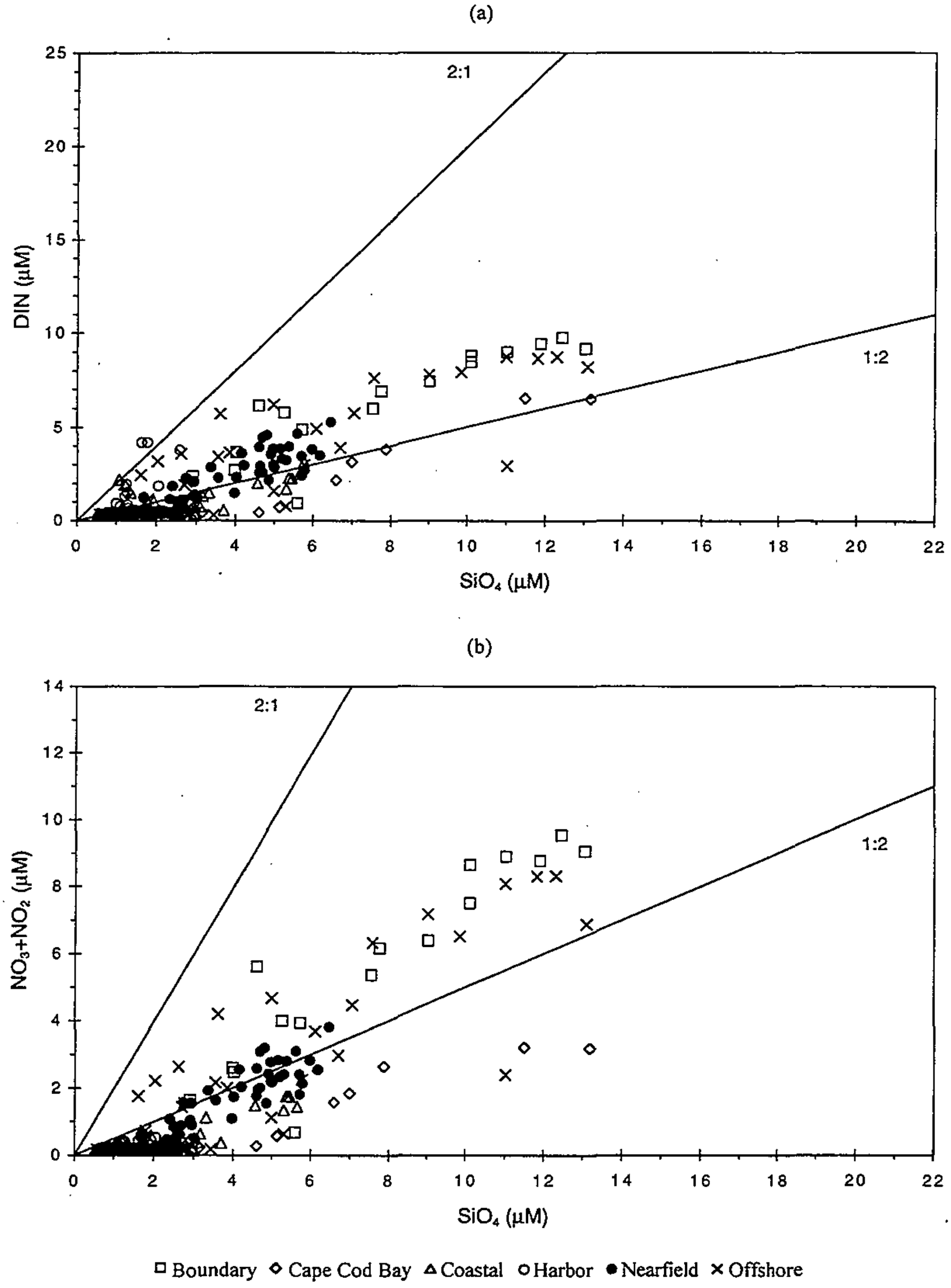


FIGURE 4-97
Nutrient vs. nutrient plots for farfield survey W9607, (Jun 96).

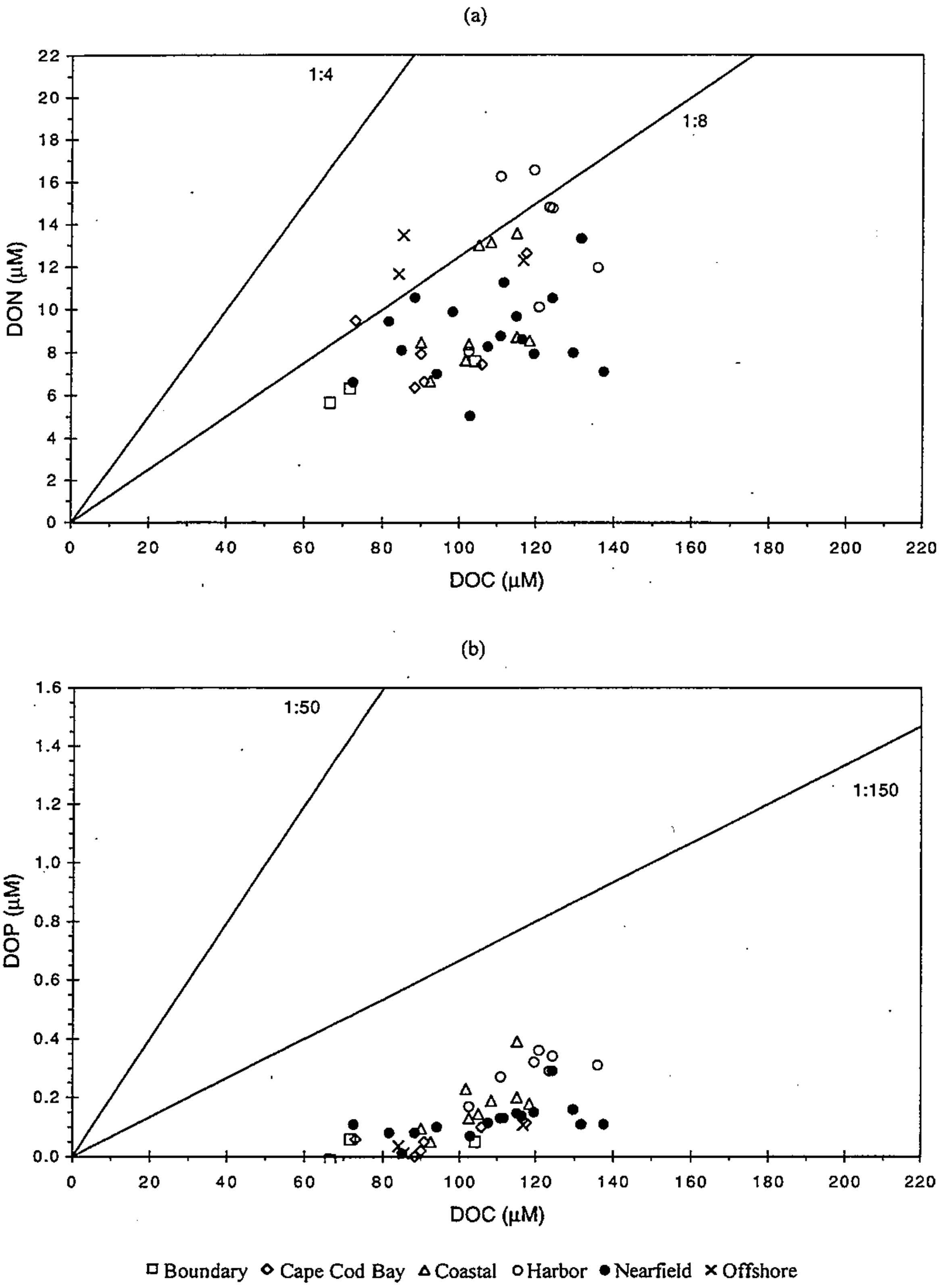


FIGURE 4-98
Nutrient vs. nutrient plots for farfield survey W9607, (Jun 96).

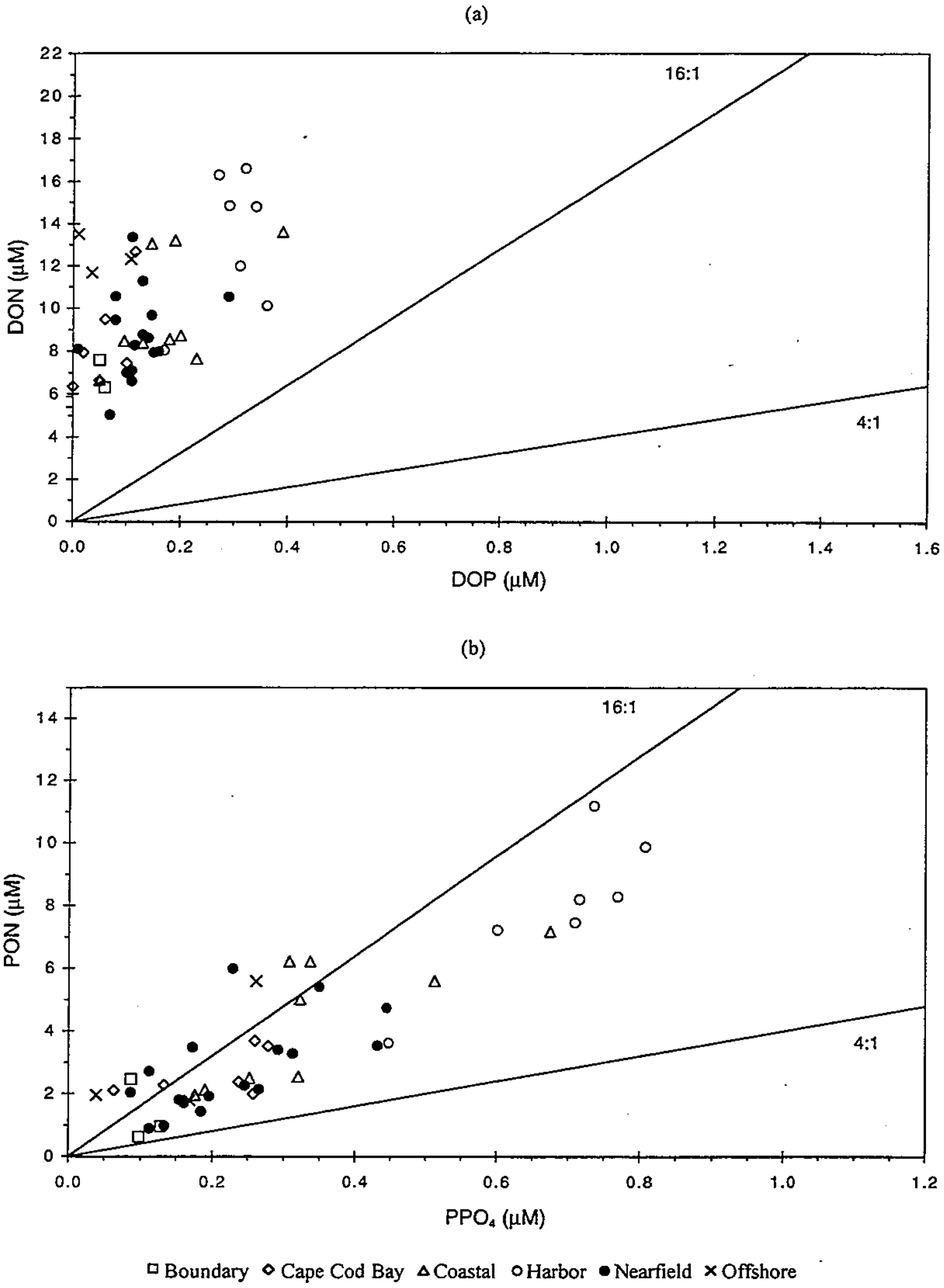


FIGURE 4-99
Nutrient vs. nutrient plots for farfield survey W9607, (Jun 96).

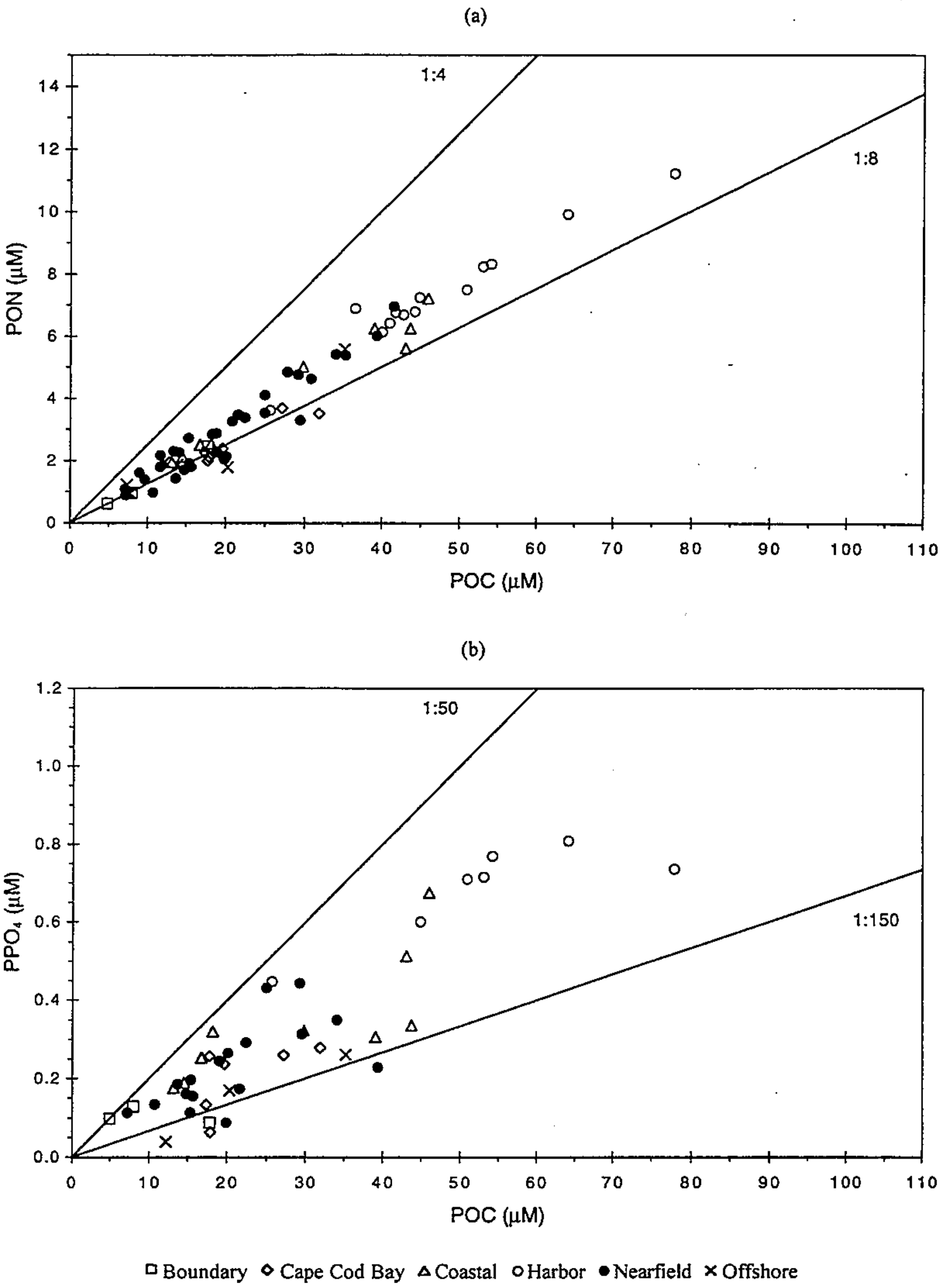


FIGURE 4-100
Nutrient vs. nutrient plots for farfield survey W9607, (Jun 96).

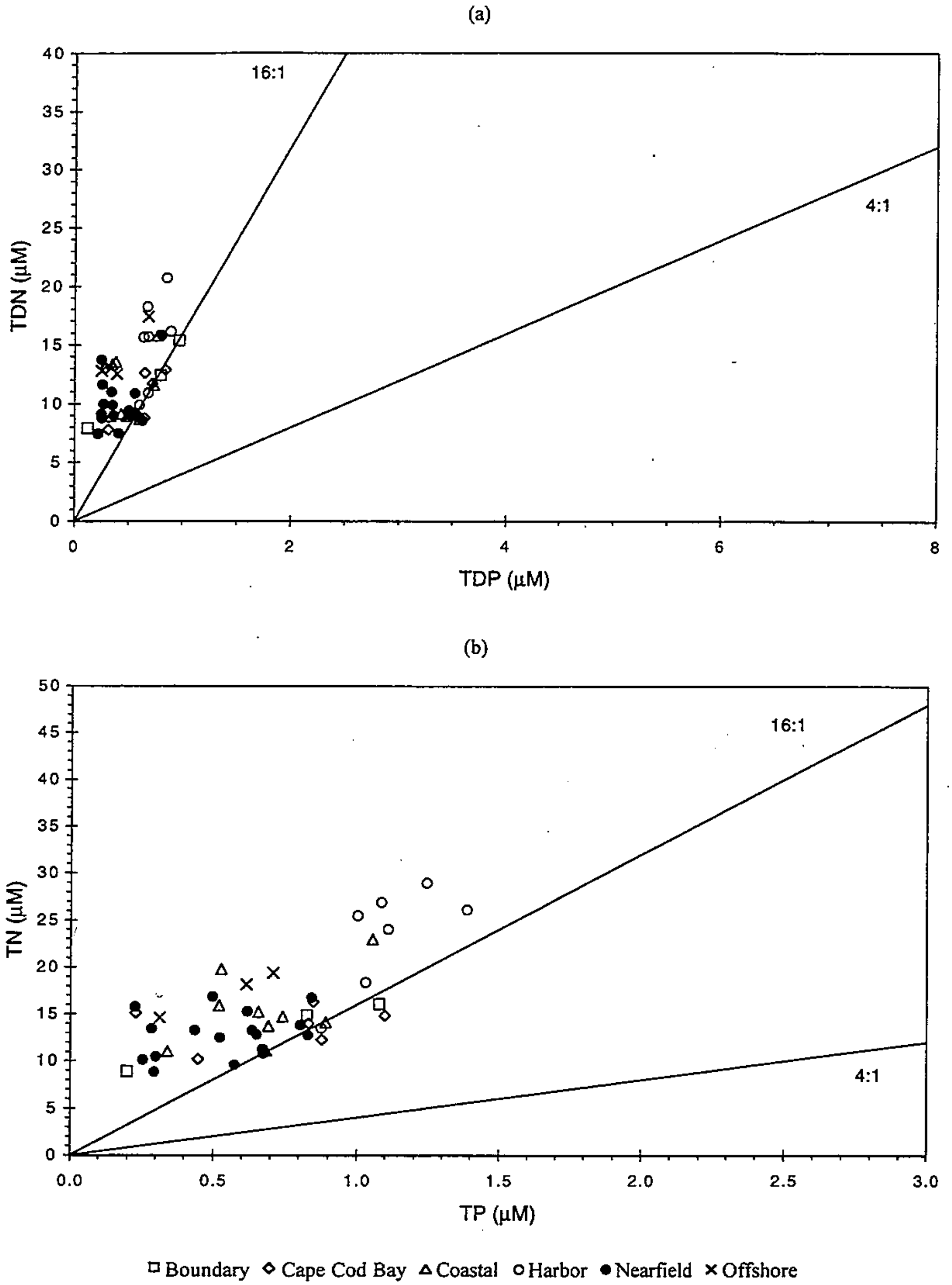


FIGURE 4-101
Nutrient vs. nutrient plots for farfield survey W9607, (Jun 96).

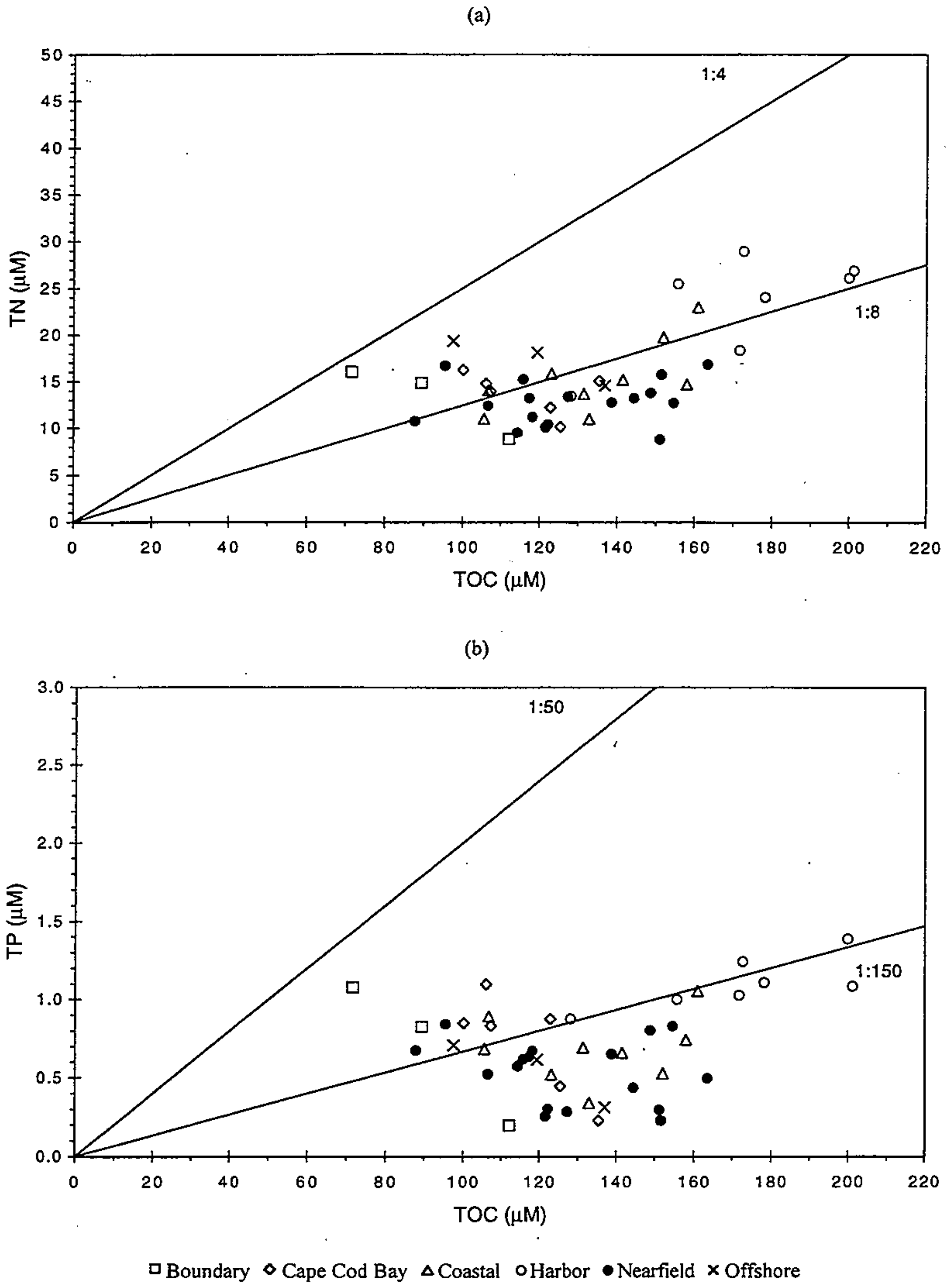


FIGURE 4-102
Nutrient vs. nutrient plots for farfield survey W9607, (Jun 96).

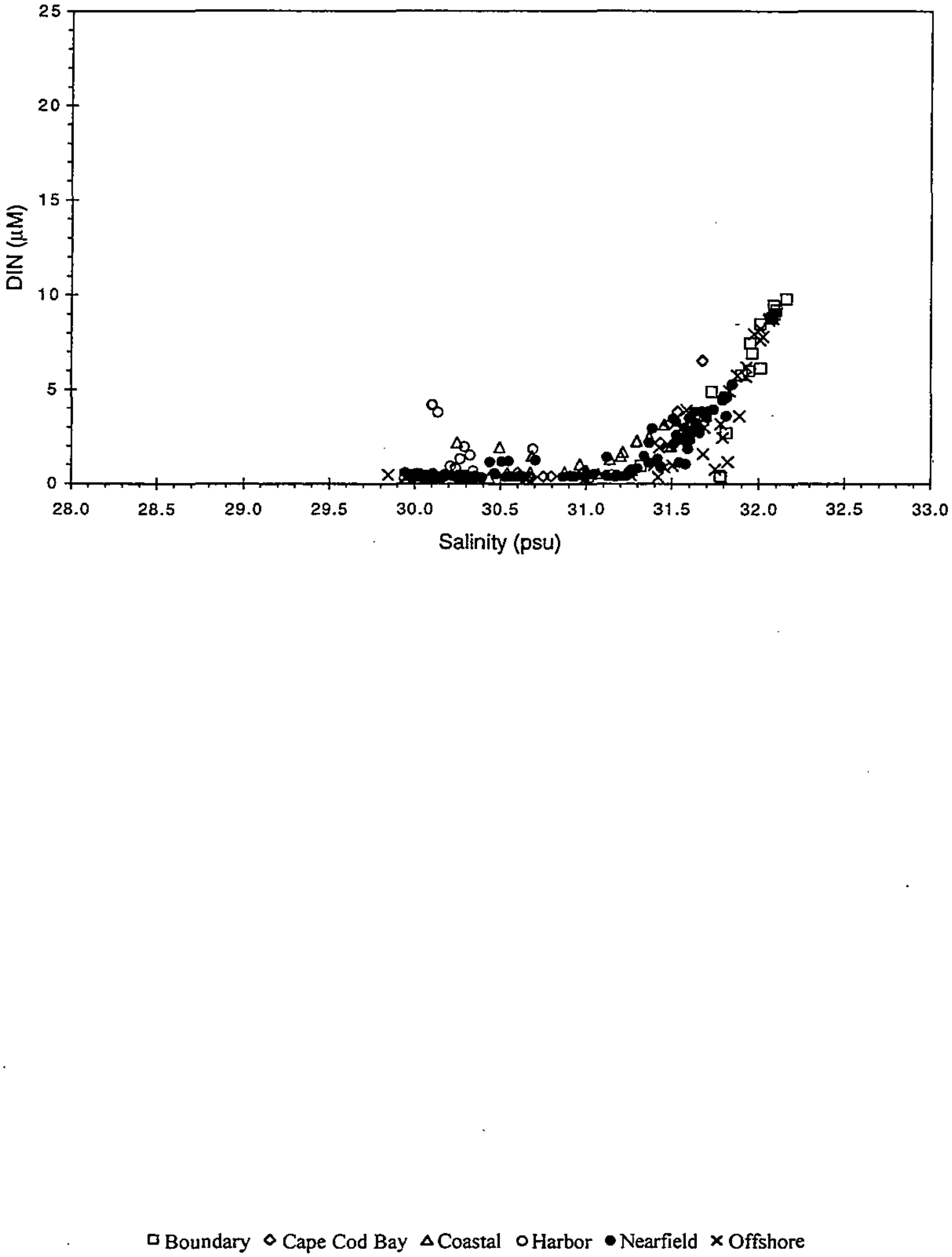


FIGURE 4-103

Nutrient vs. salinity plots for farfield survey W9607, (Jun 96).

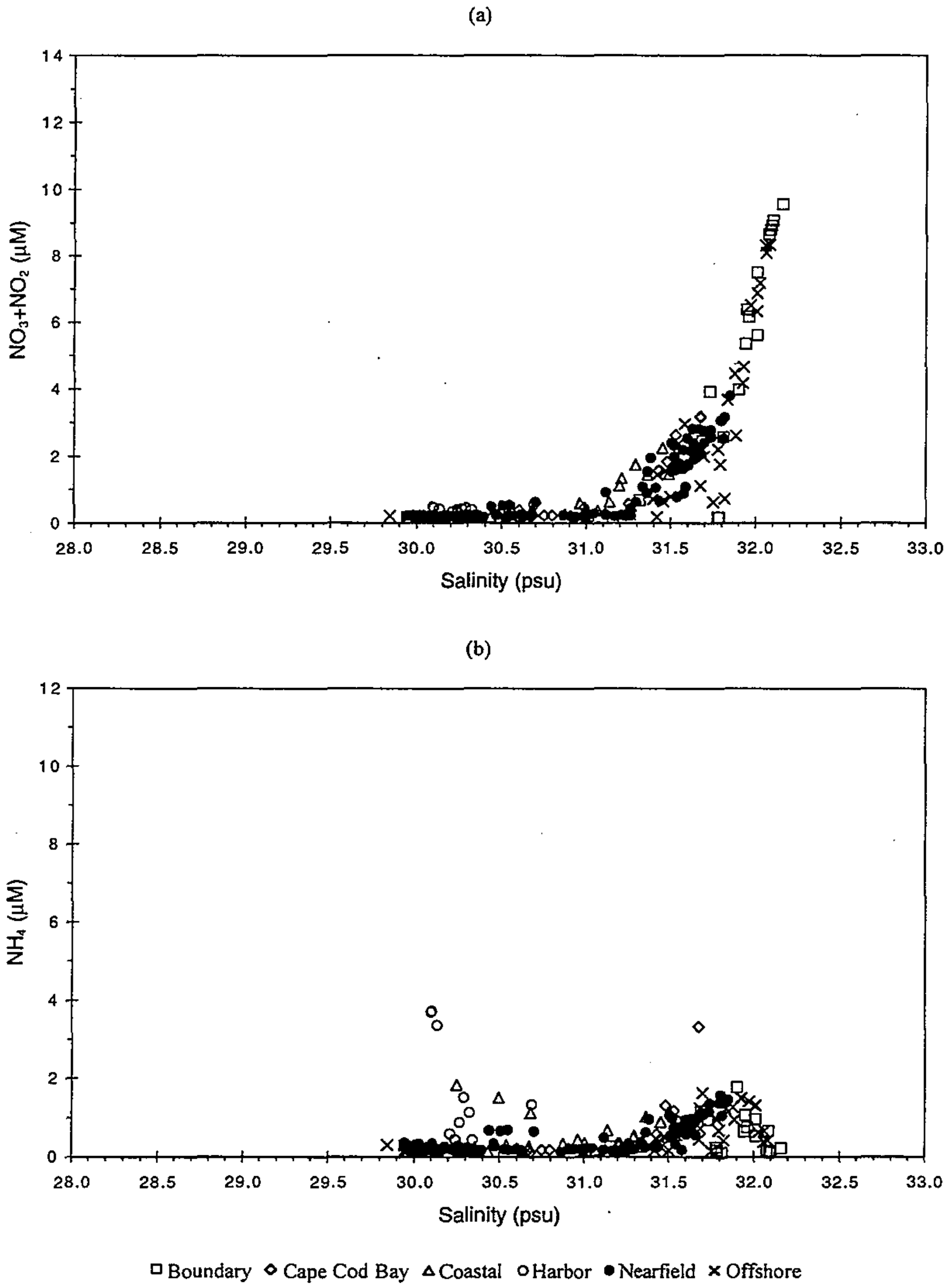


FIGURE 4-104
Nutrient vs. salinity plots for farfield survey W9607, (Jun 96).

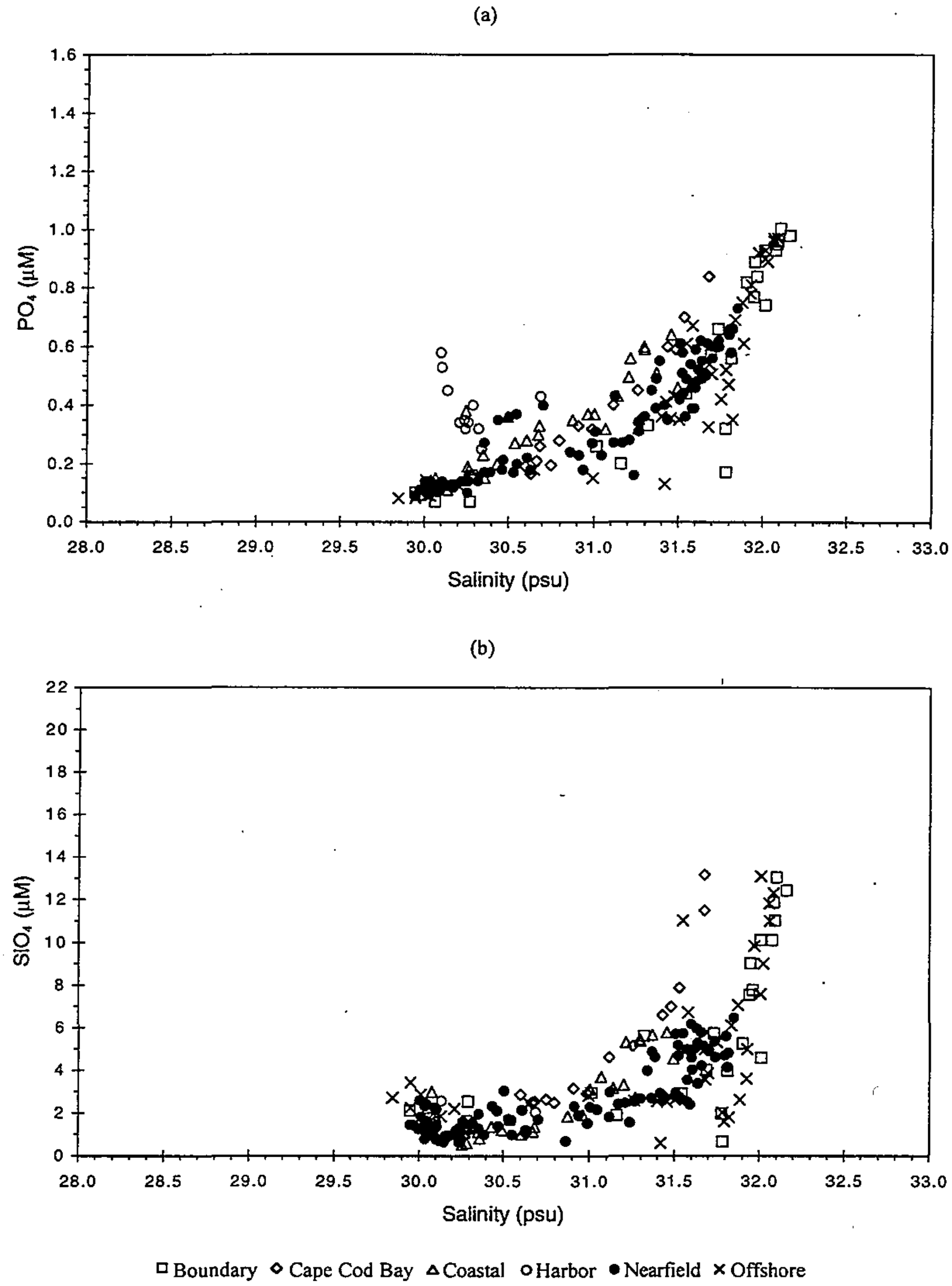


FIGURE 4-105

Nutrient vs. salinity plots for farfield survey W9607, (Jun 96).

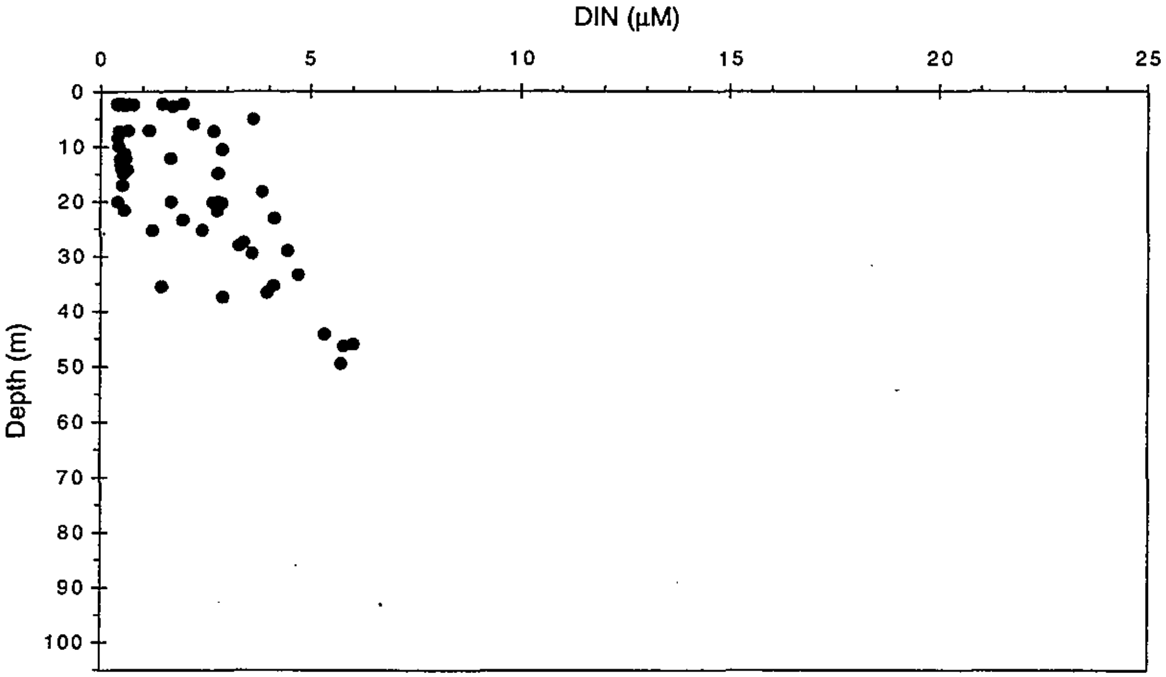


FIGURE 4-106

Depth vs. nutrient plots for nearfield survey W9608, (Jul 96).

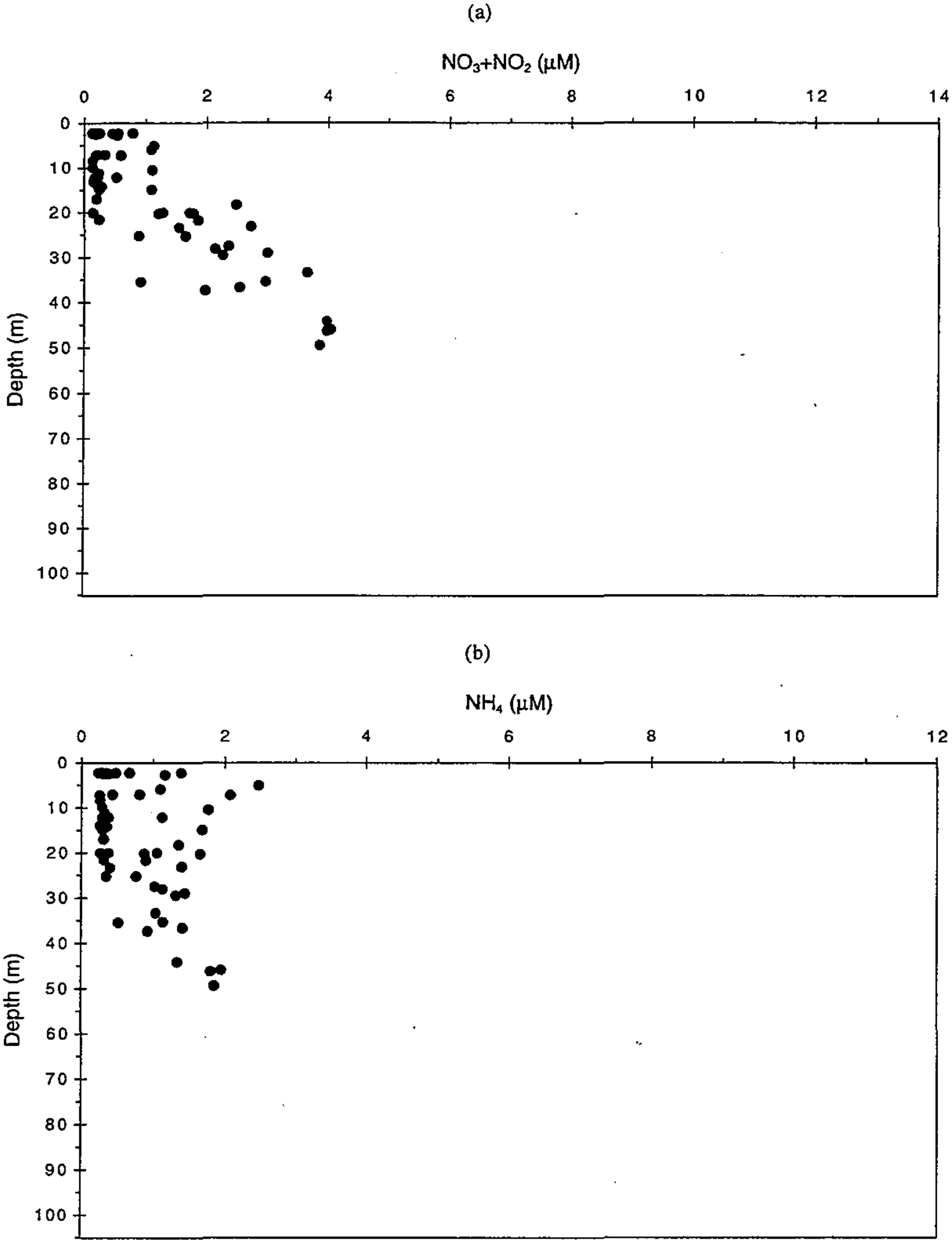


FIGURE 4-107
Depth vs. nutrient plots for nearfield survey W9608, (Jul 96).

