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THE PHYSICAL OCEANOGRAPHY OFF THE CENTRAL CALIFORNIA COAST DURING MAY-JUNE 1995: A SUMMARY OF CTD DATA FROM PELAGIC JUVENILE ROCKFISH SURVEYS

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U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Southwest Fisheries Science Center

NOAA Technical Memorandum NMFS

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ABSTRACT

Hydrographic conditions during three periods of approximately ten days each from mid-May through mid-June 1995 in the coastal ocean bounded by Cypress Pt. (36°35'N) and Pt. Reyes, California (38°10'N), and from the coast to about 75 km offshore, are summarized in a series of horizontal maps and vertical sections. A total of 238 standard conductivity-temperature-depth (CTD) casts were obtained during the NOAA R/V *David Starr Jordan* cruise DSJ9506 over the course of three consecutive sweeps of the region. Data products contained in this report include (1) a master list of CTD stations during the cruise; (2) surface meteorological time series from the region's four National Data Buoy Center (NDBC) meteorological buoys; (3) horizontal maps of sea surface temperatures from AVHRR (Channel 4) satellite images; (4) acoustic Doppler current profiler (ADCP) data; (5) horizontal maps of temperature, salinity, and density (sigma-theta [σ_θ]) at depths of 2 m, 10 m, 30 m, 100 m, 200 m, 300 m, and 500 m; (6) temperature, salinity and σ_θ along four cross-shelf vertical transects; (7) horizontal maps of chlorophyll a at 10 m and integrated from the surface to 150 m; and (8) dynamic height topography (0/500 m and 200/500 m) in the survey region.

INTRODUCTION

The current regime off central California is hydrodynamically complex, driven by both geostophic and wind driven forces. The California Current provides the backdrop for large-scale, seasonal circulation patterns (Hickey 1979), while coastal upwelling occurs regionally for most of the year, especially from April to September (Huyer 1983). On the mesoscale (10-100 km), irregularities in the coastline interact with the wind stress field (Kelly 1985), resulting in turbulent jets, eddies and upwelling filaments, all of which are common features along the central California coast (Mooers and Robinson 1984; Flament et al. 1985; Njoku et al. 1985; Rosenfeld et al. 1994). Moreover, wind-driven fluctuations in coastal flow (Chelton et al. 1988) and freshwater discharge from San Francisco Bay (Applied Environmental Science Division [1]) add further complexity to the circulation regime.

Since 1983, the National Marine Fisheries (NMFS) Southwest Fisheries Science Center's (SWFSC) Tiburon Laboratory has attempted to develop a recruitment index for rockfish within the hydrographic region off central California. Data obtained during annual juvenile rockfish surveys aboard the National Oceanographic Atmospheric Administration (NOAA) research vessel (R/V) *David Starr Jordan* (DSJ) have provided information regarding distributional and abundance patterns of young-of-the-year pelagic juveniles in the area between Monterey Bay and Pt. Reyes (latitude 36°30'-38°10'N) (Wyllie Echeverria et al. 1990). Results of this research show a complex pattern in the spatial distribution of pre-recruits of a variety of commercially significant species (e.g., widow rockfish, *S. entomelas;* chilipepper, *S. goodei;* yellowtail rockfish, *S. flavidus;* bocaccio, *S. paucispinis;* and shortbelly rockfish, *S. jordani*). Moreover, extreme interannual fluctuations in abundance have occurred, with combined stratified mean catches per haul ranging from 0.1-78.6 juvenile rockfish/tow (Eldridge 1994 [2]).

Realizing that a basic description of the physical environment is necessary to better understand the distribution and abundance of young-of-the-year rockfish, collection of conductivity-temperature-depth (CTD) data was initiated in 1987 as part of the NMFS SWFSC Tiburon Laboratory's annual juvenile rockfish surveys. The staff of the NMFS SWFSC Pacific Fisheries Environmental Group (PFEG) subsequently developed an interest in analyzing the CTD data and were enlisted in this recruitment fisheries oceanography study. Ultimately, it is our goal to determine and forecast the manner in which rockfish year-class strength is affected by variations in the physical environment.

This report summarizes results obtained from the CTD data collected in 1995. Due to the large quantity of data analyzed and the extensive array of results presented herein, we make little attempt to provide detailed interpretations of our findings. Reports covering the juvenile rockfish surveys of 1988 (DSJ8804 and DSJ8806), 1989 (DSJ8904), 1991 (DSJ9102 and DSJ9105), 1992 (DSJ9203 and DSJ9206), 1993 (DSJ9304 and DSJ9307), and 1994 (DSJ9403 and DSJ9406) have been published (Schwing et al. 1990; Johnson et al. 1992; Sakuma et al. 1994a; Sakuma et al. 1994b; Sakuma et al. 1995a; Sakuma et al. 1995b). A companion volume (Schwing

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[1]Applied Environmental Science Division. Final Report, California Seabird Ecology Study. Volume II, Satellite Data Analysis. Science Applications International Corporation, Monterey, California.

[2]Eldridge, M. B. (editor). 1994. Progress in rockfish recruitment studies. SWFSC Admin. Rep. T-94-01, 55 p., unpublished report.

and Ralston 1990[3]) contains individual traces of temperature, salinity, and sigma-t (σ_t, a representation of water density) plotted against depth for each CTD cast conducted in 1989. Further scientific analysis of these data, and their linkages to fisheries recruitment, will be compiled in future peer-reviewed scientific publications (e.g., Schwing et al. 1991).

MATERIALS AND METHODS

Meteorological Data

Meteorological data were obtained for selected sites in the juvenile rockfish survey region. These sites include the region's four National Data Buoy Center (NDBC) moored buoys: 46013 (Bodega Bay; 38.2°N, 123.3°W), 46026 (Farallones; 37.8°N, 122.7°W), 46012 (Half Moon Bay; 37.4°N, 122.7°W) and 46042 (Monterey Bay; 36.8°N, 122.4°W) (Appendix 2). Daily averages of several surface meteorological parameters, including air and sea temperature, east and north wind components, and barometric pressure, were calculated for the time period that includes the 1995 juvenile rockfish survey. Plots of several of these products are provided in this report to aid in the interpretation of results and to suggest possible atmospheric-oceanic interactions (Appendix 3).

Sea Surface Temperature Data from AVHRR Satellite Imagery

AVHRR (Advanced Very High Resolution Radiometer) satellite images were transmitted to the NOAA R/V DSJ 12-48 hours after a NOAA-11 polar orbiting satellite pass, from the NOAA CoastWatch Group in La Jolla, CA. The NOAA CoastWatch Group first received the images as geographically corrected HRPT image files from Ocean Imaging Co. of San Diego. The image files are checked for excessive cloud/fog cover and if clear enough are then calibrated into radiances from the satellite sensor's channels. These radiances are then converted into sea surface temperatures. A cloud masking routine is run on each image file and then the images are partitioned into different geographic regions along the West Coast. This yields a high resolution (1.1 km) IMGMAP image file of approximately 270 kilobytes which can be read and analyzed by the PC based CCOAST or WIM software. CCOAST is a color satellite image display program developed by NOAA and NASA which operates in the MS-DOS environment. WIM (Windows Image Manager) is a Windows application that displays color and grayscale satellite images and was developed by Mati Kahru of Scripps Institution of Oceanography. The IMGMAP image files were compressed and downloaded to the Ship's PC by using a cellular telephone, a cellular telephone modem interface, and a commercial modem communications software. Once an image is received, the CCOAST or WIM software was used to decompress, display and manipulate the satellite image in order to discern sea surface temperature gradients and areas of upwelling and mesoscale eddy activity. All images which were clear or relatively clear of clouds/fog were saved on a PC computer and stored at the NMFS SWFSC, Tiburon Laboratory and at the NMFS SWFSC PFEG as part of the Oceanographic database system.

ADCP Data Processing

Acoustic Doppler current profiler (ADCP) data were collected with an RD Instruments 150 kHz, hull-mounted transducer on the NOAA R/V DSJ. The data acquisition software (DAS) was provided by the manufacturer and data were logged using a 386-based PC. These data were processed at the NMFS SWFSC PFEG with a series of post-processing programs described in Jessen (1992) and Jessen et al. (1992).

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[3]Schwing, F. B., and S. Ralston. 1990. Individual cast data for CTD stations conducted during cruise DSJ8904 (May 14-June 13, 1989). SWFSC Admin. Rep. PFEG-91-01, 7 p. + figs., unpublished report.

The data were collected in 64 depth bins, each 8 m deep, and averaged over 180 seconds into one ensemble. The onboard Magnavox Global Positioning System provided navigation information to the acquisition software. Information from the Sperry Gyrocompass allowed transformation of x-y coordinates to latitude and longitude coordinates. The first 4 m of the data were blanked as the depth of the transducer heads was 3 m, resulting in the 7-15 m bin providing the shallowest, usable data. The bottom tracking feature was employed only during the routine calibration-run segment of data collection. In general, bottom tracking is used in water shallower than 400 m, but for the purposes of this series of cruises, and for clearer post-processing, the bottom-tracking option was left off during the bulk of data collection.

A calibration run was conducted at the beginning of the cruise for the purpose of collecting data that would later quantify the rotation and sensitivity errors in the ADCP data. The rotation error (α) has two components: alignment error between the ship's centerline and the mounted instrument's orientation, as well as the gyrocompass error. The sensitivity errors (β), caused by errors in the beams' geometry, are generally small but important to quantify. The computation of these errors was guided by the methods prescribed in Joyce (1989). The calibration coefficients for this cruise were: $\alpha = 1.377$ and $\beta = 1.000$. The raw Doppler data were rotated by α and multiplied by $1+\beta$ prior to post-processing.

Initial processing required correction of navigation data followed by computation of ship's velocity from these data. Geographic positions as recorded by the DAS were checked for obvious "bad" points and, if necessary, were corrected by interpolation. From these, clean navigation data were generated for the ***u*** (eastward) and ***v*** (northward) components of ship velocity.

Subsequent processing involved determining the depth (bin number) to which data remained reliable for each three-minute ensemble. This depth of reliable data was a function of the bottom depth or the Percent Good Return (PGR). PGR is the percentage of data returns (pings) for a particular ensemble with good solutions, based on a signal-to-noise threshold or error velocity. PGR values below 50% were defined as poor data, and all data in the ensemble deeper than that were eliminated from further analysis.

The bottom depth provided another limit for the deepest bin of good data when the ship passed over the continental shelf. Bottom depth is evident when the bottom tracking feature is on or if there is a sharp subsurface increase in the AGC signal. The deepest bin as determined by PGR or bottom depth was defined as the bin to which data remained reliable for a particular ensemble.

Calculation of a reference layer velocity was the next step. A reference layer width of three bins (24 m) was chosen for these data. Choosing a reference layer depth was somewhat arbitrary, yet followed a general criteria of choosing one deep enough that the velocity within the referenced layer was nearly constant, yet shallow enough that all or nearly all the ensembles being processed had good data down to the depth of their reference layer. The bins used to define a reference layer varied between data sets.

An absolute reference layer velocity was calculated by subtracting the ship's velocity components, determined from the navigation data, from the components of the raw reference layer velocity. A low-pass filter with a cutoff period of 30 minutes was then applied to this absolute reference layer velocity to smooth the data. These smoothed absolute reference layer velocities were used for adjustment of the raw velocity profiles of each three-minute ensemble, resulting in the final absolute water velocity profiles. As a final check, bad data were determined from a visual examination of each profile and removed.

Juvenile Rockfish Survey Design

Annual cruises aboard the NOAA R/V DSJ began in 1983 and have been conducted during late spring (April-June), a time when most pelagic-stage juvenile rockfishes are identifiable as to species, but prior to their settling to nearshore and benthic habitats. Throughout this time, a standard haul consisted of a 15-minute nighttime tow of a large midwater trawl set to a depth of 30 m. Additional tows were made at other depths (i.e., 10 and 100 m) as allowed by constraints imposed by time and bottom bathymetry.

In 1986, the sampling design was altered to permit three consecutive "sweeps" through a study area bounded by Cypress Pt. (36°35'N) and Pt. Reyes (38°10'N), California, and from the coast to about 75 km offshore. Trawls are now conducted at five or six stations along a transect each night; each sweep is composed of seven transects. Starting in 1987, a CTD cast was conducted at each trawl station occupied. In addition, daytime activities were restructured to permit sampling of a new grid of standard CTD stations (Appendix 2). Standard CTD stations were specific locations where CTD casts were scheduled and repeated for each sweep of each cruise. CTD cast locations that were only specific to a particular sweep during a cruise were considered as additional CTD stations. Although each sweep typically lasts approximately ten days (seven nights of scheduled work plus 3 nights of additional discretionary sampling), adverse weather conditions can extend the completion date of a sweep. Logistical constraints can also restrict the number of casts completed. Discretionary sampling typically was focused on specific bathymetric features, such as Cordell Bank or Pioneer Canyon, or devoted to the intense study of oceanic features or processes that may be key to successful recruitment. CTD casts conducted during discretionary sampling were considered additional stations and not included in the grid of standard CTD stations.

Collection of CTD Data at Sea

All CTD data from the 1995 rockfish survey presented in this report were collected with two Sea-Bird Electronics, Inc., SEACAT-SBE-19 profilers[4]. These particular units are rated to a depth of 600 m and contained 256K of memory. One CTD was also equipped with a WETStar model WS3-030 miniature fluorometer. Four data channels were used to record pressure (0.05% of full scale range [50-5,000 psia]), temperature (0.01 °C from -5 to +35 °C), conductivity (0.001 S/m from 0 to 7 S/m), and fluorometer voltage at a baud rate of 9,600. Dual casts using both units yielded similar profile data for temperature and salinity. Both profilers have been recalibrated annually by Sea-Bird Electronics, Inc., prior to their use aboard ship.

During deployment, the vessel was brought to a dead stop and the profiler was attached to a hydrographic winch cable. The profiler was then switched on and suspended underwater at the surface for a period of two minutes to allow the conductivity, temperature, and fluorometer sensors to equilibrate. The rate of descent was 45 m/minute to a depth 10 m off the bottom if water depths were less than 500 m. Otherwise the profiler was lowered to a maximum depth of 520 m to insure collection of data at 500 m. Only data collected on the downcast were ultimately preserved for analysis. During the cast, certain collection information was recorded on data sheets, including (1) the date, (2) time, (3) a profiler-assigned cast number, (4) a cruise-specific consecutive index number, (5) the trawl station number (when appropriate), (6) latitude, (7)

[4]Sea-Bird Electronics, Inc., 1808 - 136th Place NE, Bellevue, Washington 98005 USA. Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

longitude, (8) bucket temperature (temperature [°C] of a bucket sample of surface water using a mercury thermometer, and (9) bottom depth in meters. In addition, salinity from 19 surface bucket samples was measured back at the NMFS SWFSC Tiburon Laboratory for comparison with the TS and CTD salinity readings at the surface. Position fixes were obtained using the Global Positioning System (GPS). All collection information recorded on the data sheets was eventually entered into a data file (####.LST where #### is the four-digit cruise number) on a personal computer.

Data collected from a short series of casts (usually no more than 5-7) were periodically uploaded to a personal computer on board the vessel. During this step, each cast was stored as a separate file and named using the convention C####&&&.HEX, where #### is the four-digit cruise number and &&& is the three-digit consecutive index number. After uploading, the profiler was reinitialized and the *.HEX files on the personal computer were backed up on diskette.

An additional source of hydrographic data was the vessel's Sea-Bird Electronics, Inc., thermosalinometer (TS) unit, which provided a continuous data stream of surface temperature and salinity. These data were stored on diskette and transferred to a personal computer on board the vessel for further processing, analysis, and comparison with and verification of CTD observations. Position fixes for the TS unit were based on GPS.

<u>Data Processing</u>

The first step in data processing was to convert the uploaded CTD *.HEX files to ASCII files. This was accomplished using programs supplied by Sea-Bird Electronics, Inc., in SEASOFT menu-driven release Version 4.201[5]. All *.HEX files were batch-processed through the SEASOFT modules DATCNV, FILTER, ALIGNCTD, LOOPEDIT, BINAVG, and DERIVE (refer to footnote 5 and past Technical Memorandums, e.g. Sakuma et al. 1995b, for more information) and output as ASCII files using SAS[6] macros. All data were averaged into two-meter depth bins and subsequently transferred to a SUN file server.

Each CTD ASCII file was manually edited to remove large outliers (i.e., data spikes) in salinity and/or density, which sometimes occurred near the surface and at the thermocline. Comparisons were made between CTD temperature and salinity from the two-meter depth bin, TS temperature and salinity, bucket temperature at each CTD station, and bucket salinity at 19 CTD stations using a simple regression to check for data outliers and any blatant calibration problems (Appendix 6).

Processed hydrographic data were summarized, by sweep, in a series of horizontal maps and vertical transects, and are presented in this report. Although additional CTD casts were completed during DSJ9506, only casts from the grid of standard CTD stations and only those casts which provided a relatively continuous sampling track within a specific sweep were included in the data summary for the horizontal maps (Appendix 7). This was done in an attempt to generate a relatively synoptic representation of each individual sweep and to spatially standardize hydrographic comparisons among sweeps. Vertical transects from the three sweeps of DSJ9506 were also spatially standardized (Appendix 8). However, the Farallones transect line was less synoptic than the Pt. Reyes, Pescadero, and Davenport lines, because casts were combined over a 2- to

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[5]CTD Data Acquisition software, SEASOFT Version 4.201, February 1994, Sea-Bird Electronics, Inc., 1808 - 136th Place NE, Bellevue, Washington 98005, USA. Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

[6]SAS Institutes Inc., SAS Circle Box 8000, Cary, North Carolina 27512. Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

3-day time period instead of the more usual 24-hour period. In addition, the Farallones transect line does not follow a straight course, which may lead to some distortion of the vertical transect contours nearshore. All contouring of CTD data for horizontal maps and vertical transects was done using SURFER FOR WINDOWS graphics software[7], which estimates values throughout a specified region based on the available data. Kriging was selected as the optimal interpolation method used for the algorithm grid (Cressie 1991).

The TS raw data were edited to provide a nearly continuous sampling track for each sweep of DSJ9506. However, there appeared to be a consistent offset between salinity recorded by the TS and salinity recorded by the CTD at 2-m depth for the entire cruise (Appendix 6). Because the CTD was calibrated annually by the manufacturer, and because problems occurred with the TS unit in the past during DSJ9203, DSJ9304, and DSJ9406, TS salinity values were considered less reliable and, when necessary, were adjusted using a regression comparison with the CTD. That is, $TS' = \alpha + \beta(TS)$, where TS' is the adjusted thermosalinometer value (either temperature or salinity), TS is the unadjusted value, and α and β are the intercept and slope parameters of the regression of 2-m CTD data (temperature or salinity) on the corresponding TS value. TS data were subsequently contoured using SURFER FOR WINDOWS[7].

The WETStar fluorometer that was used during the survey was new from the manufacturer and came with a calibration equation to convert the output fluorometer voltages to estimates of chlorophyll concentration. The actual calibration was based on measurements of the instrument's response to pure water (0.0372 volts) and a 1 mg/l coproporphyrin tetramethyl ester solution (3.06 volts). According documentation provided by the manufacturer, the latter solution is approximately equal to 20 µg/l of chlorophyll in a *Thalassiosira weissflogii* phytoplankton culture. Thus, the equation used to convert fluorometer voltages to estimates of chlorophyll concentration was:

$$C_{sample}\ [\mu g/l] = 6.6164 \cdot (V_{sample} - 0.0372),$$

where C_{sample} is the estimated concentration of chlorophyll in a particular sample and V_{sample} is the output voltage from the fluorometer. For each sweep the converted data were then summarized by contouring the chlorophyll concentration at 10 m and the integrated total chlorophyll from the surface to 150 m.

Dynamic height was calculated for stations occupied during DSJ9506 using a 500 db base. CTD casts conducted in areas with bottom depths less than 500 m were not included in this analysis. The dynamic height topography of the 0 db surface relative to the 500 db surface and the 200 db surface relative to the 500 db surface for the three sweeps of DSJ9506 were output from the DERIVE module of SEASOFT Version 4.201 and these data were gridded in SURFER FOR WINDOWS[7]. A 0.01 contour interval was chosen for the 0 db surface relative to the 500 db surface maps and a 0.005 contour interval for the 200 db surface relative to the 500 db surface (Appendix 10).

To date, no attempt has been made to calculate vertical sections of geostrophic velocity because the large number of shallow stations during the juvenile rockfish surveys necessitates the extrapolation of isopycnals into the shore, a procedure that is subject to great uncertainty. In addition, recent studies (Berryman 1989; Tisch 1990) suggest that geostrophic velocities calculated for stations spaced closer than the internal Rossby radius frequently feature alternating current bands of reversed flow, which are thought to be associated with inertial currents. The Rossby radius in the survey region is generally about 10-20 km, which is similar to the typical station spacing of the rockfish surveys. We are presently investigating the method that best

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[7]SURFER FOR WINDOWS, Golden Software, Inc., 809 14th Street, Golden, Colorado 80402. Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

determines geostrophic velocities from dynamic heights, based on closely spaced shallow water stations, before attempting to calculate the geostrophic velocity field during these surveys.

RESULTS

Data Products

Below are a few brief comments on each of the data products contained in this report in the order that they appear.

Appendix 1: Lists of CTD Stations Summarized from Cruise DSJ9506

The station list includes, from left to right, CTD cast number (only acceptable casts included), date, local military time, latitude and longitude (degrees, minutes), and station bottom depth. Cruise DSJ9506, Sweep 1 (May 17-May 26) includes 82 standard stations (casts 1-88), Sweep 2 (May 27-June 3) includes 78 standard stations (casts 97-177), and Sweep 3 (June 8-15) includes 78 standard stations (casts 214-296).

Appendix 2: CTD Stations and Bathymetric Maps of Survey Region with Locations of the NDBC Buoys

The locations of the CTD stations for DSJ9403 and the standard CTD stations for DSJ9506 along with the locations of the NDBC buoys, the place names, and the bottom bathymetry of the survey areas are shown.

Appendix 3: Meteorological Time Series

Meteorological time series are presented for only three of the four NDBC buoys as the Half Moon Bay buoy was not in operation during the first 180 days of 1995. The first figure in this section summarizes the daily average wind speed (m/s) and direction (relative to true north) at the three operating stations, in stick vector form, for the period January through June 1995. Vectors point in the direction toward which the wind was blowing; an arrow pointing toward the top of the page represents a northward-directed wind.

The following figures show scalar time series of sea surface temperature, or SST (°C); air temperature (°C); the north-south component of wind speed (m/s), a crude indicator of upwelling-favorable wind; and barometric pressure (millibars) at each meteorological station for the first 180 calendar days of 1995. A positive wind value denotes a northward-directed wind component. The survey periods for DSJ9506 (divided by sweep) are shaded in all time series plots.

Appendix 4: AVHRR Satellite Images of Sea Surface Temperatures

Sea surface temperatures along the central and northern California coast from radiances sensed by channel 4 of the NOAA-11 polar orbiting satellite are presented for each of the three sweeps during DSJ9506. Each image represents a single pass during the afternoon hours, local time. The temperature color spectrum ranges from 7 to 17 degrees Celsius. Areas experiencing upwelling appear as blue and dark blue whereas areas with warmer water appear as orange and red. Cloud cover and/or fog appear as white.

Appendix 5: ADCP Data

The ADCP data are separated by the individual sweeps according to the dates defined previously. The combined series of absolute, three-minute water velocities for each sweep were averaged over 5-km intervals to produce the vector maps presented here. Current fields are presented for each sweep of DSJ9506 at four depths (15-31 m, 47-63 m, 95-111 m, and 191-207 m). The vectors point in the direction of flow; their magnitudes are relative to the scaled, 50 cm/s vector displayed in the plot's legend.

Appendix 6: Regression Comparisons of CTD, TS, and Bucket

The plots presented show comparisons between CTD, TS, and bucket temperatures and CTD and TS salinities. The solid lines represent the lines of equality in order to show how the different data varied from each other. The regression statistics for each comparison were as follows:

CTD temperature versus TS temperature,
CTDtemp. = TStemp. x 0.9845 + 0.1026
R^2 = 0.9854

CTD temperature versus bucket temperature,
CTDtemp. = buckettemp. x 0.9823 + 0.0240
R^2 = 0.9723

TS temperature versus bucket temperature,
TStemp. = buckettemp. x 0.9923 - 0.0166
R^2 = 0.9747

CTD salinity versus TS salinity,
CTDsal. = TSsal. x 1.001 + 0.4842
R^2 = 0.9356

CTD salinity versus bucket salinity,
CTDsal. = bucketsal. x 0.9560 + 1.4382
R^2 = 0.9405

TS salinity versus bucket salinity,
TSsal. = bucketsal. x 0.8723 + 3.7162
R^2 = 0.9311

Appendix 7: Horizontal Maps of CTD and TS

a) Maps of TS temperature and salinity

Maps of surface temperature (°C) and salinity (ppt) obtained from the vessel's TS continuous profiling unit are presented for each sweep of DSJ9506. The TS maps are located in front of the corresponding horizontal map for the CTD at 2 m. The contour intervals are 0.2 °C for temperature and 0.1 ppt for salinity. They are included to provide some verification of hydrographic spatial patterns inferred from the CTD data. The 2-m CTD and surface TS maps display good quantitative agreement, despite the fact that the data used to generate each were collected by different instrument packages.

b) Maps of CTD temperature, salinity and density, by depth

Horizontal maps of temperature (°C), salinity (ppt) and density (sigma-theta [σ_θ]) (kg/m^3) are presented at depths of 2 m, 10 m, 30 m, 100 m, 200 m, 300 m, and 500 m. The locations of the CTD casts used in generating the horizontal contours are shown by a + symbol. The 2-m depth was selected to represent surface conditions. The 10-m depth was selected to represent near-surface conditions because (1) the quality of data in the first few meters below the surface was not acceptable at some stations, and (2) localized, ephemeral conditions, related to factors such as strong surface heating and low vertical mixing that did not reflect the realistic, longer-term conditions of the region, were generally confined to the upper 5 m (refer to footnote 3). The 30-m depth was contoured to coincide with the standard midwater trawl depth during the surveys. The contour intervals are 0.2°C, 0.1 ppt and 0.1 kg/m^3, respectively for depths 2-100 m. For the 200- to 500-m depths, the contour intervals were lowered to 0.1°C, 0.02 ppt, and 0.02 kg/m^3.

Appendix 8: Vertical Transects

Vertical transects of temperature, salinity and density are presented for four cross-shelf transects off Pt. Reyes, Pacifica, Pescadero, and Davenport for DSJ9403 and off Pt. Reyes, the Farallones, Pescadero, and Davenport for DSJ9406. Station maps denote the location of each transect and the offshore extent of stations used to generate plots for each sweep. The locations of CTD casts used in generating the vertical transects are shown by an I. The contour intervals are 0.5 °C for temperature, 0.1 ppt for salinity, and 0.2 kg/m ^{3} for density.

Appendix 9: Horizontal Maps of Chlorophyll a

Horizontal maps of chlorophyll a at 10 m and integrated from the surface to 150 m are presented for two of the three sweeps of DSJ9506 as the CTD equipped with the WETStar fluorometer was only used during sweeps 2 and 3. Contour intervals are 0.5 mg/m^3 for the 10 m contour map and 10 mg/m^2 for the integrated (0-150 m) map. The locations of the CTD casts used in generating the horizontal contours are shown by a + symbol.

Appendix 10: Dynamic Height Topography

Horizontal maps of dynamic height (0/500 m and 200/500 m) are presented for the three sweeps of DSJ9506. Contour intervals are 0.01 for the 0/500 m maps and 0.005 for the 200/500 m maps. The locations of the CTD casts used in generating the horizontal contours are shown by a + symbol.

Synopsis of Hydrographic Conditions

Winds in the weeks prior to and during the survey were predominantly southward with some episodes of wind relaxation (weakening southward wind), and one reversal to northward flow during sweep 3. Vectors aligned strongly with the local coastline. Winds during 1995 appear fundamentally similar to 1994, and to the long-term climatology (Dorman and Winant 1995). Specifically, winds were upwelling favorable (southward) through spring and summer along the entire coast with typical magnitudes for this time of year. In contrast, strong negative anomaly (weaker than normal) upwelling index values (Bakun 1975) were estimated for May and June at this latitude. The survey occurred during a period of negative anomalies, which began in January 1995 (Hayward et al. 1995) and extended through the summer.

Coastal ocean conditions off central California during May-June 1995 suggest a continuation of the more typical conditions that developed in early 1994 following an extended ENSO, a tendency consistent with the results of the CalCOFI surveys off southern California (Hayward et al. 1995). Upper water column temperatures and salinities were generally near average for this area, and cooler and more saline in comparison to 1992 and 1993. Extremely low (<30 ppt) salinities, a result of high runoff from heavy spring rains and floods in northern California, were confined to the upper 10 m, primarily in the Gulf of the Farallones. Otherwise, near-surface temperature and salinity values and distributions imply typical coastal upwelling conditions (cf. Schwing et al. 1991). Cool, saline plumes of recently upwelled water extended south and offshore past Pt. Reyes, and immediately seaward of Monterey Bay. A strong, meandering alongshelf front, at times apparent to 200 m depth, developed between the upwelled water and the warmer, fresher water of the California Current. High concentrations of chlorophyll a were associated with the upwelling plumes. Satellite AVHRR images and temperature and salinity maps from the upper 30 m reflect the intensification of upwelling during the survey.

Slope water temperatures and salinities at 200 m depth in 1995 were similar to the long-term means, but more saline relative to 1994, when hydrographic conditions suggested a reduced Countercurrent or increased transport in the California Current. Further offshore, isopycnal surfaces at 200-500 m were shallower in 1994 and 1995, compared to ENSO conditions when relatively warm, fresh California Current water is displaced shoreward by anomalous northward wind stress (Simpson 1984; Lynn et al. 1995).

ADCP currents in May-June 1995 off central California reflect the meandering southward flow typical of the upper water column during this time of year, highlighted by a strong offshore flow of recently upwelled water off Bodega Bay seen to at least 200 m depth during sweep 3. While recently upwelled water, identified from hydrographic data and AVHRR images, had a southward component of flow, highest ADCP velocities were actually located off Pt. Reyes (38°N) and Davenport (37°N) in the frontal areas separating upwelled and California Current water, seaward of the upwelling plumes. The region also featured northward flow over the continental slope off Half Moon Bay (37.25°N) and Monterey Bay (36.75°N), a pattern even more evident in the 1993 and 1994 ADCP fields. The northward flowing California Undercurrent predominated at 200 m. Geostrophic currents inferred from the dynamic topography were similar to the ADCP circulation patterns, although the ADCP data reveal a much more complex current field. Circulation features appear to have a long lifetime (> one month), but their position changes noticeably from sweep to sweep. Dynamic heights were very similar in magnitude and structure to those in 1994 (Sakuma et al. 1995). The upper ocean was as much as 10 dyn. cm lower than during ENSO conditions in May-June 1992 (Lynn et al. 1995) and 1993 (Sakuma et al. 1994).

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APPENDIX 1: LIST OF CTD STATIONS SUMMARIZED FROM CRUISE DSJ9506

DSJ9506 Sweep 1

CAST	DATE	TIME	LATITUDE	LONGITUDE	DEPTH(M)
1	17MAY95	2236	36 51.1	121 59.0	87
6	18MAY95	0513	36 39.7	121 59.0	101
7	18MAY95	0716	36 40.0	122 10.1	1010
8	18MAY95	0845	36 46.2	122 16.1	811
9	18MAY95	0955	36 40.1	122 22.3	2002
10	18MAY95	1130	36 46.3	122 28.5	2358
11	18MAY95	1250	36 40.1	122 34.5	2612
12	18MAY95	1420	36 46.2	122 40.8	2000
13	18MAY95	1540	36 40.0	122 47.1	2800
14	18MAY95	1700	36 33.7	122 40.7	2975
15	18MAY95	1837	36 33.7	122 28.5	2790
16	18MAY95	2005	36 33.6	122 16.4	2600
17	18MAY95	2111	36 35.0	122 10.6	2375
18	19MAY95	0158	36 36.2	122 03.3	1250
21	19MAY95	0530	36 45.3	122 07.5	999
22	19MAY95	0653	36 52.5	122 10.1	102
23	19MAY95	0815	36 52.6	122 22.4	1020
24	19MAY95	0948	36 52.6	122 34.7	1820
25	19MAY95	1120	36 52.7	122 47.1	3068
26	19MAY95	1255	36 52.9	122 59.4	2650
27	19MAY95	1415	36 59.0	122 53.2	1350
28	19MAY95	1535	37 04.9	122 47.2	645
29	19MAY95	1710	37 05.1	122 34.7	115
30	19MAY95	1827	37 05.1	122 22.3	59
31	19MAY95	2044	36 58.9	122 35.4	420
32	20MAY95	0100	37 01.1	122 25.2	125
33	20MAY95	0140	36 58.8	122 22.5	130
34	20MAY95	0335	36 57.7	122 18.3	105
35	20MAY95	0500	36 57.8	122 13.8	72
36	20MAY95	0712	37 10.6	122 28.6	71
37	20MAY95	0827	37 10.8	122 40.9	113
38	20MAY95	0945	37 10.7	122 53.2	421
39	20MAY95	1115	37 10.8	123 05.3	836
40	20MAY95	1300	37 22.4	123 05.4	760
41	20MAY95	1430	37 22.3	122 52.9	192
42	20MAY95	1545	37 22.3	122 40.9	87
43	20MAY95	1930	37 22.3	122 28.5	33
44	20MAY95	2018	37 16.6	122 29.1	52
45	20MAY95	2244	37 16.0	122 32.2	79
46	20MAY95	2333	37 16.3	122 39.1	96
47	21MAY95	0330	37 15.4	122 50.9	240
48	21MAY95	0520	37 15.2	122 57.6	258
49	21MAY95	0738	37 30.7	122 59.4	214
50	21MAY95	0905	37 30.8	123 11.5	1557
51	21MAY95	1038	37 30.9	123 23.9	2751
52	21MAY95	1215	37 30.9	123 36.3	2990
53	21MAY95	1345	37 38.4	123 36.4	3150
54	21MAY95	1509	37 46.2	123 36.5	2900
55	21MAY95	1640	37 46.3	123 23.9	1535
56	21MAY95	1811	37 46.3	123 11.5	113
57	21MAY95	2037	37 39.2	123 02.6	113
58	21MAY95	2315	37 38.4	123 12.7	1540
59	22MAY95	0037	37 44.6	123 08.2	83
60	22MAY95	0335	37 51.6	123 18.2	107
61	22MAY95	0550	37 50.2	123 29.1	1600
62	22MAY95	0924	38 01.4	123 30.2	150
63	22MAY95	1055	38 01.6	123 42.5	2875
64	22MAY95	1235	38 01.5	123 55.0	3425
65	22MAY95	2030	37 57.9	122 56.2	56

CAST	DATE	TIME	LATITUDE	LONGITUDE	DEPTH(M)
66	22MAY95	2140	37 55.2	122 51.7	50
67	22MAY95	2233	37 51.1	122 46.1	42
68	23MAY95	2105	37 38.1	122 46.3	53
69	24MAY95	0020	37 42.5	122 55.4	56
70	24MAY95	0308	37 46.5	122 50.0	55
71	25MAY95	1105	38 01.6	123 17.9	119
72	25MAY95	1530	38 18.6	123 54.6	2800
73	25MAY95	1655	38 18.5	123 42.3	1488
74	25MAY95	1822	38 18.4	123 30.1	256
75	25MAY95	1945	38 09.8	123 22.0	179
76	26MAY95	0030	38 08.8	123 15.5	115
77	26MAY95	0110	38 10.1	123 10.1	92
78	26MAY95	0300	38 08.6	123 02.9	70
79	26MAY95	0330	38 10.0	122 59.9	52
80	26MAY95	0720	37 51.4	122 45.8	39
81	26MAY95	0810	37 53.6	122 51.6	54
82	26MAY95	0855	37 56.0	122 57.3	61
83	26MAY95	0946	37 57.1	123 03.9	74
84	26MAY95	1044	38 01.4	123 05.2	63
85	26MAY95	1103	38 02.5	123 04.3	61
86	26MAY95	1204	38 07.3	123 05.6	73
87	26MAY95	1246	38 11.7	123 07.0	83
88	26MAY95	1415	38 18.5	123 18.0	190

DSJ9506 Sweep 2

CAST	DATE	TIME	LATITUDE	LONGITUDE	DEPTH(M)
97	27MAY95	1921	36 53.0	121 56.0	39
98	27MAY95	2050	36 50.7	121 59.0	90
99	27MAY95	2303	36 46.4	121 53.3	200
100	27MAY95	2350	36 44.4	121 58.6	283
101	28MAY95	0145	36 41.0	121 53.1	77
102	28MAY95	0215	36 38.4	121 51.4	32
103	28MAY95	0500	36 40.2	121 58.1	98
104	28MAY95	0618	36 40.0	122 10.1	1553
105	28MAY95	0747	36 46.3	122 16.3	854
106	28MAY95	0900	36 40.0	122 22.3	2002
107	28MAY95	1020	36 46.4	122 28.5	2373
108	28MAY95	1144	36 39.8	122 34.9	2617
109	28MAY95	1313	36 46.3	122 40.8	2150
110	28MAY95	1430	36 39.9	122 47.1	2800
111	28MAY95	1550	36 33.5	122 40.6	2900
112	28MAY95	1725	36 33.5	122 28.5	2800
113	28MAY95	1902	36 33.7	122 16.2	2600
114	28MAY95	2003	36 35.1	122 10.7	2375
115	29MAY95	0050	36 33.3	122 01.3	750
116	29MAY95	0228	36 38.7	122 02.9	820
118	29MAY95	0530	36 47.1	122 08.5	886
119	29MAY95	0724	36 52.4	122 10.1	101
120	29MAY95	0854	36 52.6	122 22.3	1053
121	29MAY95	1028	36 52.7	122 34.6	1841
122	29MAY95	1203	36 52.6	122 47.1	2205
123	29MAY95	1340	36 52.6	122 59.3	2650
124	29MAY95	1500	36 59.0	122 53.1	1400
125	29MAY95	1620	37 04.9	122 47.0	650
126	29MAY95	1750	37 05.0	122 34.5	116
127	29MAY95	1905	37 05.0	122 22.2	60

CAST	DATE	TIME	LATITUDE	LONGITUDE	DEPTH(M)
128	29MAY95	1843	36 58.8	122 35.5	443
129	30MAY95	0037	36 58.0	122 27.5	265
130	30MAY95	0124	36 59.2	122 22.7	123
131	30MAY95	0320	36 57.8	122 16.2	90
132	30MAY95	0425	37 00.1	122 13.6	42
133	30MAY95	0635	37 10.6	122 28.3	69
134	30MAY95	0755	37 10.8	122 40.7	113
135	30MAY95	0915	37 10.8	122 53.1	421
136	30MAY95	1040	37 10.8	123 05.3	839
137	30MAY95	1200	37 16.5	123 11.4	1180
138	30MAY95	1340	37 22.6	123 05.4	762
139	30MAY95	1510	37 22.3	122 53.1	200
140	30MAY95	1818	37 22.2	122 40.7	80
141	30MAY95	1934	37 22.4	122 28.3	32
142	30MAY95	2020	37 16.5	122 29.0	53
143	30MAY95	2223	37 17.3	122 34.6	86
144	30MAY95	2258	37 16.5	122 38.9	96
145	31MAY95	0240	37 14.9	122 48.9	204
146	31MAY95	0432	37 18.0	122 58.8	518
147	31MAY95	0627	37 30.7	122 59.4	213
148	31MAY95	0747	37 30.8	123 11.6	1300
149	31MAY95	0916	37 30.9	123 24.0	2752
150	31MAY95	1045	37 30.8	123 36.3	3351
151	31MAY95	1200	37 38.5	123 36.4	3300
152	31MAY95	1317	37 46.3	123 36.4	2650
153	31MAY95	1450	37 46.2	123 24.0	1350
154	31MAY95	1620	37 46.2	123 11.5	112
155	31MAY95	2030	37 39.3	123 02.4	108
156	31MAY95	2320	37 38.2	123 11.8	1010
157	01JUN95	0043	37 44.6	123 08.4	100
159	01JUN95	0540	37 50.7	123 25.9	1600
160	01JUN95	0845	38 01.5	123 30.1	143
161	01JUN95	1013	38 01.6	123 42.5	2896
162	01JUN95	1145	38 01.6	123 54.8	3941
163	01JUN95	1400	38 10.1	123 54.8	3450
164	01JUN95	1520	38 09.9	123 42.6	1792
165	01JUN95	1827	38 09.9	123 30.3	460
166	01JUN95	1950	38 10.7	123 22.7	140
167	01JUN95	2317	38 09.2	123 15.8	198
168	02JUN95	0014	38 10.9	123 10.3	92
169	02JUN95	0222	38 08.0	123 03.7	72
170	02JUN95	0314	38 10.7	123 00.6	60
171	02JUN95	0500	38 01.7	123 05.6	65
172	02JUN95	0620	38 01.7	123 15.6	114
173	02JUN95	2051	37 37.9	122 45.8	50
174	03JUN95	0015	37 42.2	122 54.4	60
175	03JUN95	0120	37 48.2	122 53.2	60
177	03JUN95	0513	37 57.1	122 54.6	51

DSJ9506 Sweep 3

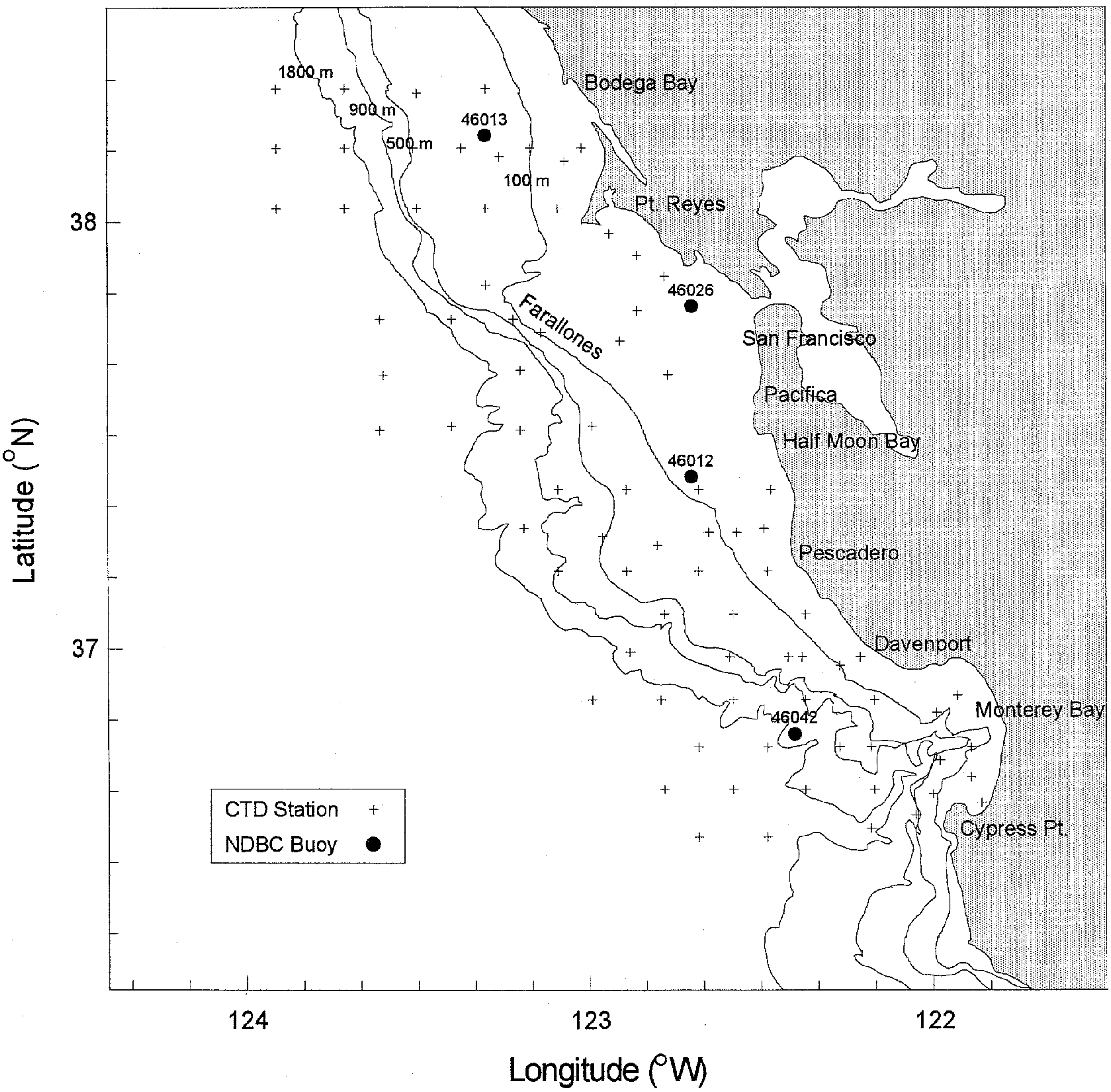
CAST	DATE	TIME	LATITUDE	LONGITUDE	DEPTH(M)
214	08JUN95	1959	36 53.1	121 55.9	38
215	08JUN95	2036	36 50.8	121 59.3	88
216	08JUN95	2332	36 46.4	121 53.6	267
217	09JUN95	0020	36 44.4	121 58.6	301
218	09JUN95	0204	36 41.7	121 53.1	77

CAST	DATE	TIME	LATITUDE	LONGITUDE	DEPTH(M)
219	09JUN95	0240	36 38.5	121 51.6	41
220	09JUN95	0550	36 39.4	121 59.8	107
221	09JUN95	0658	36 40.0	122 10.0	194
222	09JUN95	0808	36 46.2	122 16.2	1005
223	09JUN95	0923	36 40.0	122 22.2	2002
224	09JUN95	1051	36 46.4	122 28.5	2373
225	09JUN95	1212	36 40.0	122 34.6	2250
226	09JUN95	1332	36 46.4	122 40.8	2070
227	09JUN95	1452	36 39.9	122 47.0	2825
228	09JUN95	1608	36 33.8	122 40.6	2790
229	09JUN95	1739	36 33.8	122 28.5	2790
230	09JUN95	2307	36 34.6	122 10.6	2000
231	10JUN95	0147	36 36.6	122 02.7	1000
235	10JUN95	0515	36 46.3	122 10.6	750
236	10JUN95	0628	36 52.7	122 10.0	100
237	10JUN95	0748	36 52.6	122 22.4	910
238	10JUN95	0915	36 52.7	122 34.8	1800
239	10JUN95	1058	36 52.5	122 47.2	2606
240	10JUN95	1242	36 52.8	122 59.3	2650
241	10JUN95	1402	36 59.1	122 53.0	1350
242	10JUN95	1518	37 05.0	122 46.8	650
243	10JUN95	1657	37 05.0	122 34.7	105
244	10JUN95	1815	37 05.0	122 22.3	62
245	10JUN95	2114	36 58.9	122 35.6	430
246	11JUN95	0058	36 58.6	122 25.4	275
247	11JUN95	0130	36 59.0	122 22.6	123
248	11JUN95	0310	36 57.6	122 16.3	91
249	11JUN95	0438	36 59.0	122 12.5	45
250	11JUN95	0654	37 10.9	122 28.5	70
251	11JUN95	0813	37 10.8	122 40.8	113
252	11JUN95	0930	37 10.8	122 53.1	419
253	11JUN95	1059	37 10.7	123 05.4	842
254	11JUN95	1217	37 16.5	123 11.5	1150
255	11JUN95	1338	37 22.3	123 05.2	820
256	11JUN95	1507	37 22.3	122 53.1	195
257	11JUN95	1626	37 22.3	122 40.7	89
258	11JUN95	1941	37 22.2	122 28.4	37
259	11JUN95	2029	37 16.5	122 29.1	53
260	11JUN95	2249	37 16.3	122 34.3	87
261	11JUN95	2329	37 16.4	122 38.9	96
262	12JUN95	0307	37 14.3	122 48.0	190
263	12JUN95	0510	37 15.4	122 57.7	415
264	12JUN95	0731	37 31.3	122 59.5	230
265	12JUN95	0856	37 30.8	123 11.7	1557
266	12JUN95	1028	37 30.9	123 24.0	2700
267	12JUN95	1201	37 30.8	123 36.4	2900
268	12JUN95	1320	37 38.5	123 36.2	3250
269	12JUN95	1444	37 46.1	123 36.6	2660
270	12JUN95	1622	37 46.2	123 24.2	1564
271	12JUN95	1748	37 46.2	123 13.2	124
273	13JUN95	0018	37 38.8	123 12.0	1200
274	13JUN95	0135	37 44.6	123 08.4	90
275	13JUN95	0503	37 51.0	123 17.8	105
276	13JUN95	0711	38 01.7	123 30.1	140
277	13JUN95	0832	38 01.5	123 42.5	2855
278	13JUN95	1002	38 01.7	123 54.7	3941
280	13JUN95	1258	38 18.5	123 54.8	2800
281	13JUN95	1429	38 18.5	123 42.3	1440
282	13JUN95	1557	38 18.2	123 30.0	244
283	13JUN95	1717	38 18.4	123 17.9	110
284	13JUN95	2045	38 10.0	123 22.0	178
285	14JUN95	0016	38 08.8	123 15.6	116
286	14JUN95	0100	38 10.1	123 10.0	92

CAST	DATE	TIME	LATITUDE	LONGITUDE	DEPTH(M)
287	14JUN95	0245	38 08.5	123 04.0	73
288	14JUN95	0350	38 10.0	123 01.4	66
289	14JUN95	0545	38 01.5	123 18.2	119
290	14JUN95	0710	38 01.7	123 05.3	67
291	14JUN95	2123	37 38.1	122 46.2	55
292	14JUN95	2321	37 42.9	122 54.4	54
293	15JUN95	0003	37 47.6	122 51.8	58
294	15JUN95	0140	37 52.0	122 46.7	44
295	15JUN95	0226	37 55.1	122 51.6	50
296	15JUN95	0306	37 57.9	122 56.1	56

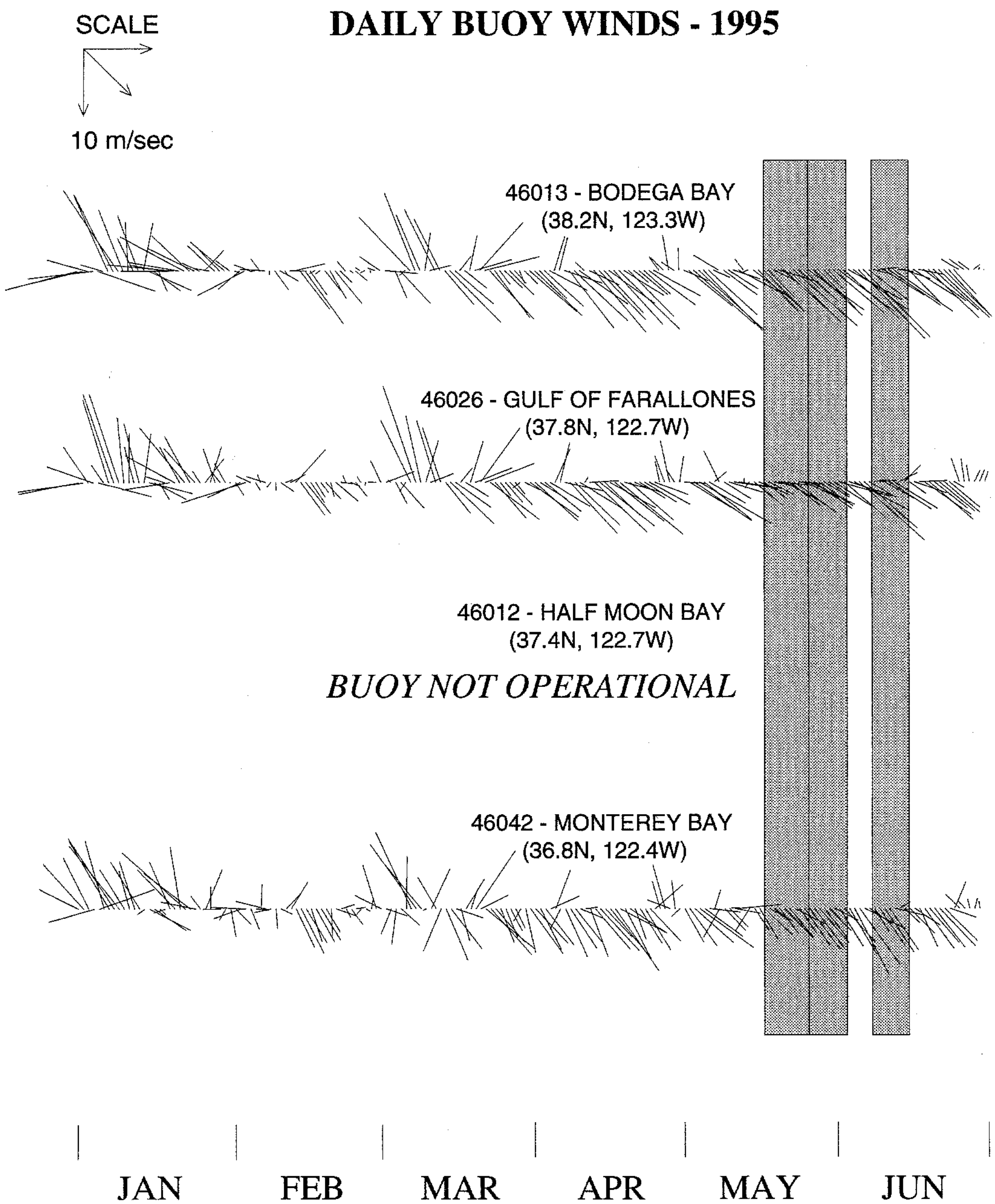
APPENDIX 2: DSJ9506 CTD STATIONS AND BATHYMETRIC MAP OF SURVEY REGION WITH LOCATIONS OF THE NDBC BUOYS

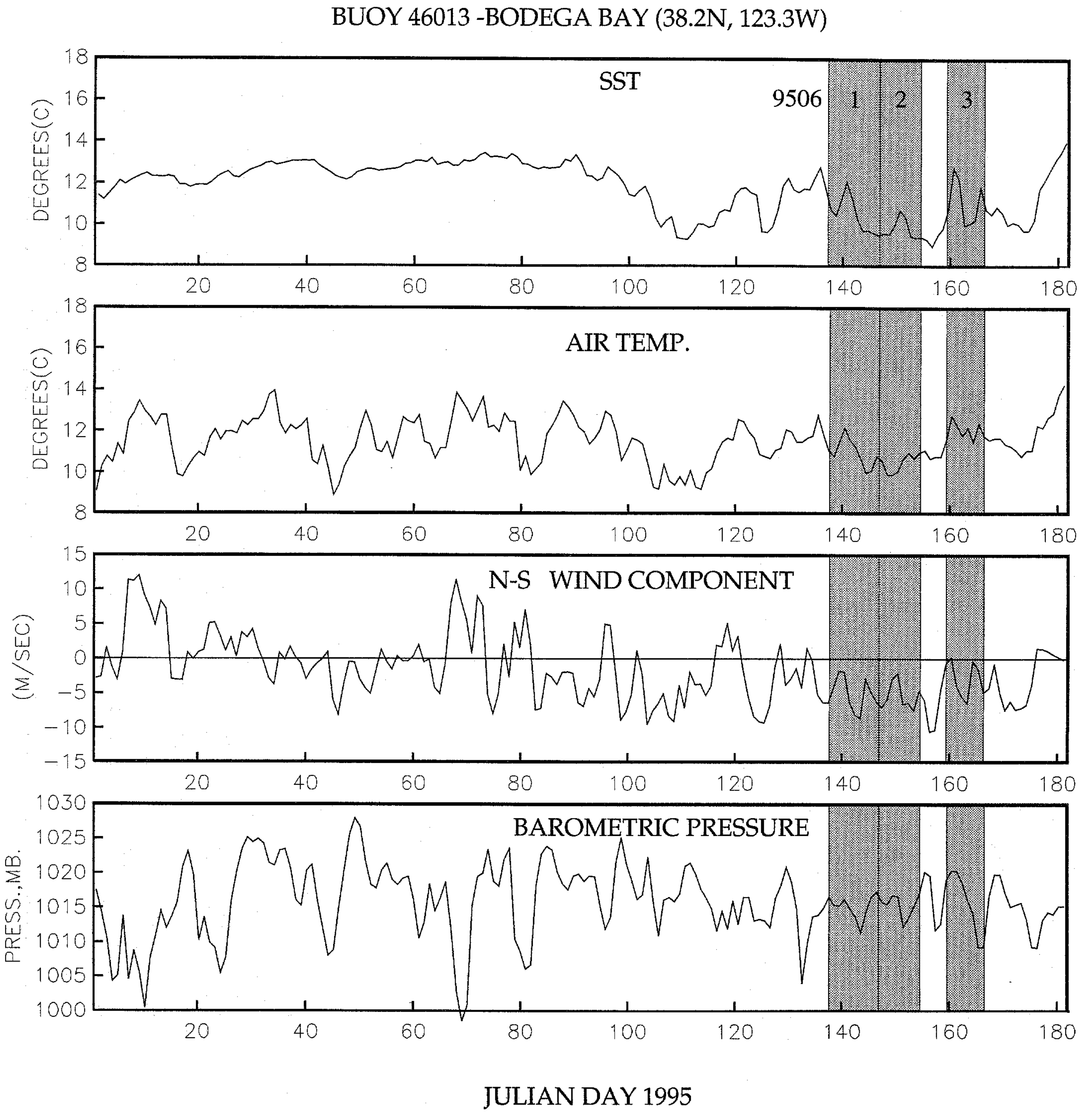
DSJ9506 Station Locations



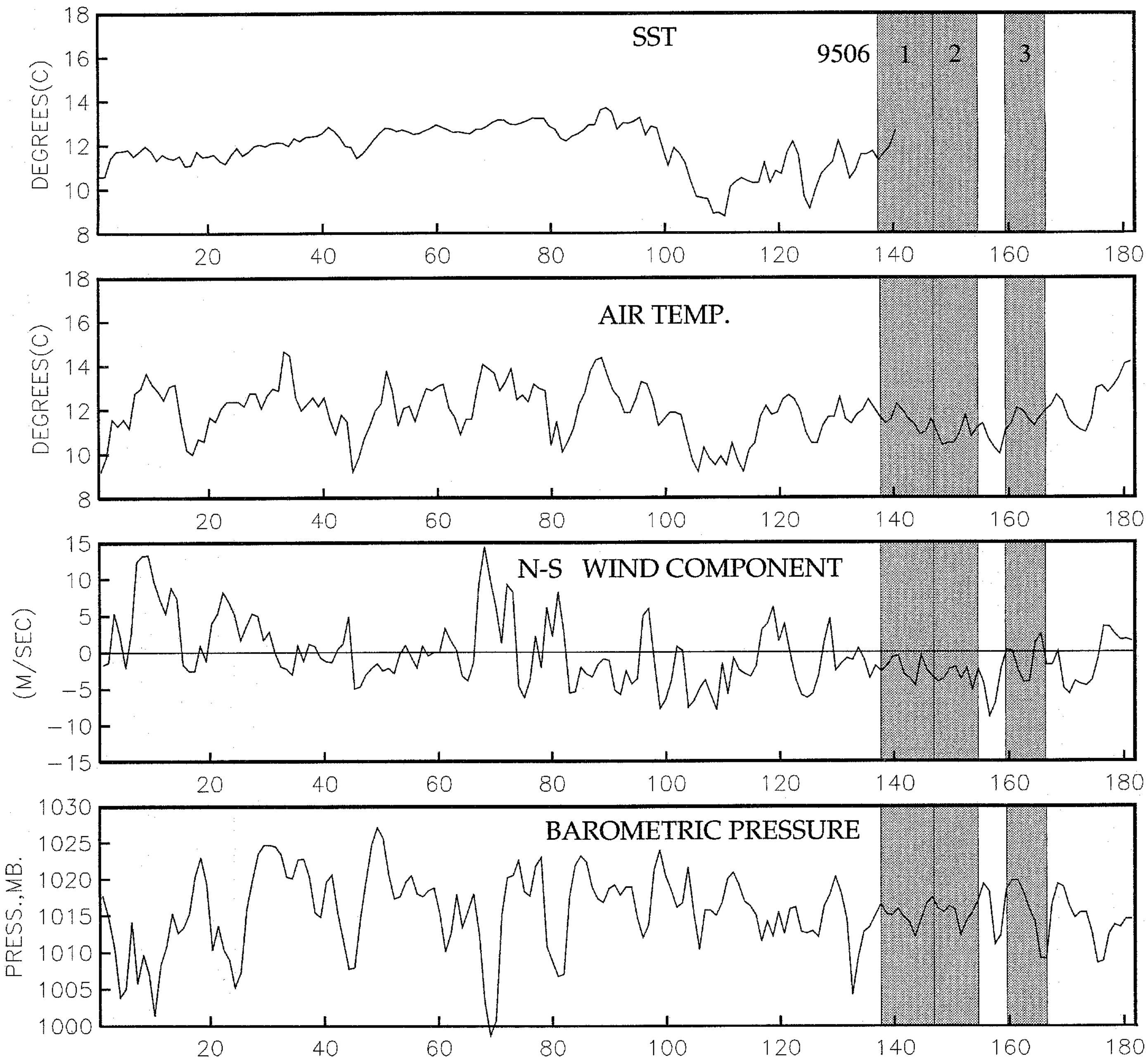
APPENDIX 3: METEOROLOGICAL TIME SERIES

DAILY BUOY WINDS - 1995

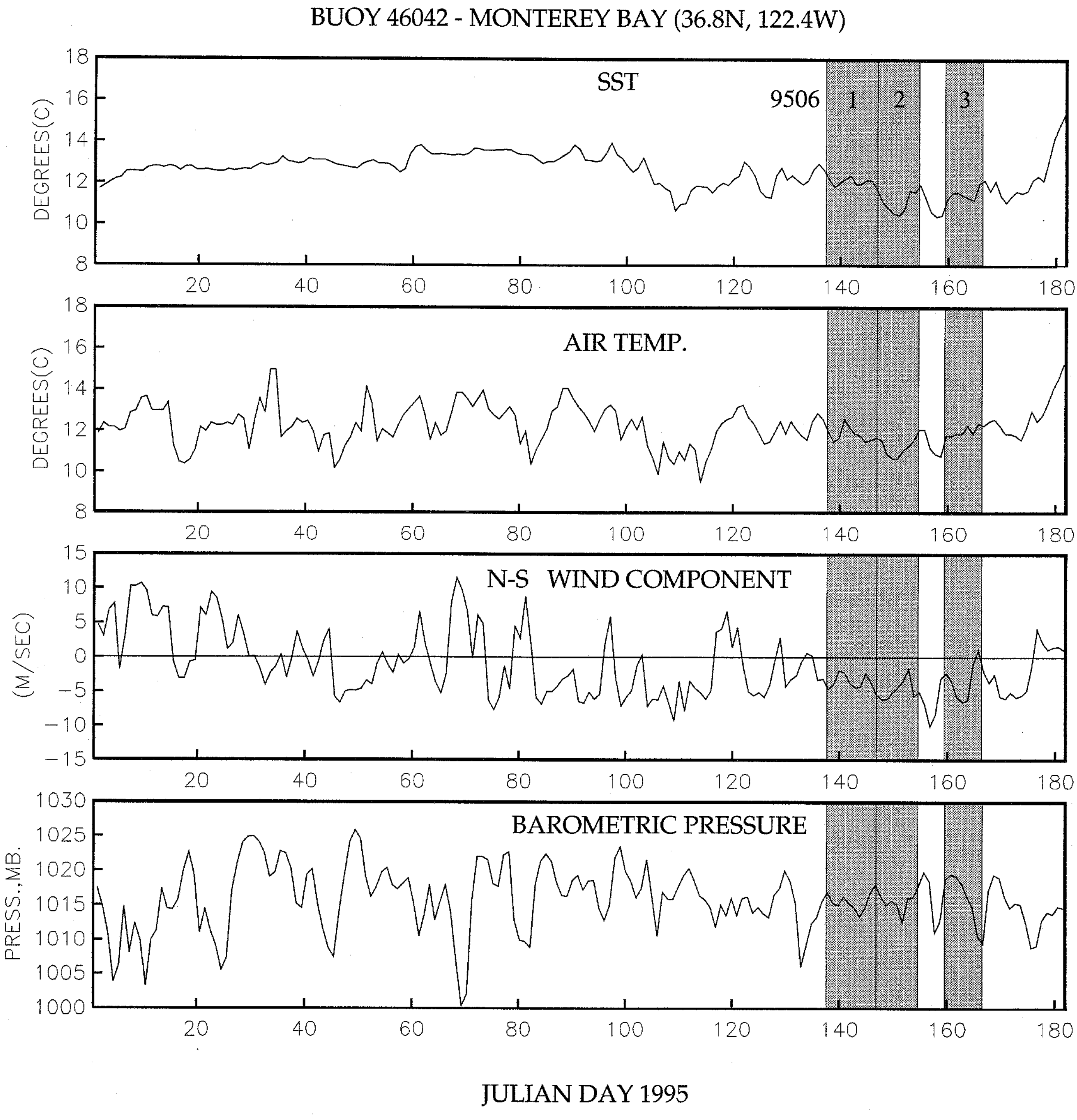



BUOY 46013 -BODEGA BAY (38.2N, 123.3W)
SST
9506
1
2
3
DEGREES(C)
AIR TEMP.
N-S WIND COMPONENT
(M/SEC)
BAROMETRIC PRESSURE
PRESS.,MB.
JULIAN DAY 1995

