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U.S. DEPARTMENT OF COMMERCE
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ABSTRACT

Hydrographic conditions during three periods of approximately ten days each from mid-May through mid-June 1997 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 216 standard conductivity-temperature-depth (CTD) casts were obtained during the NOAA R/V *David Starr Jordan* cruise DSJ9707 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 (SST) from AVHRR (Channel 4) satellite images; (4) 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; (5) temperature, salinity and σ_θ along four cross-shelf vertical transects; and (6) dynamic height topography (0/500 m and 200/500 m) in the survey region.

INTRODUCTION

The current regime off central California is hydrodynamically complex, composed of both geostrophic 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 add further complexity to the circulation regime.

Since 1983, the National Marine Fisheries (NMFS) Southwest Fisheries Science Center's (SWFSC) Tiburon Laboratory has worked on developing a recruitment index for rockfish within the hydrographic region off central California. Annual juvenile rockfish surveys aboard the National Oceanic and 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*; and bocaccio, *S. paucispinis*). Moreover, extreme interannual fluctuations in abundance have occurred, with combined back-transformed mean $\log_e$ catches ranging from 0.1-78.6 juvenile rockfish/tow (Adams 1995[1]).

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 Laboratory (PFEL) subsequently began analyzing the CTD data to assist 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 1997. 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), 1994 (DSJ9403 and DSJ9406), 1995 (DSJ9506), and 1996 (DSJ9606) 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, Sakuma et al. 1996, Sakuma et al. 1997). A companion volume (Schwing and Ralston 1990[2]) 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).

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[1]Adams, P. B. (editor). 1995. Progress in rockfish recruitment studies. SWFSC Admin. Rep. T-95-01, 51 p., unpublished report.

[2]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.

MATERIALS AND METHODS

Meteorological Data

Surface data were obtained from four NOAA National Data Buoy Center (NDBC) moored buoys located within the rockfish survey region. These four buoys are 46013 (Bodega Bay; 38°12'N, 123°18'W), 46026 (Farallones; 37°48'N, 122°42'W), 46012 (Half Moon Bay; 37°24'N, 122°42'W) and 46042 (Monterey Bay; 36°48'N, 122°24'W) (Appendix 2). Daily averages of sea surface temperature (SST) and the east and north wind components were calculated from hourly mean buoy measurements. The angle of the alongshore wind component, relative to north, was determined by a principal component analysis (PCA) of the daily-averaged wind data from each buoy. This angle can be thought of as the predominant direction toward which the wind blows.

Annual climatologies and variance were determined for SST and the alongshore wind component at each buoy with a biharmonic analysis of all daily mean data over the buoy's entire operating period. These operating periods were 1981 to 1996 for buoy 46013, 1982 to 1996 for buoy 46026, 1980 to 1996 for buoy 46012, and 1987 to 1996 for buoy 46042. The annual cycles were estimated by a least squares regression of the data to an annual and semiannual harmonic signal of the form

$$SST(t) = A_0 + A_1 cos(2\pi t) + B_1 sin(2\pi t) + A_2 cos(4\pi t) + B_2 sin(4\pi t)$$

where t is the Julian Day/365 and the A_i and B_i are coefficients determined by regression at each buoy. The fits were not improved significantly by including higher harmonics. Standard errors were calculated for each Julian day, then fit with the same biharmonic model.

SST 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 were checked for excessive cloud/fog cover and if clear enough were then calibrated into radiances from the satellite sensor's channels. These radiances were then converted into SSTs. A cloud masking routine was run on each image file, and then the images were partitioned into different geographic regions along the West Coast. This yielded a high resolution (1.1 km) IMGMAP image file of approximately 270 kilobytes which could then be read and analyzed by the PC-based Windows Image Manager (WIM) software developed by Mati Kahru of Scripps Institution of Oceanography in La Jolla, California. 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 was received, the WIM software was used to decompress, display and manipulate the satellite image in order to discern SST 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 PFEL as part of the Oceanographic database system.

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 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. Five or six stations along a transect were sampled each night and seven transects were completed for each sweep. 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 three nights of additional discretionary sampling), adverse weather conditions can extend the duration 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 used in this report.

Collection of CTD Data at Sea

CTD data from the 1997 juvenile rockfish survey presented in this report was collected with a Sea-Bird Electronics, Inc., SEACAT-SBE-19 profiler[3]. This particular unit was rated to a depth of 600 m and contained 256K of memory. The 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. The tempurature and conductivity sensors of the profiler have been recalibrated annually by Sea-Bird Electronics, Inc., prior to its 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 520 m of cable was let out 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) longitude, (8) bucket temperature (temperature [°C] of a bucket sample of surface water using a mercury thermometer), (9) bucket salinity (salinity of a bucket sample of surface water using a hand-held portable salinometer), and (10) bottom depth in meters. In addition, a water sample from 10 m was collected once a day (using a Nisken bottle attached to the hydrographic winch cable) for later use in calibrating the WETStar fluorometer dsta. Position fixes were obtained using the Global Positioning System (GPS). Collection information recorded on the data sheets were eventually entered into data files on a personal computer.

Data collected from a short series of casts (usually no more than 5-7) were periodically uploaded to a laptop computer. During this step, each cast was stored as a separate file. After uploading, the profiler was reinitialized and the files on the laptop computer were backed up onto a desktop computer on board the vessel.

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[3]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.

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 logged by the vessel's scientific computer system and transferred to a personal computer for further processing, analysis, and comparison with, and verification of, CTD observations. Position fixes for the TS unit were based on GPS.

Data Processing

The first step in data processing was to convert the uploaded CTD files to ASCII files. This was accomplished using programs supplied by Sea-Bird Electronics, Inc., in SEASOFT menu-driven release Version 4.221[4]. All files were batch-processed through the SEASOFT modules DATCNV, FILTER, ALIGNCTD, LOOPEDIT, BINAVG, and DERIVE (refer to footnote 4 and past Technical Memorandums, e.g., Sakuma et al. 1995b, for more information) and output as ASCII files macros. All data were averaged into two-meter depth bins. Each CTD ASCII file was subsequently 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, and bucket salinity at each CTD station using a simple regression to check for data outliers and any blatant calibration problems (Appendix 5).