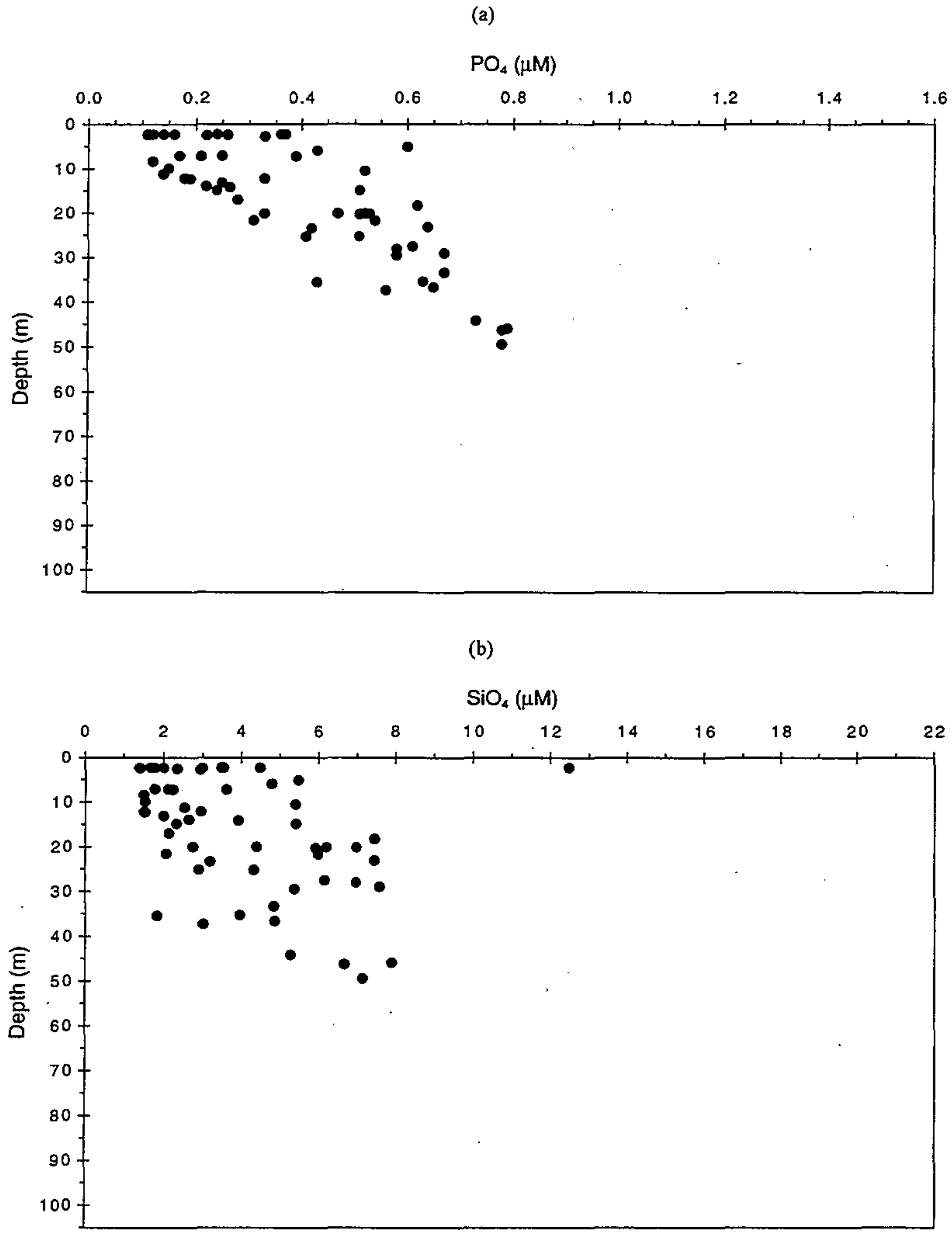
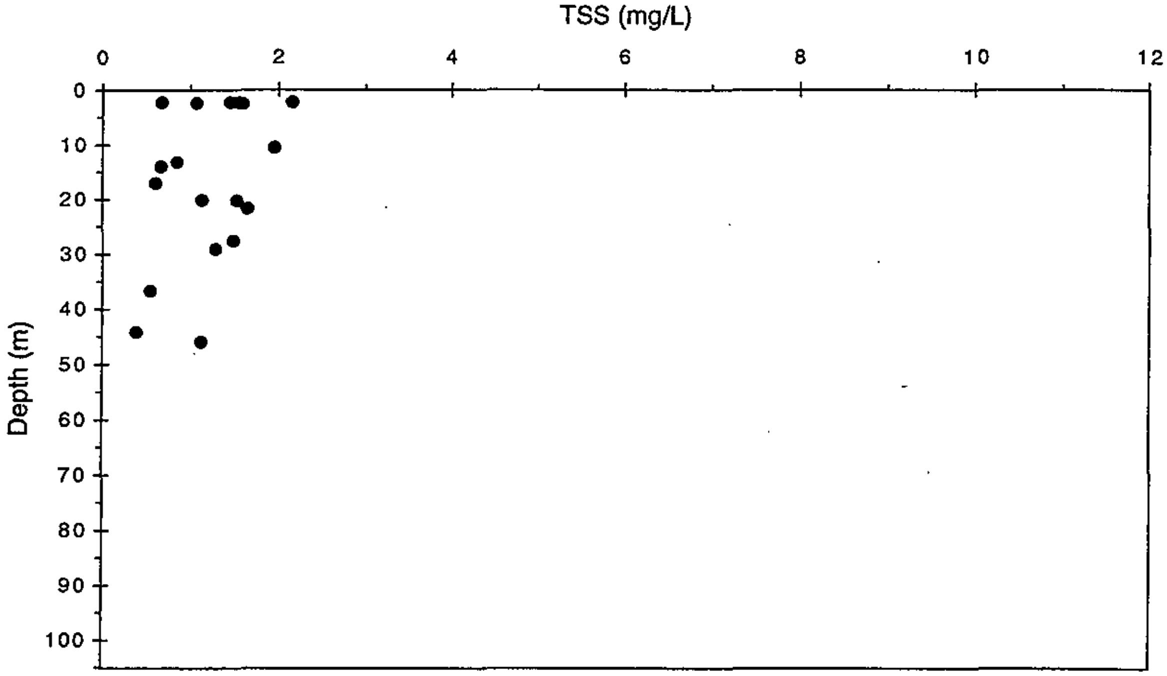


FIGURE 4-108
Depth vs. nutrient plots for nearfield survey W9608, (Jul 96).

(a)



(b)

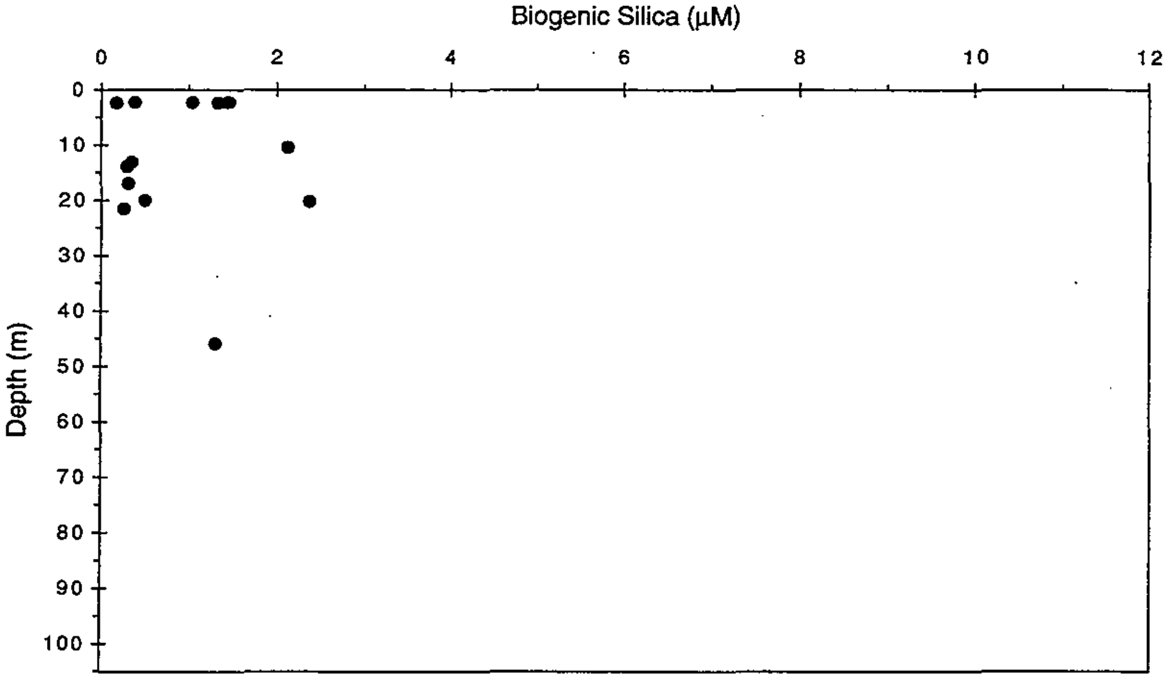


FIGURE 4-109
Depth vs. nutrient plots for nearfield survey W9608, (Jul 96).

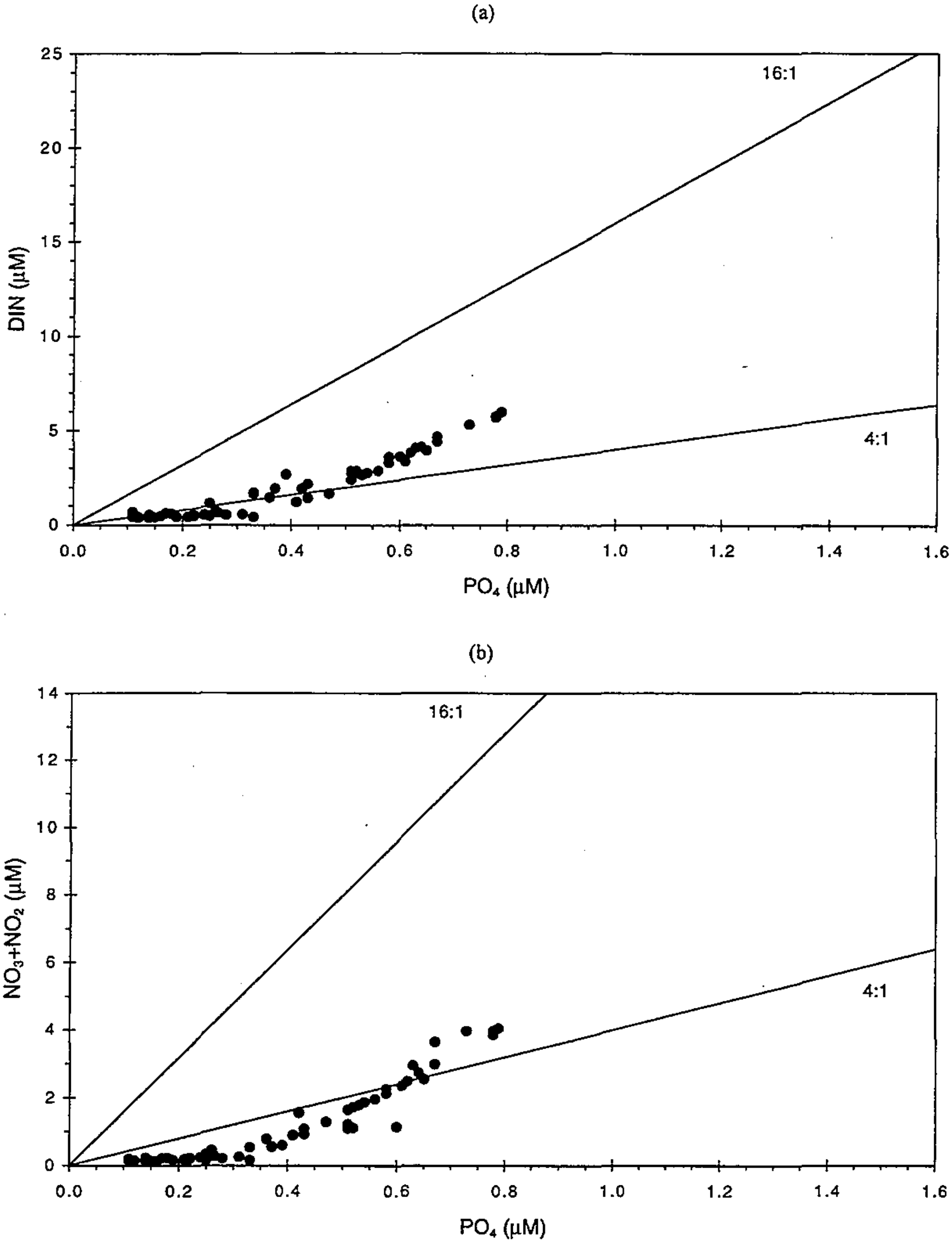


FIGURE 4-110
Nutrient vs. nutrient plots for nearfield survey W9608, (Jul 96).

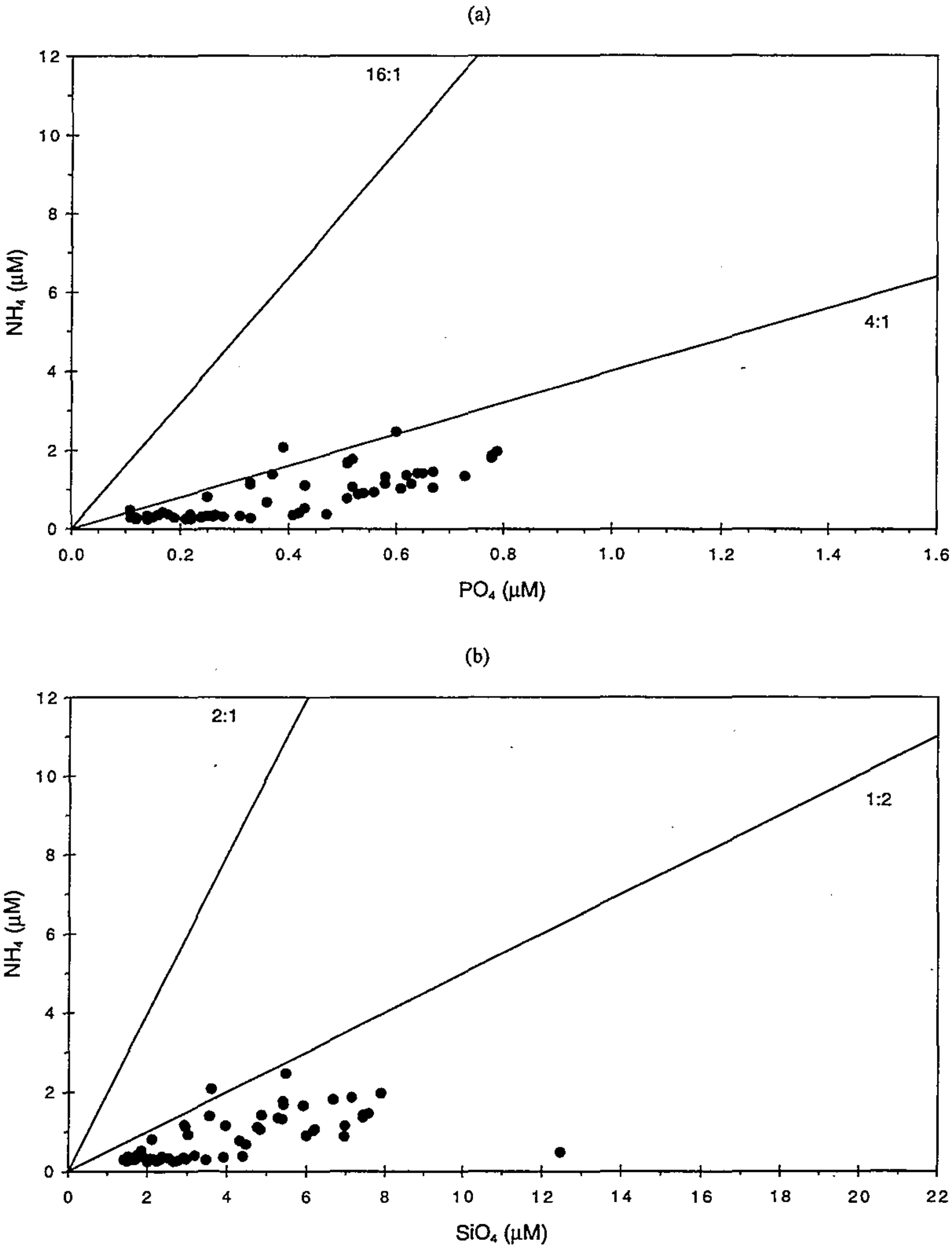


FIGURE 4-111
Nutrient vs. nutrient plots for nearfield survey W9608, (Jul 96).

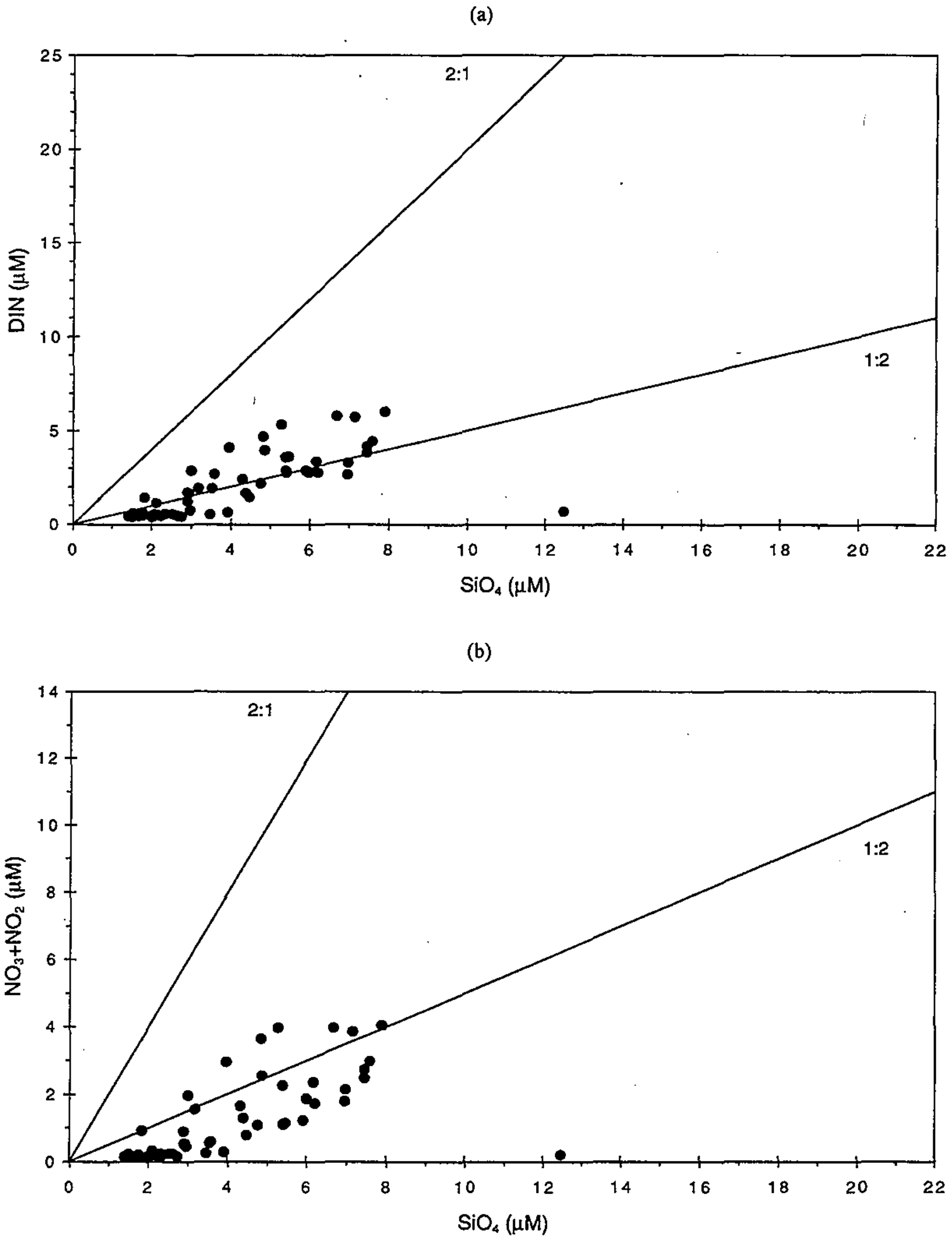


FIGURE 4-112
Nutrient vs. nutrient plots for nearfield survey W9608, (Jul 96).

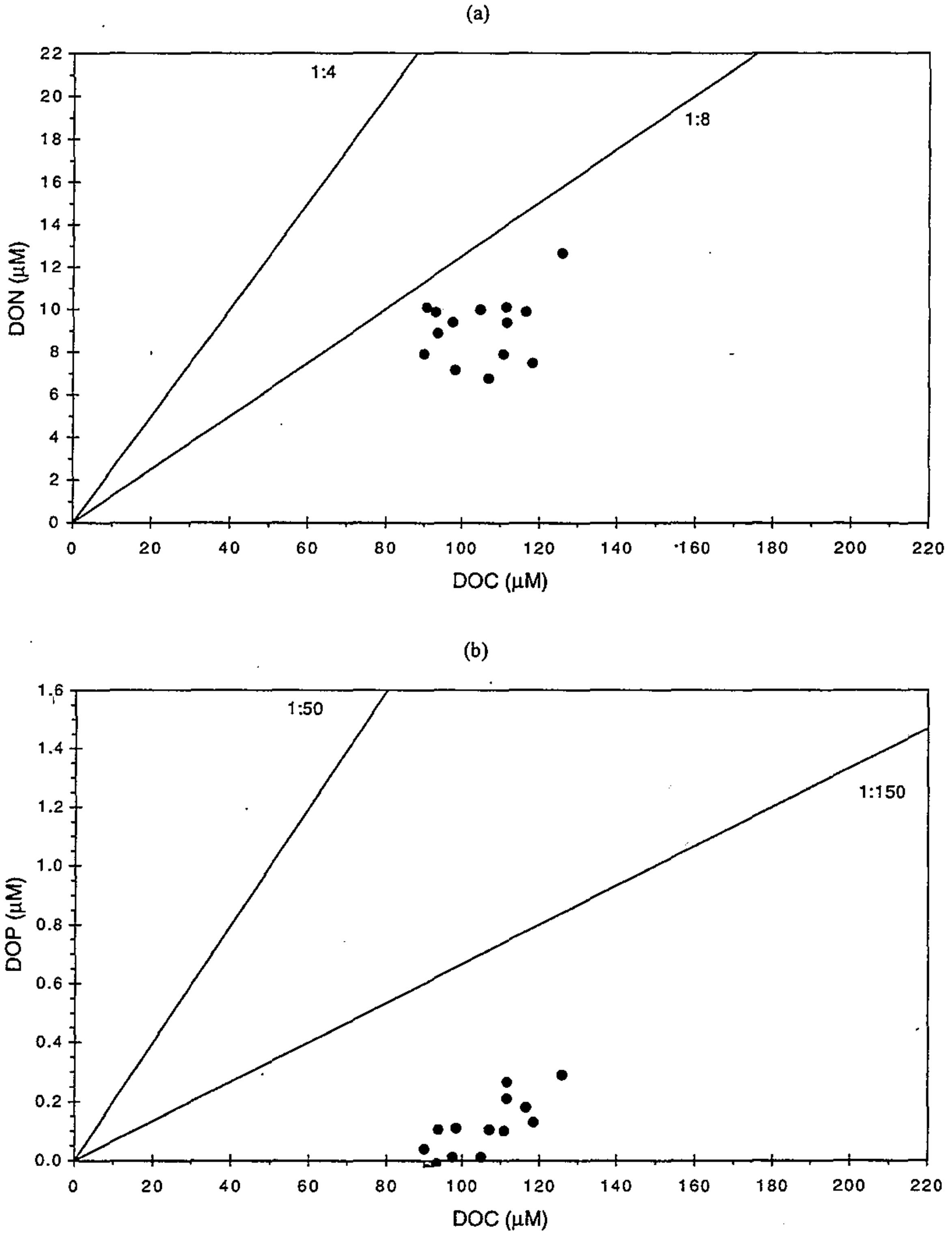


FIGURE 4-113
Nutrient vs. nutrient plots for nearfield survey W9608, (Jul 96).

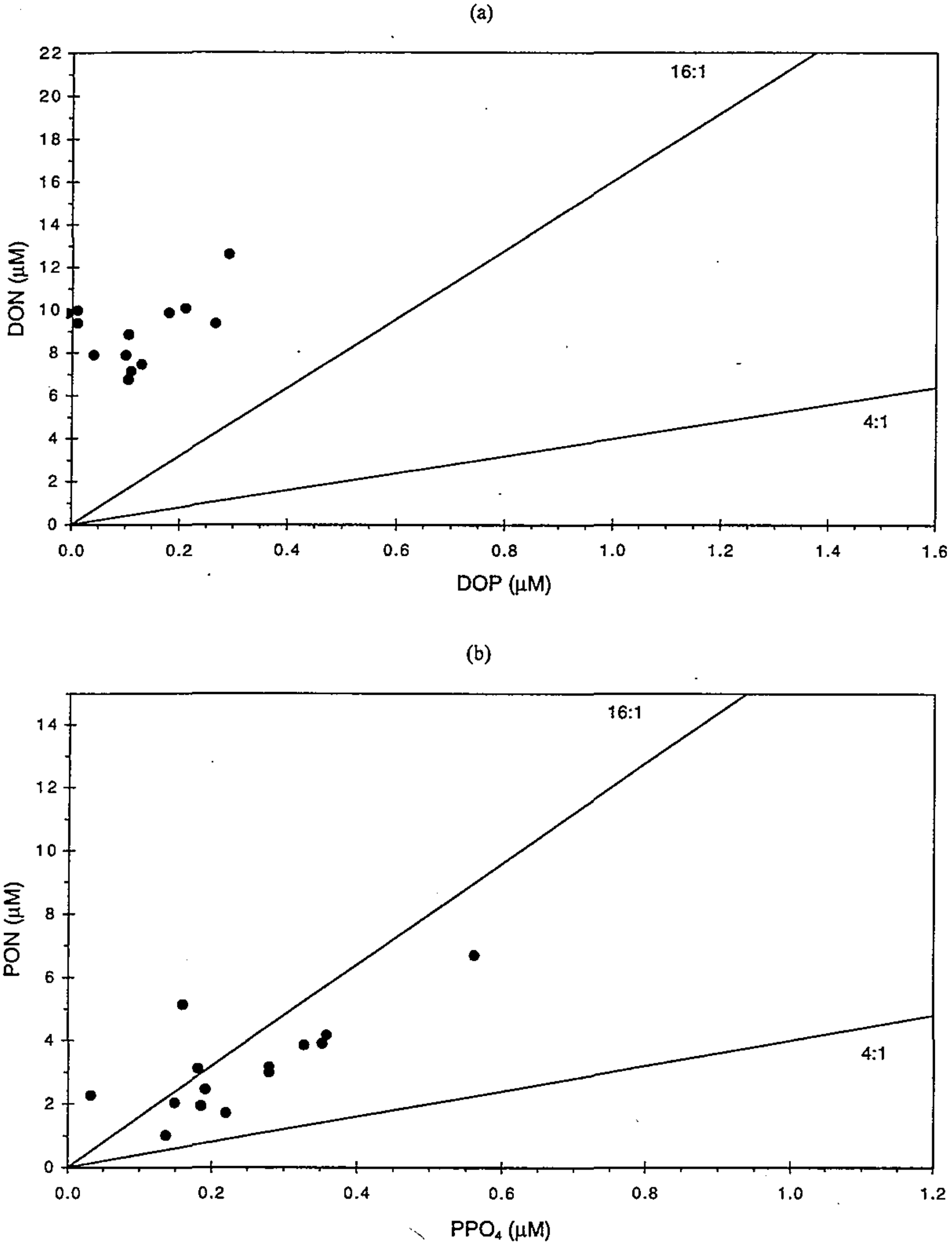


FIGURE 4-114
Nutrient vs. nutrient plots for nearfield survey W9608, (Jul 96).

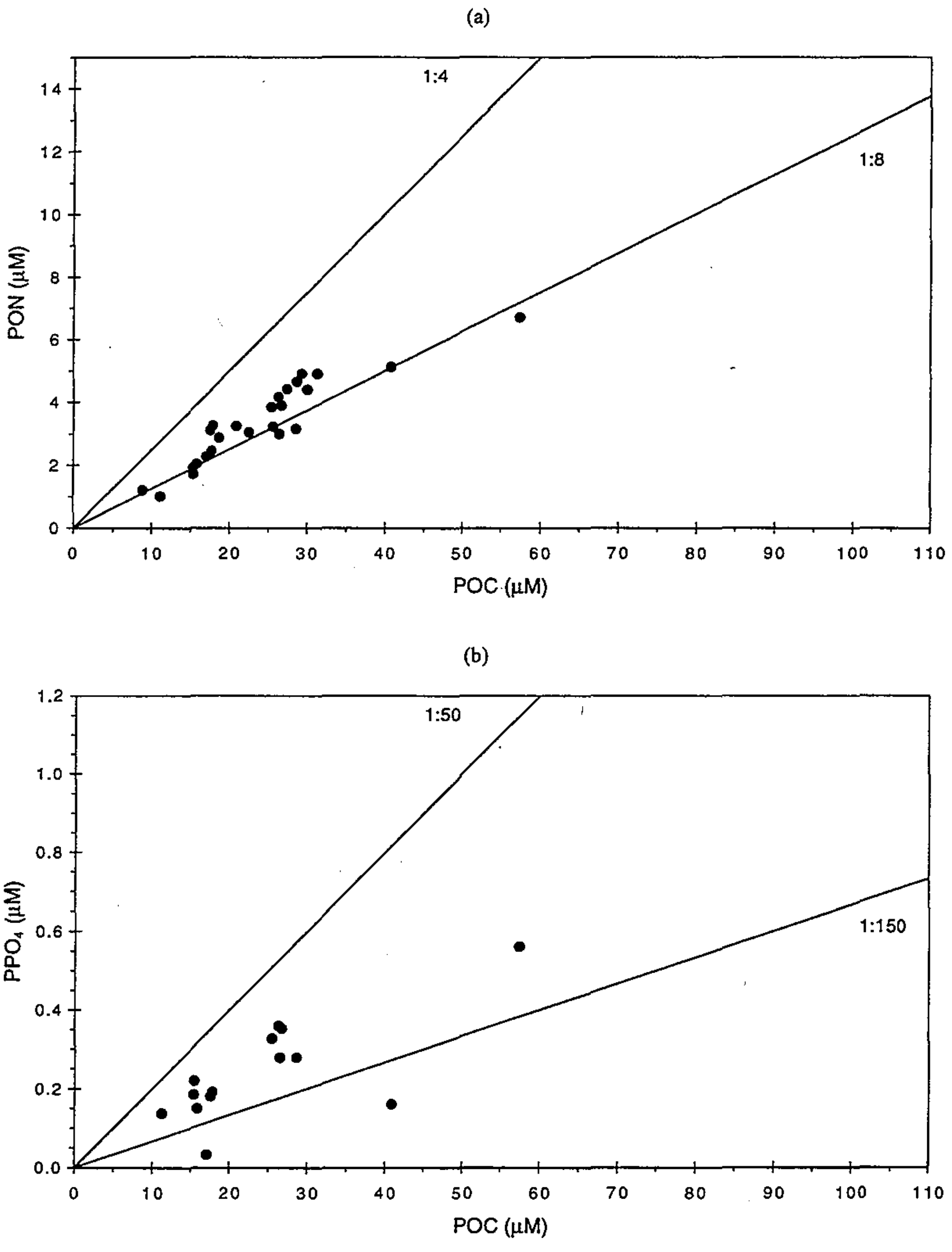


FIGURE 4-115
Nutrient vs. nutrient plots for nearfield survey W9608, (Jul 96).

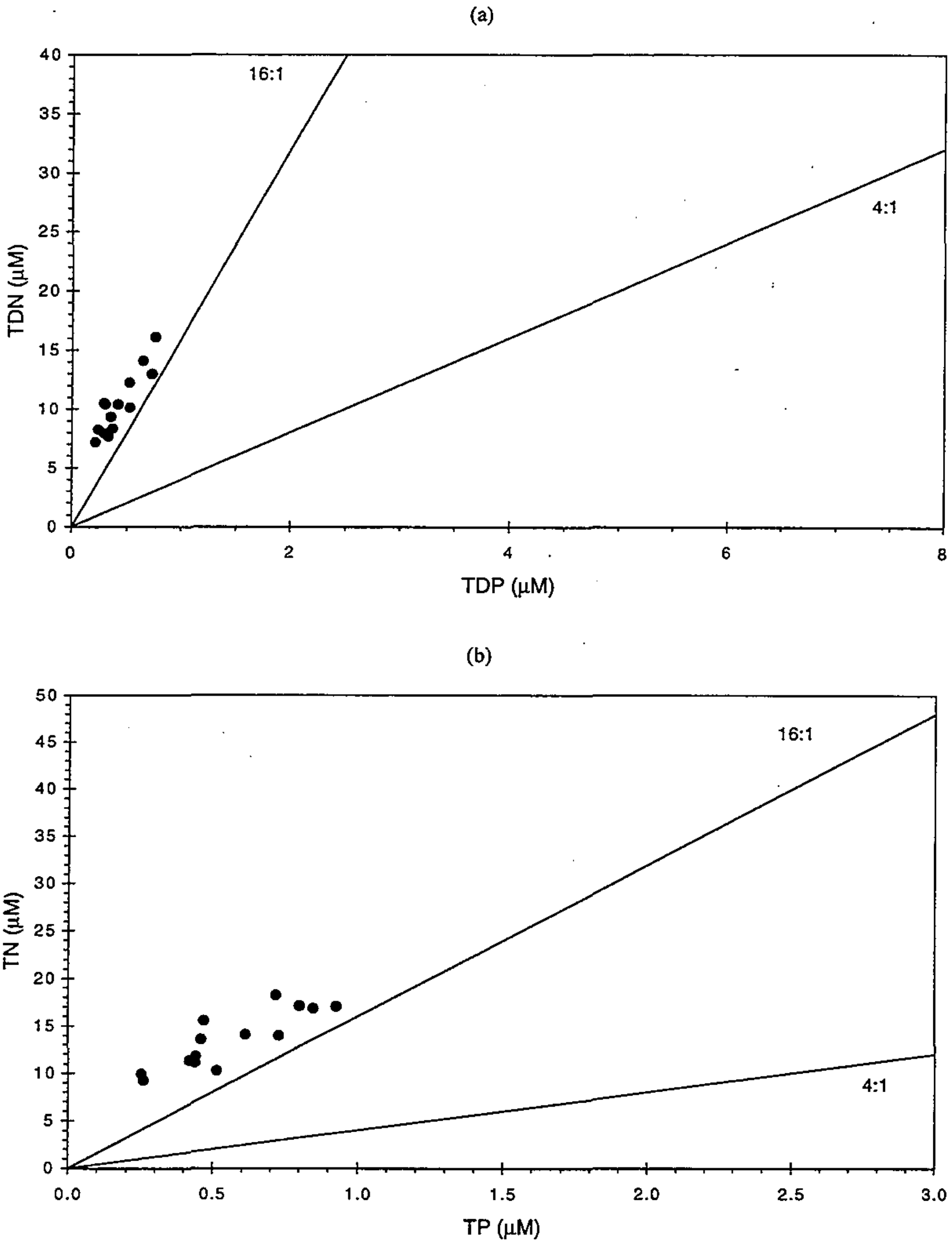


FIGURE 4-116
Nutrient vs. nutrient plots for nearfield survey W9608, (Jul 96).

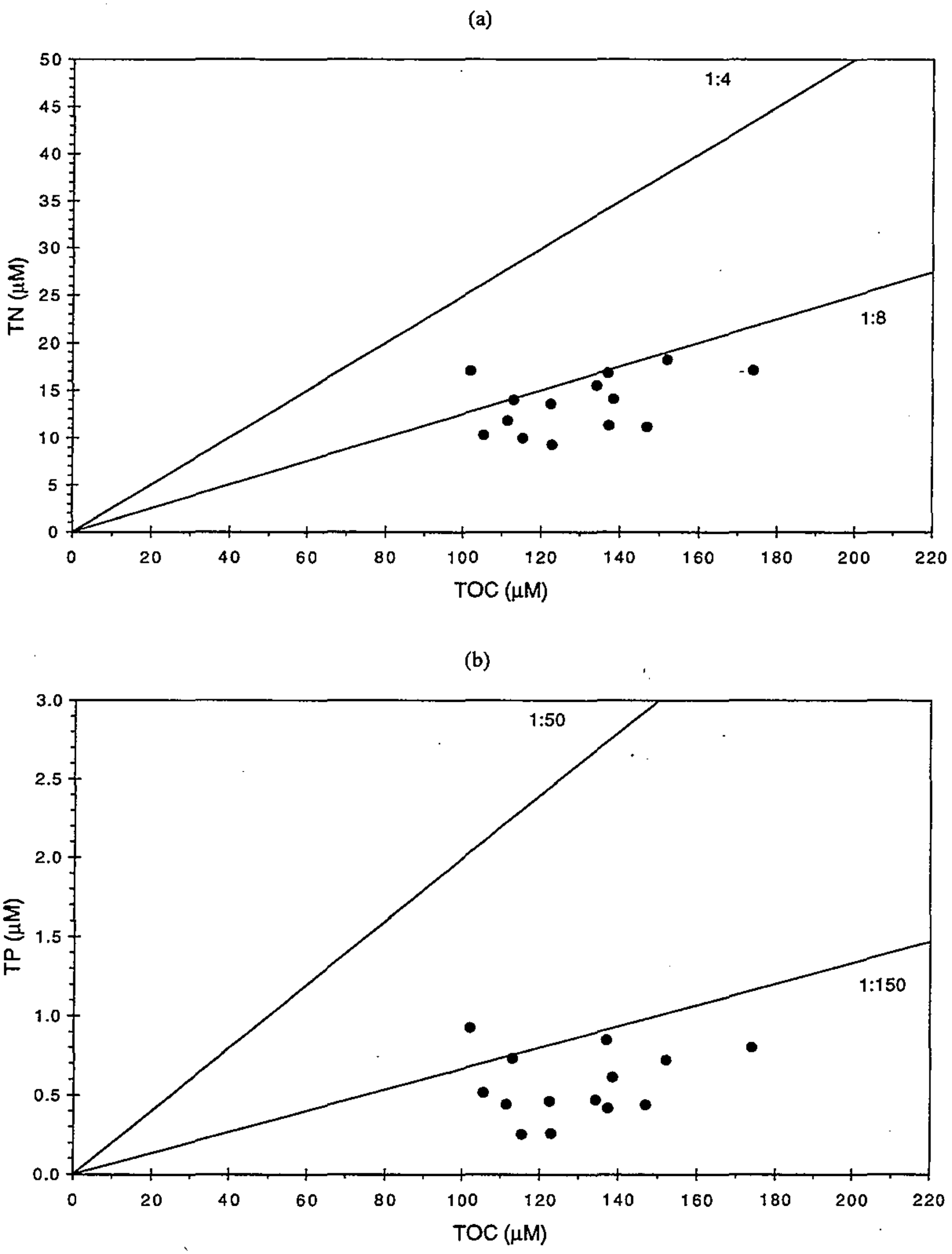


FIGURE 4-117
Nutrient vs. nutrient plots for nearfield survey W9608, (Jul 96).

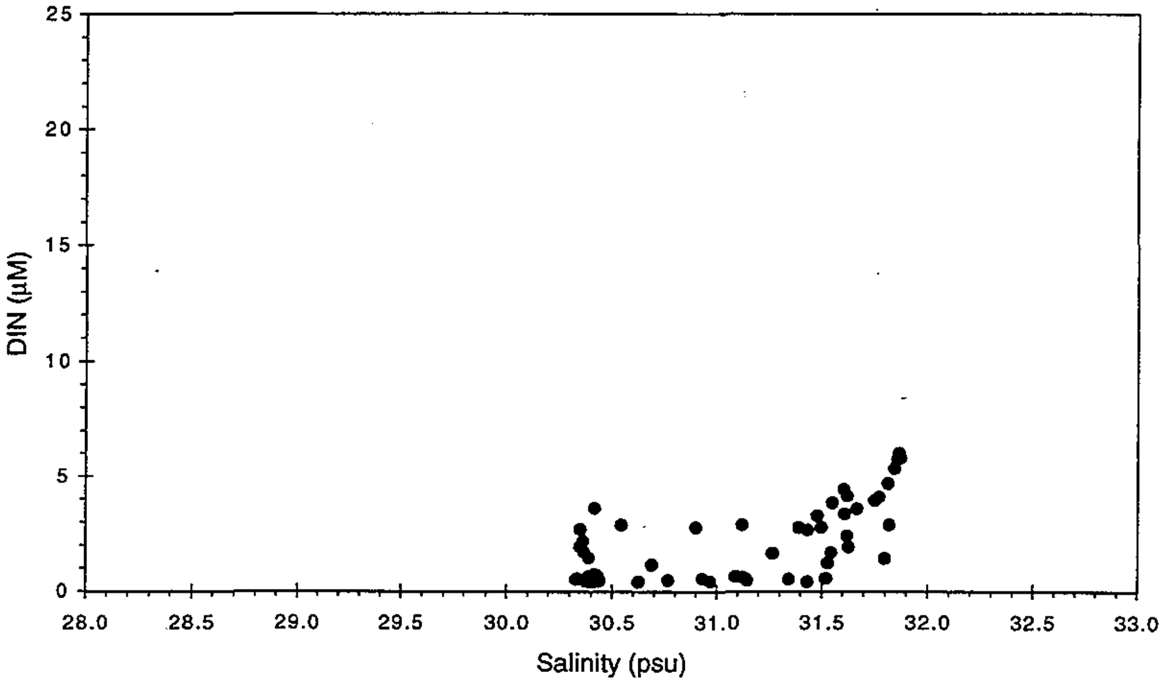


FIGURE 4-118
Nutrient vs. salinity plots for nearfield survey W9608, (Jul 96).

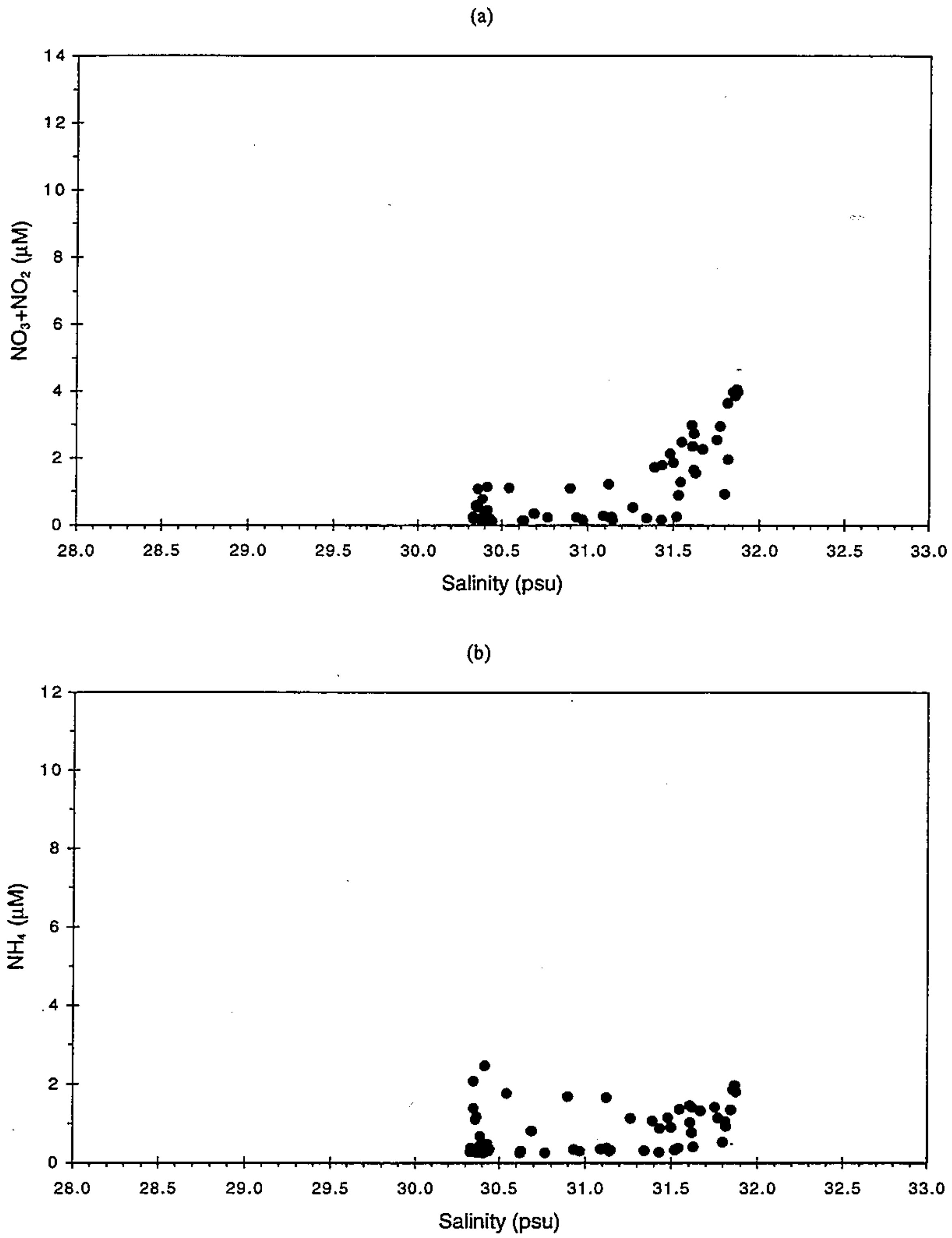


FIGURE 4-119

Nutrient vs. salinity plots for nearfield survey W9608, (Jul 96).