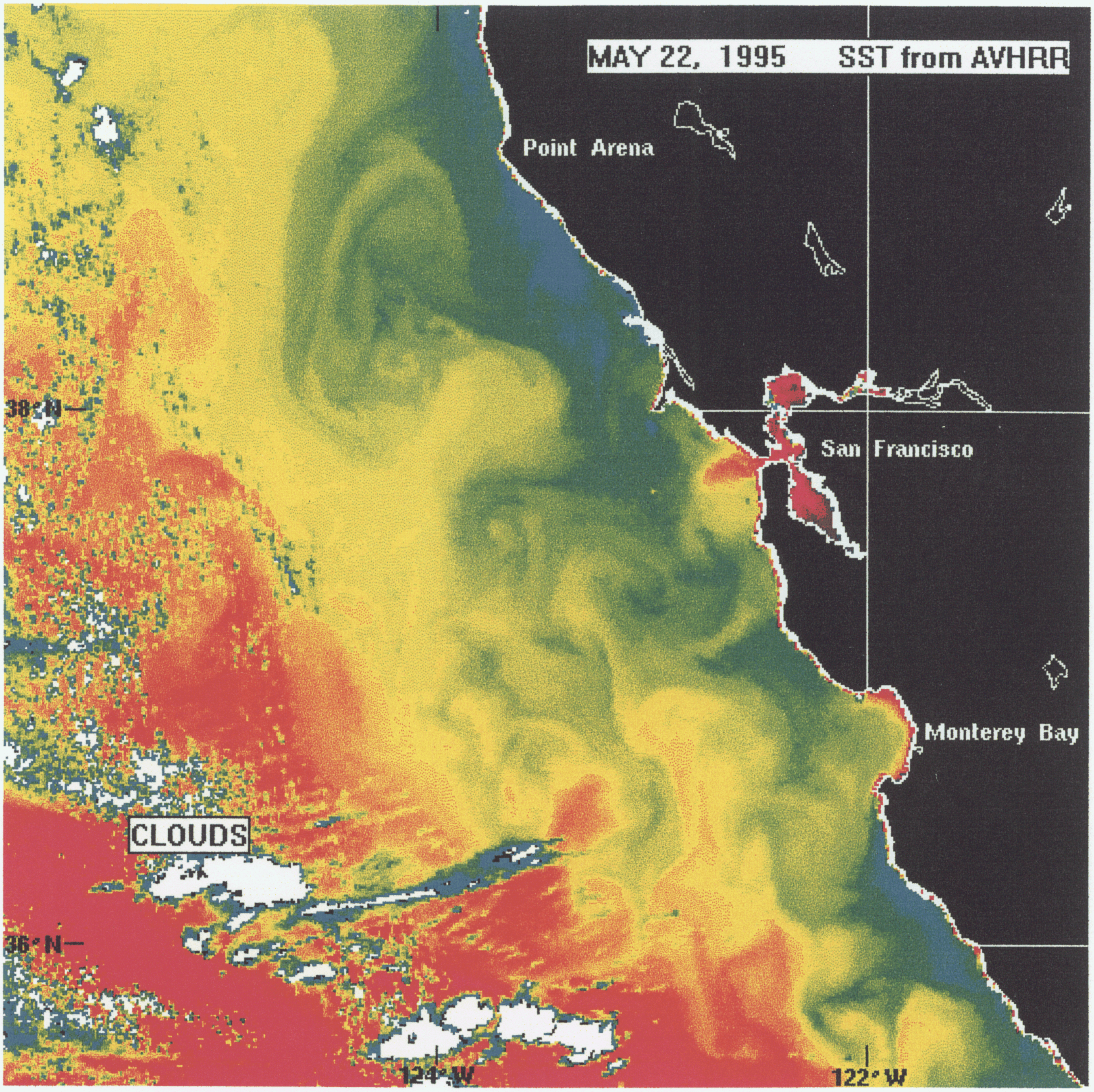
BUOY 46026 - FARALLONES (37.8N, 122.7W)



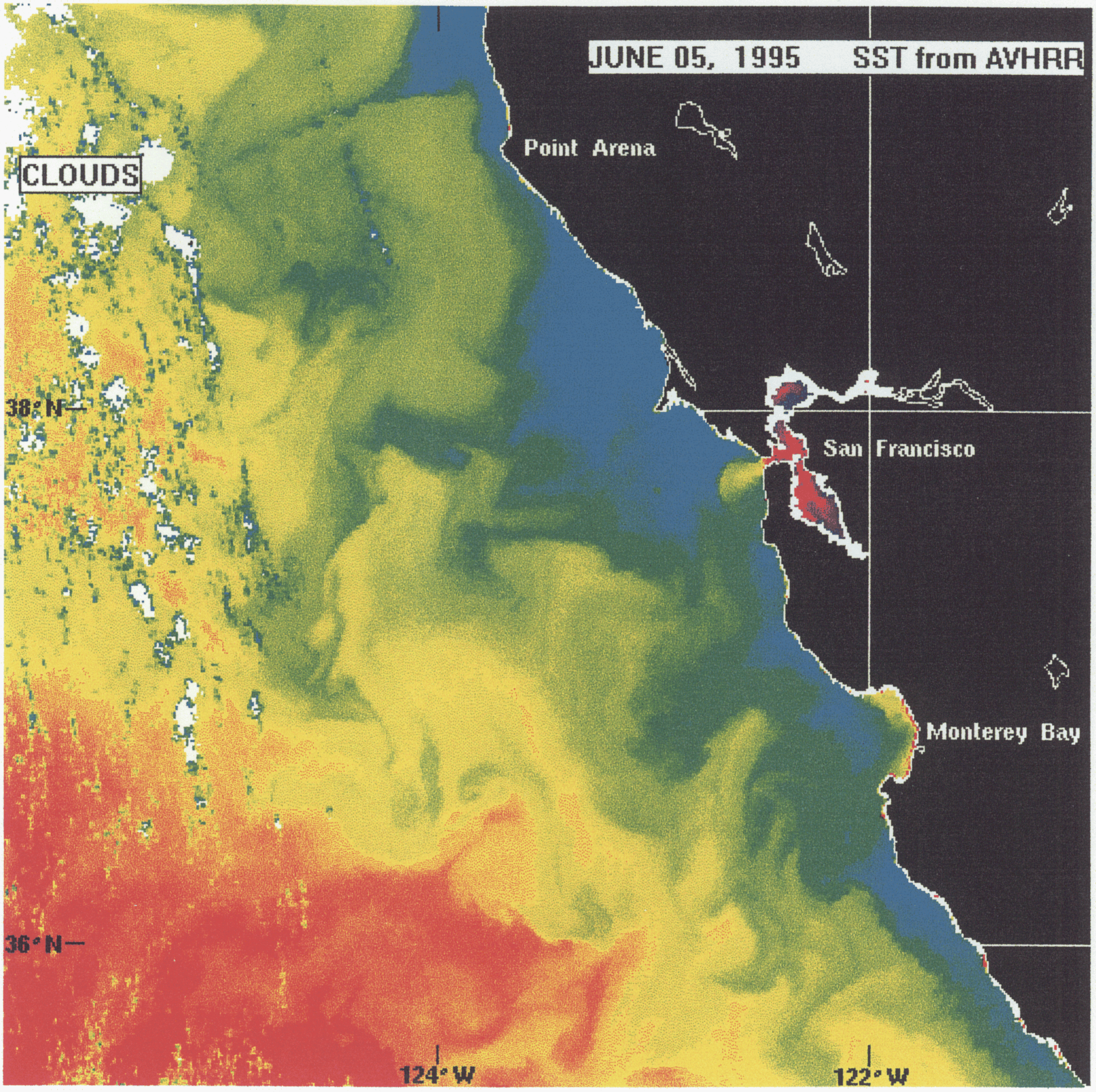
JULIAN DAY 1995


BUOY 46042 - MONTEREY BAY (36.8N, 122.4W)
SST
9506
1
2
3
DEGREES(C)
AIR TEMP.
N-S WIND COMPONENT
(M/SEC)
BAROMETRIC PRESSURE
PRESS.,MB.
JULIAN DAY 1995

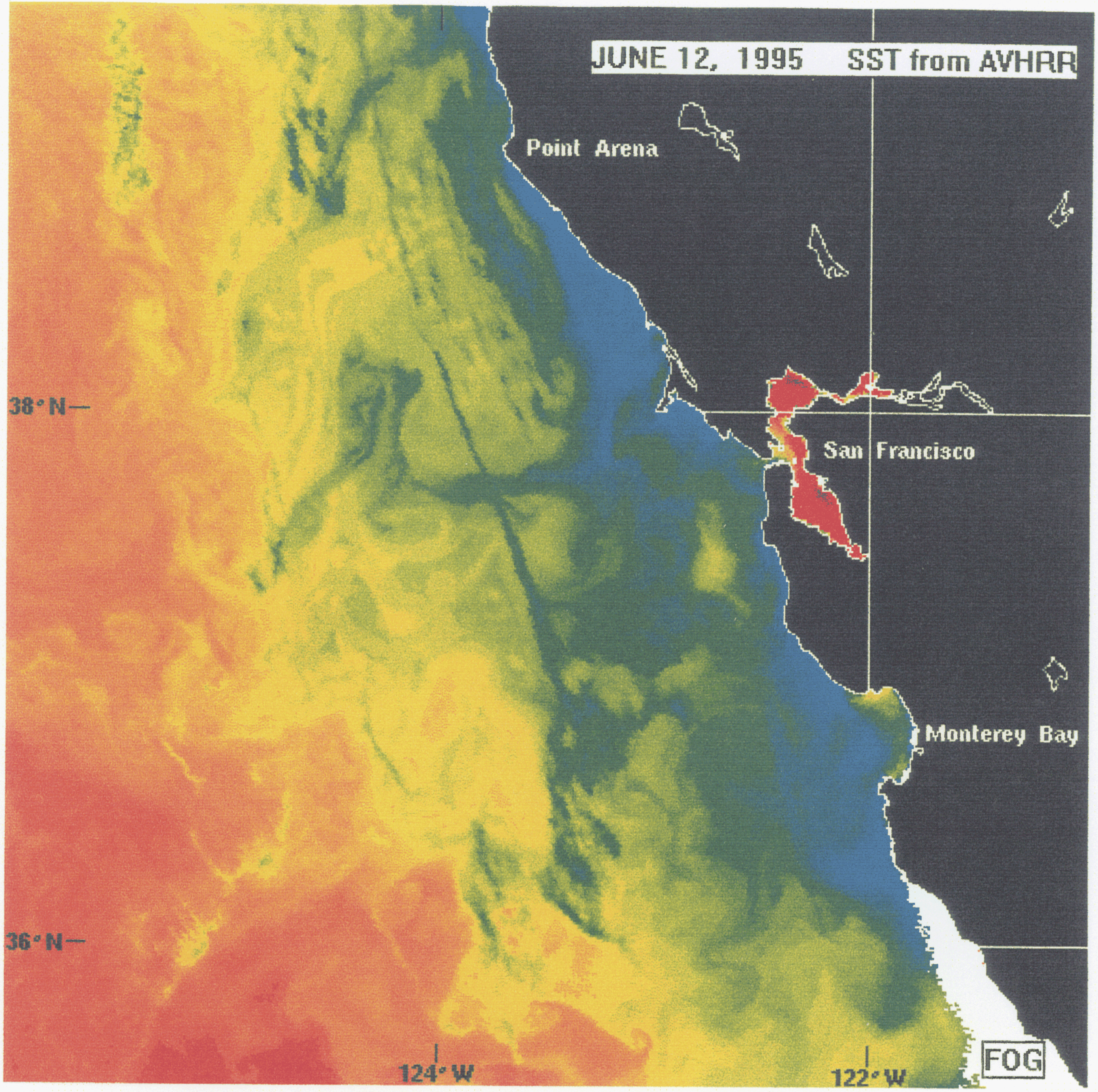
APPENDIX 4: AVHRR SATELLITE IMAGES OF SEA SURFACE TEMPERATURES



AVHRR Satellite Image of Sea Surface Temperatures
During Sweep 1 of DSJ9506 Cruise

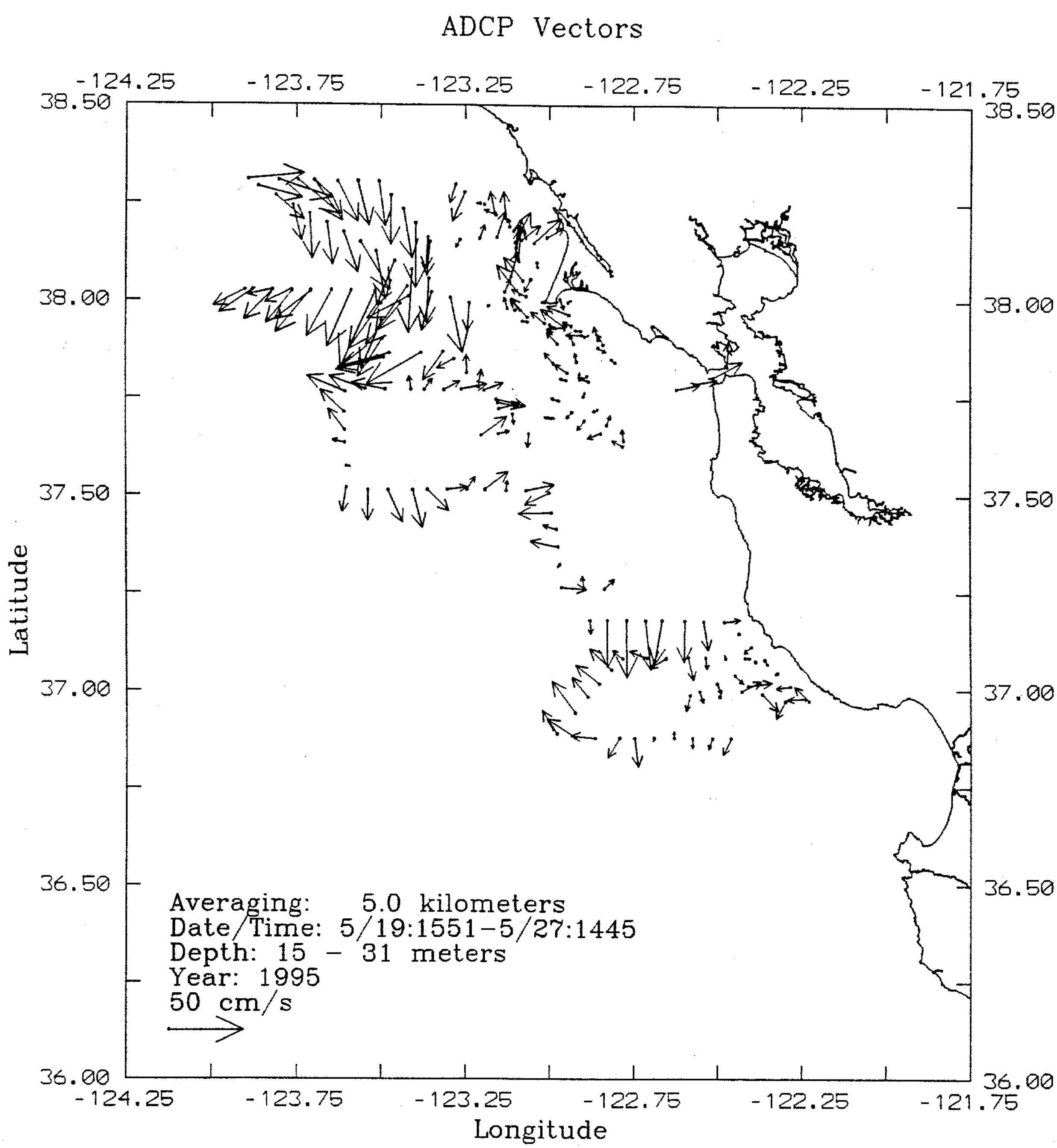


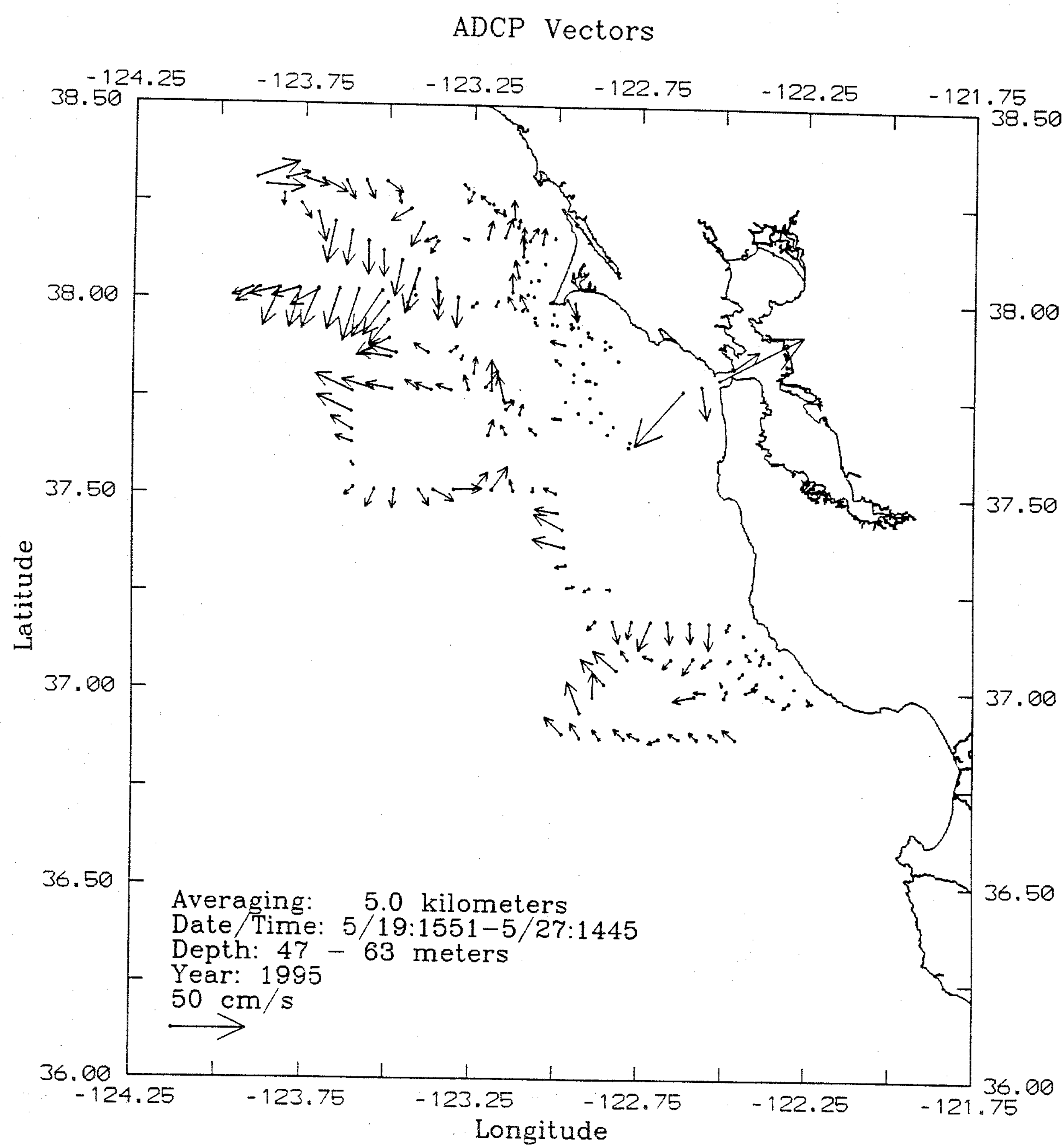
AVHRR Satellite Image of Sea Surface Temperatures
During Sweep 2 of DSJ9506 Cruise



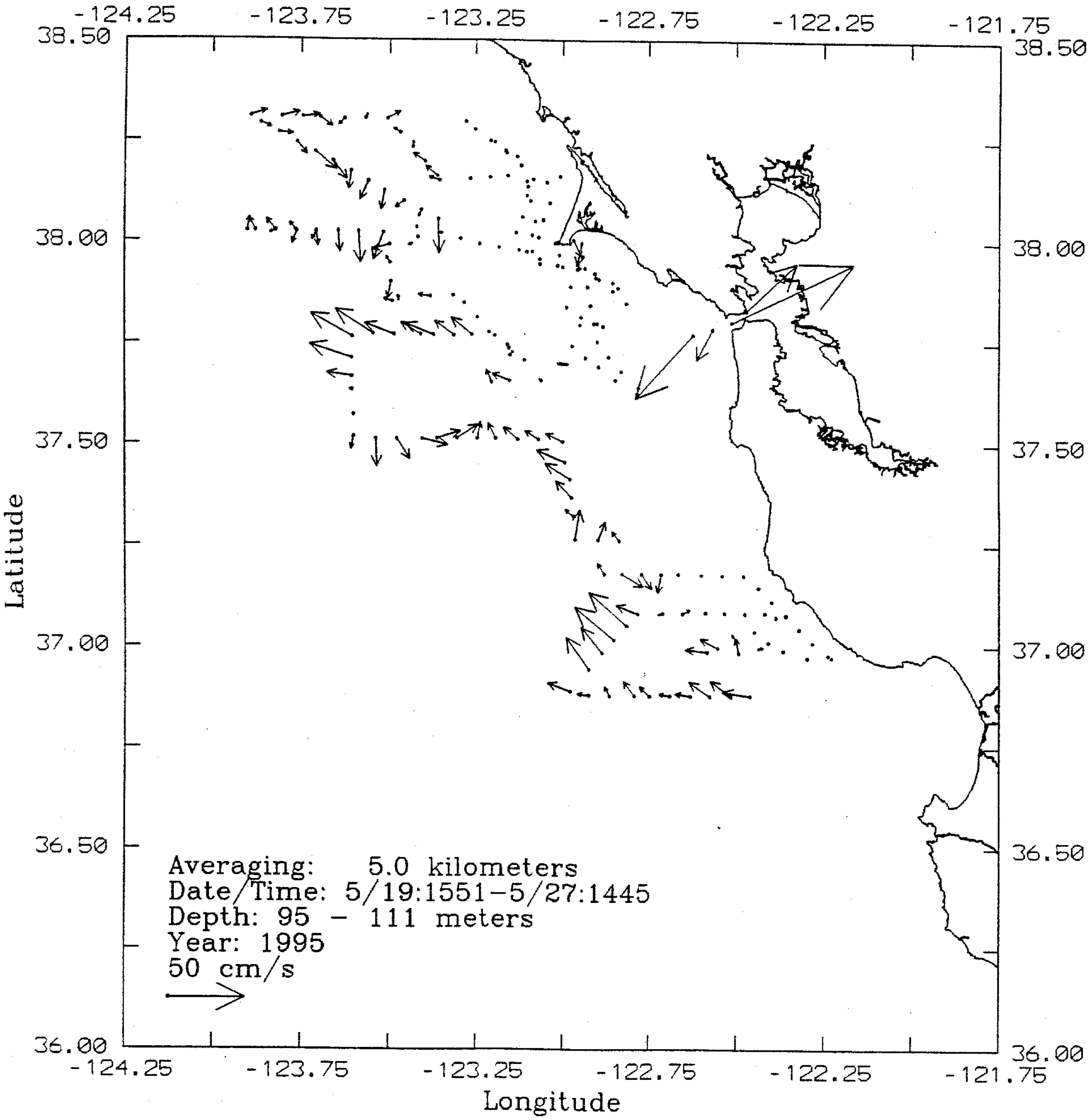
AVHRR Satellite Image of Sea Surface Temperatures
During Sweep 3 of DSJ9506 Cruise

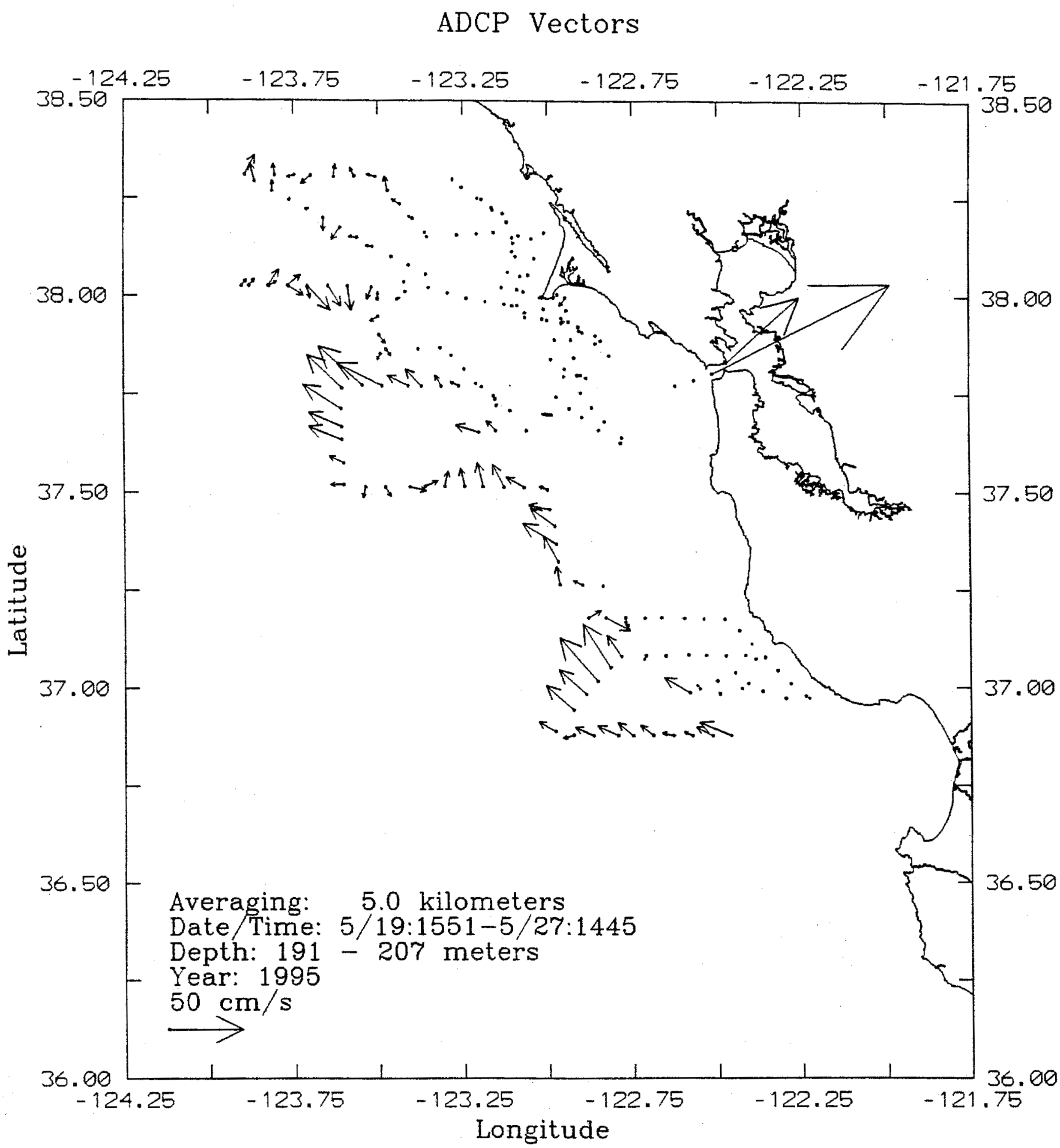
APPENDIX 5:   ADCP DATA

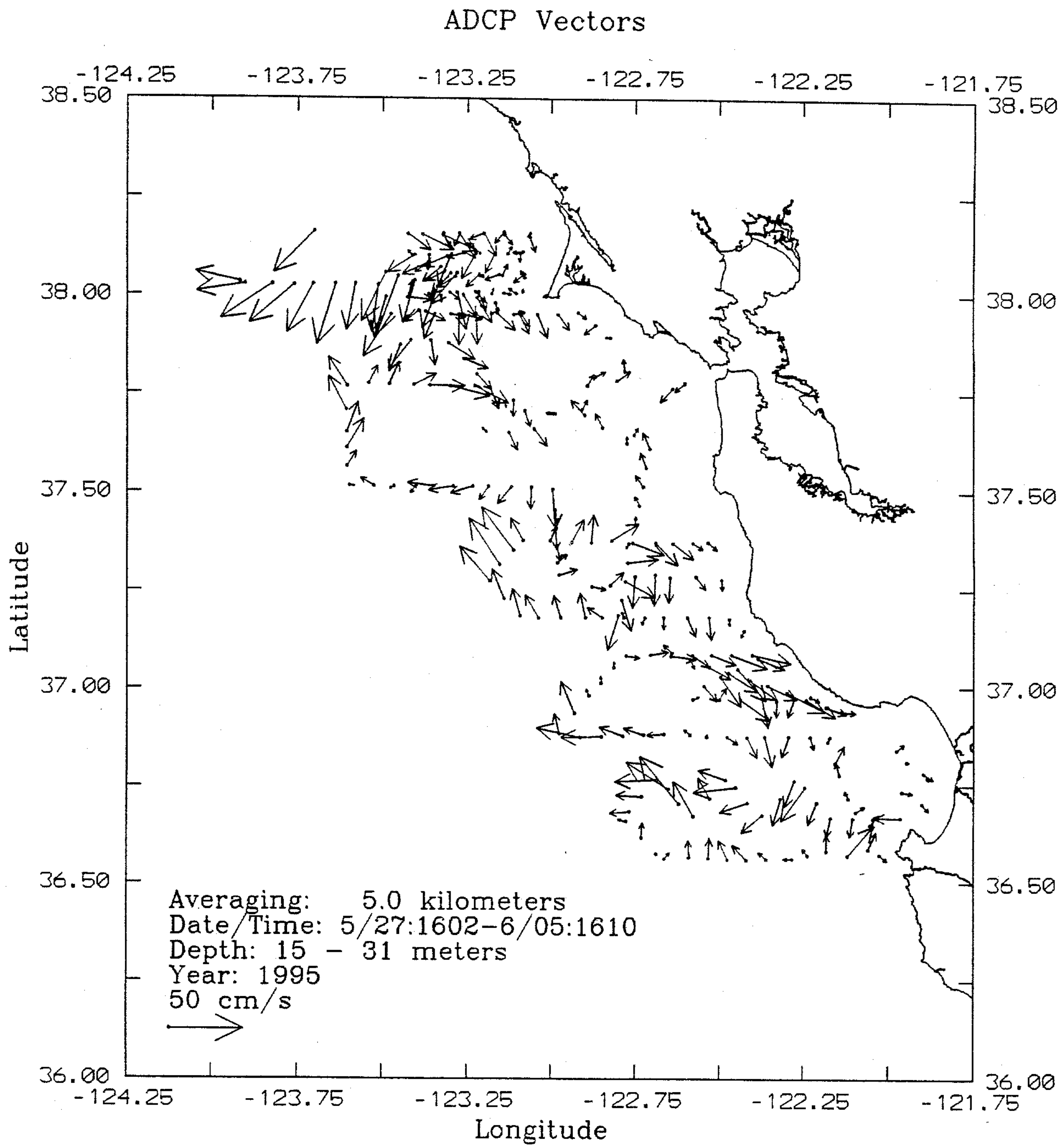

ADCP Vectors
-124.25
-123.75
-123.25
-122.75
-122.25
-121.75
38.50
38.00
37.50
37.00
36.50
36.00
Latitude
Longitude
Averaging: 5.0 kilometers
Date/Time: 5/19:1551-5/27:1445
Depth: 15 - 31 meters
Year: 1995
50 cm/s

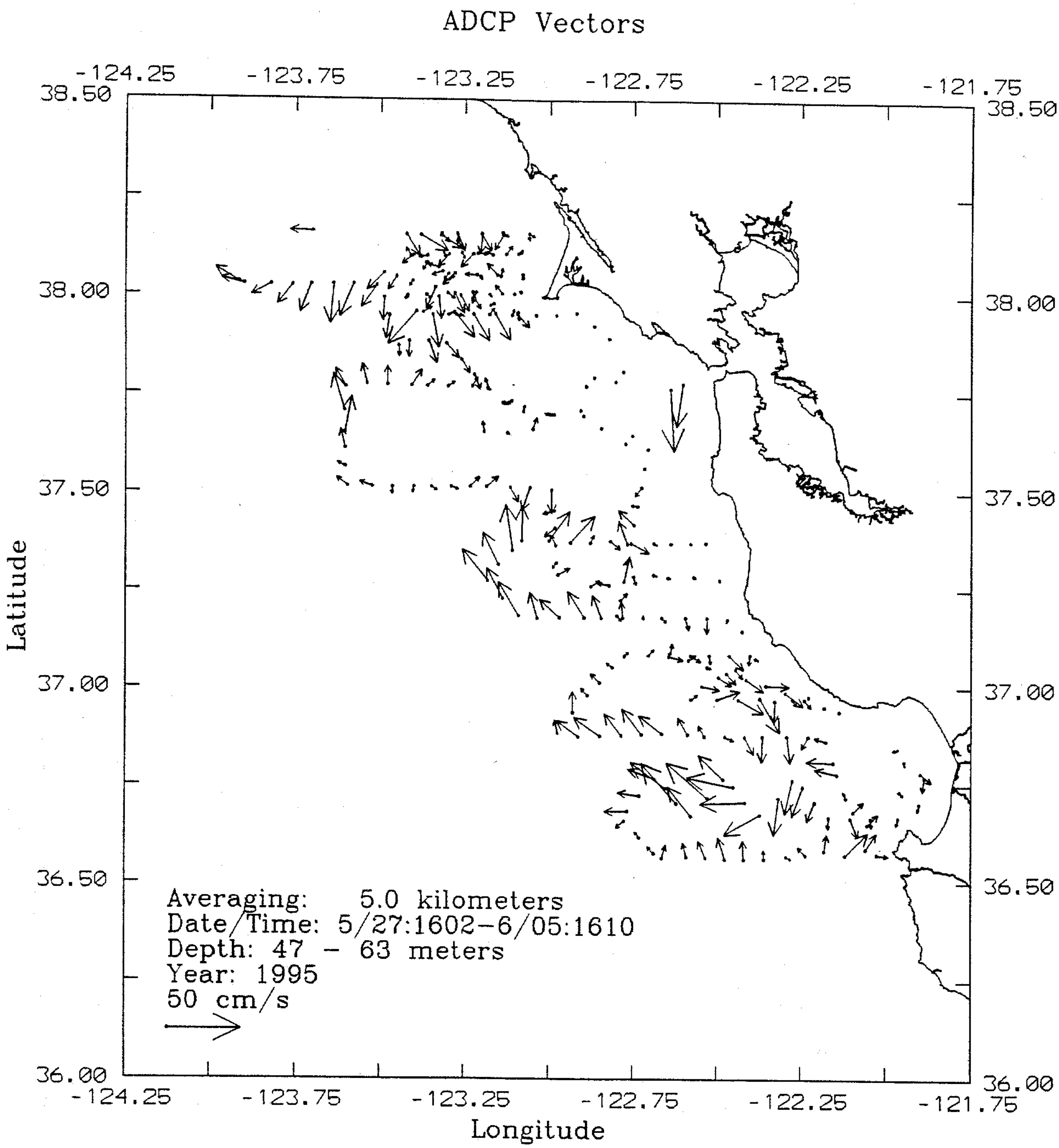

ADCP Vectors
-124.25
-123.75
-123.25
-122.75
-122.25
-121.75
38.50
38.00
37.50
37.00
36.50
36.00
Latitude
Longitude
Averaging: 5.0 kilometers
Date/Time: 5/19:1551–5/27:1445
Depth: 47 – 63 meters
Year: 1995
50 cm/s

ADCP Vectors



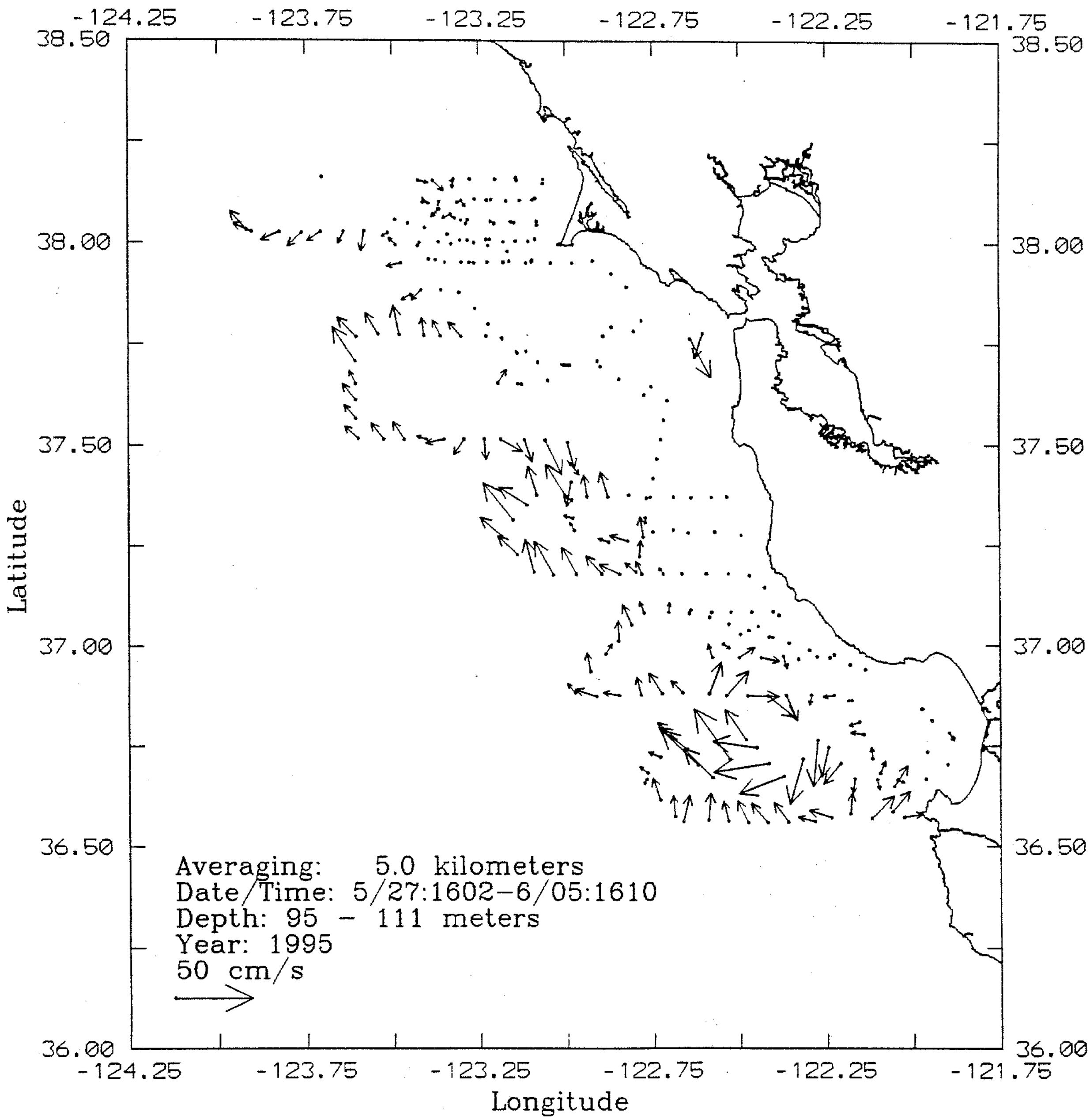

ADCP Vectors
-124.25
-123.75
-123.25
-122.75
-122.25
-121.75
38.50
38.00
37.50
37.00
36.50
36.00
Latitude
Longitude
Averaging: 5.0 kilometers
Date/Time: 5/19:1551-5/27:1445
Depth: 191 - 207 meters
Year: 1995
50 cm/s

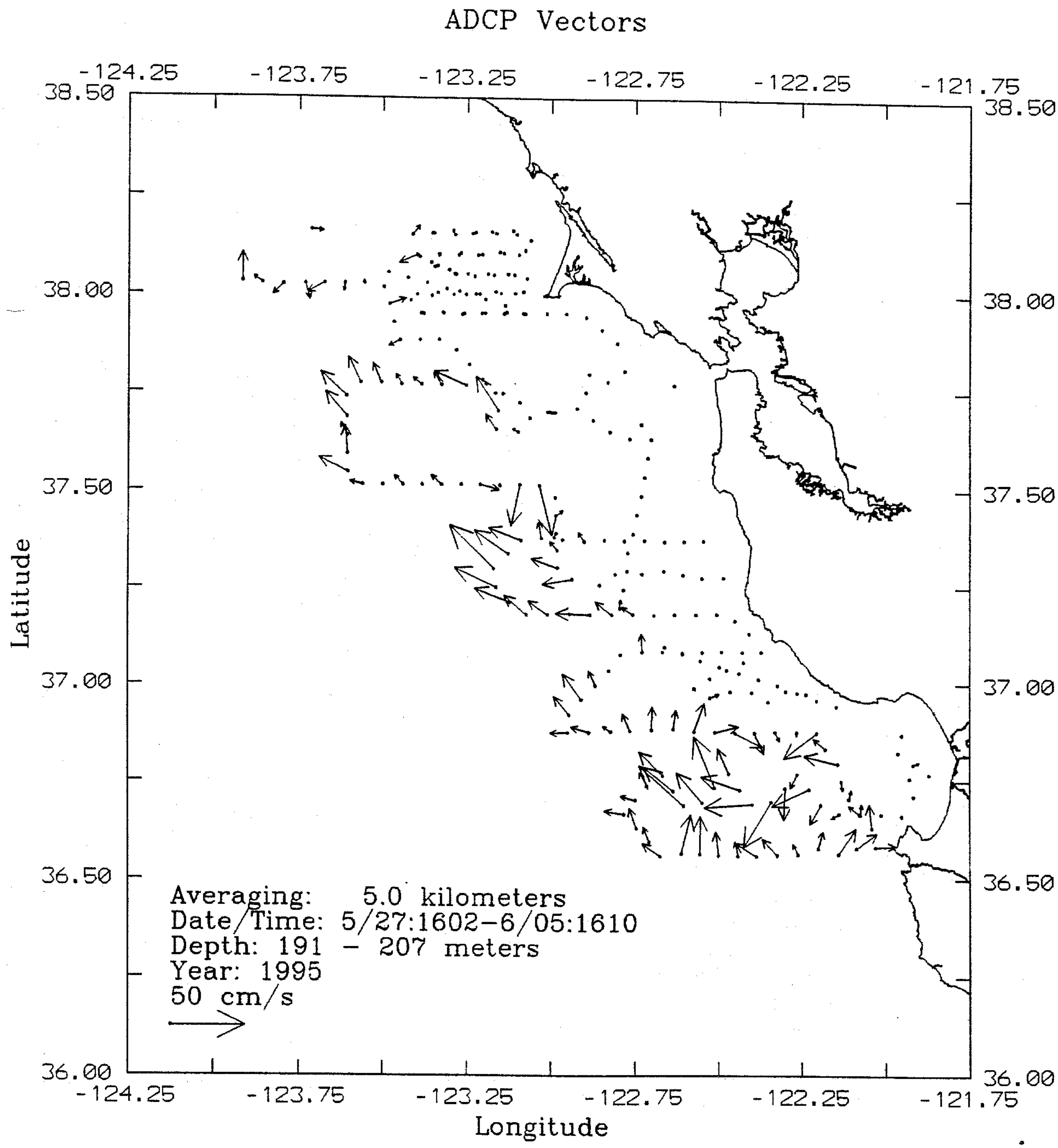

ADCP Vectors
-124.25
-123.75
-123.25
-122.75
-122.25
-121.75
38.50
38.00
37.50
37.00
36.50
36.00
Latitude
Longitude
Averaging: 5.0 kilometers
Date/Time: 5/27:1602-6/05:1610
Depth: 15 - 31 meters
Year: 1995
50 cm/s

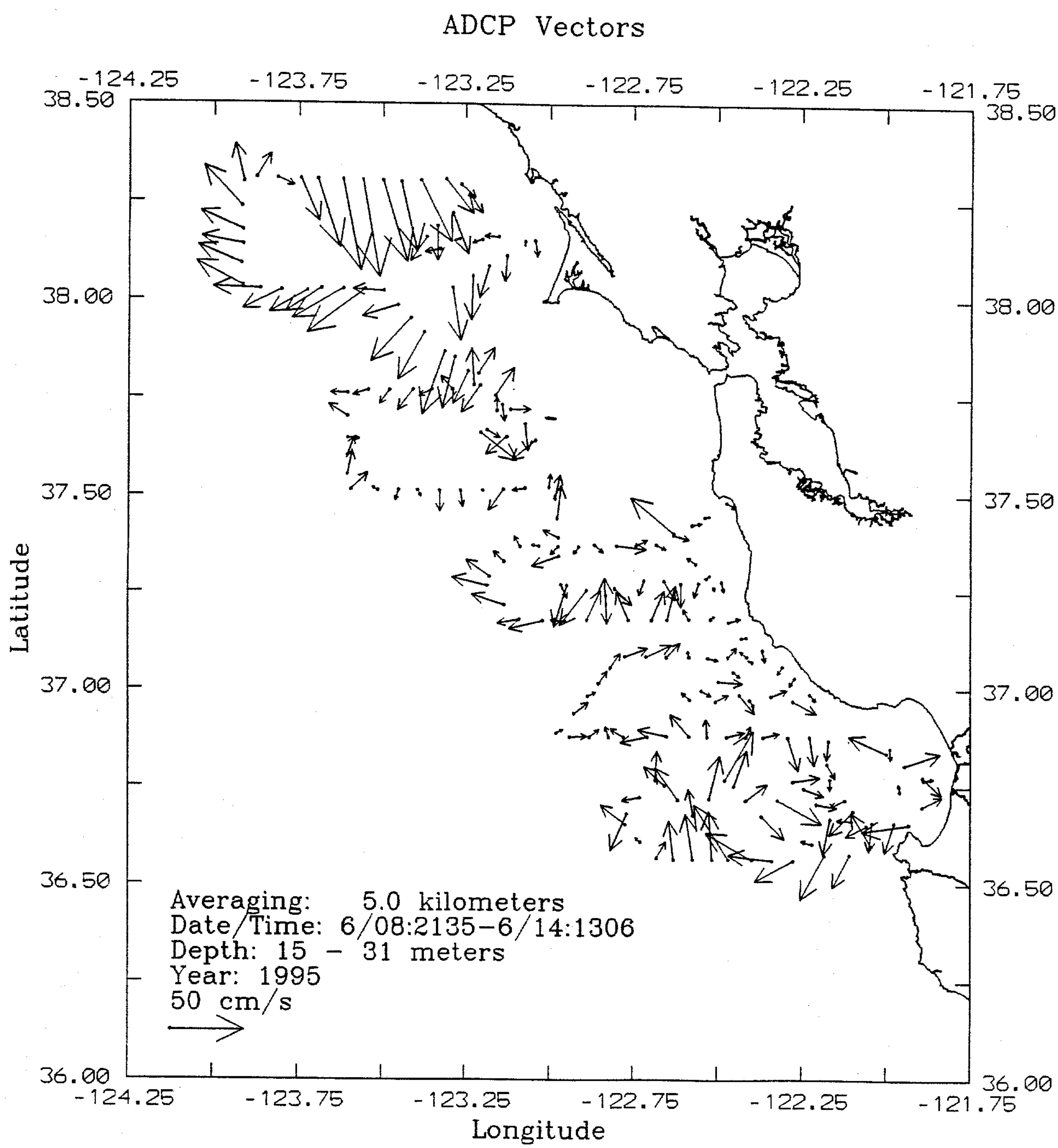


ADCP Vectors
-124.25
-123.75
-123.25
-122.75
-122.25
-121.75
38.50
38.00
37.50
37.00
36.50
36.00
Latitude
Longitude
Averaging: 5.0 kilometers
Date/Time: 5/27:1602-6/05:1610
Depth: 47 - 63 meters
Year: 1995
50 cm/s

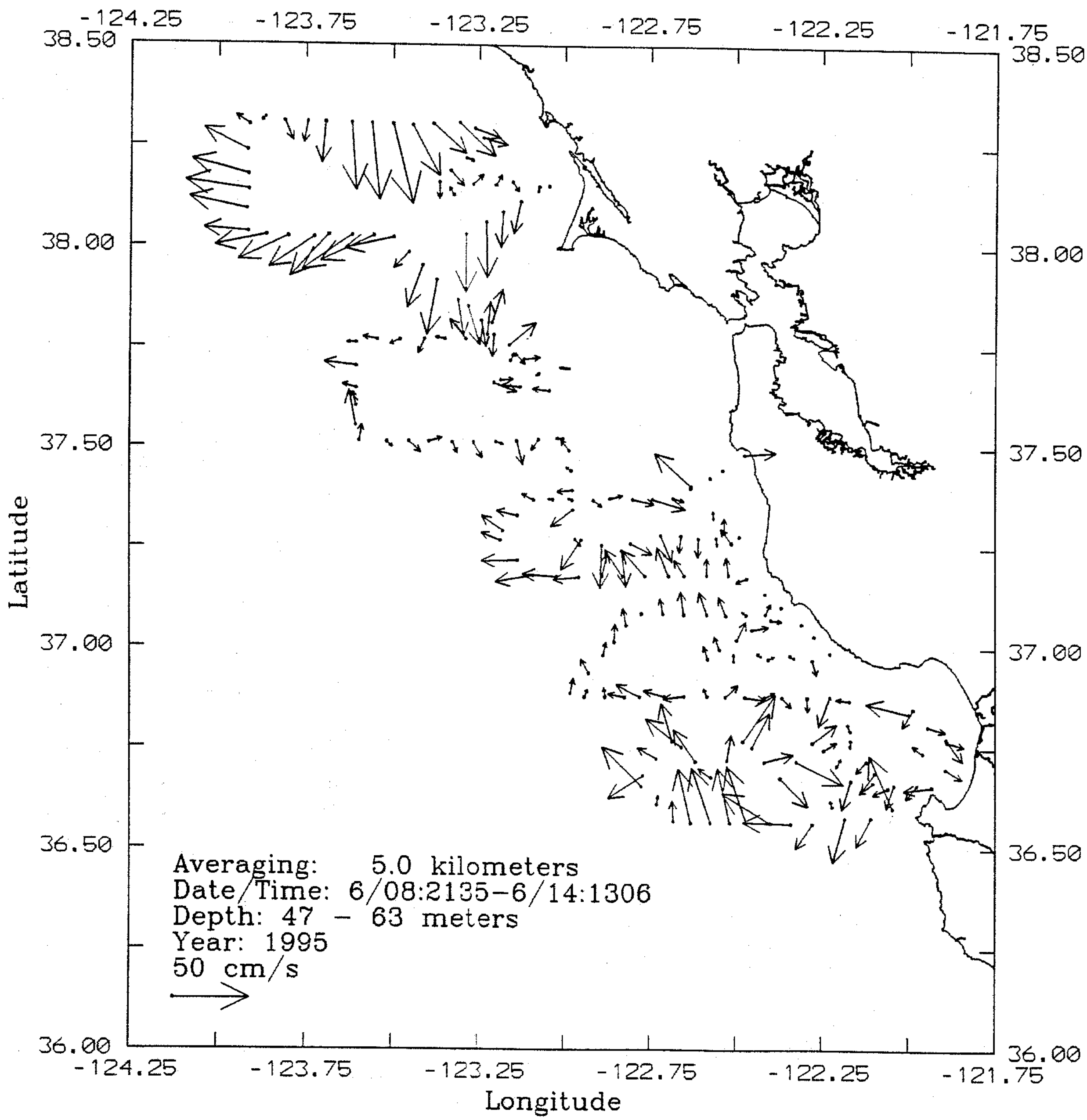
ADCP Vectors

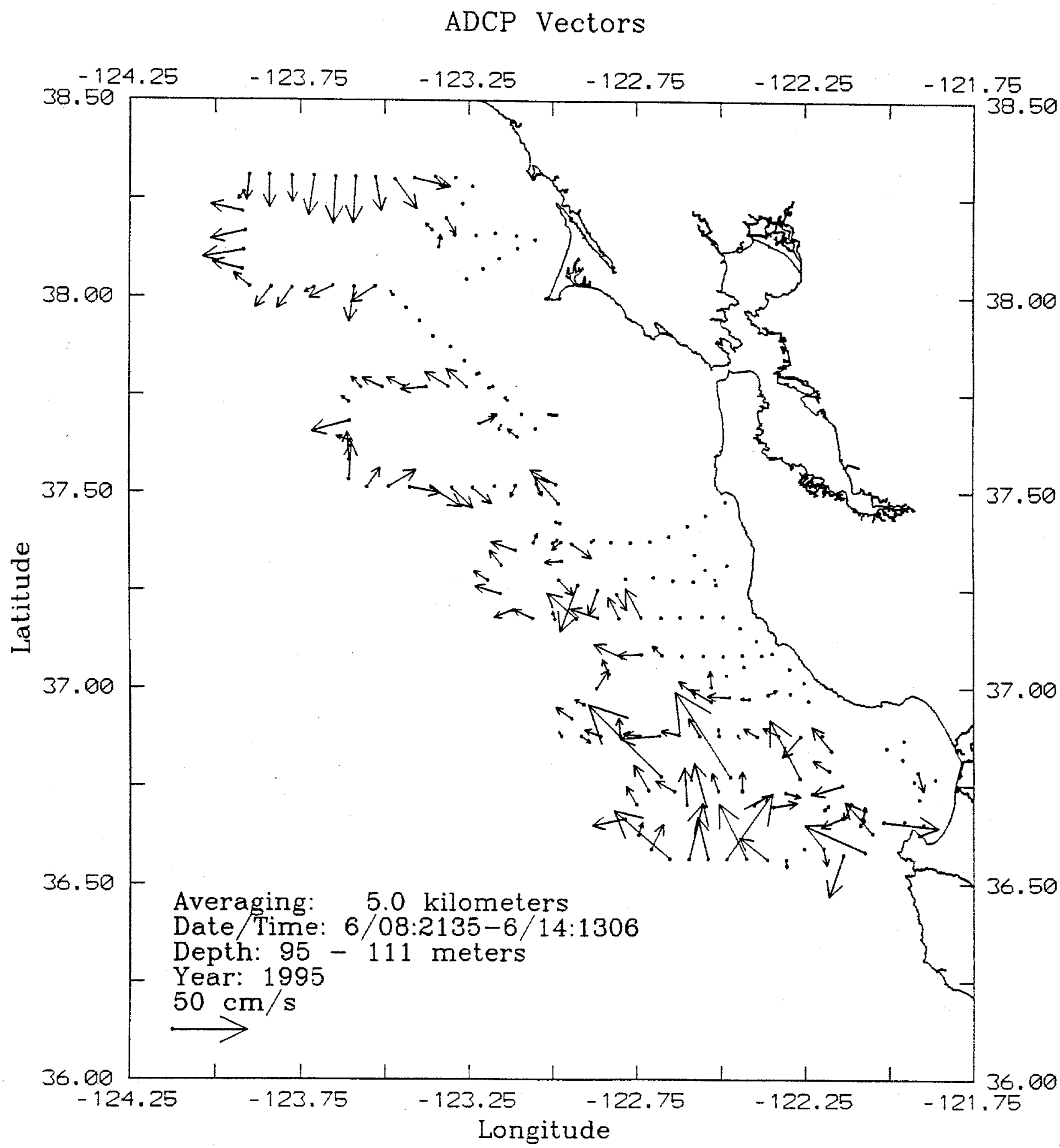


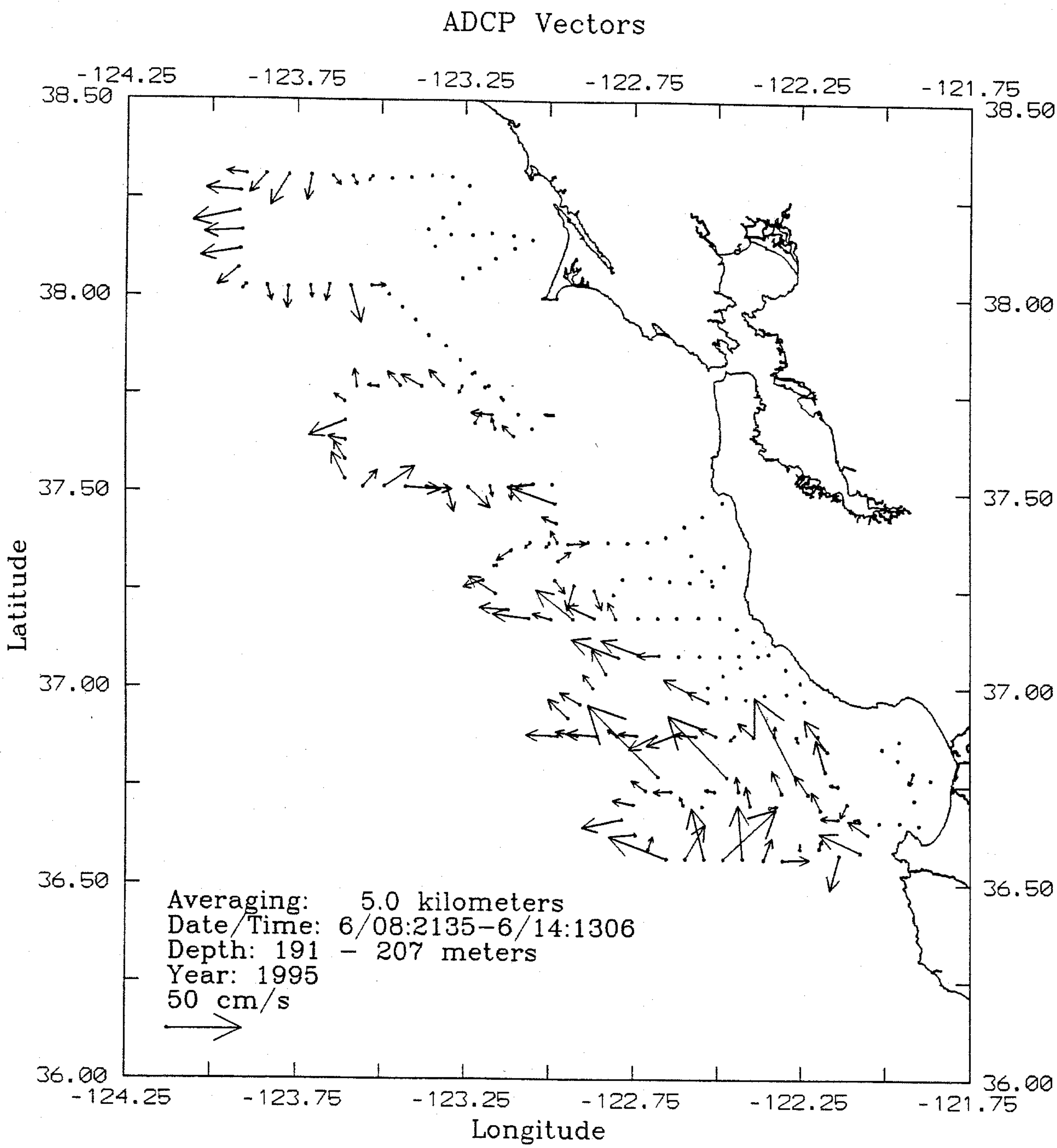

ADCP Vectors
-124.25
-123.75
-123.25
-122.75
-122.25
-121.75
38.50
38.00
37.50
37.00
36.50
36.00
Latitude
Longitude
Averaging: 5.0 kilometers
Date/Time: 5/27:1602-6/05:1610
Depth: 191 - 207 meters
Year: 1995
50 cm/s