Processed hydrographic data were summarized, by sweep, in a series of horizontal maps and vertical sections. Although additional CTD casts were completed during DSJ9707, only casts from the grid of standard CTD stations and those casts which provided a relatively continuous sampling track within a specific sweep were included in the data summary for the horizontal maps (Appendix 6). 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 sections from the three sweeps of DSJ9707 were also spatially standardized (Appendix 7). However, the Farallones transect line was less synoptic than the Pt. Reyes, Pescadero, and Davenport transect lines, because casts were combined over a 2- to 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 section contours nearshore. All contouring of CTD data for horizontal maps and vertical sections was done using SURFER FOR WINDOWS graphics software[5], 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 DSJ9707. 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 5). 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

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[4]CTD Data Acquisition software, SEASOFT Version 4.221, October 1996, 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.

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

data (temperature or salinity) on the corresponding TS value. TS data were subsequently contoured using SURFER FOR WINDOWS[5].

There was a problem in obtaining a satisfactory calibration for the WETStar fluorometer using the Nisken bottle samples from DSJ9707, which we are currently trying to resolve. Due to the lack of an accurate calibration, the fluorometer data for DSJ9707 will not be presented.

Dynamic height was calculated for stations occupied during DSJ9707 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 DSJ9707 were output from the DERIVE module of SEASOFT Version 4.221[4] and these data were gridded in SURFER FOR WINDOWS[5]. 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 8).

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 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: List of CTD Stations Summarized from Cruise DSJ9707

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 DSJ9707, Sweep 1 (May 14-21) includes 79 standard stations (casts 1-79), Sweep 2 (May 22-27) includes 68 standard stations (casts 80-148), and Sweep 3 (June 8-15) includes 69 standard stations (casts 199-267).

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

The locations of the standard CTD stations for DSJ9707 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

Wind vectors and SST and alongshore wind time series are presented for January-June 1997 for the four NOAA NDBC buoys located within the survey region. The first figure in this section summarizes the daily-averaged wind velocities (m/s) in stick vector form. Vectors point in the direction toward which the daily-mean wind was blowing; a vector pointing toward the south-southeast (bottom right of page) represents an upwelling-favorable wind. The scaling vector to the left of each series represents a 10 m/s wind blowing alongshore at each location, from a principal component analysis (PCA). The times of the three sweeps are shaded.

The following figures show the January-June 1997 time series of daily-averaged buoy SST and alongshore wind plotted against the climatology. In each plot, the bold solid line represents the daily-mean values of the parameter. The bold dotted line represents the biharmonic fit to the climatology derived from daily data over the operating period of the buoy to date. The gray shaded envelope about the biharmonic fit line is ±1 standard error of the daily values on each Julian day. Negative values denote southward (upwelling-favorable) winds. The "PCA direction" legends on the alongshore wind plots represent the direction of the alongshore wind relative to north, which was derived from a principal component analysis. The temperature sensor was not functioning at the Half Moon Bay buoy during the first half of 1997, and stopped operating at the Bodega buoy in late February.

Appendix 4: AVHRR Satellite Images of SST

SSTs 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 DSJ9707. Each image represents a single pass during the afternoon hours, local time. The temperature color spectrum ranges from 7.5-18°C. 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: 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 0.995 - 0.100
$R^2 = 0.97$
CTD temperature versus bucket temperature,
CTDtemp. = buckettemp. x 0.962 + 0.130
$R^2 = 0.92$
TS temperature versus bucket temperature,
TStemp. = buckettemp. x 0.976 + 0.102
$R^2 = 0.97$
CTD salinity versus TS salinity,
CTDsal. = TSsal. x 0.803 + 6.763
$R^2 = 0.91$
CTD salinity versus bucket salinity,
CTDsal. = bucketsal. x 0.949 + 1.711
$R^2 = 0.93$
TS salinity versus bucket salinity,
TSsal. = bucketsal. x 1.089 - 3.222
$R^2 = 0.87$

Appendix 6: Horizontal Maps of CTD and TS

a) Maps of TS temperature and salinity

Maps of surface temperature (°C) and salinity obtained from the vessel's TS continuous profiling unit are presented for each sweep of DSJ9707. The TS maps are located in front of the corresponding horizontal map for the CTD at 2 m. The contour intervals are 0.5 °C for temperature and 0.05 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 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, 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 0.5°C, 0.05, 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, and 0.02 kg/m^3.

Appendix 7: Vertical sections

Vertical sections of temperature, salinity and density are presented for four cross-shelf transects off Pt. Reyes, the Farallones, Pescadero, and Davenport for DSJ9707. Station maps denote the location of each transect and the offshore extent of stations (marked by a +) used to generate plots for each sweep. The locations of CTD casts used in generating the vertical sections are shown on each section by a ◆. The contour intervals are 0.5°C for temperature, 0.1 for salinity, and 0.2 kg/m^3 for density.

Appendix 8: Dynamic Height Topography

Horizontal maps of dynamic height (0/500 m and 200/500 m) are presented for the three sweeps of DSJ9707. 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 Meteorological and Hydrographic Conditions

Long-term climatologies of alongshore wind and SST at each buoy are superimposed on the January-June 1997 time series. The seasonal pattern of winds observed in 1997 at the area's four NDBC buoys corresponded to their long-term climatologies. Wind vectors align strongly with the local coastline. Winds in the first half of 1997 were highly variable, a consequence of numerous storms crossing the coast. Poleward winds dominated through the latter part of January, but otherwise winds were to the southeast (upwelling-favorable) in the months prior to this survey. Unlike most years, such as 1996 (Sakuma et al. 1997), winds during the survey were not sustained, but were more similar to the high frequency variability associated with winter storms. Upwelling was unusually weak during sweeps 1 and 2. A brief wind reversal (downwelling) occurred in the middle of sweep 1. A burst of very strong southeastward wind, followed by a reversal, preceded sweep 3. Another reversal took place near the end of the survey.