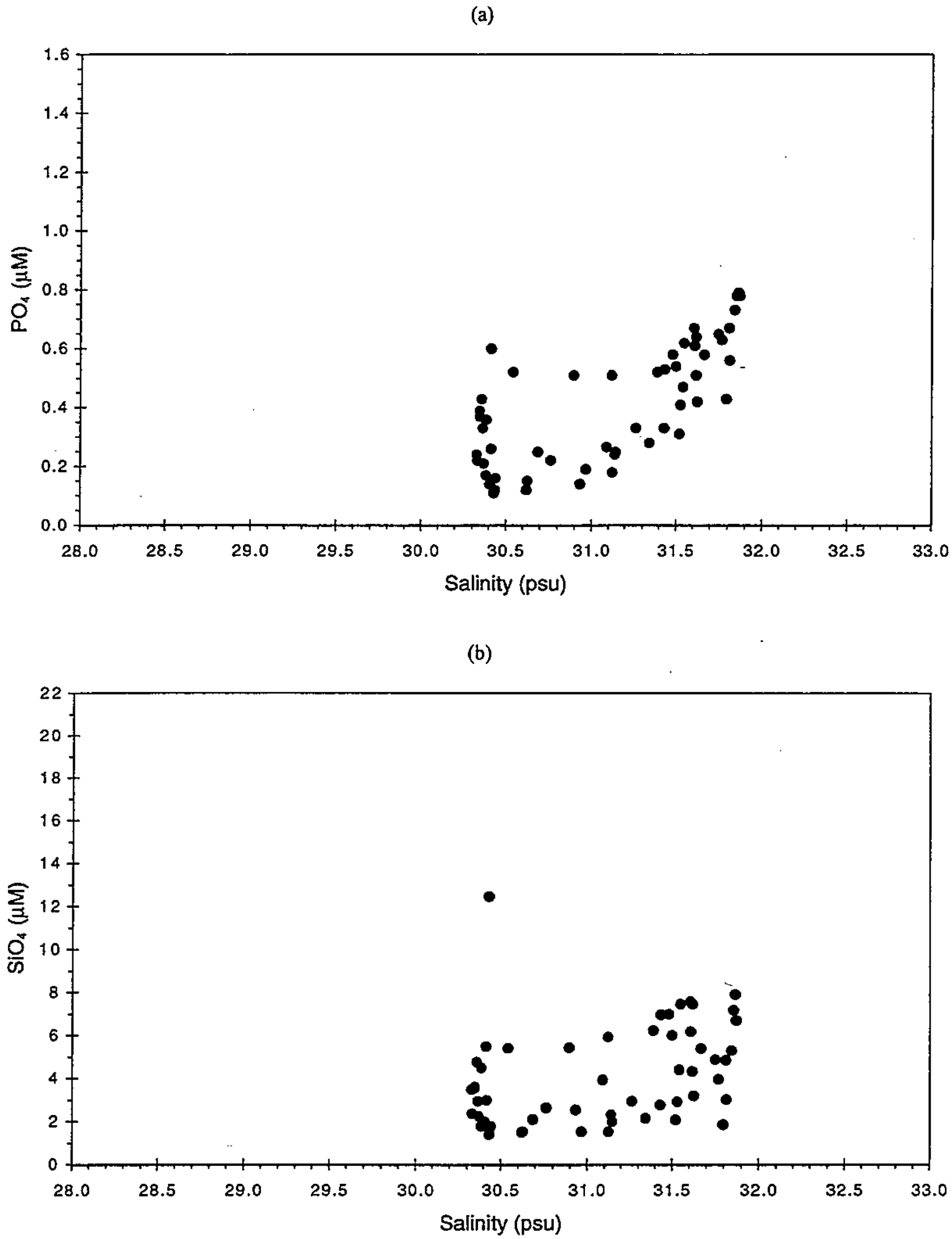


FIGURE 4-120
Nutrient vs. salinity plots for nearfield survey W9608, (Jul 96).

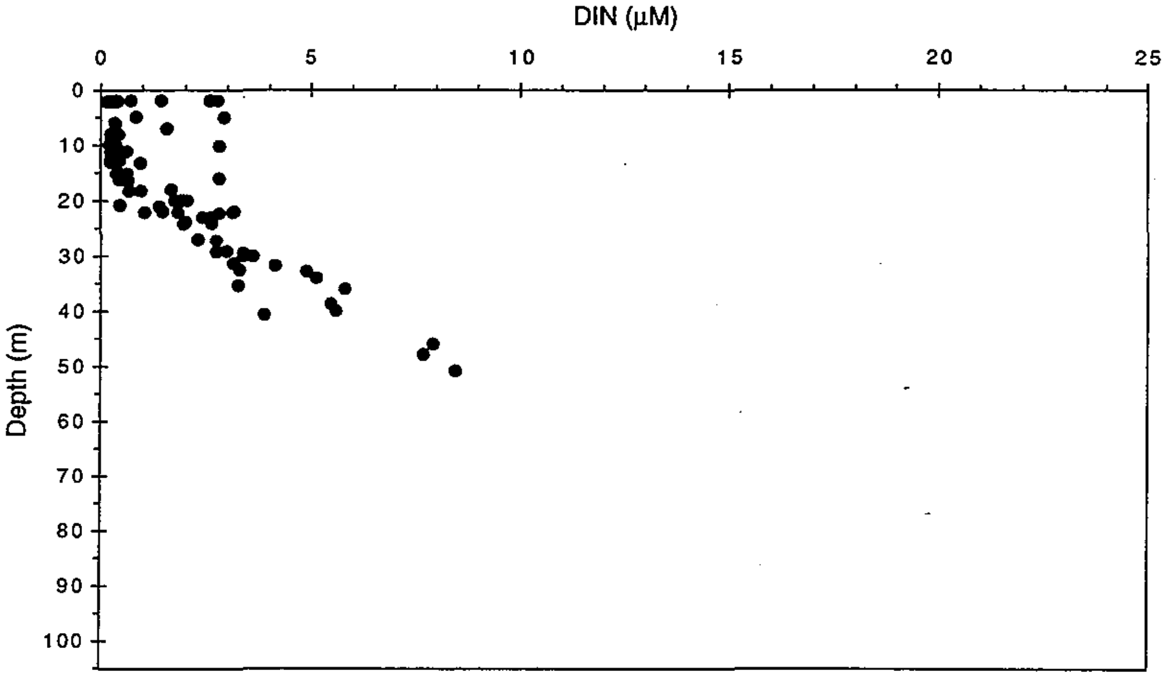


FIGURE 4-121
Depth vs. nutrient plots for nearfield survey W9609, (Jul 96).

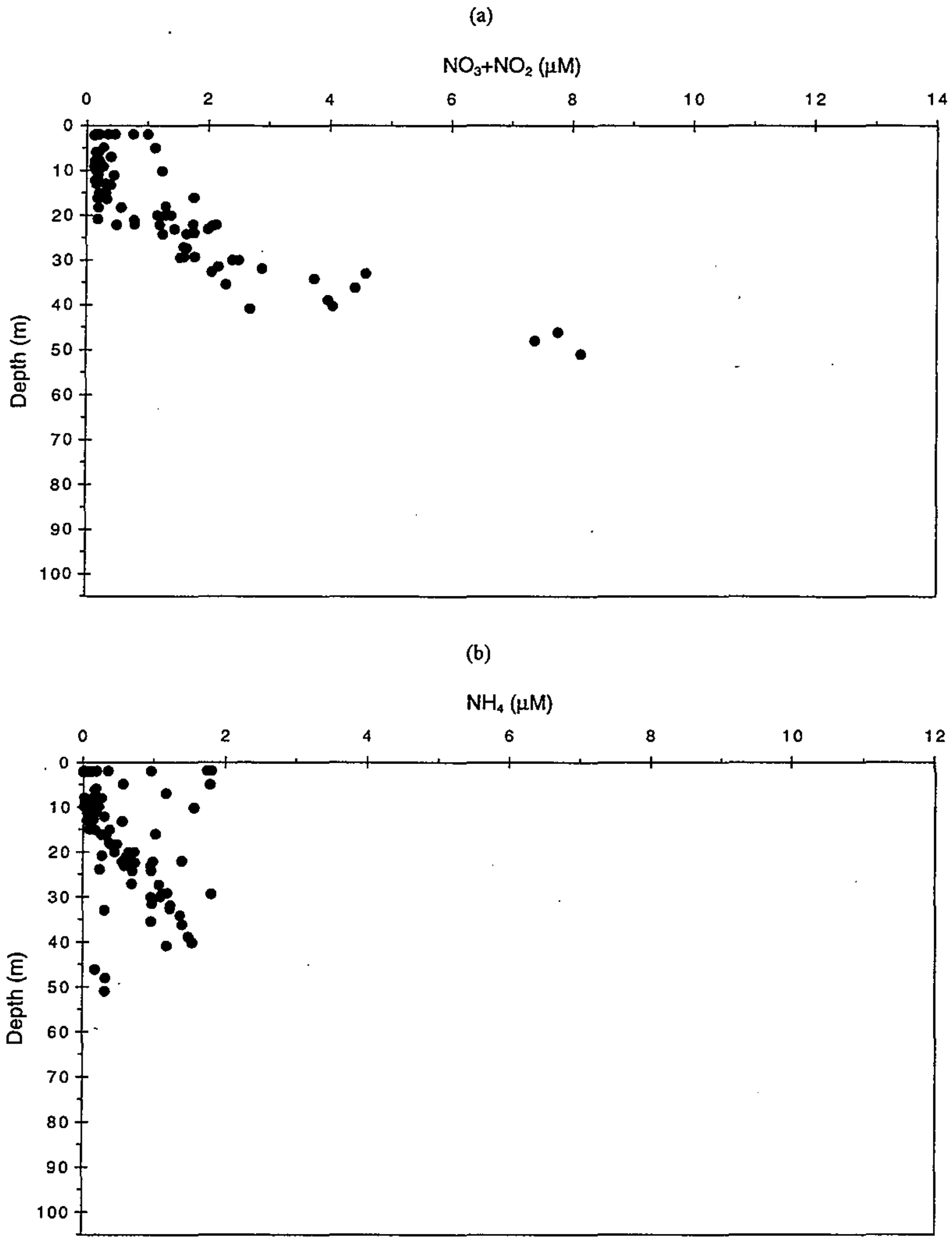
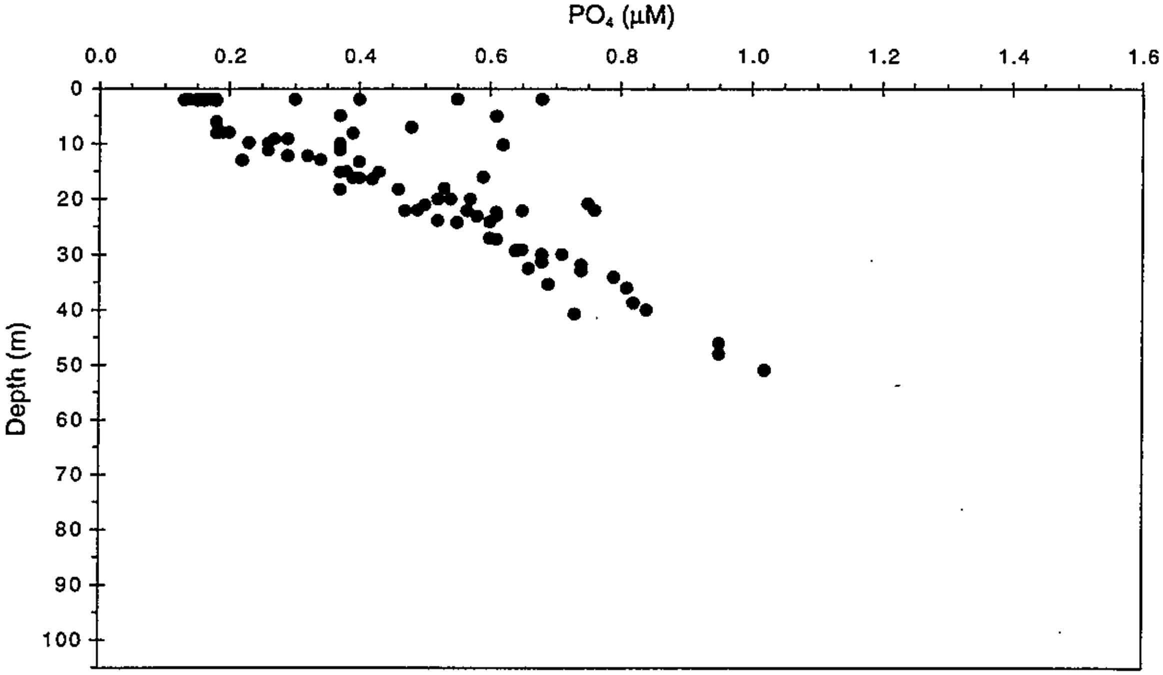


FIGURE 4-122

Depth vs. nutrient plots for nearfield survey W9609, (Jul 96).

(a)



(b)

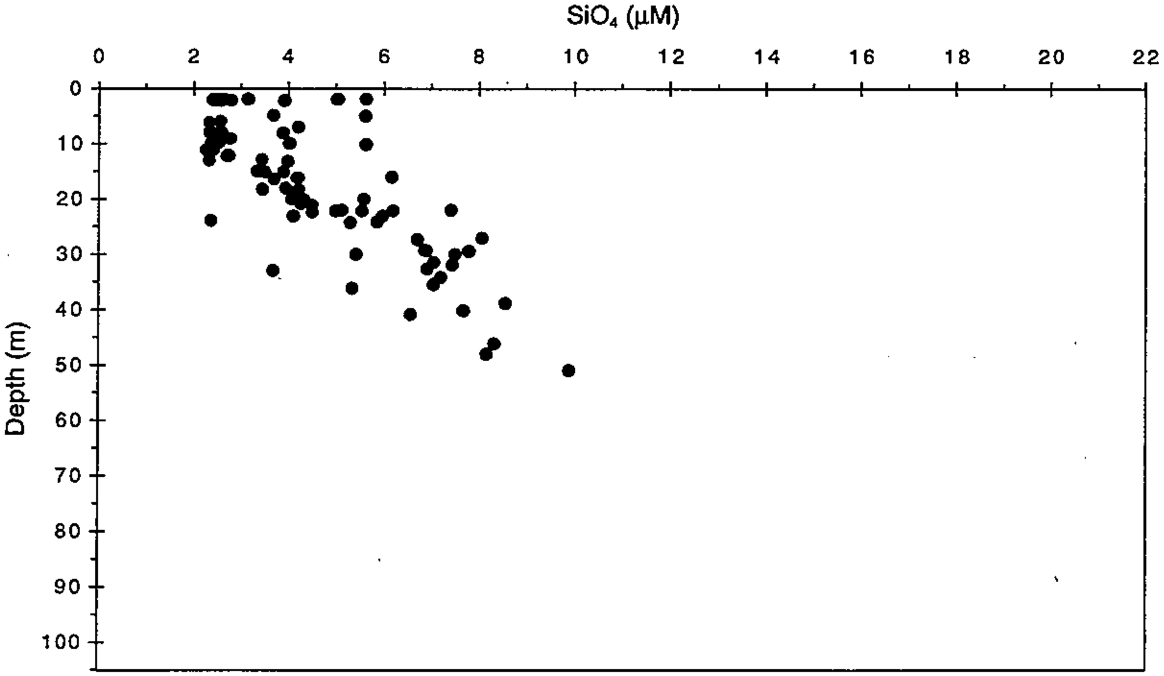


FIGURE 4-123
Depth vs. nutrient plots for nearfield survey W9609, (Jul 96).

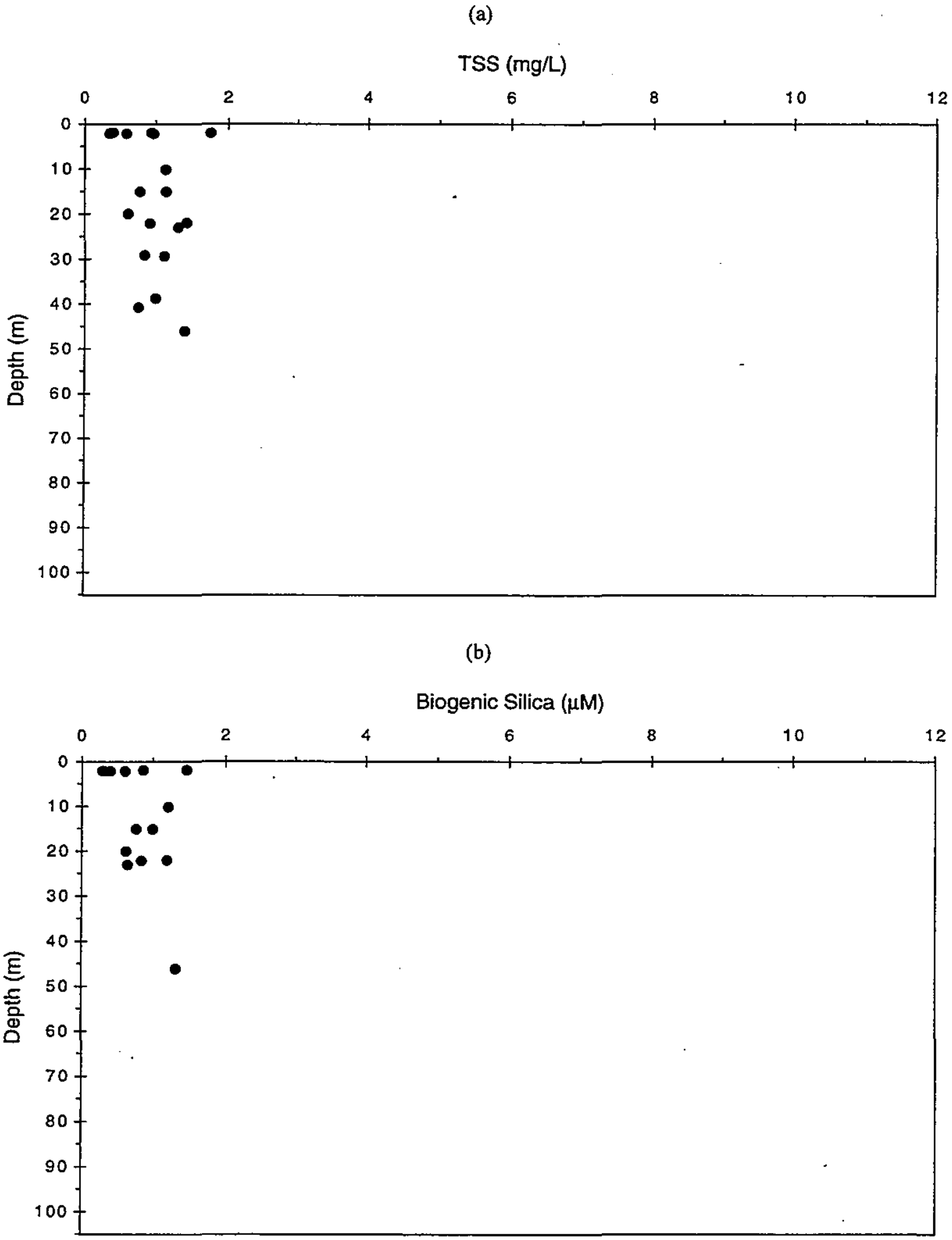


FIGURE 4-124
Depth vs. nutrient plots for nearfield survey W9609, (Jul 96).

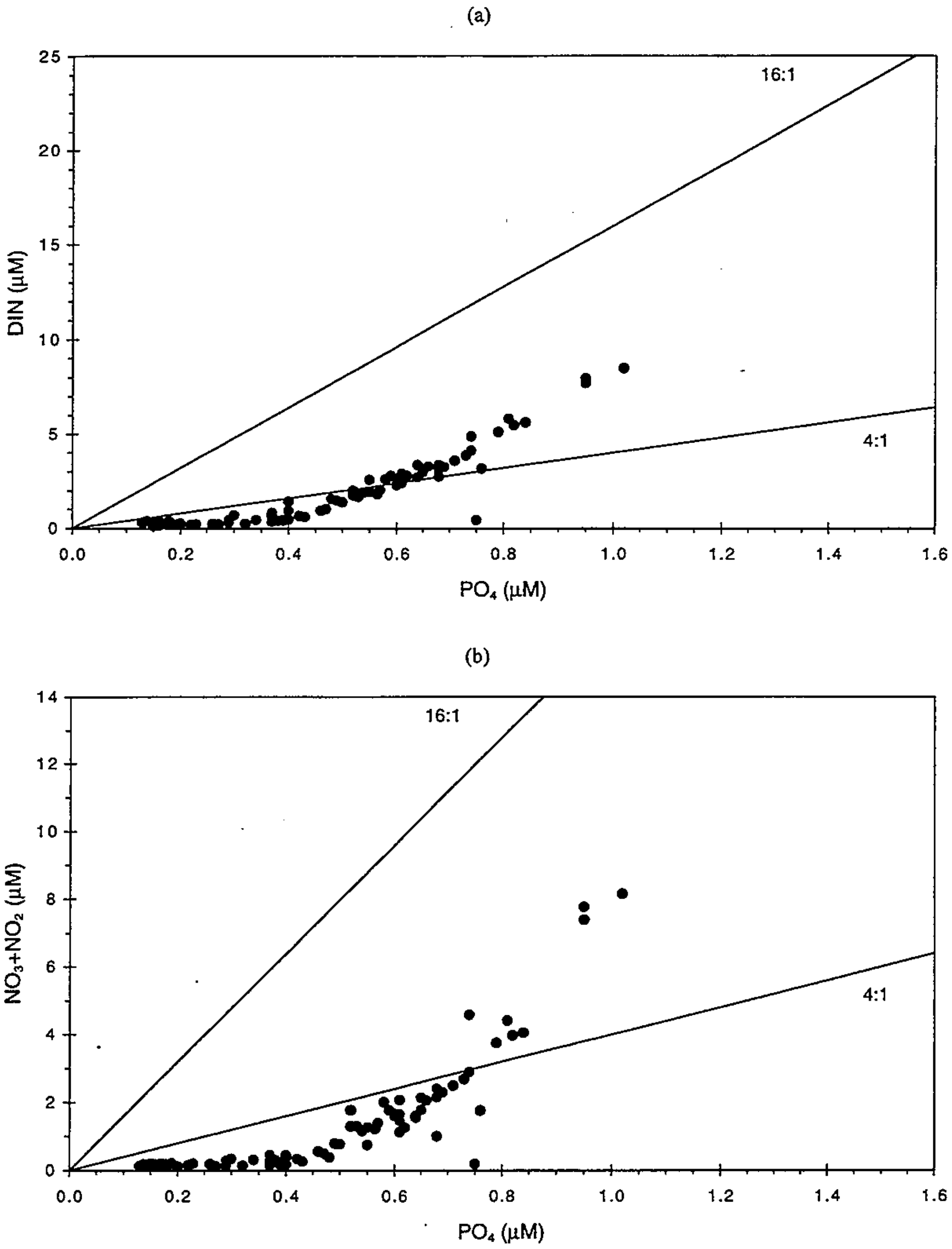


FIGURE 4-125
Nutrient vs. nutrient plots for nearfield survey W9609, (Jul 96).

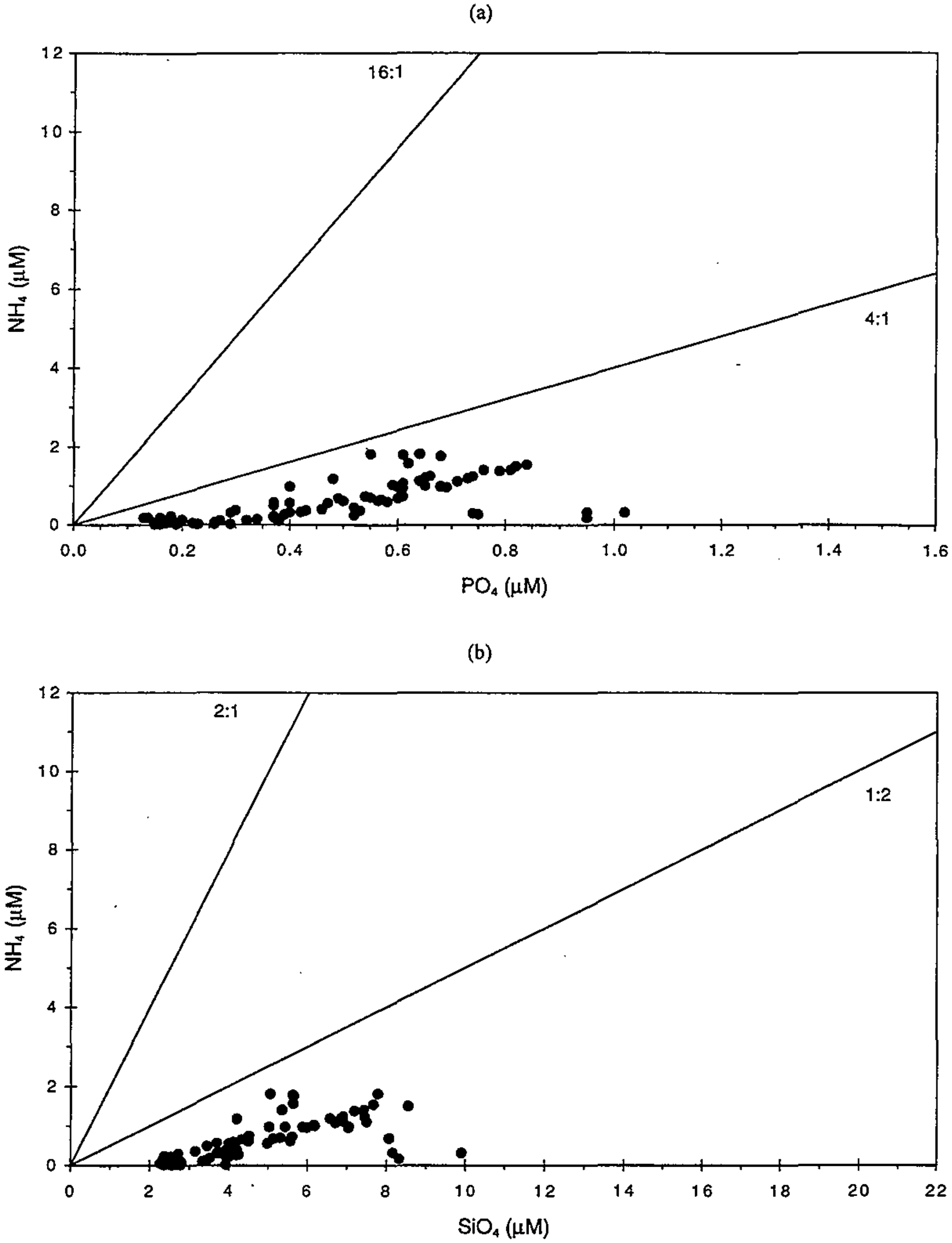


FIGURE 4-126
Nutrient vs. nutrient plots for nearfield survey W9609, (Jul 96).

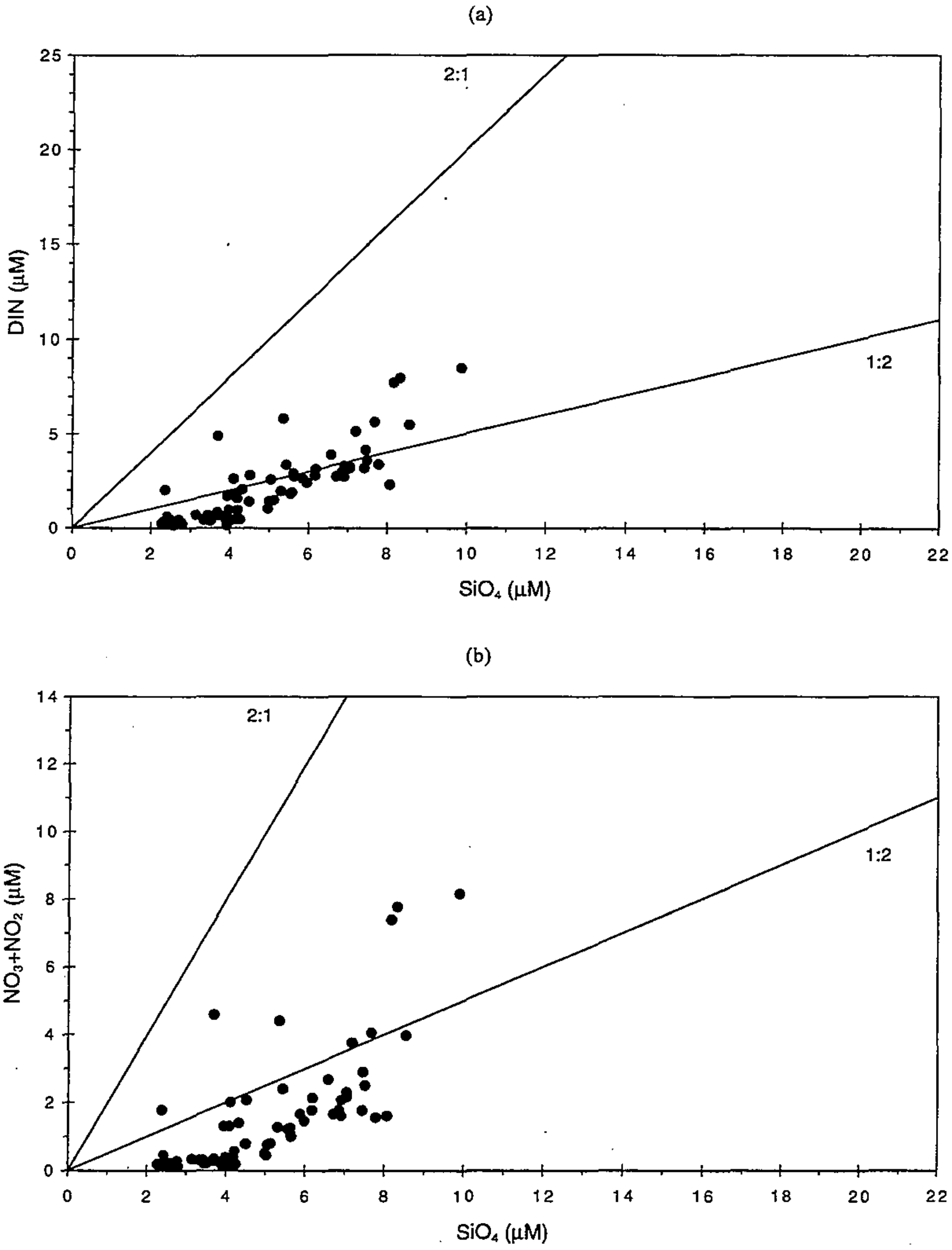


FIGURE 4-127

Nutrient vs. nutrient plots for nearfield survey W9609, (Jul 96).

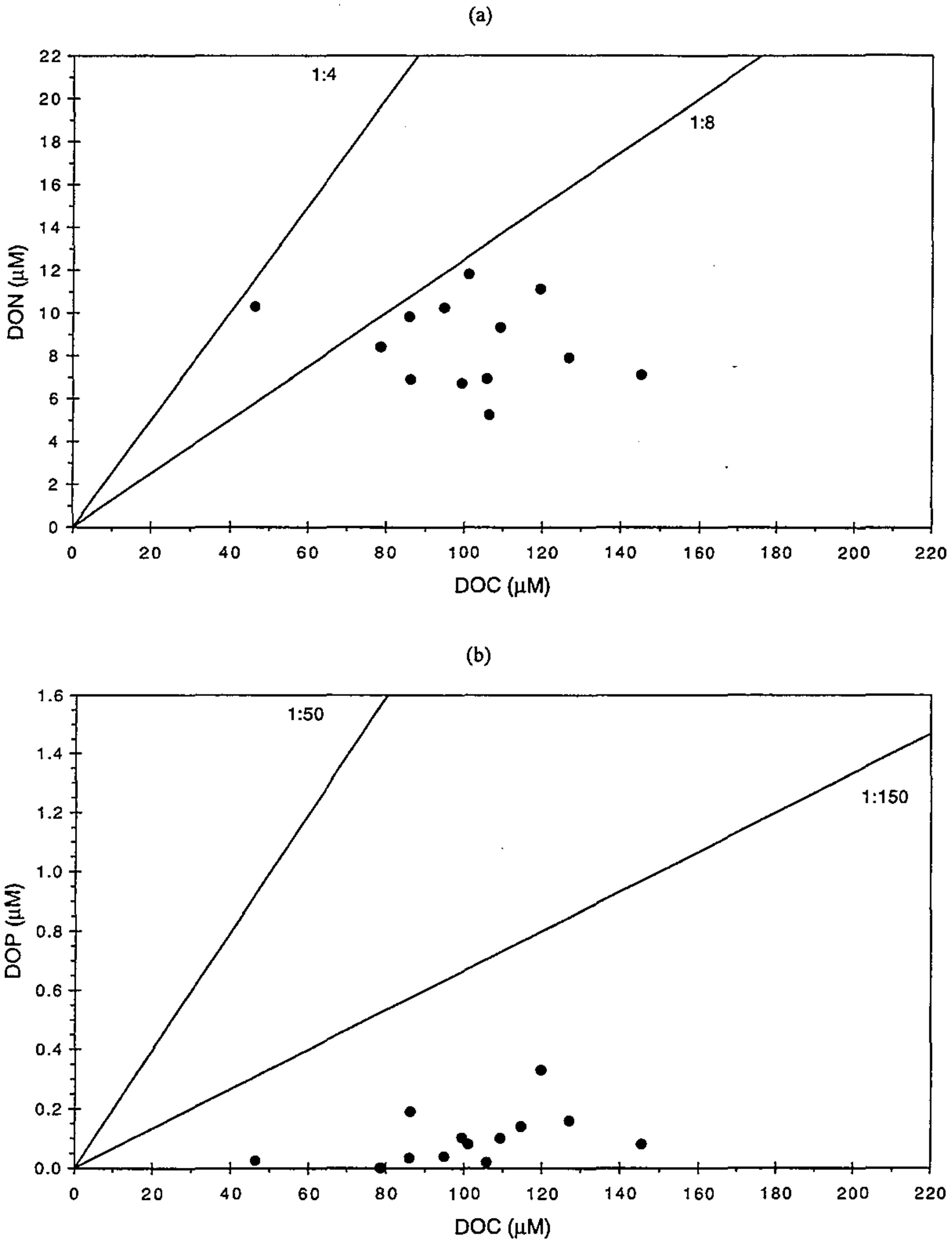


FIGURE 4-128
Nutrient vs. nutrient plots for nearfield survey W9609, (Jul 96).

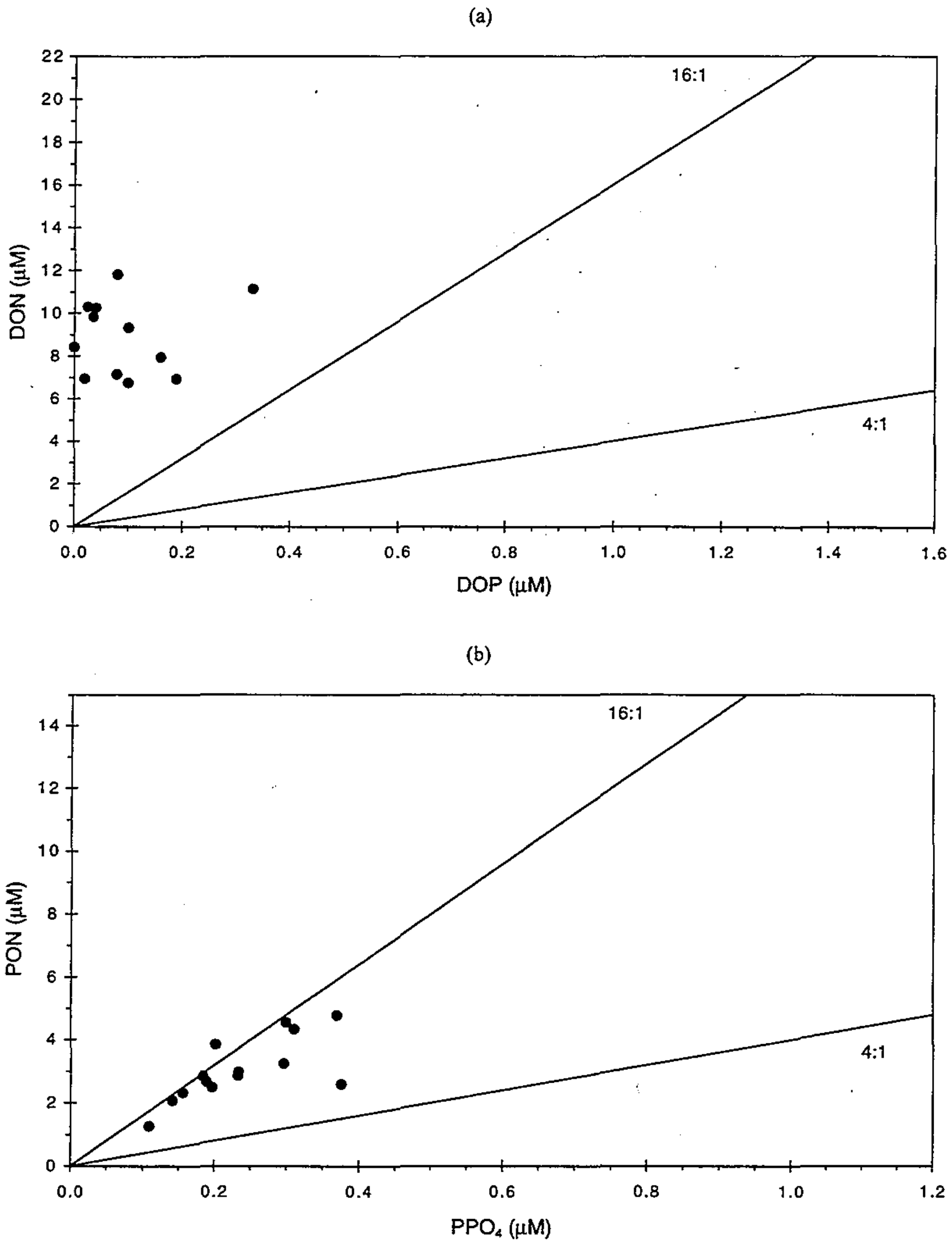


FIGURE 4-129
Nutrient vs. nutrient plots for nearfield survey W9609, (Jul 96).

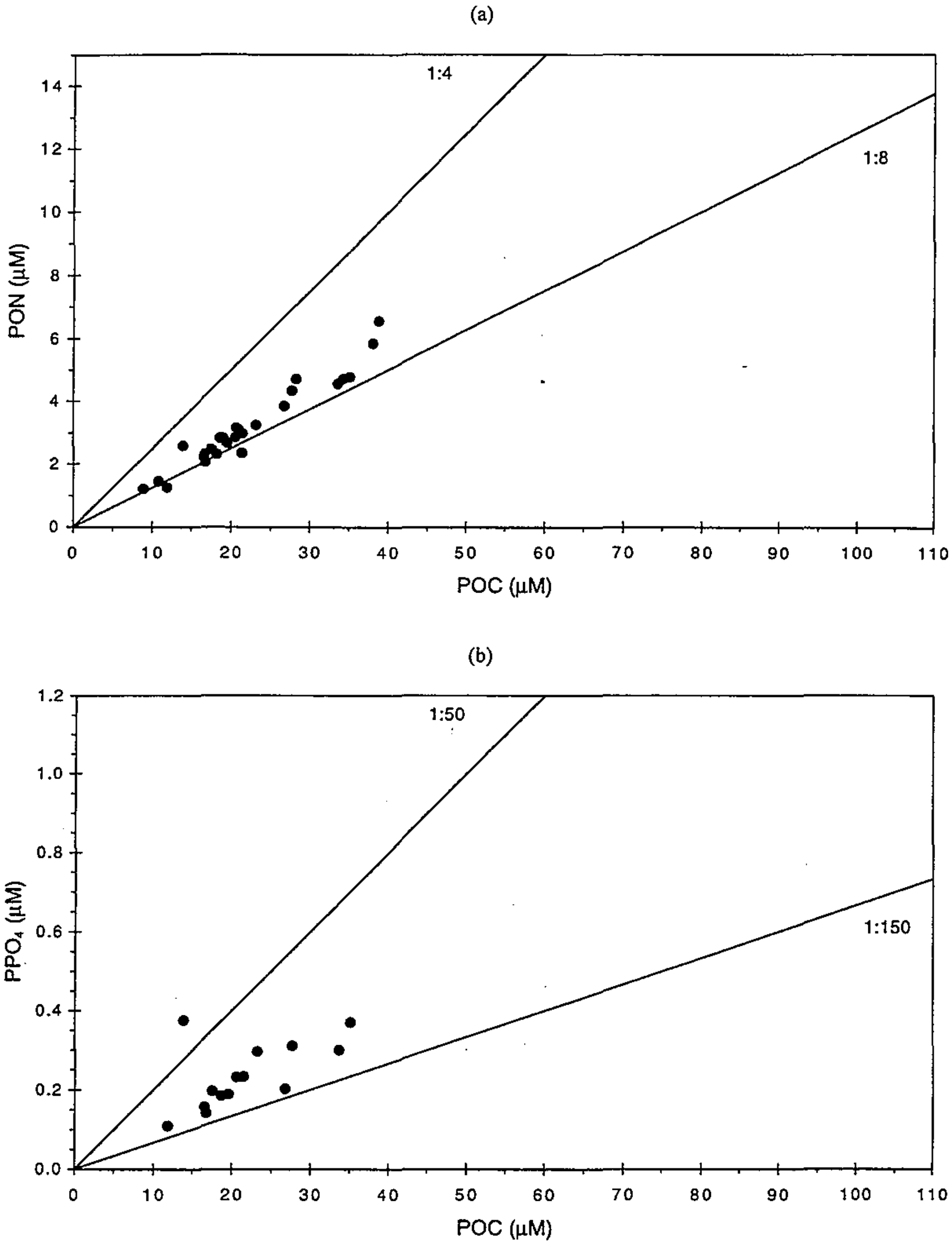
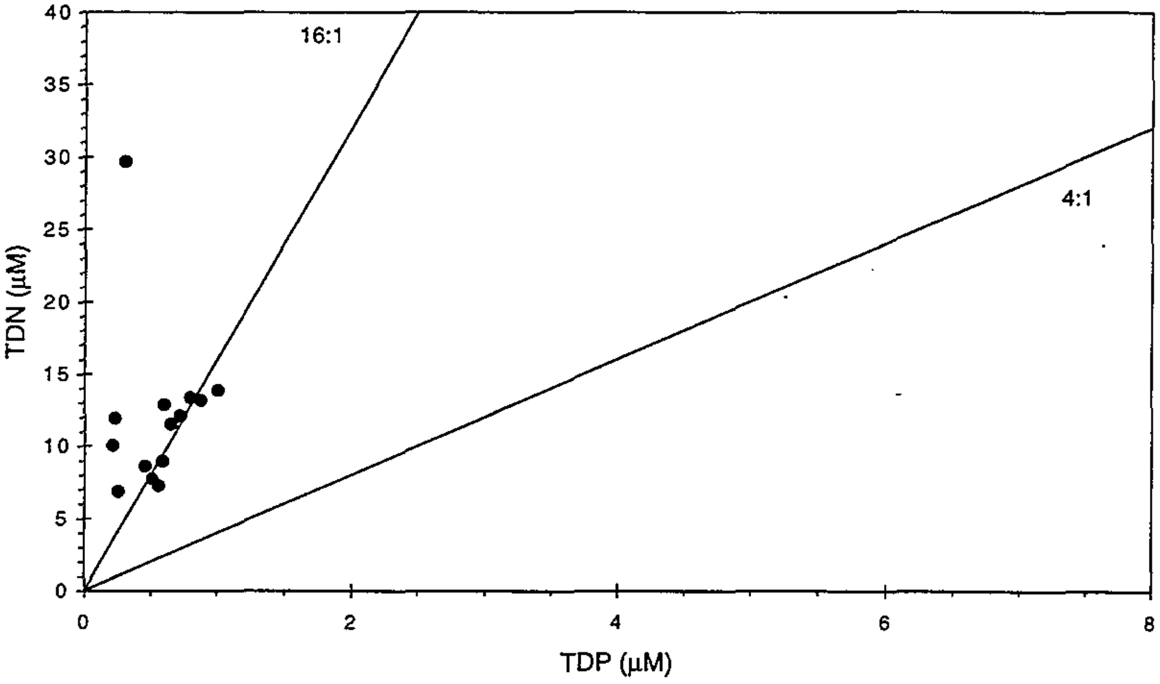


FIGURE 4-130
Nutrient vs. nutrient plots for nearfield survey W9609, (Jul 96).