ADCP Vectors
-124.25
-123.75
-123.25
-122.75
-122.25
-121.75
38.50
38.00
37.50
37.00
36.50
36.00
Latitude
Longitude
Averaging: 5.0 kilometers
Date/Time: 6/08:2135-6/14:1306
Depth: 15 - 31 meters
Year: 1995
50 cm/s

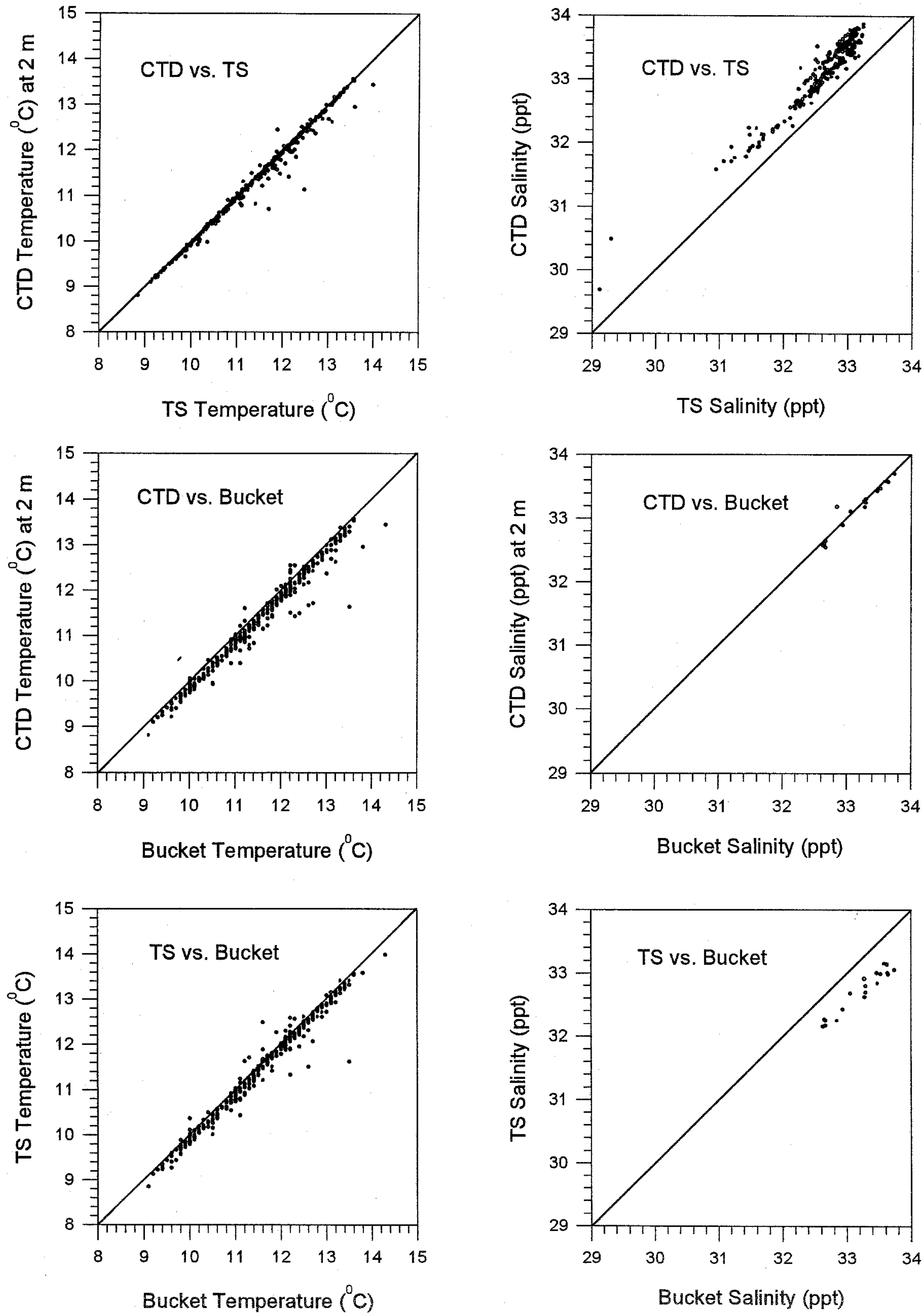
ADCP Vectors



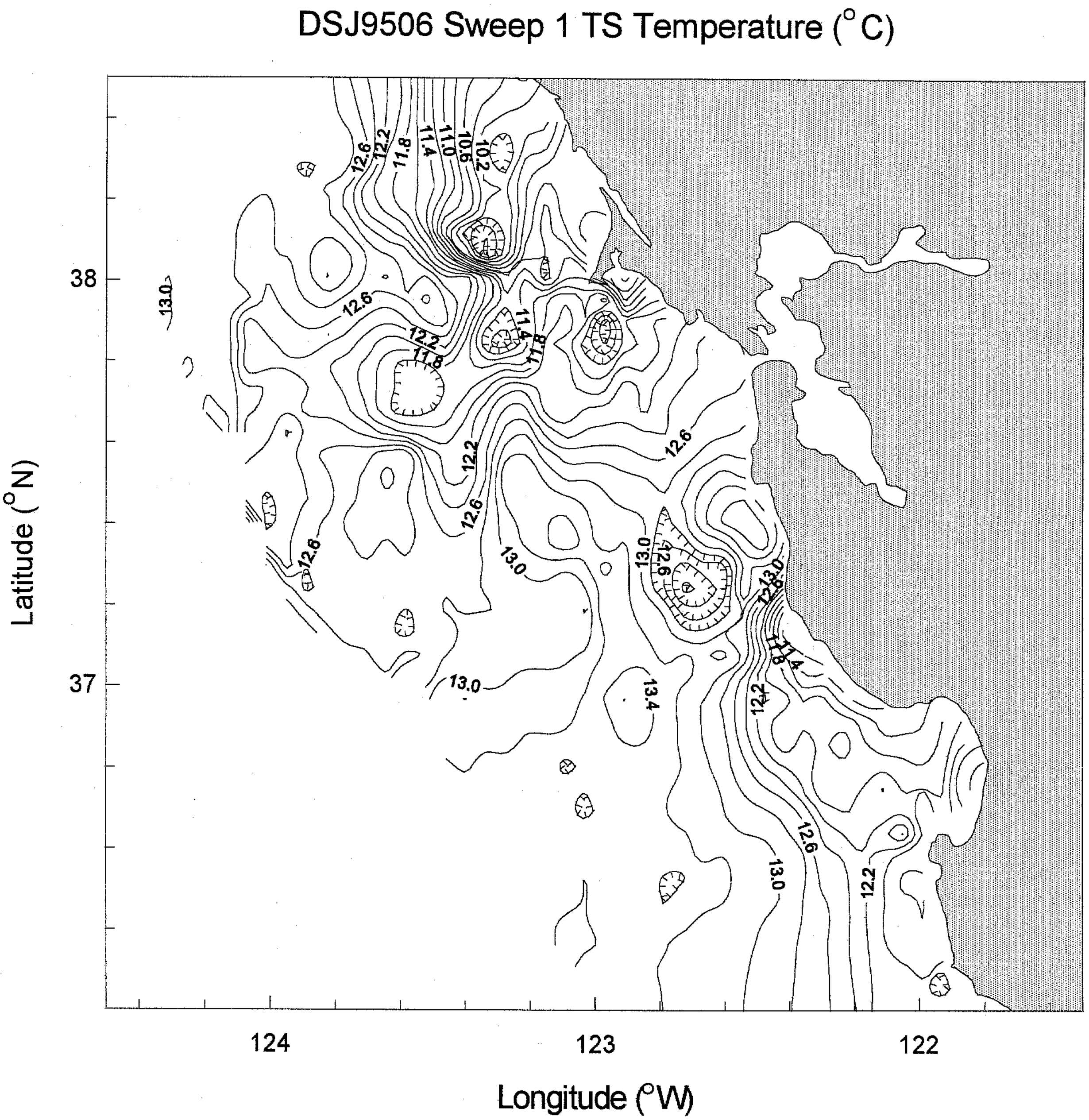

ADCP Vectors
-124.25
-123.75
-123.25
-122.75
-122.25
-121.75
38.50
38.00
37.50
37.00
36.50
36.00
Latitude
Longitude
Averaging: 5.0 kilometers
Date/Time: 6/08:2135-6/14:1306
Depth: 95 - 111 meters
Year: 1995
50 cm/s


ADCP Vectors
-124.25
-123.75
-123.25
-122.75
-122.25
-121.75
38.50
38.00
37.50
37.00
36.50
36.00
Latitude
Longitude
Averaging: 5.0 kilometers
Date/Time: 6/08:2135-6/14:1306
Depth: 191 - 207 meters
Year: 1995
50 cm/s

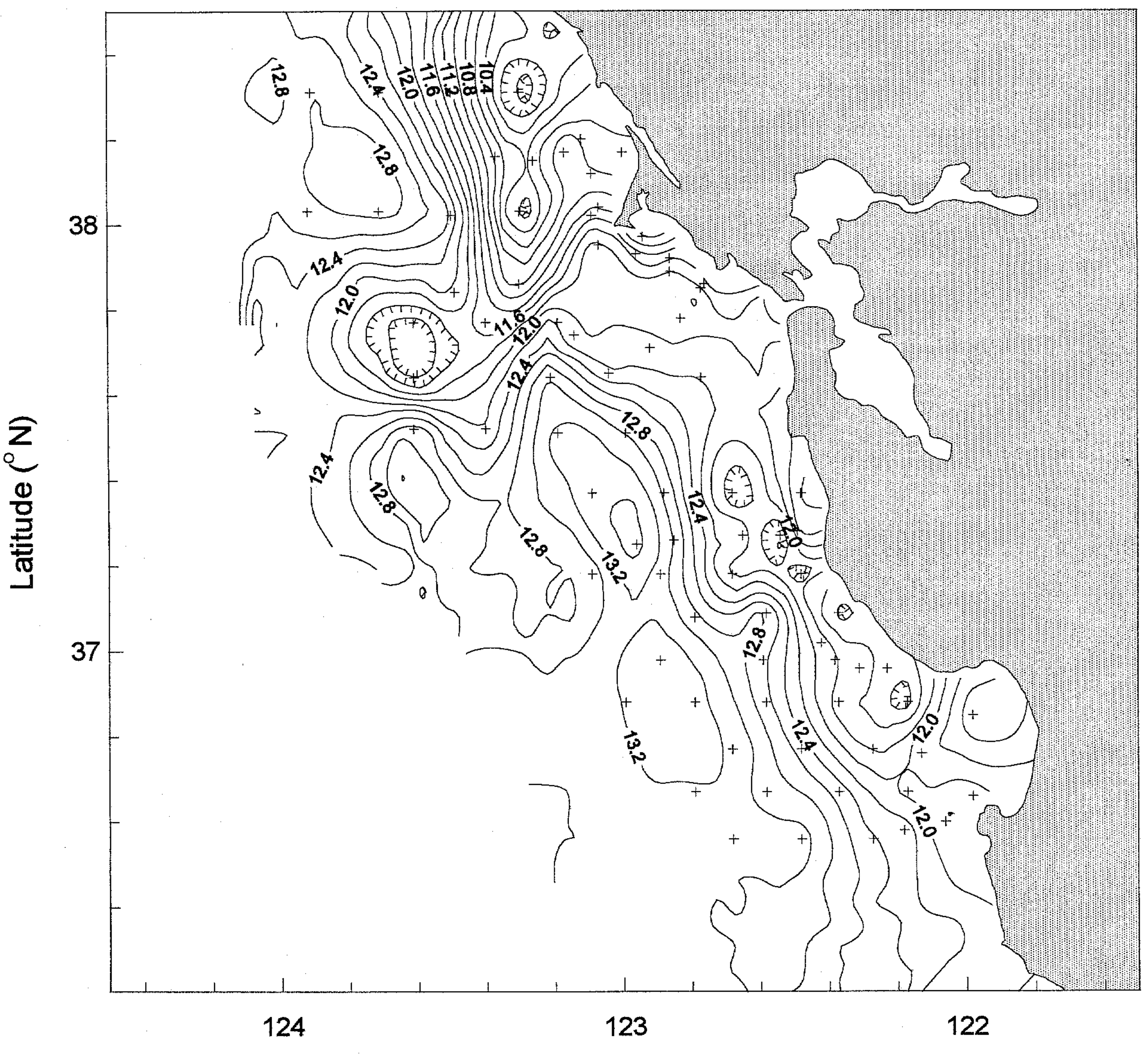
APPENDIX 6: REGRESSION COMPARISONS OF CTD, TS, AND BUCKET FOR DSJ9506


CTD vs. TS
CTD Temperature (°C) at 2 m
TS Temperature (°C)
CTD vs. TS
CTD Salinity (ppt)
TS Salinity (ppt)
CTD vs. Bucket
CTD Temperature (°C) at 2 m
Bucket Temperature (°C)
CTD vs. Bucket
CTD Salinity (ppt) at 2 m
Bucket Salinity (ppt)
TS vs. Bucket
TS Temperature (°C)
Bucket Temperature (°C)
TS vs. Bucket
TS Salinity (ppt)
Bucket Salinity (ppt)

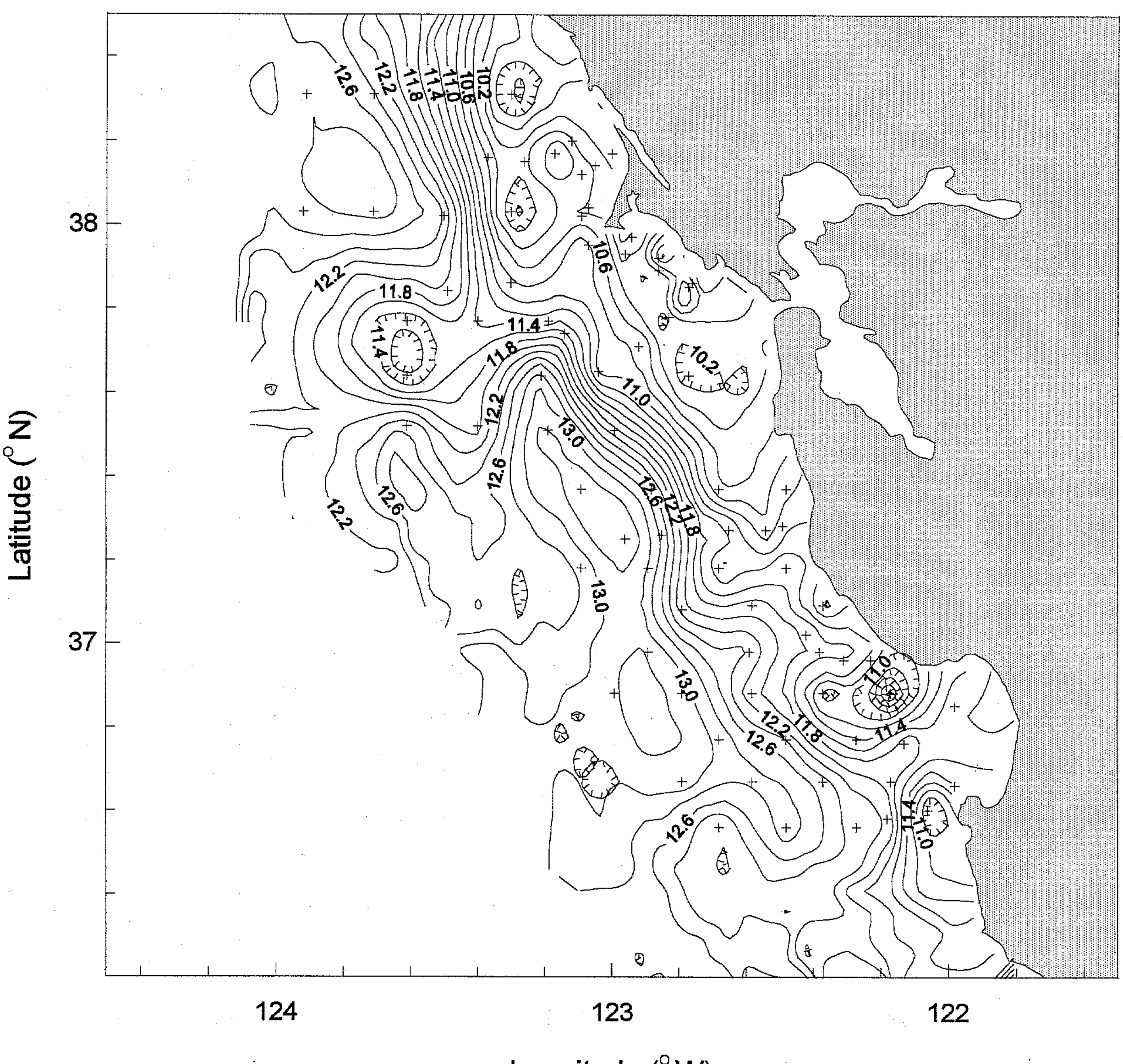
APPENDIX 7.1: HORIZONTAL MAPS OF CTD AND TS FOR DSJ9506, SWEEP 1


DSJ9506 Sweep 1 TS Temperature (°C)
Latitude (°N)
Longitude (°W)
38
37
124
123
122

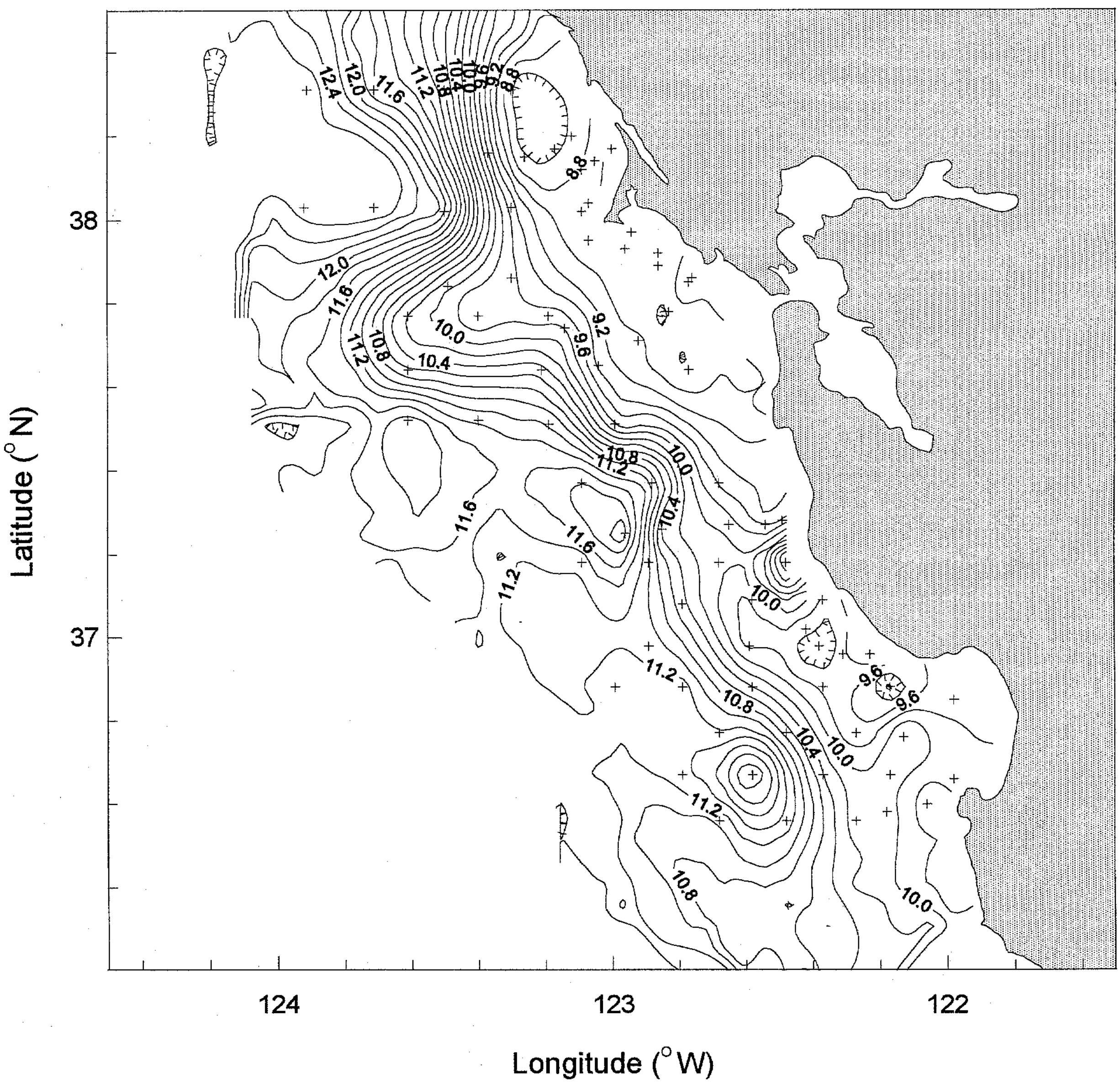
DSJ9506 Sweep 1 Temperature (°C) at 2 m

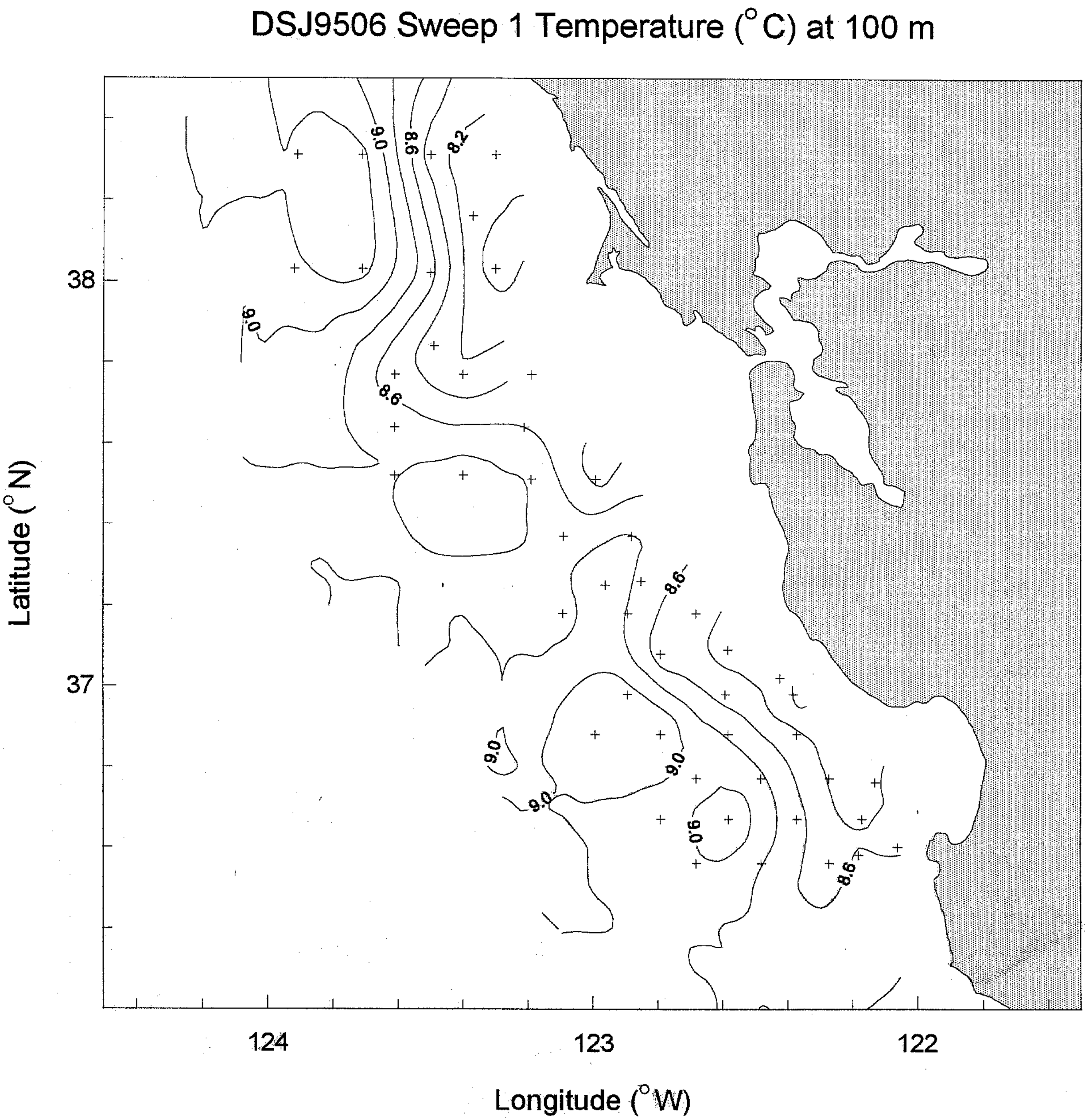


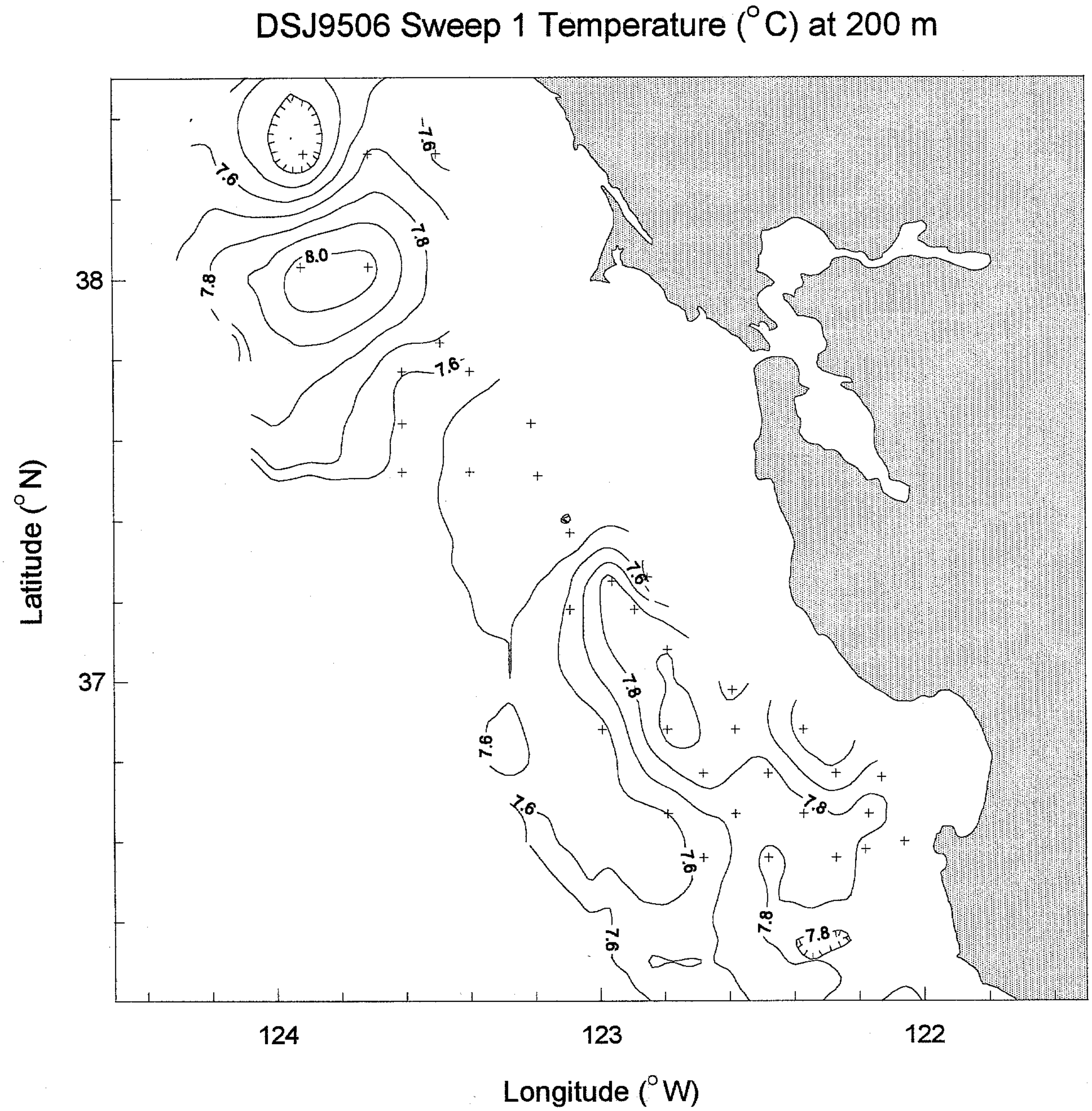
DSJ9506 Sweep 1 Temperature (°C) at 10 m



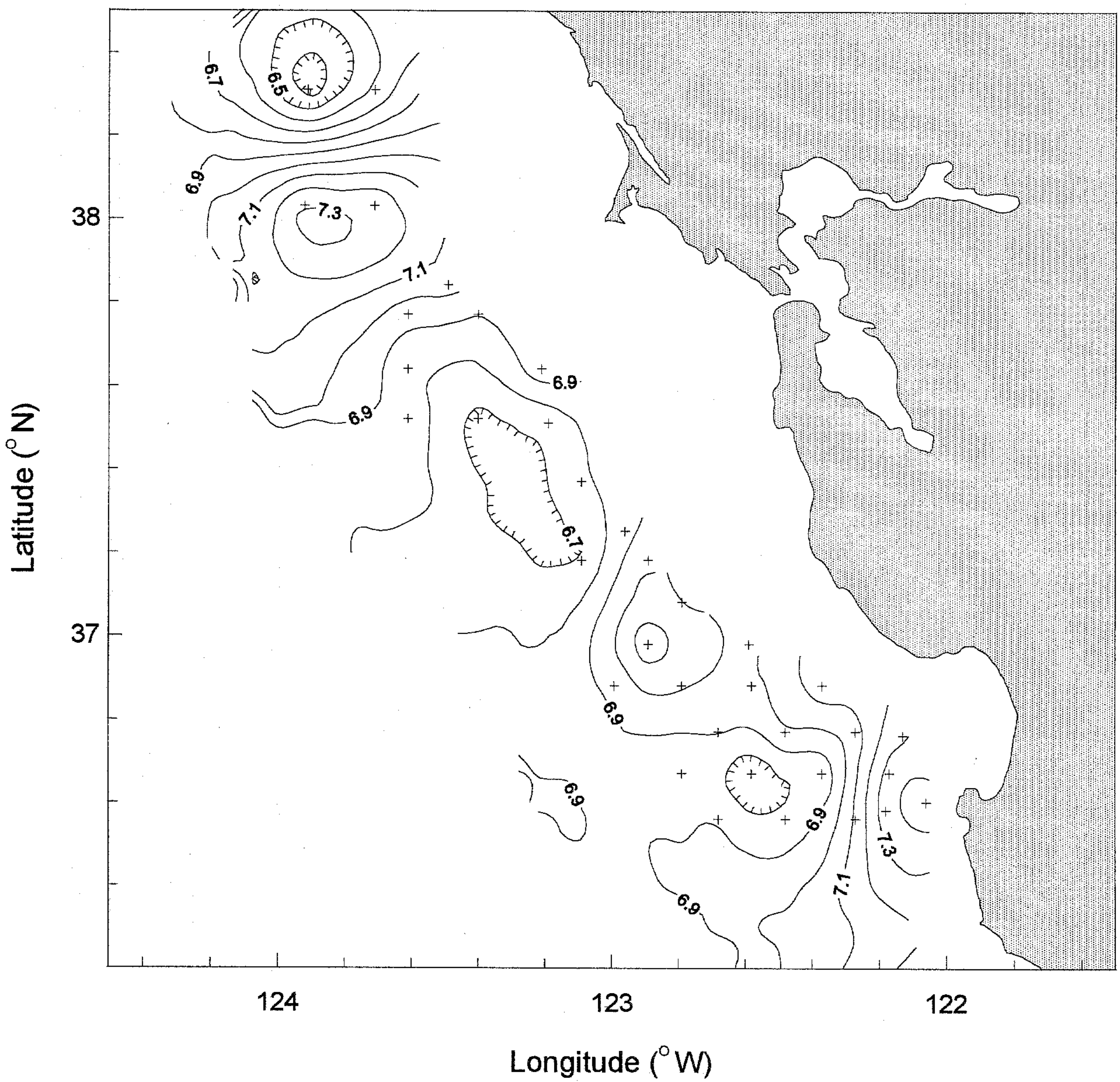
DSJ9506 Sweep 1 Temperature (°C) at 30 m

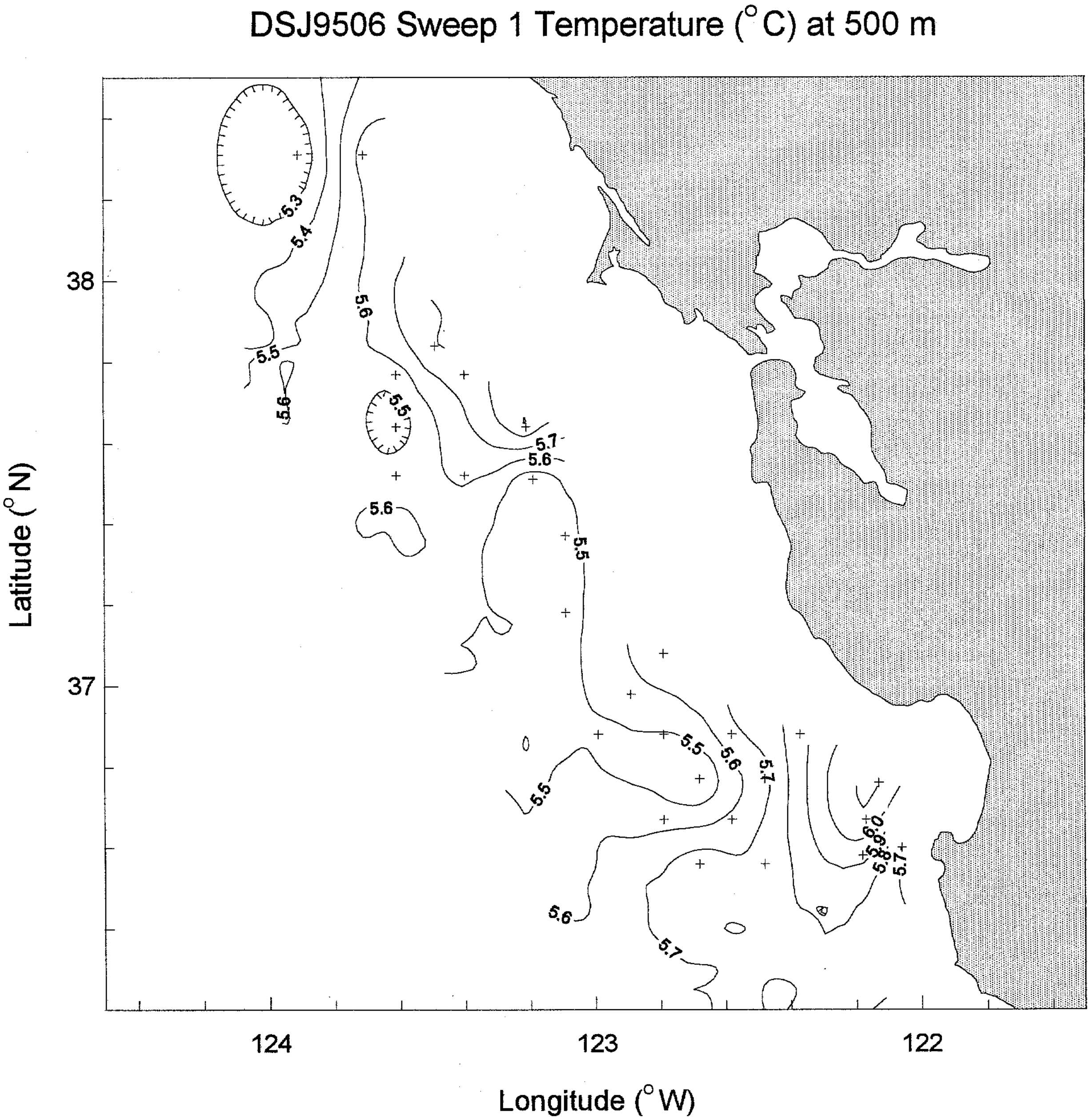


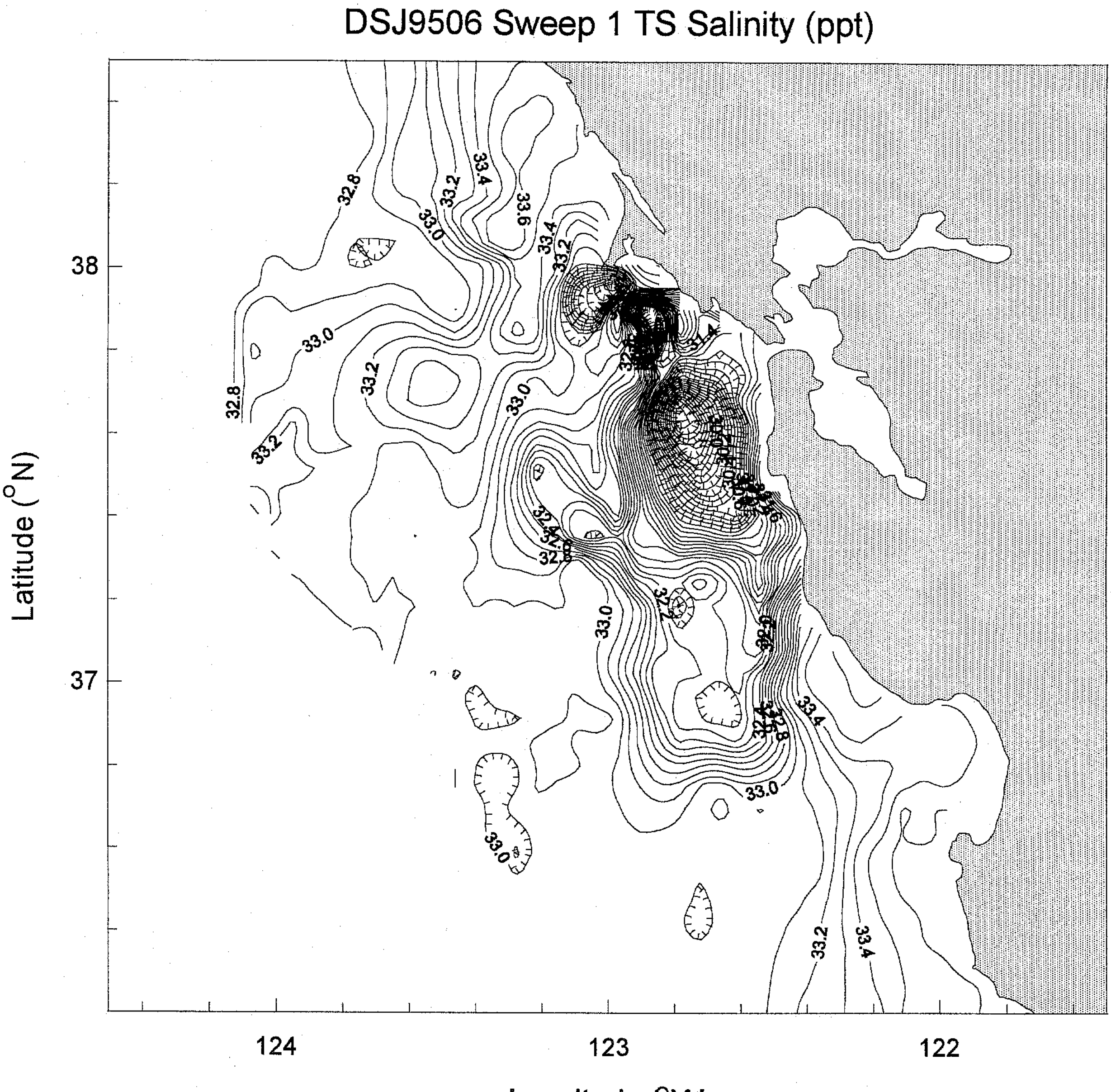

DSJ9506 Sweep 1 Temperature (°C) at 100 m
Latitude (°N)
38
37
Longitude (°W)
124
123
122
9.0
8.6
8.2
9.0
8.6
8.6
9.0
9.0
9.0
9.0
8.6


DSJ9506 Sweep 1 Temperature (°C) at 200 m
Latitude (°N)
Longitude (°W)
38
37
124
123
122
7.6
7.8
8.0

DSJ9506 Sweep 1 Temperature ($^{\circ}$C) at 300 m

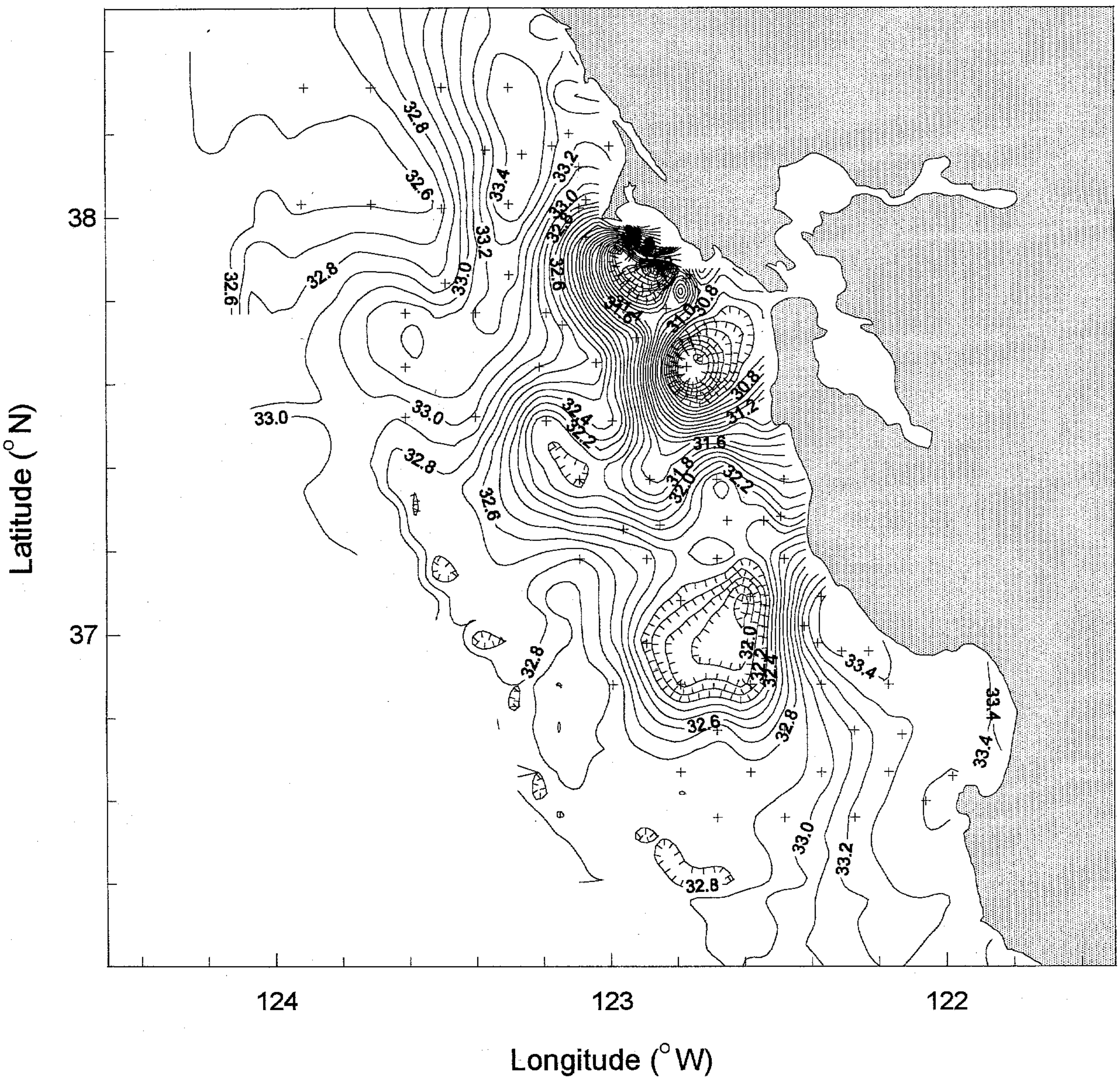



DSJ9506 Sweep 1 Temperature (°C) at 500 m
Latitude (°N)
38
37
Longitude (°W)
124
123
122
5.3
5.4
5.5
5.6
5.7

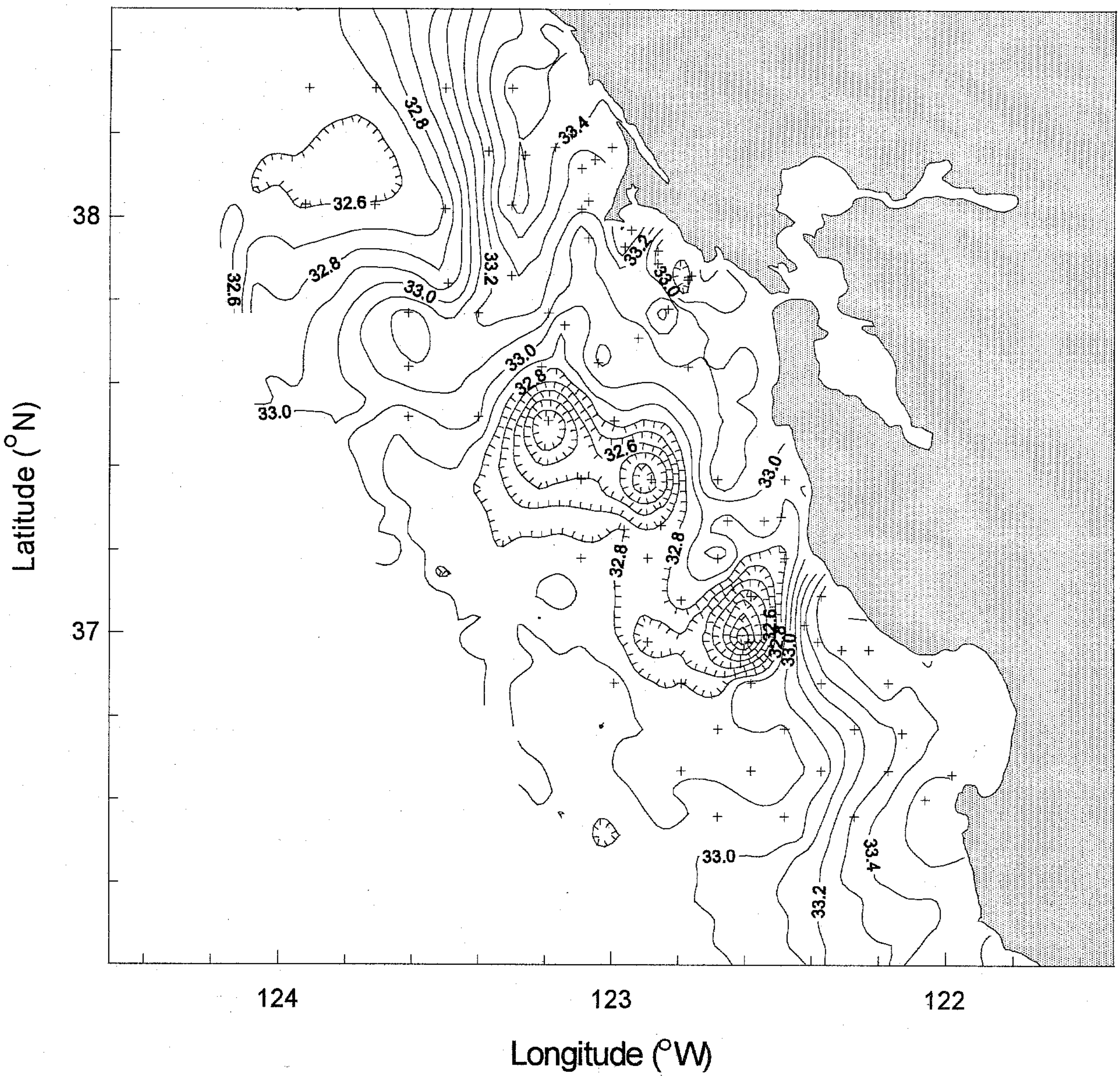


DSJ9506 Sweep 1 TS Salinity (ppt)
Latitude (°N)
Longitude (°W)
38
37
124
123
122
32.8
33.0
33.2
33.4
33.6

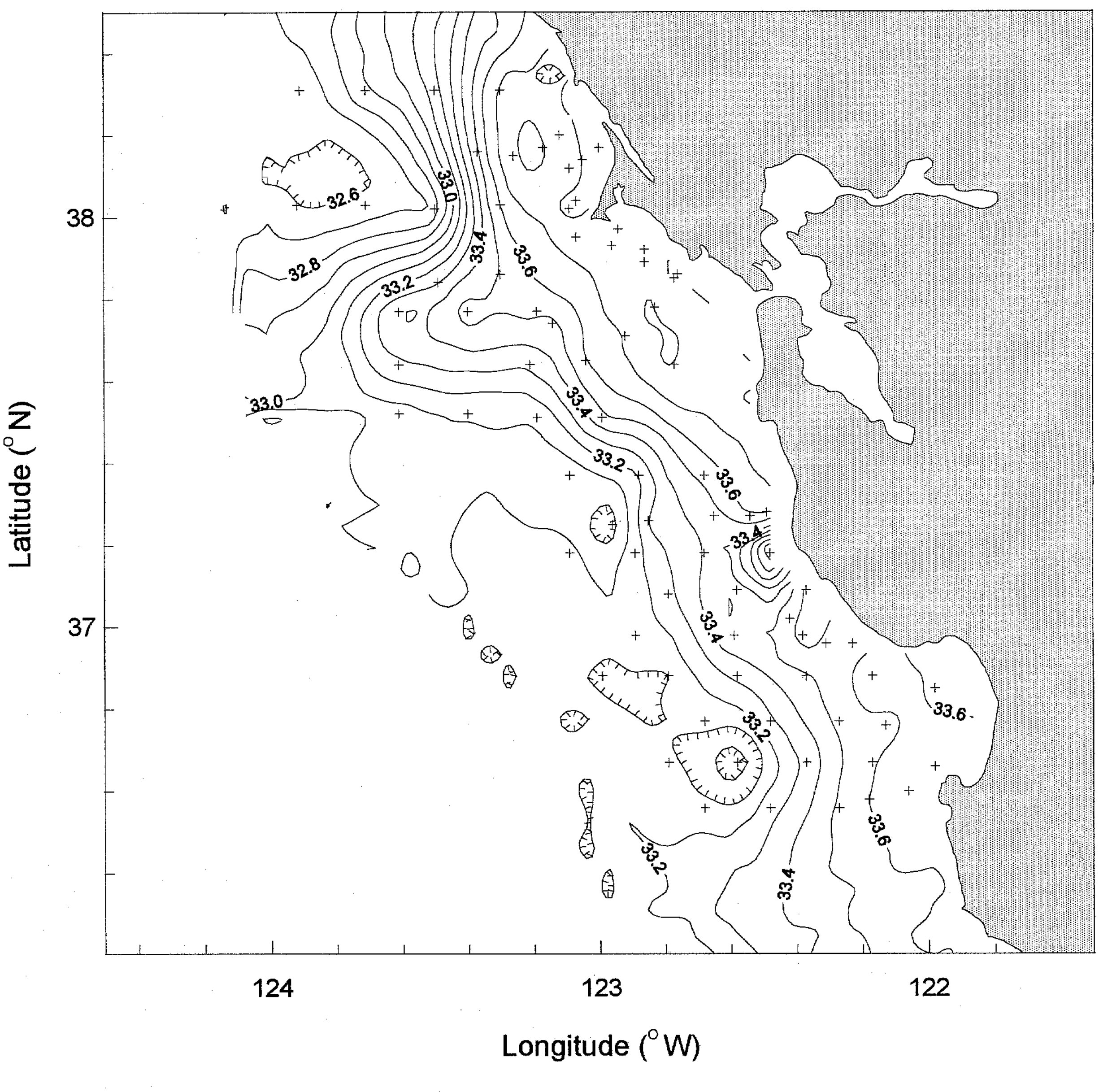
DSJ9506 Sweep 1 Salinity (ppt) at 2 m

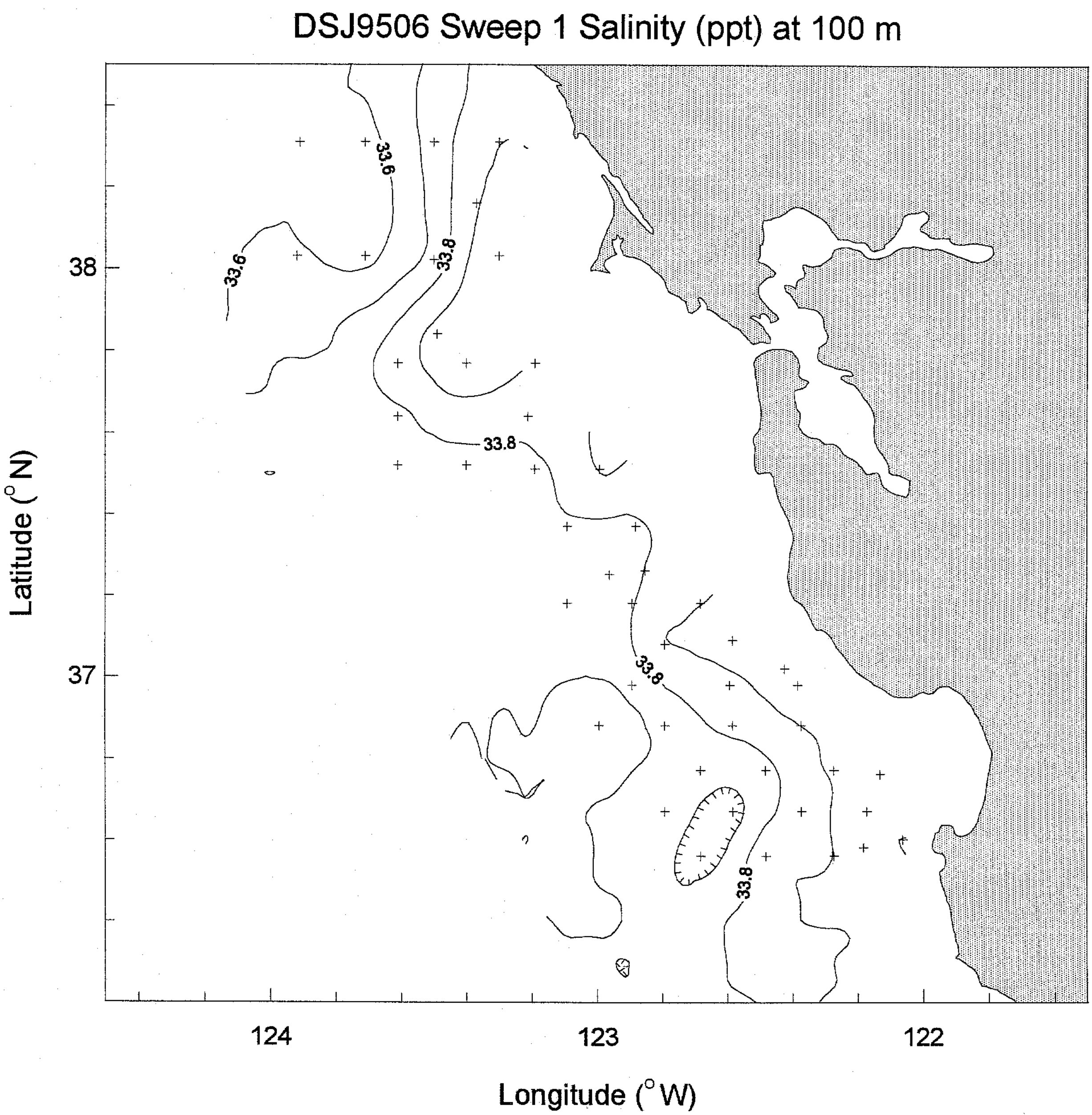


DSJ9506 Sweep 1 Salinity (ppt) at 10 m

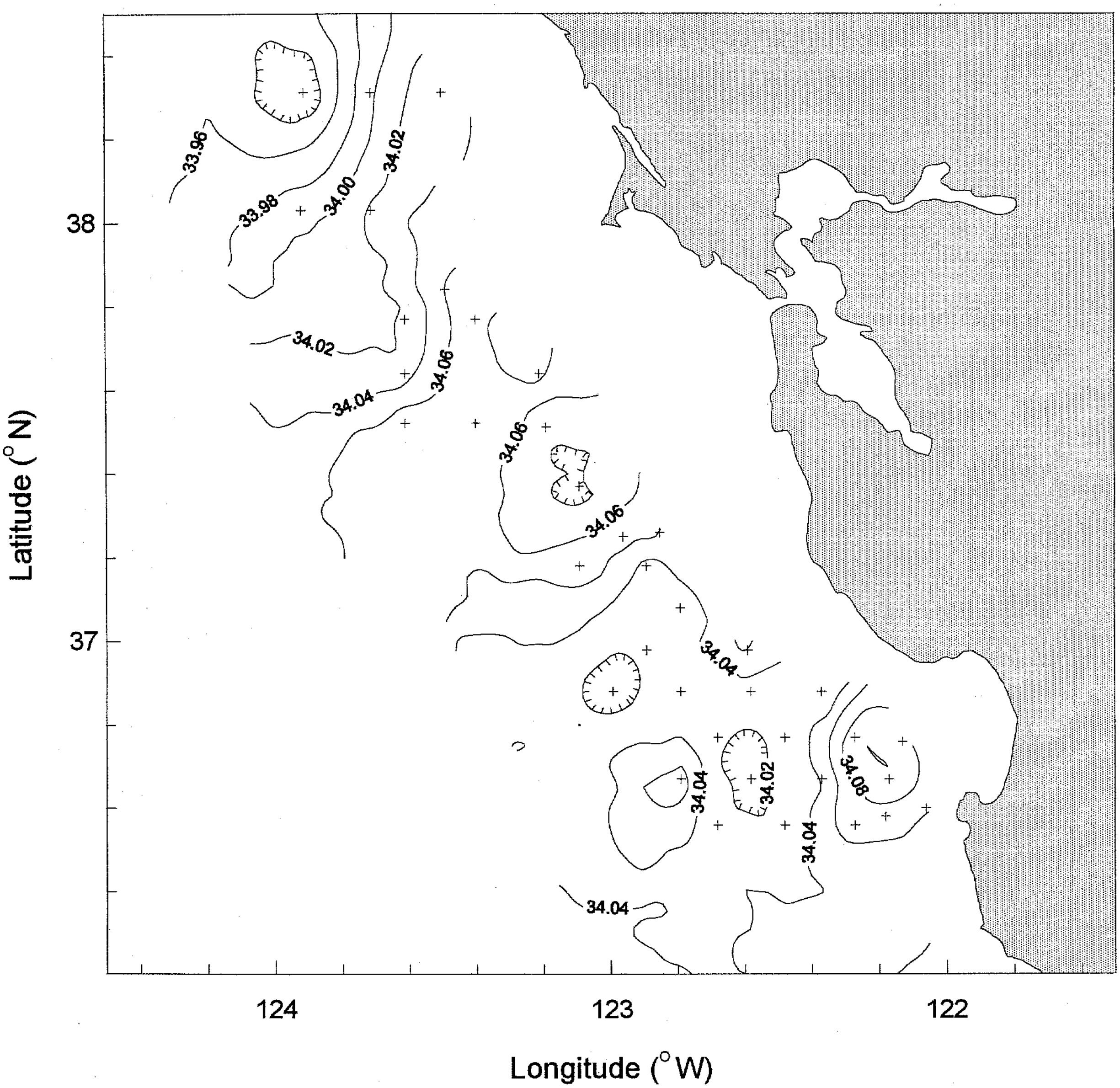


DSJ9506 Sweep 1 Salinity (ppt) at 30 m

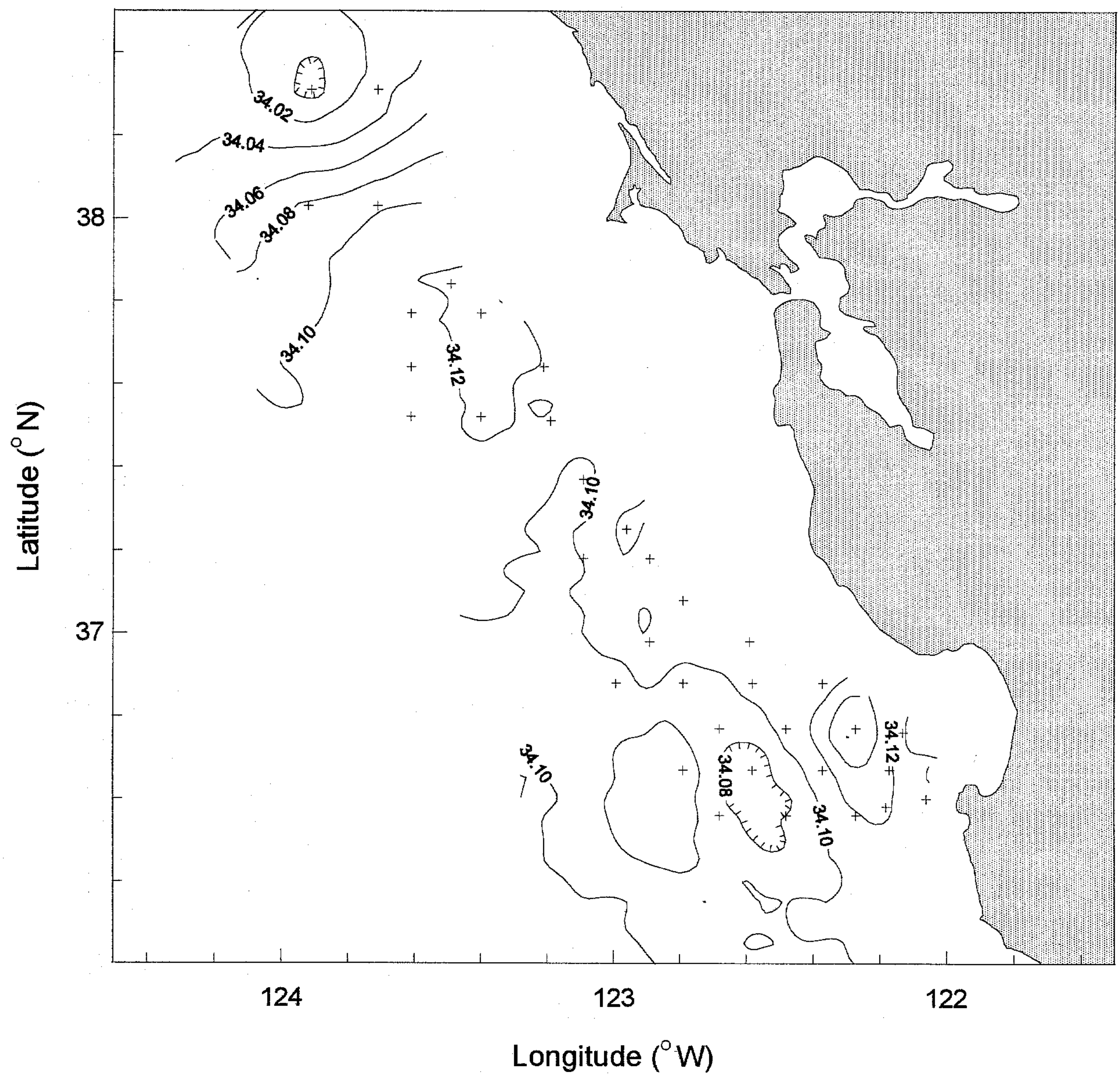


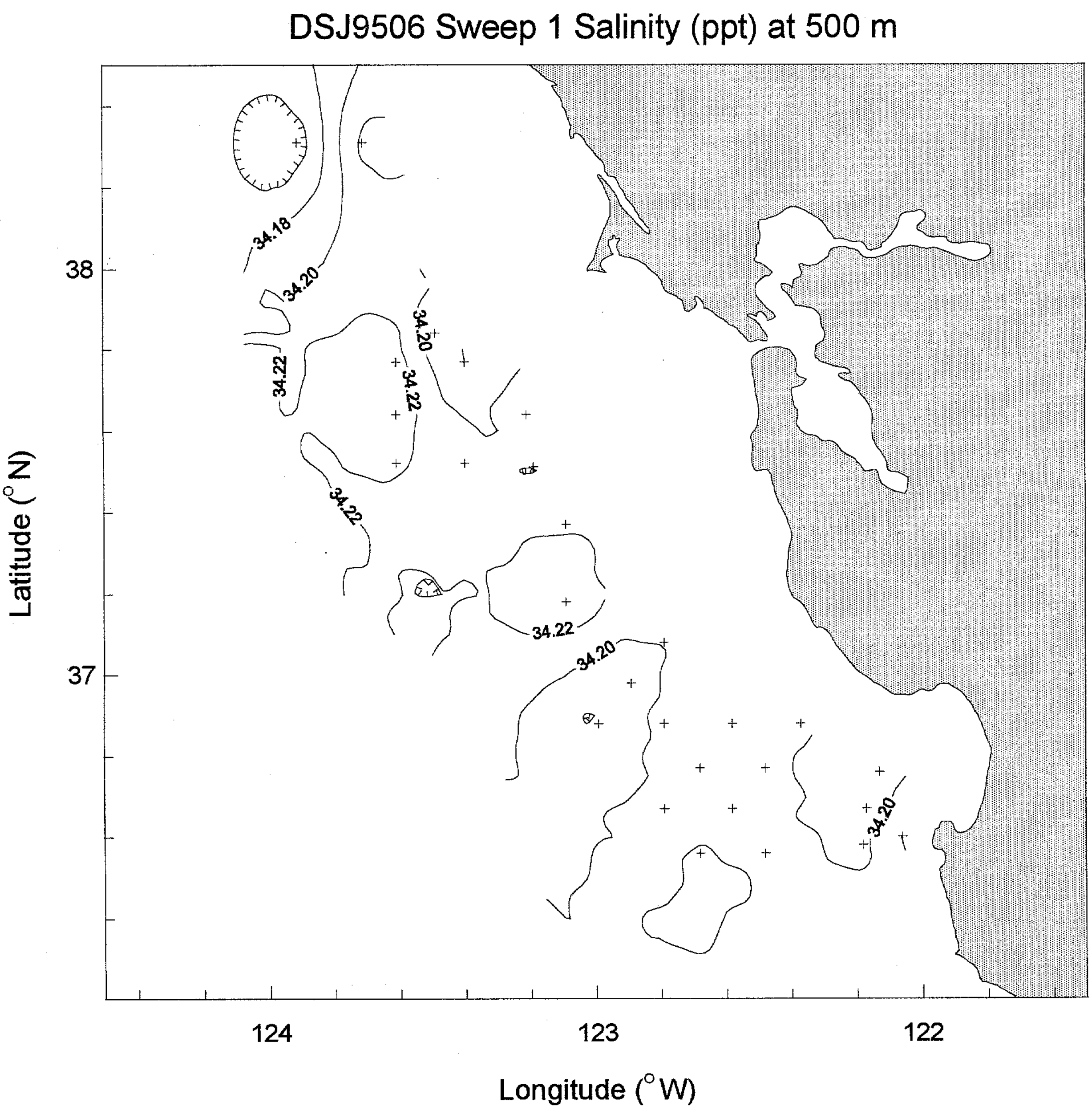

DSJ9506 Sweep 1 Salinity (ppt) at 100 m
33.6
33.6
33.8
33.8
33.8
33.8
38
37
Latitude (°N)
124
123
122
Longitude (°W)