SSTs at the two operating buoys reflected these variations in wind forcing. Wind reversals in January, March, and April led to warming events. However SSTs were abnormally cool during March-April, suggesting an early "spring transition" toward upwelling-favorable conditions in late February. The rapid warming in the Gulf of the Farallones during May also occurred in conjunction with a wind reversal event. However the magnitude of this warming (5°C) was much greater than during reversals of similar magnitude. A return to below-seasonal SST in the Gulf accompanied stronger upwelling-favorable wind in early June. A more gradual warming trend in Monterey Bay began in March, pushing SSTs above normal beginning in mid-April. Buoys south of Monterey show a similar pattern, while buoys off northern California, and Pacific Grove shore temperature, reflect the brief but dramatic warming seen in the Gulf in May (Lynn et al. 1998). The usual southward winds along the west coast during this time of year were exceptionally weak, or even northeastward out of the subtropics.

This pattern corresponds to the PFEL coastal upwelling index time series (Bakun 1973, Schwing et al. 1996) at 36 and 39°N (Figure 1) and the AVHRR images. Upwelling was unusually strong during January-April 1997, resulting in generally cooler than normal coastal waters. A dramatic shift to weaker than normal upwelling occurred in May, contributing to a rapid warming. This can be attributed to a weakening of the North Pacific High in the Northeast Pacific, at a time when it is expected to strengthen and drive upwelling-favorable winds along the California coast (T. Murphree, pers. comm.). Stronger upwelling returned in June, cooling coastal waters. However waters outside of Monterey Bay and generally seaward of the survey region remained very warm.

During April-June 1997, an El Niño developed very rapidly in the tropical Pacific and reached an intensity rarely seen. However its early equatorial signal appeared to have little direct impact in the northeast Pacific. This is not surprising, since the atmospheric teleconnections from the equatorial Pacific to the North Pacific that produce most of these impacts are generally very weak in the northern summer and most pronounced during the northern winter (Lynn et al. 1998).

While short-term changes in buoy SST are related to wind forcing, much of the warming prior to the survey appears to be due to non-local factors. During April-June 1997, warm SST anomalies strengthened in a roughly triangular region of the northeast Pacific extending between Cabo San Lucas, Hawaii, and Vancouver Island, part of a large-scale pattern seen during most of the mid-1995 - early 1997 period (Schwing et al. 1997; Lynn et al. 1998). This exceptionally warm offshore water presumably was linked to sightings of a number of exotic warm-water fish off the west coast, and appears to have been largely a response to anomalous surface Ekman transports resulting from weaker winds about the North Pacific High (Schwing et al. 1997; Lynn et al. 1998). The intensification of this pattern in spring-summer 1997 appears to have been primarily due to regional wind anomalies in the northeast Pacific that were not related to El Niño. The interaction of this very warm offshore region with upwelled coastal water in the survey area can be seen in the AVHRR images taken during the three sweeps, as well as in the CTD observations.

Relative to the climatologies computed at 30 m from the 1987-96 rockfish surveys by Baltz (1997), coastal upwelling areas near Pt. Reyes and Pt. Año Nuevo featured normal temperature and salinity values during May-June 1997. Water seaward of the Pt. Reyes upwelling jet, in the northwest corner of the survey region, however, was extremely warm and fresh. Sweep 1 and 2 temperatures and salinities at 30 m were 3°C warmer and 0.2-0.3 ppt fresher than normal, respectively, in this area, possibly related to very weak winds and the subsequent weak offshore surface Ekman transport. Generally warmer surface water also may be attributed to low wind mixing. Very strong lateral gradients in these variables were present in all three sweeps, separating nearshore and offshore water masses, and associated with strong geostrophic currents. The cross-shore gradient in dynamic height during 1997 was generally 2-3 times stronger compared to the previous year, particularly off Pt. Reyes. From this, it appears that the upwelling jet commonly seen off Pt. Reyes (Baltz 1997) was unusually intense during the 1997 survey. The contrast in SST across this jet is particularly evident in the sweep 2 AVHRR image. Near-surface salinities were generally 0.3 ppt lower than usual in the southern half of the region. As is typical for the region, the CTD survey revealed considerable mesoscale variability. Unlike the past few years (e.g. Sakuma et al. 1997), however, no low salinity signature of San Francisco Bay water was observed.