(a)



(b)

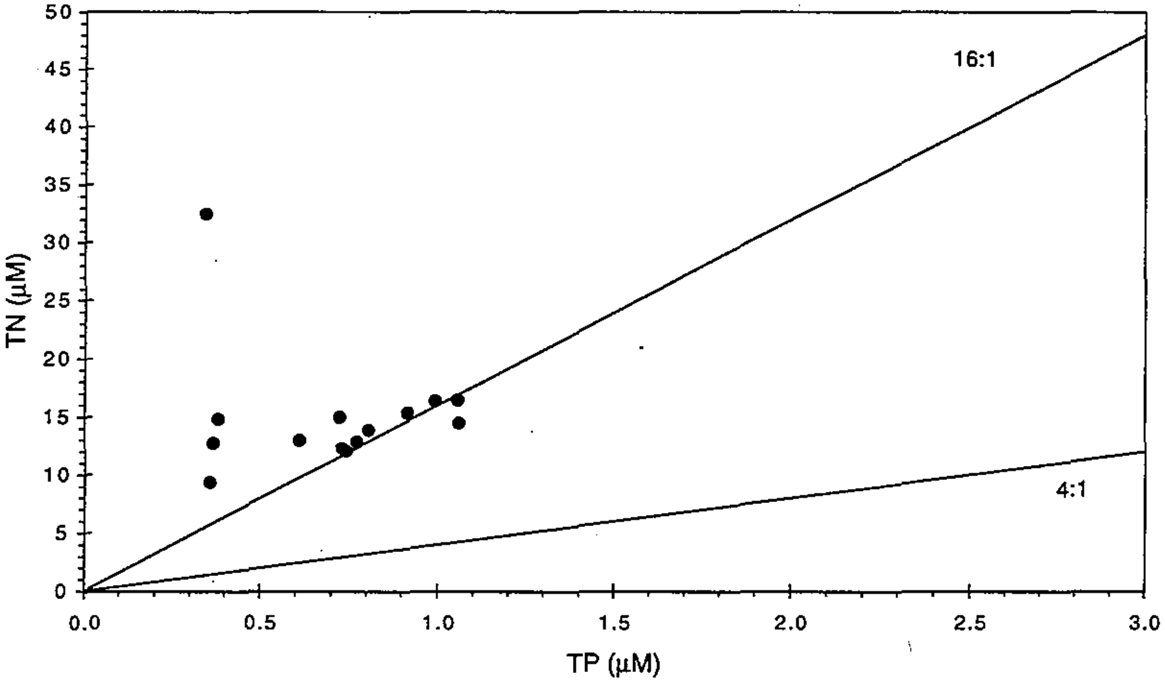


FIGURE 4-131
Nutrient vs. nutrient plots for nearfield survey W9609, (Jul 96).

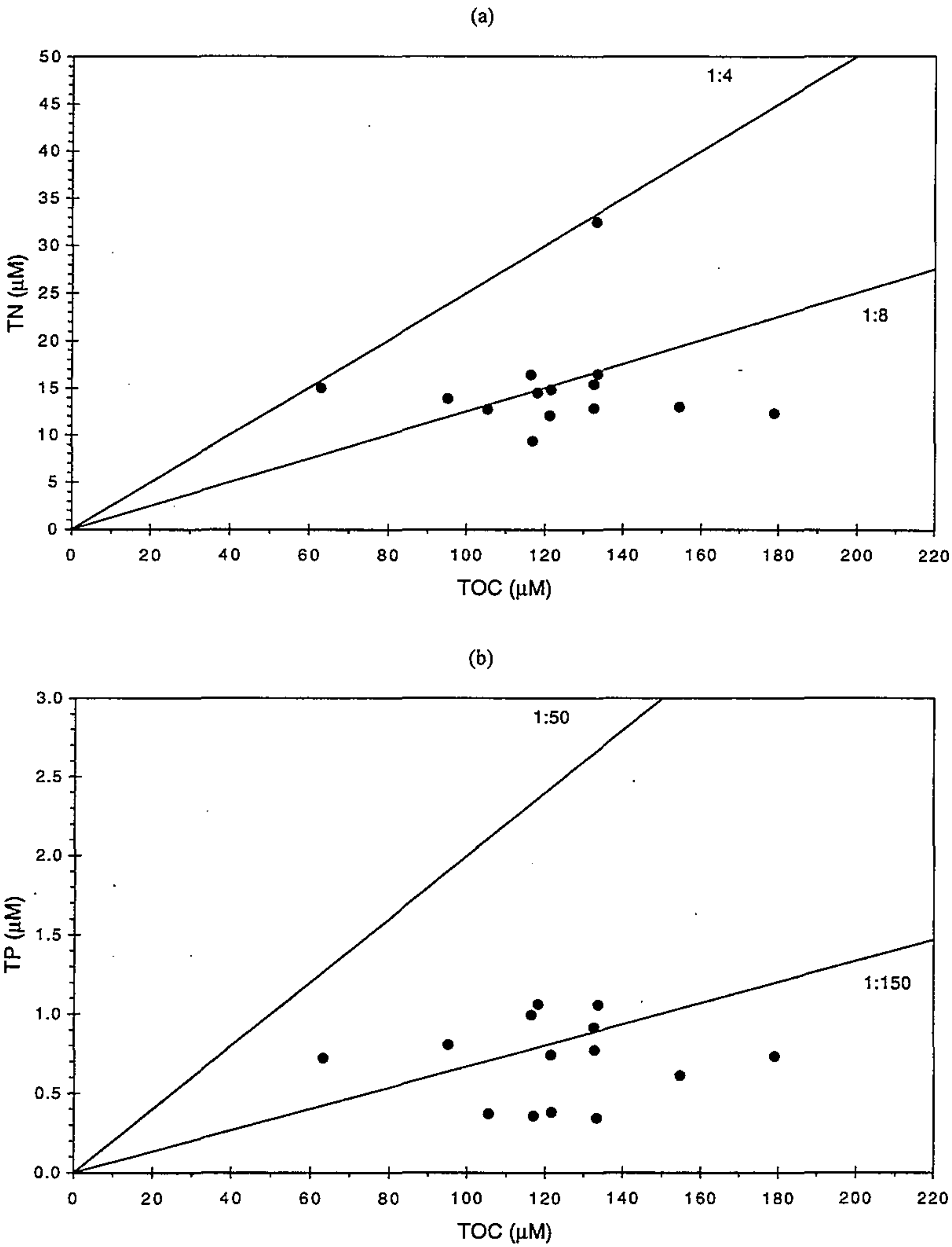


FIGURE 4-132
Nutrient vs. nutrient plots for nearfield survey W9609, (Jul 96).

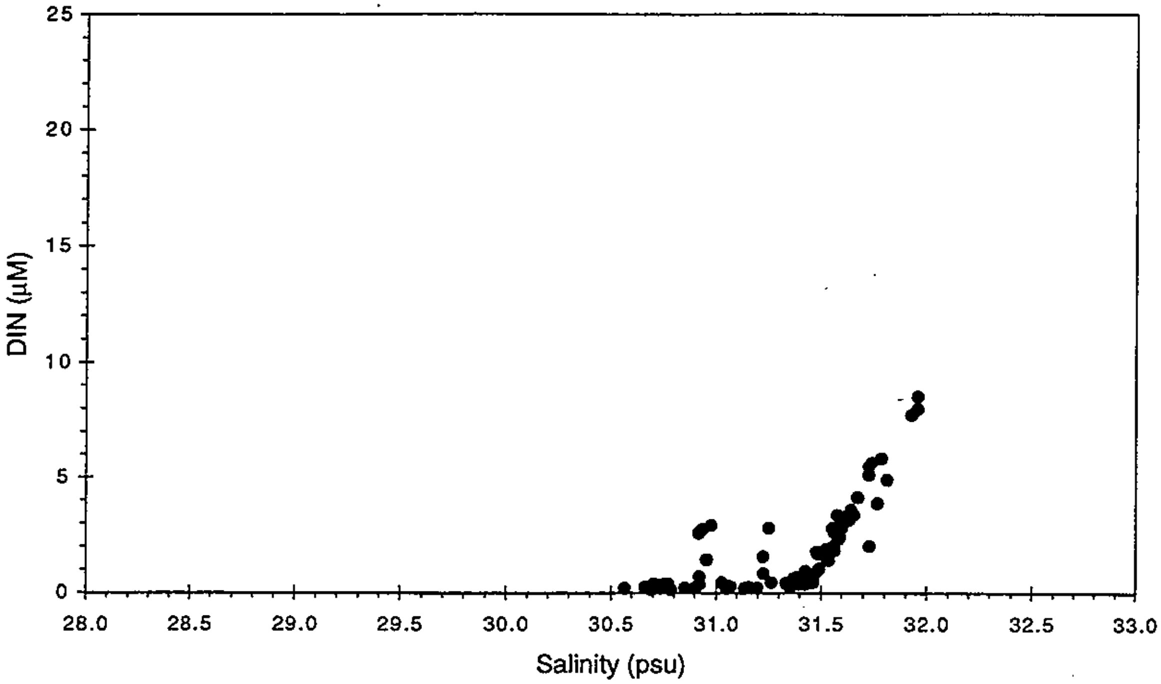
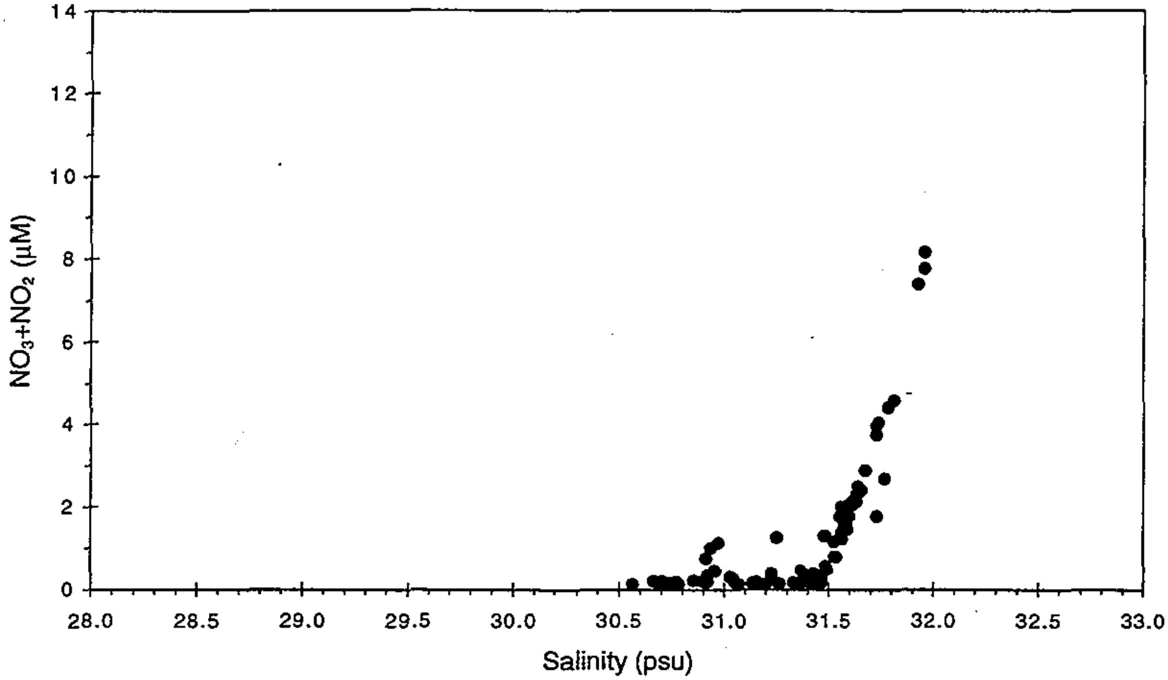


FIGURE 4-133

Nutrient vs. salinity plots for nearfield survey W9609, (Jul 96).

(a)



(b)

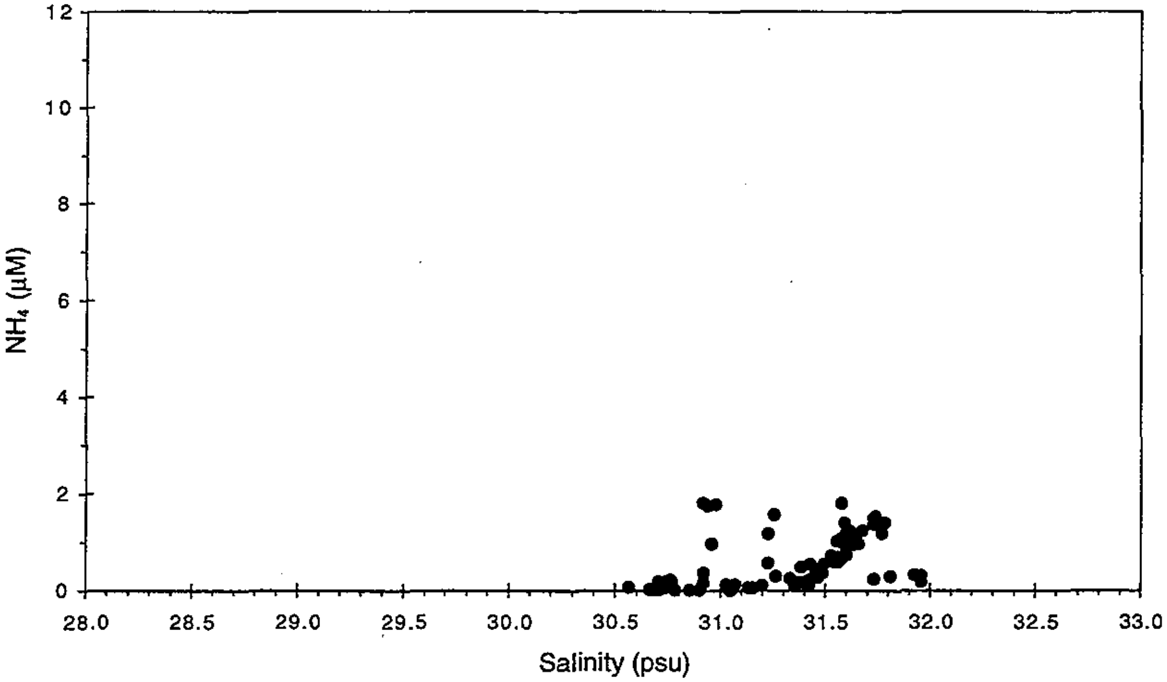


FIGURE 4-134
Nutrient vs. salinity plots for nearfield survey W9609, (Jul 96).

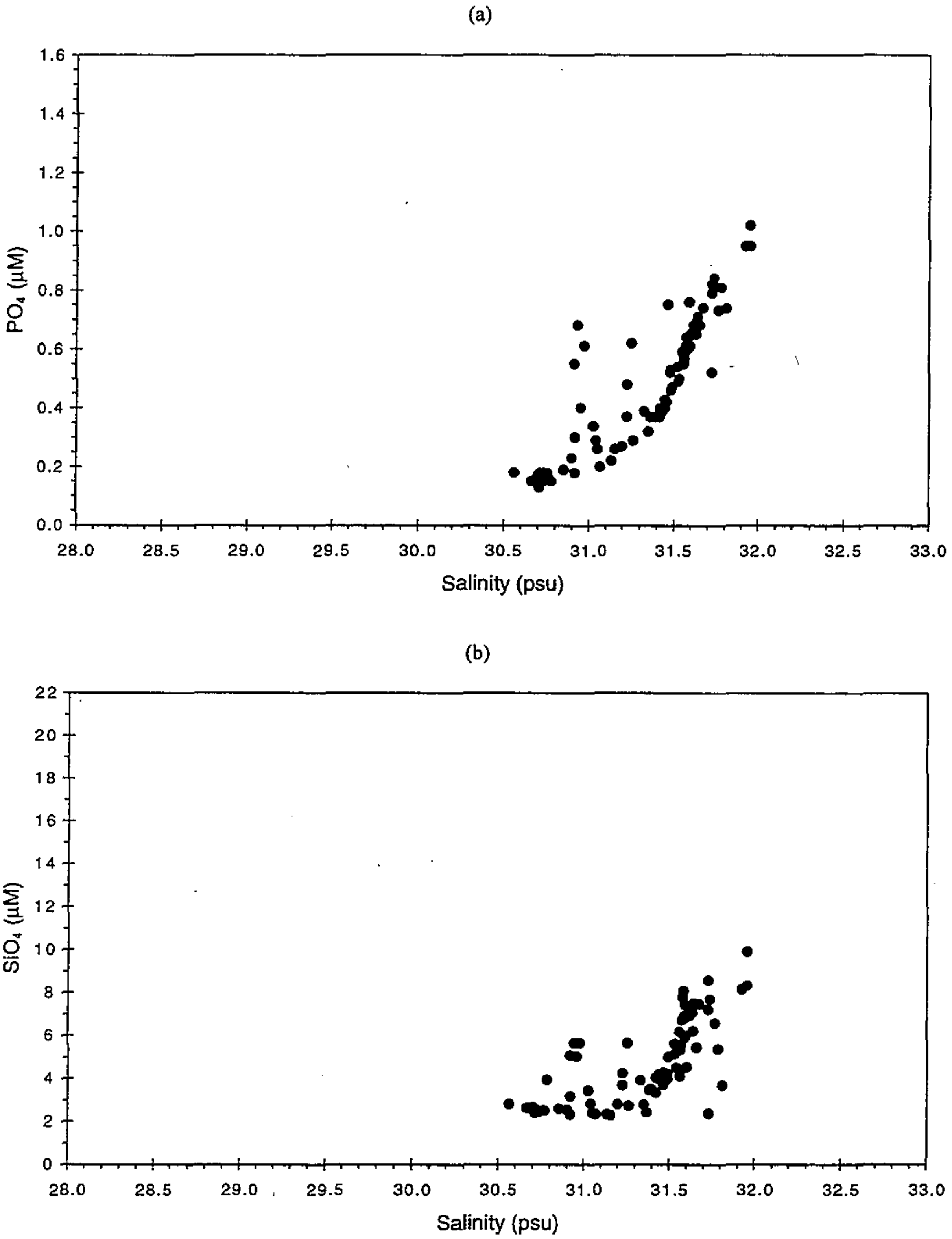


FIGURE 4-135
Nutrient vs. salinity plots for nearfield survey W9609, (Jul 96).

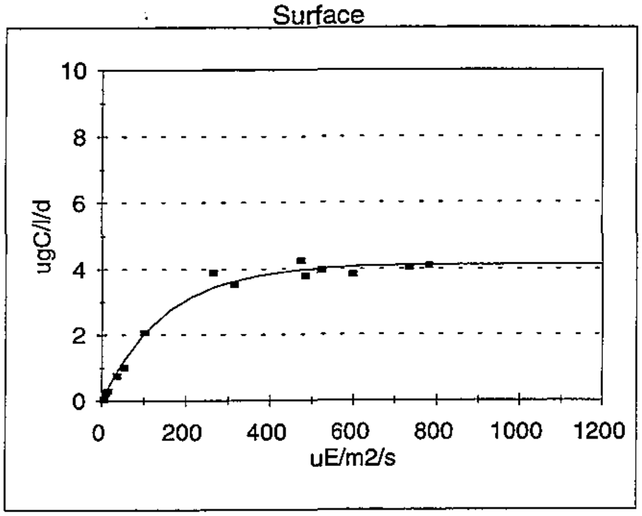
APPENDIX E

Photosynthesis-Irradiance (P-I) Curves

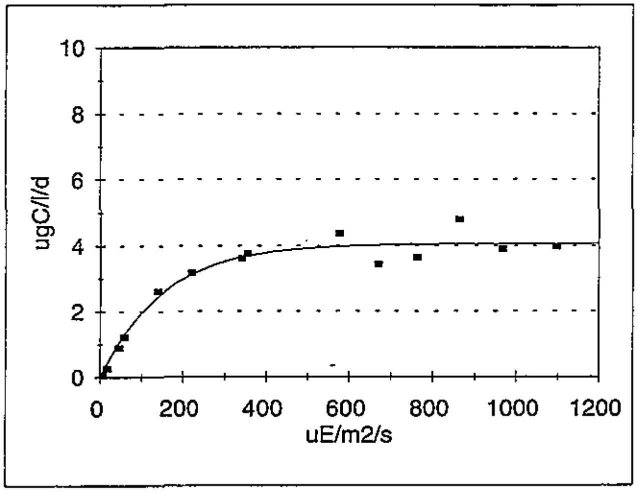
Productivity calculations (Appendix A) utilized light attenuation data from a CTD-mounted 4π sensor and incident light time-series data from an on-deck 2π irradiance sensor. After collection of the productivity samples, they were incubated in a temperature-controlled incubator. The resulting photosynthesis ($mgC/m^3/h$) versus light irradiance ($\mu E/m^2/s$, P-I) curves are comprehensively presented in this appendix. These data were used to determine hourly production at intervals throughout the day for each sampling depth.

W9601 Station F23

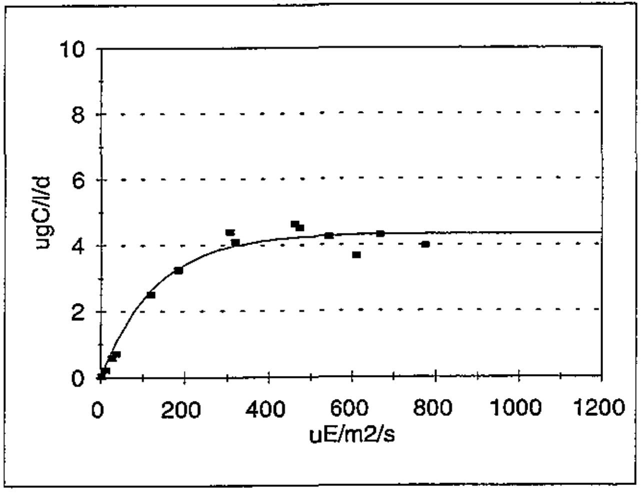
Surface



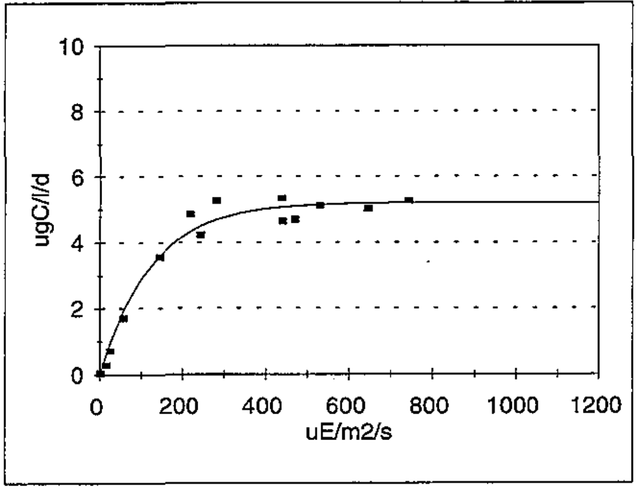
Mid-Surface



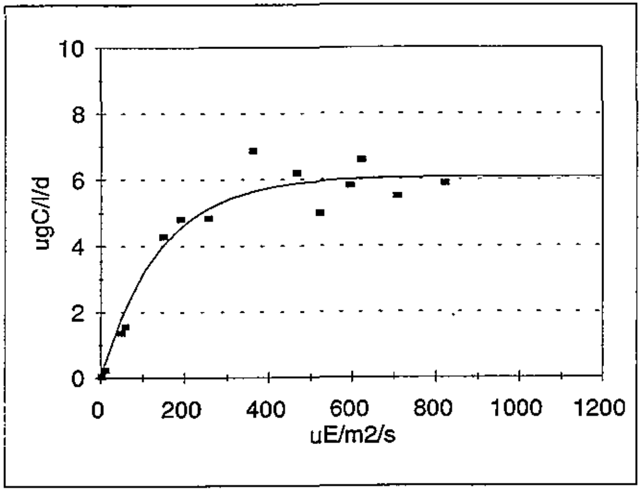
Middle



Mid-Bottom

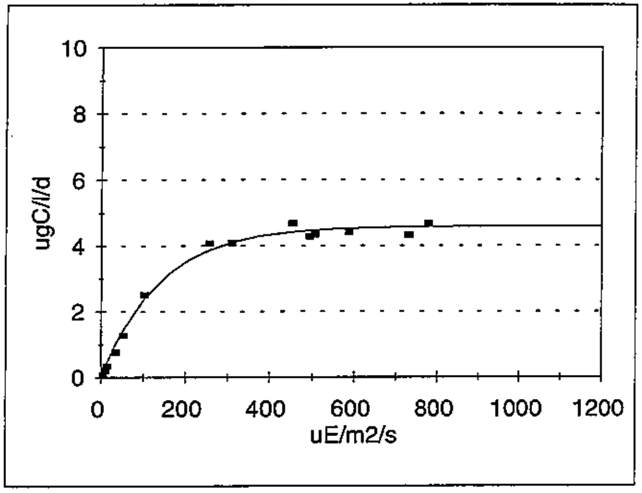


Bottom

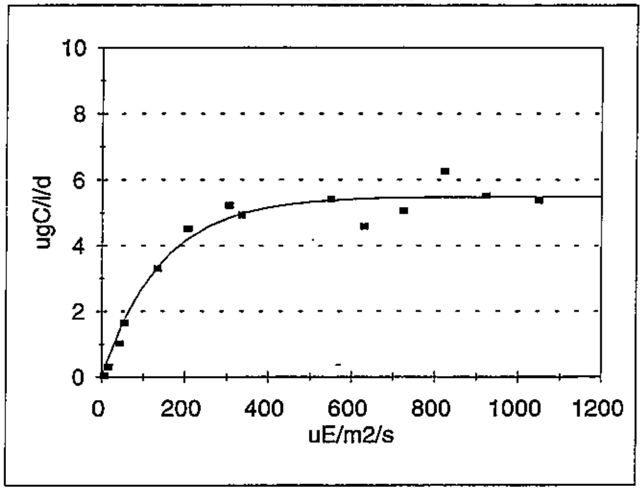


W9601 Station N10

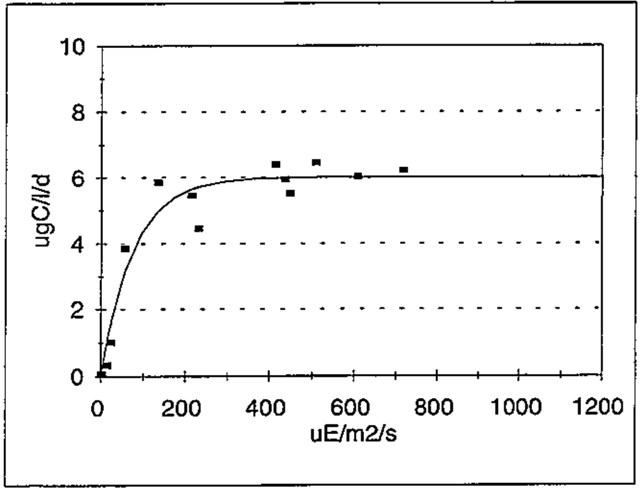
Surface



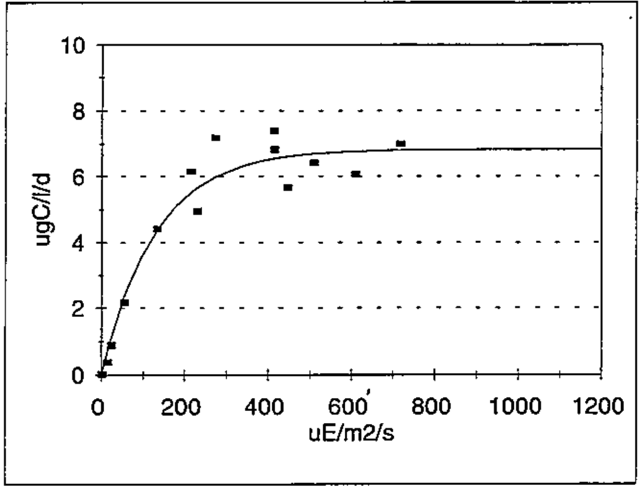
Mid-Surface



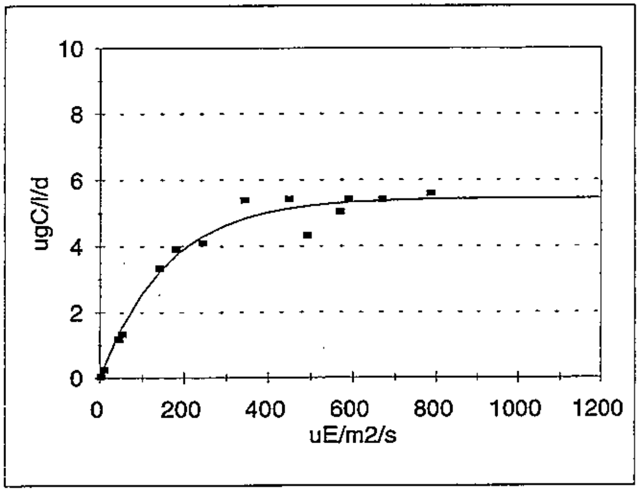
Middle



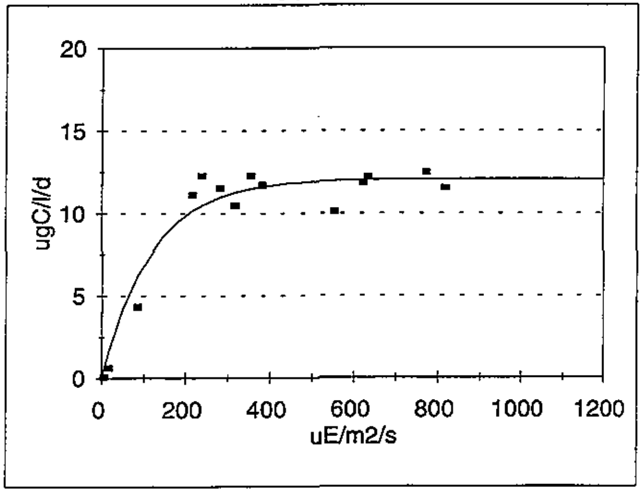
Mid-Bottom



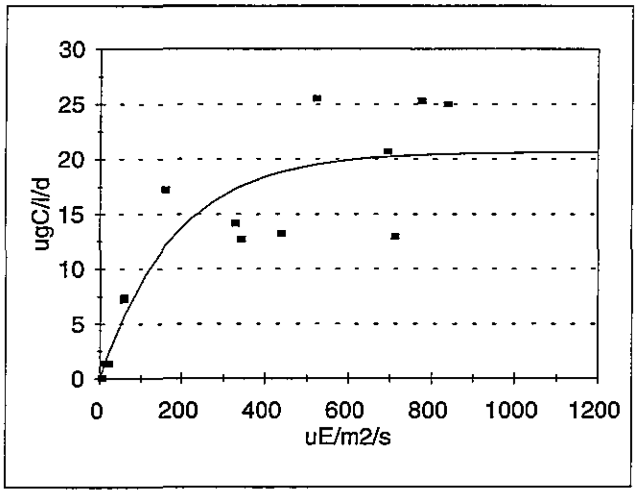
Bottom



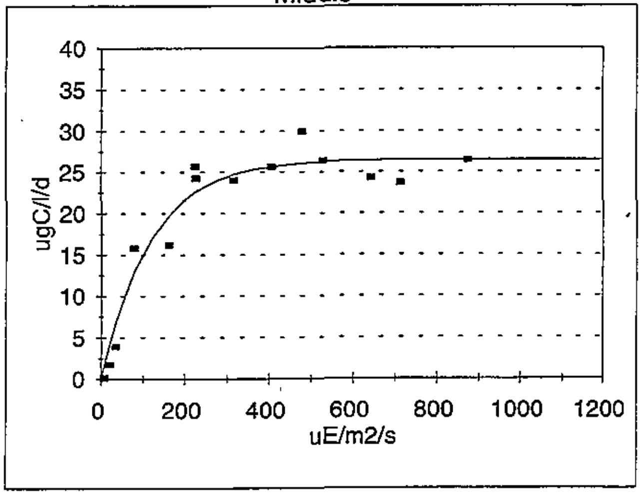
W9601 Station N16



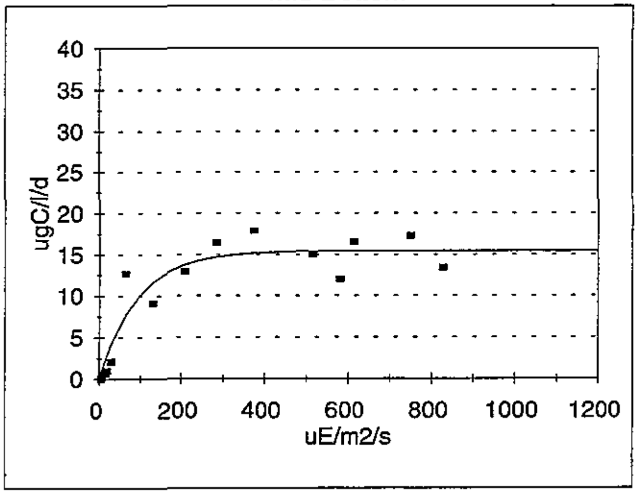
Surface



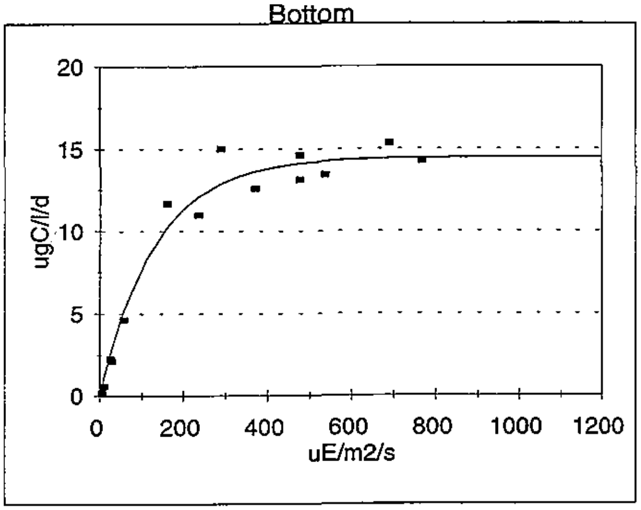
Mid-Surface



Middle



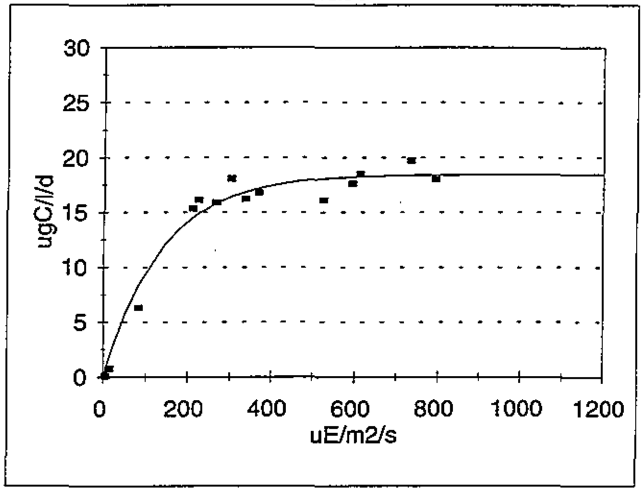
Mid-Bottom



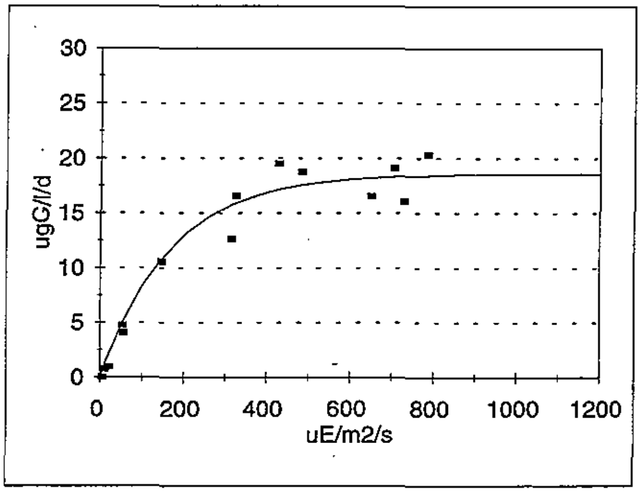
Bottom

W9601 Station N04

Surface



Mid-Surface



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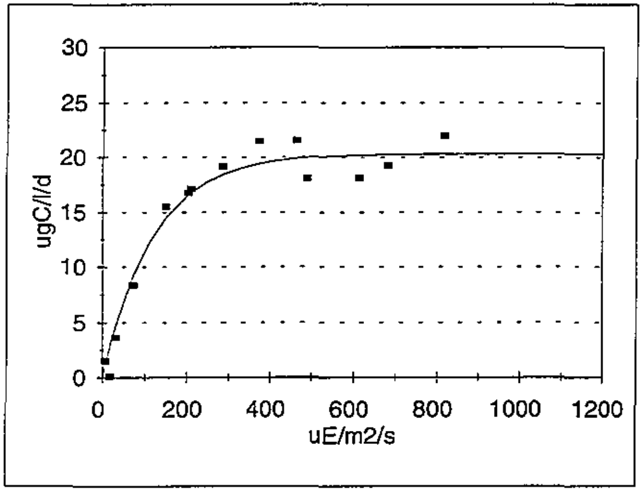
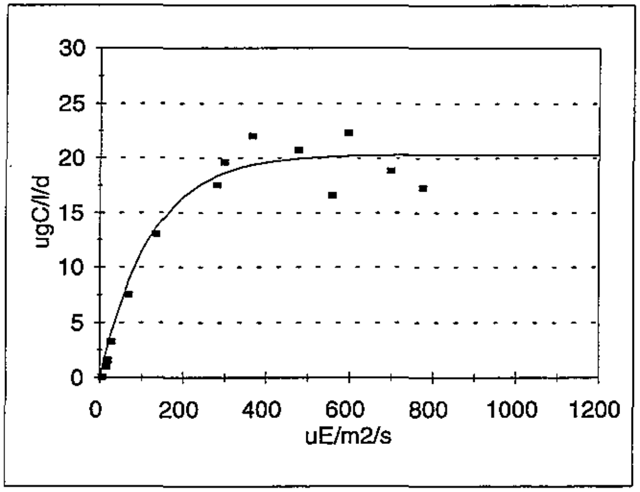


Mid-Bottom



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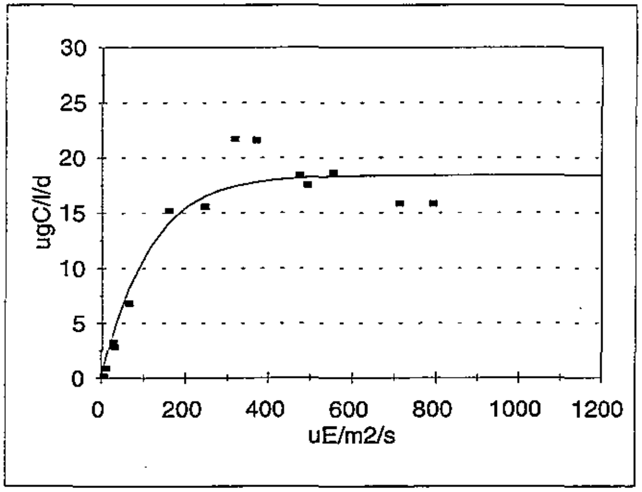
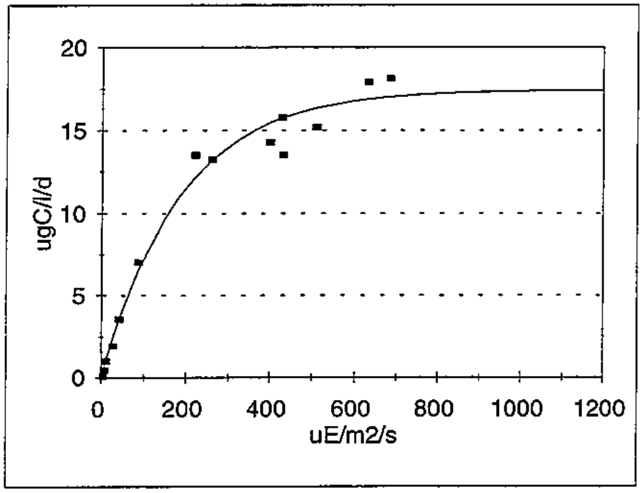


W9602 Station F23

Surface



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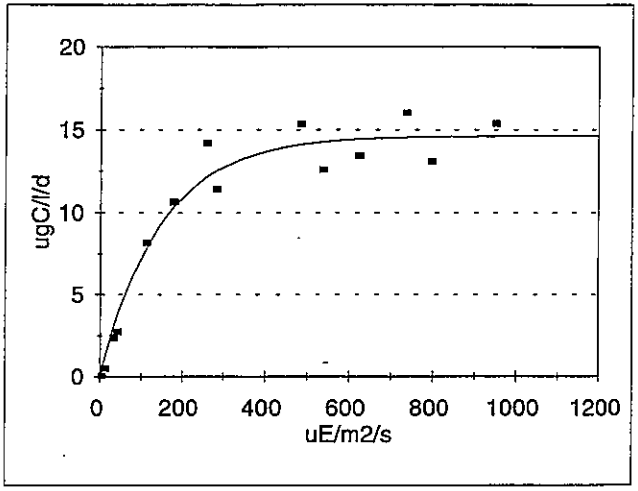