DSJ9506 Sweep 1 Salinity (ppt) at 200 m

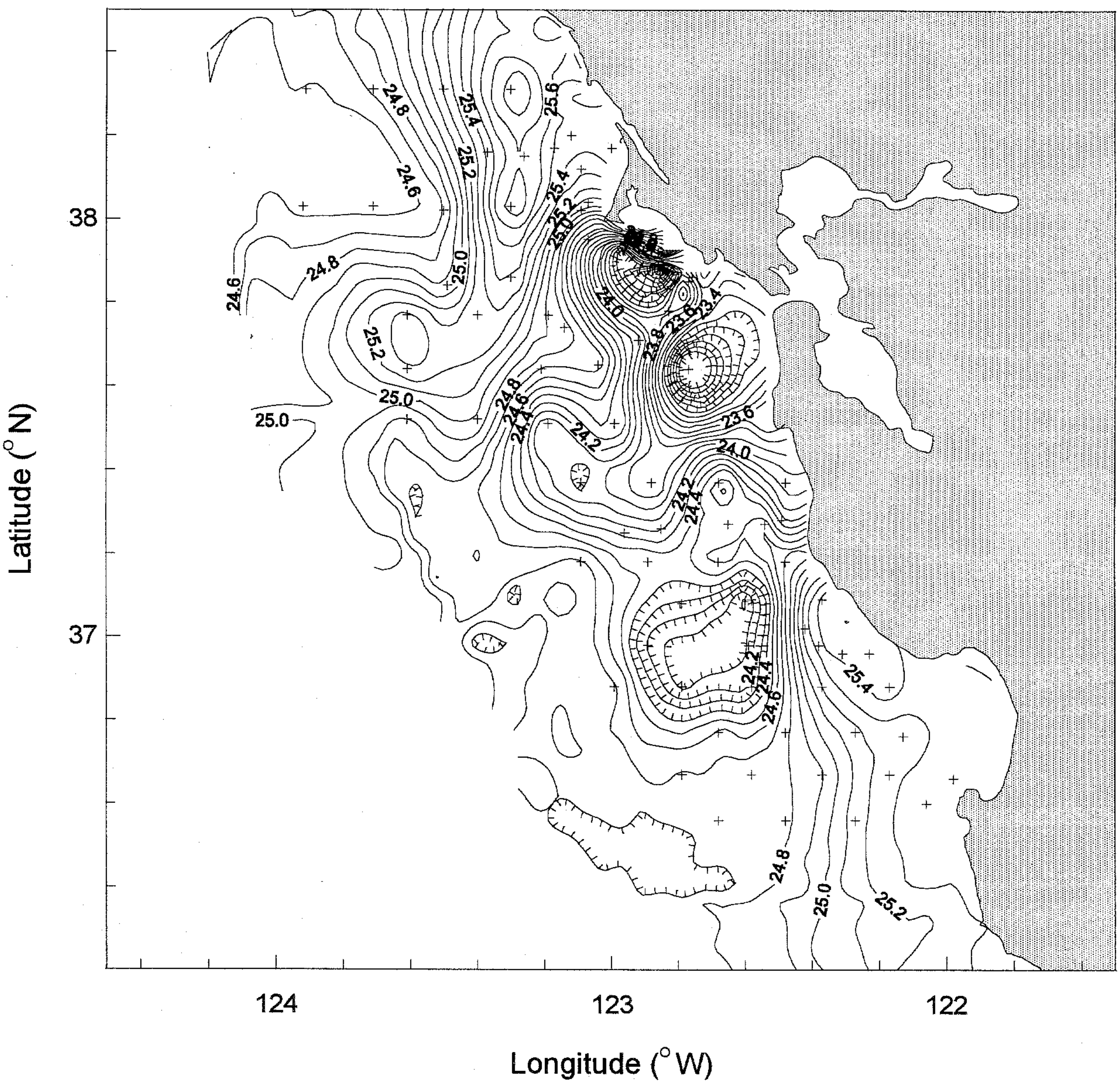


DSJ9506 Sweep 1 Salinity (ppt) at 300 m

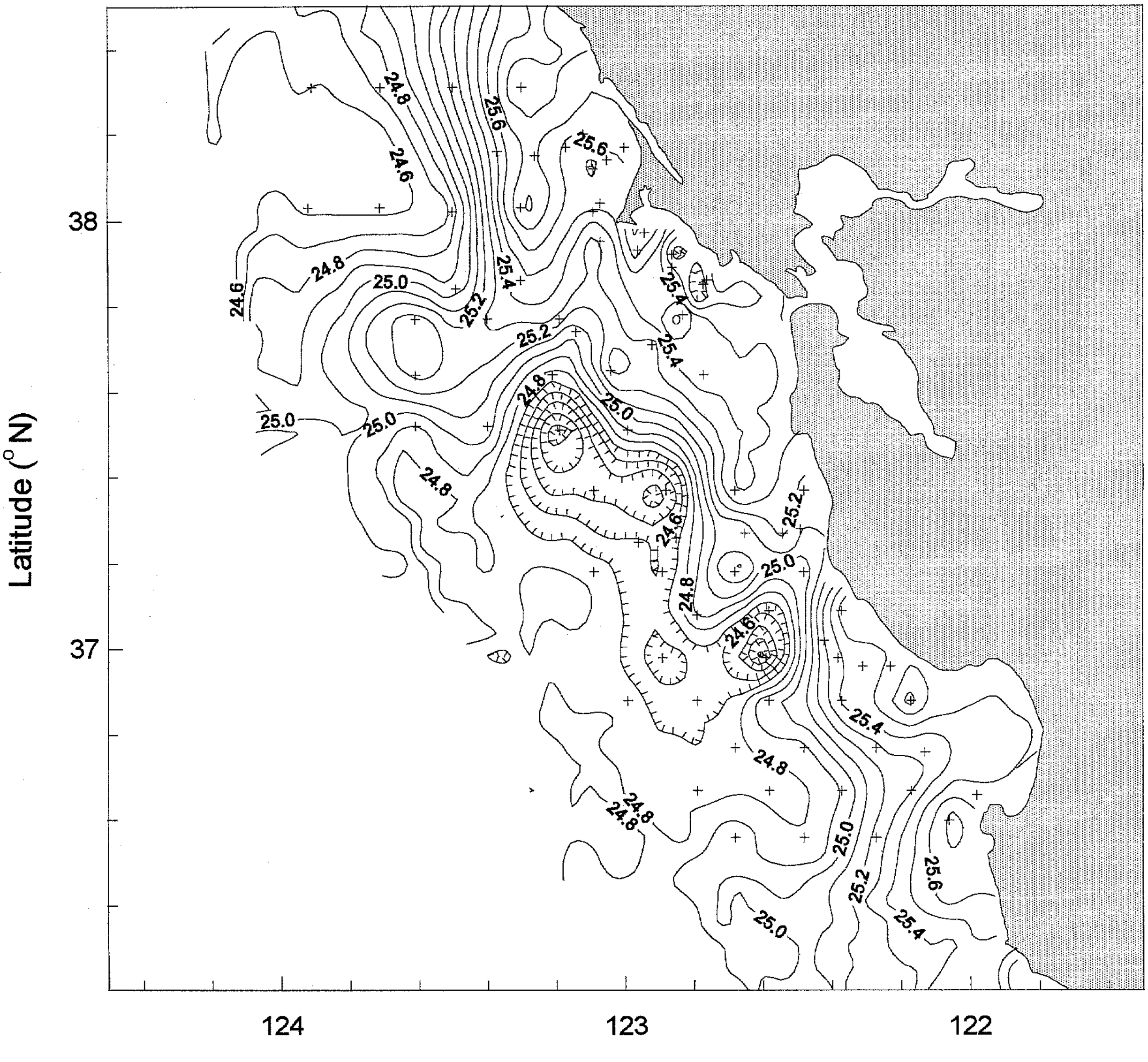


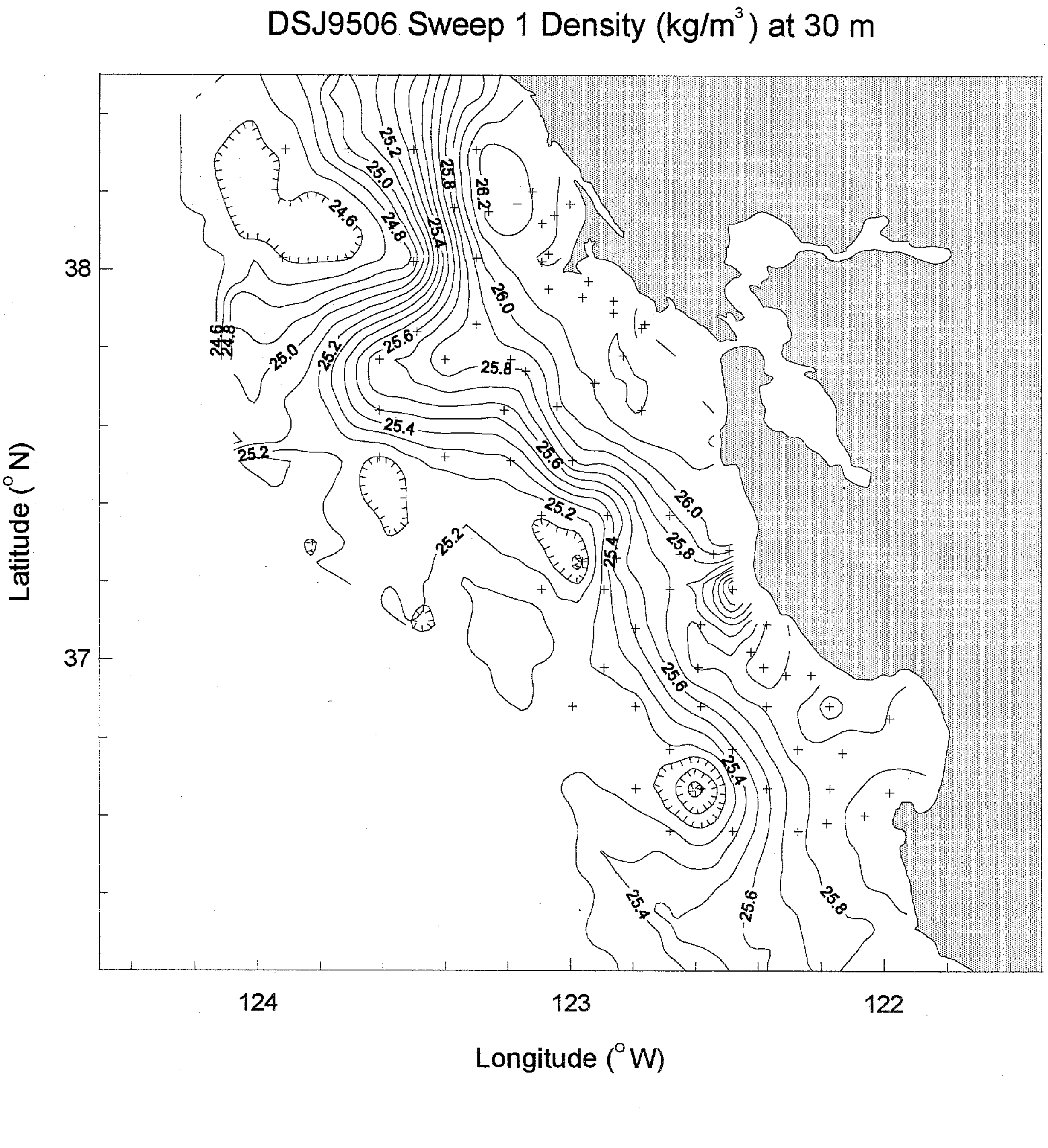

DSJ9506 Sweep 1 Salinity (ppt) at 500 m
34.18
34.20
34.22
34.20
34.22
34.22
34.22
34.20
34.20
38
37
124
123
122
Latitude (°N)
Longitude (°W)

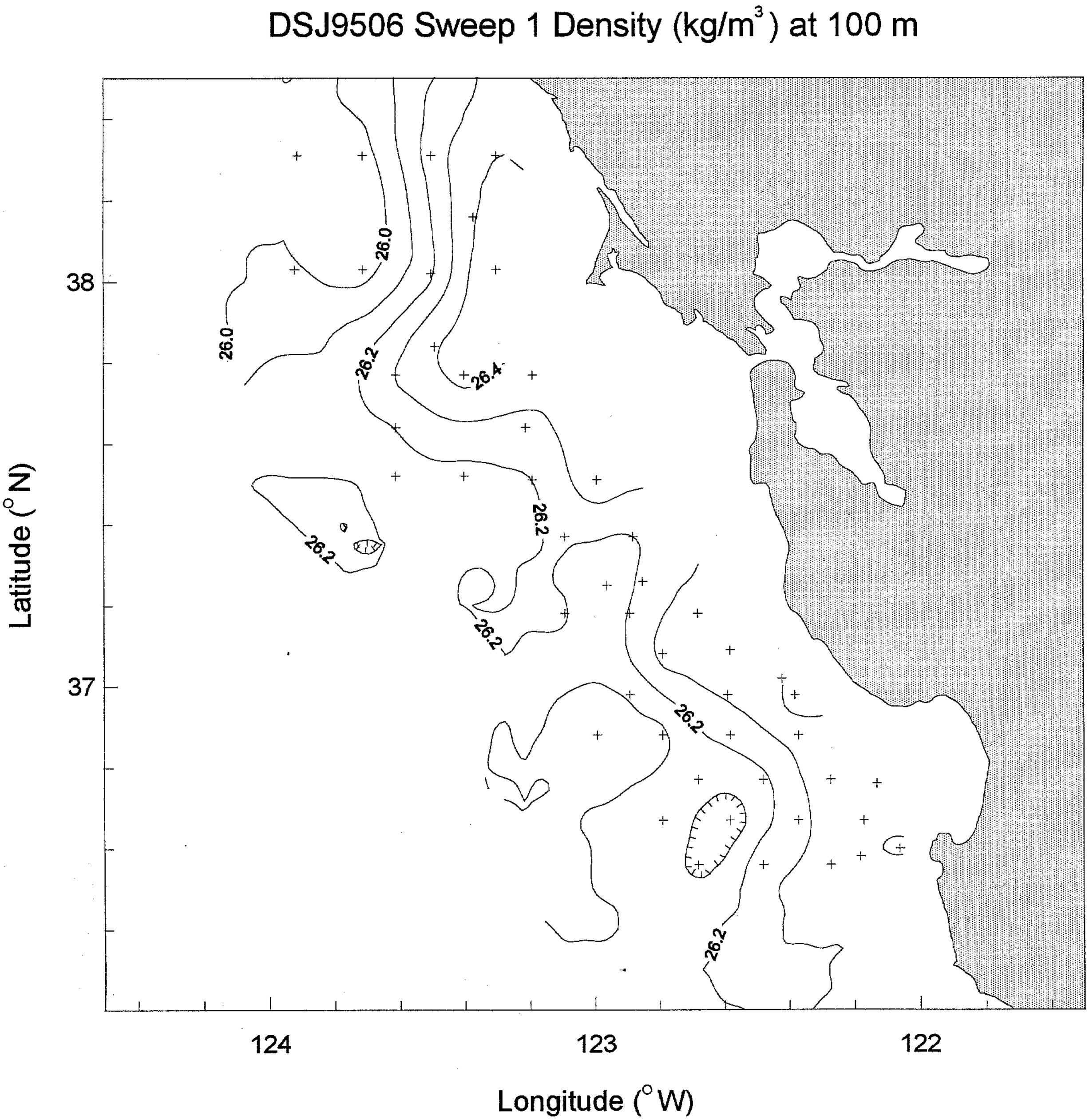
DSJ9506 Sweep 1 Density (kg/m^3) at 2 m



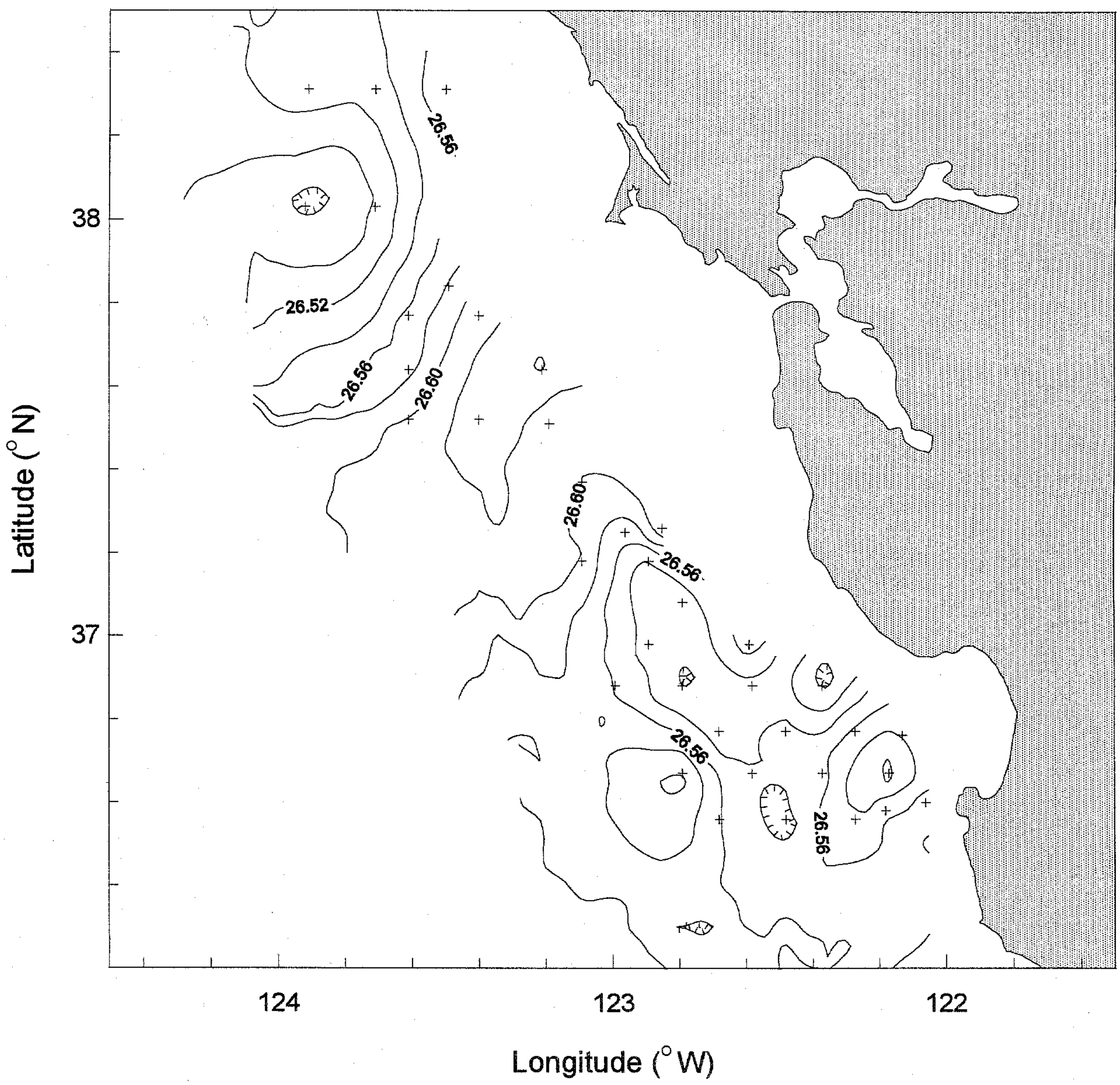
DSJ9506 Sweep 1 Density (kg/m^3) at 10 m



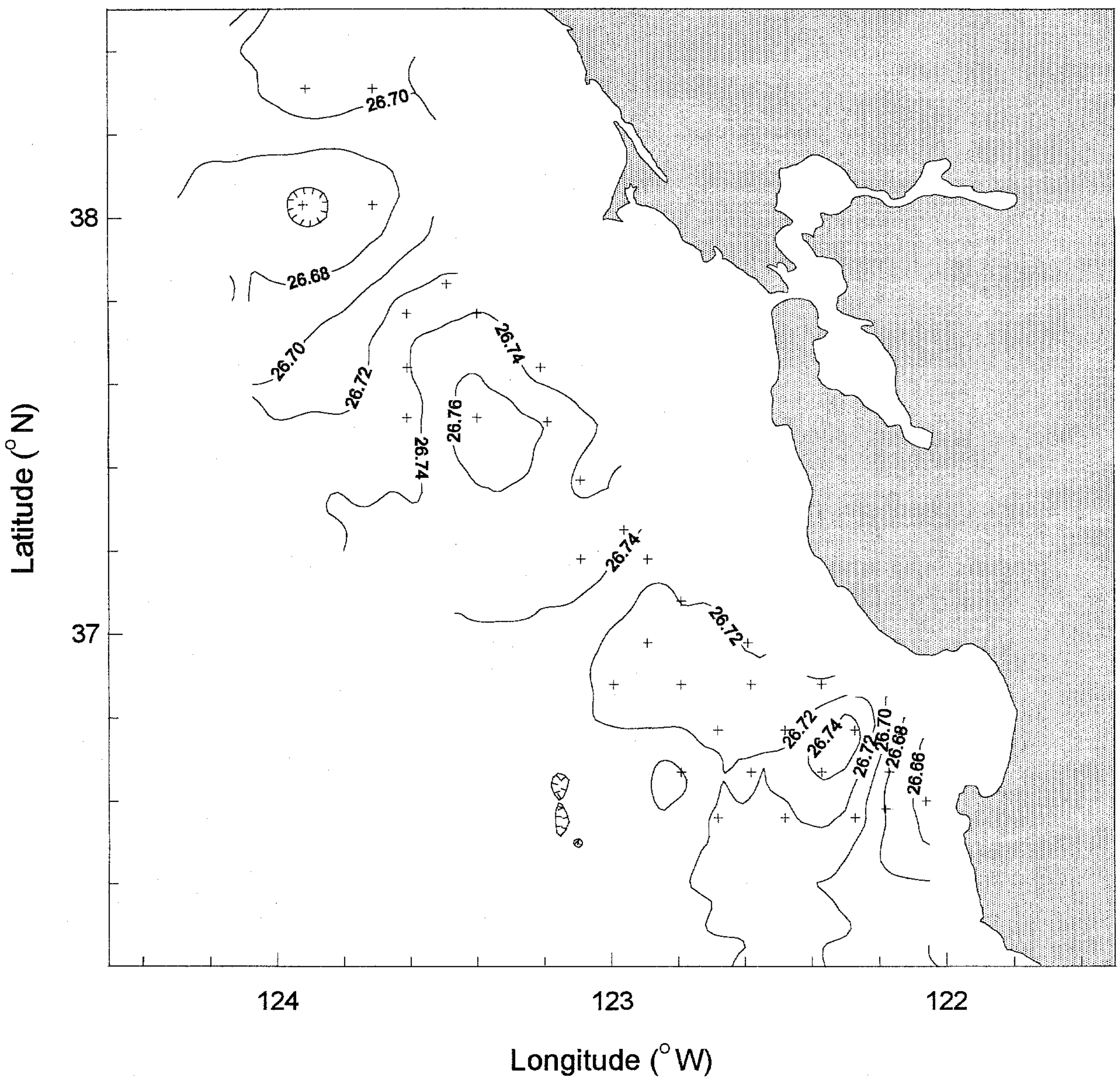

DSJ9506 Sweep 1 Density (kg/m³) at 30 m
Latitude (° N)
Longitude (° W)
38
37
124
123
122
25.2
25.0
24.6
24.8
25.8
25.4
26.2
26.0
25.6
25.8
24.6
24.8
25.0
25.2
25.4
25.6
25.2
25.2
25.2
26.0
25.8
25.4
25.6
25.4
25.4
25.6
25.8

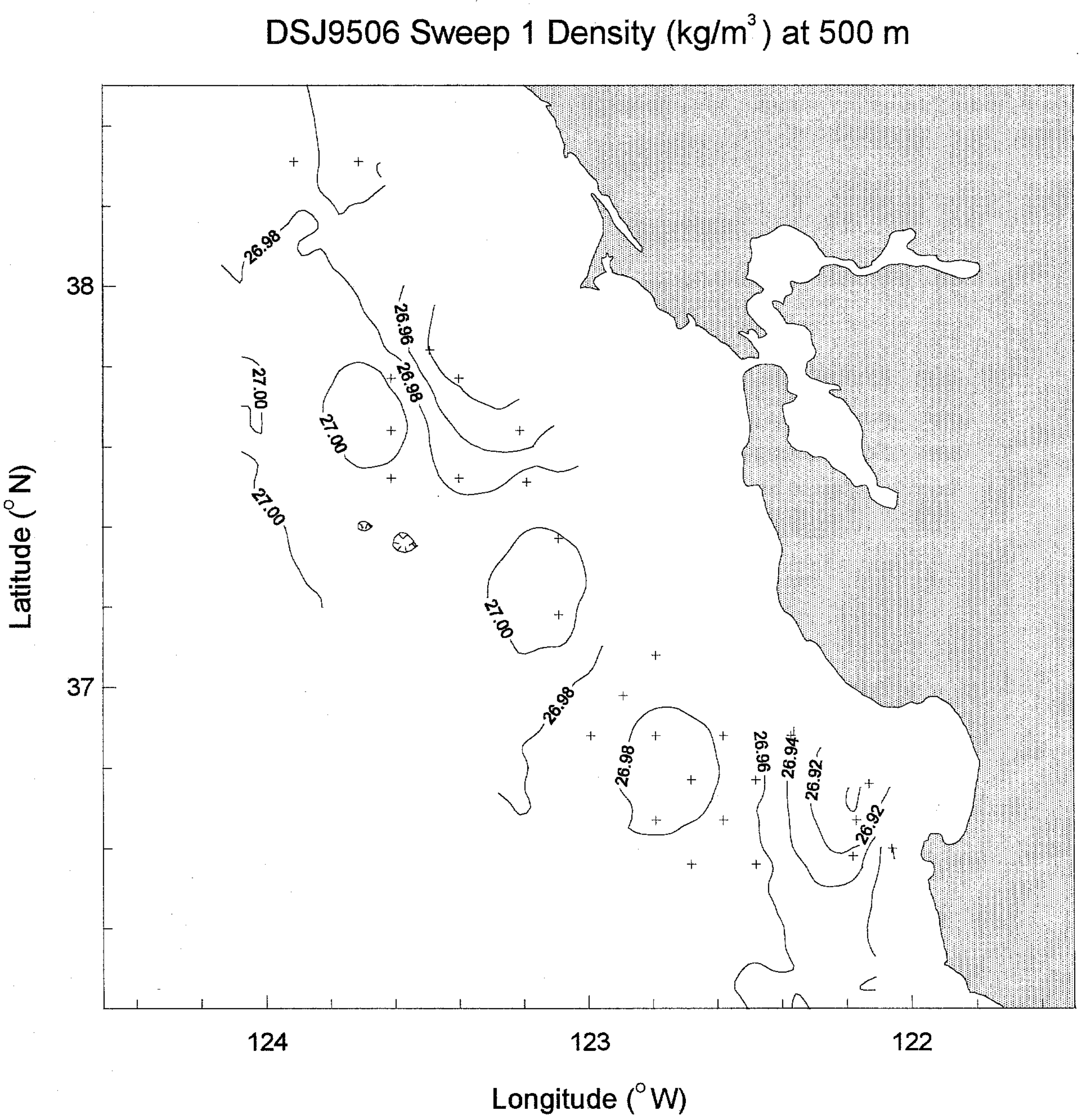

DSJ9506 Sweep 1 Density (kg/m^3) at 100 m
26.0
26.0
26.2
26.4
26.2
26.2
26.2
26.2
26.2
38
37
124
123
122
Latitude (°N)
Longitude (°W)

DSJ9506 Sweep 1 Density (kg/m^3) at 200 m



DSJ9506 Sweep 1 Density (kg/m^3) at 300 m

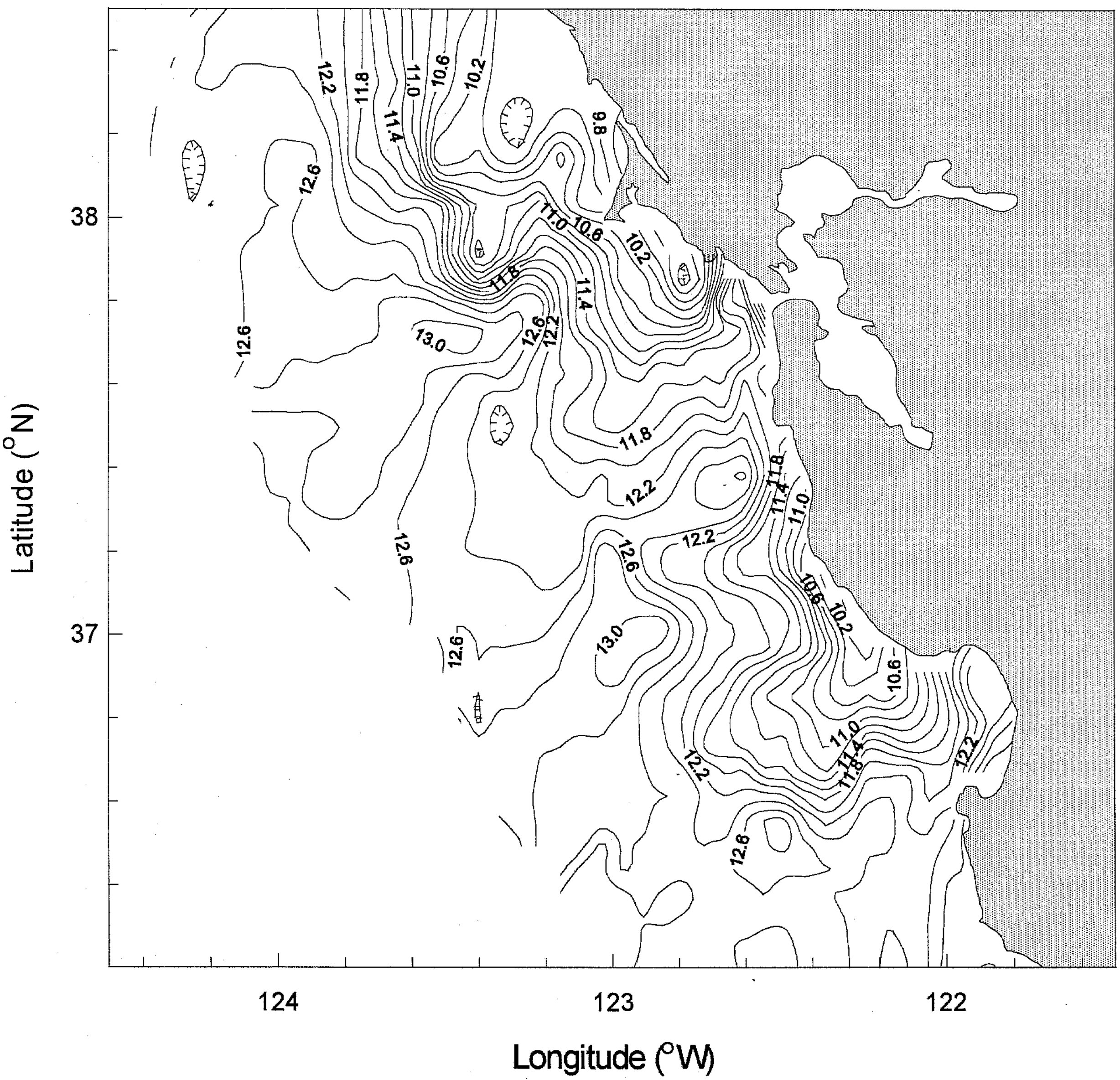


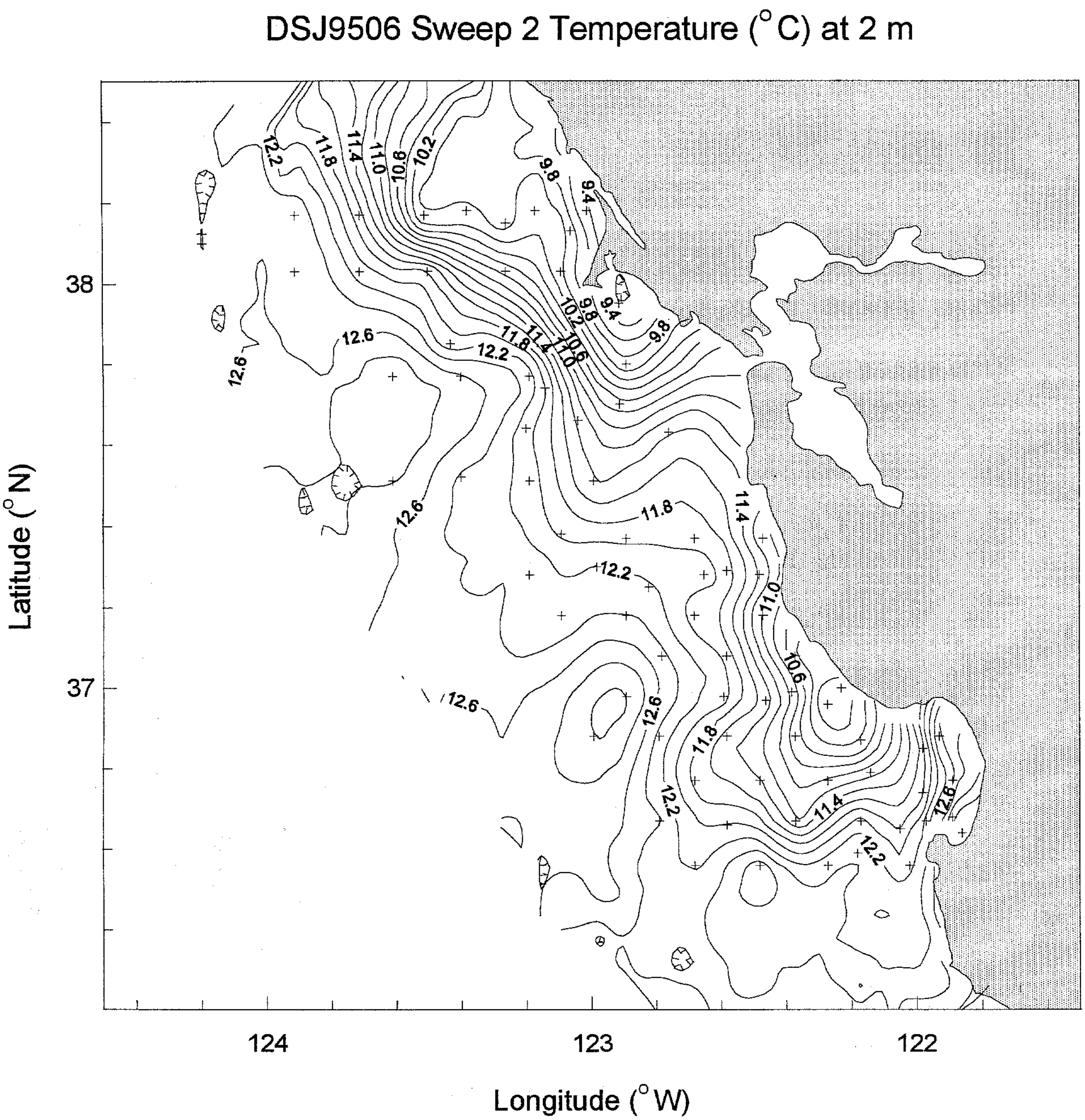


DSJ9506 Sweep 1 Density (kg/m^3) at 500 m
Latitude (°N)
38
37
124
123
122
Longitude (°W)
26.98
26.96
27.00
26.94
26.92

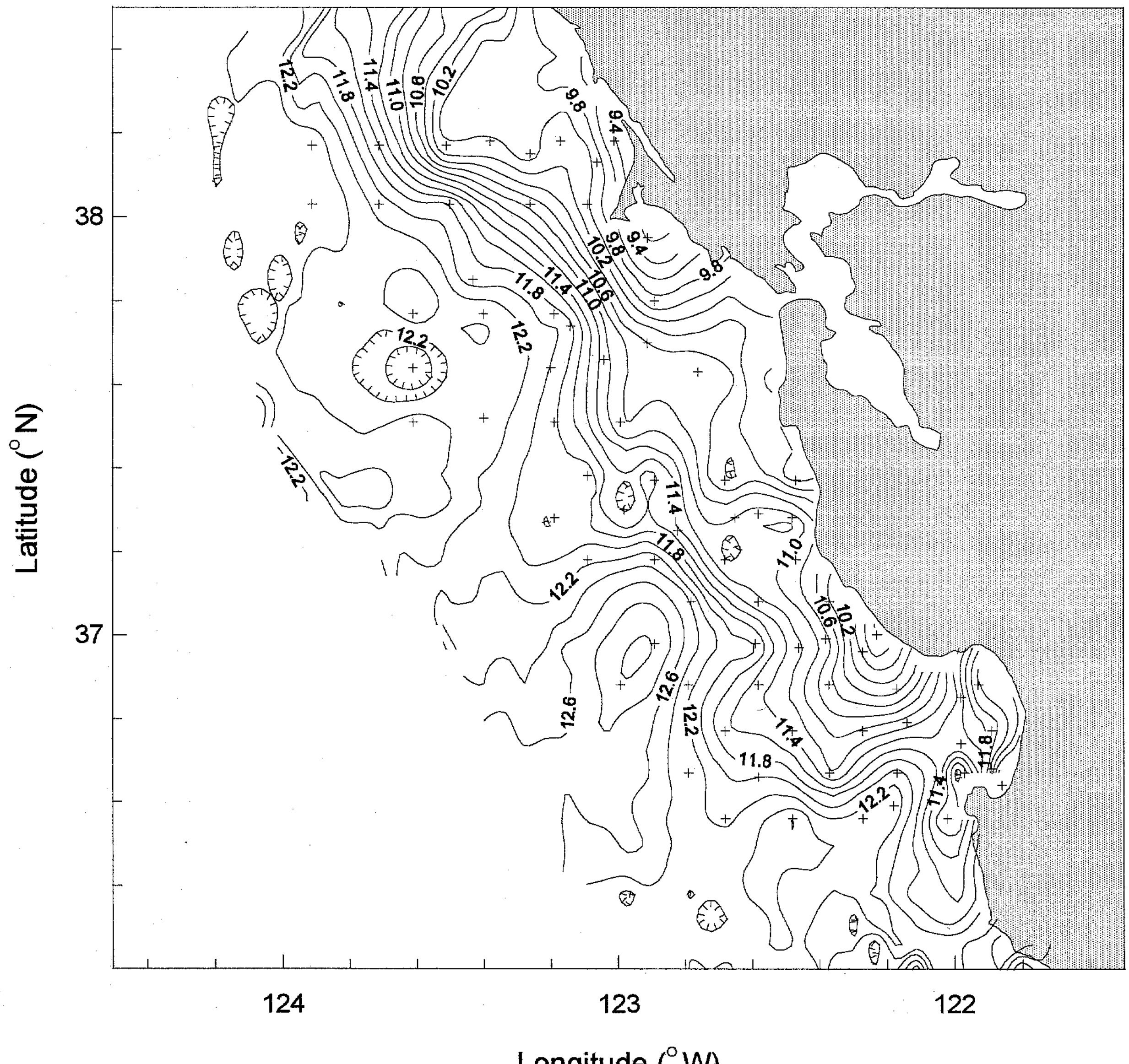
APPENDIX 7.2: HORIZONTAL MAPS OF CTD AND TS FOR DSJ9506, SWEEP 2

DSJ9506 Sweep 2 TS Temperature (°C)

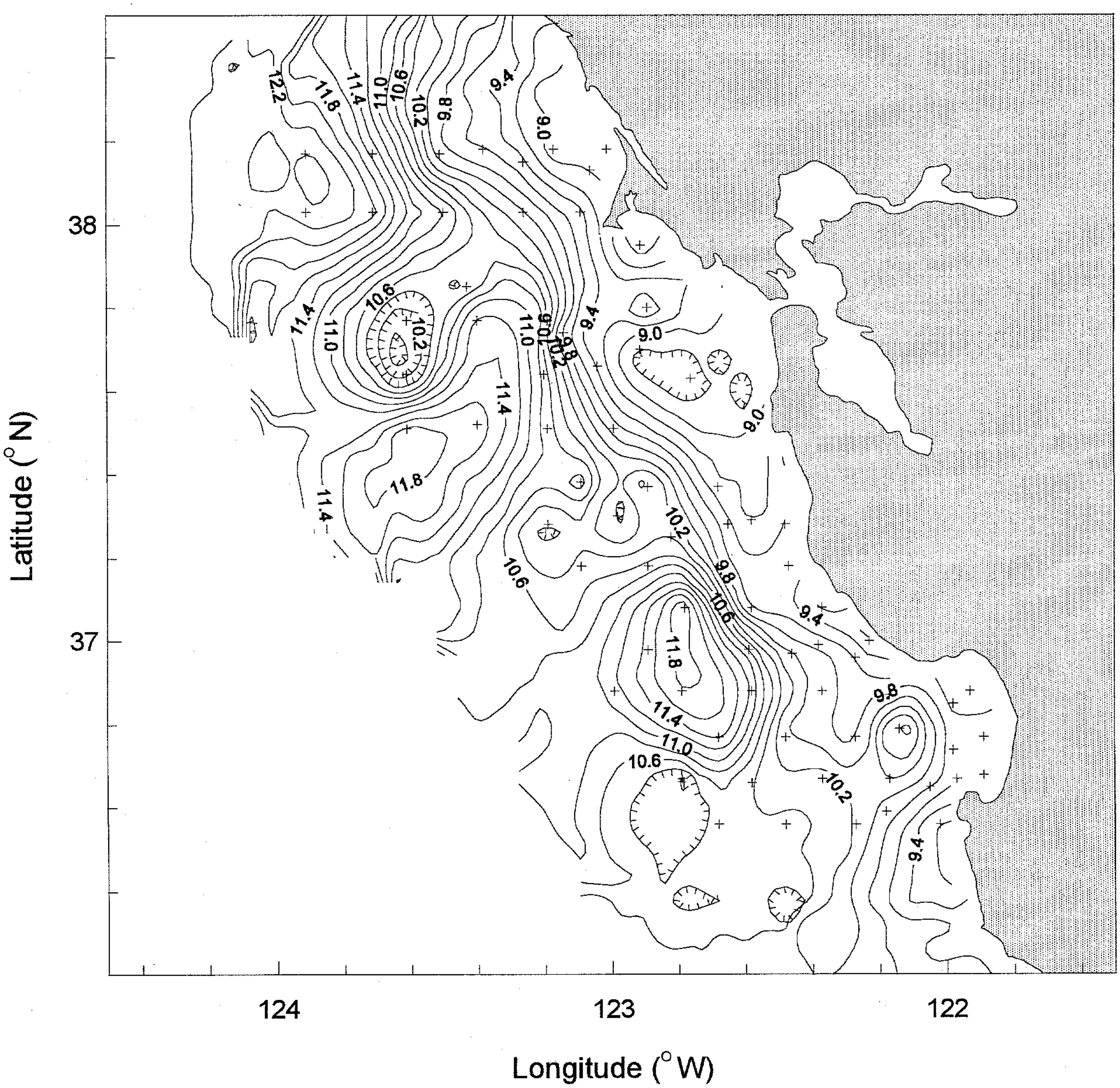


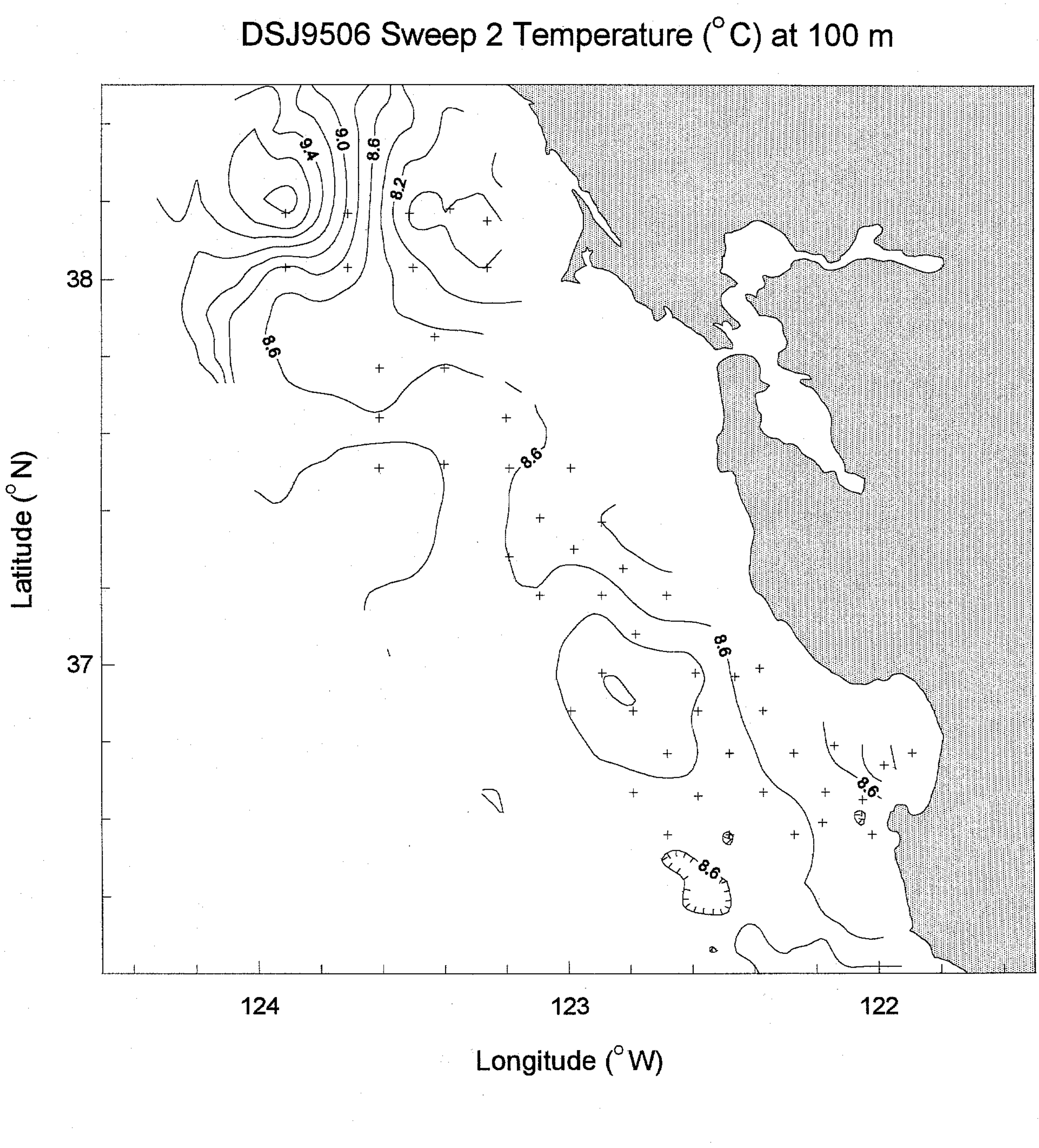

DSJ9506 Sweep 2 Temperature (°C) at 2 m
38
37
Latitude (°N)
124
123
122
Longitude (°W)
12.2
11.8
11.4
11.0
10.8
10.2
9.8
9.4
12.6
10.6
11.4
11.0
11.8
12.2
12.6
12.6
12.6
11.8
12.2

DSJ9506 Sweep 2 Temperature (°C) at 10 m



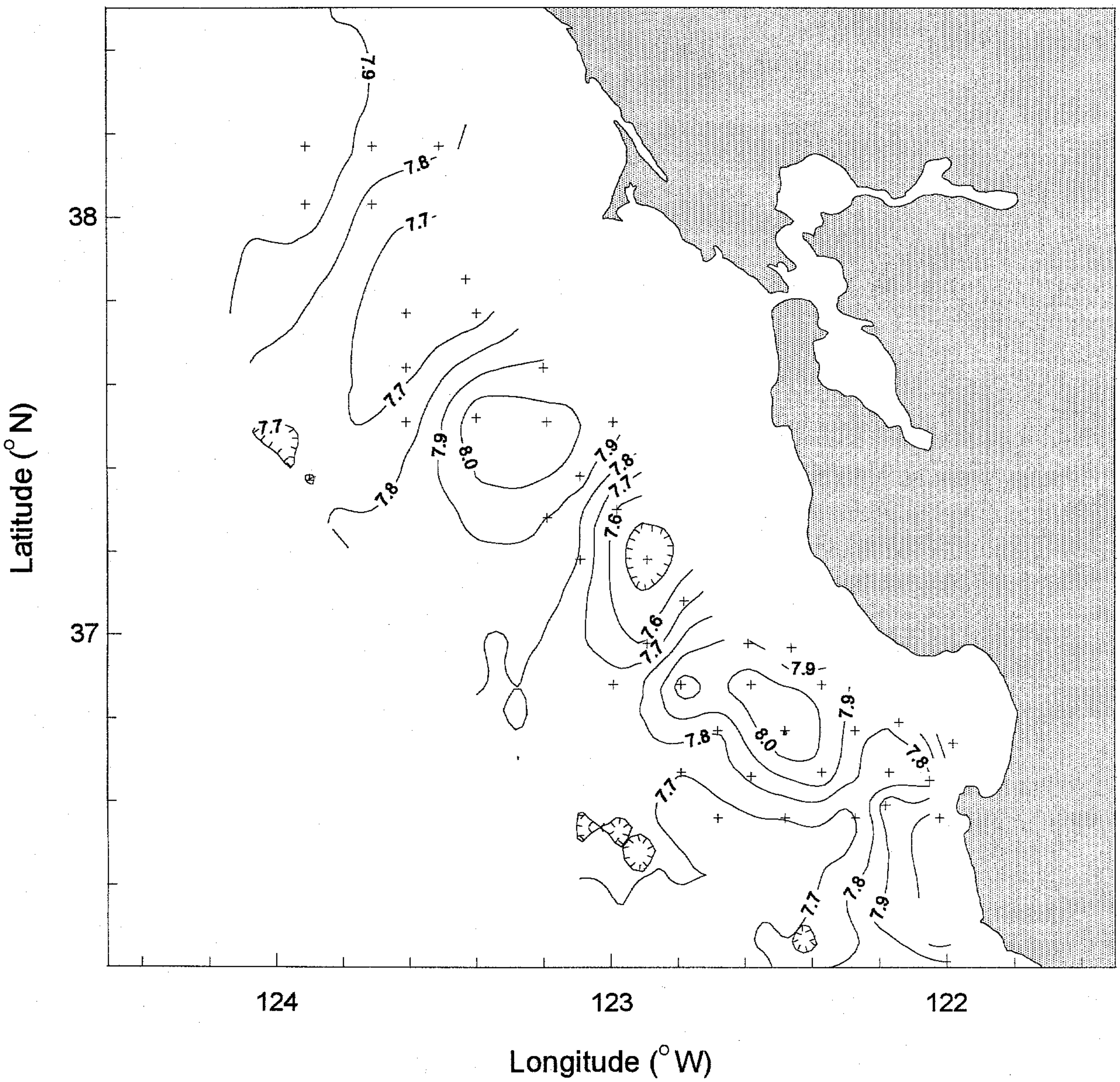
DSJ9506 Sweep 2 Temperature (°C) at 30 m

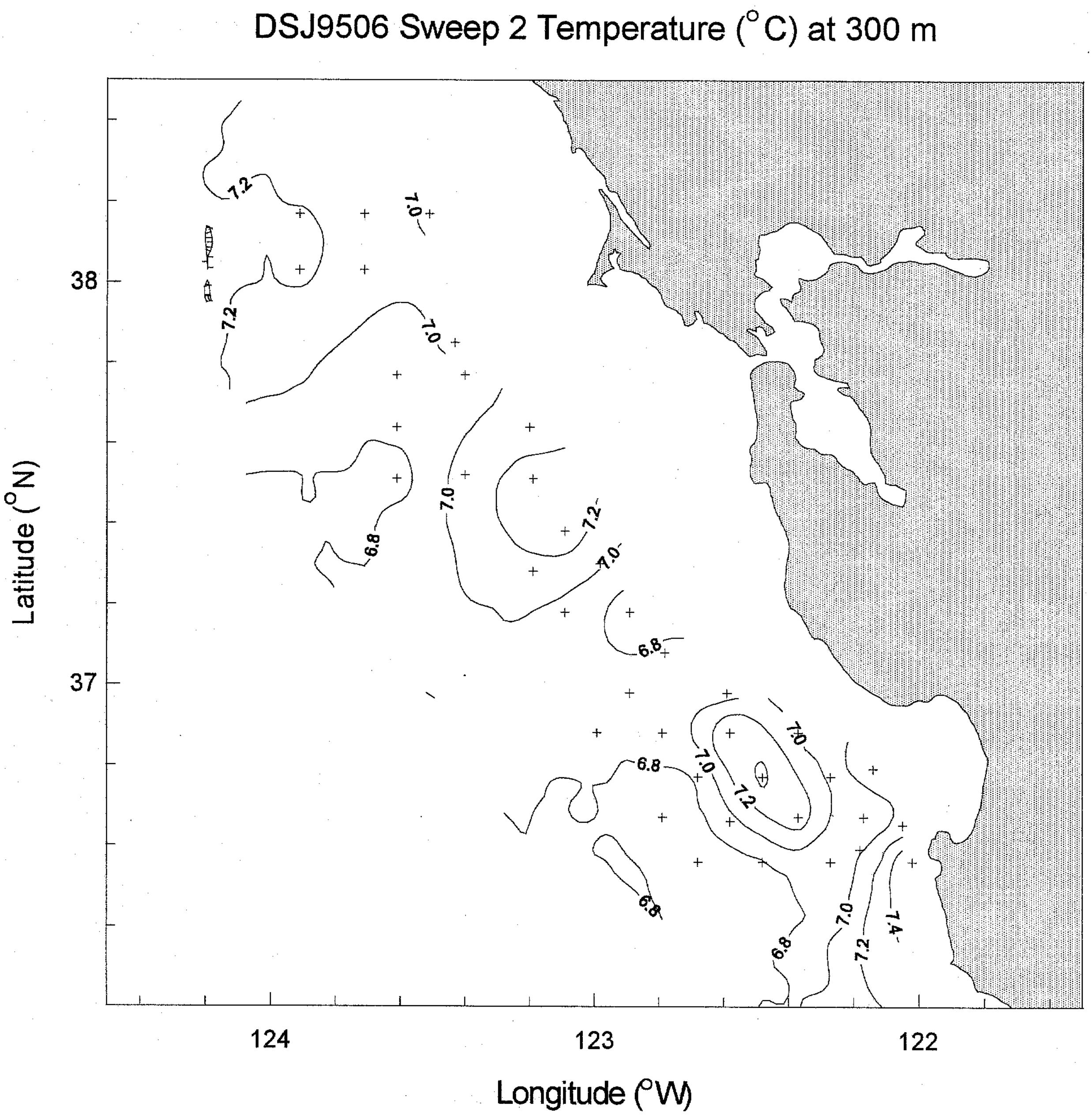




DSJ9506 Sweep 2 Temperature (°C) at 100 m
9.4
9.0
8.6
8.2
8.6
8.6
8.6
8.6
8.6
38
37
Latitude (°N)
124
123
122
Longitude (°W)