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FIGURES

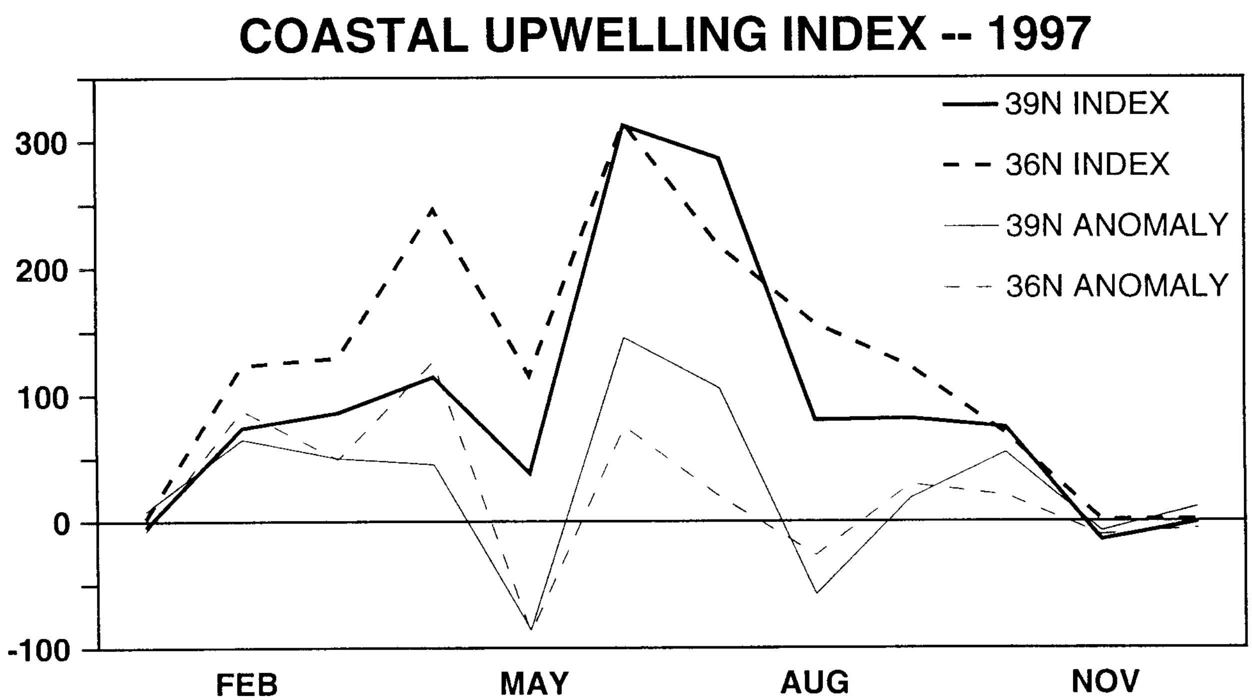


Figure 1. Monthly coastal upwelling indices for 1997 at 36°N 122°W and 39°N 125°W, and their anomalies relative to 20-year period (1948-67). Units are $m^3/s/100$ km of coastline.

APPENDIX 1: LIST OF CTD STATIONS SUMMARIZED FROM CRUISE DSJ9707

DS9707 Sweep 1

CAST	DATE	TIME	LATITUDE	LONGITUDE	DEPTH(M)
1	14MAY97	1745	36 52.8	121 56.0	38
2	14MAY97	2030	36 50.5	121 59.0	86
3	14MAY97	2119	36 46.0	121 52.1	75
4	14MAY97	2300	36 44.4	121 58.5	273
5	15MAY97	0054	36 42.0	121 52.4	68
6	15MAY97	0129	36 38.7	121 51.6	38
7	15MAY97	0352	36 38.9	121 59.5	94
8	15MAY97	0456	36 40.1	122 09.9	2180
9	15MAY97	0610	36 46.3	122 16.1	817
10	15MAY97	0735	36 40.2	122 22.3	1729
11	15MAY97	0850	36 46.3	122 28.5	1500
12	15MAY97	1005	36 40.1	122 34.6	1500
13	15MAY97	1140	36 40.0	122 47.1	1500
14	15MAY97	1305	36 33.8	122 40.9	1500
15	15MAY97	1500	36 33.7	122 28.7	2700
16	15MAY97	1625	36 33.7	122 16.5	2600
17	15MAY97	2036	36 34.9	122 10.7	3500
18	16MAY97	0032	36 34.7	122 04.2	820
19	16MAY97	0140	36 38.9	122 03.4	1040
20	16MAY97	0402	36 41.3	122 05.0	1900
21	16MAY97	0600	36 43.7	122 08.9	1200
22	16MAY97	0720	36 51.2	122 10.3	219
23	16MAY97	0850	36 52.7	122 22.4	1125
24	16MAY97	1015	36 52.7	122 34.6	1900
25	16MAY97	1120	36 52.7	122 47.0	2275
26	16MAY97	1310	36 52.5	122 59.2	2684
27	16MAY97	1425	36 59.0	122 53.3	1425
28	16MAY97	1545	37 05.0	122 47.1	630
29	16MAY97	1715	37 05.2	122 34.8	110
30	16MAY97	1824	37 05.1	122 22.3	64
31	16MAY97	2033	36 58.7	122 17.5	84
32	17MAY97	0014	36 58.5	122 24.2	154
33	17MAY97	0040	36 59.0	122 25.6	600
34	17MAY97	0455	36 58.4	122 38.5	585
35	17MAY97	0650	37 10.6	122 28.5	68
36	17MAY97	0813	37 10.7	122 40.7	109
37	17MAY97	0922	37 10.8	122 53.2	417
38	17MAY97	1045	37 10.7	123 05.3	833
39	17MAY97	1200	37 16.4	123 11.3	1005
40	17MAY97	1313	37 21.9	123 05.5	800
41	17MAY97	1410	37 20.5	122 57.9	560
42	17MAY97	1605	37 22.3	122 40.8	83
43	17MAY97	1718	37 22.3	122 28.3	28
44	17MAY97	2043	37 16.4	122 34.1	83
45	17MAY97	2305	37 17.1	122 41.2	96
46	18MAY97	0008	37 16.6	122 48.9	171
47	18MAY97	0437	37 15.0	122 59.2	514
48	18MAY97	0627	37 28.6	122 59.4	330
49	18MAY97	0747	37 30.8	123 11.5	1400
50	18MAY97	0923	37 30.9	123 24.0	2600
51	18MAY97	1052	37 31.0	123 36.4	3400
52	18MAY97	1203	37 38.3	123 36.3	3370
53	18MAY97	1318	37 46.0	123 36.4	2684
54	18MAY97	1453	37 46.2	123 24.1	1500
55	18MAY97	1623	37 46.3	123 11.5	108

CAST	DATE	TIME	LATITUDE	LONGITUDE	DEPTH(M)
56	18MAY97	2030	37 39.5	123 02.6	102
57	18MAY97	2312	37 39.1	123 13.9	1300
58	19MAY97	0031	37 45.0	123 08.4	63
59	19MAY97	0308	37 51.1	123 20.9	116
60	19MAY97	0453	37 51.2	123 29.4	1456
61	19MAY97	0649	38 01.4	123 30.1	140
62	19MAY97	0800	38 01.6	123 42.5	2600
63	19MAY97	0940	38 01.7	123 54.9	3700
64	19MAY97	1120	38 09.9	124 06.9	4100
65	19MAY97	1333	38 18.4	123 54.9	2730
66	19MAY97	1505	38 18.4	123 42.6	1456
67	19MAY97	1645	38 18.4	123 30.2	252
68	19MAY97	1759	38 18.5	123 18.0	106
69	19MAY97	2031	38 09.8	123 22.0	172
70	20MAY97	0053	38 08.9	123 15.7	111
71	20MAY97	0132	38 09.9	123 10.2	88
72	20MAY97	0312	38 08.6	123 03.0	66
73	20MAY97	0419	38 10.6	123 01.6	60
74	20MAY97	0600	38 01.6	123 05.7	61
75	20MAY97	0710	38 01.5	123 17.6	113
76	20MAY97	2037	37 42.3	123 09.9	520
77	21MAY97	0042	37 45.0	123 00.1	63
78	21MAY97	0144	37 42.1	122 54.6	54
79	21MAY97	0256	37 47.4	122 52.2	52