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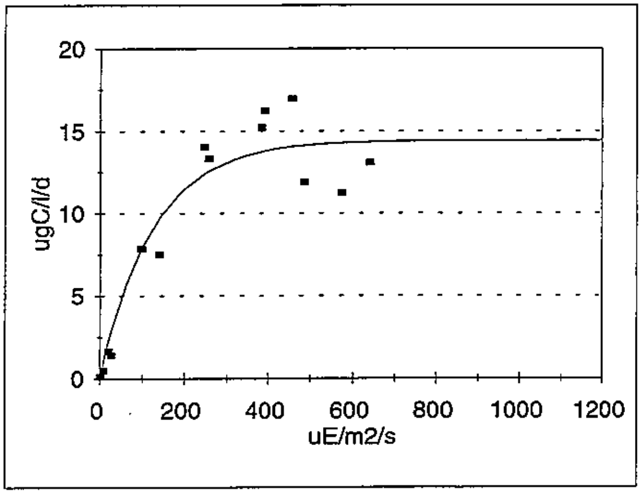
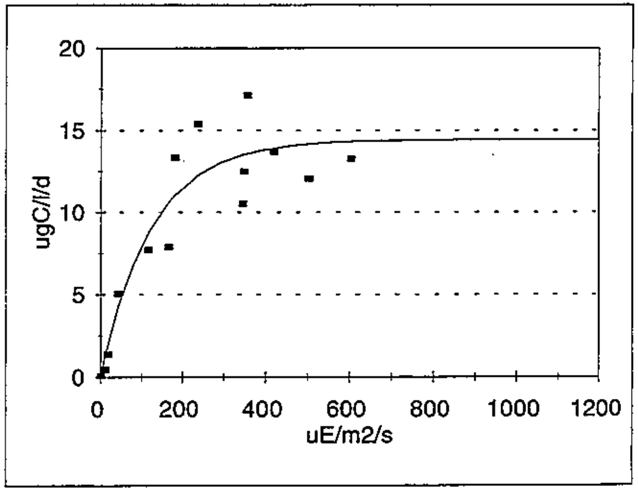


Mid-Bottom



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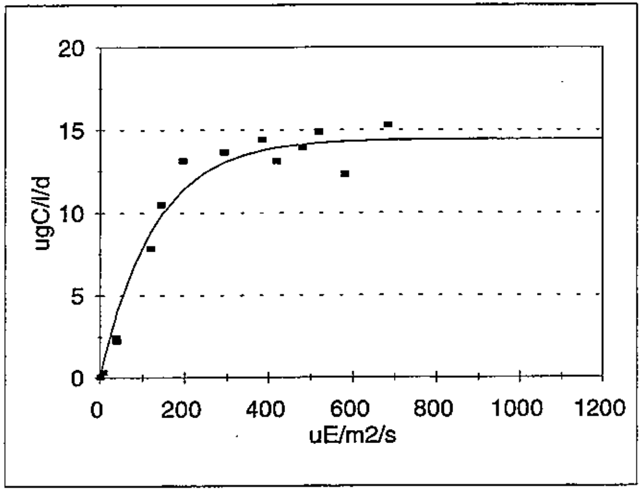
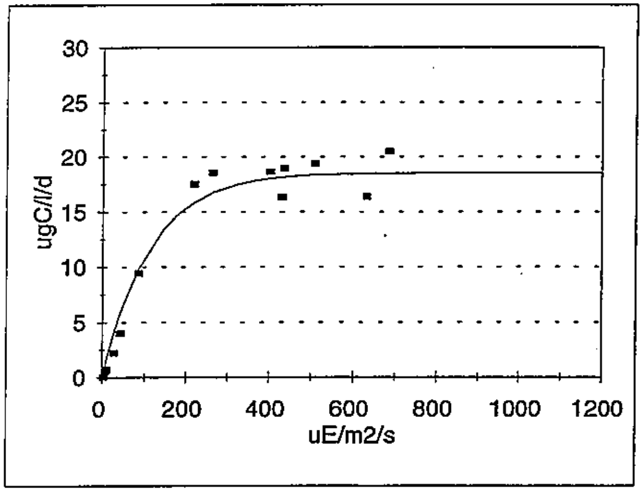
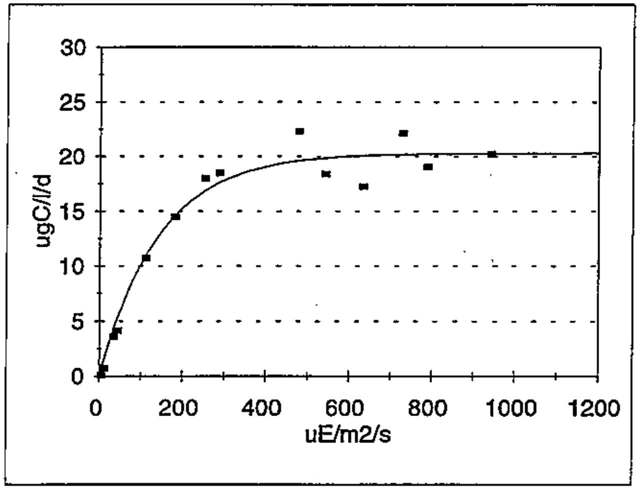
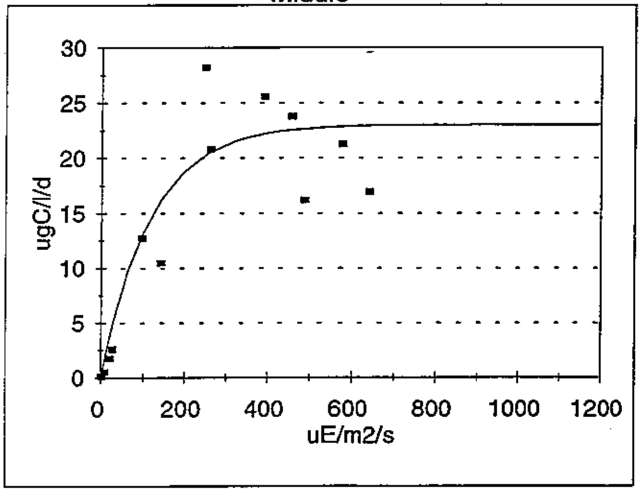


W9602 Station N10


Surface


Mid-Surface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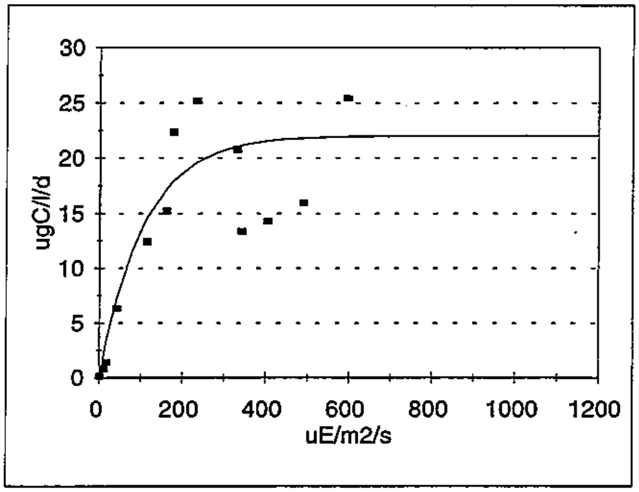
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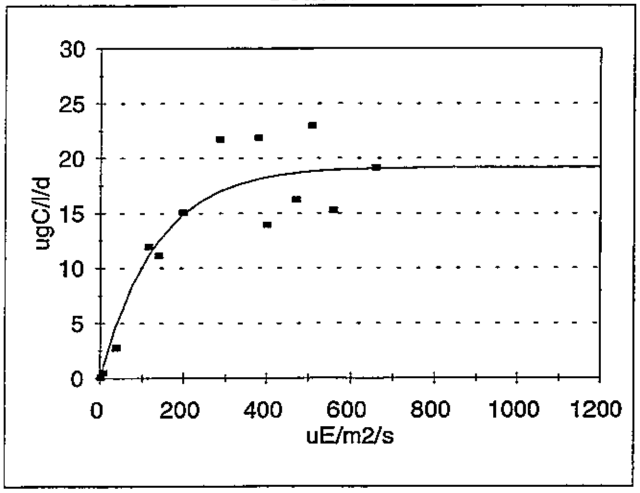
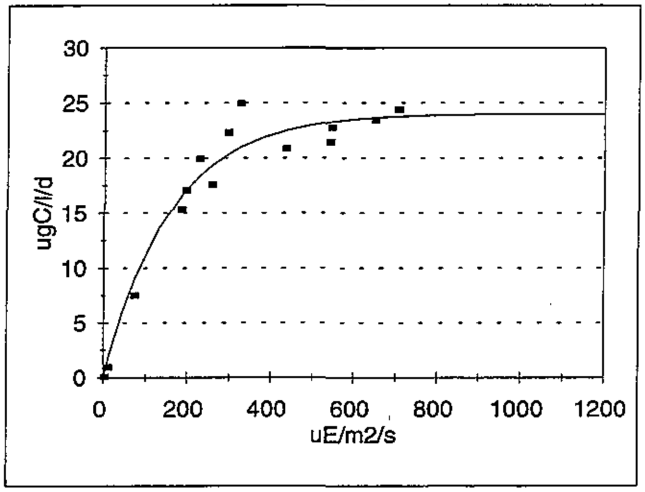

Bottom

W9602 Station N16

Surface



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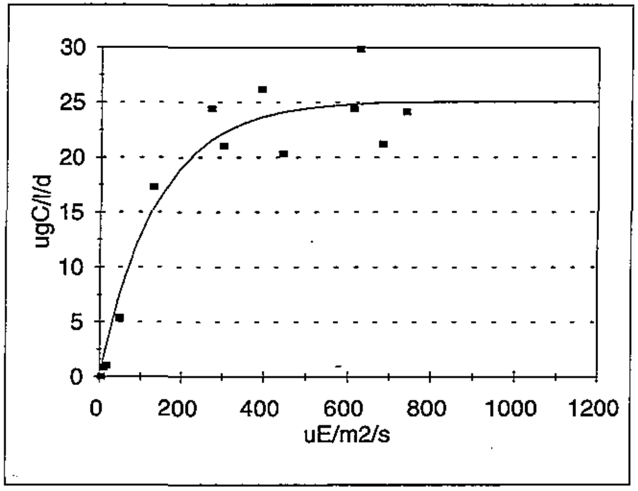
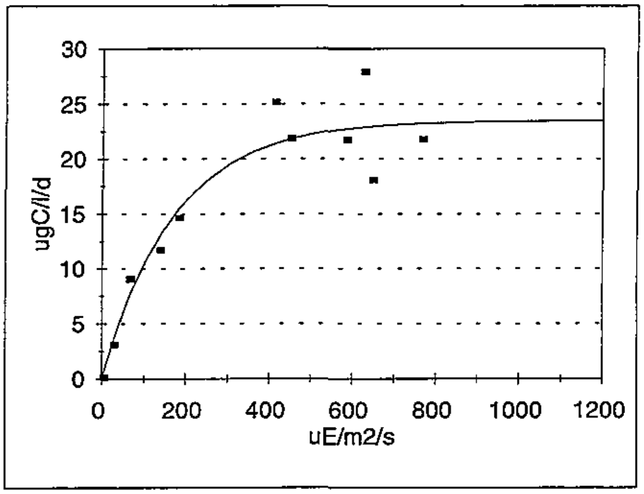
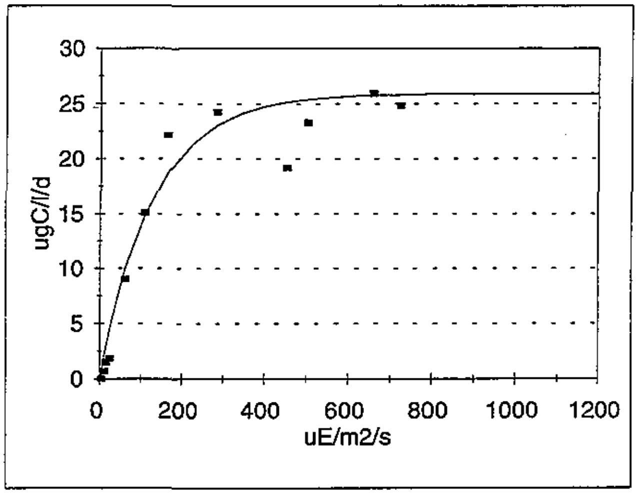
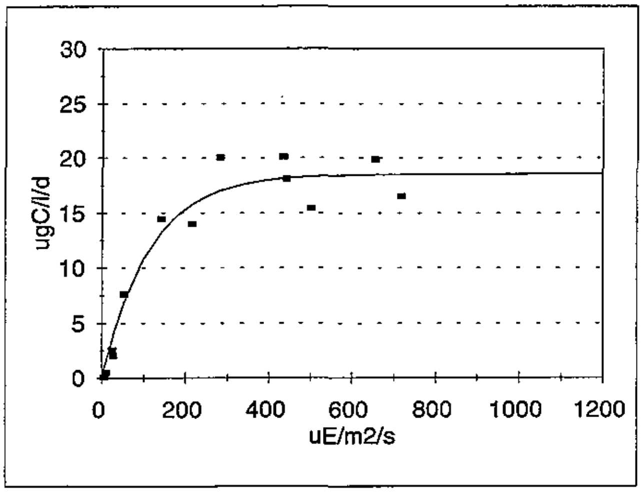


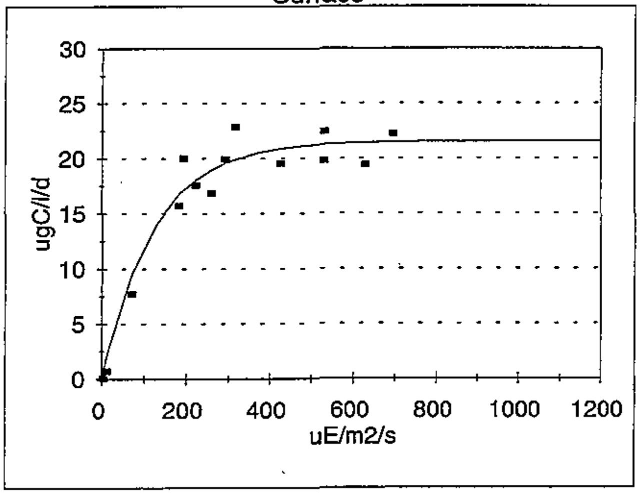




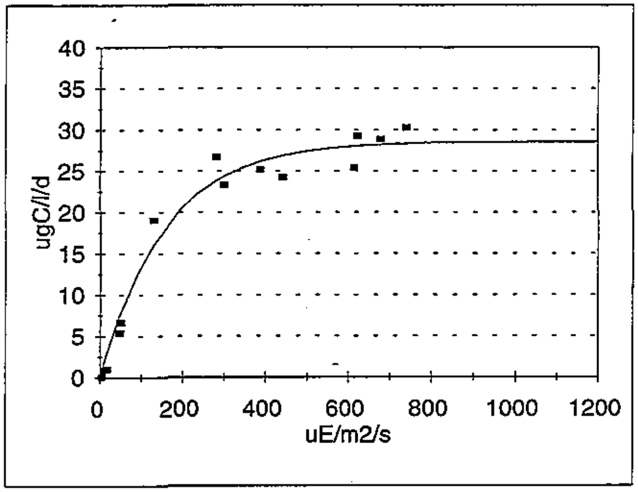


W9602 Station N04

Surface



Mid-Surface



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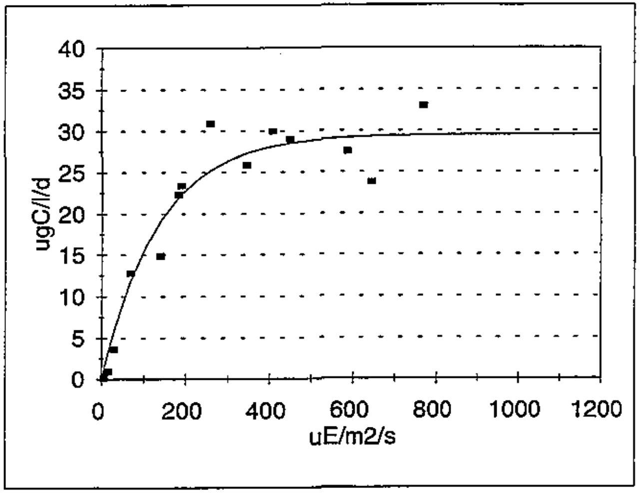
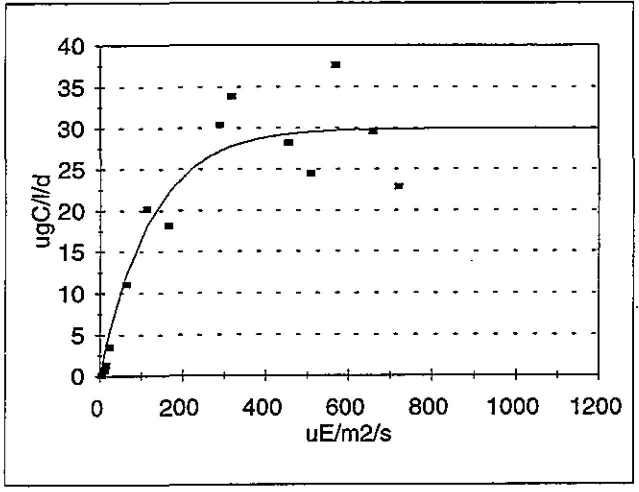


Mid-Bottom



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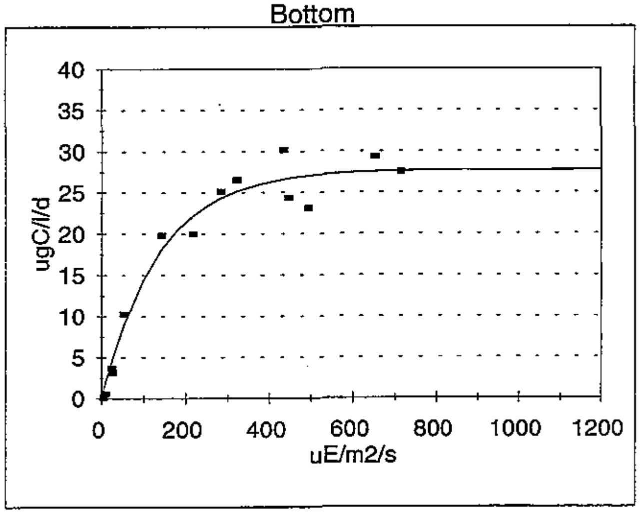
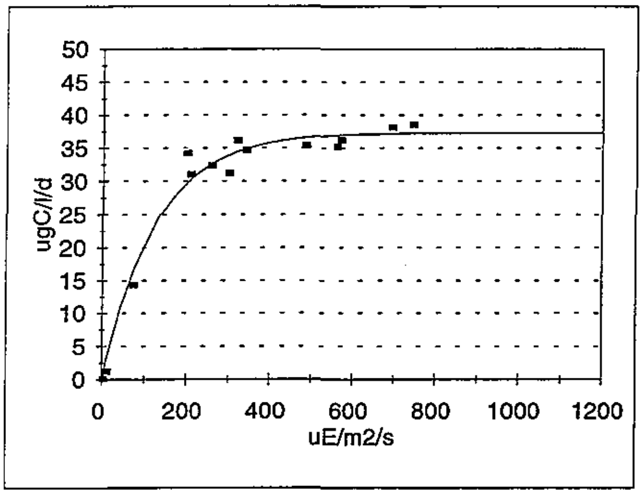
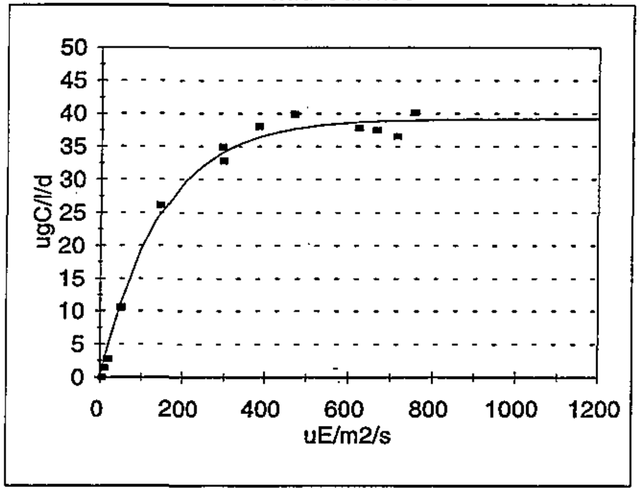


W9603 Station N10

Surface



Mid-Surface



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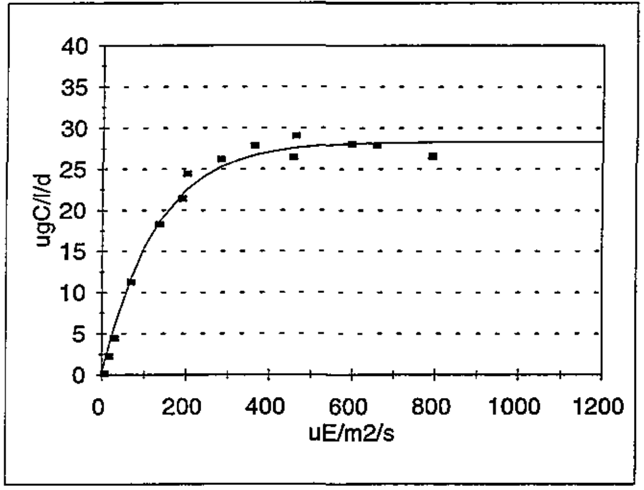
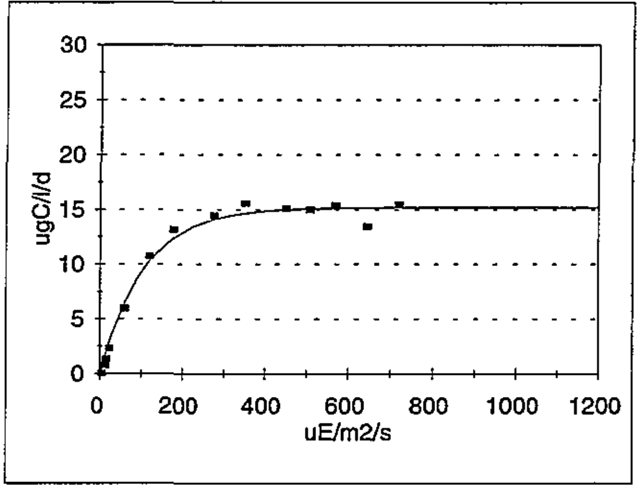


Mid-Bottom



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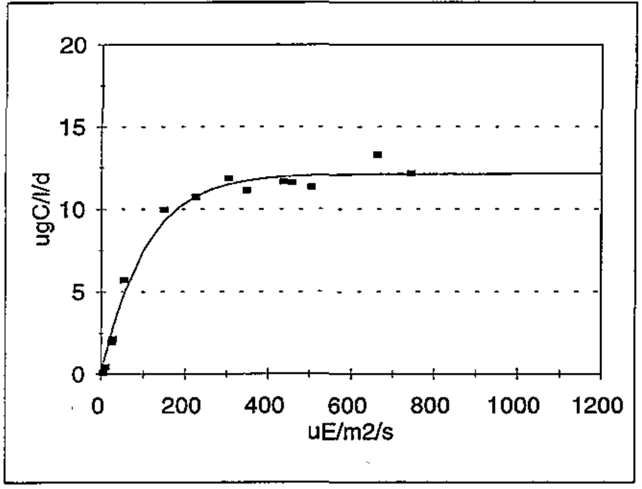
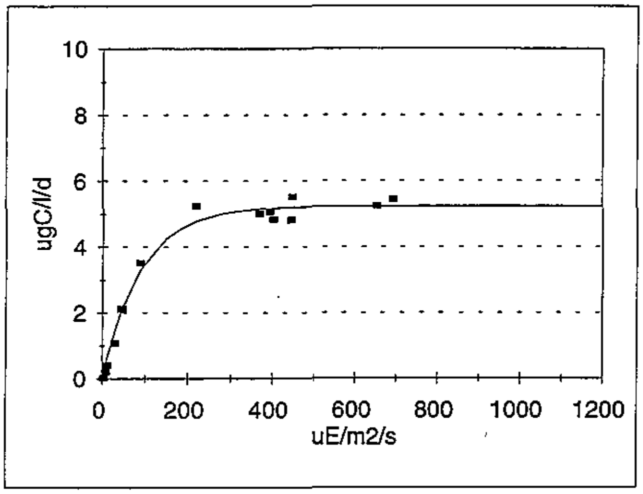


W9603 Station N04

Surface



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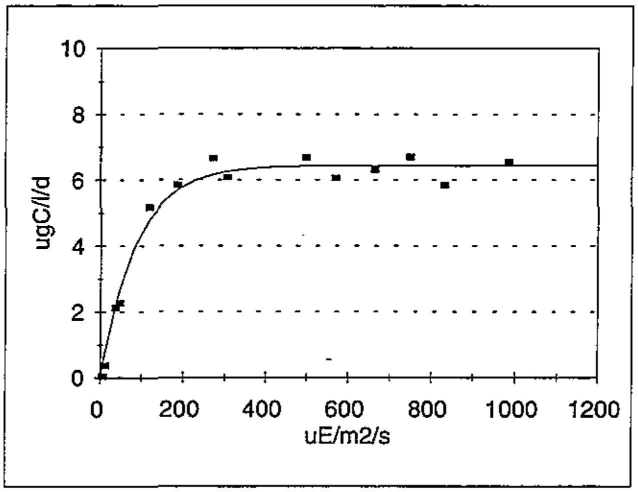

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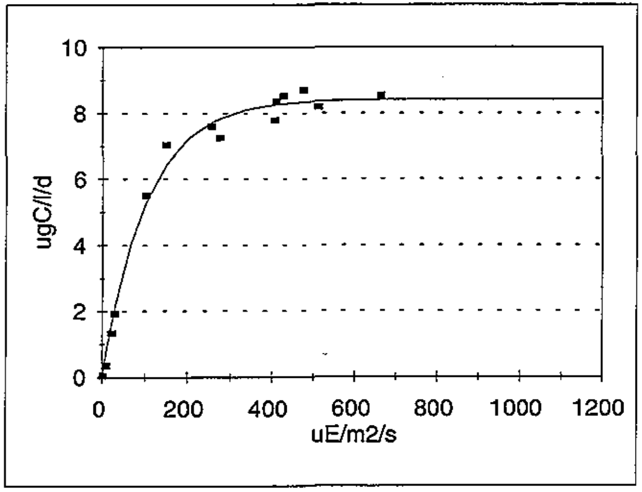
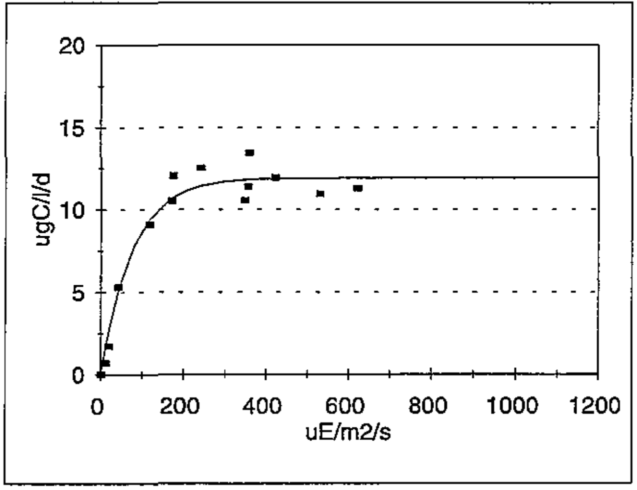


Mid-Bottom



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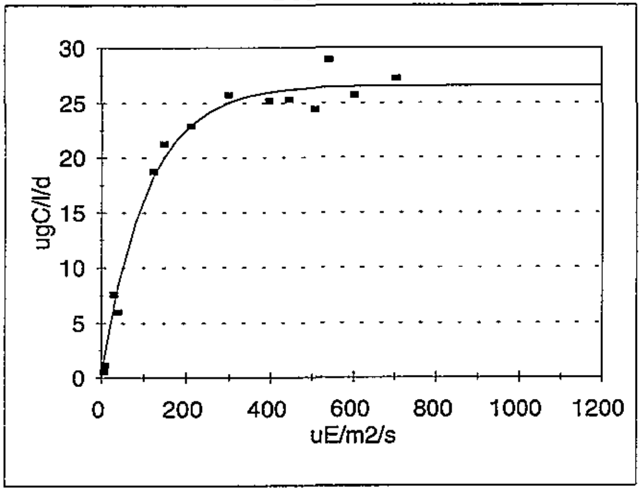
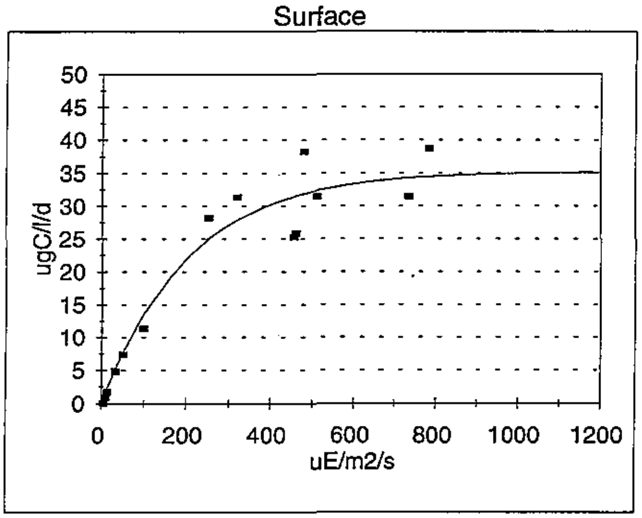
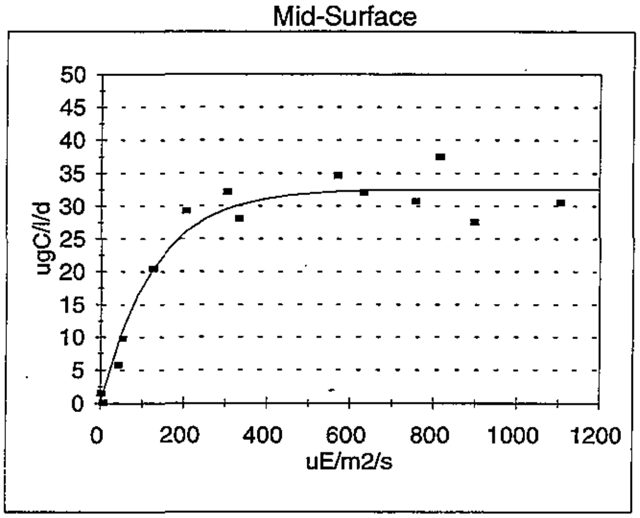
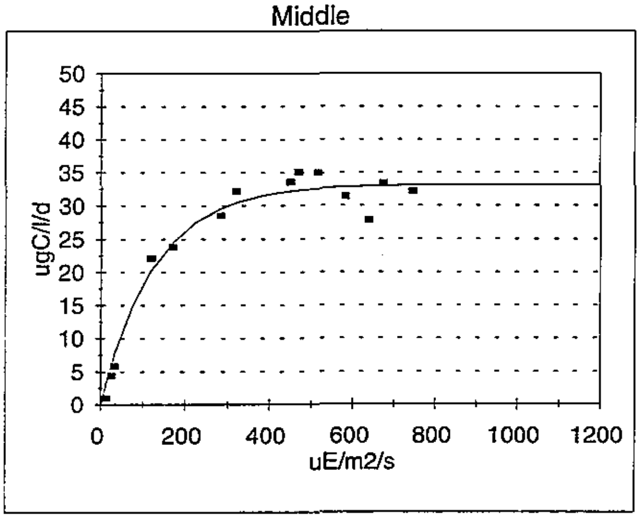
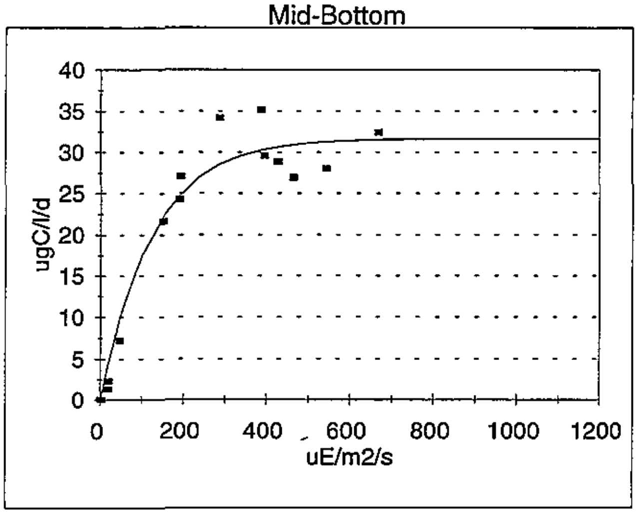


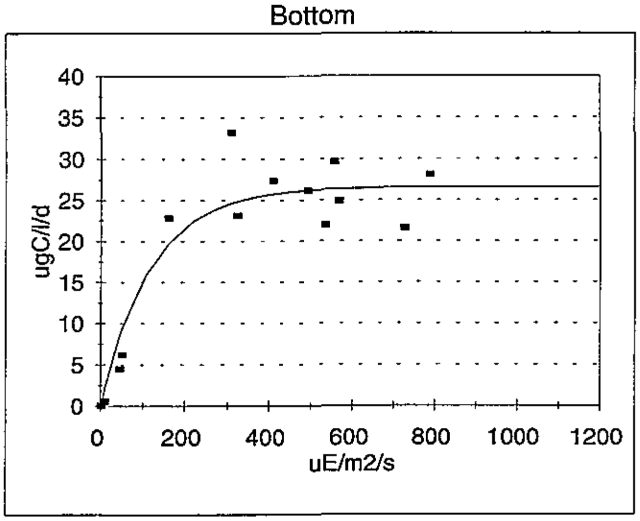
W9604 Station F23





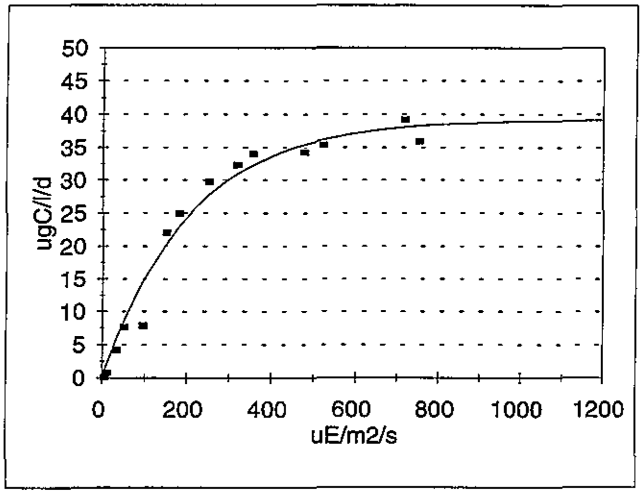






W9604 Station N10

Surface



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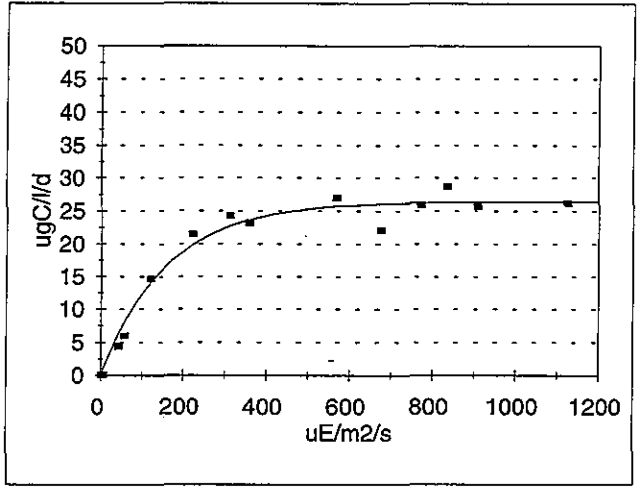

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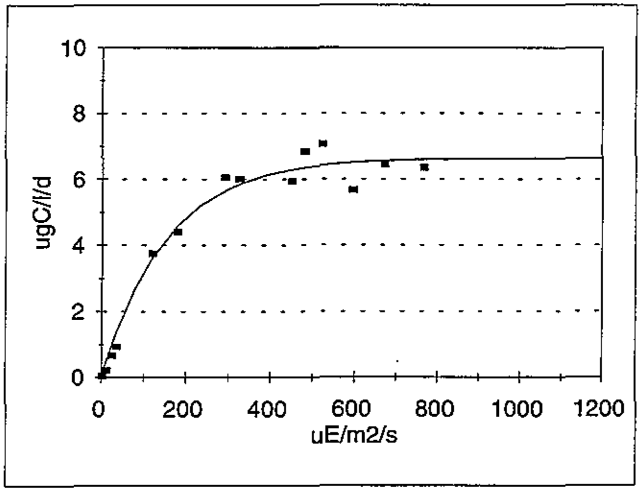
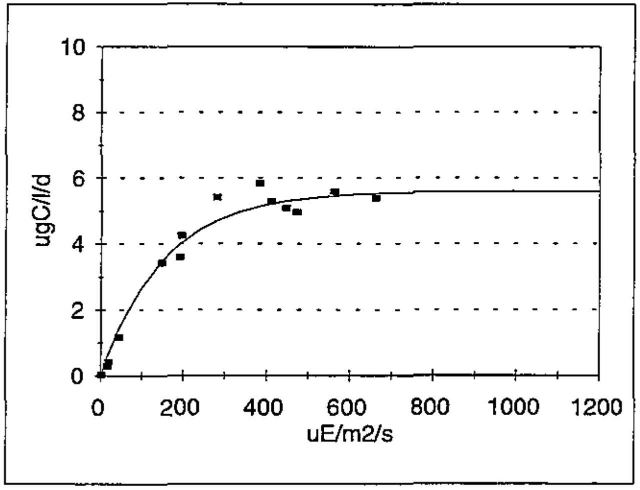


Mid-Bottom



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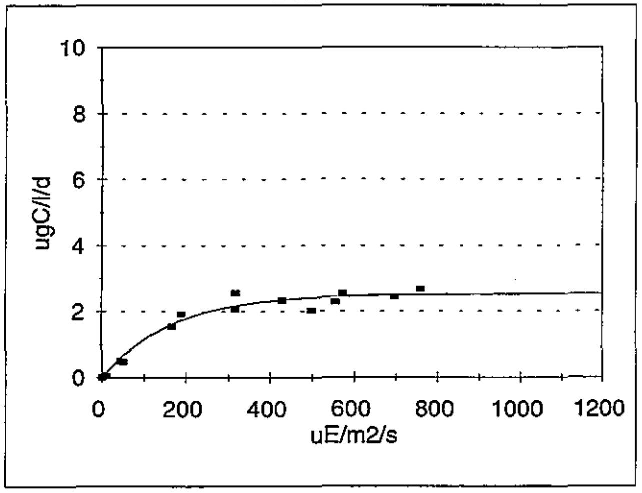
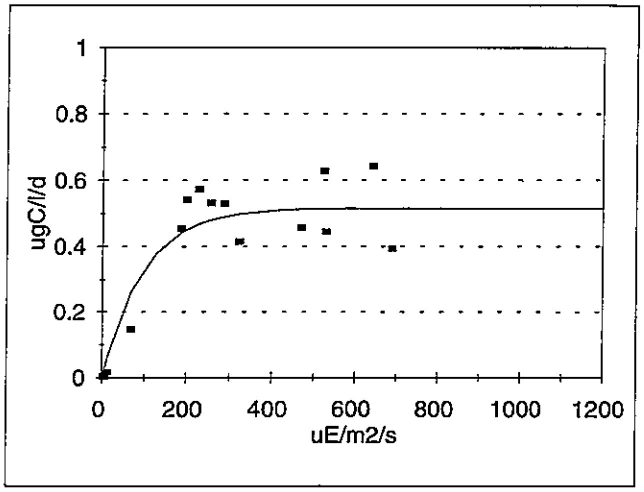


W9604 Station N16

Surface



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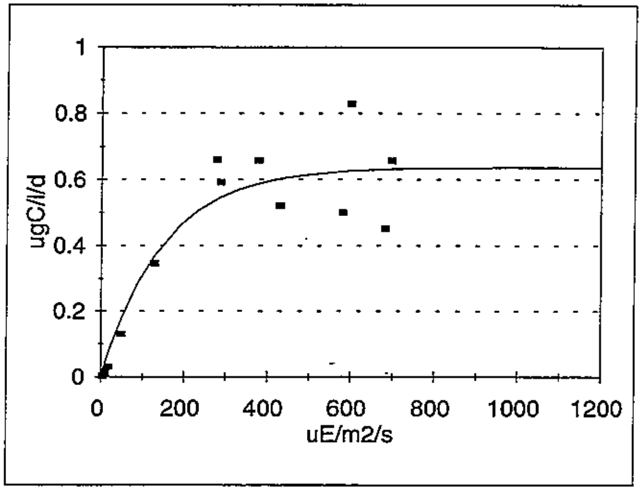

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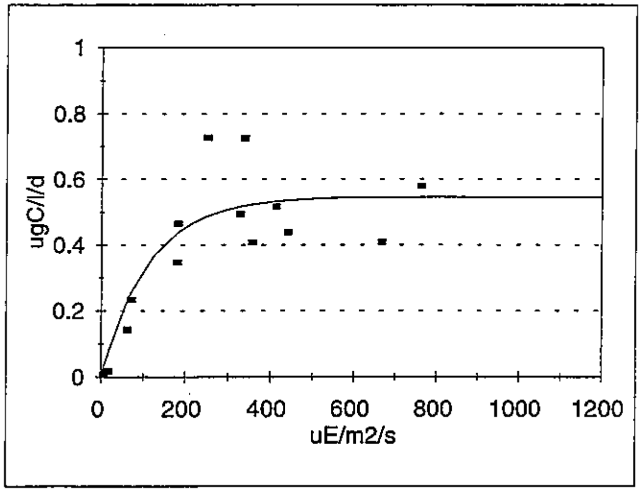
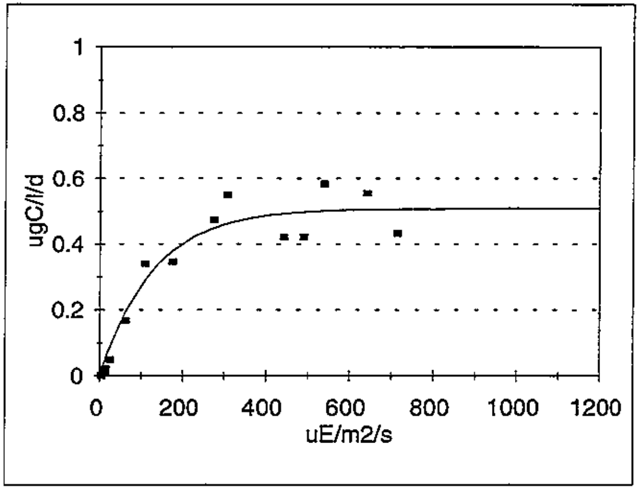