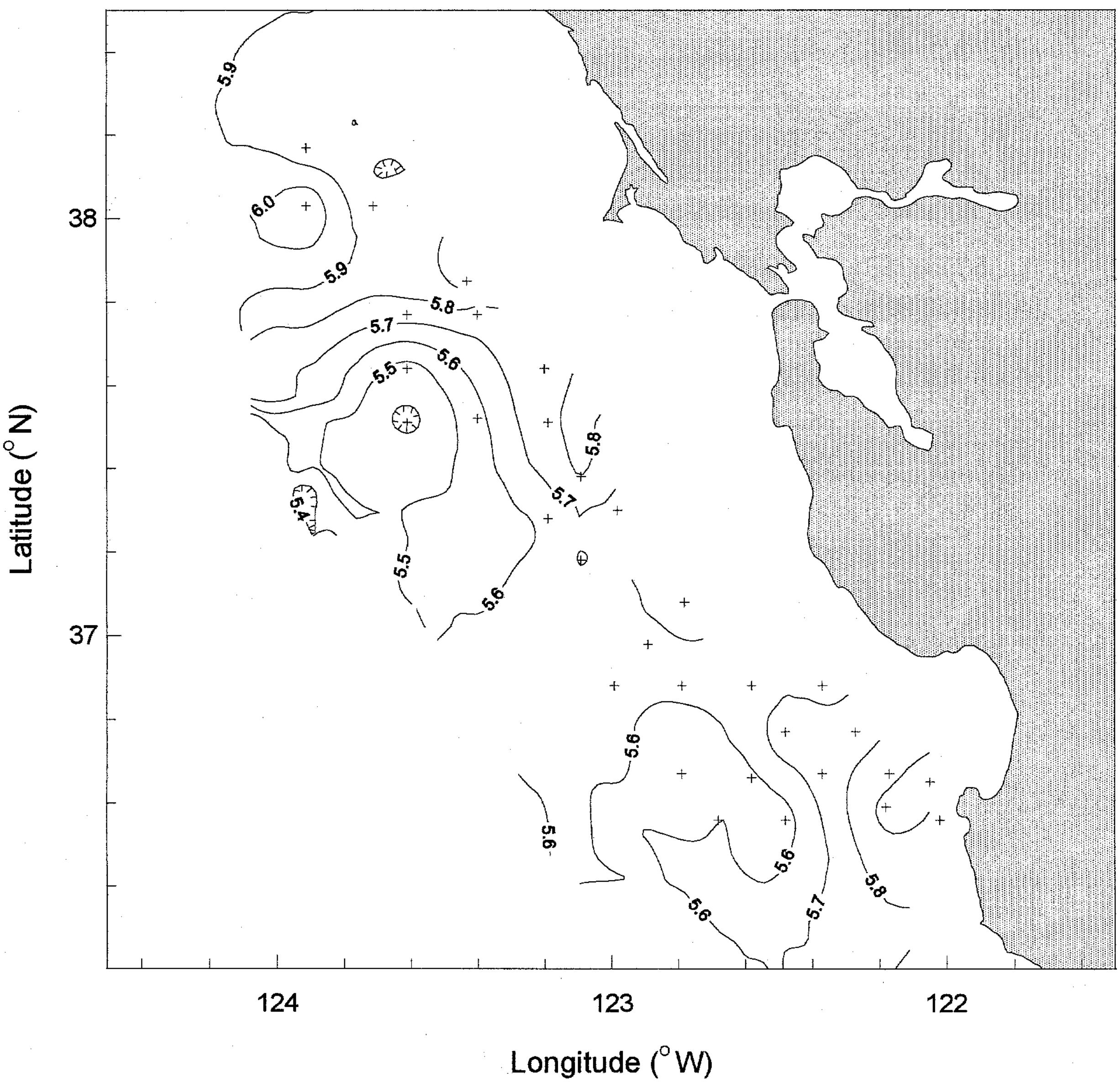
DSJ9506 Sweep 2 Temperature (°C) at 200 m



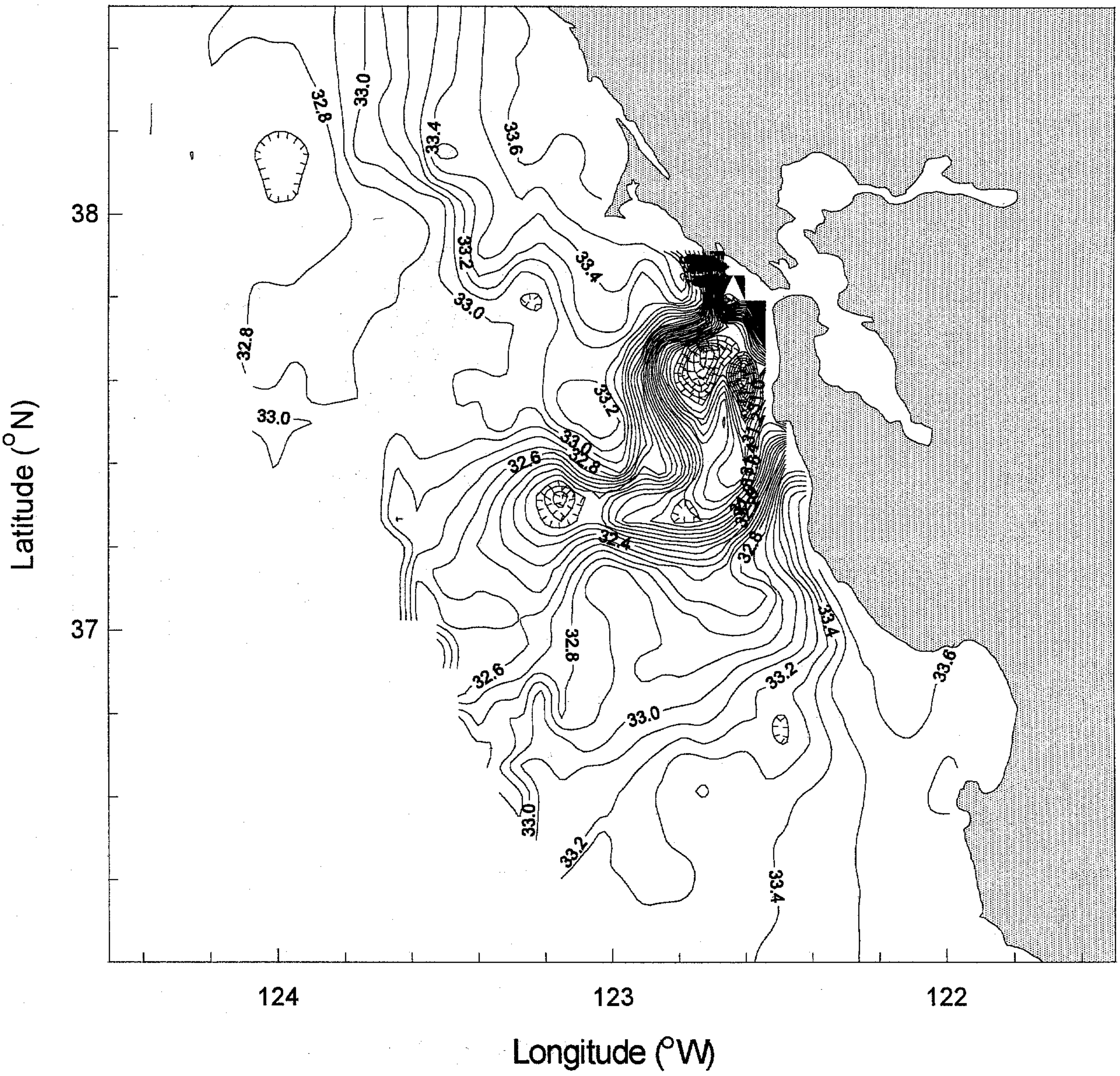


DSJ9506 Sweep 2 Temperature (°C) at 300 m
Latitude (°N)
38
37
124
123
122
Longitude (°W)
7.2
7.0
6.8
7.4

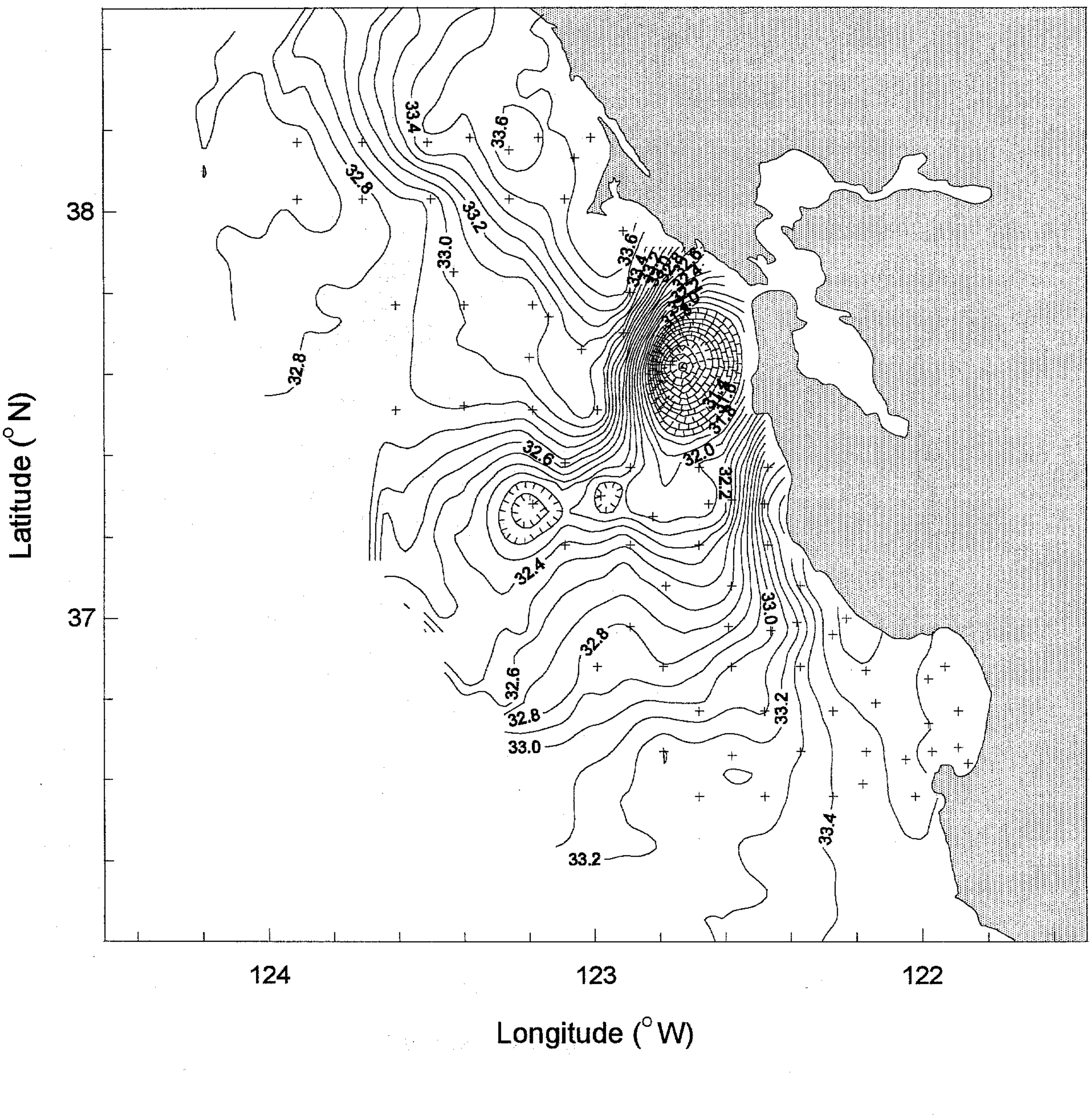
DSJ9506 Sweep 2 Temperature (°C) at 500 m



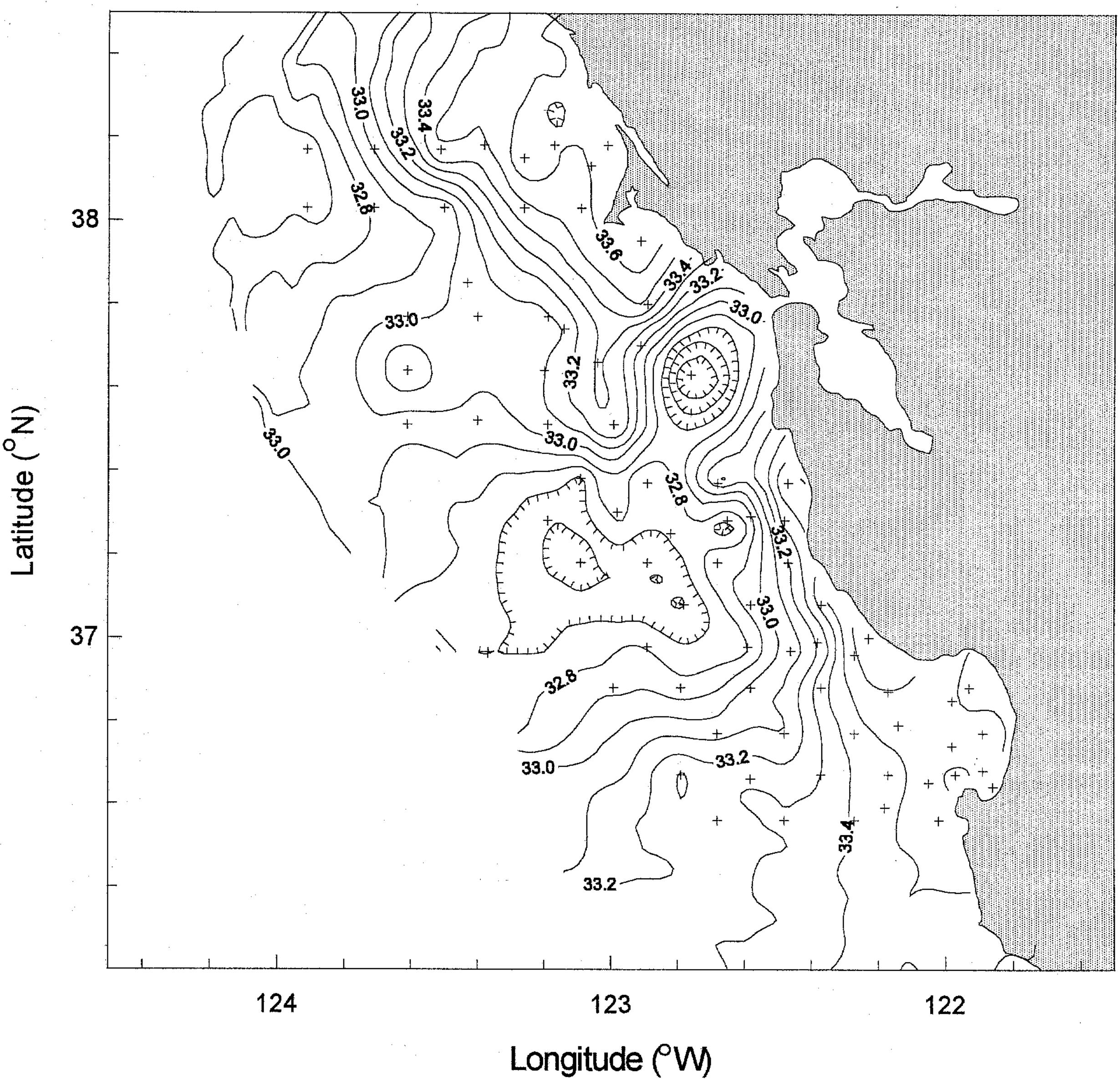
DSJ9506 Sweep 2 TS Salinity (ppt)



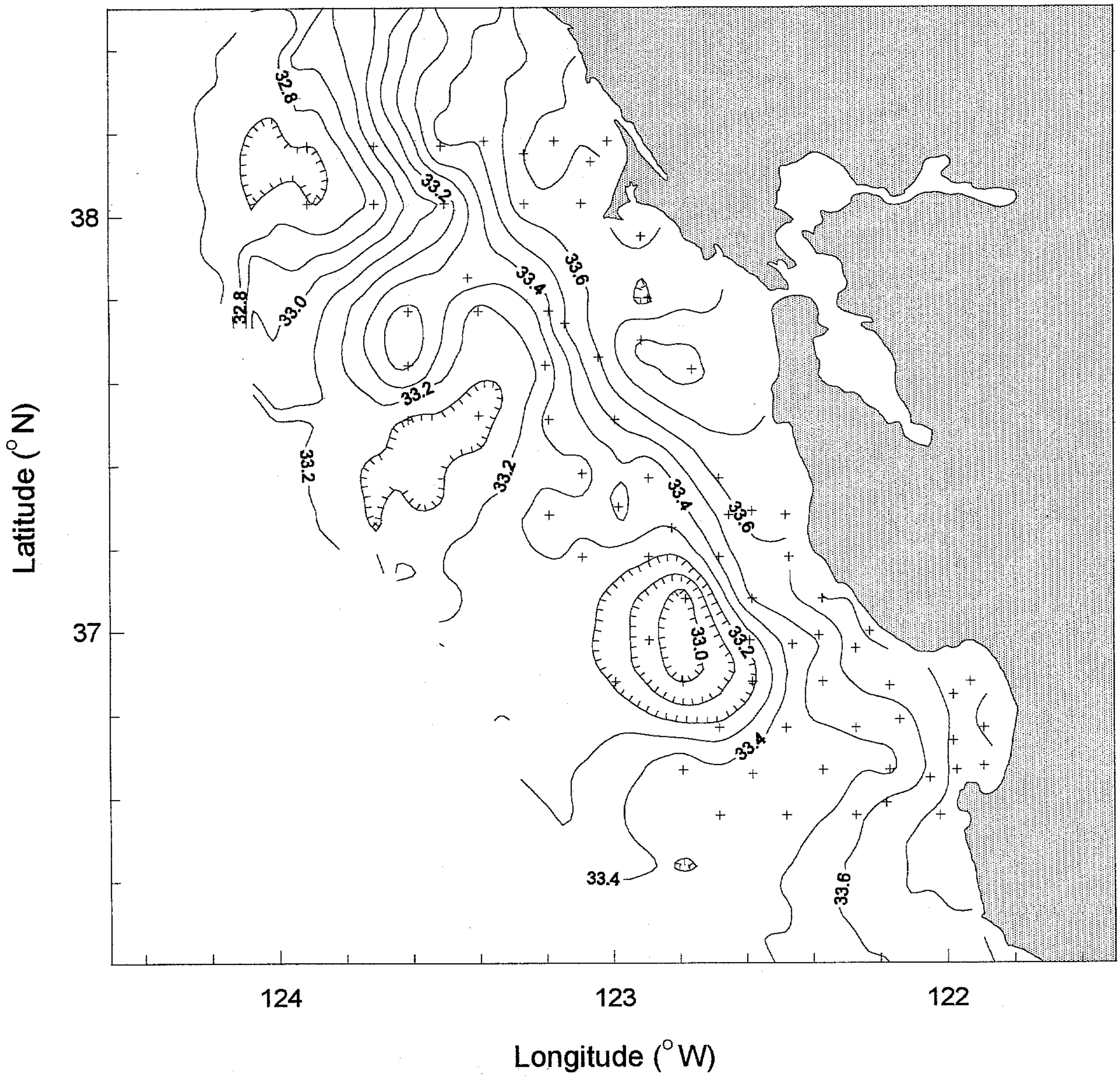
DSJ9506 Sweep 2 Salinity (ppt) at 2 m



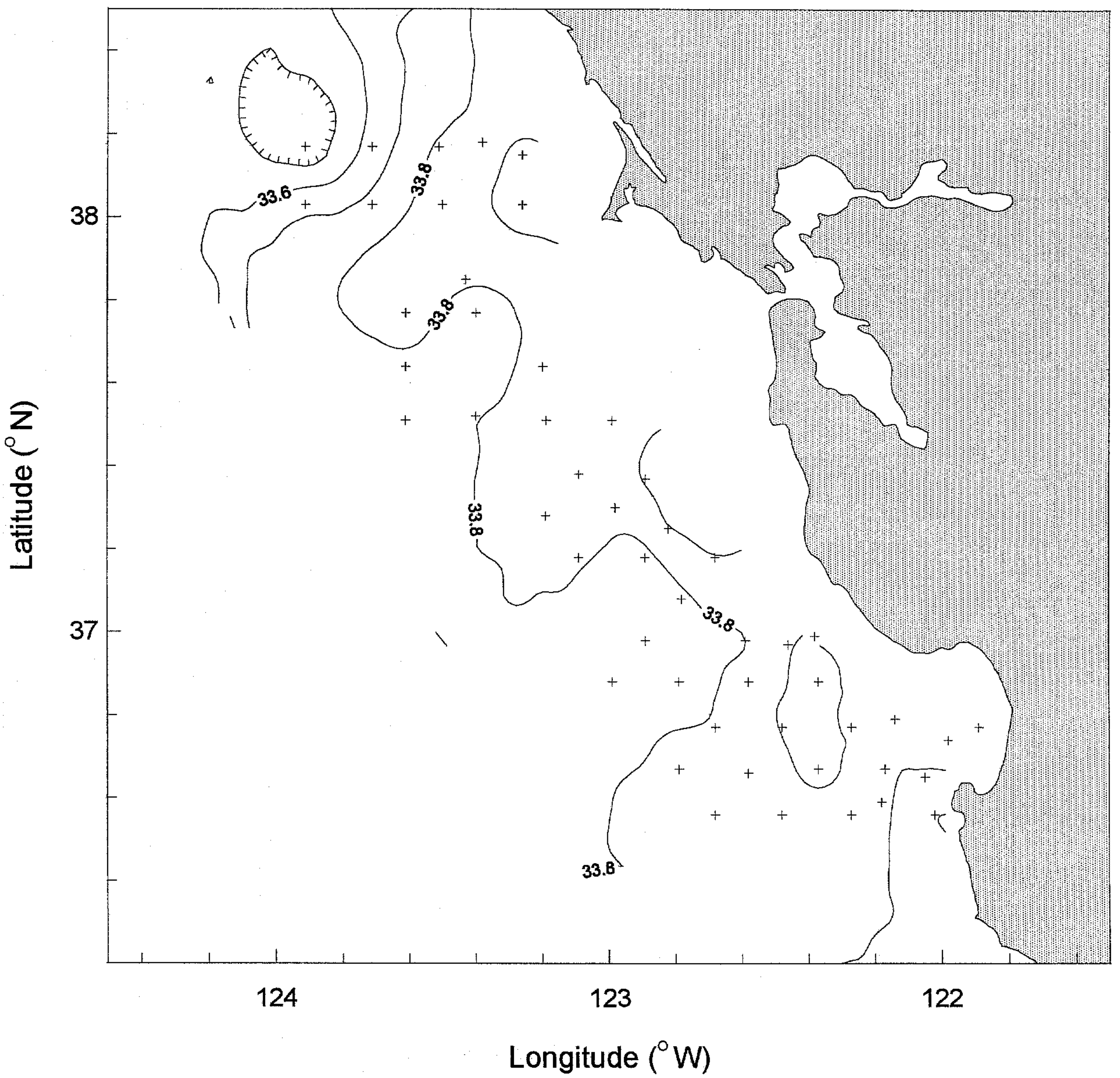
DSJ9506 Sweep 2 Salinity (ppt) at 10 m



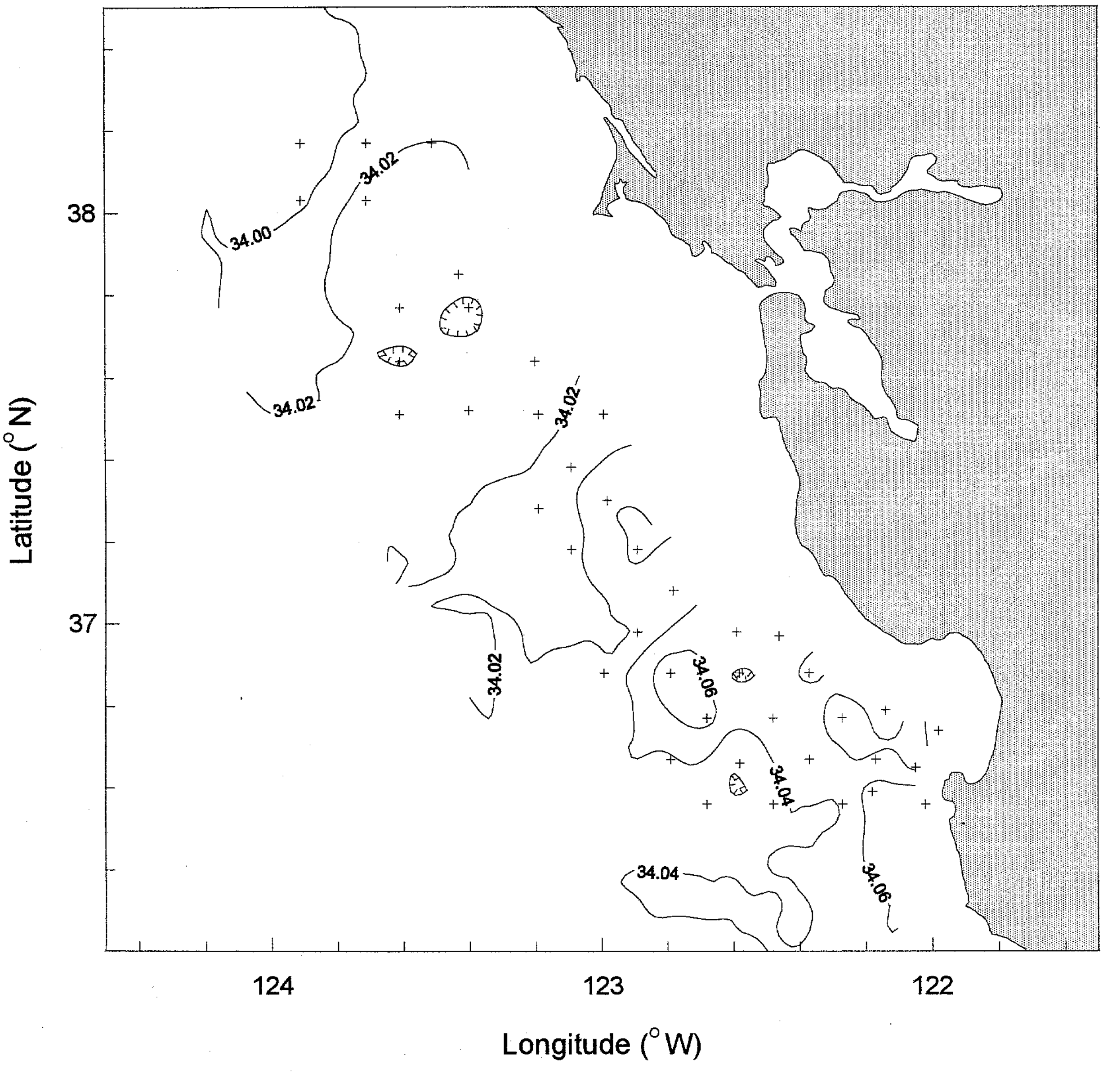
DSJ9506 Sweep 2 Salinity (ppt) at 30 m



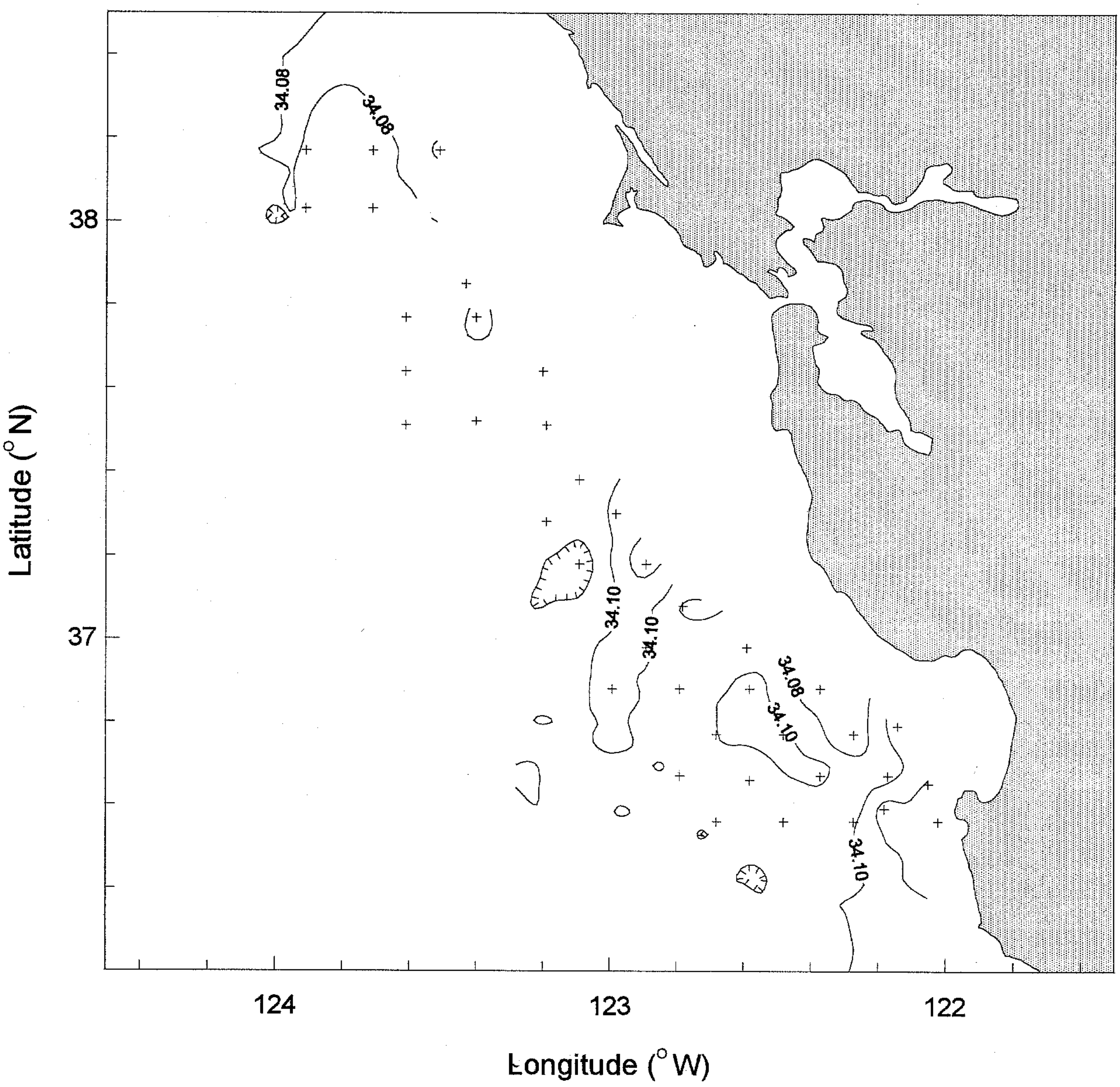
DSJ9506 Sweep 2 Salinity (ppt) at 100 m



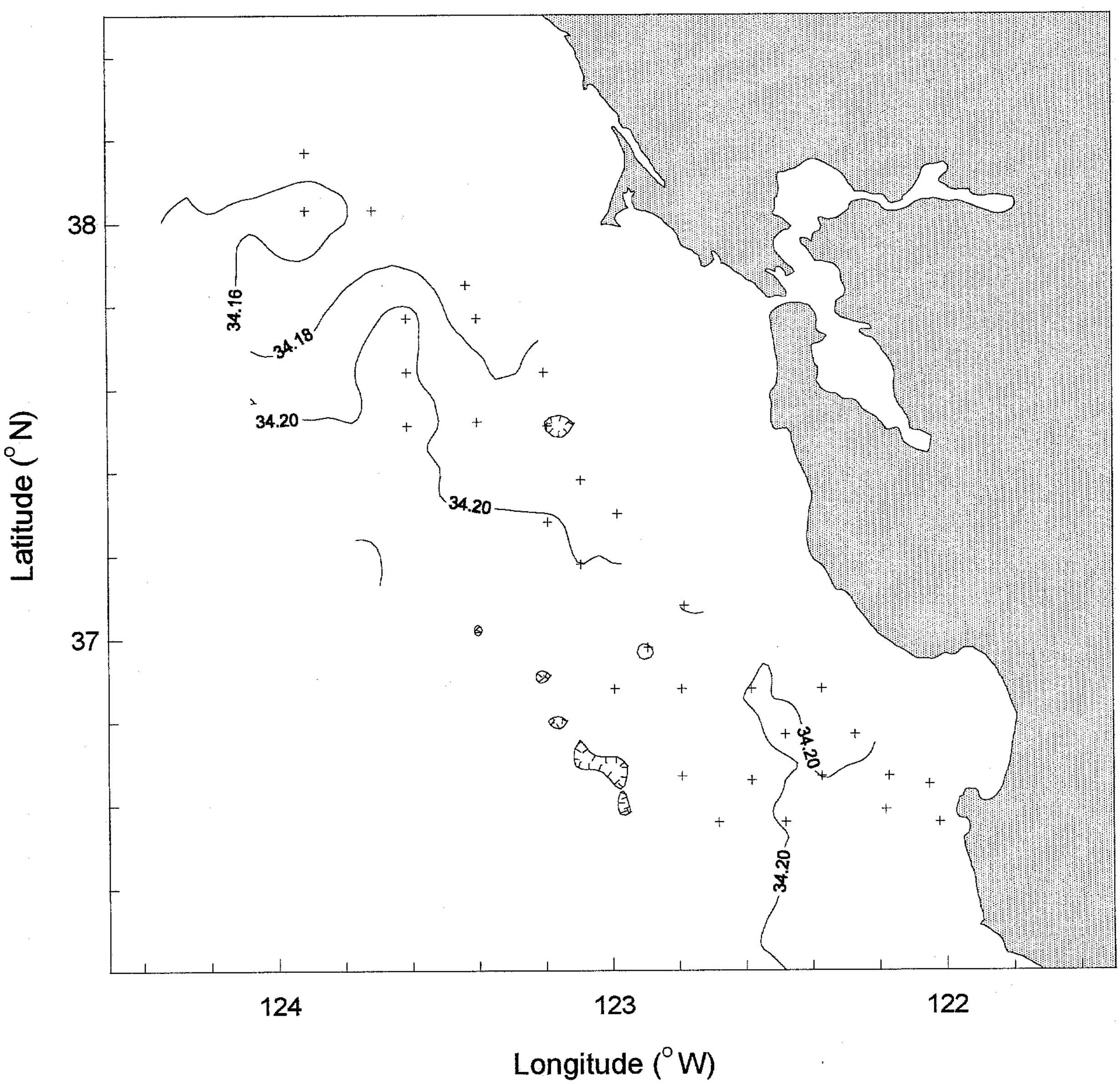
DSJ9506 Sweep 2 Salinity (ppt) at 200 m

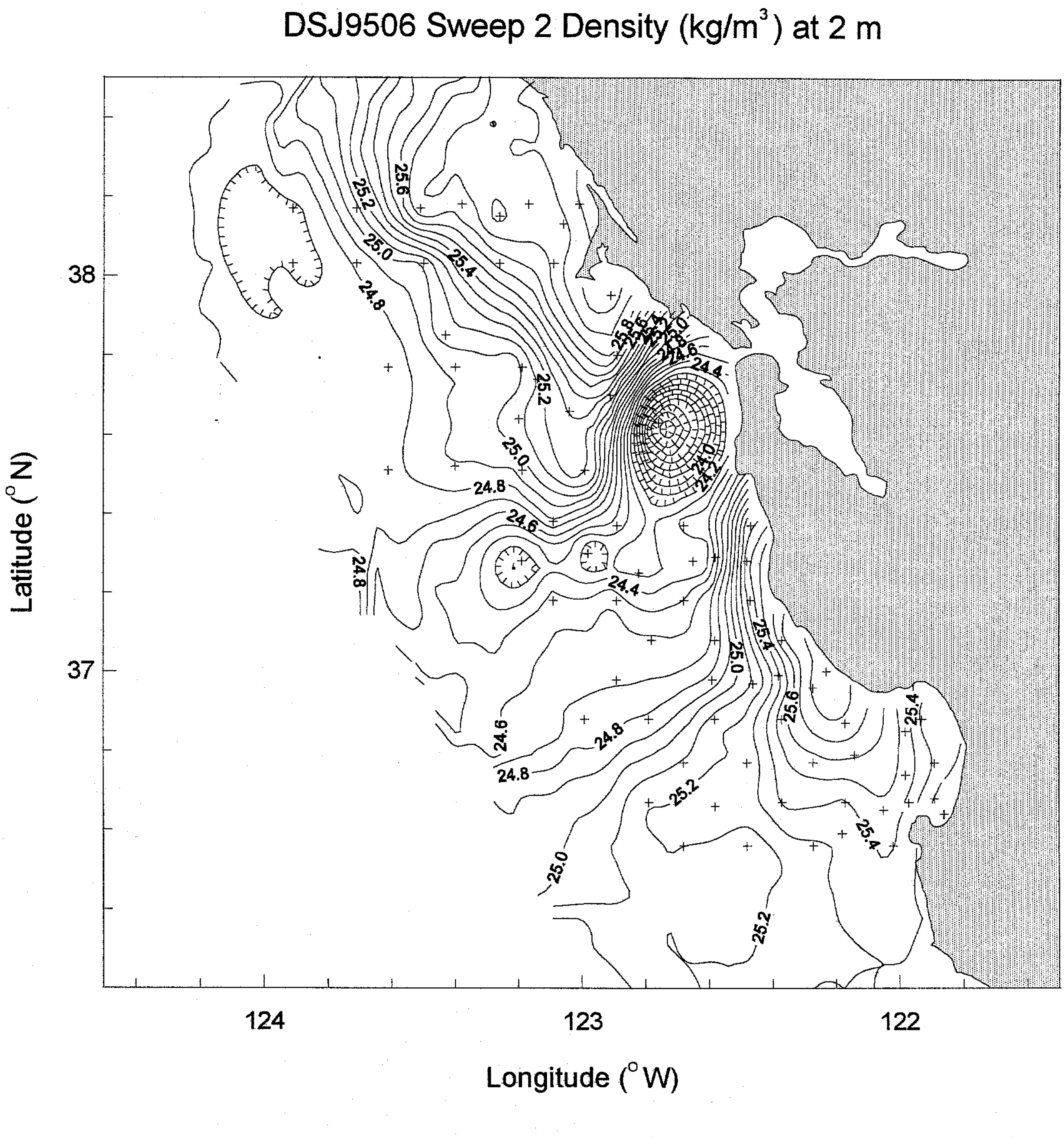


DSJ9506 Sweep 2 Salinity (ppt) at 300 m

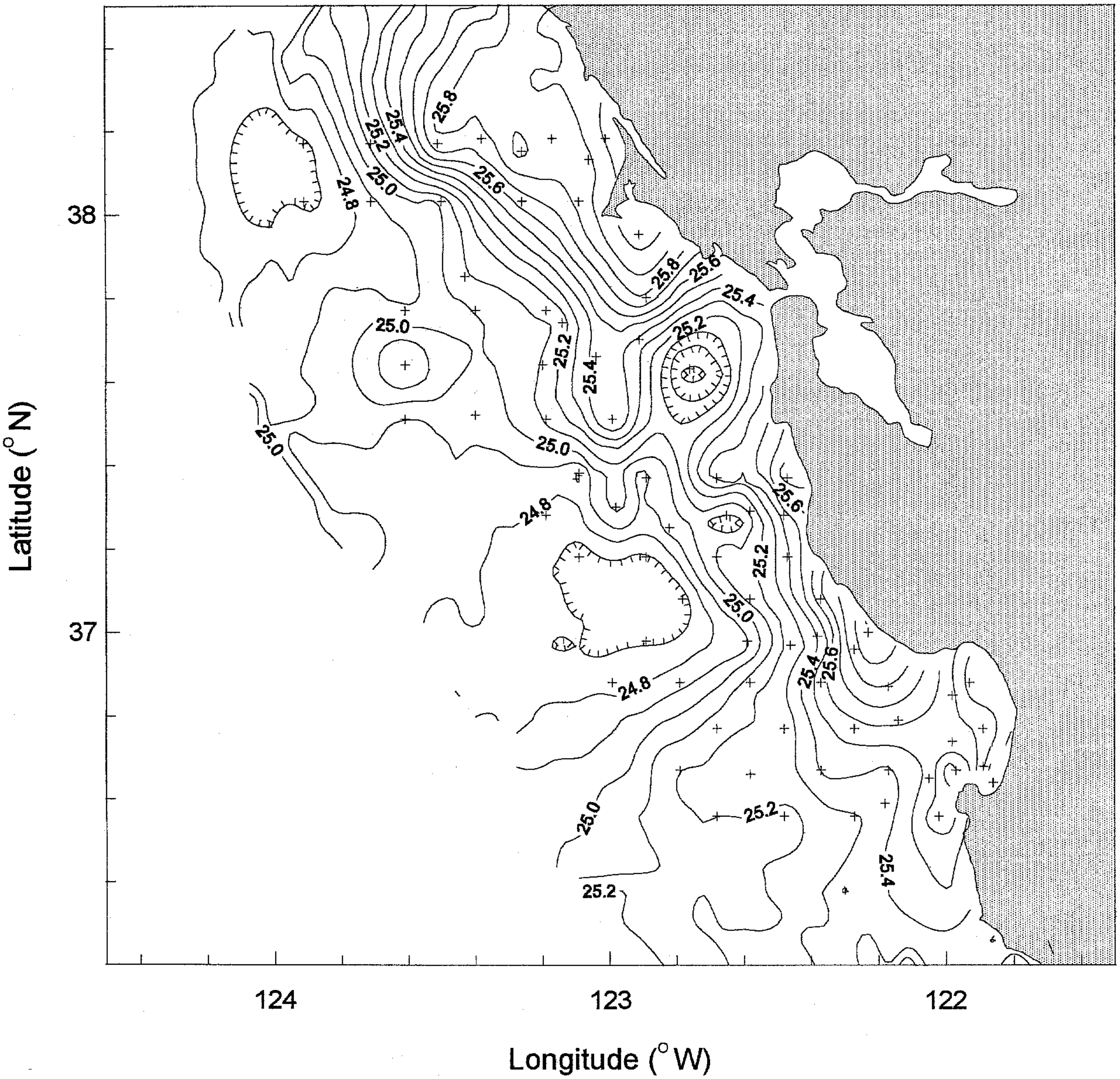


DSJ9506 Sweep 2 Salinity (ppt) at 500 m

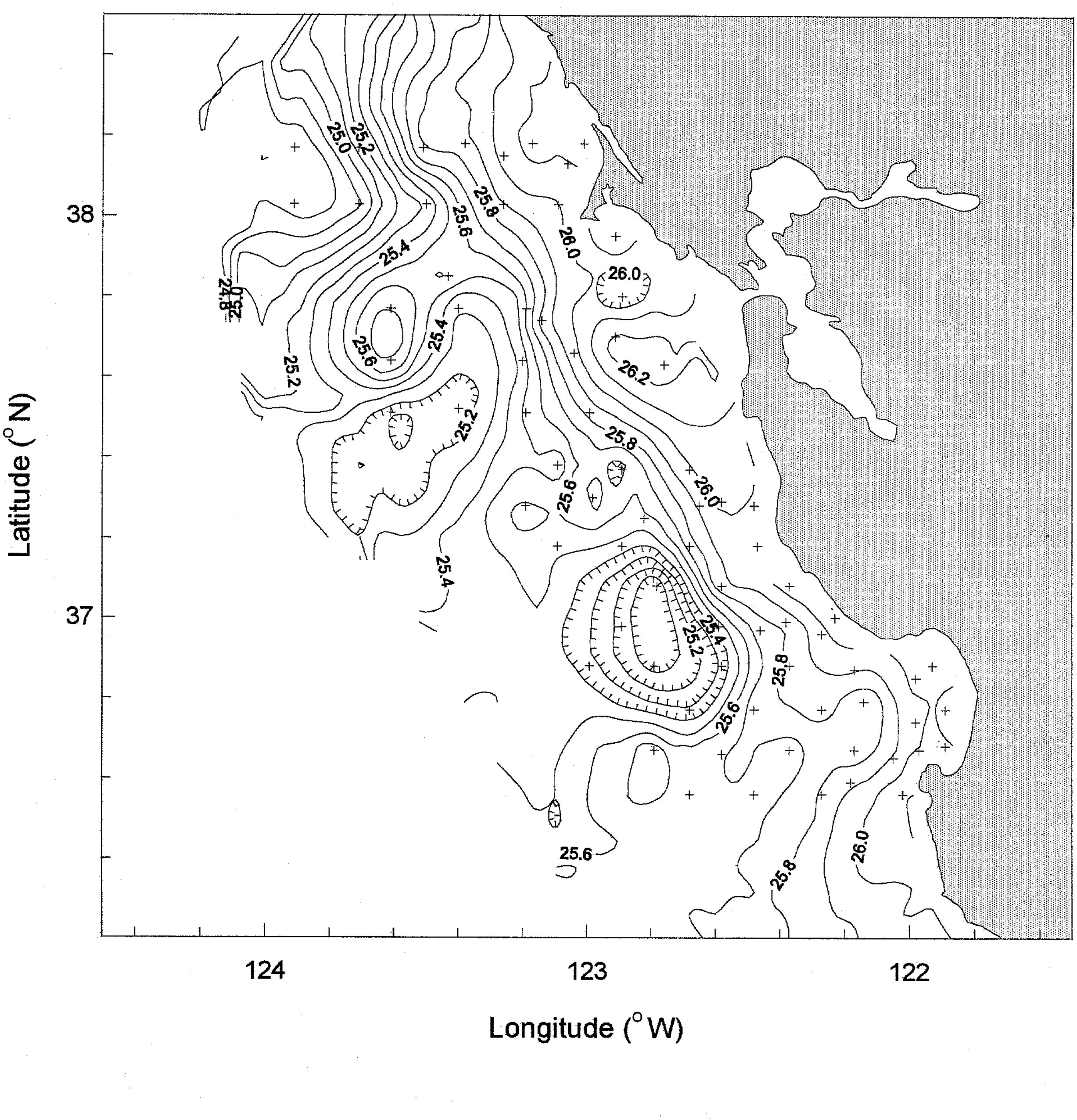


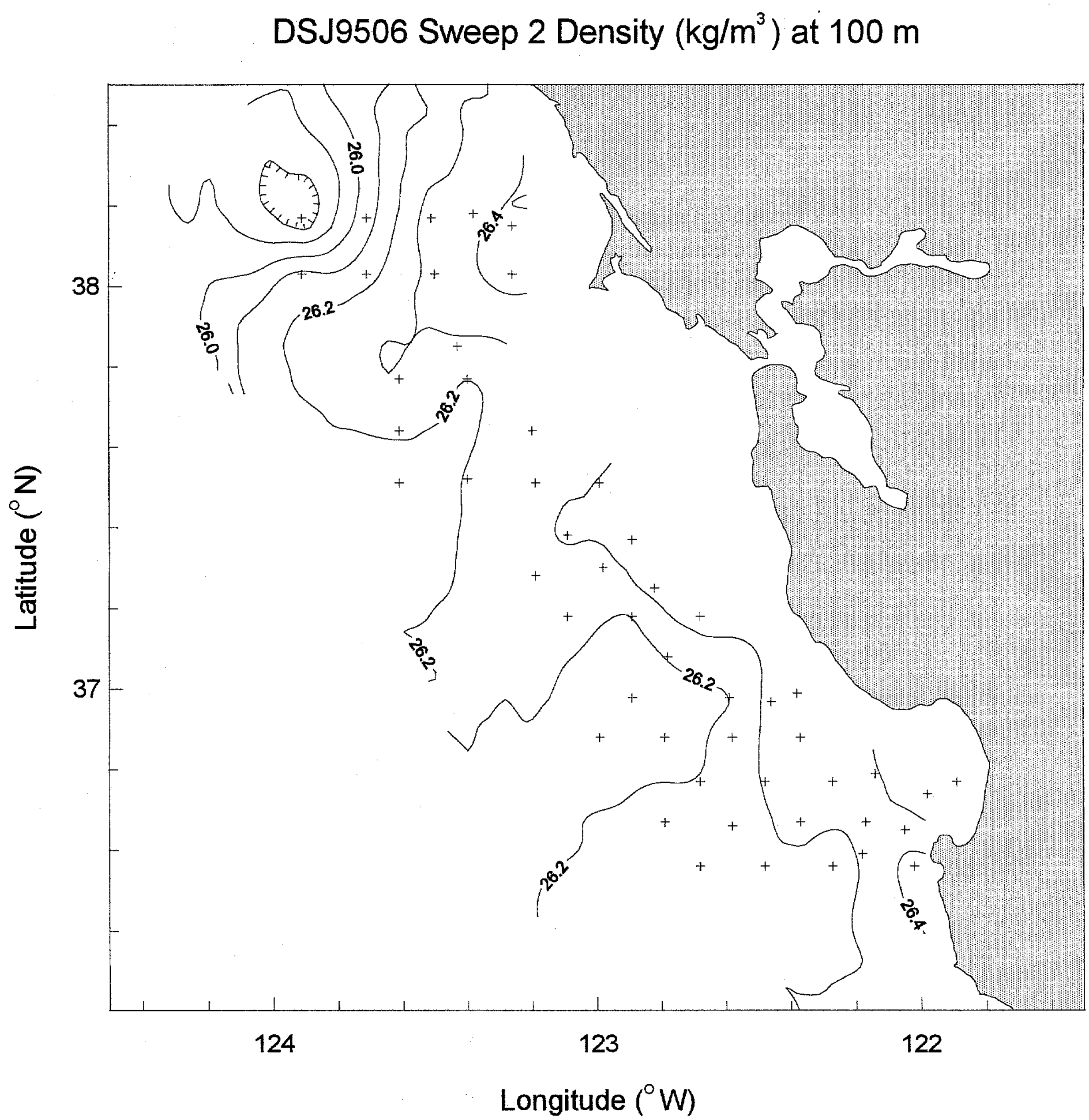

DSJ9506 Sweep 2 Density (kg/m³) at 2 m
Latitude (°N)
Longitude (°W)
38
37
124
123
122
25.6
25.2
25.0
25.4
24.8
24.6
24.4
24.0
25.8

DSJ9506 Sweep 2 Density (kg/m³) at 10 m



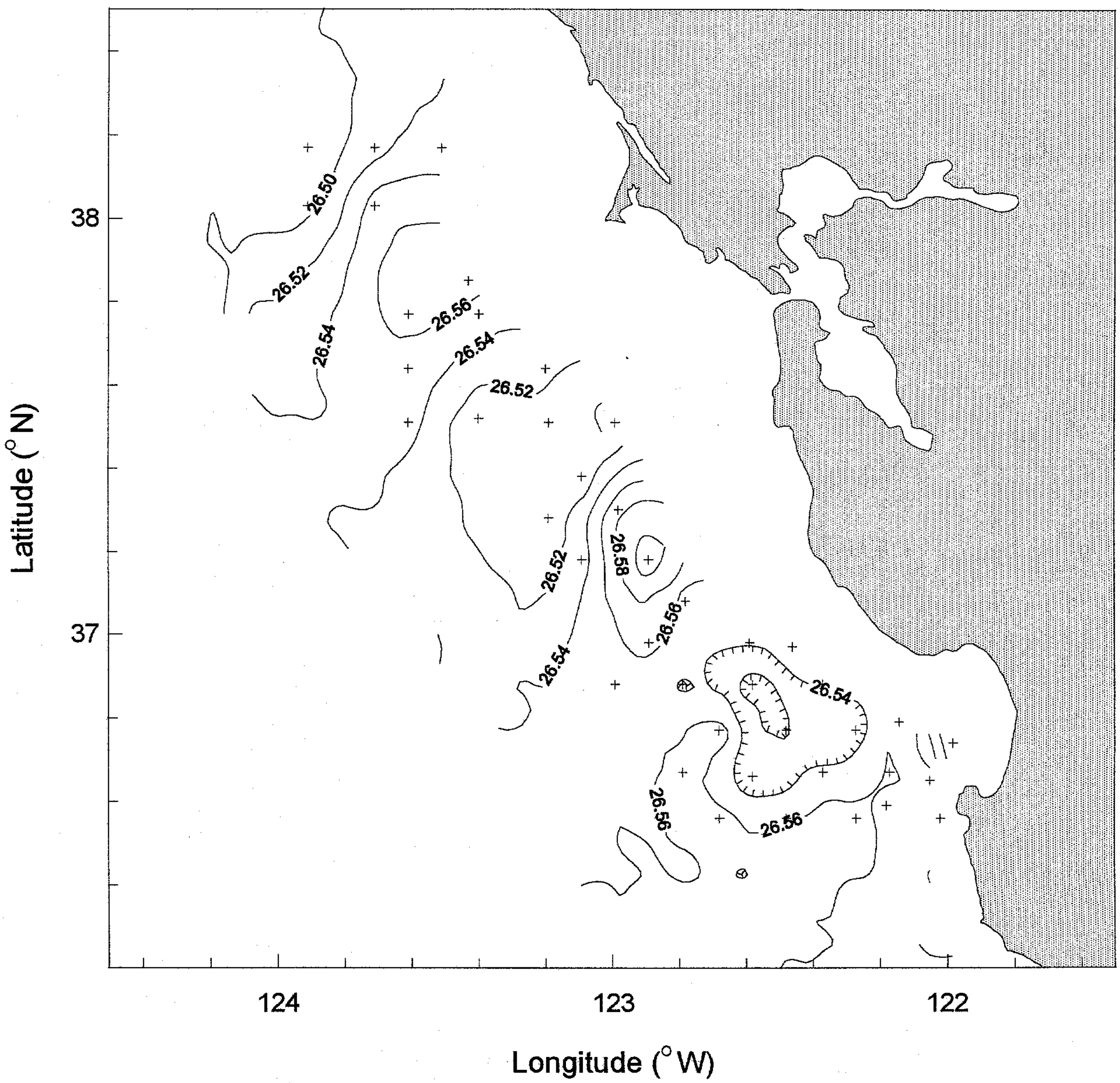
DSJ9506 Sweep 2 Density (kg/m^3) at 30 m



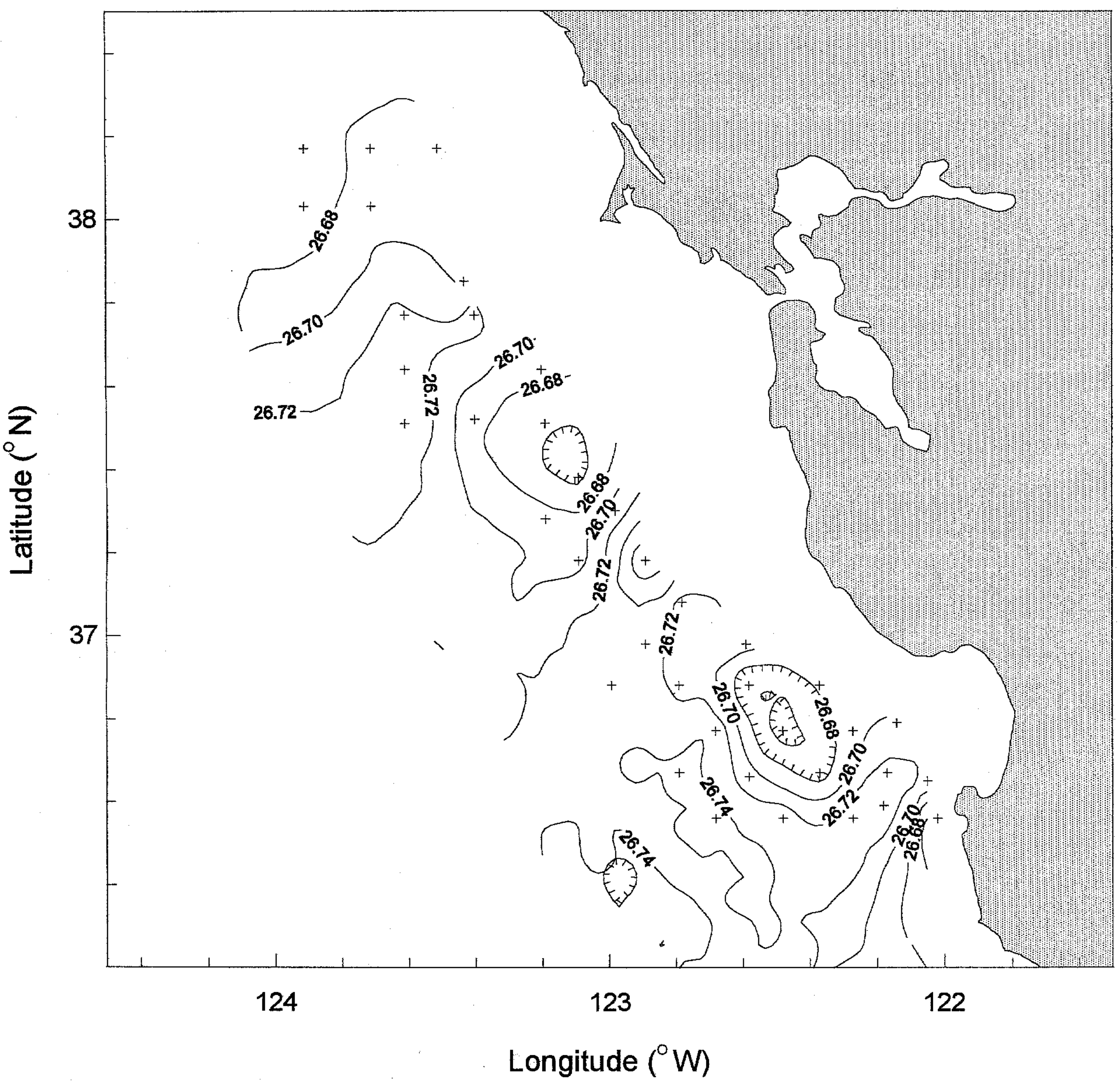


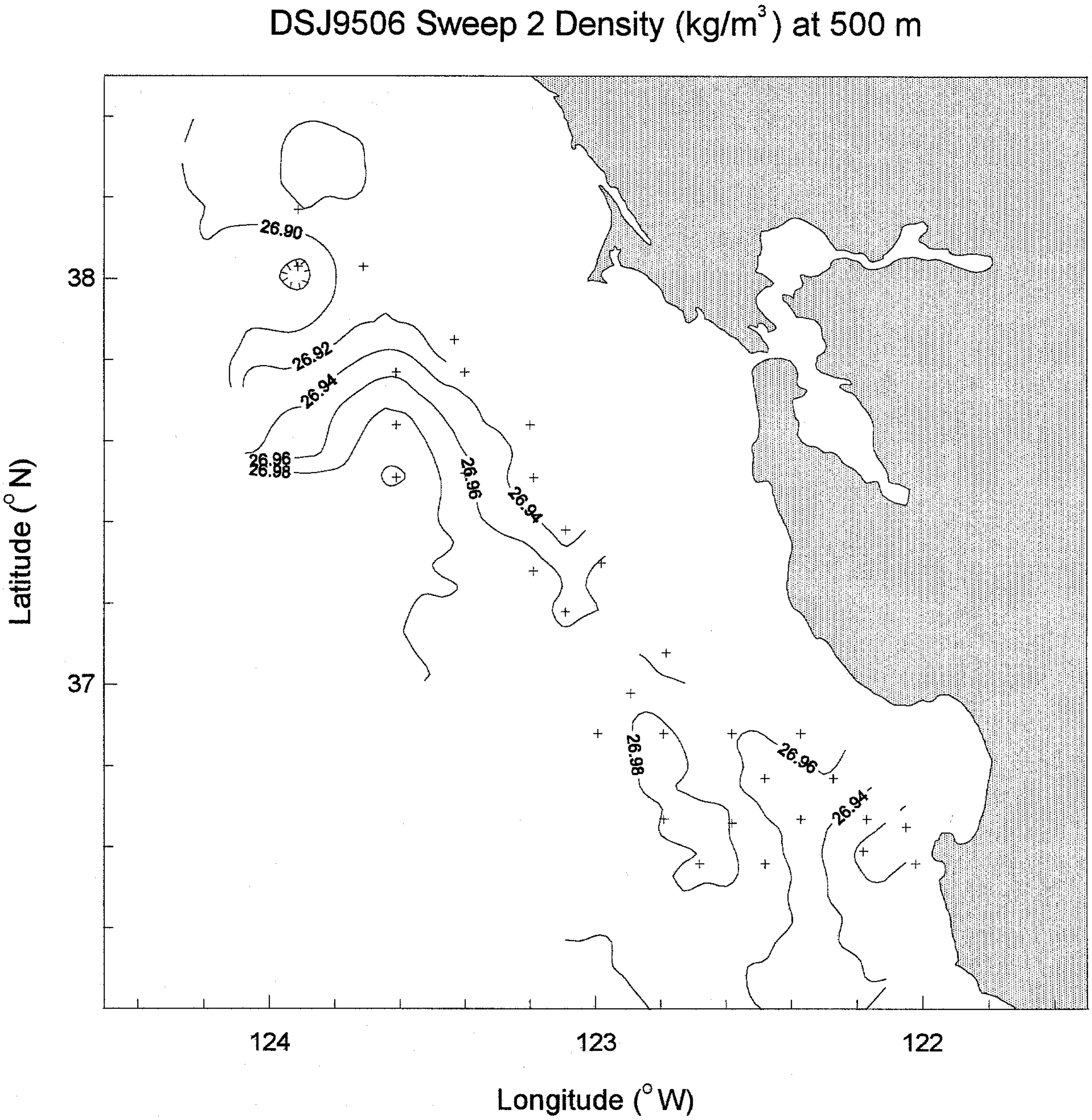
DSJ9506 Sweep 2 Density (kg/m^3) at 100 m
26.0
26.0
26.2
26.2
26.2
26.2
26.2
26.4
26.4
38
37
Latitude (°N)
124
123
122
Longitude (°W)

DSJ9506 Sweep 2 Density (kg/m^3) at 200 m



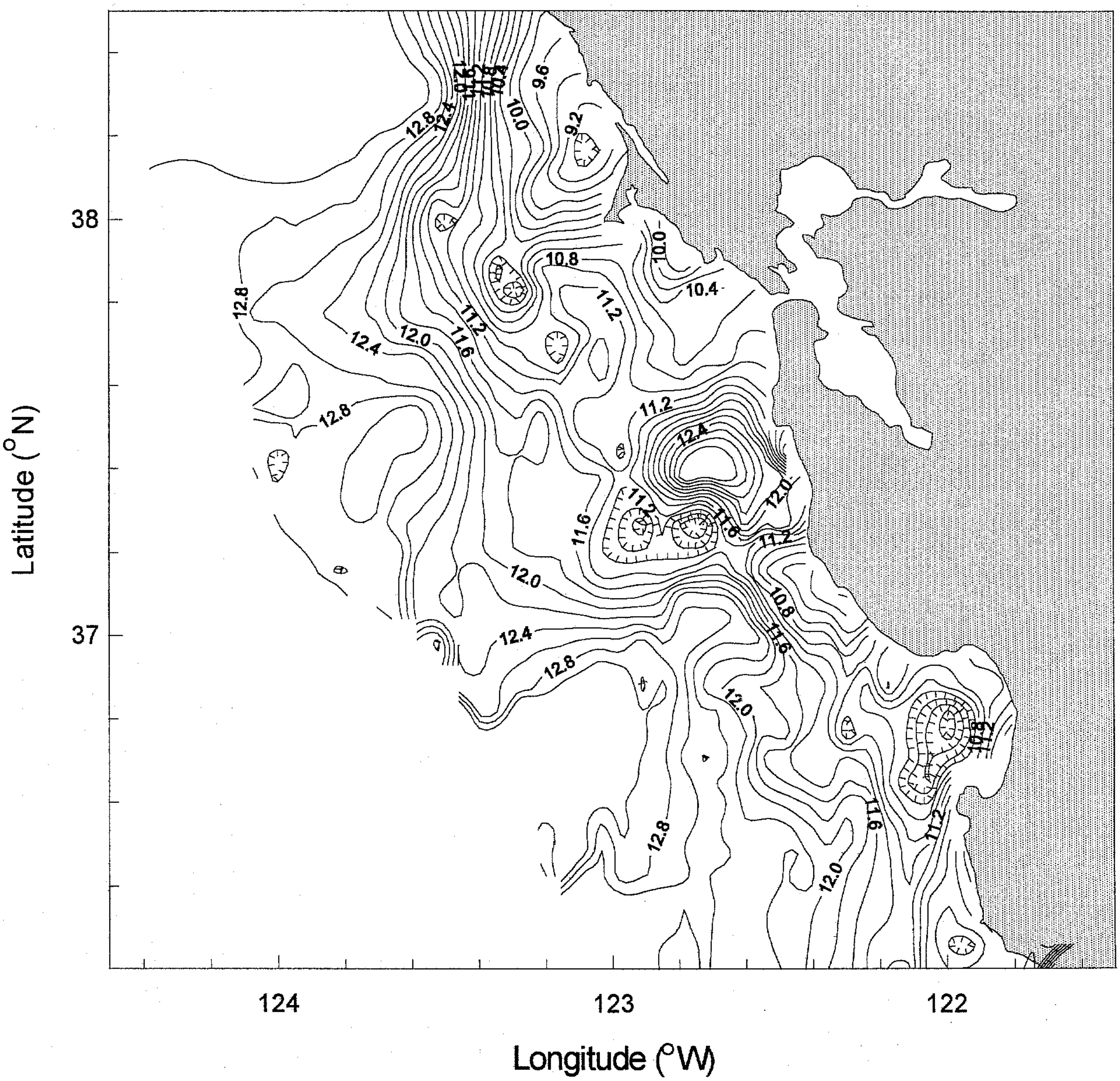
DSJ9506 Sweep 2 Density (kg/m^3) at 300 m