DSJ9707 Sweep 2

CAST	DATE	TIME	LATITUDE	LONGITUDE	DEPTH(M)
80	22MAY97	0437	36 42.2	121 57.4	94
82	22MAY97	0712	36 46.3	122 16.1	815
83	22MAY97	0829	36 40.1	122 22.6	2000
84	22MAY97	0943	36 46.4	122 28.4	2200
85	22MAY97	1058	36 40.1	122 34.6	2400
86	22MAY97	1210	36 33.8	122 40.6	2730
87	22MAY97	1340	36 33.8	122 28.6	2700
88	22MAY97	1520	36 33.8	122 16.4	2548
89	22MAY97	2033	36 35.0	122 10.5	2268
90	22MAY97	2355	36 35.1	122 02.0	563
91	23MAY97	0105	36 38.8	122 03.0	808
92	23MAY97	0222	36 41.8	122 06.5	2000
93	23MAY97	0423	36 45.5	122 11.3	685
94	23MAY97	0535	36 52.6	122 10.3	96
95	23MAY97	0645	36 52.8	122 22.4	1150
96	23MAY97	0811	36 52.6	122 34.6	2200
97	23MAY97	0935	36 52.7	122 47.1	2500
98	23MAY97	1059	36 52.7	122 59.2	2800
99	23MAY97	1210	36 59.1	122 53.2	1365
100	23MAY97	1320	37 04.9	122 46.9	684
101	23MAY97	1500	37 05.0	122 34.7	110
102	23MAY97	1607	37 05.0	122 22.4	57
103	23MAY97	2040	36 59.0	122 17.2	80
104	23MAY97	2225	36 59.0	122 22.5	123
105	23MAY97	2322	36 59.1	122 25.4	340
106	24MAY97	0413	36 59.3	122 33.6	295

CAST	DATE	TIME	LATITUDE	LONGITUDE	DEPTH(M)
107	24MAY97	0547	37 10.6	122 28.6	68
108	24MAY97	0704	37 11.0	122 40.8	105
109	24MAY97	0810	37 10.8	122 53.1	414
110	24MAY97	0928	37 10.7	123 05.5	840
111	24MAY97	1038	37 16.4	123 11.5	1400
112	24MAY97	1155	37 22.2	123 05.6	785
113	24MAY97	1325	37 22.3	122 53.2	197
114	24MAY97	1442	37 22.4	122 40.5	80
115	24MAY97	1552	37 22.5	122 28.5	30
116	24MAY97	2035	37 16.0	122 34.0	83
117	24MAY97	2227	37 16.5	122 39.0	93
118	25MAY97	0015	37 16.6	122 49.1	176
119	25MAY97	0459	37 15.5	123 00.5	564
120	25MAY97	0715	37 30.7	122 59.5	224
121	25MAY97	0838	37 30.8	123 11.7	1350
122	25MAY97	1006	37 30.9	123 24.0	2600
123	25MAY97	1132	37 30.9	123 36.3	3400
124	25MAY97	1245	37 38.4	123 36.3	3200
125	25MAY97	1408	37 46.2	123 36.4	2600
126	25MAY97	1544	37 46.4	123 23.8	1515
127	25MAY97	1713	37 46.3	123 11.7	110
128	25MAY97	2115	37 39.5	123 02.6	103
129	25MAY97	2345	37 39.4	123 12.4	1400
130	26MAY97	0118	37 44.5	123 08.4	100
131	26MAY97	0517	37 51.5	123 29.4	1456
132	26MAY97	0657	38 01.5	123 30.3	150
133	26MAY97	0805	38 01.6	123 42.5	2600
134	26MAY97	0925	38 01.7	123 54.7	3000
135	26MAY97	1105	38 10.0	124 07.0	3800
136	26MAY97	1245	38 18.4	123 54.7	2800
137	26MAY97	1405	38 18.4	123 42.5	1400
138	26MAY97	1533	38 18.5	123 30.0	249
139	26MAY97	1644	38 18.6	123 17.8	105
140	26MAY97	2033	38 10.0	123 21.9	174
141	27MAY97	0024	38 10.1	123 17.0	116
142	27MAY97	0131	38 10.1	123 10.6	90
143	27MAY97	0238	38 09.4	123 05.1	72
144	27MAY97	0414	38 10.3	123 01.8	63
145	27MAY97	0602	38 01.4	123 17.7	113
146	27MAY97	0746	38 01.7	123 05.5	60
147	27MAY97	0845	37 42.0	122 54.6	53
148	27MAY97	2225	37 47.2	122 52.0	52