Mid-Bottom



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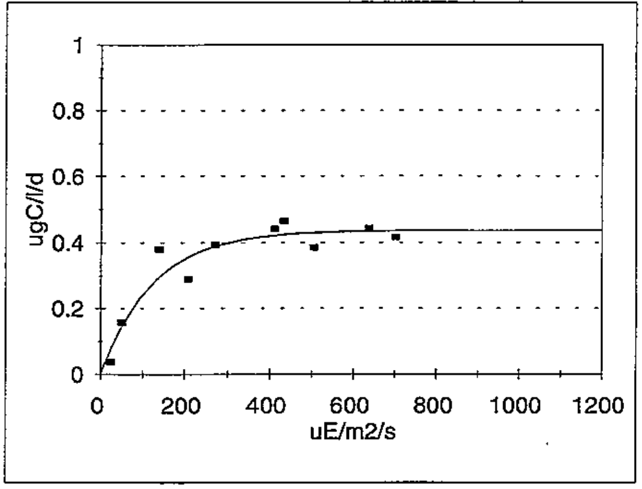
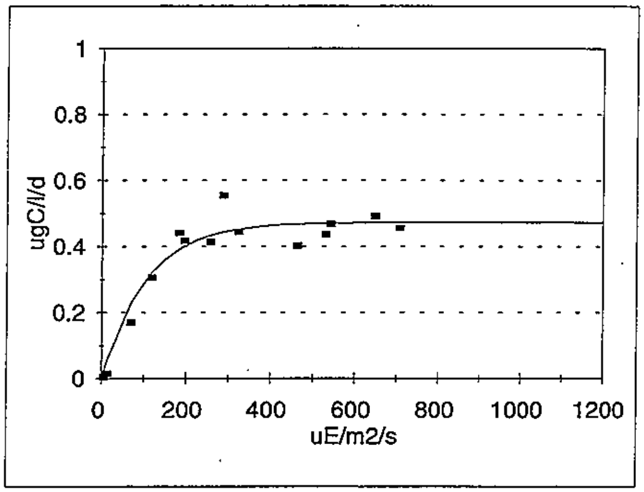


W9604 Station N04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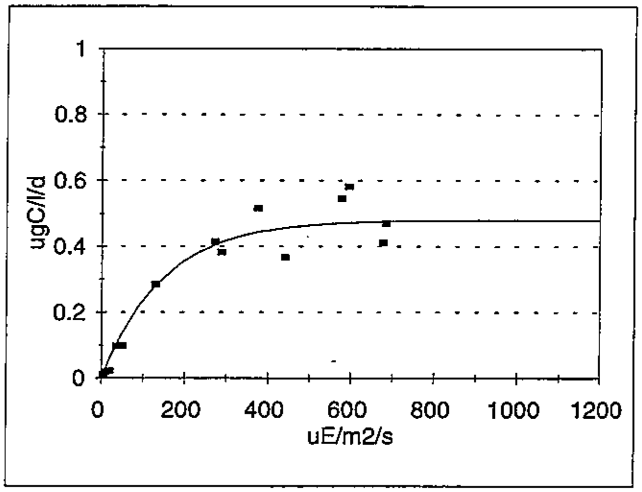
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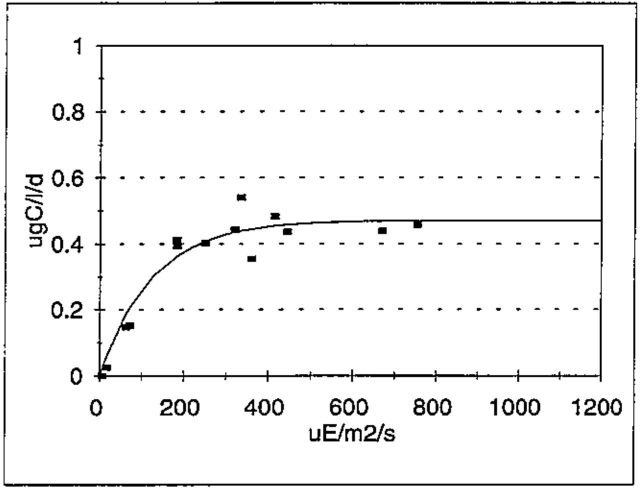
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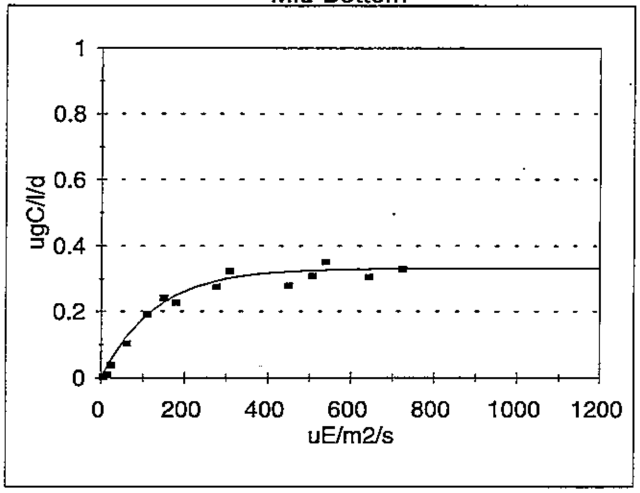
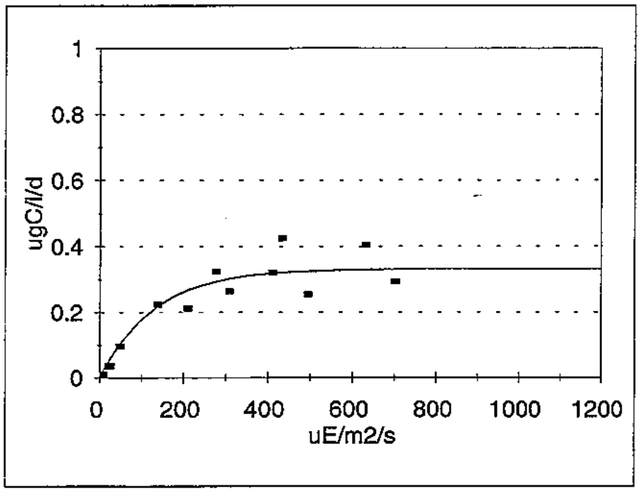
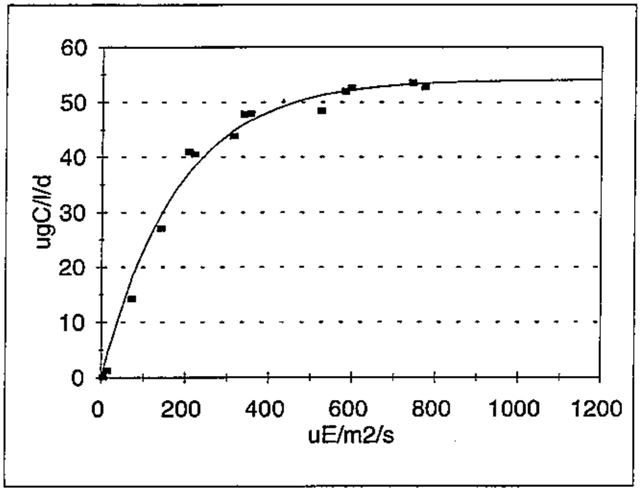

Mid-Bottom

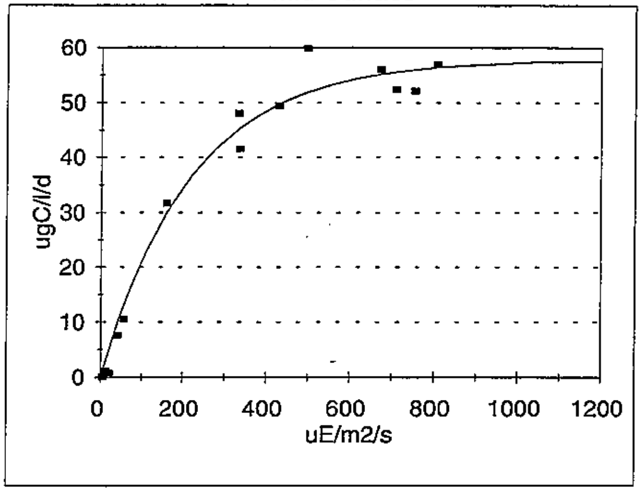

Bottom

W9605 Station N10

Surface



Mid-Surface



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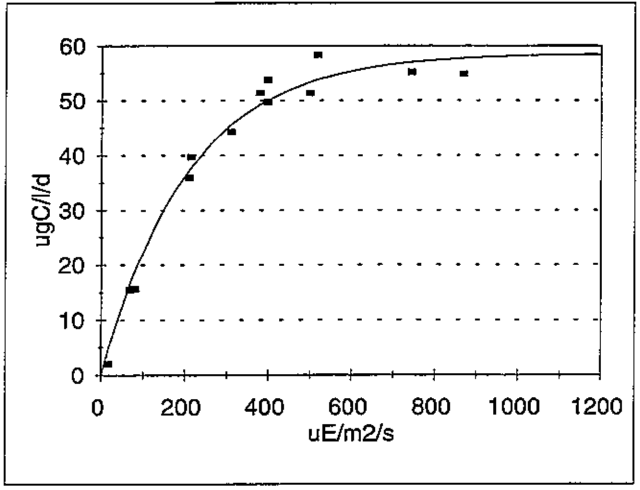
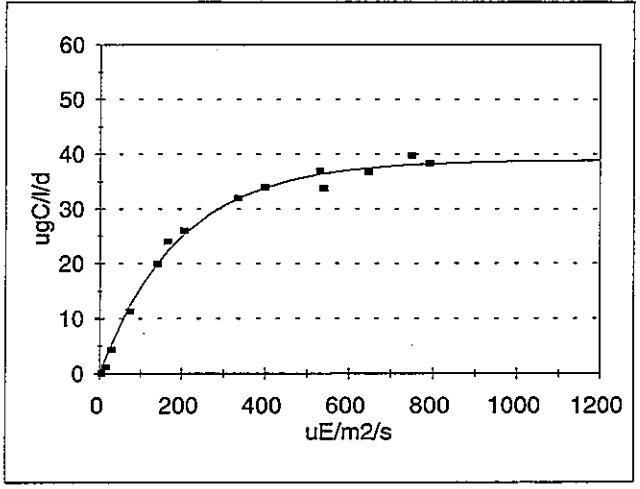


Mid-Bottom



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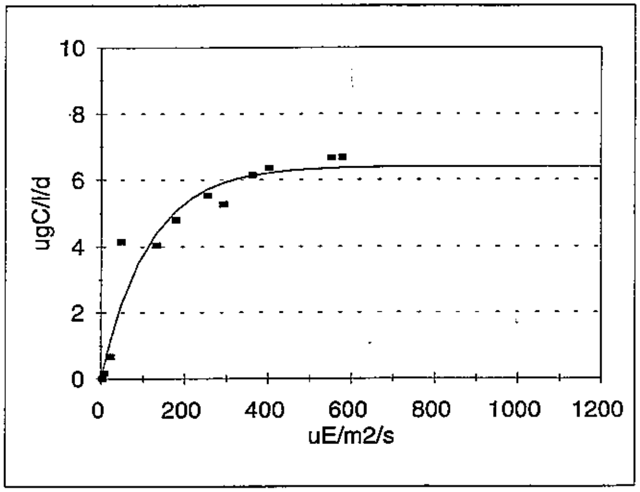
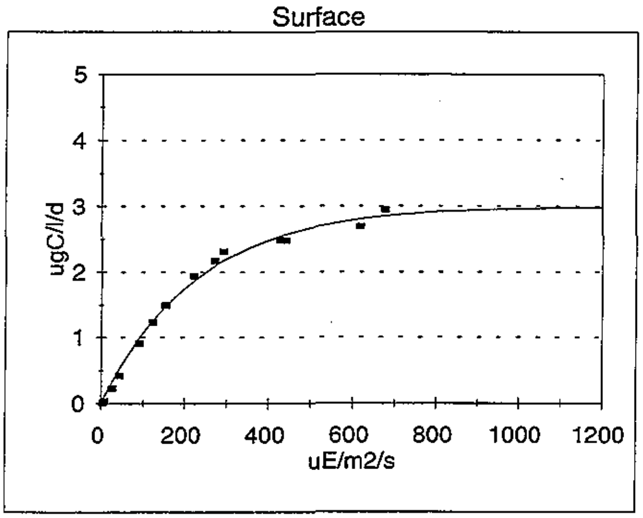
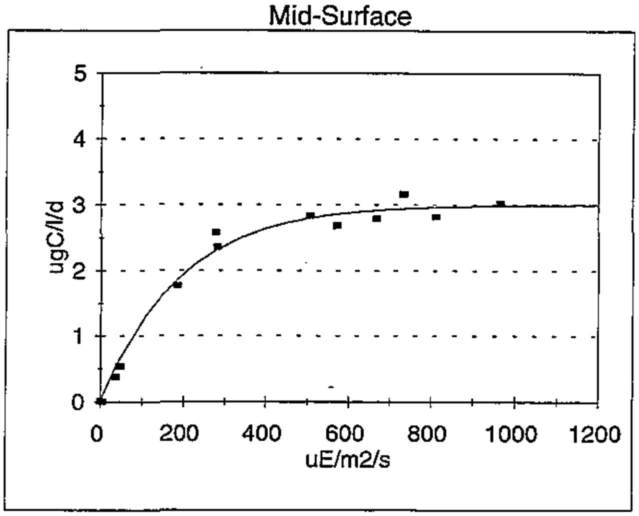


W9605 Station N04


Surface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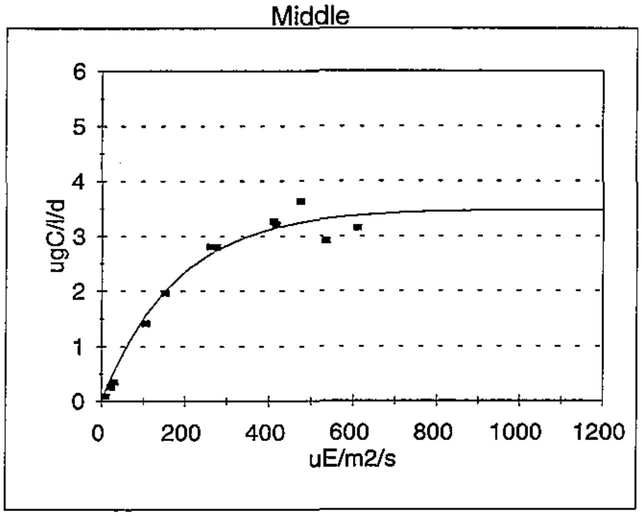
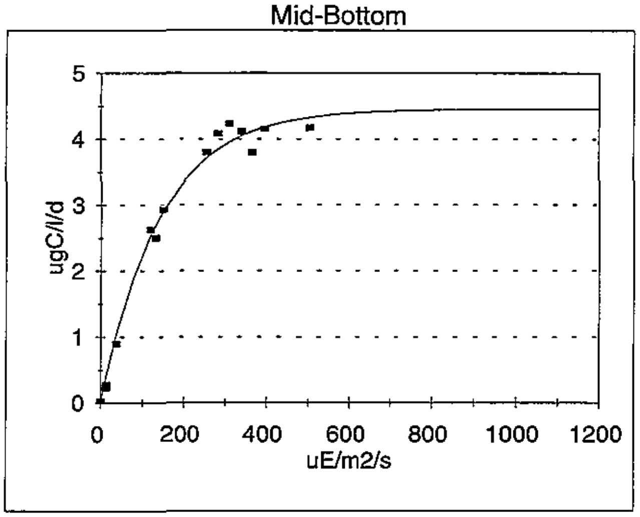
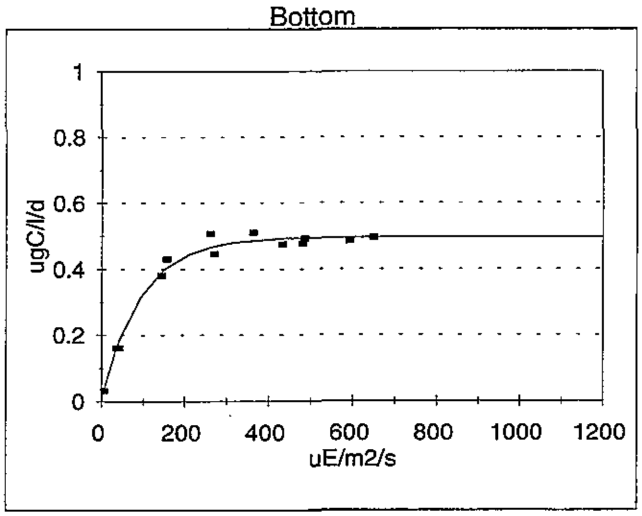
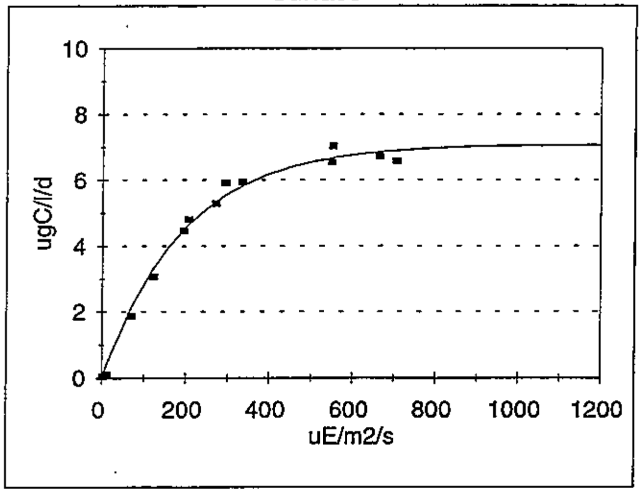
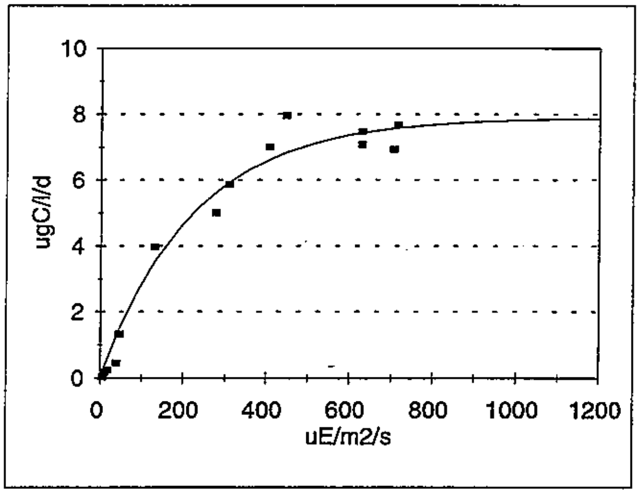

Middle

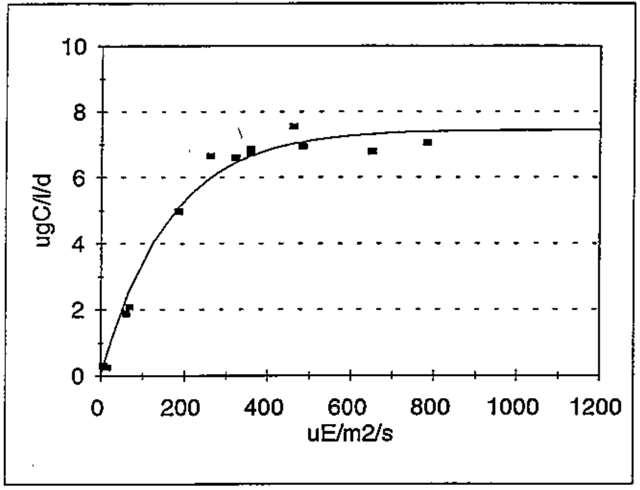

Mid-Bottom


Bottom

W9606 Station N10


Surface


Mid-Surface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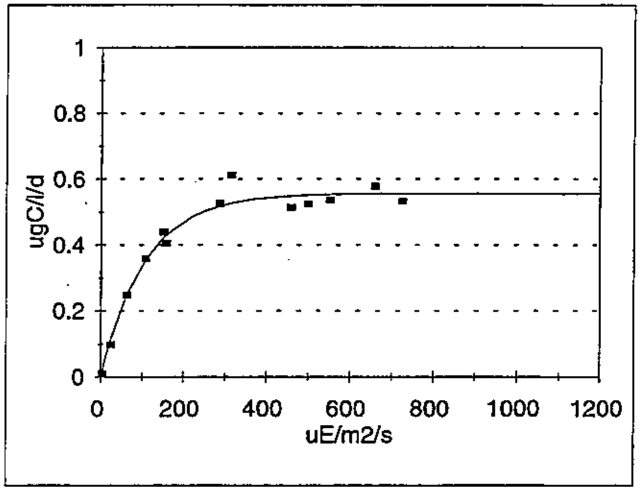
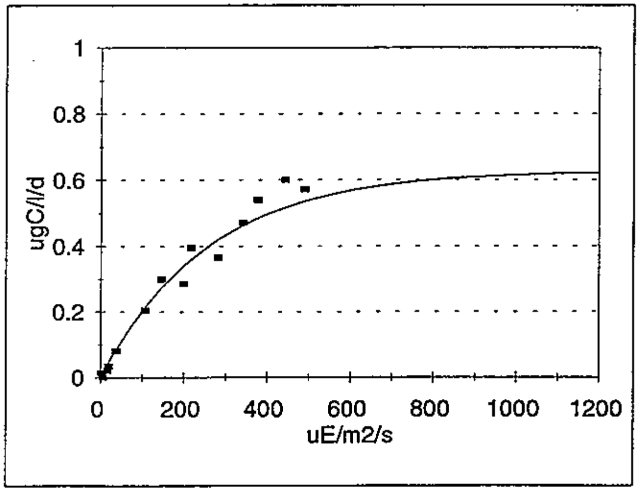
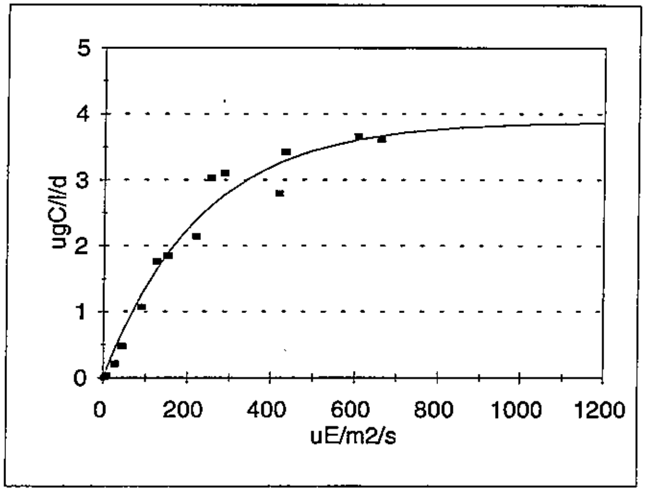

Mid-Bottom


Bottom

W9606 Station N04

Surface



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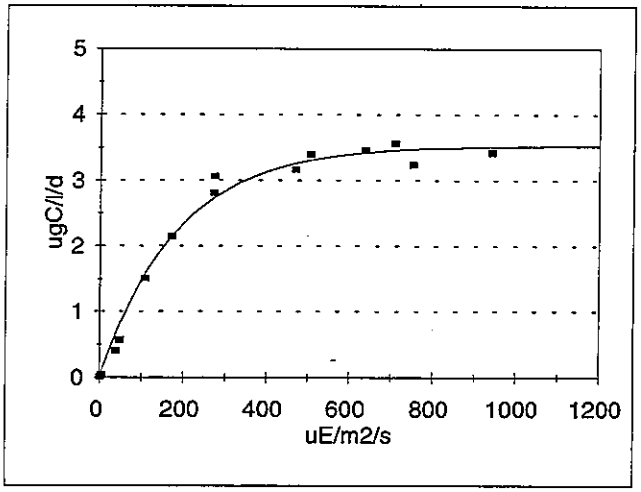

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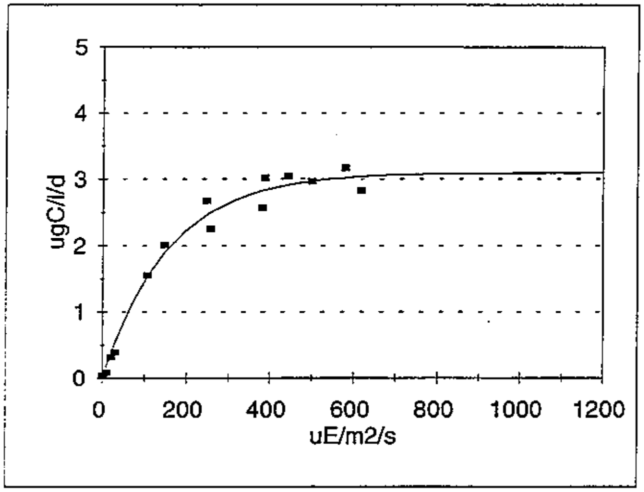
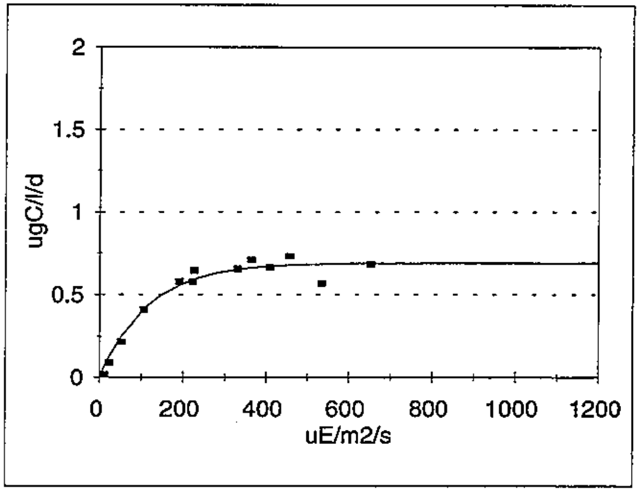


Mid-Bottom



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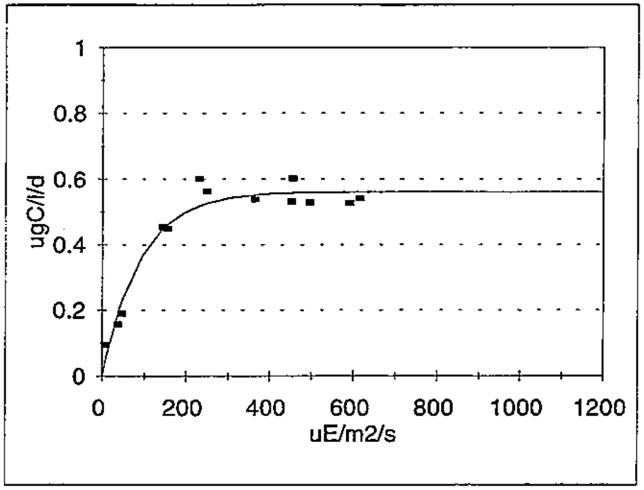

W9607 Station F23

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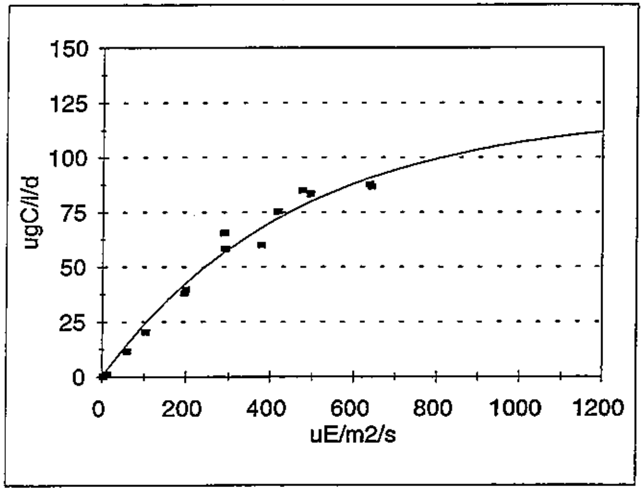

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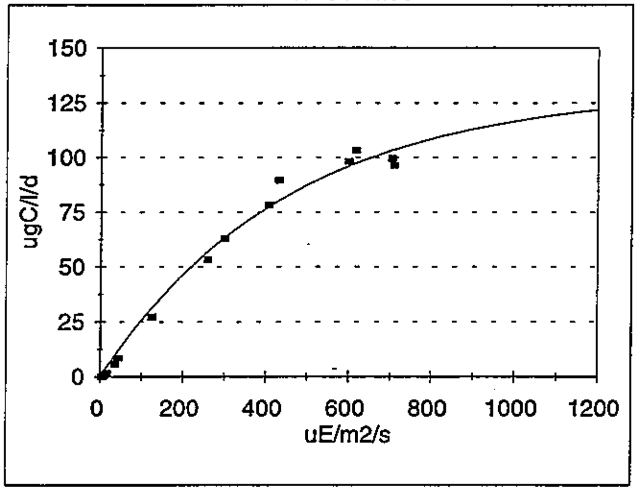

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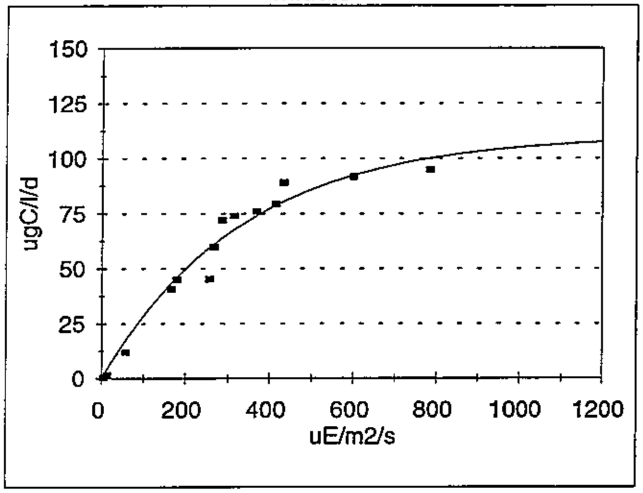

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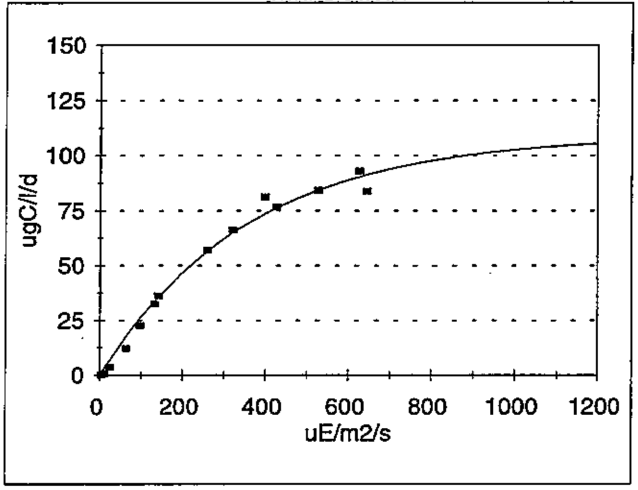

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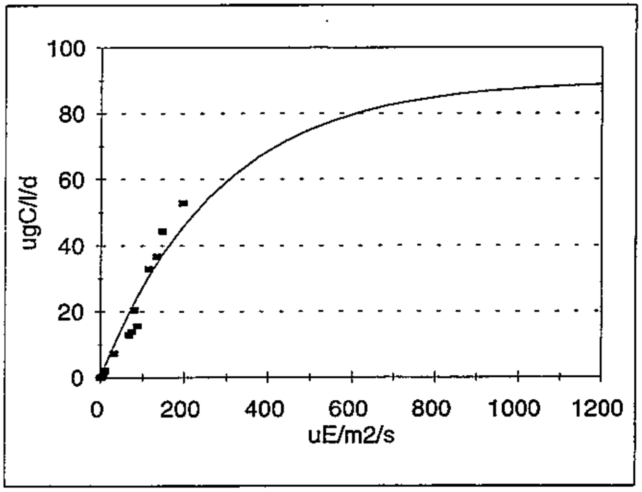

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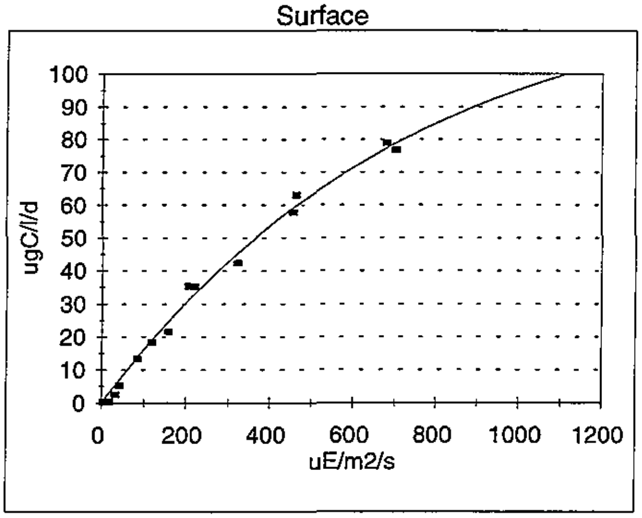

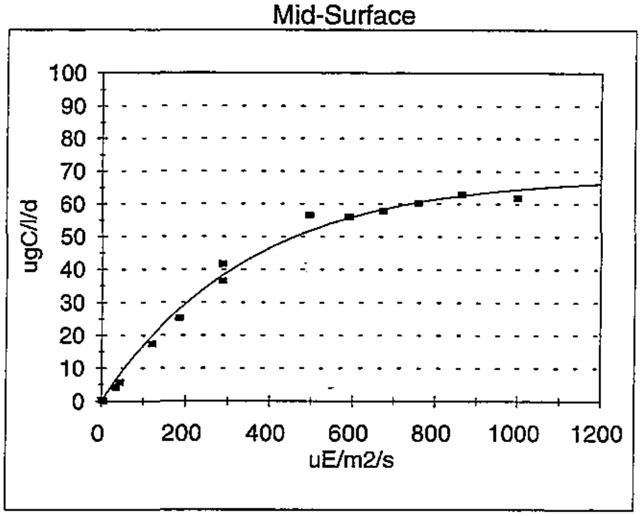

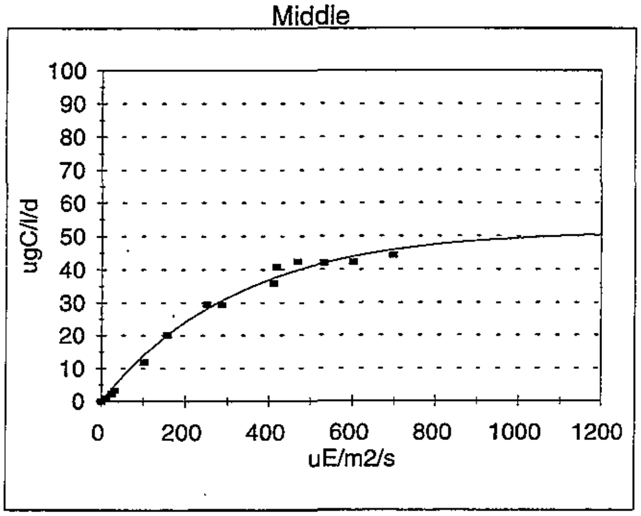

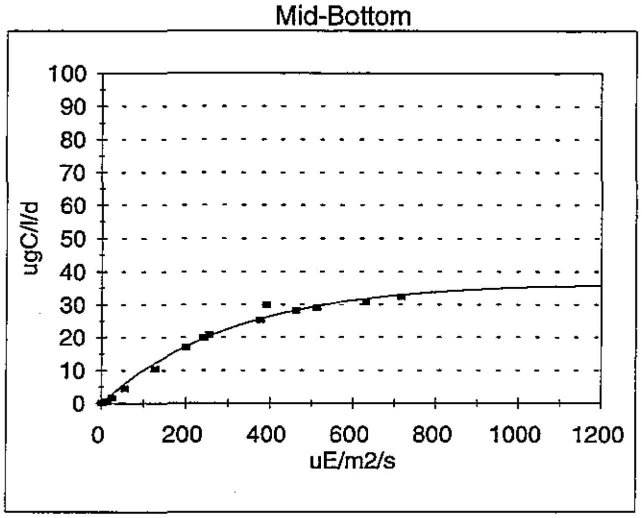

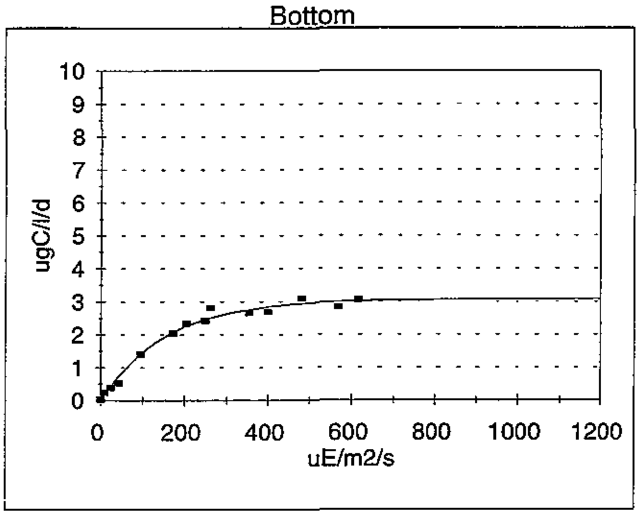

W9607 Station N16

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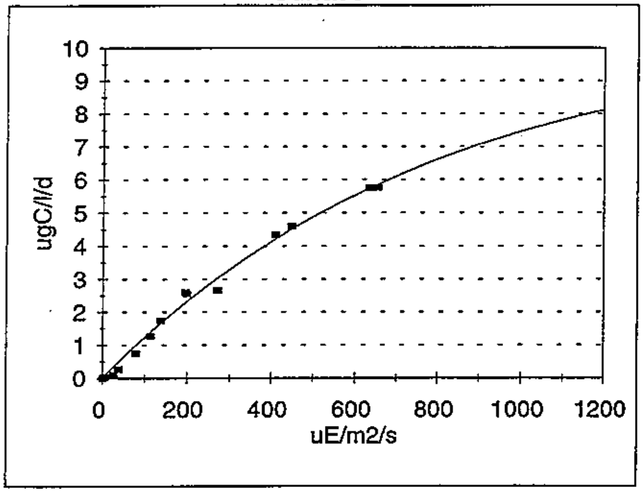

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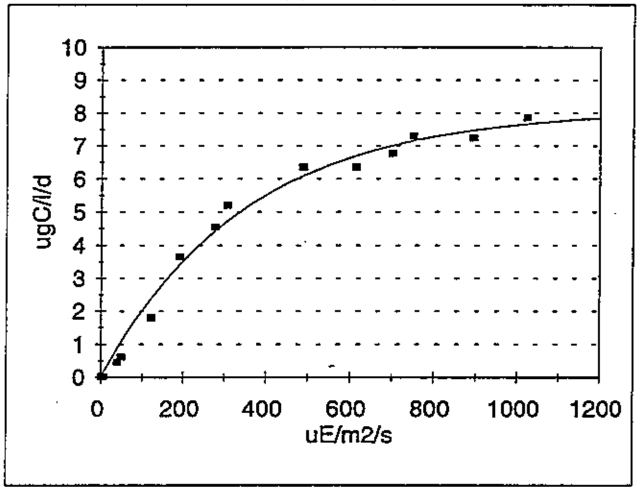

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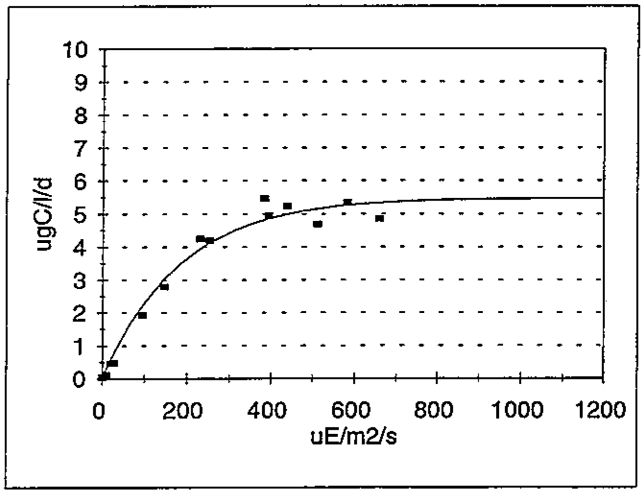

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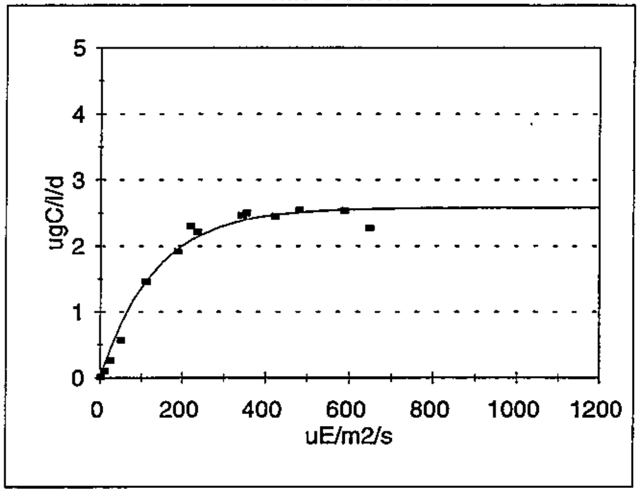

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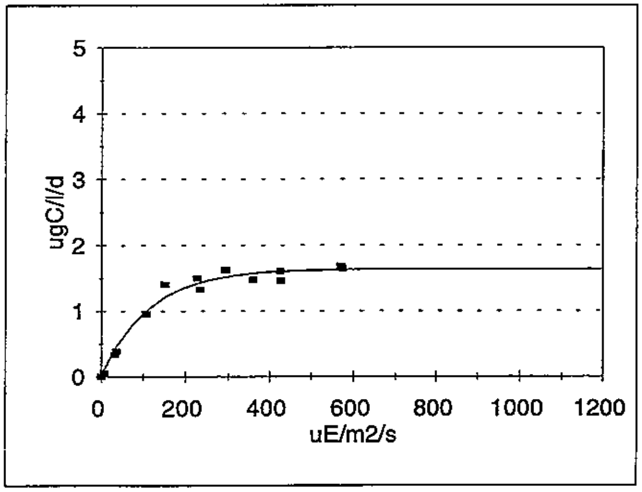
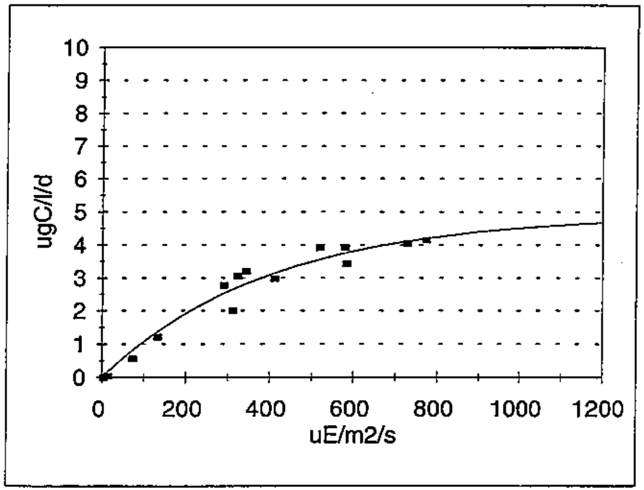