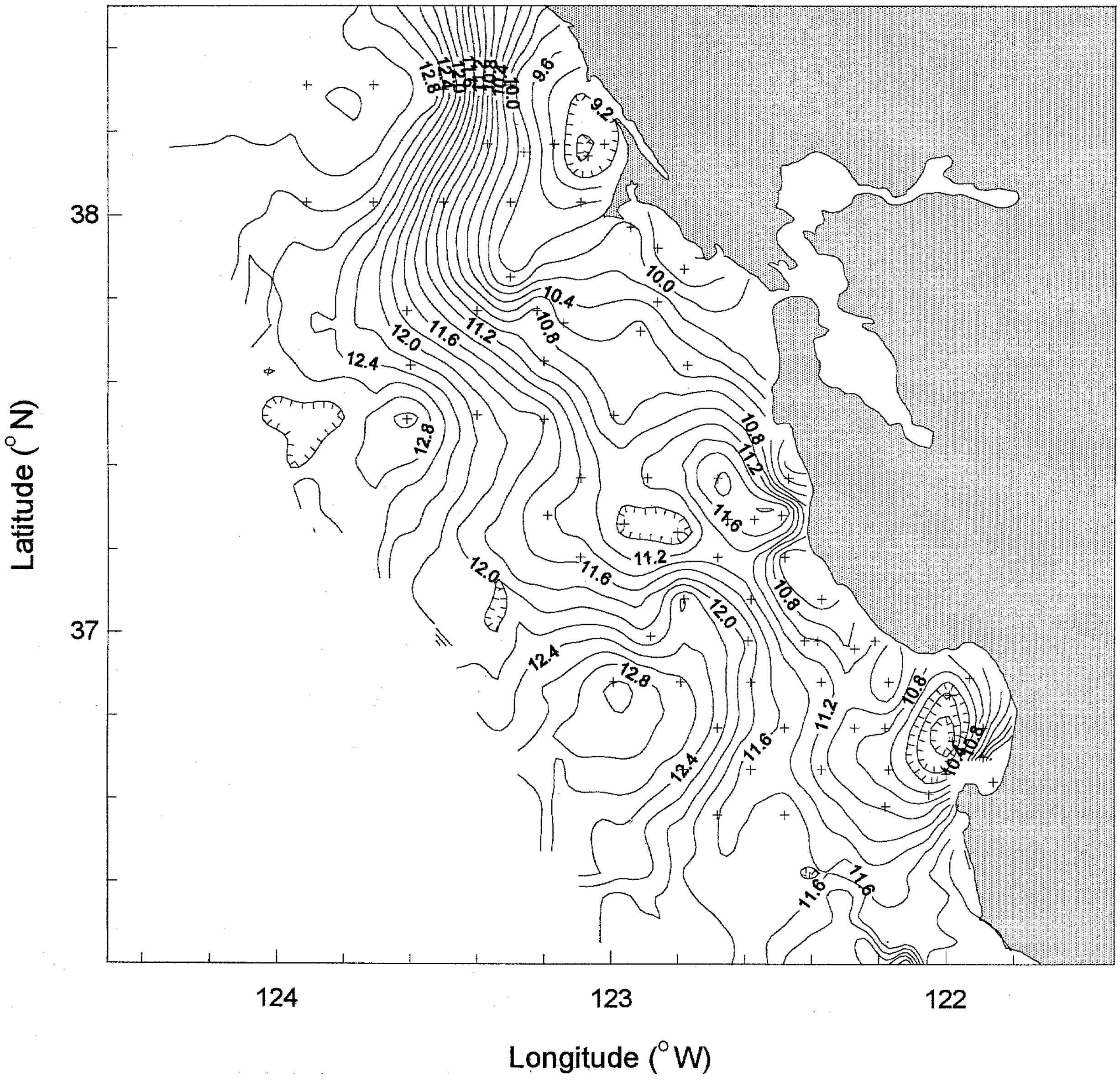

DSJ9506 Sweep 2 Density (kg/m³) at 500 m
26.90
26.92
26.94
26.96
26.98
26.96
26.94
26.98
26.96
26.94
38
37
Latitude (°N)
124
123
122
Longitude (°W)

APPENDIX 7.3: HORIZONTAL MAPS OF CTD AND TS FOR DSJ9506, SWEEP 3

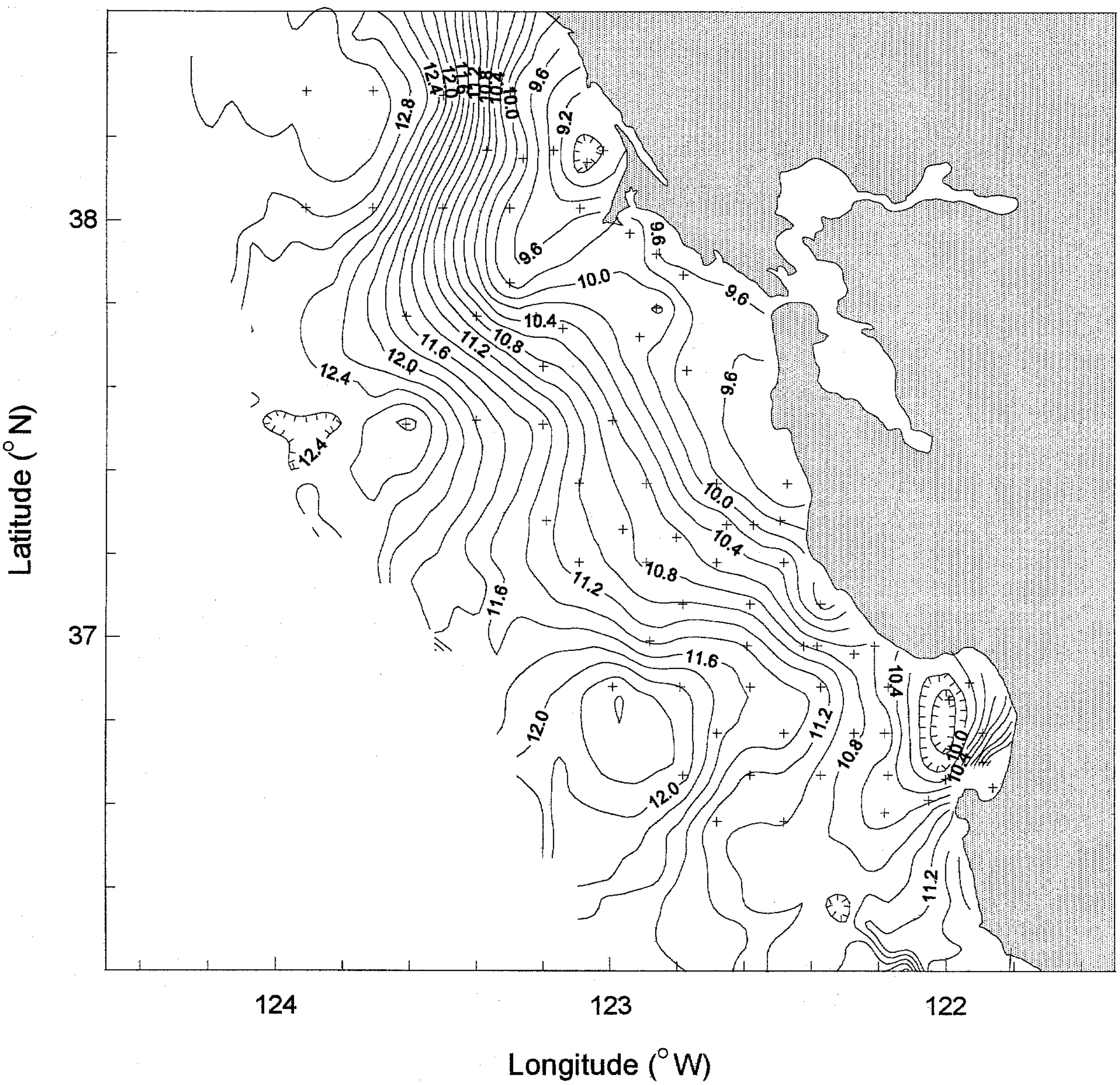
DSJ9506 Sweep 3 TS Temperature (°C)



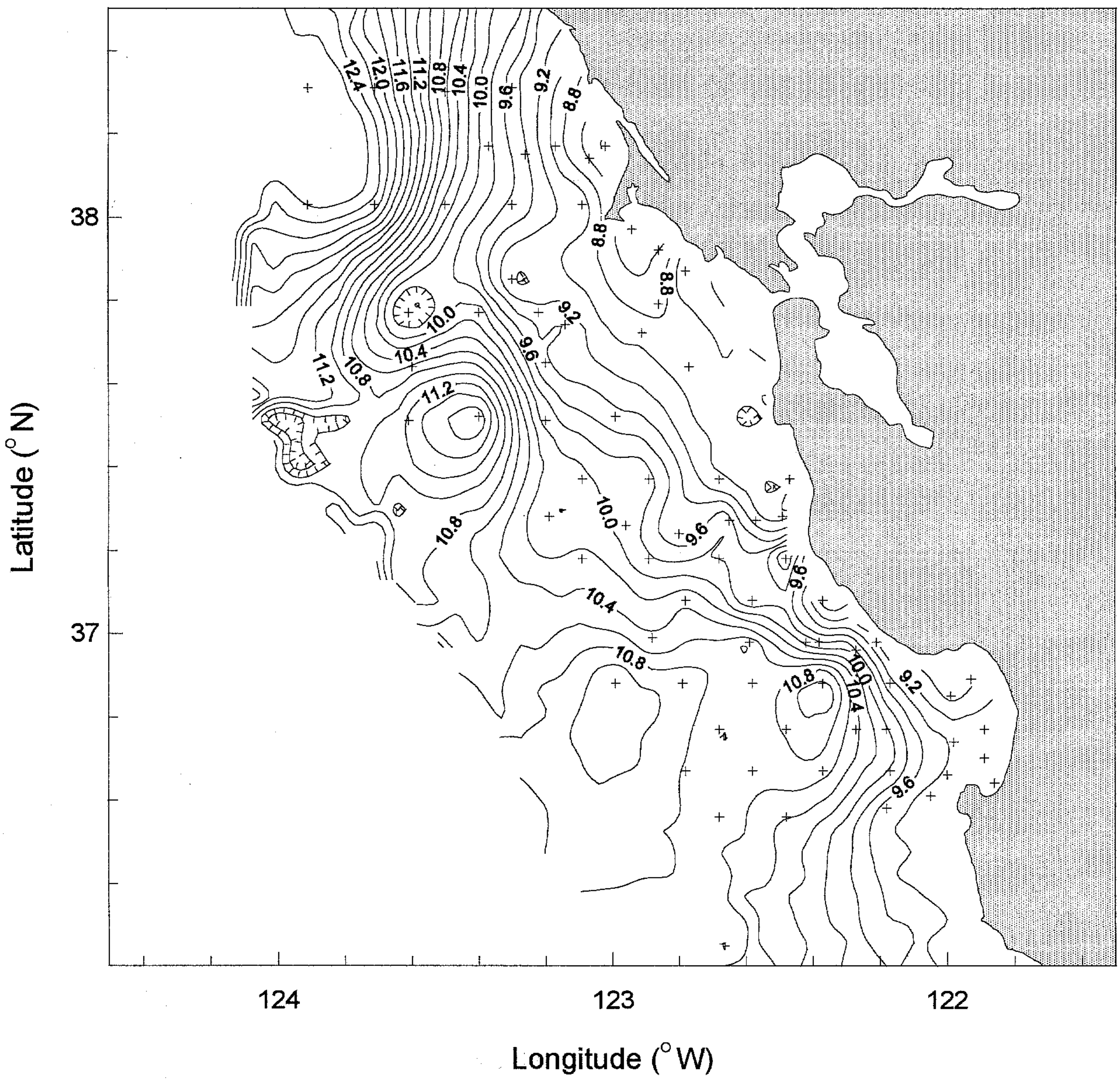
DSJ9506 Sweep 3 Temperature (°C) at 2 m

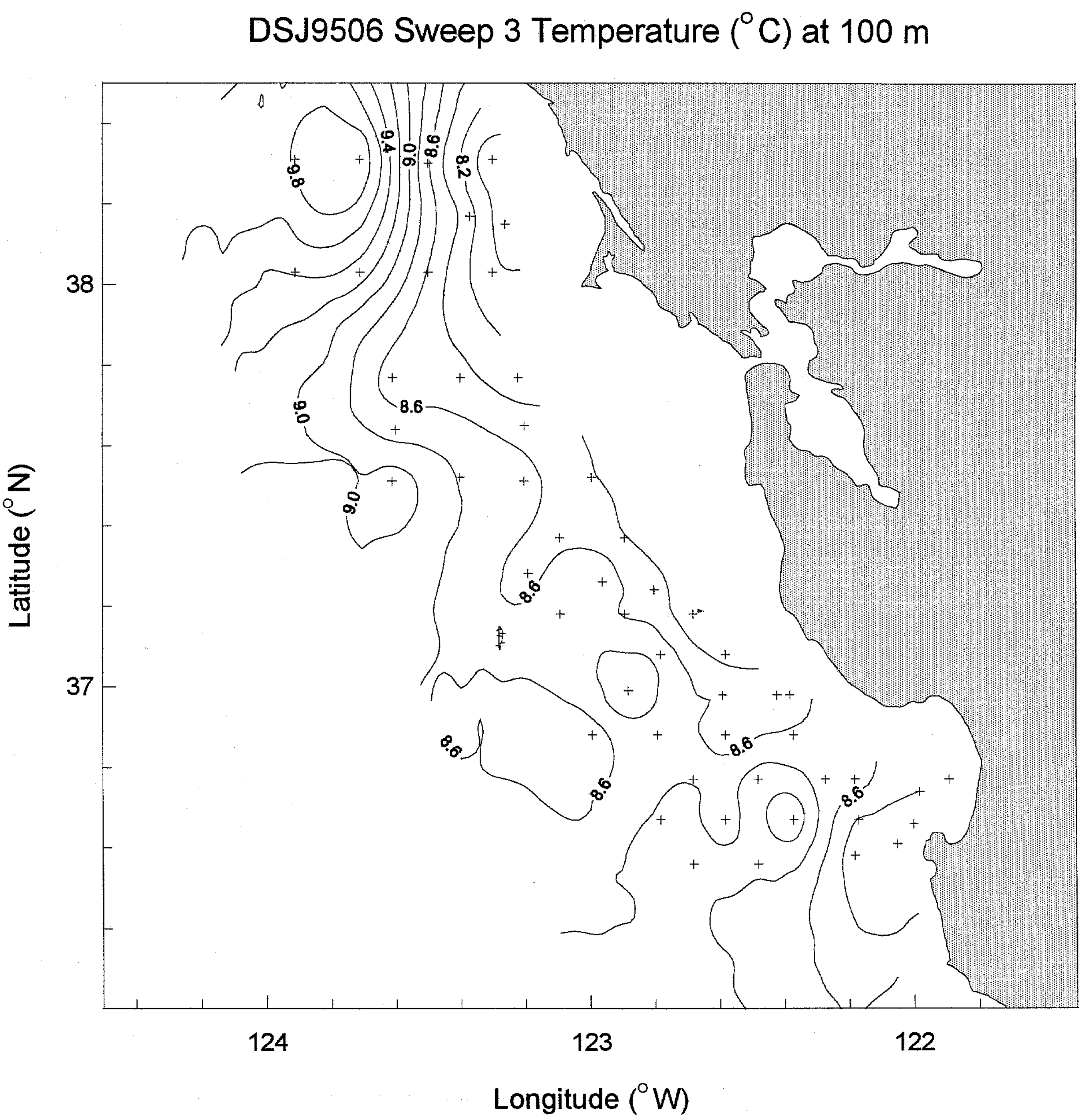


DSJ9506 Sweep 3 Temperature (°C) at 10 m

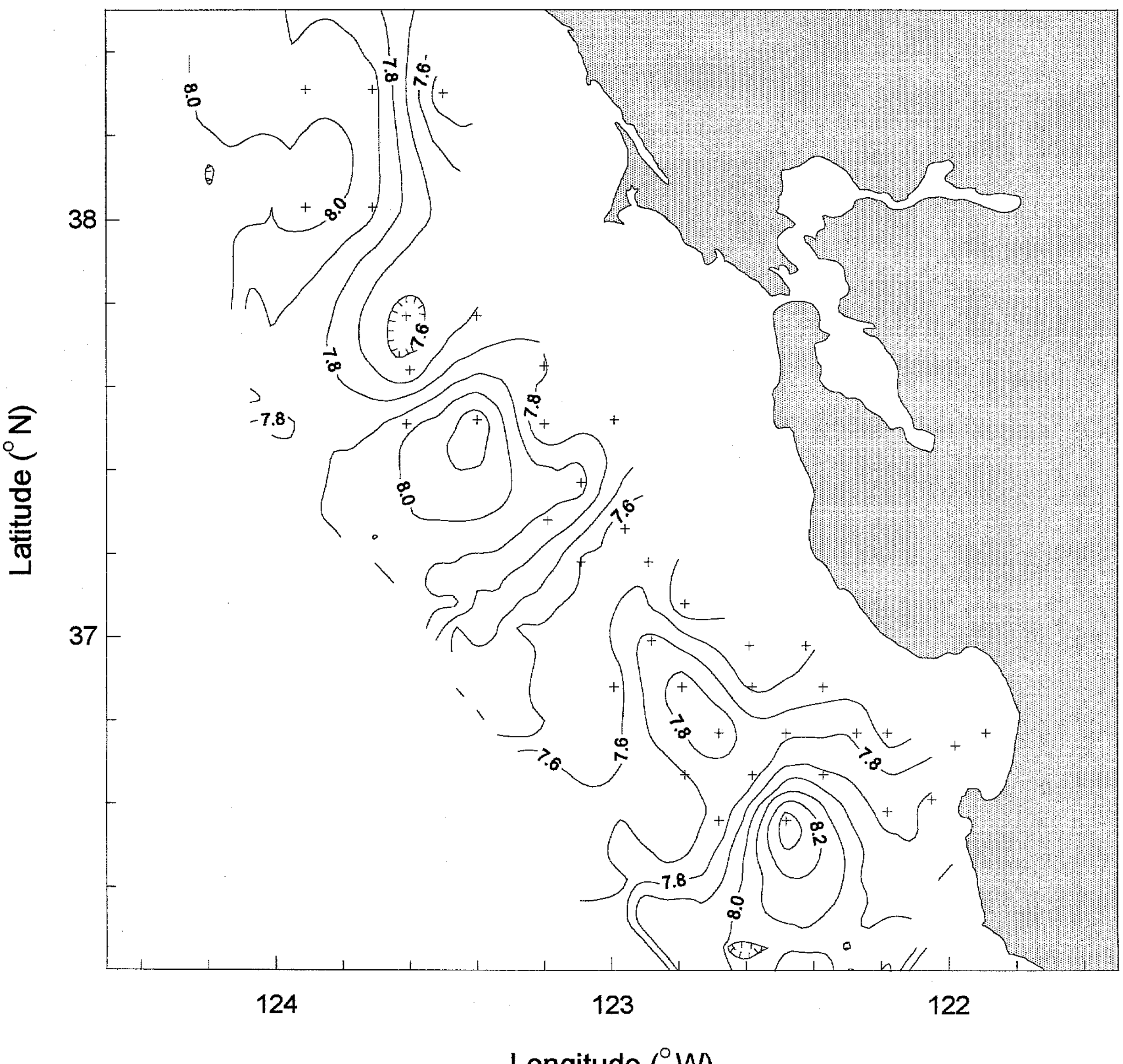


DSJ9506 Sweep 3 Temperature (°C) at 30 m

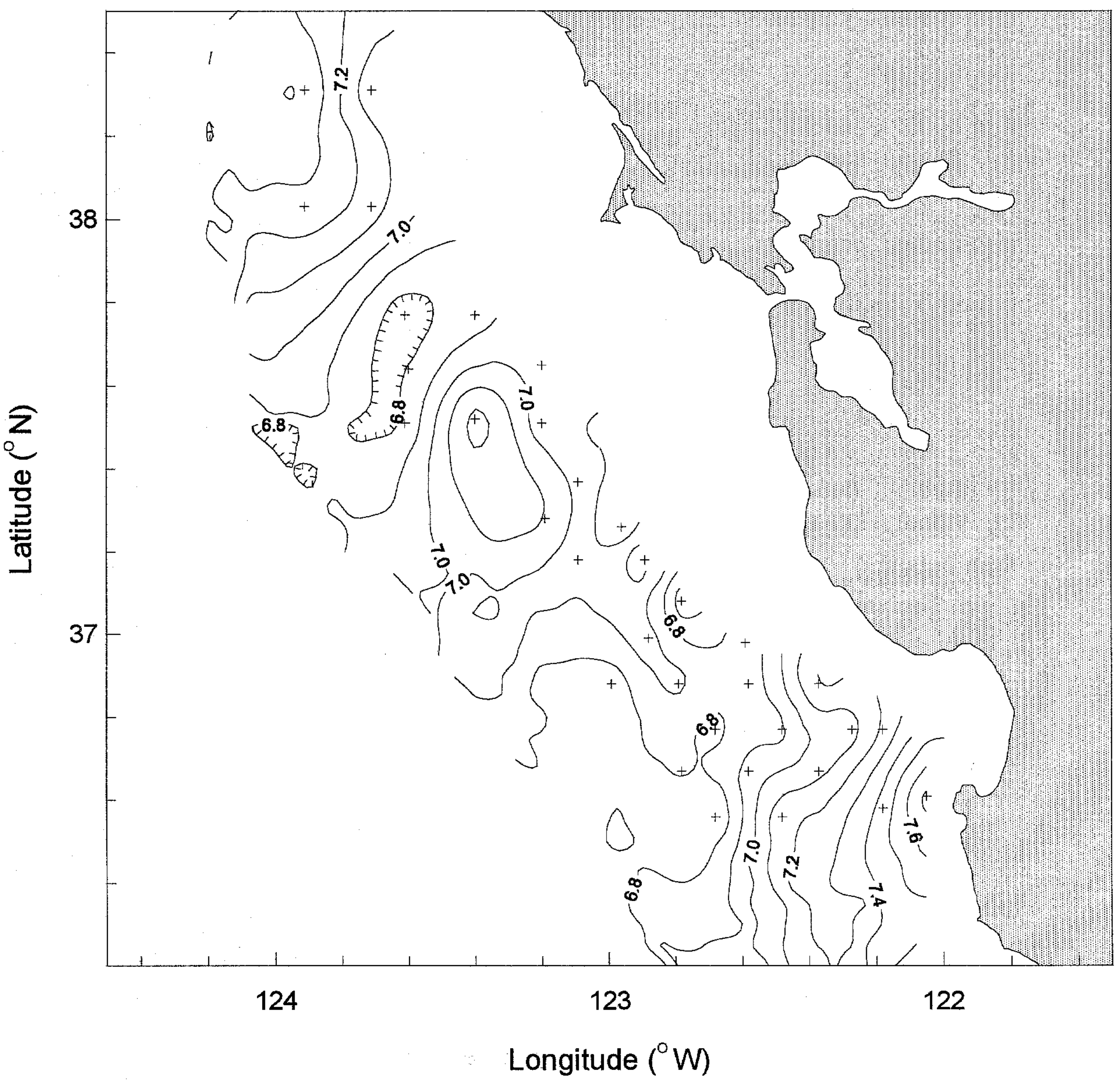



DSJ9506 Sweep 3 Temperature (°C) at 100 m
9.8
9.4
9.0
8.6
8.2
8.6
9.0
9.0
8.6
8.6
8.6
8.6
8.6
8.6
38
37
Latitude (°N)
124
123
122
Longitude (°W)

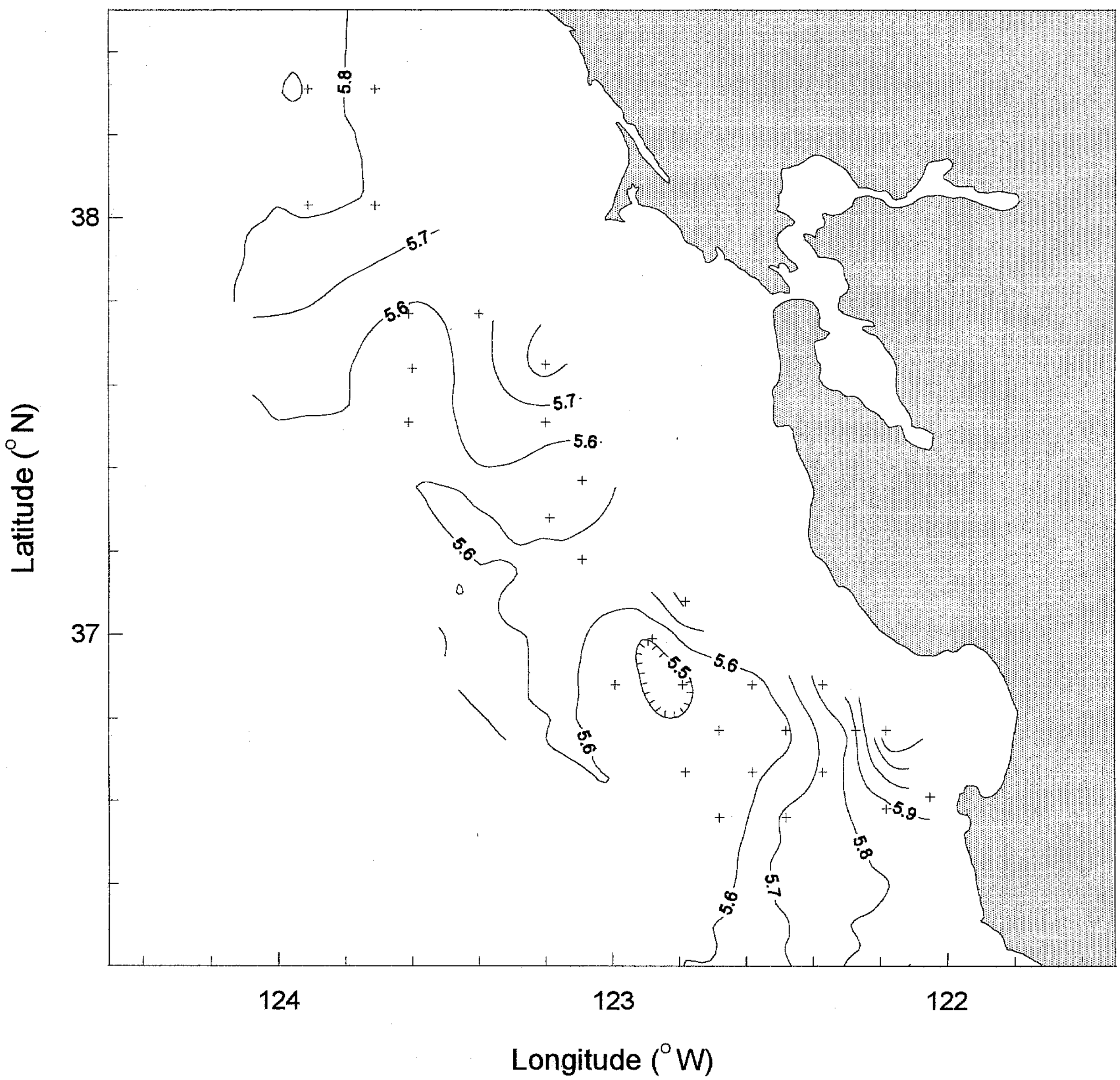
DSJ9506 Sweep 3 Temperature (°C) at 200 m



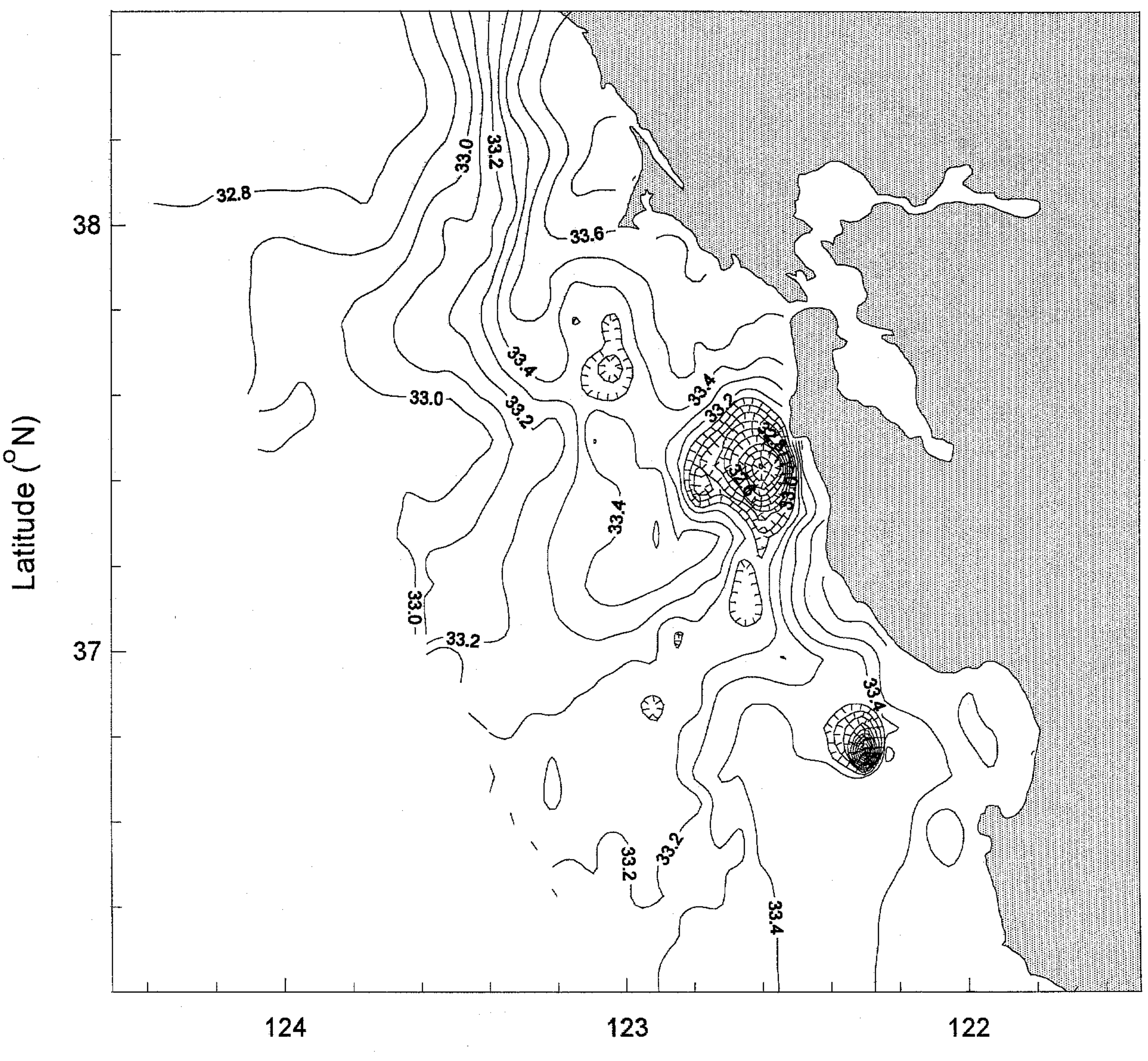
DSJ9506 Sweep 3 Temperature (°C) at 300 m

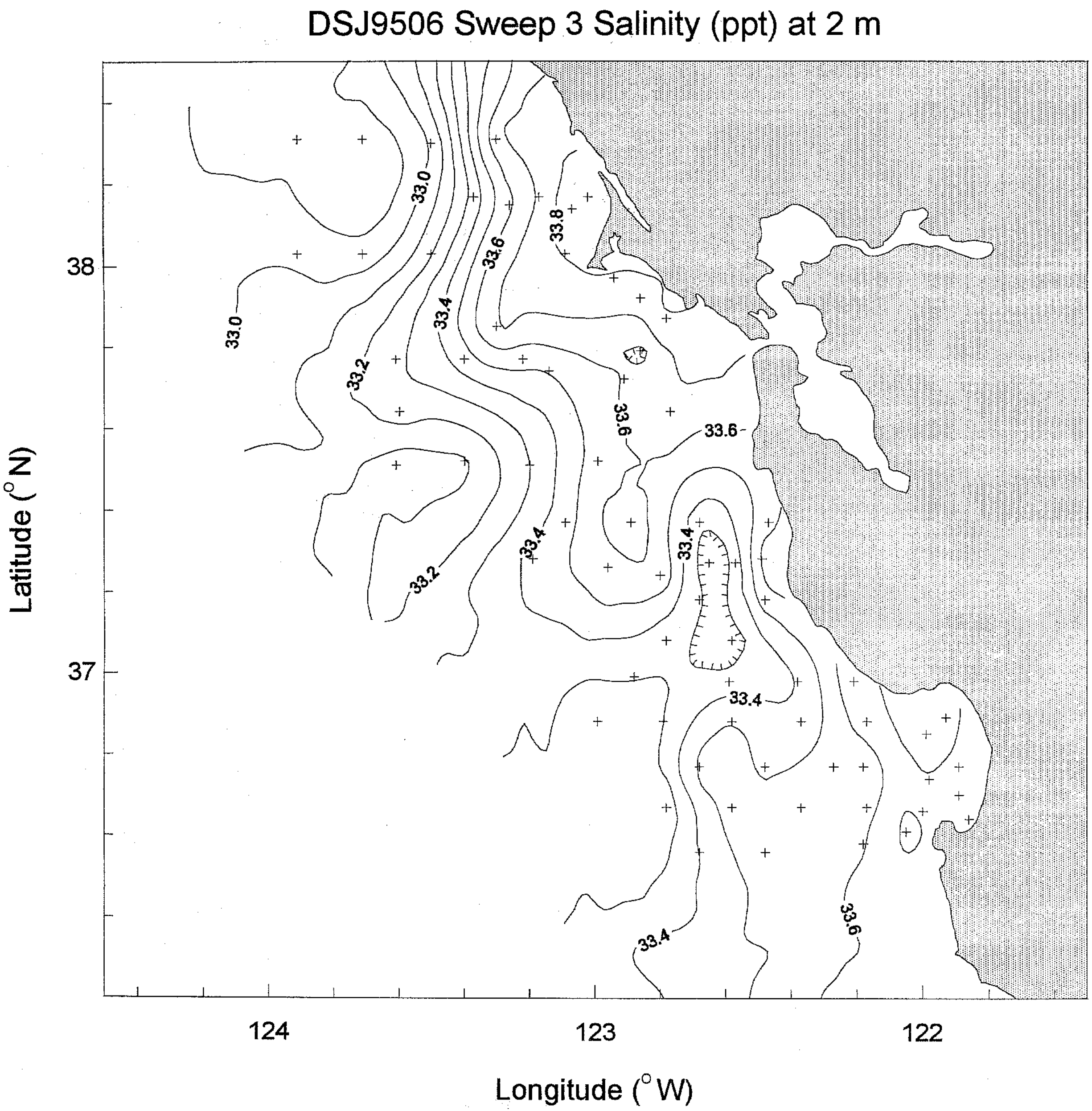


DSJ9506 Sweep 3 Temperature (°C) at 500 m



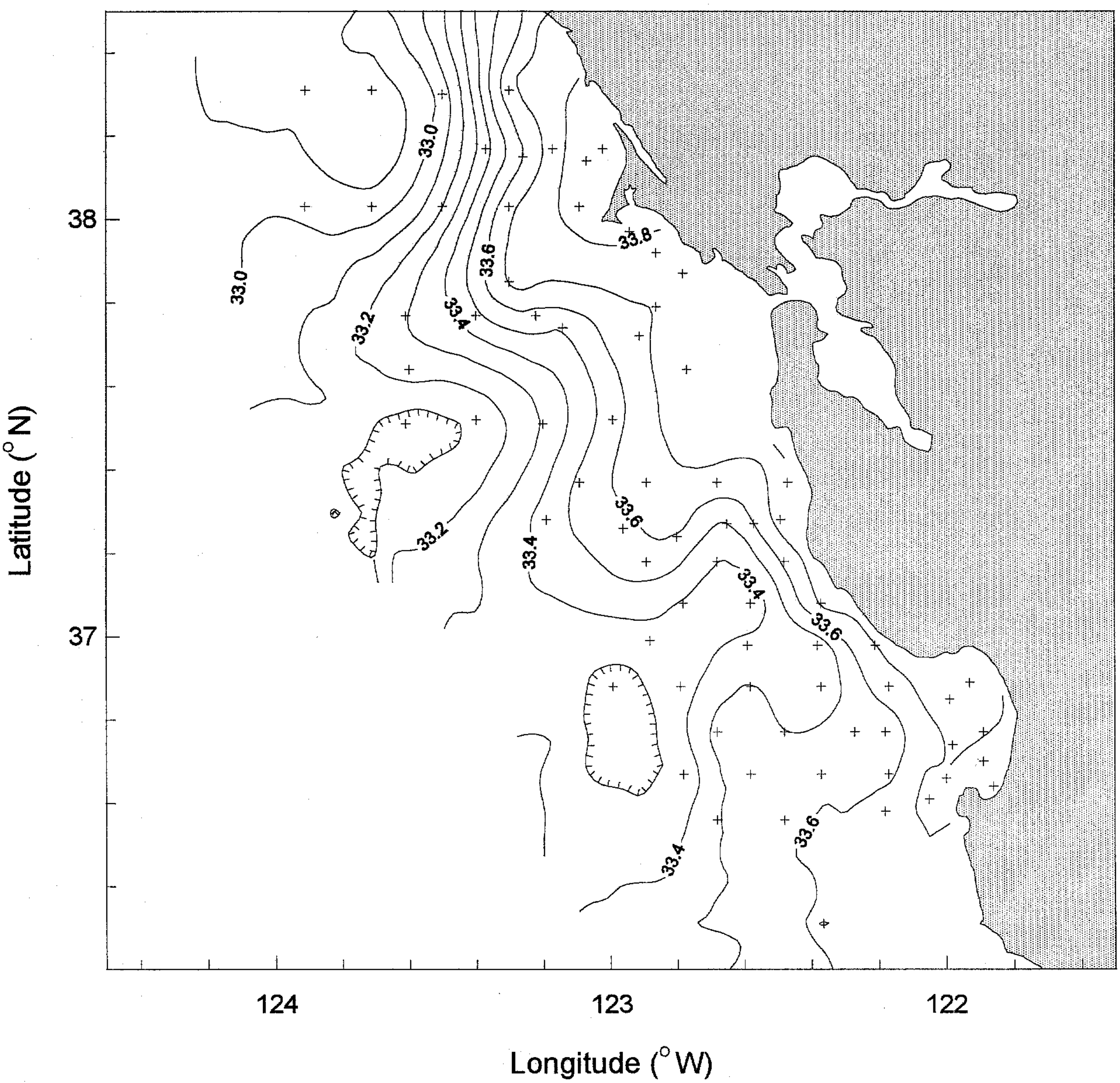
DSJ9506 Sweep 3 TS Salinity (ppt)



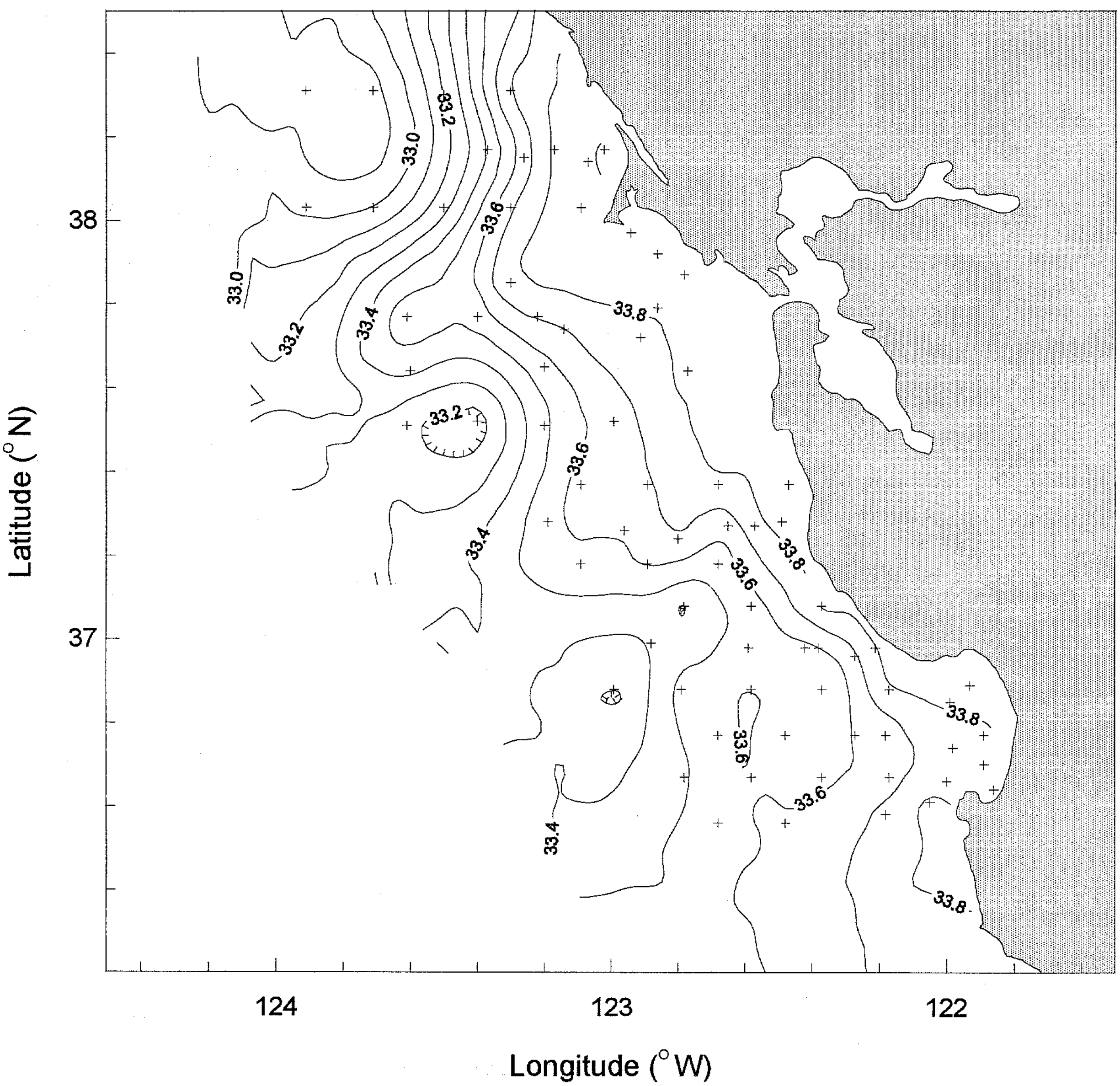


DSJ9506 Sweep 3 Salinity (ppt) at 2 m
Latitude (° N)
Longitude (° W)
38
37
124
123
122
33.0
33.2
33.4
33.6
33.8

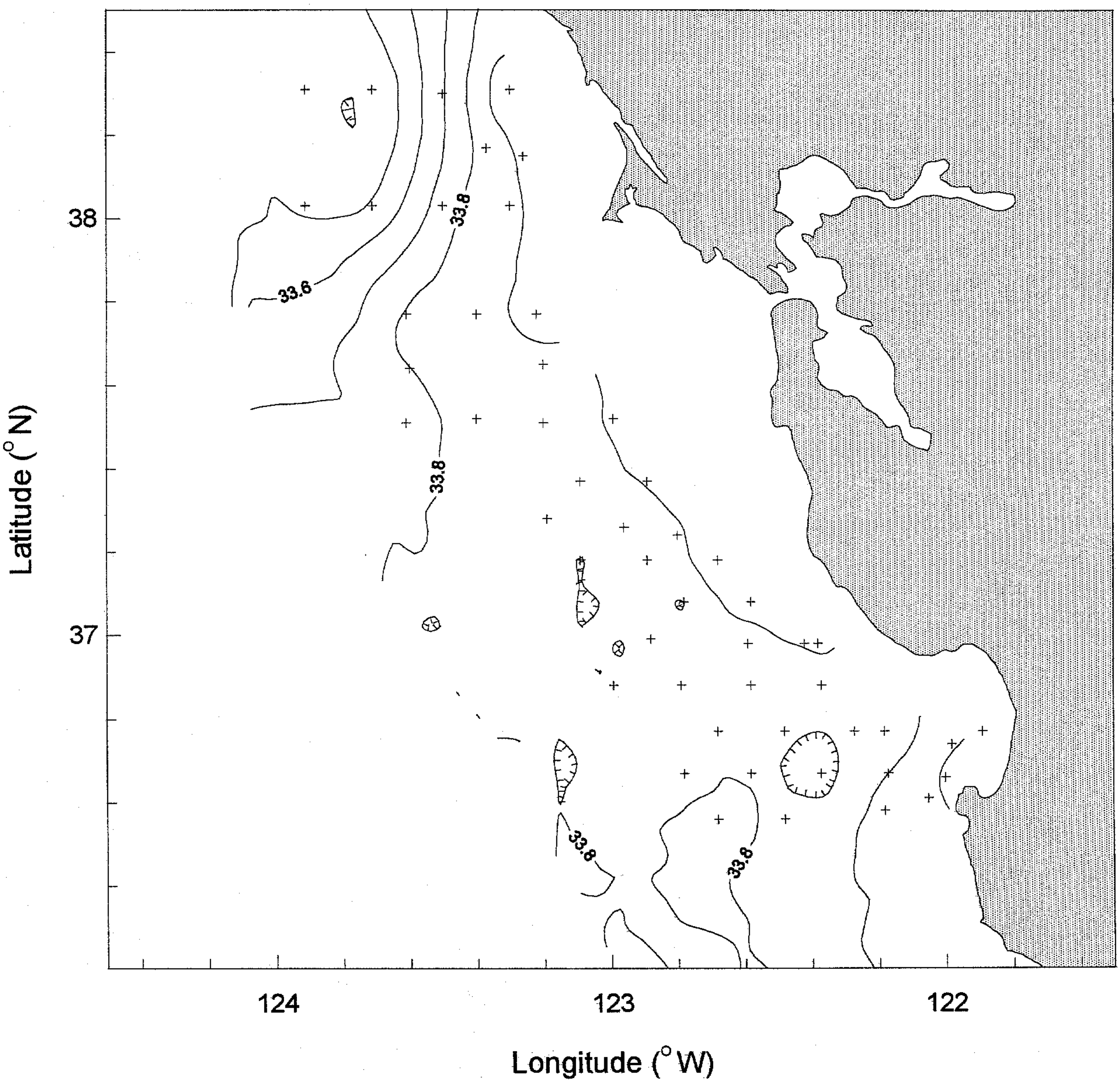
DSJ9506 Sweep 3 Salinity (ppt) at 10 m



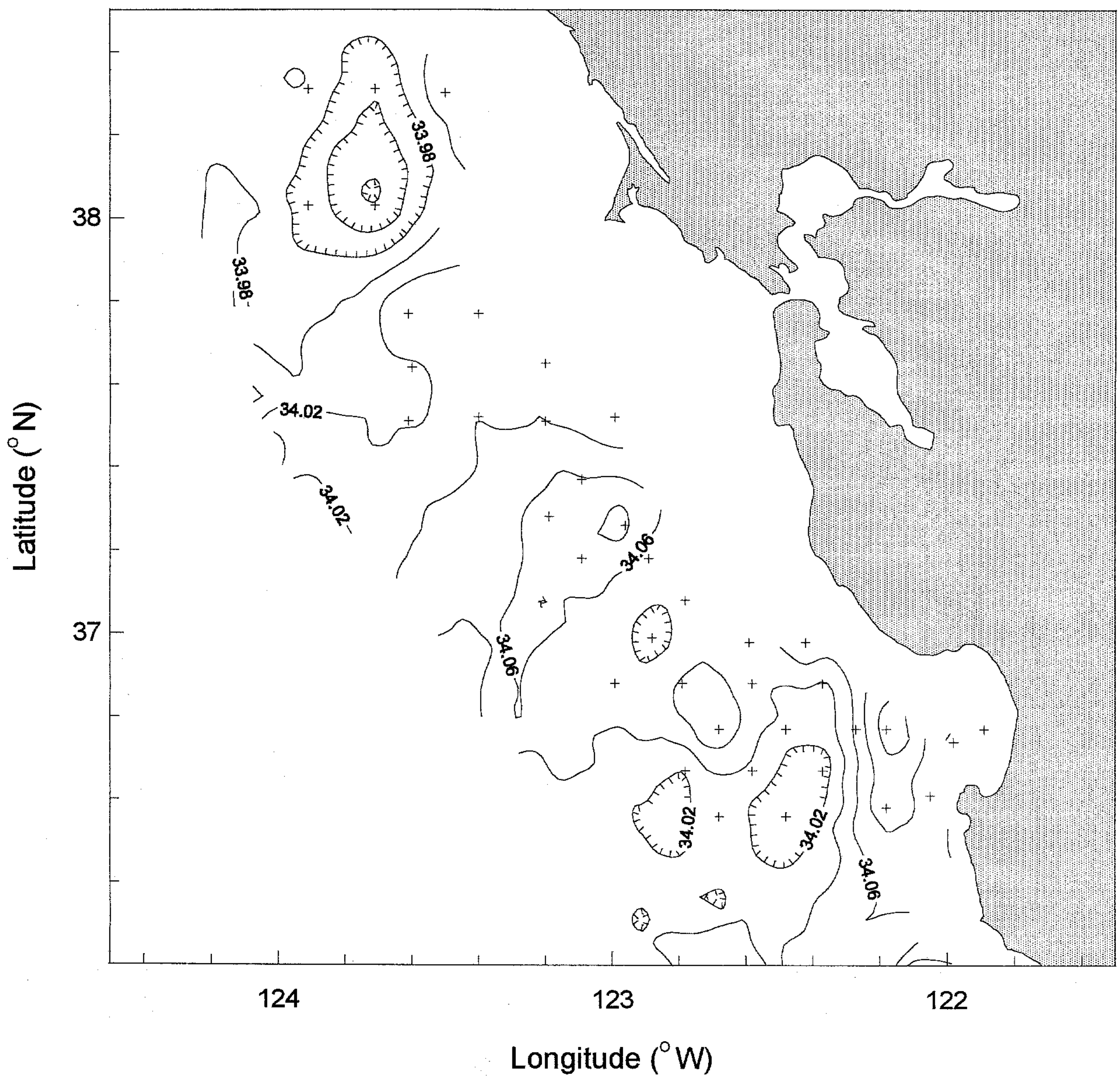
DSJ9506 Sweep 3 Salinity (ppt) at 30 m

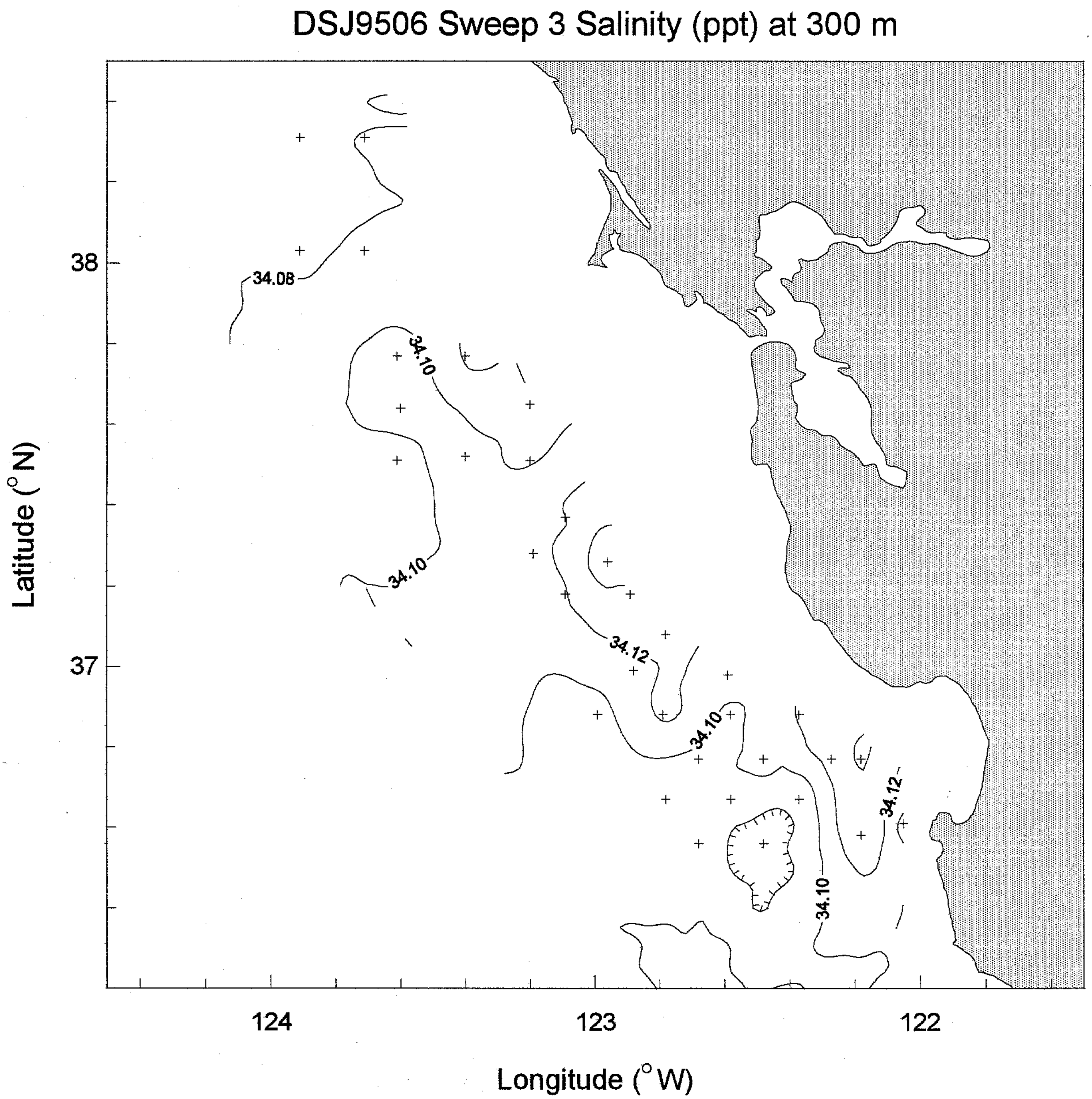


DSJ9506 Sweep 3 Salinity (ppt) at 100 m

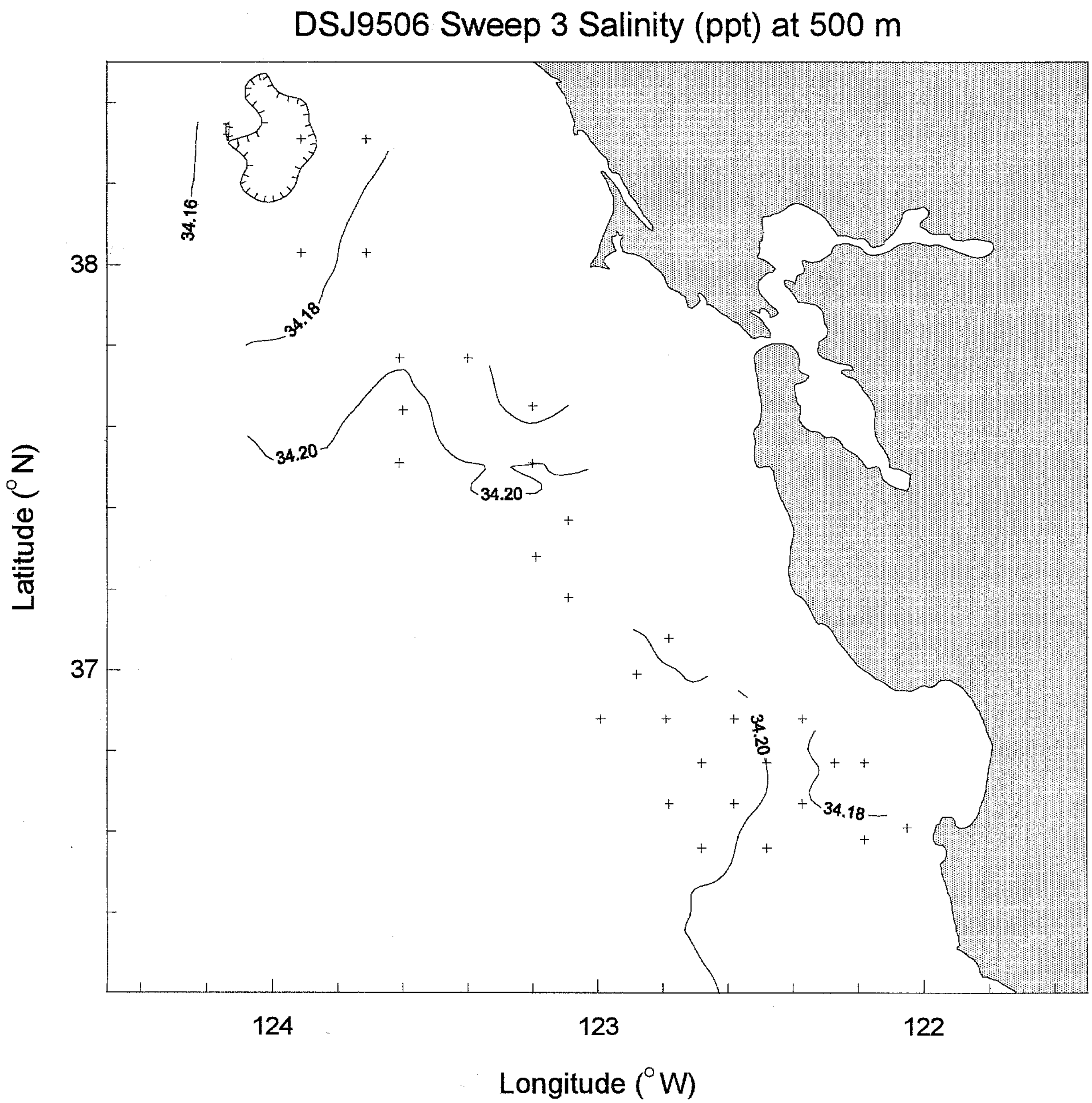


DSJ9506 Sweep 3 Salinity (ppt) at 200 m

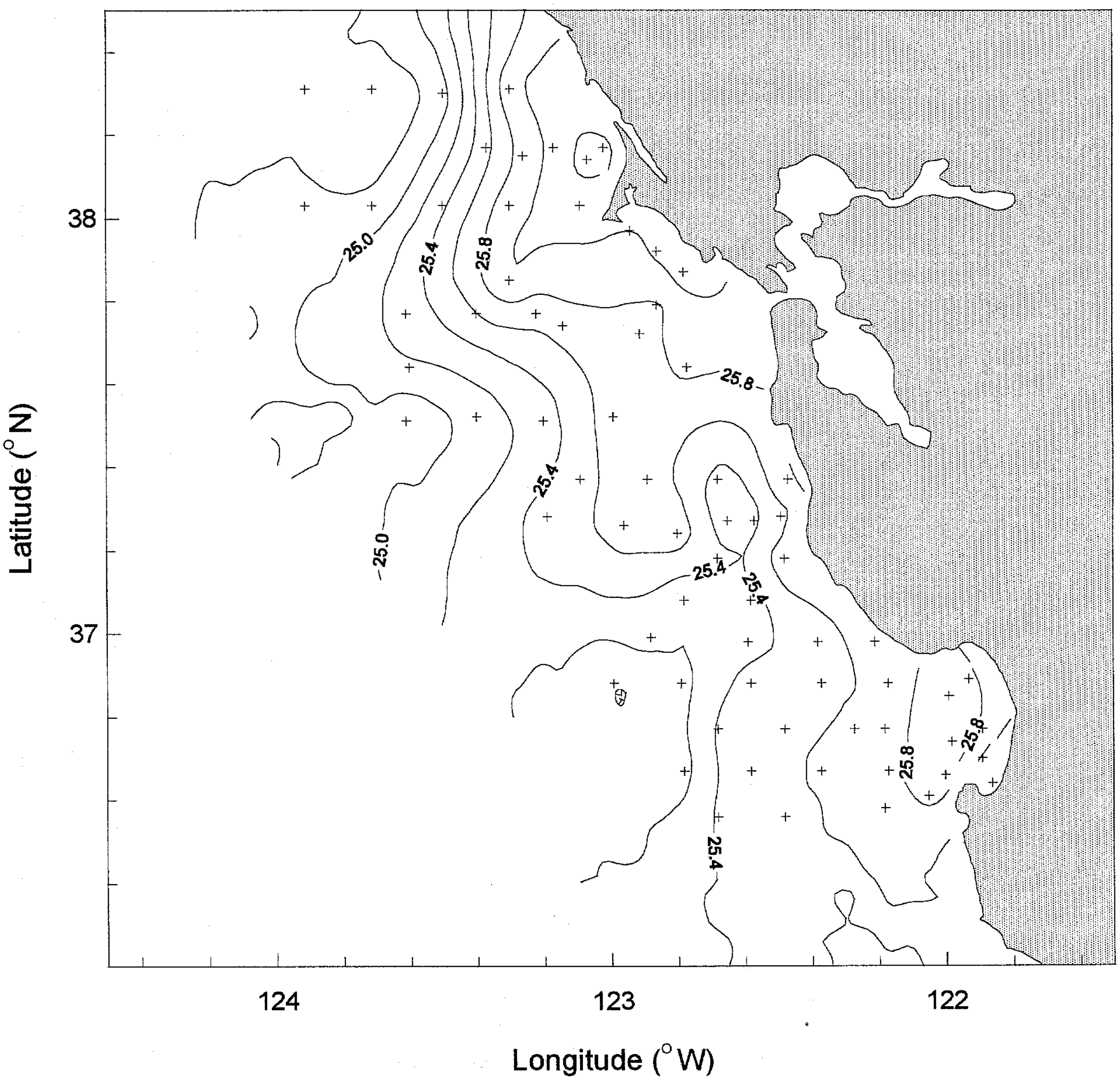




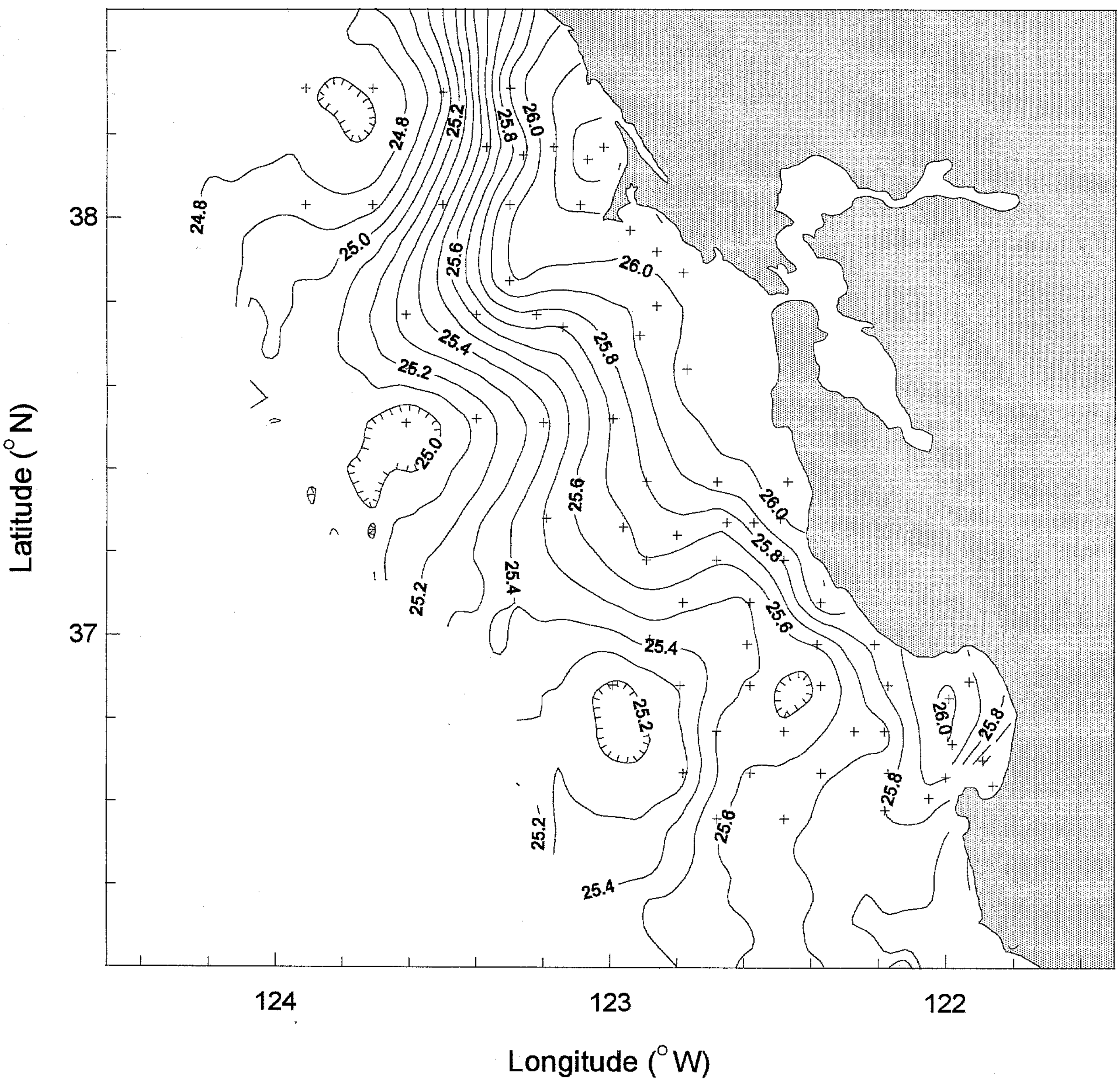
DSJ9506 Sweep 3 Salinity (ppt) at 300 m
Latitude (°N)
38
37
34.08
34.10
34.10
34.12
34.10
34.12
34.10
124
123
122
Longitude (°W)