DSJ9707 Sweep 3

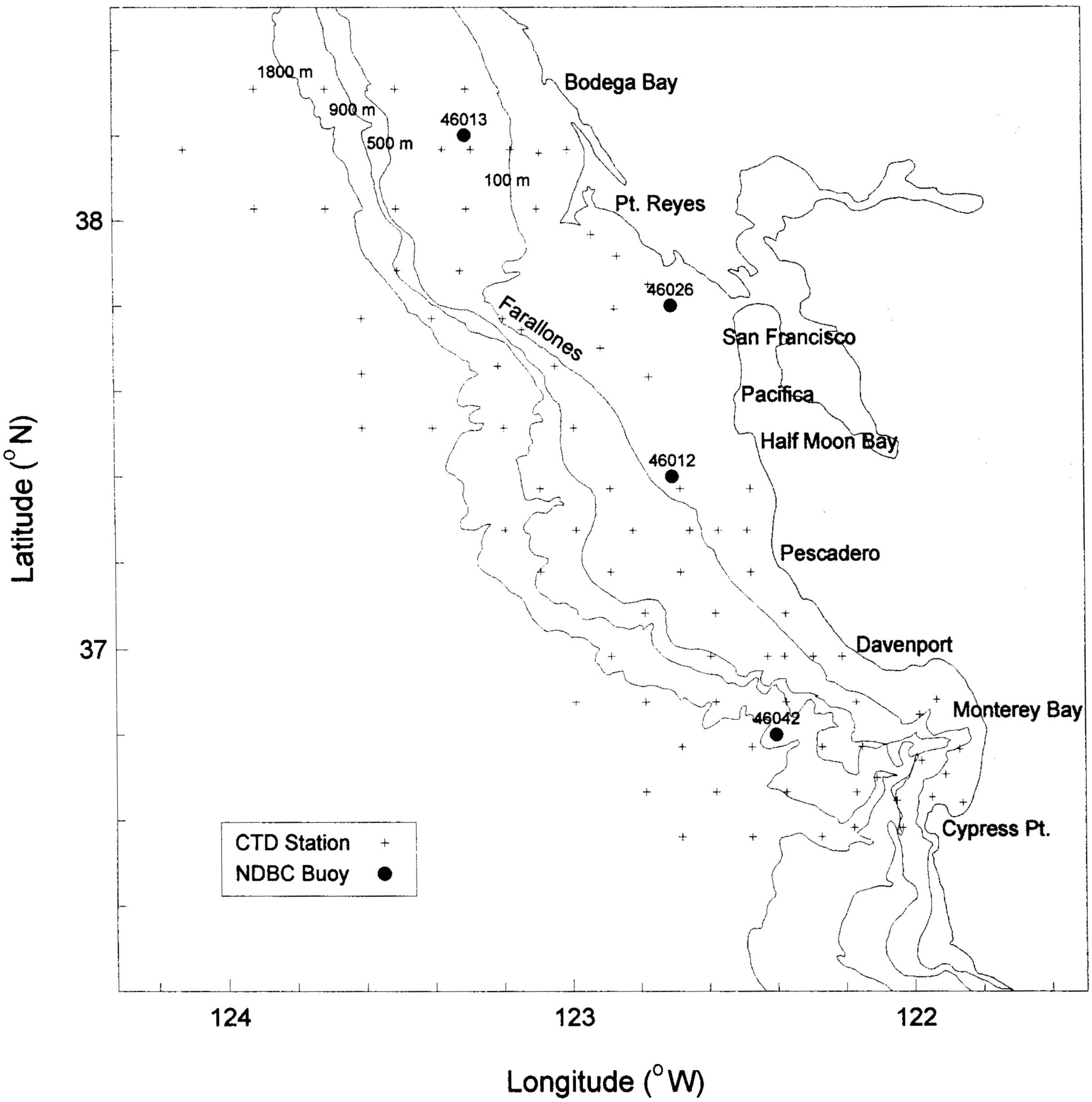
CAST	DATE	TIME	LATITUDE	LONGITUDE	DEPTH(M)
199	08JUN97	1955	36 53.0	121 56.1	37
200	08JUN97	2047	36 50.8	121 58.9	87
201	08JUN97	2248	36 46.0	121 52.1	73
202	09JUN97	0507	36 39.2	121 52.6	62
203	09JUN97	0538	36 39.4	121 56.3	73
204	09JUN97	0658	36 40.0	122 10.0	1100
205	09JUN97	0834	36 46.3	122 16.2	826

CAST	DATE	TIME	LATITUDE	LONGITUDE	DEPTH(M)
206	09JUN97	0955	36 40.1	122 22.3	1800
207	09JUN97	1115	36 46.2	122 28.3	2200
208	09JUN97	1237	36 40.0	122 34.6	4300
209	09JUN97	1400	36 33.8	122 40.8	2100
210	09JUN97	1532	36 33.7	122 28.4	2700
211	09JUN97	1655	36 33.7	122 16.4	2650
212	09JUN97	2047	36 34.9	122 10.4	2400
213	10JUN97	0009	36 35.0	122 02.1	625
214	10JUN97	0135	36 38.9	122 03.1	915
215	10JUN97	0257	36 42.1	122 06.7	1900
216	10JUN97	0505	36 47.0	122 10.5	680
217	10JUN97	0605	36 52.6	122 10.1	97
218	10JUN97	0735	36 52.8	122 22.5	1200
219	10JUN97	0913	36 52.7	122 34.6	1800
220	10JUN97	1050	36 52.7	122 46.9	1500
221	10JUN97	1225	36 52.6	122 59.4	2700
222	10JUN97	1315	36 59.0	122 53.0	1350
223	10JUN97	1503	37 05.0	122 47.0	625
224	10JUN97	1645	37 05.0	122 34.7	110
225	10JUN97	2100	36 58.8	122 17.6	86
226	10JUN97	2246	36 59.0	122 22.5	122
227	11JUN97	0005	36 59.0	122 25.7	565
228	11JUN97	0535	36 58.7	122 34.5	417
229	11JUN97	0719	37 10.7	122 28.4	87
230	11JUN97	0839	37 10.7	122 40.8	110
231	11JUN97	1130	37 10.7	122 53.1	410
232	11JUN97	1256	37 10.7	123 05.3	825
233	11JUN97	1408	37 16.5	123 11.4	1170
234	11JUN97	1521	37 22.3	123 05.3	770
235	11JUN97	1646	37 22.4	122 52.9	187
236	11JUN97	1800	37 22.3	122 40.7	83
237	11JUN97	1917	37 22.4	122 28.3	28
238	11JUN97	2112	37 16.5	122 34.1	82
239	11JUN97	2232	37 16.5	122 38.9	91
240	12JUN97	0007	37 16.6	122 49.1	175
241	12JUN97	0527	37 14.4	122 57.2	455
242	12JUN97	0747	37 30.7	122 59.4	215
243	12JUN97	0916	37 30.8	123 11.7	1500
244	12JUN97	1053	37 30.8	123 24.1	2600
245	12JUN97	1235	37 30.7	123 36.4	3400
246	12JUN97	1415	37 38.4	123 36.4	3200
247	12JUN97	1554	37 46.1	123 36.4	3000
248	12JUN97	1735	37 46.3	123 23.9	1500
249	12JUN97	1914	37 46.0	123 11.7	115
250	13JUN97	2105	37 47.4	122 52.2	53
251	13JUN97	2251	37 42.0	122 54.6	54
252	14JUN97	0023	37 39.6	123 02.7	100
253	14JUN97	0222	37 39.6	123 12.6	1350
254	14JUN97	0457	37 43.9	123 07.4	88
255	14JUN97	0815	38 01.5	123 30.2	142
256	14JUN97	0930	38 01.7	123 42.6	2800
257	14JUN97	1110	38 01.7	123 54.8	3800
258	14JUN97	1320	38 10.0	124 07.1	3600
259	14JUN97	1525	38 18.5	123 54.7	2700
260	14JUN97	1655	38 18.6	123 42.5	1500
261	14JUN97	1820	38 18.6	123 30.1	252
262	14JUN97	0195	38 18.5	123 17.9	105
263	14JUN97	2046	38 10.1	123 22.1	178