W9607 Station N04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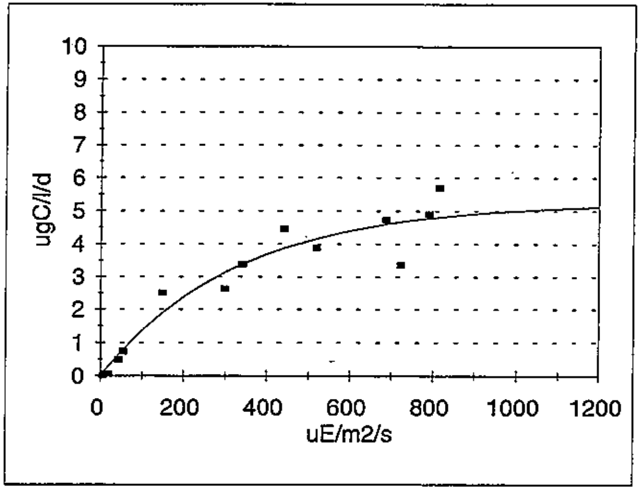
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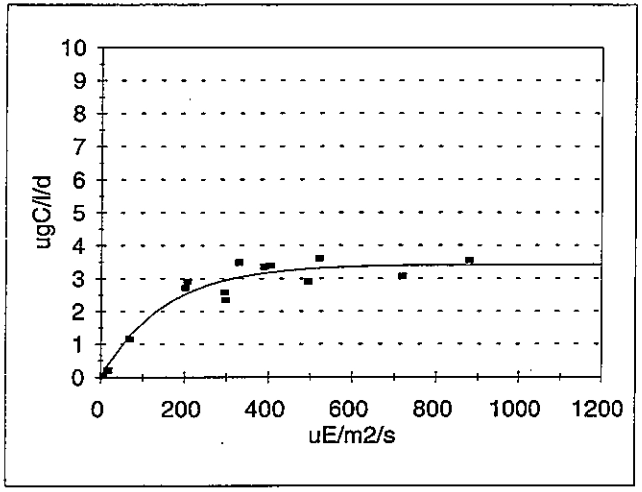
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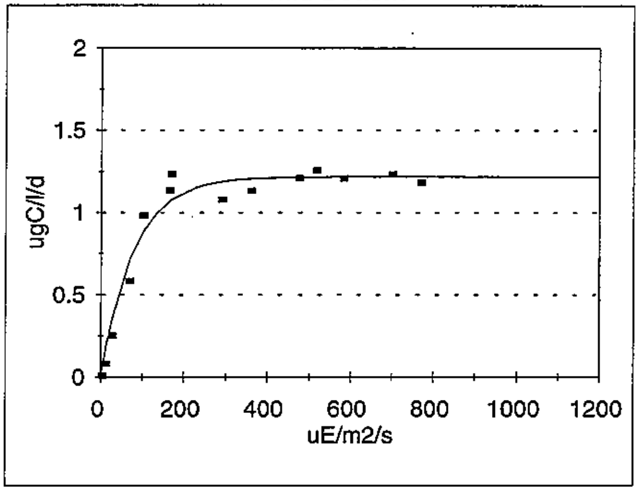
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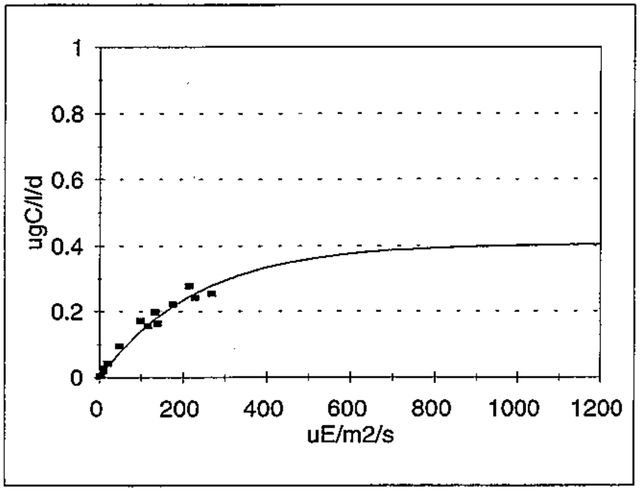
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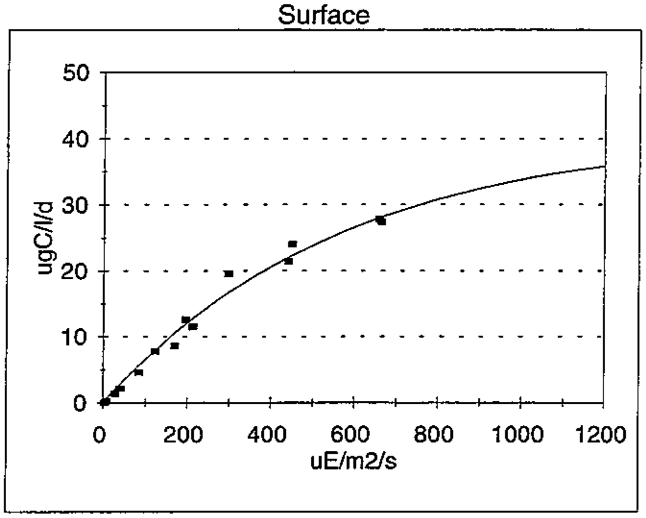
W9608 Station N10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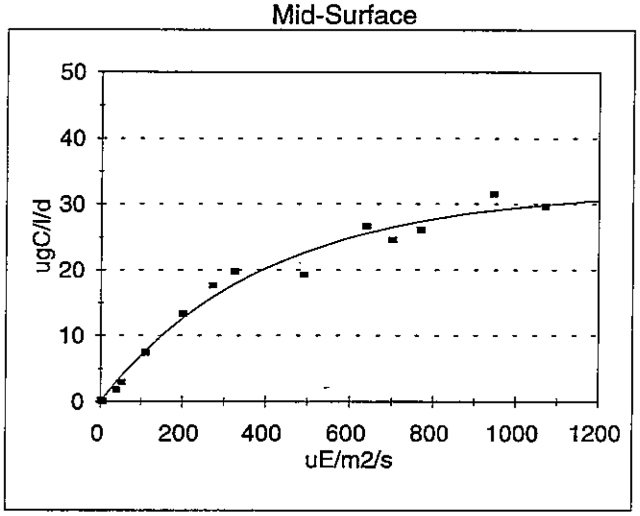
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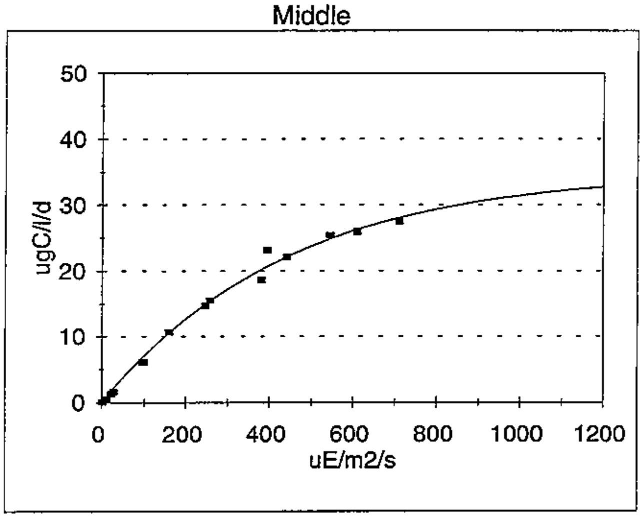
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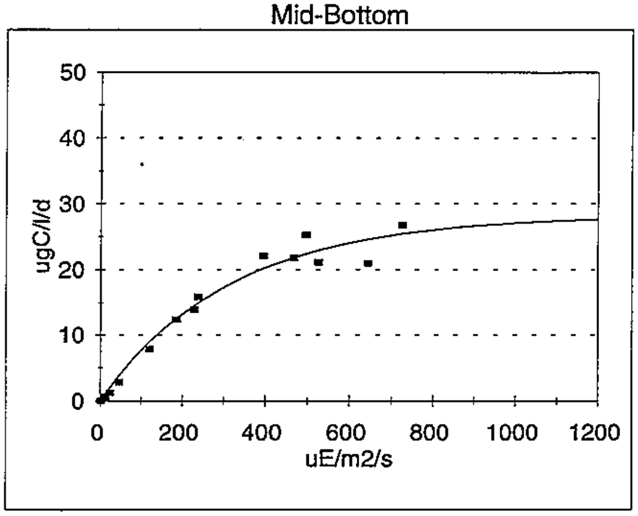
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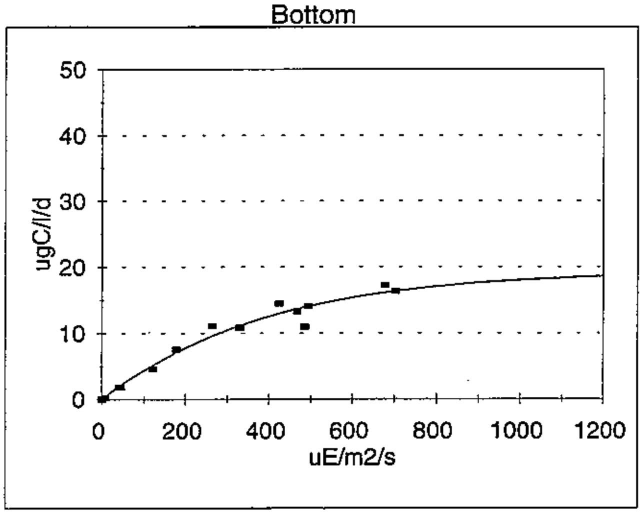
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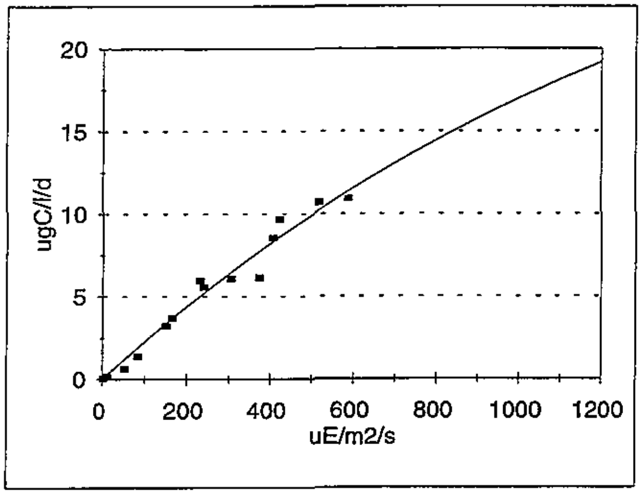
W9608 Station N04

Surface



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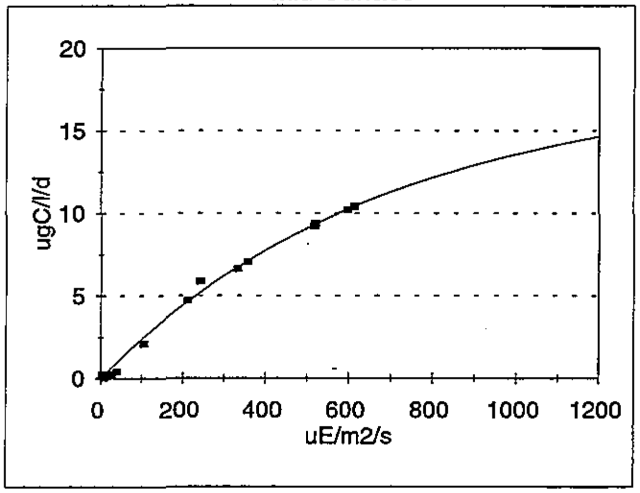

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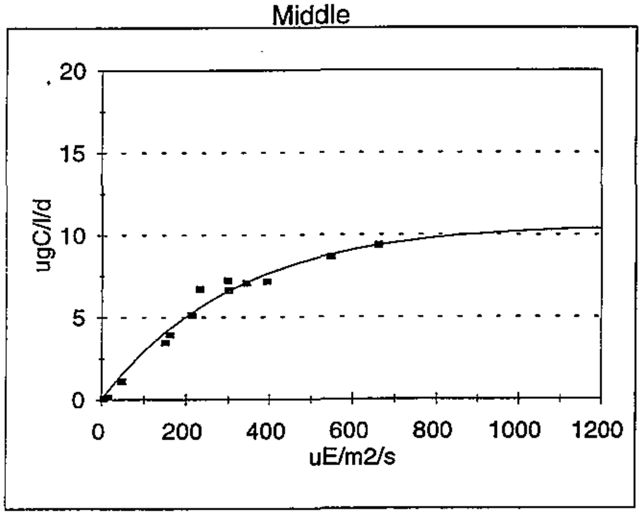

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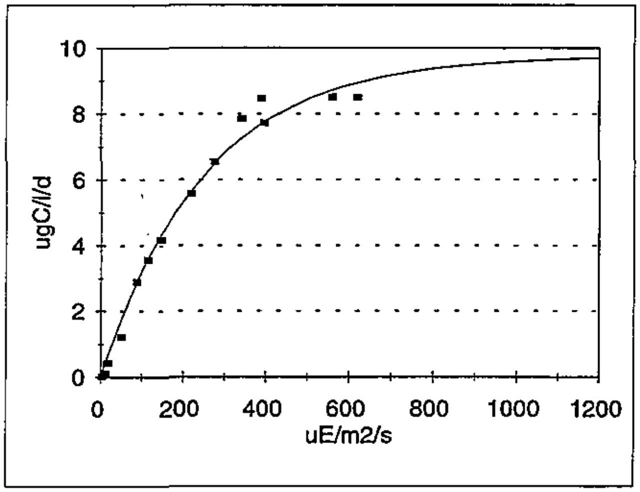

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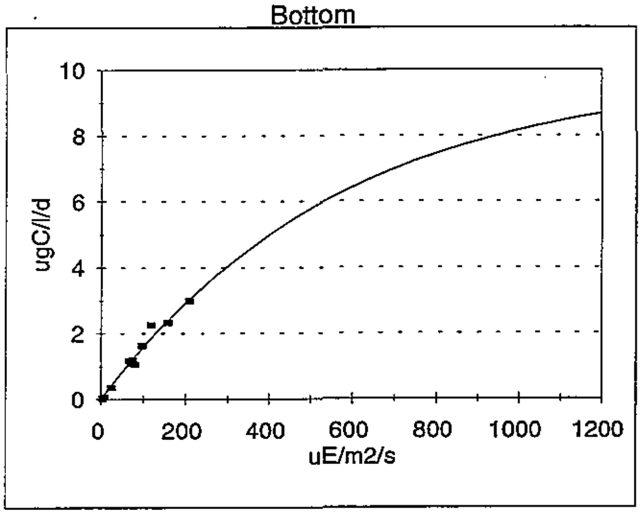
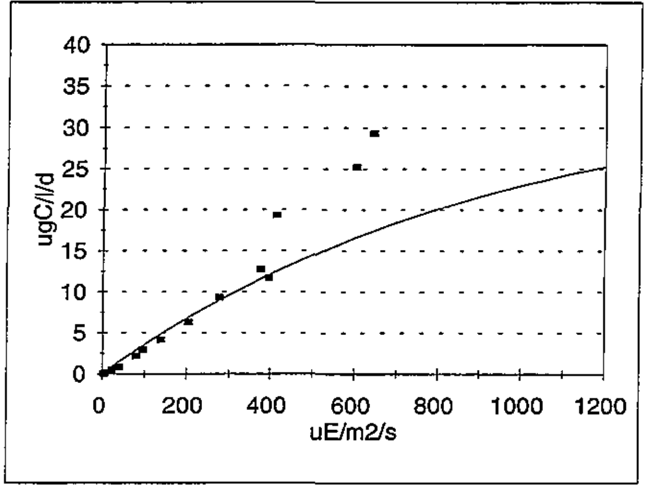


W9609 Station N10

Surface



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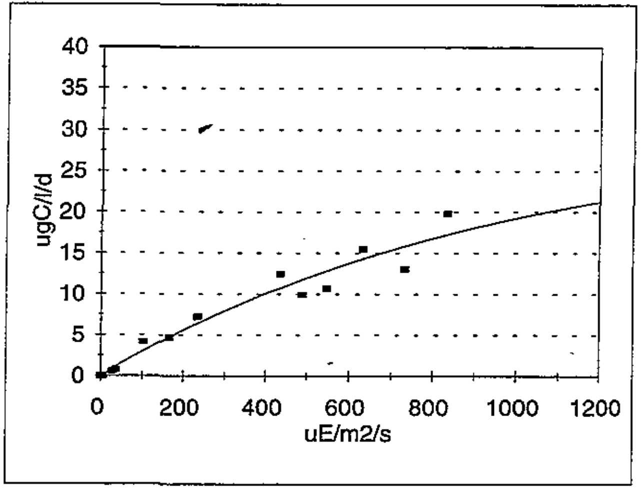

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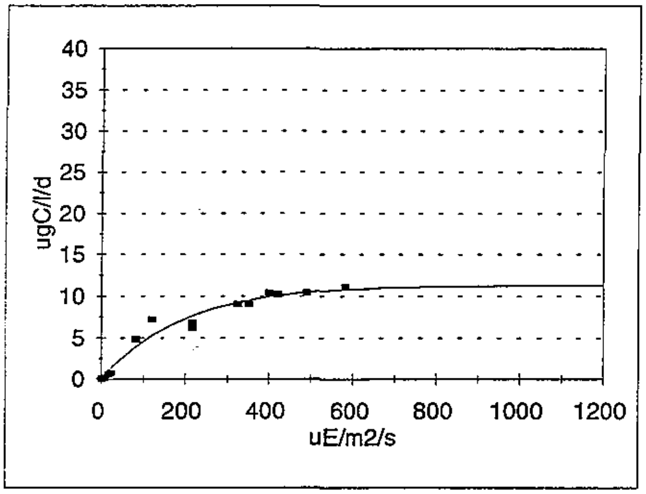

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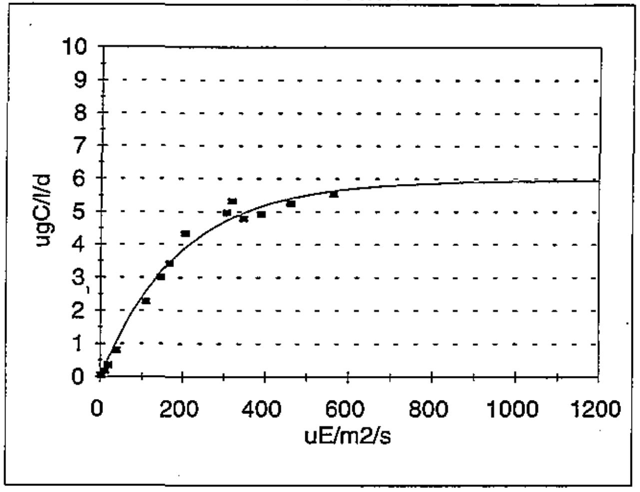

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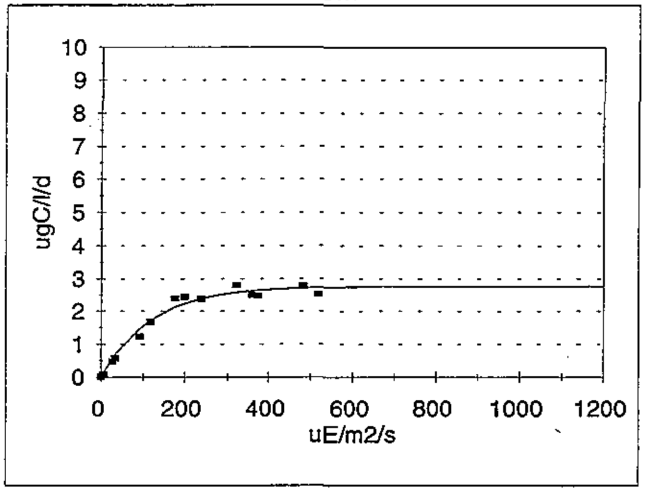
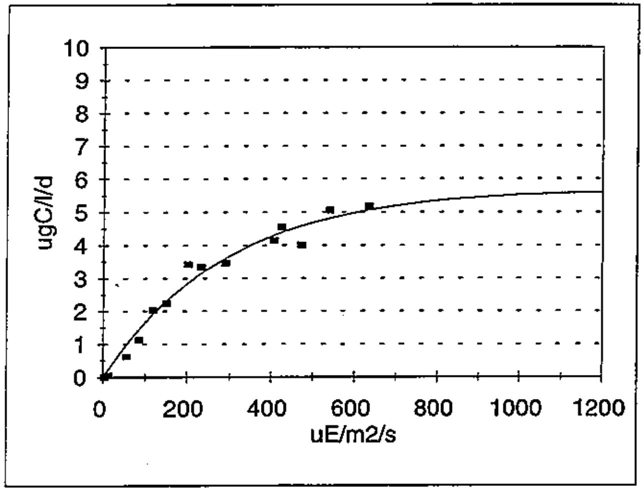


W9609 Station N04

Surface



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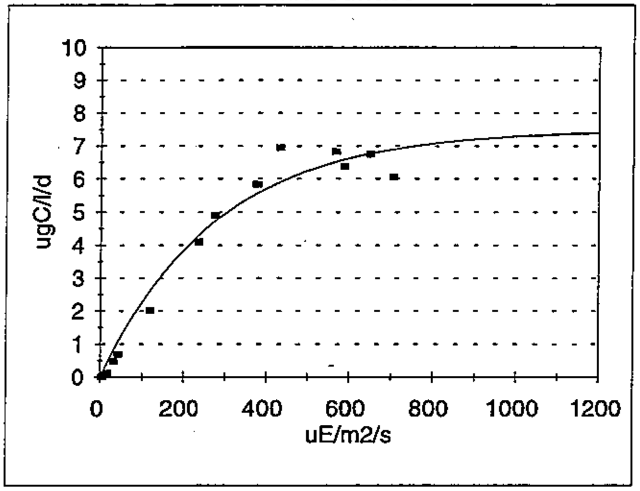

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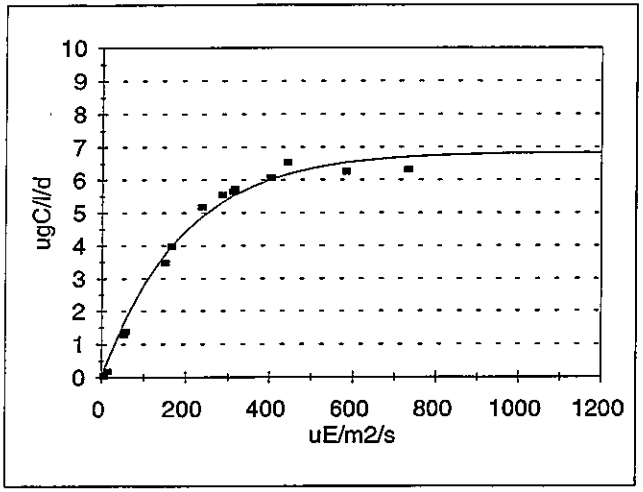

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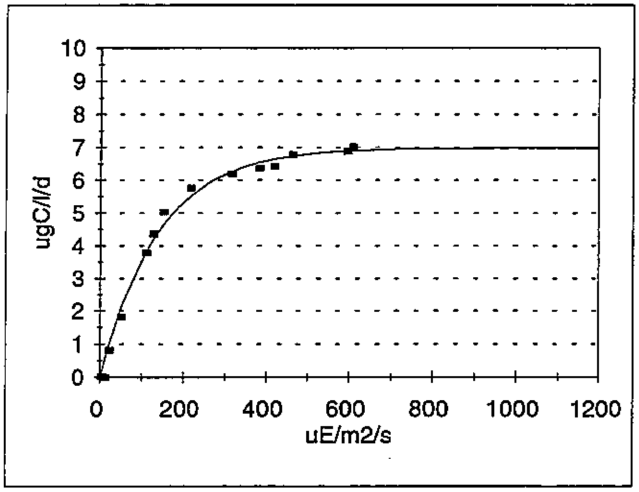

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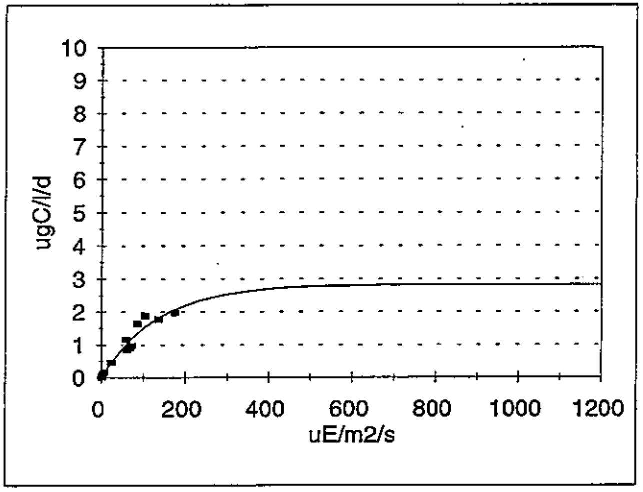

APPENDIX F-1

ABUNDANCE OF PREVALENT SPECIES IN WHOLE WATER SURFACE SAMPLES

Abundance of Prevalent Species (> 5% Total Count) in Surface Sample
Whole Water Phytoplankton, Survey W9601

Species	Group	Parameter	Station Cast												
			F23	F30	F31	F13	F24	F25	N04	N10	N16	F06	F27	F01	F02
ASTERIONELLA GLACIALIS	PD	10^6Cells/L												0.02	0.80
		%												7	24
BLUE GREEN SINGLE SPHERE SPP.	CY	10^6Cells/L			0.06										
		%			6										
BLUE GREEN TRICHOME SPP.	CY	10^6Cells/L												0.02	
		%												10	
CHAETOCEROS SP#1 DIAM <10 MICRONS	CD	10^6Cells/L	0.03												0.38
		%	6												11
CRYPTOMONAS SP#1 LENGTH <10 MICRONS	CR	10^6Cells/L												0.04	
		%												20	
CRYPTOMONAS SP#2 LENGTH >10 MICRONS	CR	10^6Cells/L							0.04		0.03	0.06			
		%							5		5	6			
PROTOPERIDINIUM SP.#2 31-75W 41-80L	DF	10^6Cells/L			0.11		0.15								
		%			10		16								
RHIZOSOLENIA DELICATULA	CD	10^6Cells/L													0.74
		%													22
THALASSIOSIRA SP#2 DIAM >20 MICRONS	CD	10^6Cells/L							0.08	0.03	0.07		0.12		
		%							11	8	10		14		
UNID. CENTRIC DIATOM DIAM <10 MICRONS	CD	10^6Cells/L	0.03			0.04			0.04		0.03			0.01	0.26
		%	8			5			6		5			6	8
UNID. MICRO-PHYTOFLAG LENGTH <10 MICRONS	MF	10^6Cells/L	0.24	0.59	0.86	0.48	0.58	0.39	0.31	0.30	0.37	0.64	0.46	0.06	0.48
		%	58	81	75	70	62	72	45	65	55	72	54	30	14
Group Definitions:	CD	Centric Diatom													
	DF	Dinoflagellate													
	MF	Microflagellate													
	O	Other													
	PD	Pennate Diatom													

Abundance of Prevalent Species (> 5% Total Count) in Surface Sample
Whole Water Phytoplankton, Survey W9602

Species	Group	Parameter	Station Cast												
			F23	F30	F31	F13	F24	F25	N04	N10	N16	F06	F27	F01	F02
BLUE GREEN TRICHOME SPP.	CY	10^6Cells/L	0.10					0.04							
		%	17					7							
CHAETOCEROS SP#1 DIAM <10 MICRONS	CD	10^6Cells/L		0.07			0.07		0.09	0.05	0.07	0.17			0.19
		%		6			7		10	13	11	14			8
CHAETOCEROS SP#2 DIAM 10-30 MICRONS	CD	10^6Cells/L	0.03		0.05		0.10		0.13		0.05	0.16	0.03	0.15	0.32
		%	5		6		11		15		8	14	9	11	14
CHOANOFLAGELLATE SPP.	MF	10^6Cells/L				0.03									
		%				6									
CRYPTOMONAS SP#1 LENGTH <10 MICRONS	CR	10^6Cells/L											0.03		
		%											10		
GYMNODINIUM SP.#1 5-20UM W 10-20UM L	DF	10^6Cells/L							0.07		0.04				
		%							8		6				
PHAEOCYSTIS POUCHETII	HP	10^6Cells/L								0.06					
		%								14					
THALASSIOSIRA NORDENSKIOLDII CLEVE	CD	10^6Cells/L	0.06			0.04	0.06	0.07	0.08	0.03	0.04	0.18		0.14	
		%	9			8	7	12	9	7	6	15		10	
THALASSIOSIRA SP#1 DIAM <20 MICRONS	CD	10^6Cells/L	0.04			0.07	0.06	0.06	0.06	0.12	0.04	0.08	0.08	0.14	
		%	6			14	6	10	6	30	6	7	23	10	
THALASSIOSIRA SP#2 DIAM >20 MICRONS	CD	10^6Cells/L	0.08	0.09	0.07	0.08	0.10	0.06	0.12	0.06	0.10	0.24	0.04	0.29	0.48
		%	12	8	8	16	11	11	13	14	17	20	11	21	21
UNID. CENTRIC DIATOM DIAM <10 MICRONS	CD	10^6Cells/L			0.05				0.05						
		%			6				5						
UNID. MICRO-PHYTOFLAG LENGTH <10 MICRONS	MF	10^6Cells/L	0.16	0.68	0.60	0.21	0.41	0.21	0.21		0.18	0.19	0.10	0.38	0.74
		%	26	59	69	41	45	36	24		29	16	28	27	32

Group Definitions:		
	CD	Centric Diatom
	DF	Dinoflagellate
	MF	Microflagellate
	O	Other
	PD	Pennate Diatom

Abundance of Prevalent Species (> 5% Total Count) in Surface Sample
Whole Water Phytoplankton, Survey W9603

Species	Group	Parameter	Station Cast												
			F23	F30	F31	F13	F24	F25	N04	N10	N16	F06	F27	F01	F02
CHAETOCEROS SP#1 DIAM <10 MICRONS	CD	10^6Cells/L							0.17	0.63					
		%							14	28					
CHAETOCEROS SP#2 DIAM 10-30 MICRONS	CD	10^6Cells/L							0.11	0.32					
		%							9	14					
THALASSIOSIRA SP#1 DIAM <20 MICRONS	CD	10^6Cells/L								0.41					
		%								18					
THALASSIOSIRA SP#2 DIAM >20 MICRONS	CD	10^6Cells/L								0.20					
		%								9					
UNID. MICRO-PHYTOFLAG LENGTH <10 MICRONS	MF	10^6Cells/L							0.71	0.42					
		%							60	19					

Group Definitions:	CD	Centric Diatom
	DF	Dinoflagellate
	MF	Microflagellate
	O	Other
	PD	Pennate Diatom

Abundance of Prevalent Species (> 5% Total Count) in Surface Sample
Whole Water Phytoplankton, Survey W9604

Species	Group	Parameter	Station Cast												
			F23	F30	F31	F13	F24	F25	N04	N10	N16	F06	F27	F01	F02
CHAETOCEROS SP#1 DIAM <10 MICRONS	CD	10^6Cells/L	0.76	1.56	4.30	1.03	0.06	1.59	0.05	1.24	0.03		0.10		
		%	34	35	69	64	7	56	8	44	6		10		
CHAETOCEROS SP#2 DIAM 10-30 MICRONS	CD	10^6Cells/L	0.20	0.33		0.09	0.06	0.17		0.27			0.15		
		%	9	7		5	8	6		9			14		
GYMNODINIUM SP.#1 5-20UM W 10-20UM L	DF	10^6Cells/L					0.05		0.04		0.04	0.02		0.02	
		%					6		6		8	8		7	
THALASSIOSIRA SP#1 DIAM <20 MICRONS	CD	10^6Cells/L	0.35	0.76	0.61	0.16		0.45		0.22					
		%	16	17	10	10		16		8					
THALASSIOSIRA SP#2 DIAM >20 MICRONS	CD	10^6Cells/L	0.20	0.35											
		%	9	8											
UNID. MICRO-PHYTOFLAG LENGTH <10 MICRONS	MF	10^6Cells/L	0.61	1.15	0.84	0.20	0.45	0.25	0.43	0.79	0.36	0.19	0.57	0.25	2.54
		%	27	26	13	13	59	9	72	28	76	76	57	73	90

Group Definitions:	CD	Centric Diatom
	DF	Dinoflagellate
	MF	Microflagellate
	O	Other
	PD	Pennate Diatom

Abundance of Prevalent Species (> 5% Total Count) in Surface Sample
Whole Water Phytoplankton, Survey W9605

Species	Group	Parameter	Station Cast												
			F23	F30	F31	F13	F24	F25	N04	N10	N16	F06	F27	F01	F02
CHAETOCEROS SP#1 DIAM <10 MICRONS	CD	10^6Cells/L							0.10	1.99					
		%							6	60					
THALASSIOSIRA SP#1 DIAM <20 MICRONS	CD	10^6Cells/L								0.31					
		%								9					
UNID. MICRO-PHYTOFLAG LENGTH <10 MICRONS	MF	10^6Cells/L							1.26	0.76					
		%							76	23					

Group Definitions:

CD	Centric Diatom
DF	Dinoflagellate
MF	Microflagellate
O	Other
PD	Pennate Diatom

Abundance of Prevalent Species (> 5% Total Count) in Surface Sample
Whole Water Phytoplankton, Survey W9606

Species	Group	Parameter	Station Cast												
			F23	F30	F31	F13	F24	F25	N04	N10	N16	F06	F27	F01	F02
CHAETOCEROS SP#1 DIAM <10 MICRONS	CD	10^{6}Cells/L								0.17					
		%								23					
CRYPTOMONAS SP#1 LENGTH <10 MICRONS	CR	10^{6}Cells/L							0.04						
		%							5						
CRYPTOMONAS SP#2 LENGTH >10 MICRONS	CR	10^{6}Cells/L							0.04	0.07					
		%							6	10					
GYMNODINIUM SP.#1 5-20UM W 10-20UM L	DF	10^{6}Cells/L							0.06						
		%							7						
PROROCENTRUM MINIMUM	DF	10^{6}Cells/L								0.07					
		%								10					
UNID. MICRO-PHYTOFLAG LENGTH <10 MICRONS	MF	10^{6}Cells/L							0.48	0.33					
		%							61	46					

Group Definitions:		
	CD	Centric Diatom
	DF	Dinoflagellate
	MF	Microflagellate
	O	Other
	PD	Pennate Diatom

Abundance of Prevalent Species (> 5% Total Count) in Surface Sample
Whole Water Phytoplankton, Survey W9607

Species	Group	Parameter	Station Cast												
			F23	F30	F31	F13	F24	F25	N04	N10	N16	F06	F27	F01	F02
CALYCOMONAS WULFFII	CH	10^6Cells/L											0.03		0.04
		%											5		6
CRYPTOMONAS SP#1 LENGTH <10 MICRONS	CR	10^6Cells/L	0.19				0.18	0.06	0.06		0.06		0.04		
		%	7				5	6	5		6		7		
CRYPTOMONAS SP#2 LENGTH >10 MICRONS	CR	10^6Cells/L	0.28	0.13				0.06		0.11	0.06				
		%	10	6				6		10	6				
GYMNODINIUM SP.#1 5-20UM W 10-20UM L	DF	10^6Cells/L				0.07		0.06	0.08	0.07	0.12	0.07		0.08	0.08
		%				6		6	6	6	12	8		12	11
SKELETONEMA COSTATUM GREV+CLEVE	CD	10^6Cells/L	0.22	0.34	0.82		2.08	0.11							
		%	8	15	54		57	11							
UNID. CENTRIC DIATOM DIAM <10 MICRONS	CD	10^6Cells/L					0.41								
		%					11								
UNID. MICRO-PHYTOFLAG LENGTH <10 MICRONS	MF	10^6Cells/L	1.39	1.42	0.45	0.80	0.43	0.51	0.98	0.67	0.69	0.70	0.40	0.42	0.46
		%	50	62	30	79	12	51	78	60	69	75	77	66	67
Group Definitions:	CD	Centric Diatom													
	DF	Dinoflagellate													
	MF	Microflagellate													
	O	Other													
	PD	Pennate Diatom													

Abundance of Prevalent Species (> 5% Total Count) in Surface Sample
Whole Water Phytoplankton, Survey W9608

Species	Group	Parameter	Station Cast												
			F23	F30	F31	F13	F24	F25	N04	N10	N16	F06	F27	F01	F02
CALYCOMONAS WULFFII	CR	10^6Cells/L								0.07					
		%								5					
CRYPTOMONAS SP#1 LENGTH <10 MICRONS	CR	10^6Cells/L								0.07					
		%								5					
CRYPTOMONAS SP#2 LENGTH >10 MICRONS	CR	10^6Cells/L								0.26					
		%								20					
KATODINIUM ROTUNDATUM	DF	10^6Cells/L								0.08					
		%								6					
RHIZOSOLENIA FRAGILISSIMA	CD	10^6Cells/L							0.91	0.19					
		%							35	14					
UNID. MICRO-PHYTOFLAG LENGTH <10 MICRONS	MF	10^6Cells/L							1.27	0.49					
		%							49	37					
Group Definitions:	CD	Centric Diatom													
	DF	Dinoflagellate													
	MF	Microflagellate													
	O	Other													
	PD	Pennate Diatom													

Abundance of Prevalent Species (> 5% Total Count) in Surface Sample
Whole Water Phytoplankton, Survey W9609

Species	Group	Parameter	Station Cast												
			F23	F30	F31	F13	F24	F25	N04	N10	N16	F06	F27	F01	F02
CRYPTOMONAS SP#1 LENGTH <10 MICRONS	CR	10^6Cells/L							0.06	0.15					
		%							7	15					
CRYPTOMONAS SP#2 LENGTH >10 MICRONS	CR	10^6Cells/L								0.10					
		%								10					
GYMNODINIUM SP.#1 5-20UM W 10-20UM L	DF	10^6Cells/L							0.07	0.11					
		%							8	11					
KATODINIUM ROTUNDATUM	DF	10^6Cells/L								0.09					
		%								10					
UNID. MICRO-PHYTOFLAG LENGTH <10 MICRONS	MF	10^6Cells/L							0.64	0.41					
		%							70	43					
Group Definitions:	CD	Centric Diatom													
	DF	Dinoflagellate													
	MF	Microflagellate													
	O	Other													
	PD	Pennate Diatom													

APPENDIX F-2

Abundance of Prevalent Species (> 5% Total Count) in Chlorophyll *a* Maximum Sample
Whole Water Phytoplankton, Survey W9601

Species	Group	Parameter	Station Cast												
			F23	F30	F31	F13	F24	F25	N04	N10	N16	F06	F27	F01	F02
ASTERIONELLA GLACIALIS	PD	10^6Cells/L													0.68
		%													21
BLUE GREEN TRICHOME SPP.	CY	10^6Cells/L						0.02							
		%						5							
CHAETOCEROS SP#2 DIAM 10-30 MICRONS	CD	10^6Cells/L							0.04						
		%							5						
CRYPTOMONAS SP#1 LENGTH <10 MICRONS	CR	10^6Cells/L						0.04							
		%						14							
CRYPTOMONAS SP#2 LENGTH >10 MICRONS	CR	10^6Cells/L					0.03				0.04	0.05			
		%					5				6	7			
CYLINDROTHECA CLOSTERIUM	PD	10^6Cells/L											0.03		
		%											6		
RHIZOSOLENIA DELICATULA	CD	10^6Cells/L													0.57
		%													18
SKELETONEMA COSTATUM GREV+CLEVE	CD	10^6Cells/L													0.29
		%													9
THALASSIOSIRA SP#1 DIAM <20 MICRONS	CD	10^6Cells/L						0.03							
		%						8							
THALASSIOSIRA SP#2 DIAM >20 MICRONS	CD	10^6Cells/L						0.03	0.13	0.04	0.06		0.05		
		%						8	16	6	7		9		
UNID. CENTRIC DIATOM DIAM <10 MICRONS	CD	10^6Cells/L				0.04		0.03			0.05				0.25
		%				6		9			6				8
UNID. MICRO-PHYTOFLAG LENGTH <10 MICRONS	MF	10^6Cells/L	0.47	0.32	0.46	0.36	0.42	0.08	0.40	0.45	0.45	0.43	0.36	0.55	0.68
		%	74	72	69	58	67	26	51	66	60	65	63	77	21

Group Definitions:		
	CD	Centric Diatom
	DF	Dinoflagellate
	MF	Microflagellate
	O	Other
	PD	Pennate Diatom

Abundance of Prevalent Species (> 5% Total Count) in Chlorophyll *a* Maximum Sample
Whole Water Phytoplankton, Survey W9602

Species	Group	Parameter	Station Cast												
			F23	F30	F31	F13	F24	F25	N04	N10	N16	F06	F27	F01	F02
CHAETOCEROS DEBILIS	CD	10^6Cells/L		0.06				0.03					0.01		0.08
		%		12				6					5		8
CHAETOCEROS SP#1 DIAM <10 MICRONS	CD	10^6Cells/L	0.02			0.04	0.06	0.04	0.07	0.05	0.06	0.08		0.10	
		%	8			6	7	8	7	7	7	12		8	
CHAETOCEROS SP#2 DIAM 10-30 MICRONS	CD	10^6Cells/L		0.03		0.05	0.08		0.10	0.08	0.09	0.05		0.15	0.10
		%		5		8	10		11	11	11	7		12	10
CHOANOFLAGELLATE SPP.	MF	10^6Cells/L		0.04		0.04									
		%		8		7									
CRYPTOMONAS SP#1 LENGTH <10 MICRONS	CR	10^6Cells/L											0.02		
		%											11		
GYMNODINIUM SP.#1 5-20UM W 10-20UM L	DF	10^6Cells/L									0.06				
		%									7				
THALASSIOSIRA NORDENSKIOLDII CLEVE	CD	10^6Cells/L	0.02			0.07		0.04	0.10	0.05	0.08			0.10	
		%	6			11		8	12	6	10			8	
THALASSIOSIRA SP#1 DIAM <20 MICRONS	CD	10^6Cells/L	0.11	0.08		0.11	0.09	0.10	0.05	0.08	0.04	0.19	0.02	0.17	0.21
		%	37	16		19	11	20	6	11	5	27	12	14	21
THALASSIOSIRA SP#2 DIAM >20 MICRONS	CD	10^6Cells/L	0.05	0.05	0.06	0.06	0.11	0.06	0.12	0.11	0.07	0.05	0.02	0.28	0.15
		%	17	10	8	11	14	11	14	15	9	7	11	24	16
UNID. CENTRIC DIATOM DIAM <10 MICRONS	CD	10^6Cells/L									0.04				
		%									5				
UNID. MICRO-PHYTOFLAG LENGTH <10 MICRONS	MF	10^6Cells/L	0.02	0.13	0.48	0.14	0.32	0.14	0.26	0.30	0.27	0.16	0.08	0.25	0.18
		%	7	26	60	24	40	27	30	38	35	24	39	21	18

Group Definitions:	CD	Centric Diatom
	DF	Dinoflagellate
	MF	Microflagellate
	O	Other
	PD	Pennate Diatom