DSJ9506 Sweep 3 Salinity (ppt) at 500 m
34.16
34.18
34.20
34.20
34.20
34.18
38
37
Latitude (° N)
124
123
122
Longitude (° W)

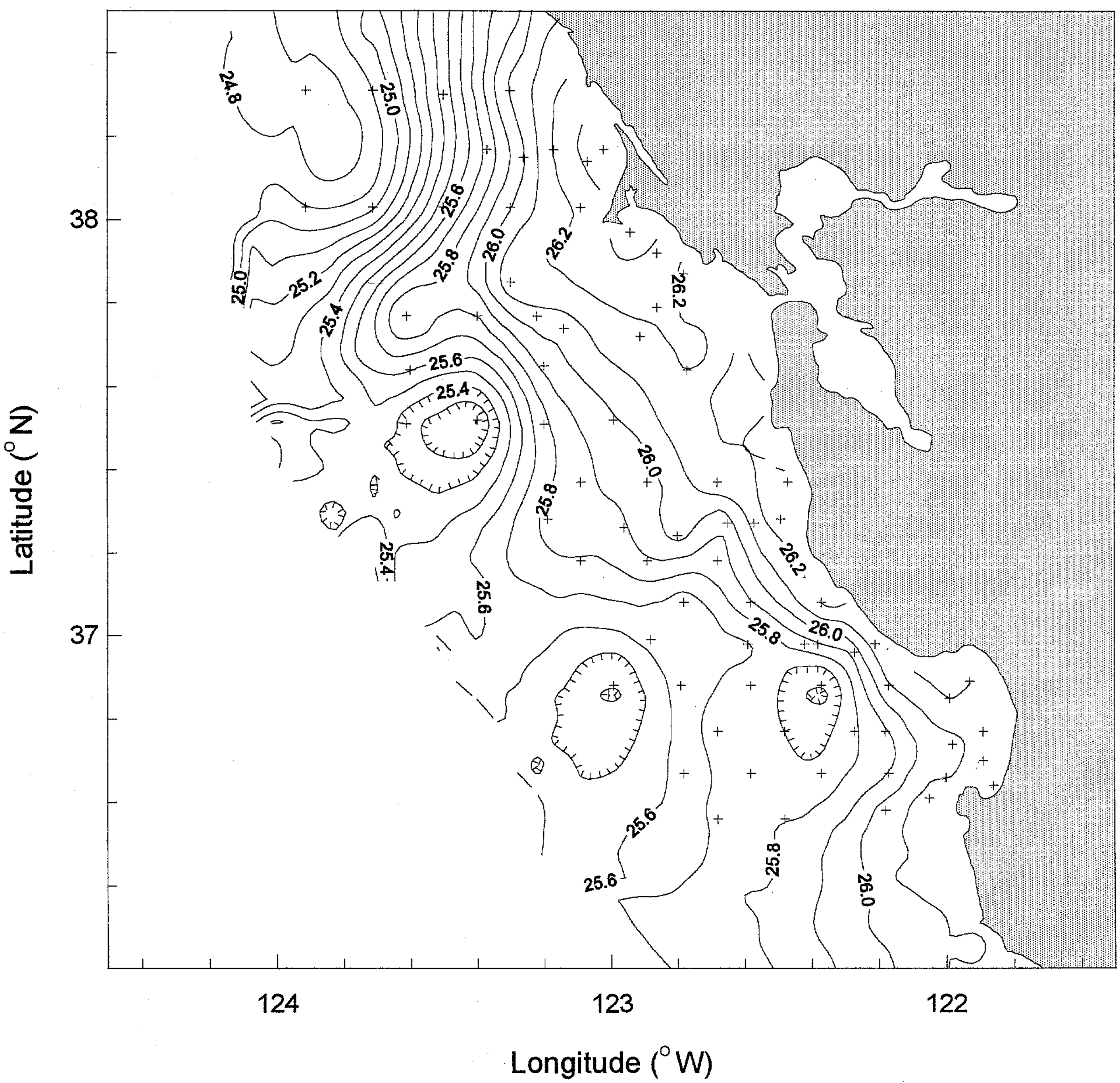
DSJ9506 Sweep 3 Density (kg/m^3) at 2 m



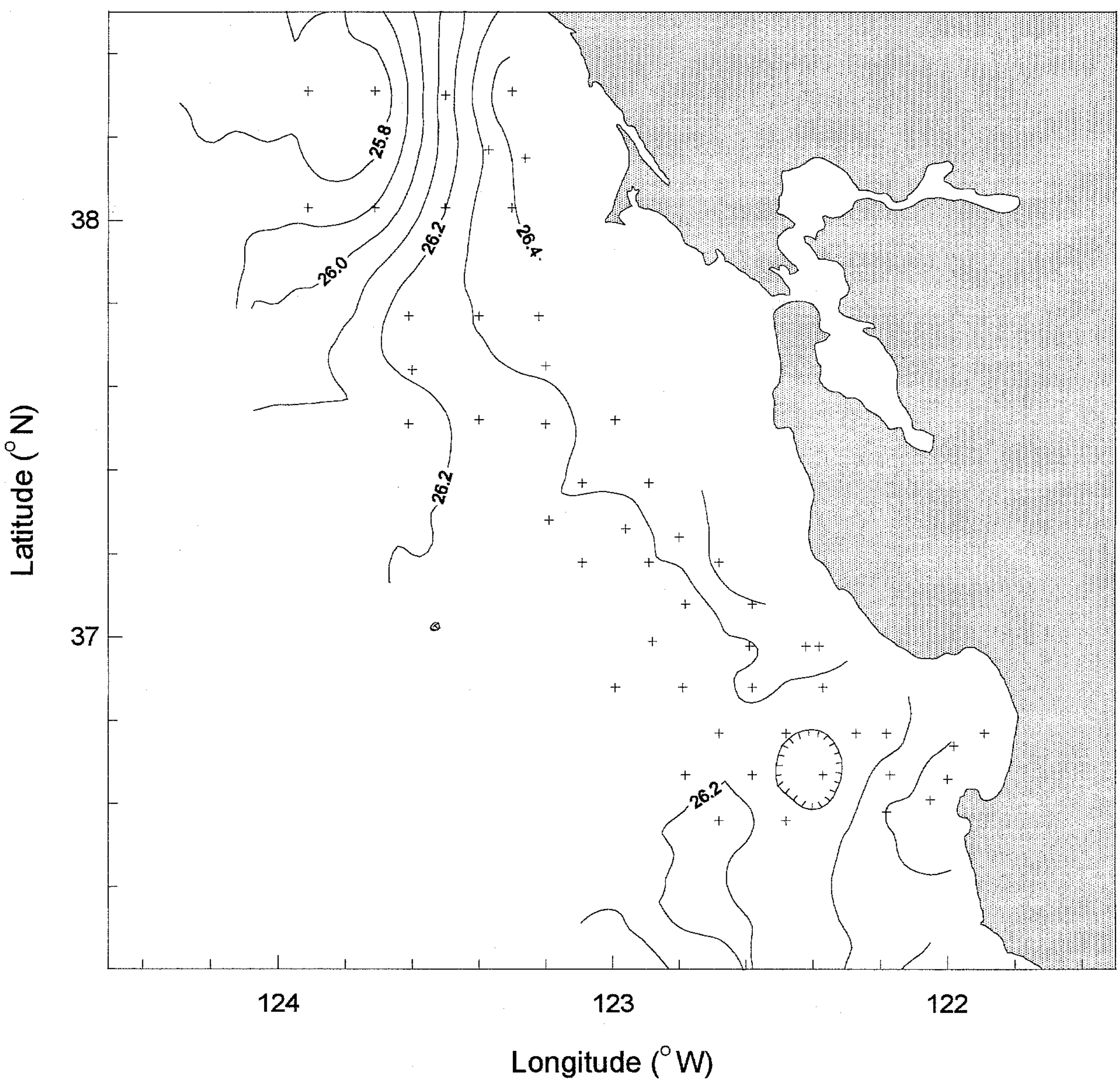
DSJ9506 Sweep 3 Density (kg/m^3) at 10 m

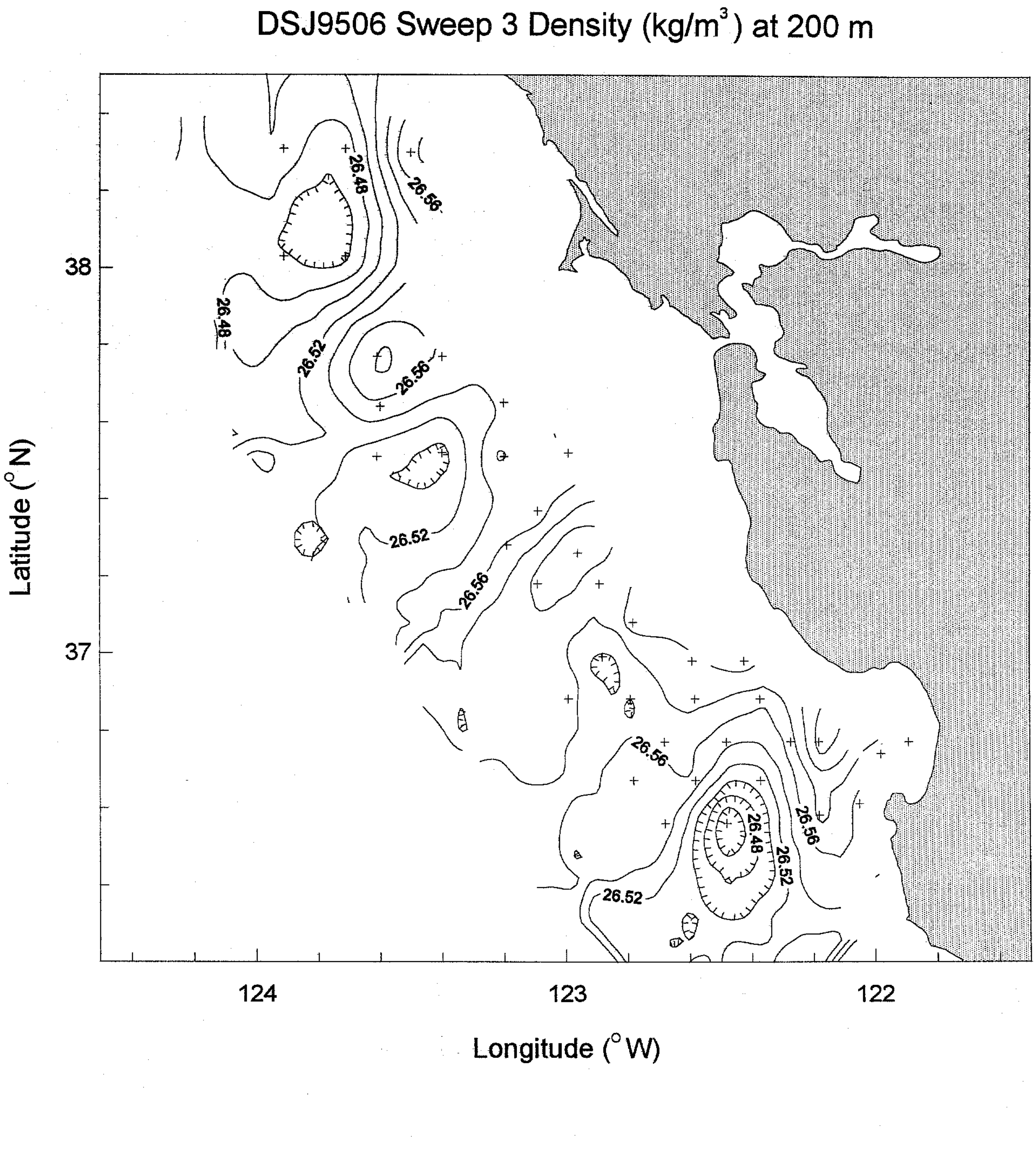


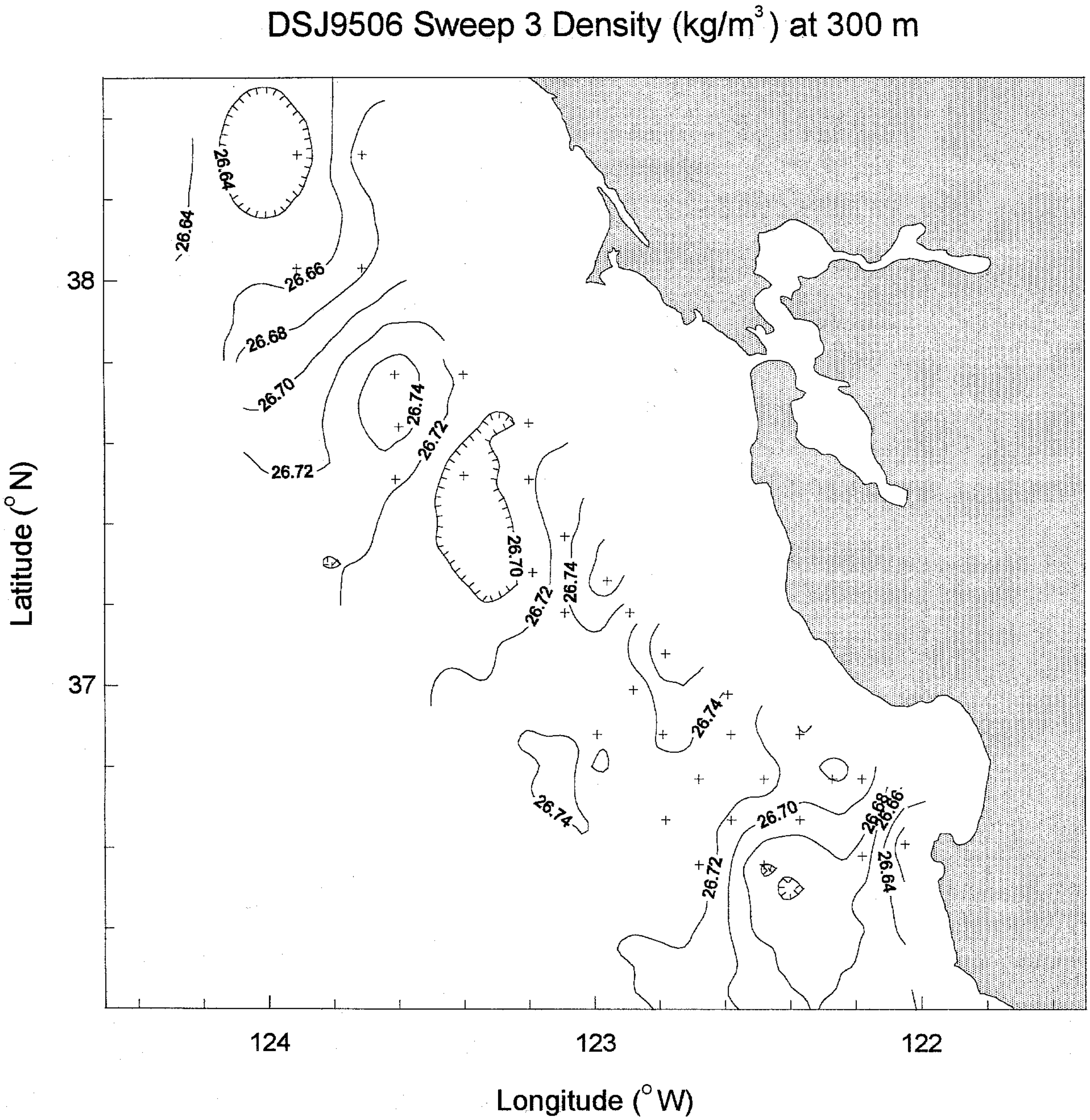
DSJ9506 Sweep 3 Density (kg/m^3) at 30 m

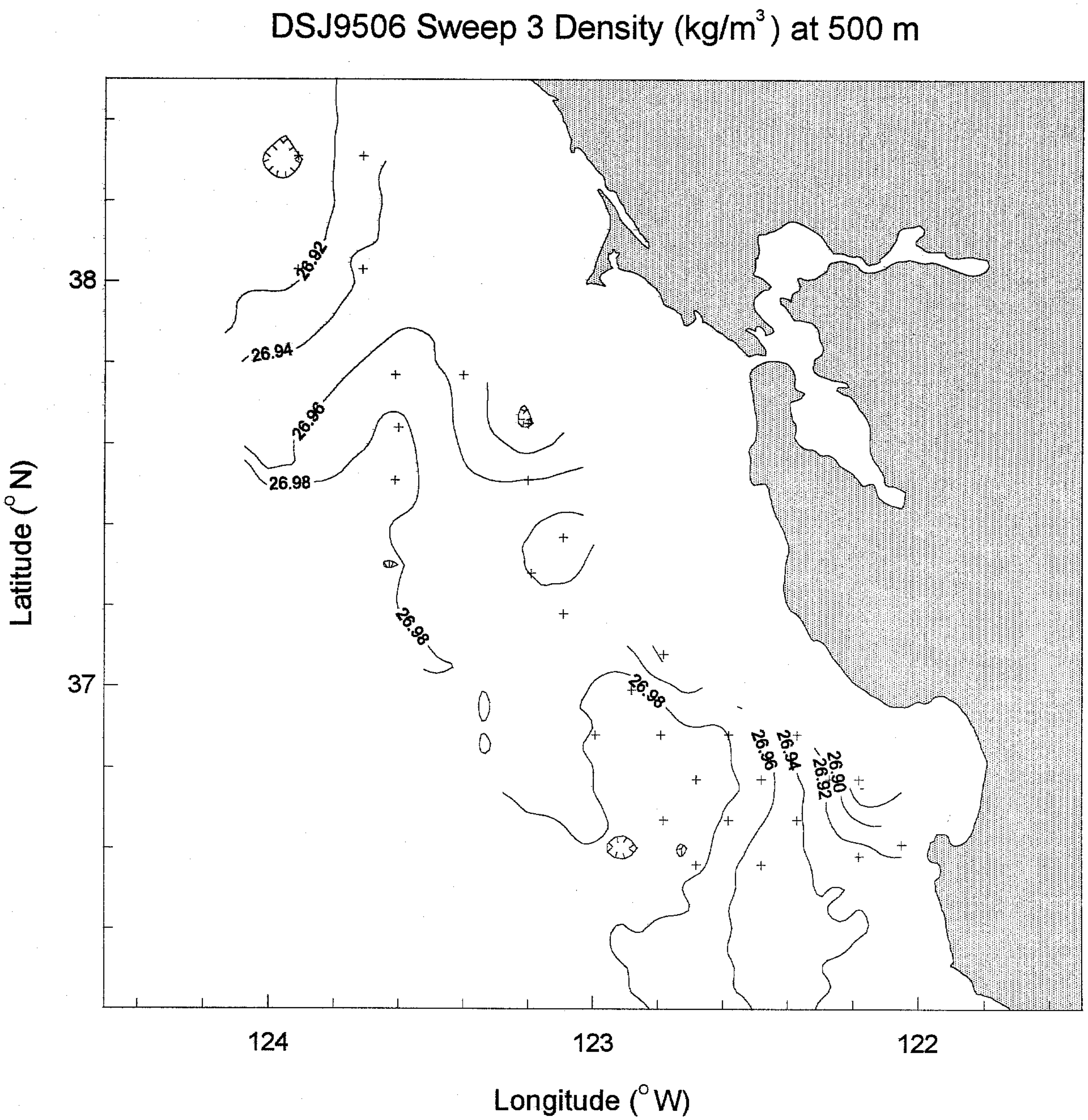


DSJ9506 Sweep 3 Density (kg/m³) at 100 m



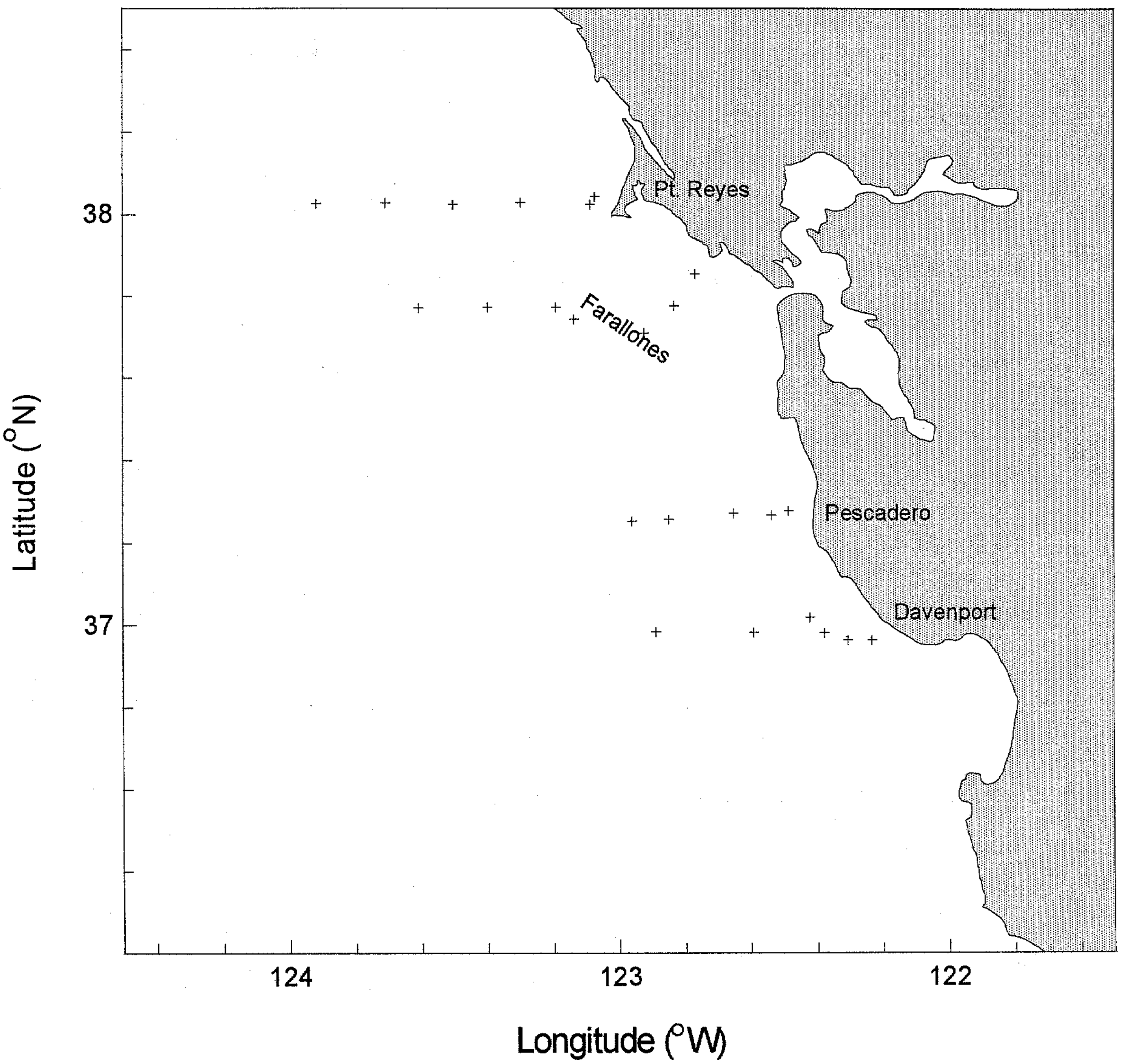

DSJ9506 Sweep 3 Density (kg/m³) at 200 m
Latitude (°N)
Longitude (°W)
38
37
124
123
122
26.48
26.52
26.56

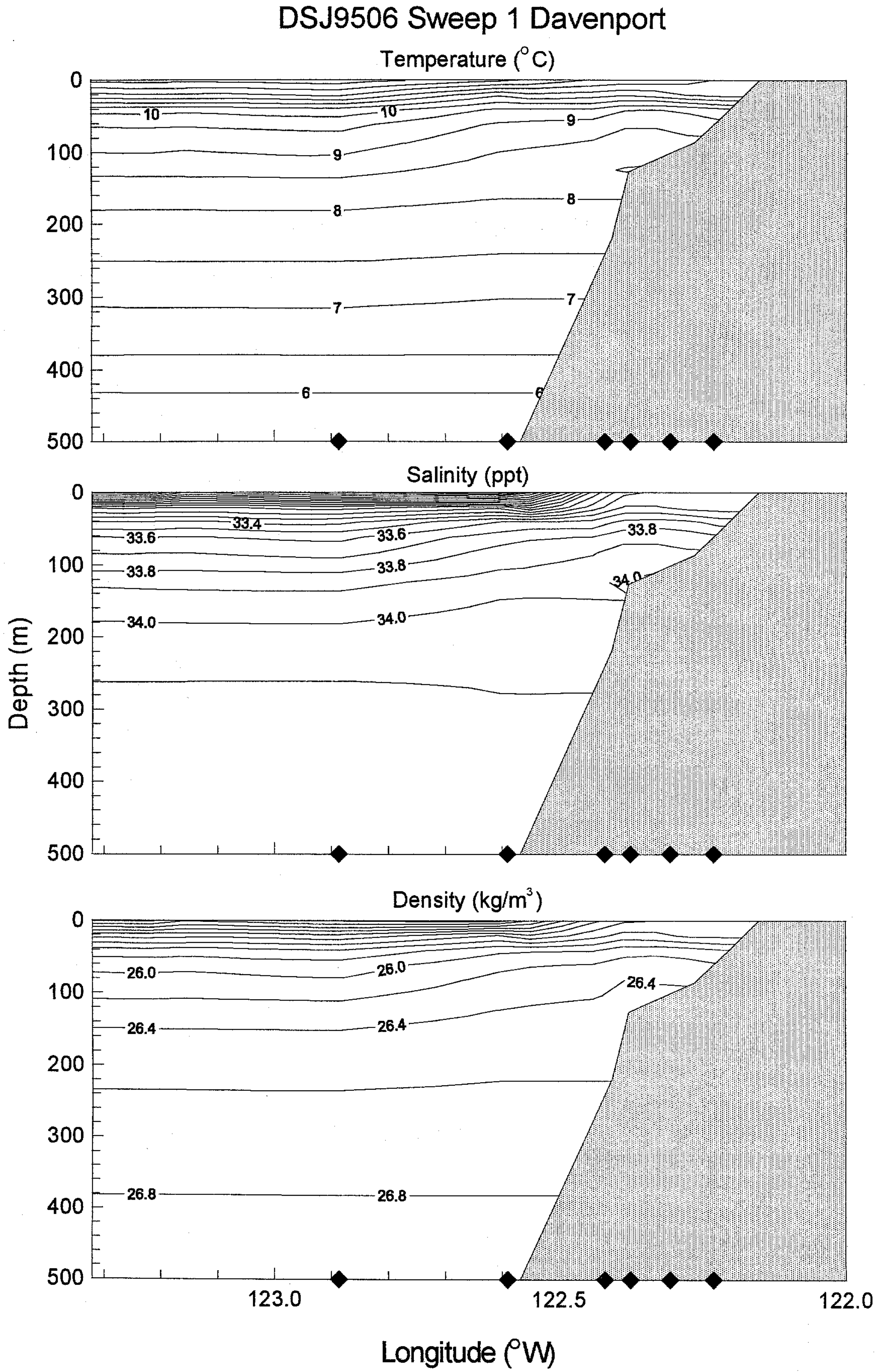

DSJ9506 Sweep 3 Density (kg/m³) at 300 m
Latitude (°N)
Longitude (°W)
38
37
124
123
122
26.64
26.66
26.68
26.70
26.72
26.74

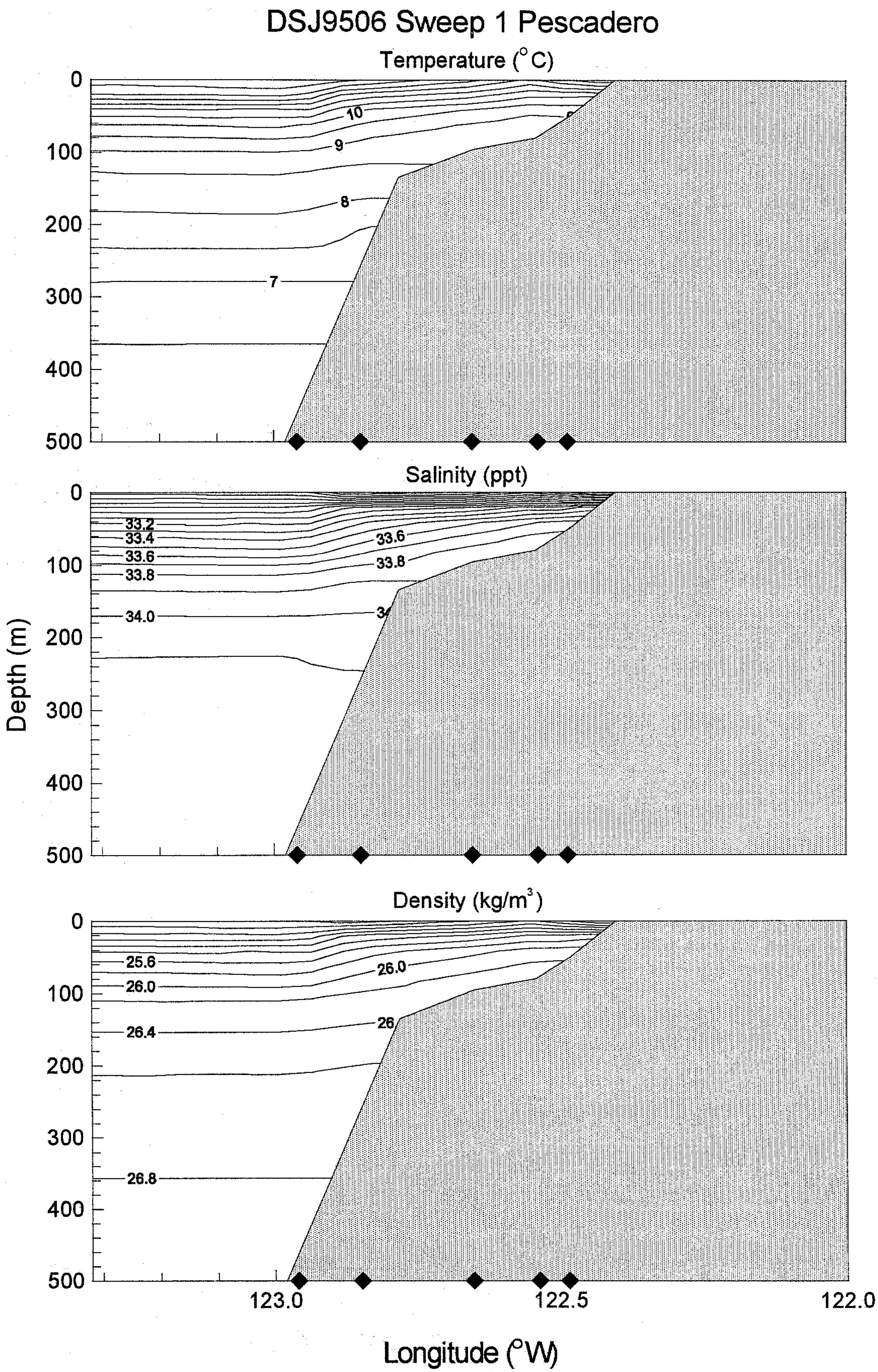

DSJ9506 Sweep 3 Density (kg/m³) at 500 m
26.92
26.94
26.96
26.98
26.98
26.98
26.96
26.94
26.90
26.92
38
37
124
123
122
Latitude (° N)
Longitude (° W)

APPENDIX 8: VERTICAL TRANSECTS FOR DSJ9506

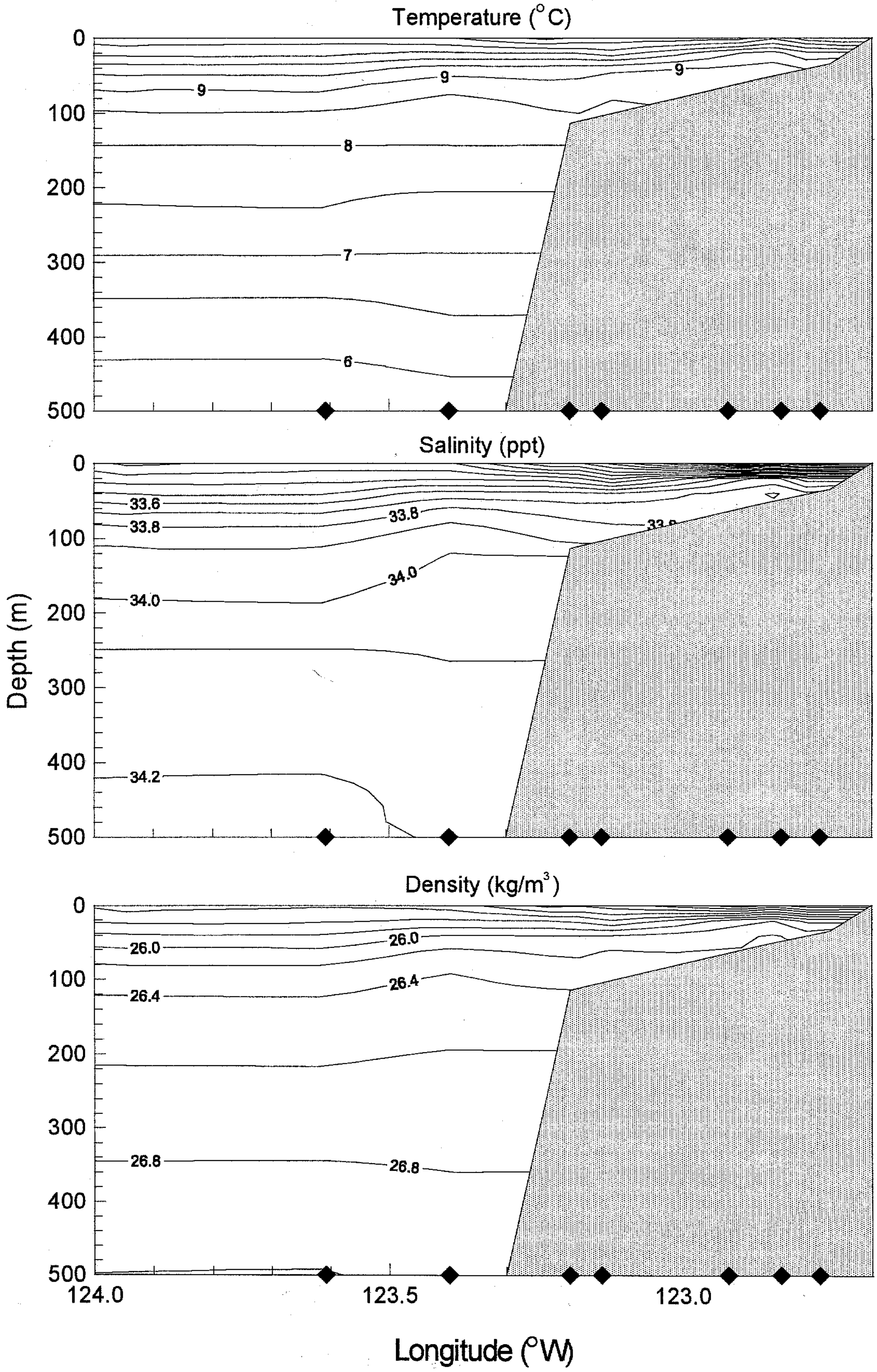
DSJ9506 Sweep 1 Vertical Transect Stations

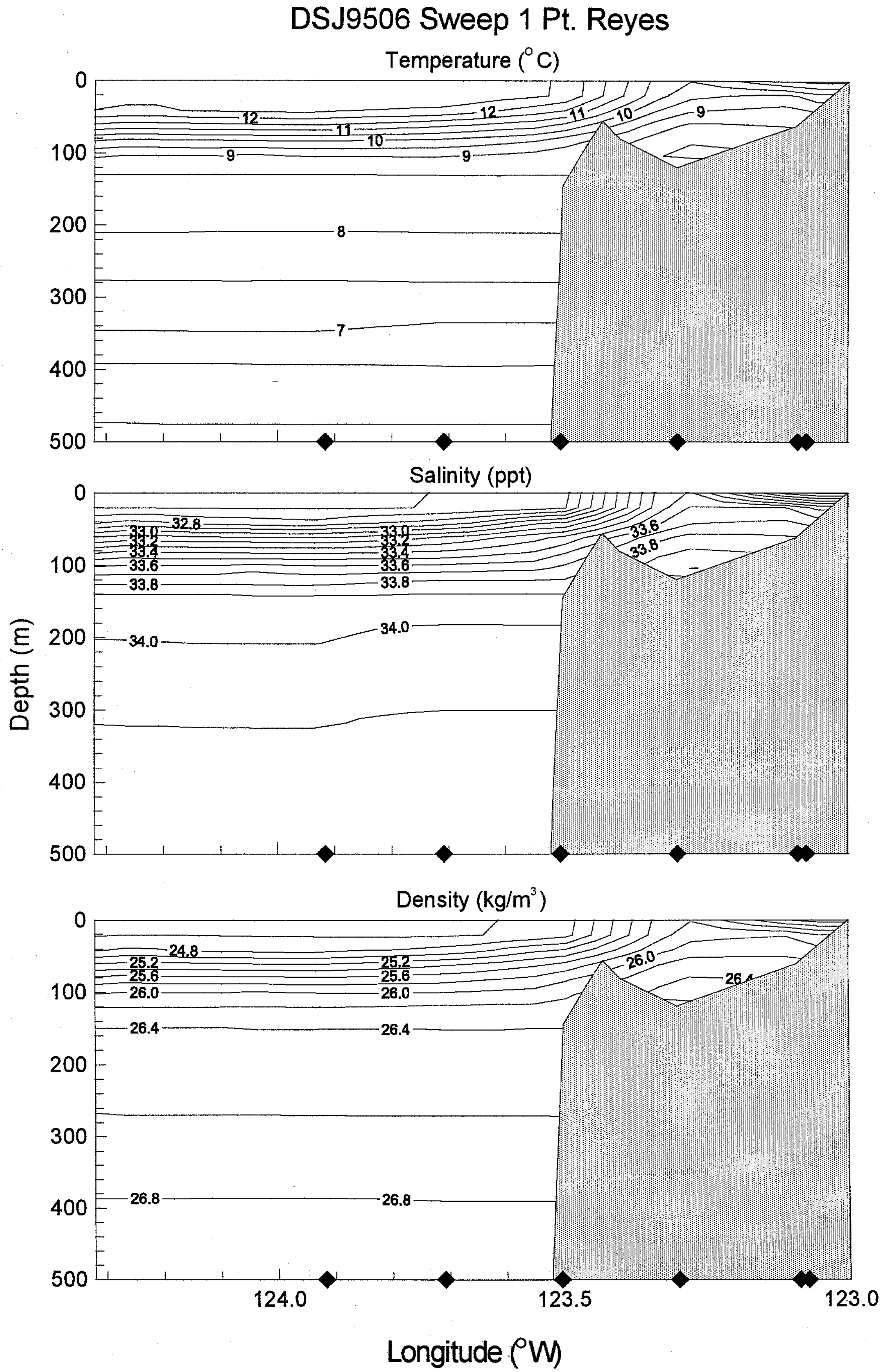



DSJ9506 Sweep 1 Davenport
Temperature (°C)
10
10
9
9
8
8
7
7
6
6
Salinity (ppt)
33.4
33.6
33.6
33.8
33.8
33.8
34.0
34.0
34.0
Density (kg/m³)
26.0
26.0
26.4
26.4
26.4
26.8
26.8
Depth (m)
0
100
200
300
400
500
123.0
122.5
122.0
Longitude (°W)

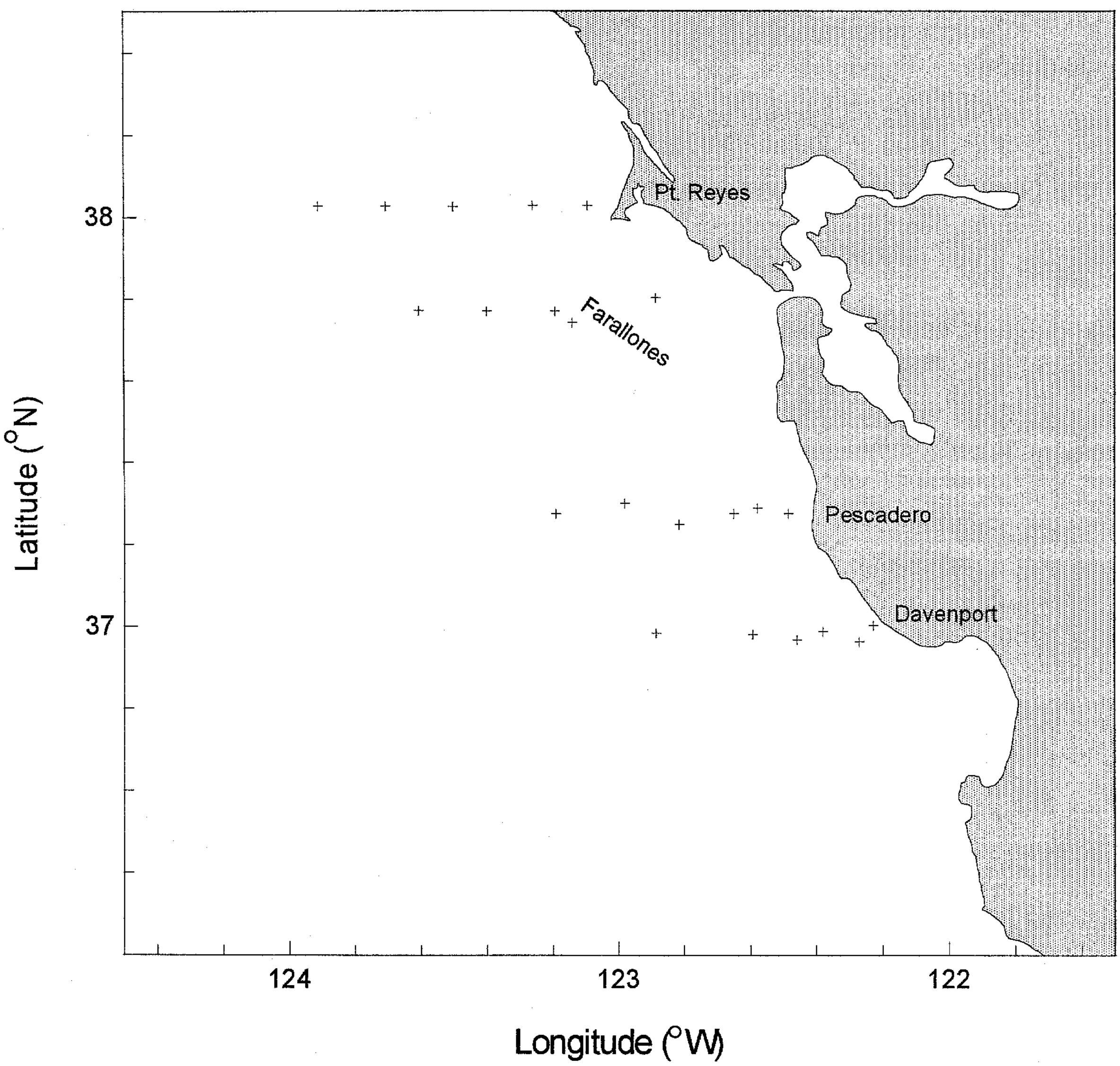

DSJ9506 Sweep 1 Pescadero
Temperature (°C)
10
9
8
7
Salinity (ppt)
33.2
33.4
33.6
33.8
34.0
33.6
33.8
Density (kg/m³)
25.6
26.0
26.4
26.8
26.0
Depth (m)
0
100
200
300
400
500
123.0
122.5
122.0
Longitude (°W)

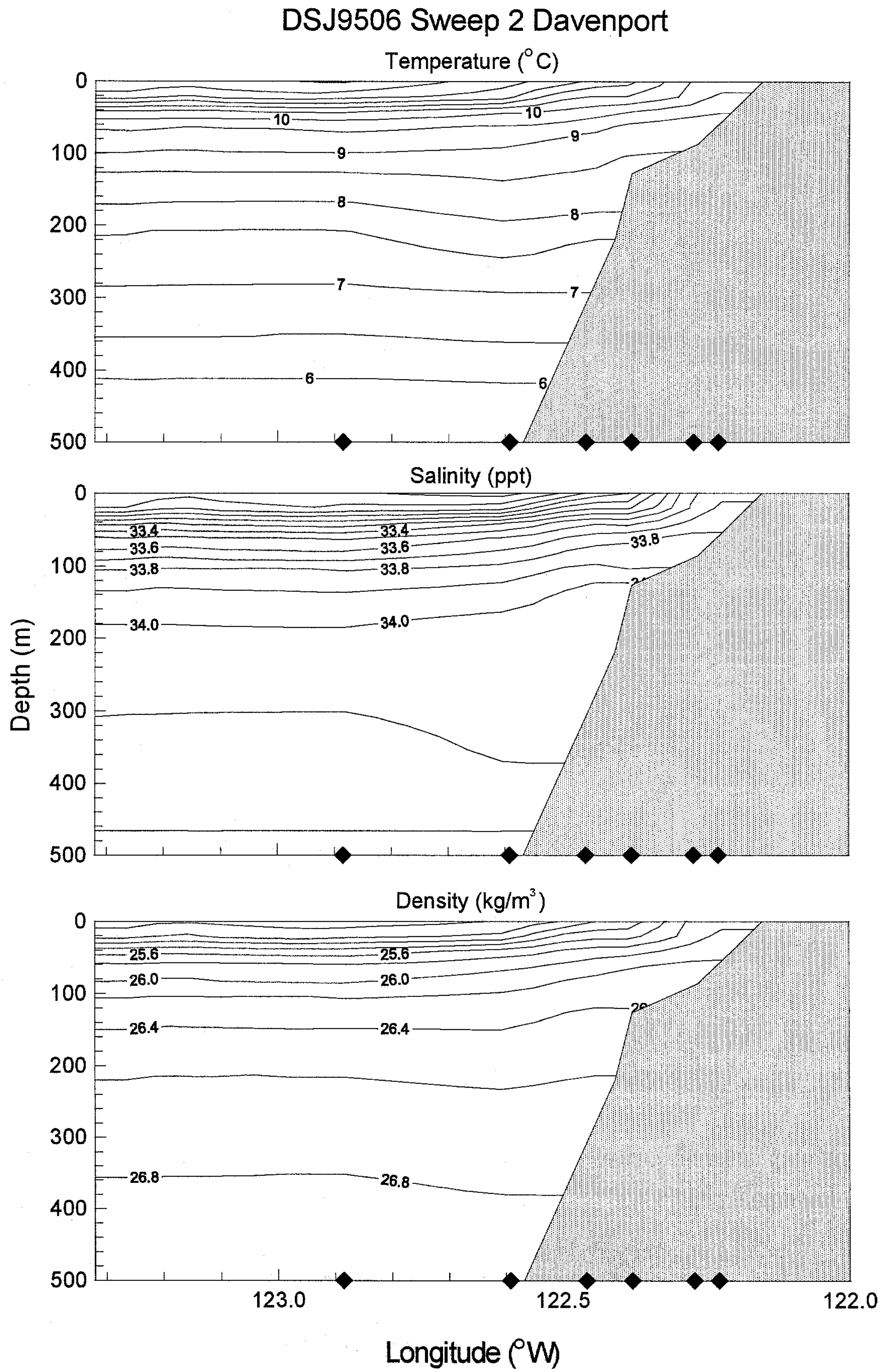
DSJ9506 Sweep 1 Farallones




DSJ9506 Sweep 1 Pt. Reyes
Temperature (°C)
Salinity (ppt)
Density (kg/m³)
Depth (m)
0
100
200
300
400
500
12
11
10
9
8
7
32.8
33.0
33.2
33.4
33.6
33.8
34.0
24.8
25.2
25.6
26.0
26.4
26.8
124.0
123.5
123.0
Longitude (°W)

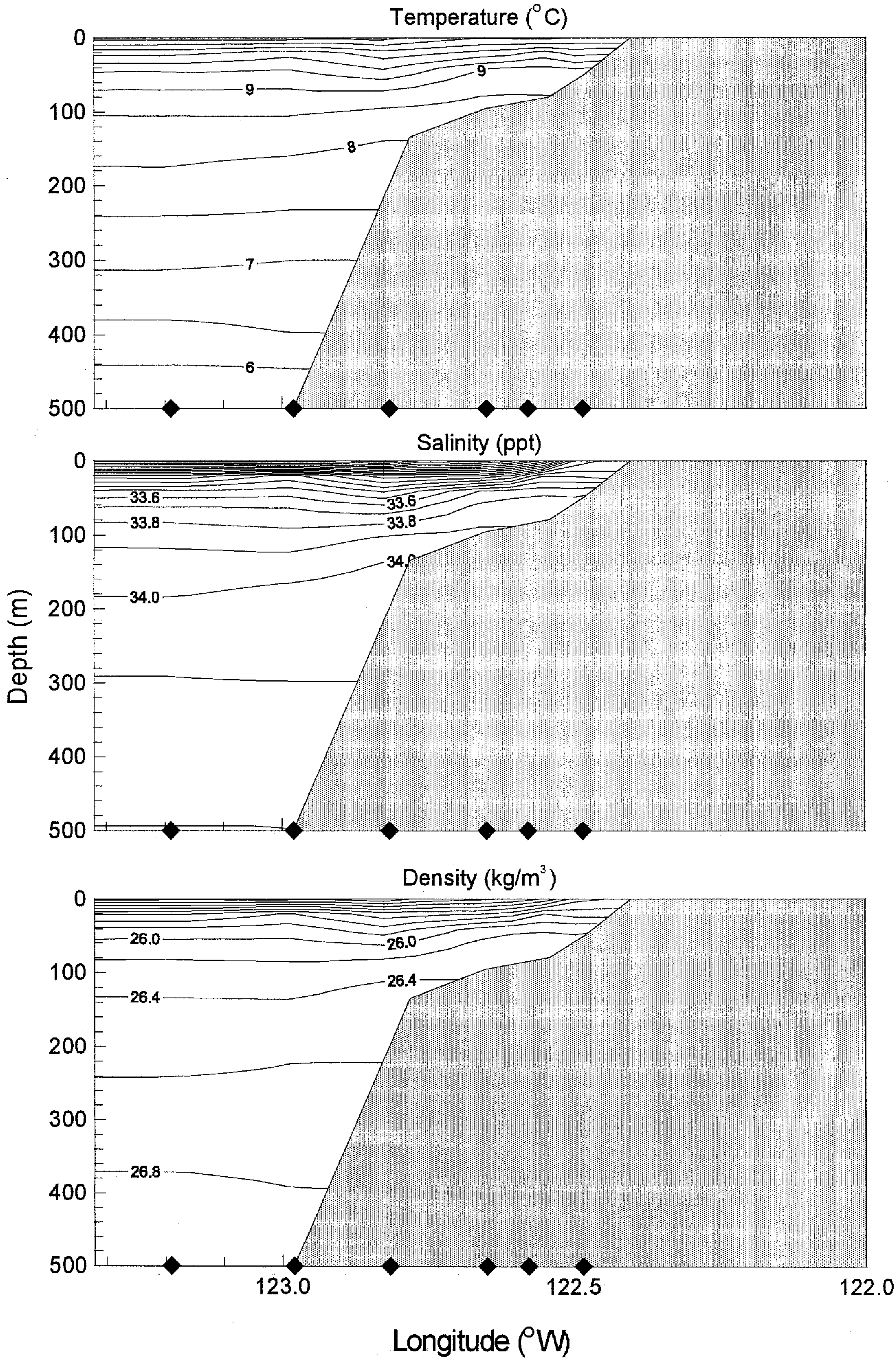
DSJ9506 Sweep 2 Vertical Transect Stations

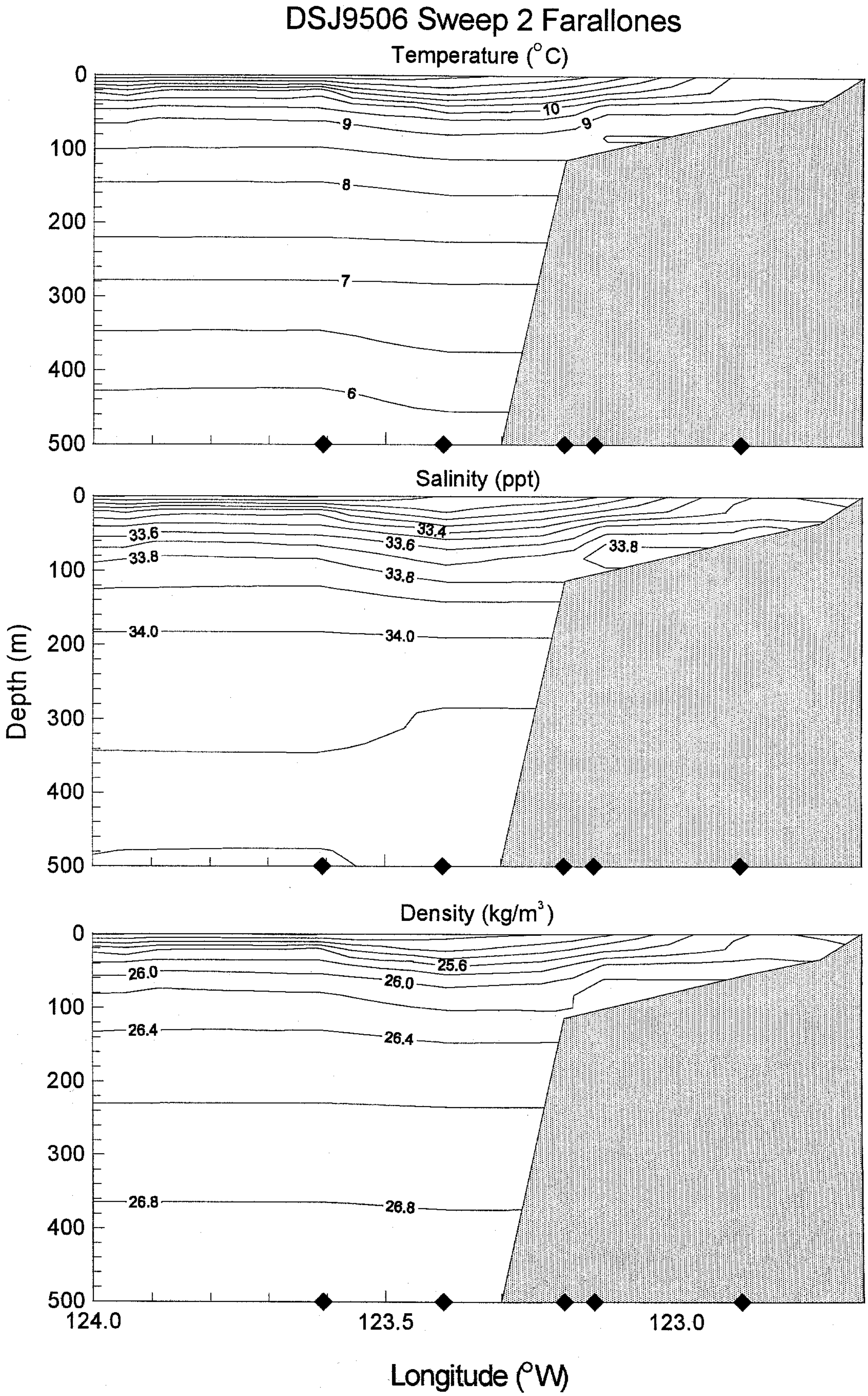


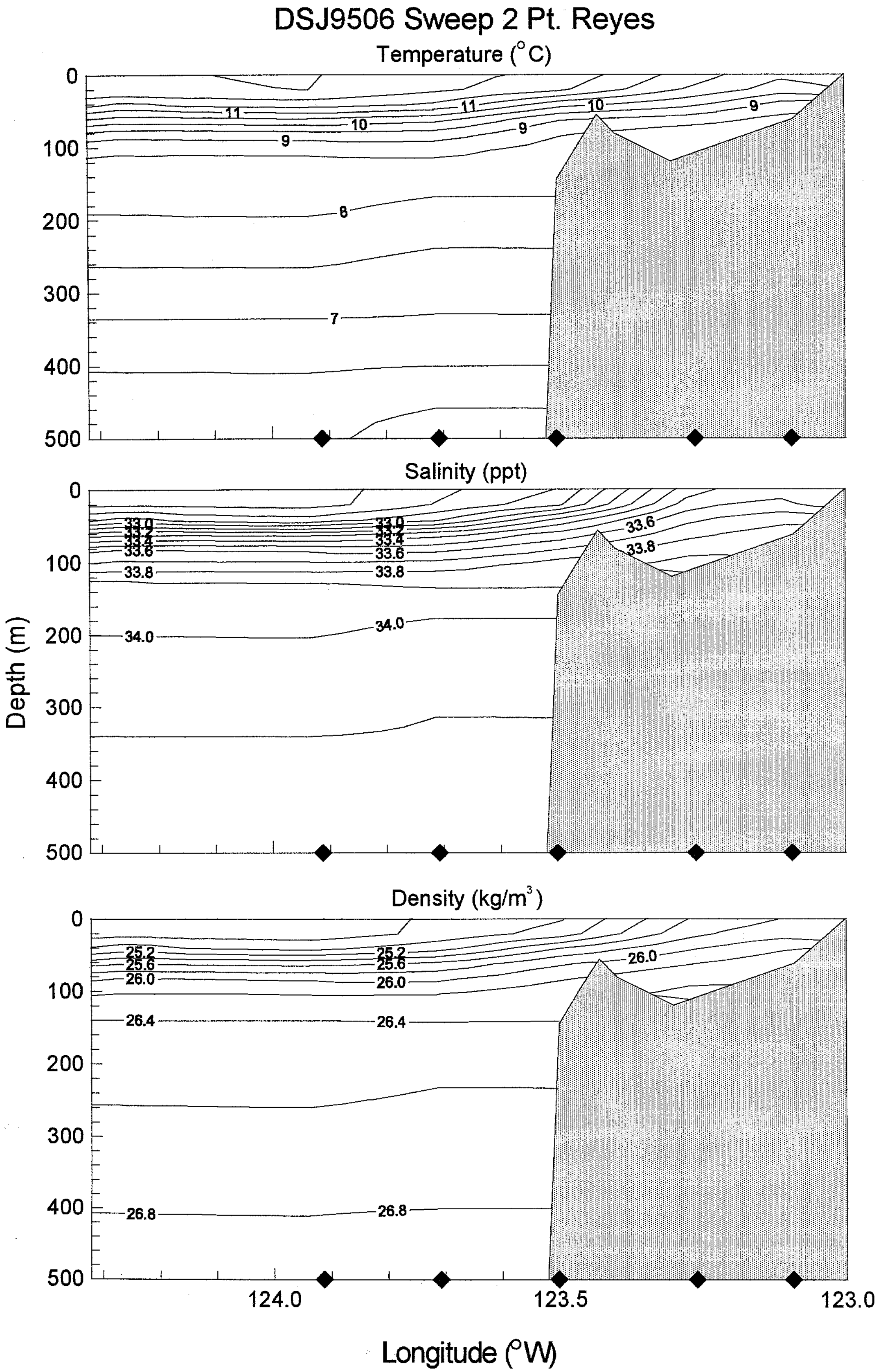


DSJ9506 Sweep 2 Davenport
Temperature (°C)
Salinity (ppt)
Density (kg/m³)
Depth (m)
Longitude (°W)
0
100
200
300
400
500
10
9
8
7
6
33.4
33.6
33.8
34.0
25.6
26.0
26.4
26.8
123.0
122.5
122.0