CAST	DATE	TIME	LATITUDE	LONGITUDE	DEPTH(M)
264	14JUN97	2345	38 10.1	123 17.1	117
265	15JUN97	0007	38 10.1	123 10.0	87
266	15JUN97	0222	38 09.5	123 05.1	71
267	15JUN97	0321	38 11.3	123 01.2	60

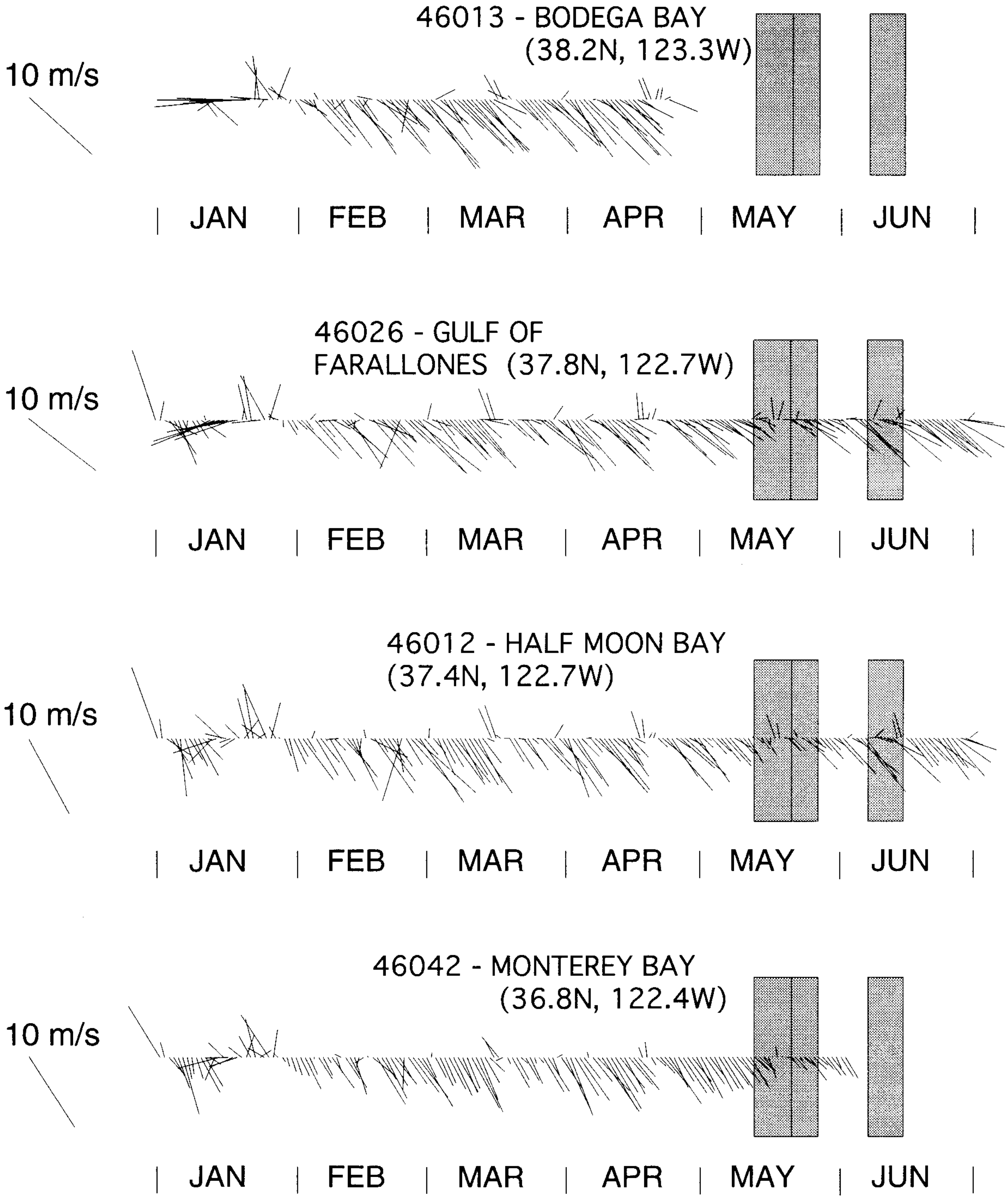
APPENDIX 2: DSJ9707 CTD STATIONS AND BATHYMETRIC MAP OF SURVEY REGION WITH LOCATIONS OF THE NDBC BUOYS