Abundance of Prevalent Species (> 5% Total Count) in Chlorophyll *a* Maximum Sample
Whole Water Phytoplankton, Survey W9603

Species	Group	Parameter	Station Cast												
			F23	F30	F31	F13	F24	F25	N04	N10	N16	F06	F27	F01	F02
CHAETOCEROS SP#1 DIAM <10 MICRONS	CD	10^6Cells/L							0.56	0.37					
		%							38	22					
CHAETOCEROS SP#2 DIAM 10-30 MICRONS	CD	10^6Cells/L							0.12	0.10					
		%							8	6					
THALASSIOSIRA SP#1 DIAM <20 MICRONS	CD	10^6Cells/L							0.09	0.20					
		%							6	12					
THALASSIOSIRA SP#2 DIAM >20 MICRONS	CD	10^6Cells/L							0.24	0.13					
		%							16	7					
UNID. MICRO-PHYTOFLAG LENGTH <10 MICRONS	MF	10^6Cells/L							0.31	0.76					
		%							21	44					
Group Definitions:	CD	Centric Diatom													
	DF	Dinoflagellate													
	MF	Microflagellate													
	O	Other													
	PD	Pennate Diatom													

Abundance of Prevalent Species (> 5% Total Count) in Chlorophyll *a* Maximum Sample
Whole Water Phytoplankton, Survey W9604

Species	Group	Parameter	Station Cast												
			F23	F30	F31	F13	F24	F25	N04	N10	N16	F06	F27	F01	F02
CHAETOCEROS SP#1 DIAM <10 MICRONS	CD	10^6Cells/L	0.54	1.60	3.15	0.74	0.07	2.26		0.48	0.03		0.07		
		%	34	38	60	36	7	60		29	5		7		
CHAETOCEROS SP#2 DIAM 10-30 MICRONS	CD	10^6Cells/L	0.20	0.39		0.20				0.11					
		%	13	9		10				7					
GYMNODINIUM SP.#1 5-20UM W 10-20UM L	DF	10^6Cells/L					0.06		0.04		0.05	0.03	0.06	0.04	
		%					5		15		10	12	6	12	
THALASSIOSIRA SP#1 DIAM <20 MICRONS	CD	10^6Cells/L	0.24	0.52	0.53	0.13		0.49							
		%	15	12	10	6		13							
THALASSIOSIRA SP#2 DIAM >20 MICRONS	CD	10^6Cells/L	0.14	0.27		0.17									
		%	9	6		8									
UNID. MICRO-PHYTOFLAG LENGTH <10 MICRONS	MF	10^6Cells/L	0.35	1.20	1.07	0.61	0.77	0.65	0.20	0.79	0.34	0.18	0.77	0.22	1.09
		%	23	29	20	30	72	17	71	48	69	74	74	71	87
Group Definitions:	CD	Centric Diatom													
	DF	Dinoflagellate													
	MF	Microflagellate													
	O	Other													
	PD	Pennate Diatom													

Abundance of Prevalent Species (> 5% Total Count) in Chlorophyll *a* Maximum Sample
Whole Water Phytoplankton, Survey W9605

Species	Group	Parameter	Station Cast												
			F23	F30	F31	F13	F24	F25	N04	N10	N16	F06	F27	F01	F02
CHAETOCEROS SP#1 DIAM <10 MICRONS	CD	10^6Cells/L								0.94					
		%								52					
THALASSIOSIRA SP#1 DIAM <20 MICRONS	CD	10^6Cells/L								0.25					
		%								14					
UNID. MICRO-PHYTOFLAG LENGTH <10 MICRONS	MF	10^6Cells/L							0.66	0.41					
		%							92	23					
Group Definitions:	CD	Centric Diatom													
	DF	Dinoflagellate													
	MF	Microflagellate													
	O	Other													
	PD	Pennate Diatom													

Abundance of Prevalent Species (> 5% Total Count) in Chlorophyll *a* Maximum Sample
Whole Water Phytoplankton, Survey W9606

Species	Group	Parameter	Station Cast												
			F23	F30	F31	F13	F24	F25	N04	N10	N16	F06	F27	F01	F02
CHAETOCEROS SP#1 DIAM <10 MICRONS	CD	10^6Cells/L								0.54					
		%								56					
CRYPTOMONAS SP#2 LENGTH >10 MICRONS	CR	10^6Cells/L							0.02						
		%							6						
GYMNODINIUM SP.#1 5-20UM W 10-20UM L	DF	10^6Cells/L							0.04						
		%							12						
PROROCENTRUM MINIMUM	DF	10^6Cells/L								0.11					
		%								12					
UNID. MICRO-PHYTOFLAG LENGTH <10 MICRONS	MF	10^6Cells/L							0.21	0.20					
		%							67	21					
Group Definitions:	CD	Centric Diatom													
	DF	Dinoflagellate													
	MF	Microflagellate													
	O	Other													
	PD	Pennate Diatom													

Abundance of Prevalent Species (> 5% Total Count) in Chlorophyll *a* Maximum Sample
Whole Water Phytoplankton, Survey W9607

Species	Group	Parameter	Station Cast												
			F23	F30	F31	F13	F24	F25	N04	N10	N16	F06	F27	F01	F02
CALYCOMONAS OVALIS	CH	10^6Cells/L			0.08										
		%			6										
CHAETOCEROS SP#1 DIAM <10 MICRONS	CD	10^6Cells/L	0.10		0.31					0.08			1.92		
		%	6		22					7			64		
CRYPTOMONAS SP#1 LENGTH <10 MICRONS	CR	10^6Cells/L		0.12			0.08		0.09	0.08	0.15	0.20		0.28	
		%		7			8		26	7	22	14		8	
CRYPTOMONAS SP#2 LENGTH >10 MICRONS	CR	10^6Cells/L	0.11	0.09	0.09		0.08	0.09		0.08		0.08			0.04
		%	7	5	6		9	7		7		6			5
GYMNODINIUM SP.#1 5-20UM W 10-20UM L	DF	10^6Cells/L				0.08	0.06								0.06
		%				11	7								9
KATODINIUM ROTUNDATUM	DF	10^6Cells/L									0.05				
		%									7				
MICROCYSTIS AERUGINOSA	CY	10^6Cells/L								0.35					
		%								30					
SKELETONEMA COSTATUM GREV+CLEVE	CD	10^6Cells/L	0.12	0.62				0.32			0.08				
		%	8	35				24			11				
UNID. CENTRIC DIATOM DIAM <10 MICRONS	CD	10^6Cells/L		0.12							0.04				
		%		7							6				
UNID. MICRO-PHYTOFLAG LENGTH <10 MICRONS	MF	10^6Cells/L	0.88	0.51	0.68	0.54	0.51	0.66	0.21	0.44	0.29	1.04	0.71	2.52	0.49
		%	55	29	47	70	55	49	61	38	43	72	24	75	69

Group Definitions:		
	CD	Centric Diatom
	DF	Dinoflagellate
	MF	Microflagellate
	O	Other
	PD	Pennate Diatom

Abundance of Prevalent Species (> 5% Total Count) in Chlorophyll *a* Maximum Sample
Whole Water Phytoplankton, Survey W9608

Species	Group	Parameter	Station Cast												
			F23	F30	F31	F13	F24	F25	N04	N10	N16	F06	F27	F01	F02
CRYPTOMONAS SP#1 LENGTH <10 MICRONS	CR	10^6Cells/L							0.20	0.11					
		%							17	8					
CRYPTOMONAS SP#2 LENGTH >10 MICRONS	CR	10^6Cells/L							0.15	0.26					
		%							13	19					
KATODINIUM ROTUNDATUM	DF	10^6Cells/L							0.06						
		%							6						
RHIZOSOLENIA FRAGILISSIMA	CD	10^6Cells/L								0.10					
		%								8					
UNID. MICRO-PHYTOFLAG LENGTH <10 MICRONS	MF	10^6Cells/L							0.68	0.62					
		%							58	46					
Group Definitions:	CD	Centric Diatom													
	DF	Dinoflagellate													
	MF	Microflagellate													
	O	Other													
	PD	Pennate Diatom													

Abundance of Prevalent Species (> 5% Total Count) in Chlorophyll *a* Maximum Sample
Whole Water Phytoplankton, Survey W9609

Species	Group	Parameter	Station Cast												
			F23	F30	F31	F13	F24	F25	N04	N10	N16	F06	F27	F01	F02
CALYCOMONAS WULFFII	CR	10^6Cells/L							0.03						
		%							5						
CRYPTOMONAS SP#1 LENGTH <10 MICRONS	CR	10^6Cells/L							0.06	0.05					
		%							9	8					
CRYPTOMONAS SP#2 LENGTH >10 MICRONS	CR	10^6Cells/L							0.06	0.07					
		%							10	11					
GYMNODINIUM SP.#1 5-20UM W 10-20UM L	DF	10^6Cells/L							0.06	0.05					
		%							9	8					
UNID. MICRO-PHYTOFLAG LENGTH <10 MICRONS	MF	10^6Cells/L							0.36	0.32					
		%							58	51					
Group Definitions:	CD	Centric Diatom													
	DF	Dinoflagellate													
	MF	Microflagellate													
	O	Other													
	PD	Pennate Diatom													

APPENDIX G-1

Abundance of Prevalent Species (> 5% Total Count) in Surface Sample
Screened Phytoplankton, Survey W9601

Species	Group	Parameter	Station Cast												
			F23	F30	F31	F13	F24	F25	N04	N10	N16	F06	F27	F01	F02
CERATIUM FUSUS	DF	10^6Cells/L										0.00001			
		%										8			
CERATIUM LONGIPES	DF	10^6Cells/L	0.00001												
		%	6												
CERATIUM TRIPOS	DF	10^6Cells/L	0.00005		0.00001							0.00002	0.00002		
		%	33		6							14	5		
GONYAULAX SPP.	DF	10^6Cells/L	0.00002						0.00022	0.00004			0.00004		
		%	15						9	8			9		
NITZSCHIA PUNGENS	PD	10^6Cells/L	0.00001		0.00005	0.00004	0.00021	0.00004	0.00017	0.00008			0.00005		0.00100
		%	10		25	7	16	15	7	16			13		24
NITZSCHIA SERIATA	PD	10^6Cells/L	0.00003		0.00009	0.00005				0.00004	0.00011	0.00007			0.00300
		%	20		51	8				8	9	42			72
NITZSCHIA SP#2 LENGTH 30-70 MICRONS	PD	10^6Cells/L										0.00004			
		%										24			
PHAEOCYSTIS POUCHETII	HP	10^6Cells/L		0.00100		0.00042	0.00100	0.00021	0.00200	0.00033	0.00100		0.00024		
		%		83		75	78	76	80	65	78		61		

Group Definitions:	CD	Centric Diatom
	DF	Dinoflagellate
	MF	Microflagellate
	O	Other
	PD	Pennate Diatom

Abundance of Prevalent Species (> 5% Total Count) in Surface Sample
Screened Phytoplankton, Survey W9602

Species	Group	Parameter	Station Cast												
			F23	F30	F31	F13	F24	F25	N04	N10	N16	F06	F27	F01	F02
GONYAULAX SPP.	DF	10^6Cells/L	0.00100	0.00100	0.00019	0.00100	0.00028	0.00100		0.00012	0.00015	0.00100	0.00100	0.00034	0.00400
		%	78	69	58	48	20	57		5	5	30	72	7	83
NITZSCHIA PUNGENS	PD	10^6Cells/L		0.00019							0.00014				
		%		13							5				
NITZSCHIA SERIATA	PD	10^6Cells/L						0.00012			0.00027			0.00046	
		%						7			10			9	
PHAEOCYSTIS POUCHETII	HP	10^6Cells/L	0.00019	0.00024	0.00010	0.00100	0.00100	0.00046	0.00600	0.00200	0.00200	0.00200	0.00020	0.00400	0.00040
		%	15	17	32	48	71	26	91	87	75	61	15	80	8
Group Definitions:	CD	Centric Diatom													
	DF	Dinoflagellate													
	MF	Microflagellate													
	O	Other													
	PD	Pennate Diatom													

Abundance of Prevalent Species (> 5% Total Count) in Surface Sample
Screened Phytoplankton, Survey W9603

Species	Group	Parameter	Station Cast												
			F23	F30	F31	F13	F24	F25	N04	N10	N16	F06	F27	F01	F02
PHAEOCYSTIS POUCHETII	HP	10^6Cells/L							0.00200	0.00200					
		%							78	88					
Group Definitions:	CD	Centric Diatom													
	DF	Dinoflagellate													
	MF	Microflagellate													
	O	Other													
	PD	Pennate Diatom													

Abundance of Prevalent Species (> 5% Total Count) in Surface Sample
Screened Phytoplankton, Survey W9604

Species	Group	Parameter	Station Cast												
			F23	F30	F31	F13	F24	F25	N04	N10	N16	F06	F27	F01	F02
CERATIUM FUSUS	DF	10^6Cells/L										0.00001			
		%										23			
CERATIUM LONGIPES	DF	10^6Cells/L	0.00000			0.00001	0.00002	0.00001				0.00001		0.00001	
		%	6			6	8	12				19		15	
CERATIUM SPP.	DF	10^6Cells/L				0.00001						0.00001		0.00000	
		%				6						17		6	
CERATIUM TRIPOS	DF	10^6Cells/L				0.00002									
		%				15									
DINOPHYSIS NORVEGICA	DF	10^6Cells/L										0.00000		0.00001	
		%										6		15	
GONYAULAX SPP.	DF	10^6Cells/L	0.00004	0.00011	0.00010	0.00005		0.00000		0.00014					
		%	43	40	79	37		8		11					
PHAEOCYSTIS POUCHETII	HP	10^6Cells/L		0.00011			0.00015		0.00100	0.00100	0.00100		0.17900		0.00049
		%		40			58		90	78	81		99		93
PROTOPERIDINIUM DEPRESSUM	DF	10^6Cells/L						0.00000							
		%						6							
PROTOPERIDINIUM DIVERGENS	DF	10^6Cells/L												0.00000	
		%												10	
PROTOPERIDINIUM PYRIFORME	DF	10^6Cells/L												0.00000	
		%												6	
PROTOPERIDINIUM SP.#1 10-30W 10-40L	DF	10^6Cells/L	0.00002	0.00003	0.00002	0.00002	0.00002	0.00003						0.00001	
		%	21	10	16	19	7	58						24	
PROTOPERIDINIUM SP.#2 31-75W 41-80L	DF	10^6Cells/L	0.00001			0.00001	0.00002	0.00001				0.00000		0.00001	
		%	9			6	6	10				11		14	

Group Definitions:		
	CD	Centric Diatom
	DF	Dinoflagellate
	MF	Microflagellate
	O	Other
	PD	Pennate Diatom

Abundance of Prevalent Species (> 5% Total Count) in Surface Sample
Screened Phytoplankton, Survey W9605

Species	Group	Parameter	Station Cast												
			F23	F30	F31	F13	F24	F25	N04	N10	N16	F06	F27	F01	F02
CERATIUM LONGIPES	DF	10^6Cells/L							0.00001						
		%							30						
CERATIUM SPP.	DF	10^6Cells/L							0.00000						
		%							10						
DINOPHYSIS NORVEGICA	DF	10^6Cells/L							0.00000	0.00000					
		%							10	8					
GONYAULAX SPP.	DF	10^6Cells/L								0.00000					
		%								13					
NITZSCHIA SERIATA	PD	10^6Cells/L							0.00000						
		%							5						
PROTOPERIDINIUM DEPRESSUM	DF	10^6Cells/L							0.00001						
		%							14						
PROTOPERIDINIUM DIVERGENS	DF	10^6Cells/L								0.00000					
		%								8					
PROTOPERIDINIUM SP.#2 31-75W 41-80L	DF	10^6Cells/L							0.00001	0.00001					
		%							14	51					
Group Definitions:	CD	Centric Diatom													
	DF	Dinoflagellate													
	MF	Microflagellate													
	O	Other													
	PD	Pennate Diatom													

Abundance of Prevalent Species (> 5% Total Count) in Surface Sample
Screened Phytoplankton, Survey W9606

Species	Group	Parameter	Station Cast												
			F23	F30	F31	F13	F24	F25	N04	N10	N16	F06	F27	F01	F02
CERATIUM LONGIPES	DF	10^6Cells/L							0.00002	0.00004					
		%							24	14					
DINOPHYSIS NORVEGICA	DF	10^6Cells/L							0.00001	0.00004					
		%							13	13					
GONYAULAX SPP.	DF	10^6Cells/L							0.00003						
		%							35						
NITZSCHIA SERIATA	PD	10^6Cells/L								0.00009					
		%								30					
PROTOPERIDINIUM DEPRESSUM	DF	10^6Cells/L								0.00002					
		%								6					
PROTOPERIDINIUM PYRIFORME	DF	10^6Cells/L							0.00001	0.00002					
		%							7	5					
PROTOPERIDINIUM SP.#2 31-75W 41-80L	DF	10^6Cells/L							0.00001	0.00004					
		%							8	12					

Group Definitions:	CD	Centric Diatom
	DF	Dinoflagellate
	MF	Microflagellate
	O	Other
	PD	Pennate Diatom

Abundance of Prevalent Species (> 5% Total Count) in Surface Sample
Screened Phytoplankton, Survey W9607

Species	Group	Parameter	Station Cast												
			F23	F30	F31	F13	F24	F25	N04	N10	N16	F06	F27	F01	F02
CERATIUM FUSUS	DF	10^6Cells/L									0.00003	0.00002		0.00002	0.00001
		%									6	5		24	18
CERATIUM LONGIPES	DF	10^6Cells/L	0.00026	0.00016		0.00024	0.00028	0.00023	0.00033	0.00016	0.00043	0.00019	0.00013		0.00005
		%	19	12		82	20	17	72	23	82	65	76		56
CERATIUM TRIPOS	DF	10^6Cells/L												0.00002	
		%												19	
DINOPHYSIS NORVEGICA	DF	10^6Cells/L	0.00100	0.00100	0.00100	0.00003	0.00100	0.00100	0.00010	0.00049	0.00005	0.00005	0.00003	0.00005	0.00002
		%	75	79	89	11	71	76	21	68	10	17	16	51	18
DINOPHYSIS PUNCTATA	DF	10^6Cells/L		0.00007			0.00009								
		%		6			6								
POLYKRIKOS SP.	DF	10^6Cells/L										0.00003			
		%										9			

Group Definitions:	CD	Centric Diatom
	DF	Dinoflagellate
	MF	Microflagellate
	O	Other
	PD	Pennate Diatom

Abundance of Prevalent Species (> 5% Total Count) in Surface Sample
Screened Phytoplankton, Survey W9608

Species	Group	Parameter	Station Cast												
			F23	F30	F31	F13	F24	F25	N04	N10	N16	F06	F27	F01	F02
CERATIUM LONGIPES	DF	10^{6}Cells/L							0.00033	0.00008					
		%							72	66					
DINOPHYSIS NORVEGICA	DF	10^{6}Cells/L							0.00011	0.00003					
		%							23	26					
Group Definitions:	CD	Centric Diatom													
	DF	Dinoflagellate													
	MF	Microflagellate													
	O	Other													
	PD	Pennate Diatom													

Abundance of Prevalent Species (> 5% Total Count) in Surface Sample
Screened Phytoplankton, Survey W9609

Species	Group	Parameter	Station Cast												
			F23	F30	F31	F13	F24	F25	N04	N10	N16	F06	F27	F01	F02
CERATIUM FUSUS	DF	10^6Cells/L							0.00012						
		%							37						
CERATIUM LONGIPES	DF	10^6Cells/L							0.00013	0.00100					
		%							39	80					
CERATIUM TRIPOS	DF	10^6Cells/L							0.00002						
		%							7						
DINOPHYSIS NORVEGICA	DF	10^6Cells/L								0.00010					
		%								8					
PROTOPERIDINIUM SP.#1 10-30W 10-40L	DF	10^6Cells/L							0.00003						
		%							9						
Group Definitions:	CD	Centric Diatom													
	DF	Dinoflagellate													
	MF	Microflagellate													
	O	Other													
	PD	Pennate Diatom													

APPENDIX G-2

Abundance of Prevalent Species (> 5% Total Count) in Chlorophyll *a* Maximum Sample
Screened Phytoplankton, Survey W9601

Species	Group	Parameter	Station Cast												
			F23	F30	F31	F13	F24	F25	N04	N10	N16	F06	F27	F01	F02
CERATIUM FUSUS	DF	10^6Cells/L												0.00001	
		%												5	
CERATIUM TRIPOS	DF	10^6Cells/L	0.00007	0.00003	0.00002						0.00008			0.00004	
		%	6	8	6						11			29	
GONYAULAX SPP.	DF	10^6Cells/L					0.00003	0.00004	0.00023		0.00009				
		%					6	8	9		13				
GYMNODINIUM SP.#2 21-40UM W 21-50UM L	DF	10^6Cells/L			0.00002										
		%			6										
NITZSCHIA PUNGENS	PD	10^6Cells/L	0.00013	0.00003	0.00008		0.00022	0.00013	0.00024	0.00018	0.00006	0.00004		0.00007	0.00026
		%	10	7	27		37	26	9	14	9	18		51	18
NITZSCHIA SERIATA	PD	10^6Cells/L			0.00008	0.00010	0.00004			0.00007		0.00016			0.00100
		%			29	8	7			5		72			71
NITZSCHIA SP#2 LENGTH 30-70 MICRONS	PD	10^6Cells/L			0.00007										0.00010
		%			23										7
PHAEOCYSTIS POUCHETII	HP	10^6Cells/L	0.00100	0.00030		0.00100	0.00025	0.00030	0.00200	0.00100	0.00039		0.00100		
		%	78	77		78	41	58	78	75	55		92		

Group Definitions:		
	CD	Centric Diatom
	DF	Dinoflagellate
	MF	Microflagellate
	O	Other
	PD	Pennate Diatom

Abundance of Prevalent Species (> 5% Total Count) in Chlorophyll *a* Maximum Sample
Screened Phytoplankton, Survey W9602

Species	Group	Parameter	Station Cast												
			F23	F30	F31	F13	F24	F25	N04	N10	N16	F06	F27	F01	F02
GONYAULAX SPP.	DF	10^6Cells/L	0.00100	0.00100	0.00100	0.00033	0.00100	0.00100	0.00023		0.00017	0.00046	0.00011	0.00029	0.00100
		%	24	48	75	23	46	48	9		12	7	20	8	23
NITZSCHIA PUNGENS	PD	10^6Cells/L									0.00010				
		%									7				
NITZSCHIA SERIATA	PD	10^6Cells/L									0.00009	0.00046	0.00005		
		%									6	7	9		
PHAEOCYSTIS POUCHETII	HP	10^6Cells/L	0.00300	0.00100	0.00025	0.00100	0.00100	0.00100	0.00200	0.02700	0.00100	0.00600	0.00034	0.00300	0.00300
		%	71	48	18	68	46	48	77	99	69	85	61	84	69
Group Definitions:	CD	Centric Diatom													
	DF	Dinoflagellate													
	MF	Microflagellate													
	O	Other													
	PD	Pennate Diatom													

Abundance of Prevalent Species (> 5% Total Count) in Chlorophyll *a* Maximum Sample
Screened Phytoplankton, Survey W9603

Species	Group	Parameter	Station Cast												
			F23	F30	F31	F13	F24	F25	N04	N10	N16	F06	F27	F01	F02
GONYAULAX SPP.	DF	10^6Cells/L							0.00015						
		%							6						
PHAEOCYSTIS POUCHETII	HP	10^6Cells/L							0.00200	0.00100					
		%							81	93					
Group Definitions:	CD	Centric Diatom													
	DF	Dinoflagellate													
	MF	Microflagellate													
	O	Other													
	PD	Pennate Diatom													

Abundance of Prevalent Species (> 5% Total Count) in Chlorophyll *a* Maximum Sample
Screened Phytoplankton, Survey W9604

Species	Group	Parameter	Station Cast												
			F23	F30	F31	F13	F24	F25	N04	N10	N16	F06	F27	F01	F02
CERATIUM FUSUS	DF	10^6Cells/L												0.00000	
		%												7	
CERATIUM LONGIPES	DF	10^6Cells/L	0.00001				0.00003		0.00002		0.00004	0.00001		0.00001	
		%	6				20		11		13	15		25	
CERATIUM SPP.	DF	10^6Cells/L					0.00001		0.00002					0.00000	
		%					10		9					7	
CERATIUM TRIPOS	DF	10^6Cells/L										0.00001			
		%										8			
DINOPHYSIS NORVEGICA	DF	10^6Cells/L					0.00001		0.00001		0.00002			0.00000	
		%					9		8		8			11	
GONYAULAX SPP.	DF	10^6Cells/L		0.00018	0.00019			0.00008							
		%		81	77			49							
PHAEOCYSTIS POUCHETII	HP	10^6Cells/L			0.00003	0.00100		0.00005	0.00005		0.00013	0.00004	0.01700		0.00100
		%			13	84		29	31		42	50	99		97
PROTOPERIDINIUM DIVERGENS	DF	10^6Cells/L												0.00000	
		%												7	
PROTOPERIDINIUM PENTAGONUM	DF	10^6Cells/L					0.00001								
		%					6								
PROTOPERIDINIUM SP.#1 10-30W 10-40L	DF	10^6Cells/L	0.00008	0.00001			0.00003	0.00001	0.00003		0.00004	0.00001		0.00000	
		%	75	6			23	8	17		13	7		14	
PROTOPERIDINIUM SP.#2 31-75W 41-80L	DF	10^6Cells/L			0.00001		0.00002		0.00002		0.00002	0.00000		0.00001	
		%			5		14		11		6	5		22	
Group Definitions:	CD	Centric Diatom													
	DF	Dinoflagellate													
	MF	Microflagellate													
	O	Other													
	PD	Pennate Diatom													

Abundance of Prevalent Species (> 5% Total Count) in Chlorophyll a Maximum Sample
Screened Phytoplankton, Survey W9605

Species	Group	Parameter	Station Cast												
			F23	F30	F31	F13	F24	F25	N04	N10	N16	F06	F27	F01	F02
CERATIUM FUSUS	DF	10^6Cells/L							0.00000						
		%							6						
CERATIUM LONGIPES	DF	10^6Cells/L							0.00000	0.00000					
		%							15	11					
CERATIUM SPP.	DF	10^6Cells/L							0.00000						
		%							7						
DINOPHYSIS NORVEGICA	DF	10^6Cells/L							0.00000	0.00000					
		%							15	11					
GONYAULAX SPP.	DF	10^6Cells/L								0.00001					
		%								17					
GYRODINIUM SP#2 21-40UM W 21-50UM L	DF	10^6Cells/L								0.00000					
		%								6					
PROTOPERIDINIUM DEPRESSUM	DF	10^6Cells/L							0.00000						
		%							8						
PROTOPERIDINIUM DIVERGENS	DF	10^6Cells/L							0.00000						
		%							7						
PROTOPERIDINIUM PALLIDUM	DF	10^6Cells/L							0.00000						
		%							11						
PROTOPERIDINIUM SP.#2 31-75W 41-80L	DF	10^6Cells/L							0.00001	0.00002					
		%							23	41					

Group Definitions:		
	CD	Centric Diatom
	DF	Dinoflagellate
	MF	Microflagellate
	O	Other
	PD	Pennate Diatom

Abundance of Prevalent Species (> 5% Total Count) in Chlorophyll *a* Maximum Sample
Screened Phytoplankton, Survey W9606

Species	Group	Parameter	Station Cast												
			F23	F30	F31	F13	F24	F25	N04	N10	N16	F06	F27	F01	F02
CERATIUM LONGIPES	DF	10^6Cells/L								0.00005					
		%								15					
DINOPHYSIS NORVEGICA	DF	10^6Cells/L							0.00005	0.00009					
		%							23	26					
GYRODINIUM SP#2 21-40UM W 21-50UM L	DF	10^6Cells/L							0.00001						
		%							5						
NITZSCHIA SERIATA	PD	10^6Cells/L							0.00005	0.00011					
		%							20	30					
PROTOPERIDINIUM DEPRESSUM	DF	10^6Cells/L							0.00004						
		%							19						
PROTOPERIDINIUM DIVERGENS	DF	10^6Cells/L							0.00002						
		%							8						
PROTOPERIDINIUM SP.#2 31-75W 41-80L	DF	10^6Cells/L							0.00003	0.00004					
		%							14	11					
Group Definitions:	CD	Centric Diatom													
	DF	Dinoflagellate													
	MF	Microflagellate													
	O	Other													
	PD	Pennate Diatom													

Abundance of Prevalent Species (> 5% Total Count) in Chlorophyll *a* Maximum Sample
Screened Phytoplankton, Survey W9607

Species	Group	Parameter	Station Cast												
			F23	F30	F31	F13	F24	F25	N04	N10	N16	F06	F27	F01	F02
CERATIUM LONGIPES	DF	10^{6}Cells/L	0.00010	0.00011	0.00010	0.00027	0.00049	0.00016	0.00007	0.00009	0.00100	0.00100	0.00003	0.00018	0.00100
		%	27	9	8	21	7	13	29	23	33	48	16	30	49
DINOPHYSIS NORVEGICA	DF	10^{6}Cells/L	0.00024	0.00100	0.00100	0.00100	0.00600	0.00100	0.00015	0.00030	0.00200	0.00100	0.00002	0.00037	0.00100
		%	66	86	85	76	90	81	63	72	66	48	15	61	49
DINOPHYSIS PUNCTATA	DF	10^{6}Cells/L			0.00006										
		%			5										
POLYKRIKOS SP.	DF	10^{6}Cells/L											0.00001		
		%											8		
PROROCENTRUM MAXIMUM	DF	10^{6}Cells/L											0.00001		
		%											7		
PROTOPERIDINIUM DEPRESSUM	DF	10^{6}Cells/L											0.00004		
		%											26		
PROTOPERIDINIUM PALLIDUM	DF	10^{6}Cells/L											0.00001		
		%											5		
PROTOPERIDINIUM PYRIFORME	DF	10^{6}Cells/L											0.00001		
		%											6		
PROTOPERIDINIUM SP.#1 10-30W 10-40L	DF	10^{6}Cells/L											0.00001		
		%											8		
PROTOPERIDINIUM SP.#2 31-75W 41-80L	DF	10^{6}Cells/L											0.00001		
		%											7		

Group Definitions:	CD	Centric Diatom
	DF	Dinoflagellate
	MF	Microflagellate
	O	Other
	PD	Pennate Diatom

Abundance of Prevalent Species (> 5% Total Count) in Chlorophyll *a* Maximum Sample
Screened Phytoplankton, Survey W9608

Species	Group	Parameter	Station Cast												
			F23	F30	F31	F13	F24	F25	N04	N10	N16	F06	F27	F01	F02
CERATIUM LONGIPES	DF	10^6Cells/L							0.00100	0.00010					
		%							91	34					
DINOPHYSIS NORVEGICA	DF	10^6Cells/L							0.00006	0.00019					
		%							5	64					
Group Definitions:	CD	Centric Diatom													
	DF	Dinoflagellate													
	MF	Microflagellate													
	O	Other													
	PD	Pennate Diatom													

Abundance of Prevalent Species (> 5% Total Count) in Chlorophyll *a* Maximum Sample
Screened Phytoplankton, Survey W9609

Species	Group	Parameter	Station Cast												
			F23	F30	F31	F13	F24	F25	N04	N10	N16	F06	F27	F01	F02
CERATIUM LONGIPES	DF	10^6Cells/L							0.00021	0.00033					
		%							74	71					
DINOPHYSIS NORVEGICA	DF	10^6Cells/L								0.00007					
		%								15					
PROTOPERIDINIUM SP.#1 10-30W 10-40L	DF	10^6Cells/L								0.00002					
		%								5					
PROTOPERIDINIUM SP.#2 31-75W 41-80L	DF	10^6Cells/L							0.00002						
		%							7						
Group Definitions:	CD	Centric Diatom													
	DF	Dinoflagellate													
	MF	Microflagellate													
	O	Other													
	PD	Pennate Diatom													

APPENDIX H

Abundance of Prevalent Species (> 5% Total Count)
Zooplankton, Survey W9601

Species	Life Stage	Group	Parameter	Station Cast													
				F23	F30	F31	F13	F24	F25	N04	N10	N16	N18	F27	F06	F01	F02
CENTROPAGES TYPICUS	C	C	ind/m^3						194								
			%						6								
CIRRIPEDE SPP.	N	B	ind/m^3		1646	310			185								
			%		37	10			5								
COPEPOD SPP.	C	C	ind/m^3								331					567	1363
			%								6					10	6
COPEPOD SPP.	N	C	ind/m^3	1091	1867	1586	5224	1940	1977	10831	3098	6020		3573	5384	2686	12878
			%	59	42	53	65	63	58	62	61	59		55	71	47	60
MICROSETELLA NORVEGICA		C	ind/m^3													297	
			%													5	
OITHONA SIMILIS CLAUS	C	C	ind/m^3	183		379	1873	478	503	4672	780	2474		1761	1265	1316	2021
			%	10		13	23	15	15	27	15	24		27	17	23	9
OITHONA SIMILIS CLAUS	F	C	ind/m^3													358	
			%													6	
UNIDENTIFIED LARVAE	L	OZ	ind/m^3	110													
			%	6													

Life Stage Definitions:

C	Copepodite stages I-V
F	Copepoda adult female
L	Larva
M	Copepoda adult male
N	Nauplii
T	Trochophore (larval stage of polychaete)
Y	Cypris Larva of Barnacle

Group Definitions:

B	Barnacle
C	Copepod
OZ	Other Zooplankton

Abundance of Prevalent Species (> 5% Total Count)
Zooplankton, Survey W9602

Species	Life Stage	Group	Parameter	Station Cast													
				F23	F30	F31	F13	F24	F25	N04	N10	N16	N18	F27	F06	F01	F02
CALANUS FINMARCHICUS	C	C	ind/m^3					793			538			792			
			%					6			5			5			
CIRRIPEDE SPP.	N	B	ind/m^3	978	1138	4205	3337	2601	2721		1326						
			%	17	18	45	35	19	26		13						
COPEPOD SPP.	N	C	ind/m^3	2098	1471	2070	2480	4947	3153	17519	4230	4518		10069	16743	10080	14220
			%	37	24	22	26	37	30	56	41	50		66	62	54	73
GASTROPODA;MOLLUSCA	L	OZ	ind/m^3							2364		721					
			%							8		8					
OIKOPLEURA DIOICA		OZ	ind/m^3							3547		773			3164	1163	
			%							11		9			12	6	
OITHONA SIMILIS CLAUS	C	C	ind/m^3	302		485	1043	1839	1515	6019	2294	2147		1810	3559	2154	2299
			%	5		5	11	14	14	19	22	24		12	13	11	12
POLYCHAETE SPP.	L	OZ	ind/m^3	1084	2040	1035	603	983	1515								
			%	19	33	11	6	7	14								
POLYCHAETE SPP.	T	OZ	ind/m^3	284	333												
			%	5	5												
PSEUDOCALANUS NEWMANI	C	C	ind/m^3	320	353												
			%	6	6												

Life Stage Definitions:

C	Copepodite stages I-V
F	Copepoda adult female
L	Larva
M	Copepoda adult male
N	Nauplii
T	Trochophore (larval stage of polychaete)
Y	Cypris Larva of Barnacle

Group Definitions:

B	Barnacle
C	Copepod
OZ	Other Zooplankton

Abundance of Prevalent Species (> 5% Total Count)
Zooplankton, Survey W9603

Species	Life Stage	Group	Parameter	Station Cast													
				F23	F30	F31	F13	F24	F25	N04	N10	N16	N18	F27	F06	F01	F02
BIVALVIA SPP.	L	OZ	ind/m^3							1626							
			%							6							
CALANUS FINMARCHICUS	C	C	ind/m^3							1431	864						
			%							5	5						
CIRRIPEDE SPP.	N	B	ind/m^3								3124						
			%								18						
COPEPOD SPP.	N	C	ind/m^3							12878	8109						
			%							48	47						
GASTROPODA;MOLLUSCA	L	OZ	ind/m^3							1366							
			%							5							
OITHONA SIMILIS CLAUS	C	C	ind/m^3							4228	1662						
			%							16	10						

Life Stage Definitions:

C	Copepodite stages I-V
F	Copepoda adult female
L	Larva
M	Copepoda adult male
N	Nauplii
T	Trochophore (larval stage of polychaete)
Y	Cypris Larva of Barnacle

Group Definitions:

B	Barnacle
C	Copepod
OZ	Other Zooplankton

Abundance of Prevalent Species (> 5% Total Count)
Zooplankton, Survey W9604

Species	Life Stage	Group	Parameter	Station Cast													
				F23	F30	F31	F13	F24	F25	N04	N10	N16	N18	F27	F06	F01	F02
BIVALVIA SPP.	L	OZ	ind/m^3													1437	
			%													6	
CALANUS FINMARCHICUS	C	C	ind/m^3					1723	351	8483	7300	6826		14785	3263	2198	
			%					17	7	23	17	29		28	11	9	
CIRRIPEDE SPP.	N	B	ind/m^3		868		973				2755						
			%		6		7				6						
COPEPOD SPP.	N	C	ind/m^3	1899	4863	2090	8002	4031	2078	15661	17905	8363		17394	13622	10566	
			%	38	36	42	57	40	43	43	40	35		33	46	44	
ECHINODERM PLUTEI		OZ	ind/m^3											3653			
			%											7			
GASTROPODA;MOLLUSCA		OZ	ind/m^3							2719	2341						
			%							7	5						
HARPACTICOIDA SPP.		C	ind/m^3		868	744			594								
			%		6	15			12								
OIKOPLEURA DIOICA		OZ	ind/m^3					618		2610		3321		9740	2039		
			%					6		7		14		18	7		
OITHONA SIMILIS CLAUS	C	C	ind/m^3	756			919	1008	351	3861	3581	2029		2783	4813	4480	
			%	15			7	10	7	11	8	9		5	16	19	
POLYCHAETE SPP.	L	OZ	ind/m^3	465	3473	1009	919										
			%	9	26	20	7										
PSEUDOCALANUS NEWMANI	C	C	ind/m^3				1135	910	270.							1268	
			%				8	9	6							5	

Life Stage Definitions:

C	Copepodite stages I-V
F	Copepoda adult female
L	Larva
M	Copepoda adult male
N	Nauplii
T	Trochophore (larval stage of polychaete)
Y	Cypris Larva of Barnacle

Group Definitions:

B	Barnacle
C	Copepod
OZ	Other Zooplankton

Abundance of Prevalent Species (> 5% Total Count)
Zooplankton, Survey W9606

Species	Life Stage	Group	Parameter	Station Cast													
				F23	F30	F31	F13	F24	F25	N04	N10	N16	N18	F27	F06	F01	F02
BIVALVIA SPP.	L	OZ	ind/m^3							1531							
			%							6							
COPEPOD SPP.	N	C	ind/m^3							9698	4135						
			%							35	23						
GASTROPODA;MOLLUSCA		OZ	ind/m^3							2297	1393						
			%							8	8						
OIKOPLEURA DIOICA		OZ	ind/m^3							2297							
			%							8							
OITHONA SIMILIS CLAUS	C	C	ind/m^3							4594	2612						
			%							17	15						
PSEUDOCALANUS NEWMANI	C	C	ind/m^3							2042	2916						
			%							7	17						

Life Stage Definitions:

C	Copepodite stages I-V
F	Copepoda adult female
L	Larva
M	Copepoda adult male
N	Nauplii
T	Trochophore (larval stage of polychaete)
Y	Cypris Larva of Barnacle

Group Definitions:

B	Barnacle
C	Copepod
OZ	Other Zooplankton

Abundance of Prevalent Species (> 5% Total Count)
Zooplankton, Survey W9607

Species	Life Stage	Group	Parameter	Station Cast													
				F23	F30	F31	F13	F24	F25	N04	N10	N16	N18	F27	F06	F01	F02
BIVALVIA SPP.	L	OZ	ind/m^3				65996	16818	4406	49021	2192	30849			3380		2766
			%				56	21	27	26	6	29			9		7
CALANUS FINMARCHICUS	C	C	ind/m^3											4625			
			%											8			
COPEPOD SPP.	N	C	ind/m^3		25394	8286	30387	27049	4282	77345	14405	49358		32377	17447	15378	20359
			%		56	43	26	33	27	40	41	46		54	46	41	54
EVADNE SPP.		OZ	ind/m^3						931		1983						
			%						6		6						
OITHONA SIMILIS CLAUS	C	C	ind/m^3		3555	3487	9971	14015	2700	25328	5219	12596		14881	9226	9763	5643
			%		8	18	8	17	17	13	15	12		25	24	26	15
OITHONA SIMILIS CLAUS	F	C	ind/m^3			1272										2937	
			%			7										8	
POLYCHAETE SPP.	L	OZ	ind/m^3		4165												
			%		9												
PSEUDOCALANUS NEWMANI	C	C	ind/m^3			1190		5746	900	13617	2296				2740	2246	
			%			6		7	6	7	7				7	6	

Life Stage Definitions:

C	Copepodite stages I-V
F	Copepoda adult female
L	Larva
M	Copepoda adult male
N	Nauplii
T	Trochophore (larval stage of polychaete)
Y	Cypris Larva of Barnacle

Group Definitions:

B	Barnacle
C	Copepod
OZ	Other Zooplankton

Abundance of Prevalent Species (> 5% Total Count)
Zooplankton, Survey W9608

Species	Life Stage	Group	Parameter	Station Cast													
				F23	F30	F31	F13	F24	F25	N04	N10	N16	N18	F27	F06	F01	F02
ACARTIA HUDSONICA	C	C	ind/m^3								1157						
			%								5						
CALANUS FINMARCHICUS	C	C	ind/m^3							3971							
			%							6							
COPEPOD SPP.	N	C	ind/m^3							30772	9561						
			%							45	43						
OITHONA SIMILIS CLAUS	C	C	ind/m^3							17537	3315						
			%							26	15						
OITHONA SIMILIS CLAUS	F	C	ind/m^3							3640							
			%							5							
PSEUDOCALANUS NEWMANI	C	C	ind/m^3							6452	1465						
			%							10	7						

Life Stage Definitions:	C	Copepodite stages I-V	Group Definitions:	B	Barnacle
	F	Copepoda adult female		C	Copepod
	L	Larva		OZ	Other Zooplankton
	M	Copepoda adult male			
	N	Nauplii			
	T	Trochophore (larval stage of polychaete)			
	Y	Cypris Larva of Barnacle			

Abundance of Prevalent Species (> 5% Total Count)
Zooplankton, Survey W9609

Species	Life Stage	Group	Parameter	Station Cast													
				F23	F30	F31	F13	F24	F25	N04	N10	N16	N18	F27	F06	F01	F02
BIVALVIA SPP.	L	OZ	ind/m^3								12945						
			%								26						
COPEPOD SPP.	N	C	ind/m^3							17097	27785						
			%							41	56						
OITHONA SIMILIS CLAUS	C	C	ind/m^3							13429	2842						
			%							32	6						
PSEUDOCALANUS NEWMANI	C	C	ind/m^3							2804							
			%							7							

Life Stage Definitions:

C	Copepodite stages I-V
F	Copepoda adult female
L	Larva
M	Copepoda adult male
N	Nauplii
T	Trochophore (larval stage of polychaete)
Y	Cypris Larva of Barnacle

Group Definitions:

B	Barnacle
C	Copepod
OZ	Other Zooplankton

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