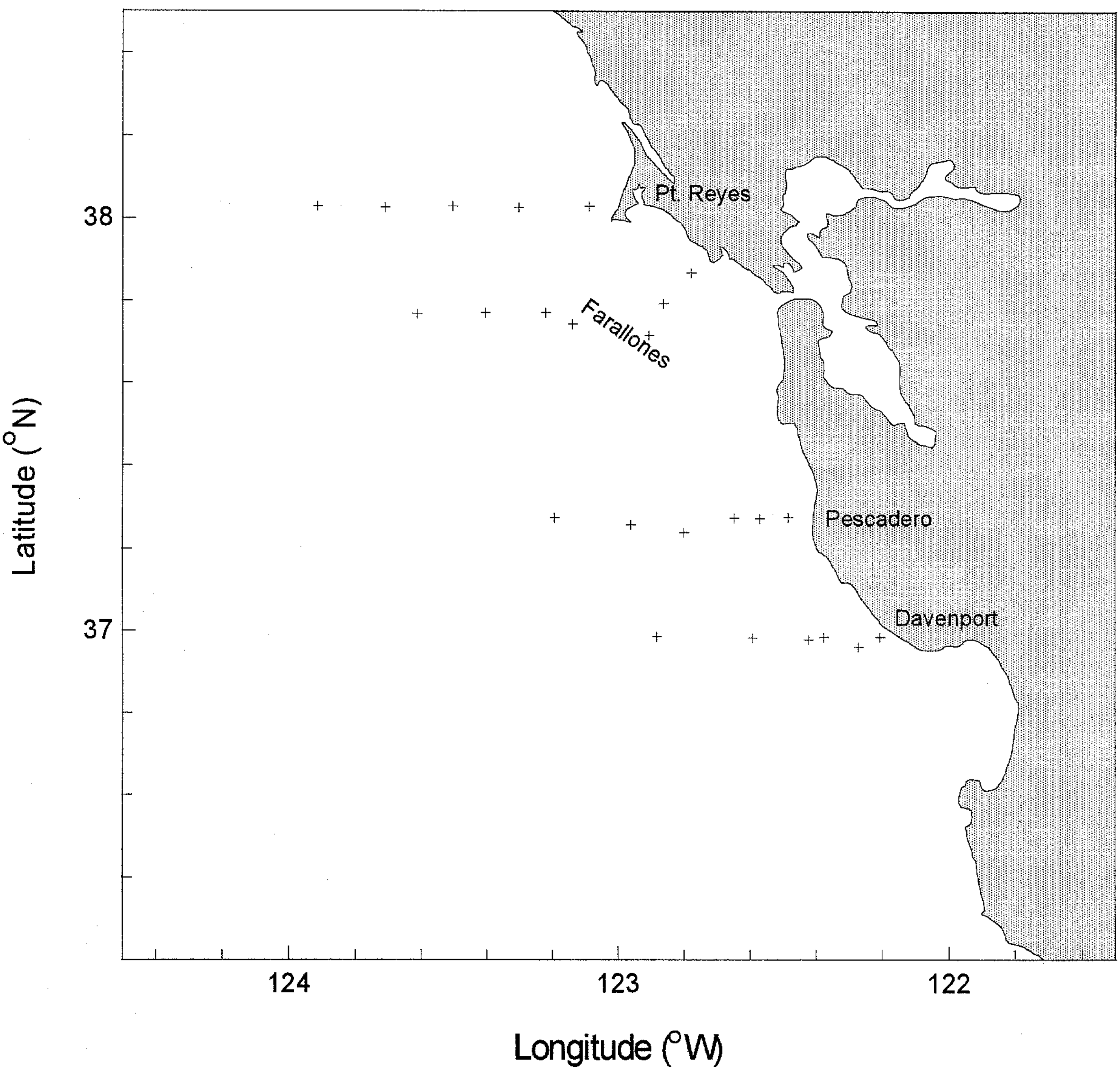
DSJ9506 Sweep 2 Pescadero

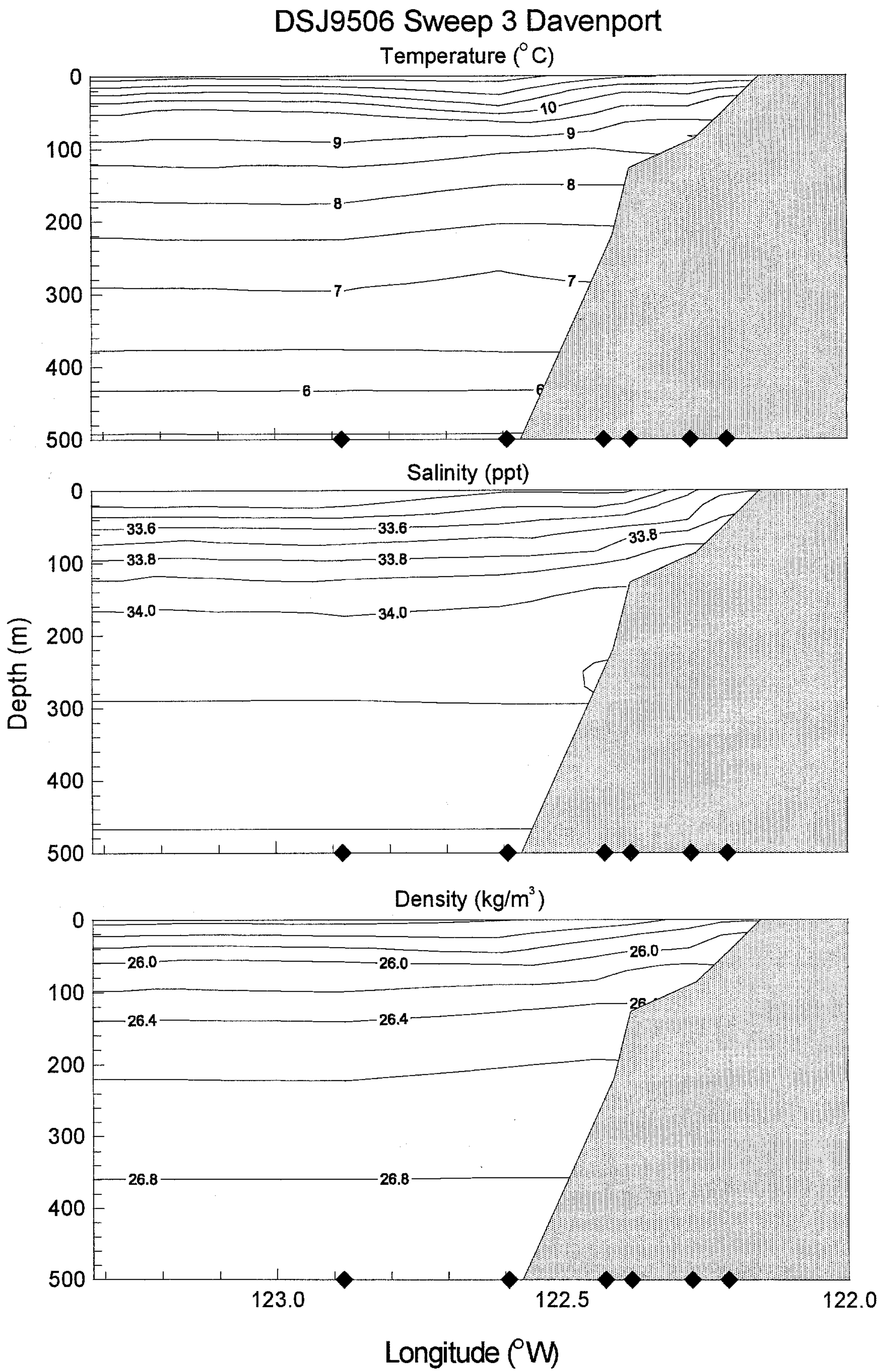


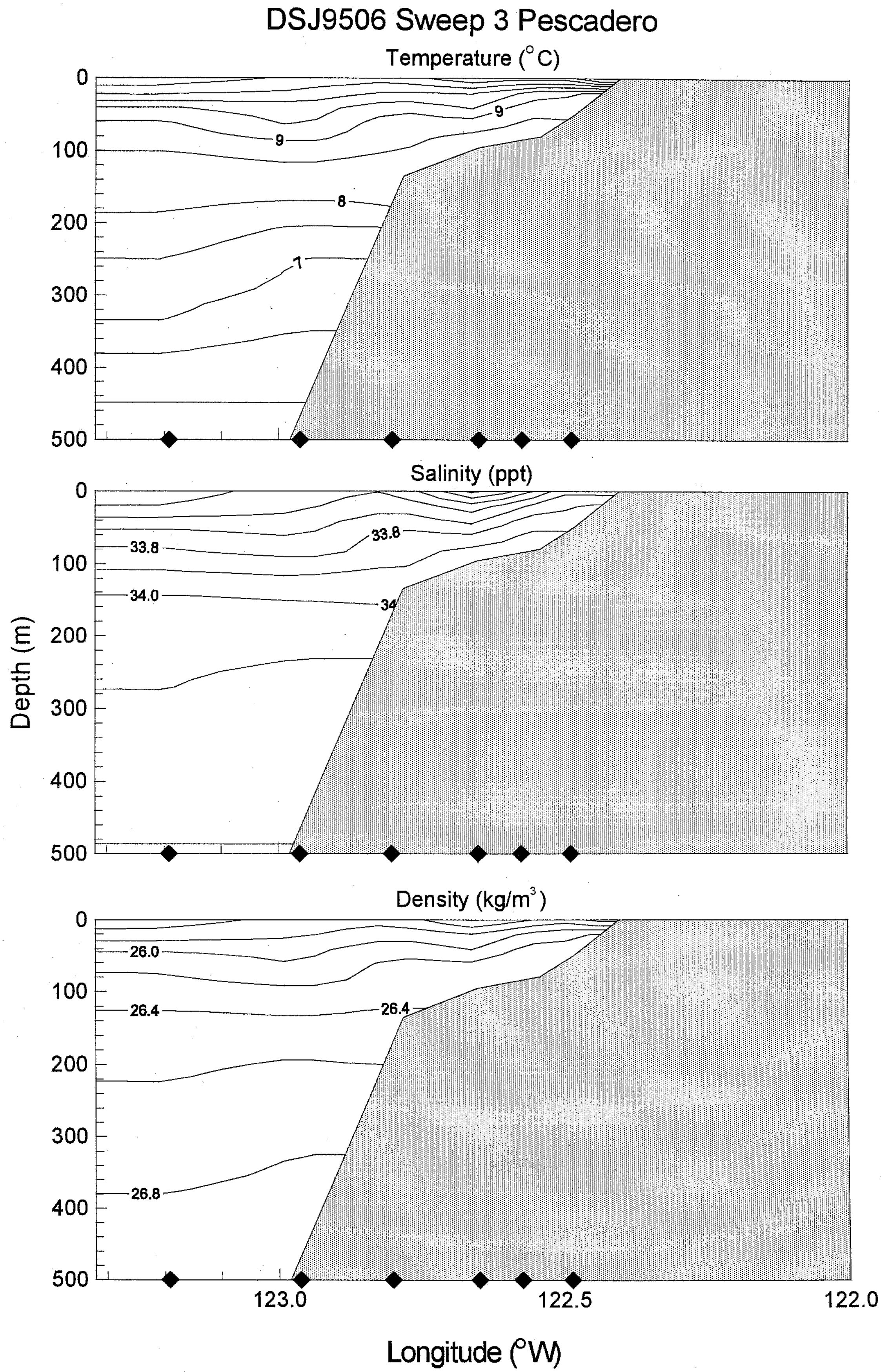

DSJ9506 Sweep 2 Farallones
Temperature (°C)
10
9
9
8
7
6
Salinity (ppt)
33.6
33.8
33.4
33.6
33.8
33.8
34.0
34.0
Density (kg/m³)
26.0
25.6
26.0
26.4
26.4
26.8
26.8
Depth (m)
0
100
200
300
400
500
124.0
123.5
123.0
Longitude (°W)

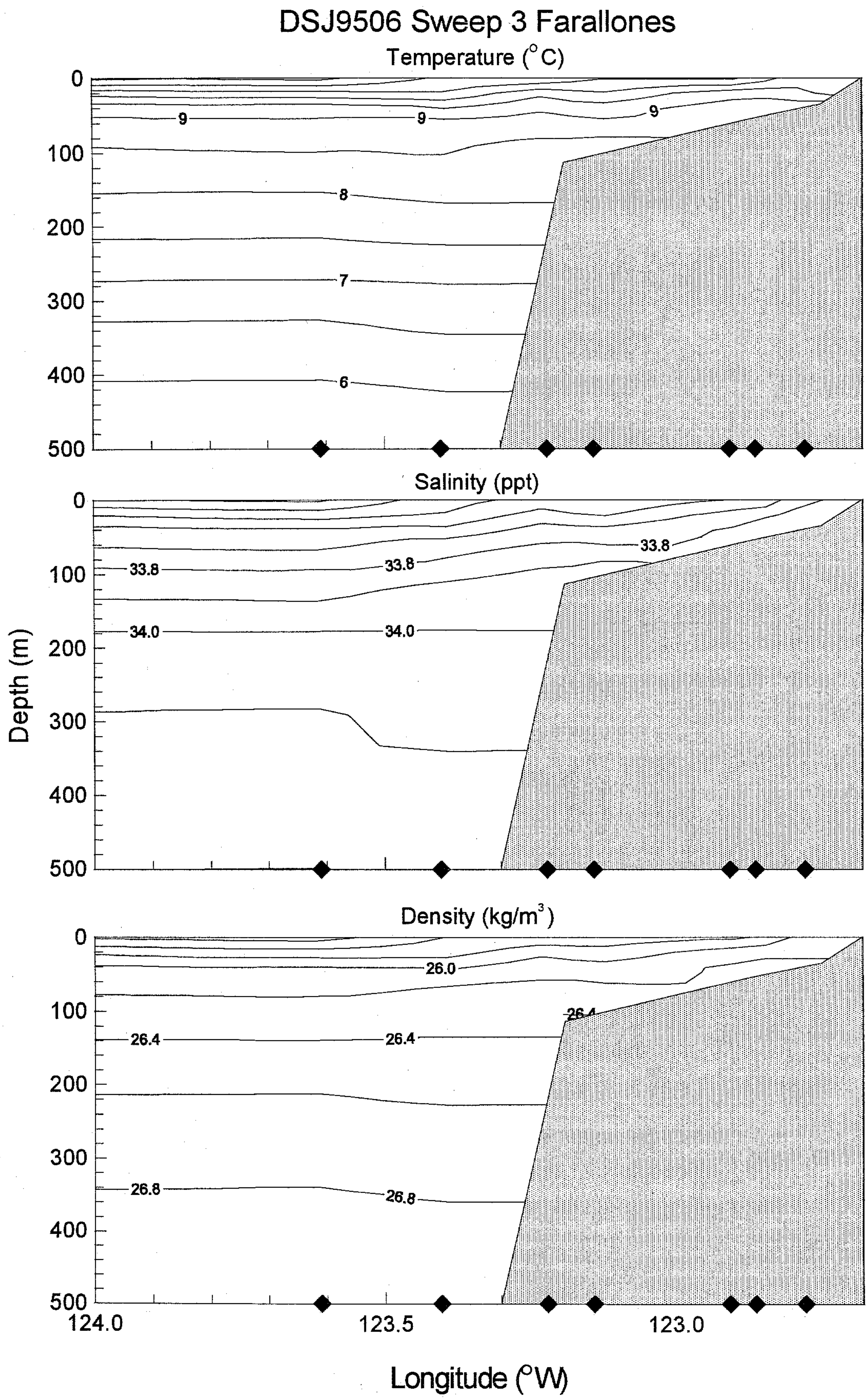

DSJ9506 Sweep 2 Pt. Reyes
Temperature (°C)
11
10
9
8
7
Salinity (ppt)
33.0
33.2
33.4
33.6
33.8
34.0
Density (kg/m³)
25.2
25.6
26.0
26.4
26.8
Depth (m)
0
100
200
300
400
500
124.0
123.5
123.0
Longitude (°W)

DSJ9506 Sweep 3 Vertical Transect Stations

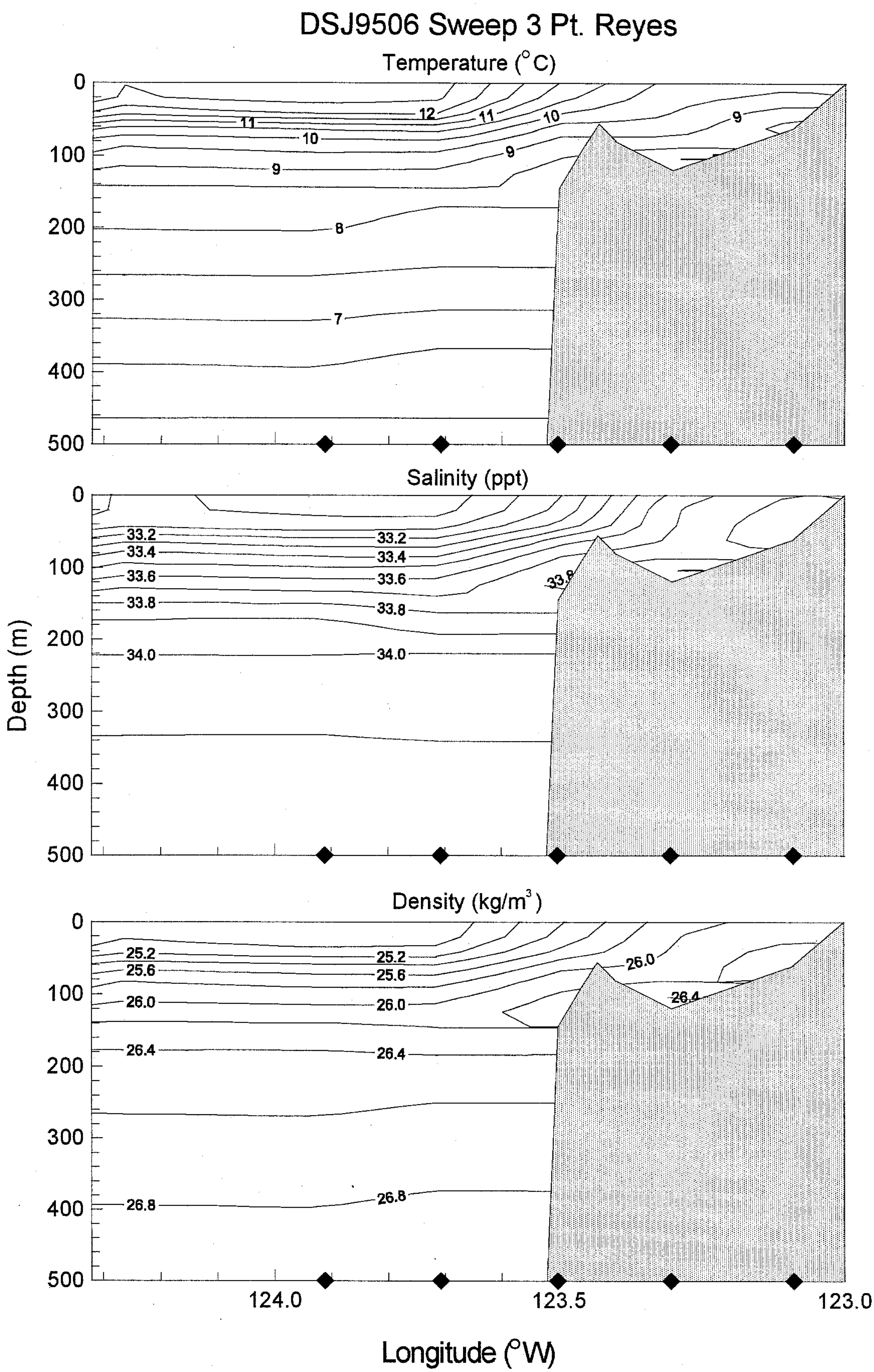



DSJ9506 Sweep 3 Davenport
Temperature (°C)
Salinity (ppt)
Density (kg/m³)
Depth (m)
Longitude (°W)
123.0
122.5
122.0
0
100
200
300
400
500
10
9
8
7
6
33.6
33.8
34.0
26.0
26.4
26.8


DSJ9506 Sweep 3 Pescadero
Temperature (°C)
Salinity (ppt)
Density (kg/m³)
Depth (m)
Longitude (°W)
9
9
8
7
33.8
33.8
34.0
34
26.0
26.4
26.4
26.8
0
100
200
300
400
500
123.0
122.5
122.0

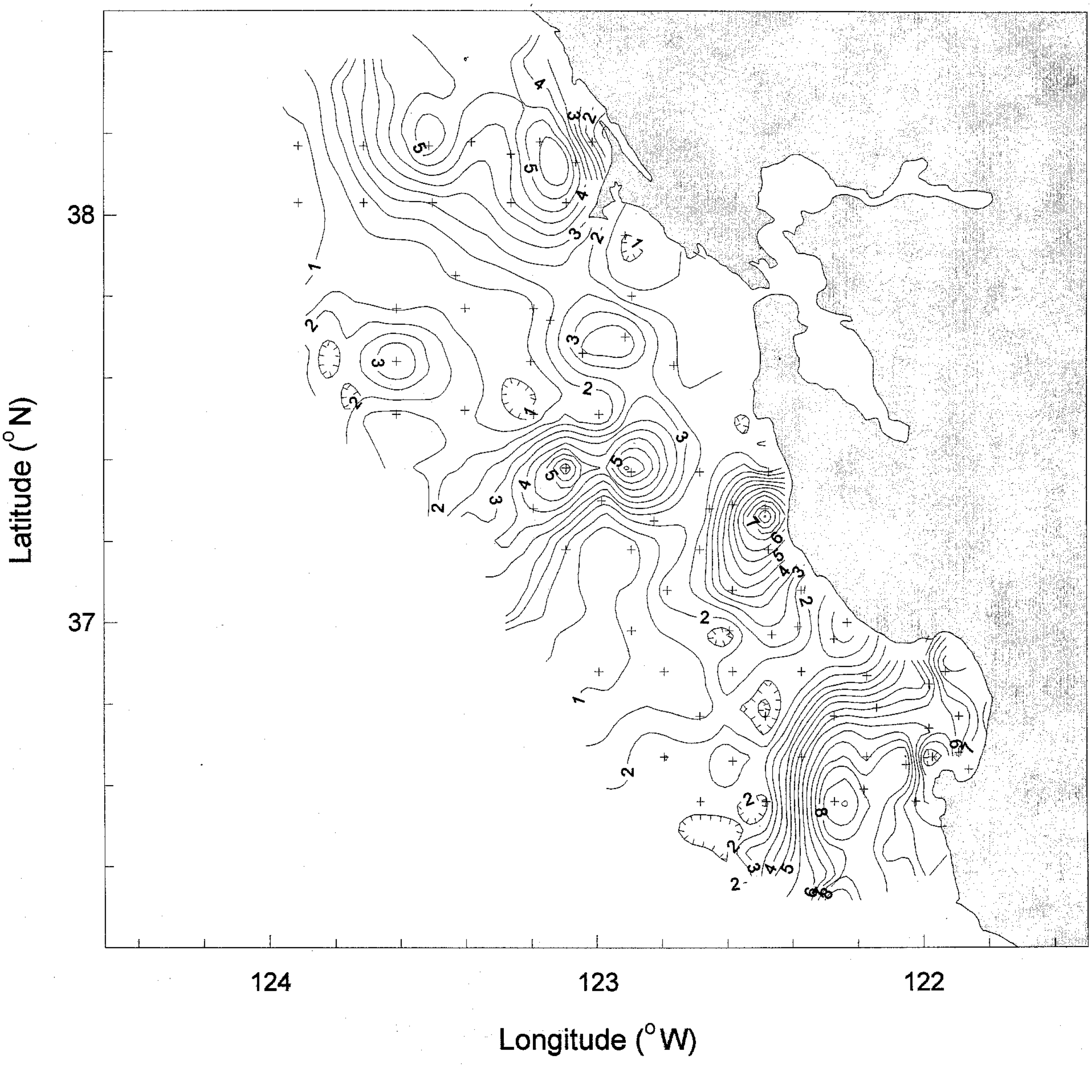


DSJ9506 Sweep 3 Farallones
Temperature (°C)
9
9
9
8
7
6
Salinity (ppt)
33.8
33.8
33.8
34.0
34.0
Density (kg/m³)
26.0
26.4
26.4
26.4
26.8
26.8
Depth (m)
0
100
200
300
400
500
124.0
123.5
123.0
Longitude (°W)

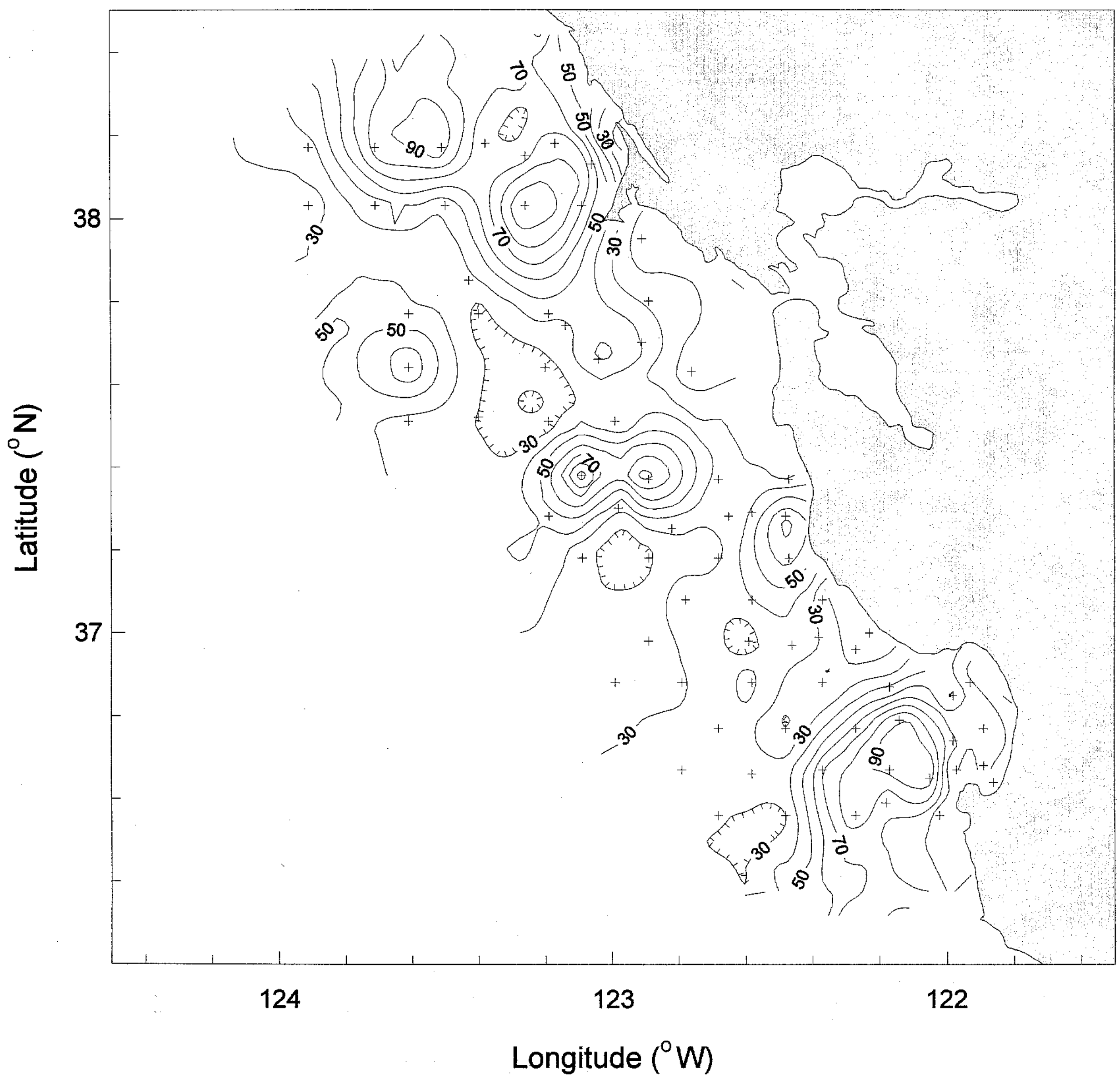

DSJ9506 Sweep 3 Pt. Reyes
Temperature (°C)
Salinity (ppt)
Density (kg/m³)
Depth (m)
Longitude (°W)
0
100
200
300
400
500
124.0
123.5
123.0
12
11
10
9
8
7
33.2
33.4
33.6
33.8
34.0
25.2
25.6
26.0
26.4
26.8

APPENDIX 9: HORIZONTAL MAPS OF CHLOROPHYLL *a* FOR DSJ9506

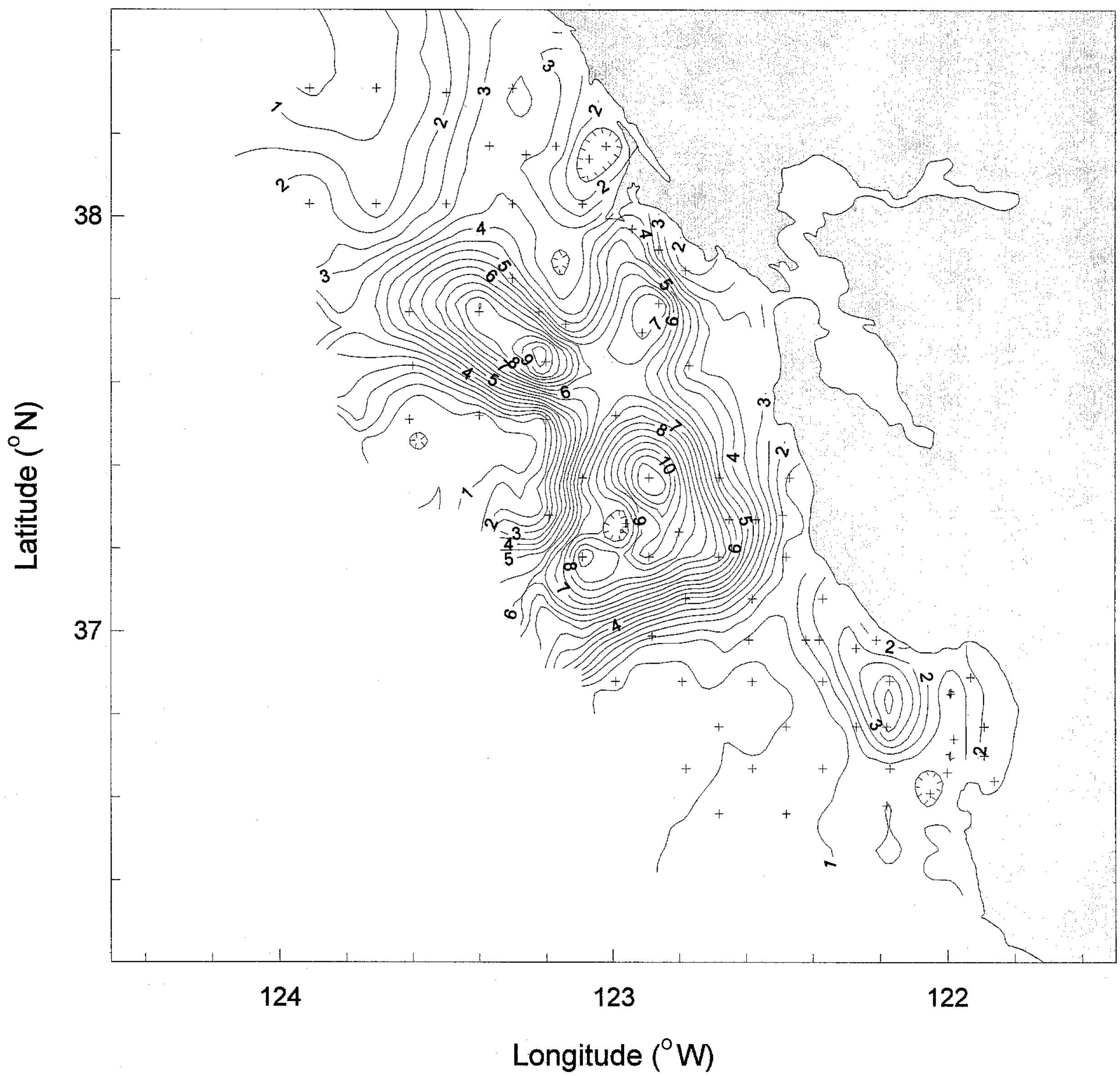
DSJ9506 Sweep 2 Chlorophyll a (mg/m³) at 10 m



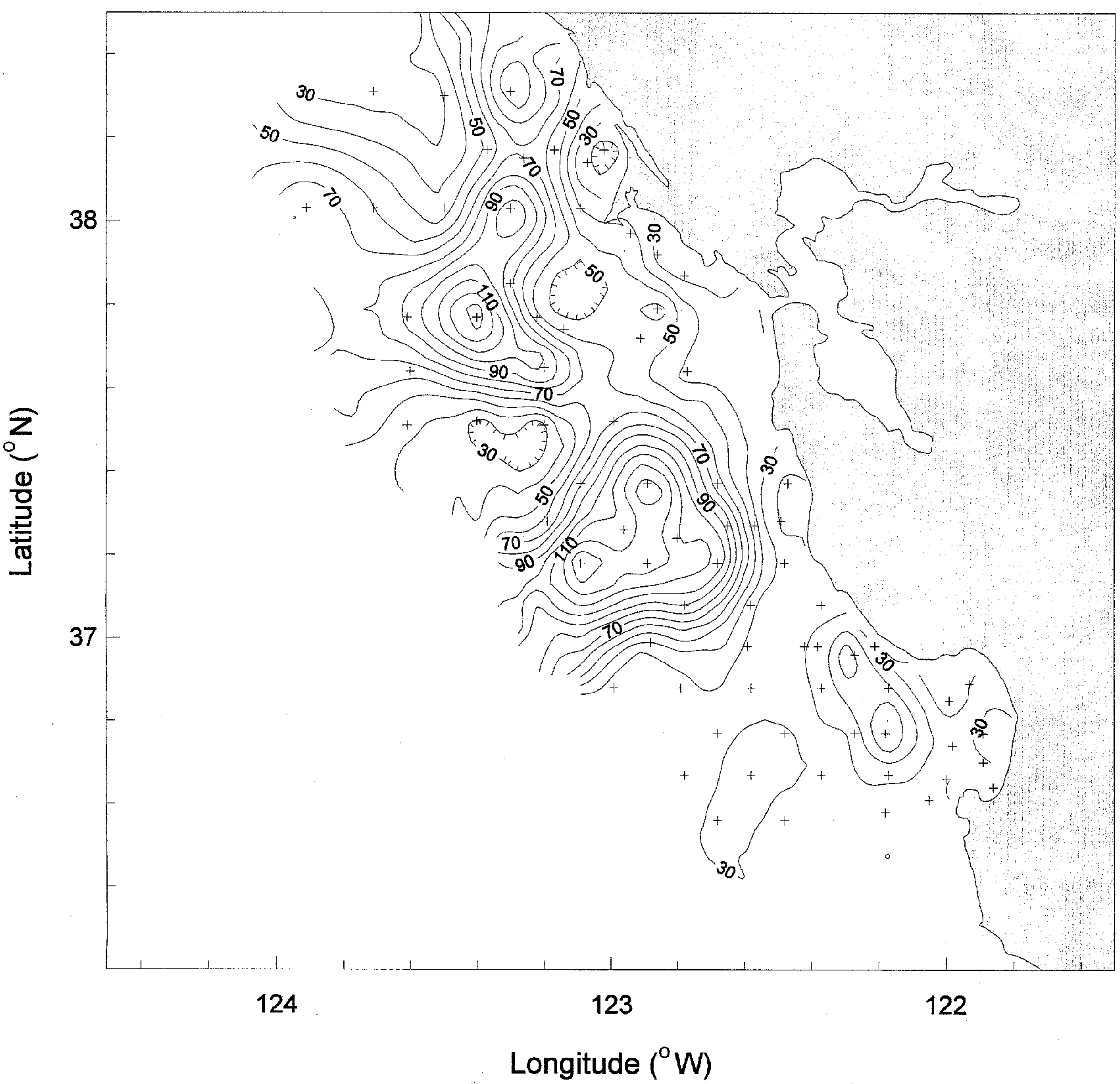
DSJ9506 Sweep 2 Chlorophyll a (mg/m^2) integrated to 150 m



DSJ9506 Sweep 3 Chlorophyll a (mg/m³) at 10 m

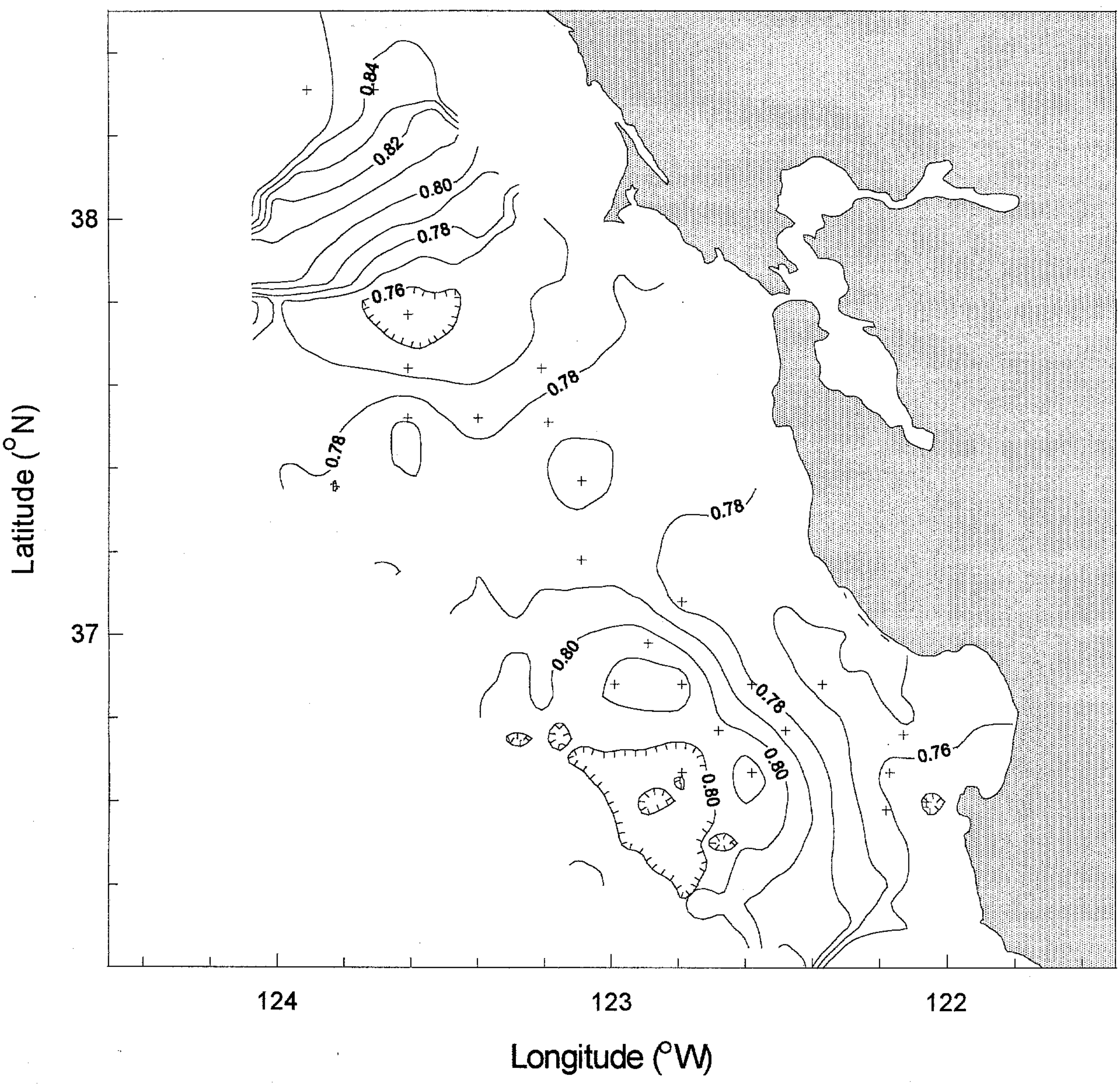


DSJ9506 Sweep 3 Chlorophyll a (mg/m^2) integrated to 150 m

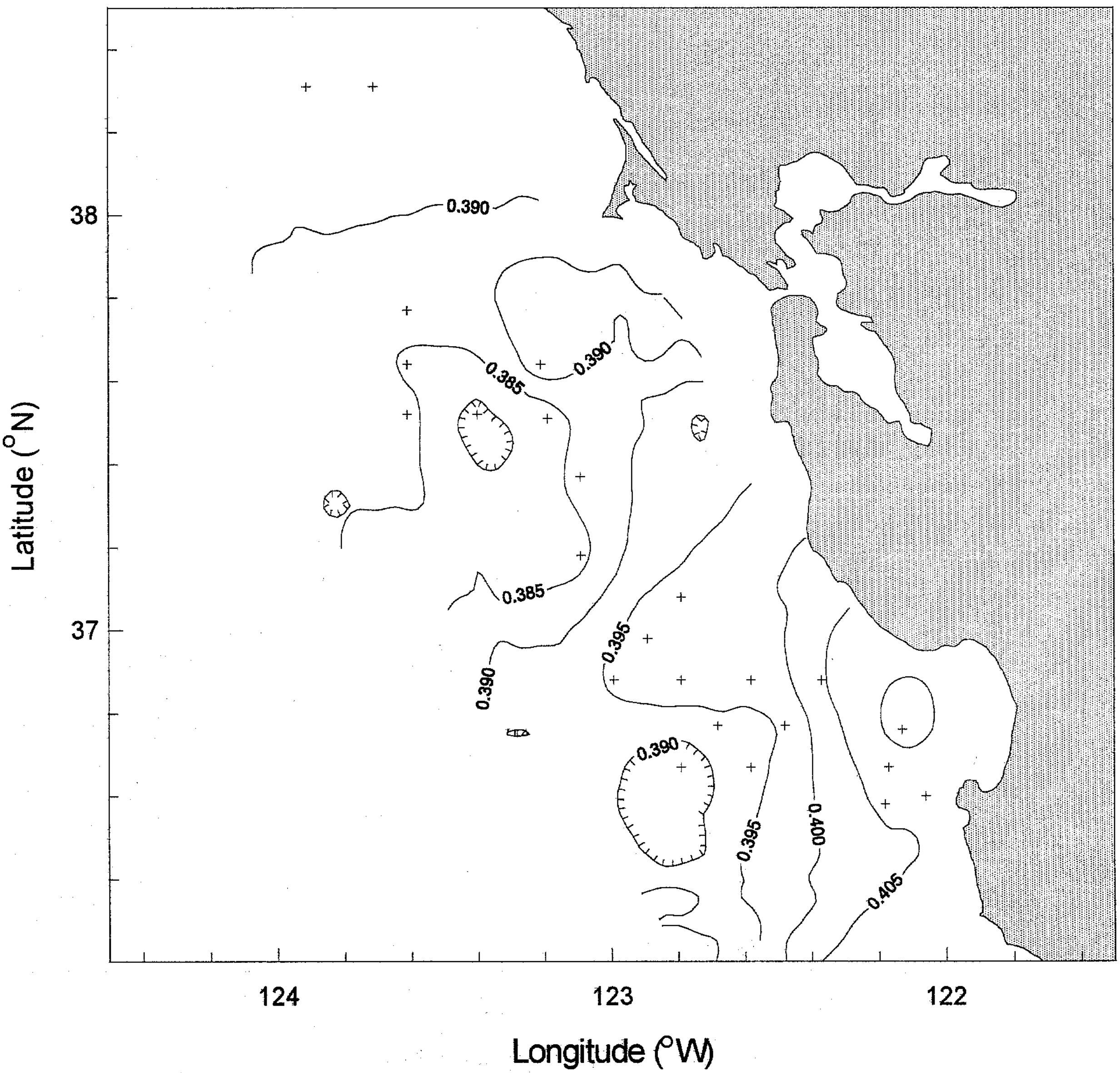


APPENDIX 10: DYNAMIC TOPOGRAPHY FOR DSJ9506

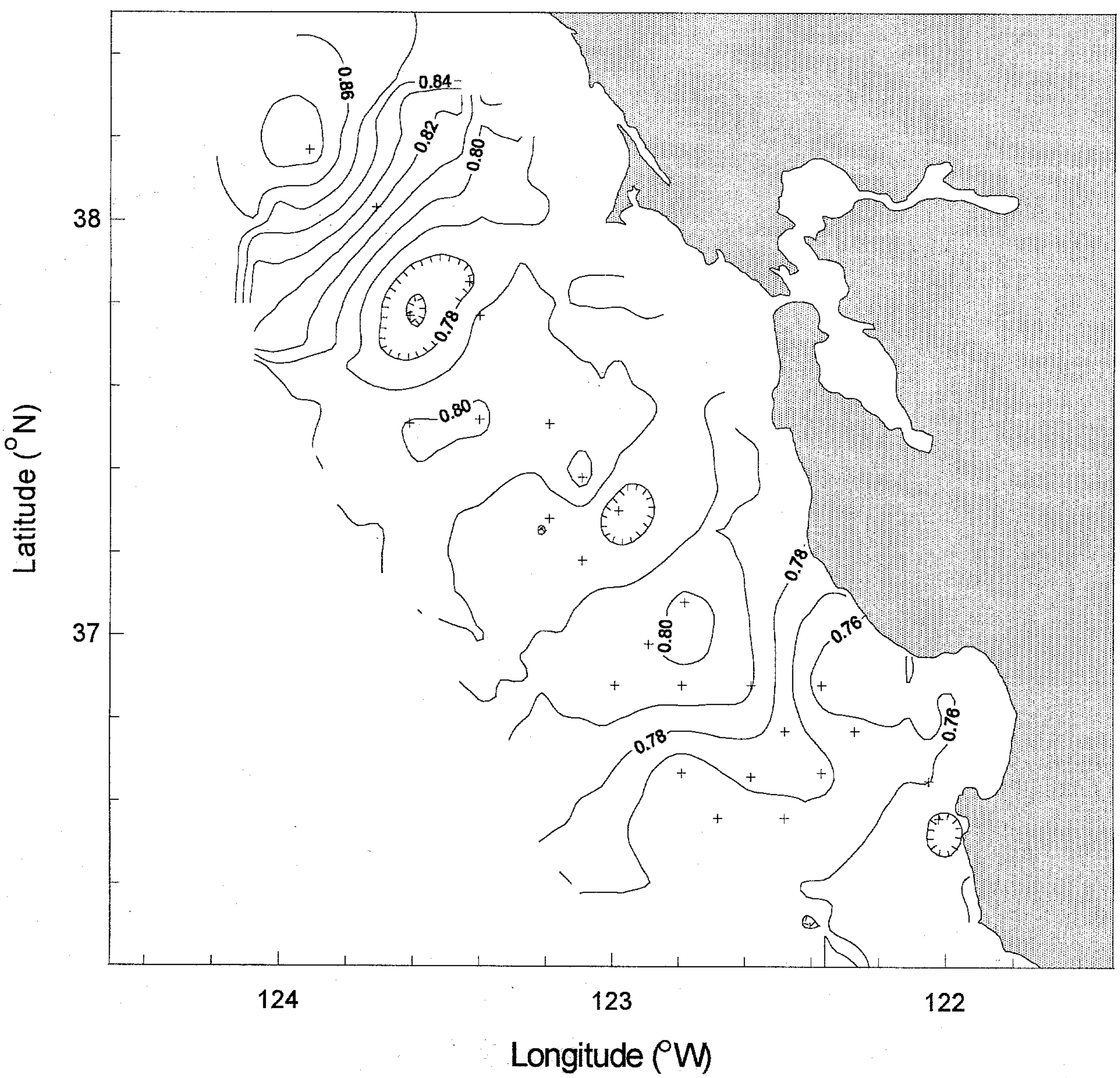
DSJ9506 Sweep 1 Dynamic Height 0/500 m



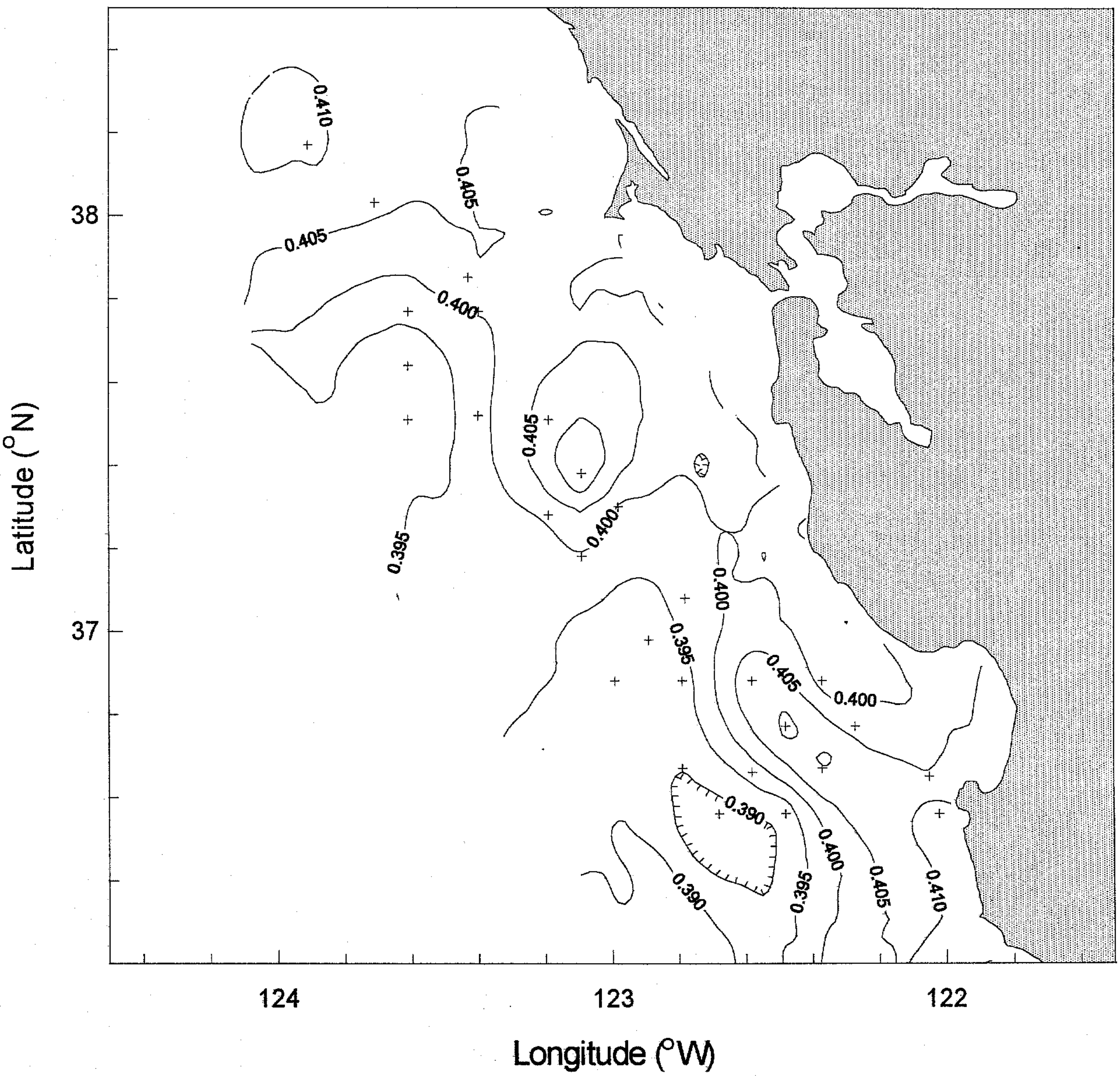
DSJ9506 Sweep 1 Dynamic Height 200/500 m



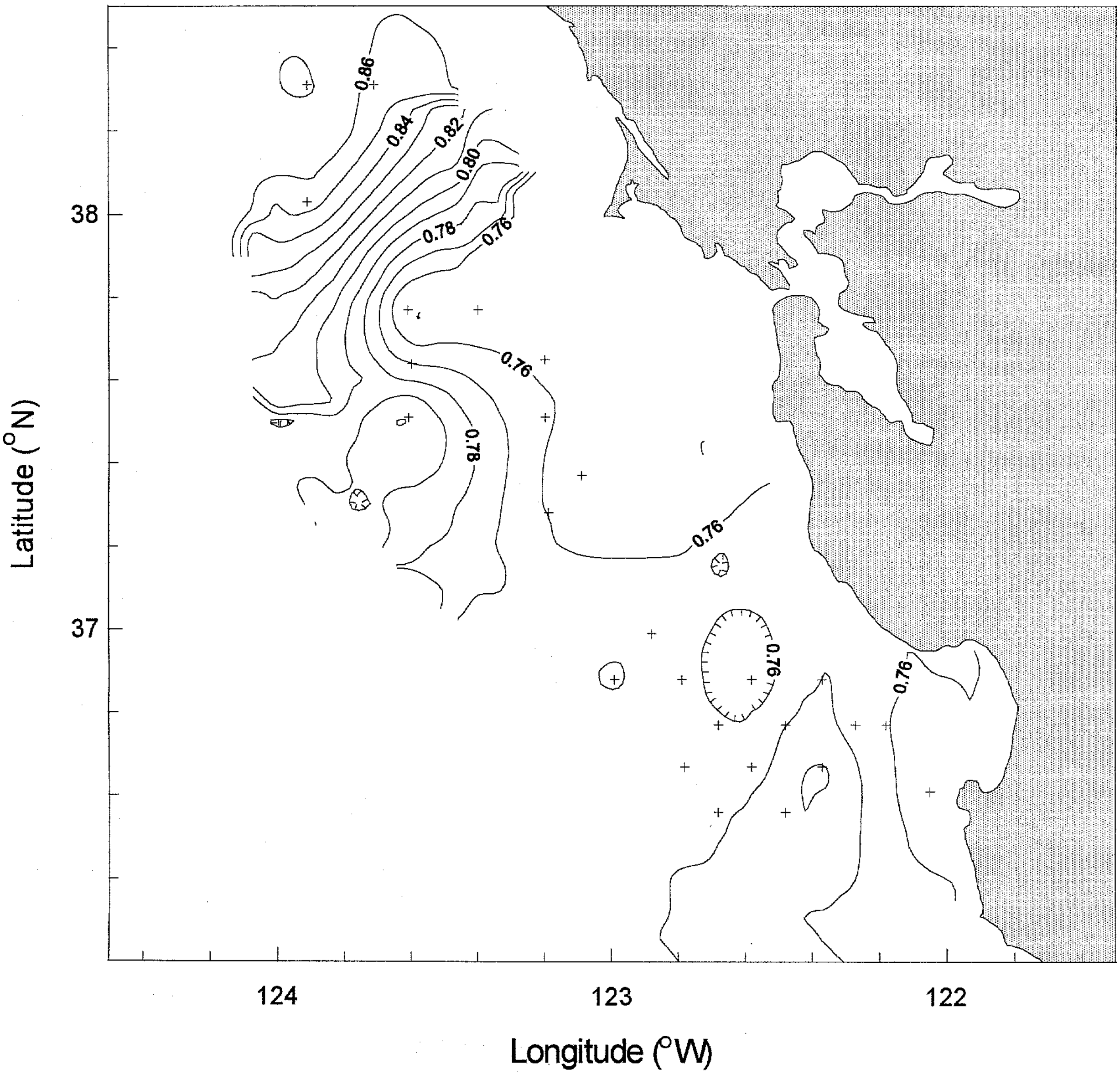
DSJ9506 Sweep 2 Dynamic Height 0/500 m

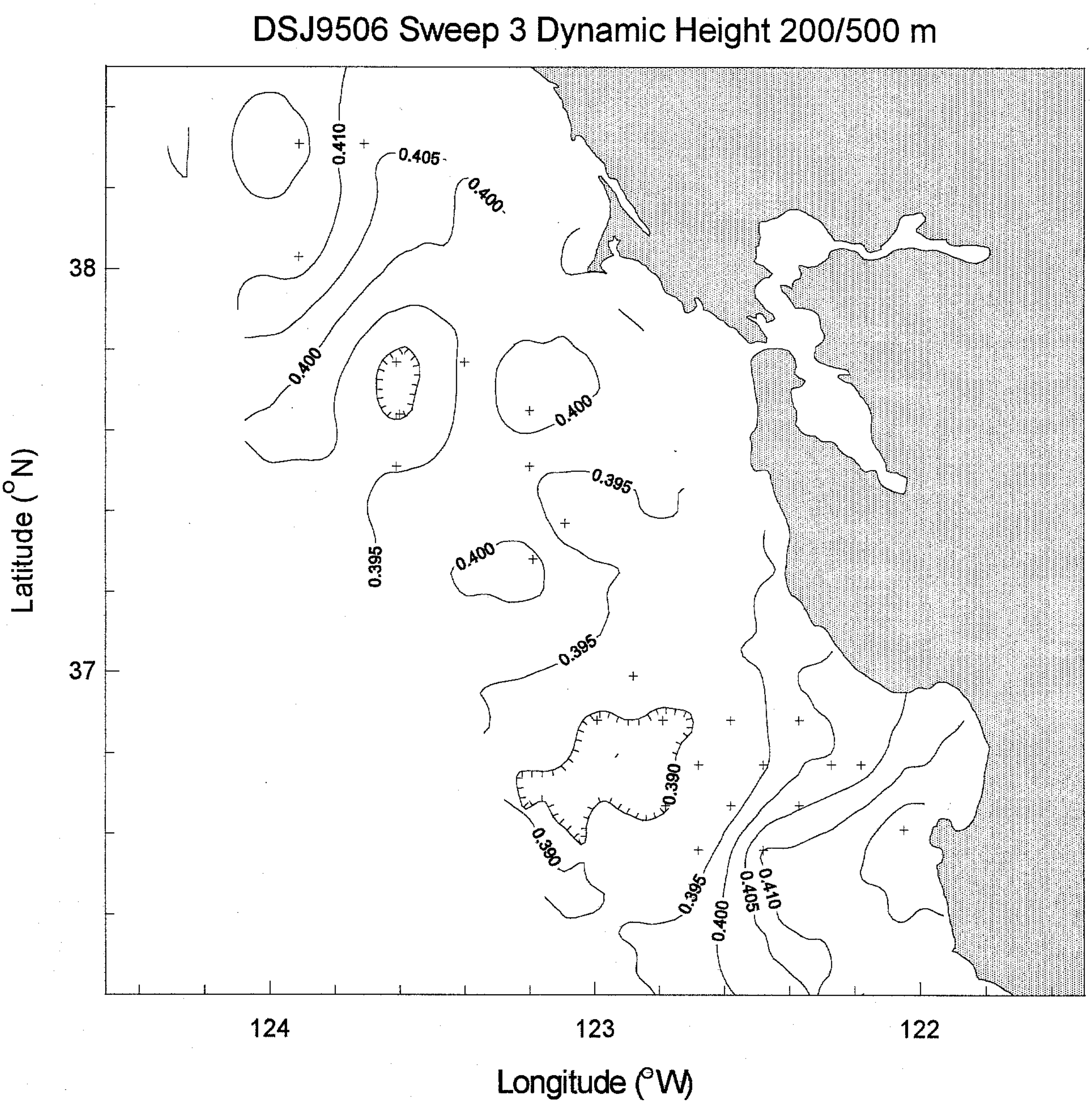


DSJ9506 Sweep 2 Dynamic Height 200/500 m



DSJ9506 Sweep 3 Dynamic Height 0/500 m




DSJ9506 Sweep 3 Dynamic Height 200/500 m
Latitude (°N)
38
37
Longitude (°W)
124
123
122
0.410
0.405
0.400
0.395
0.390

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