Standard CTD Station Locations



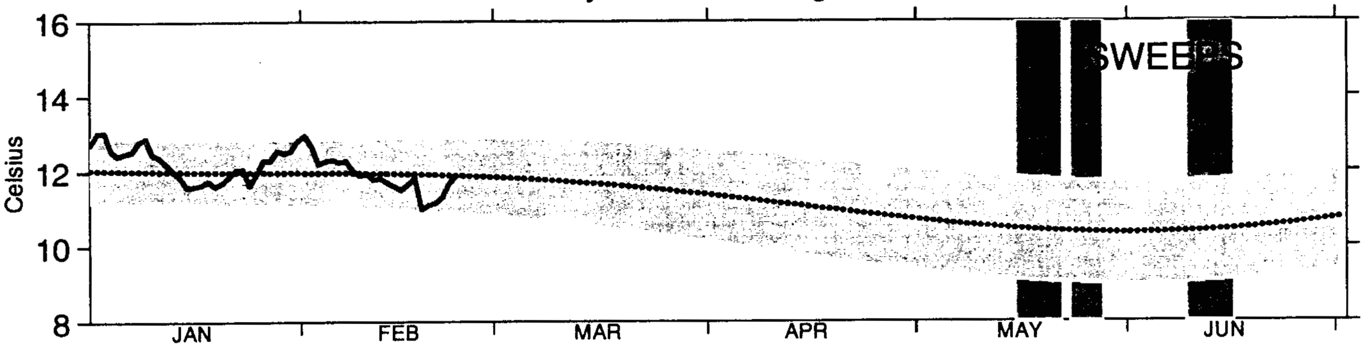
APPENDIX 3: METEOROLOGICAL TIME SERIES

DAILY BUOY WINDS - 1997

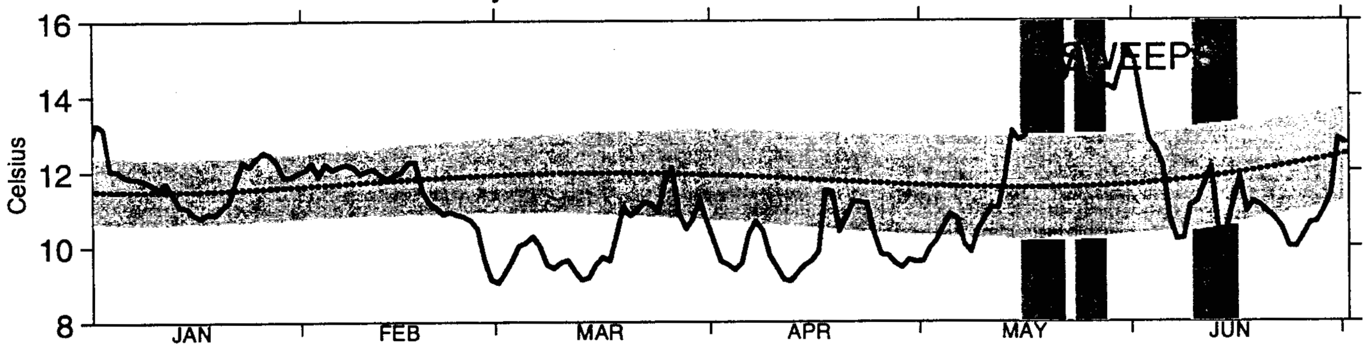


Sea Surface Temperatures from NOAA NDBC Buoys ~ 1997

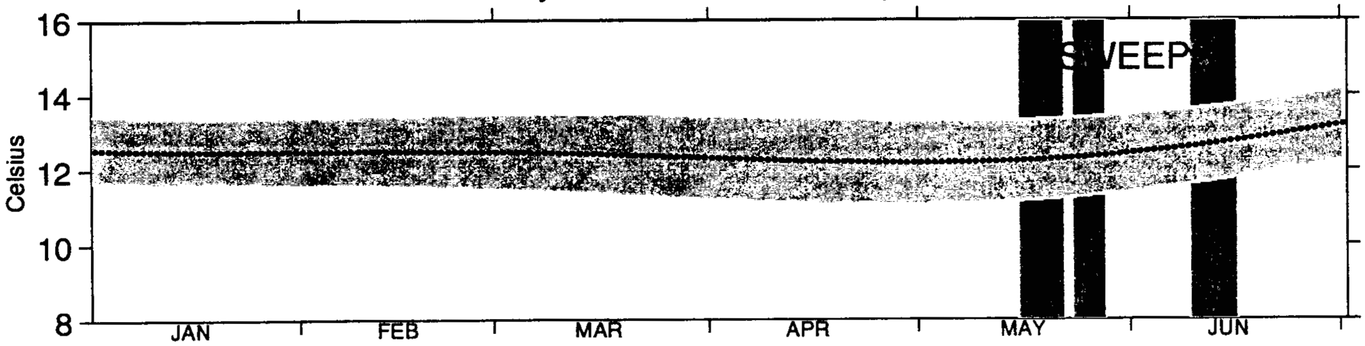
Buoy 46013 ~ Bodega, CA



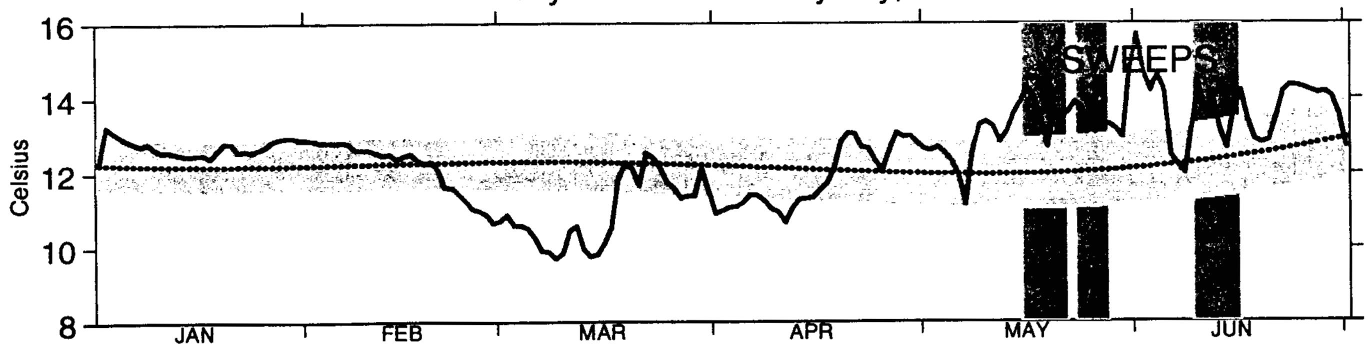
Buoy 46026 ~ Gulf of the Farallones, CA



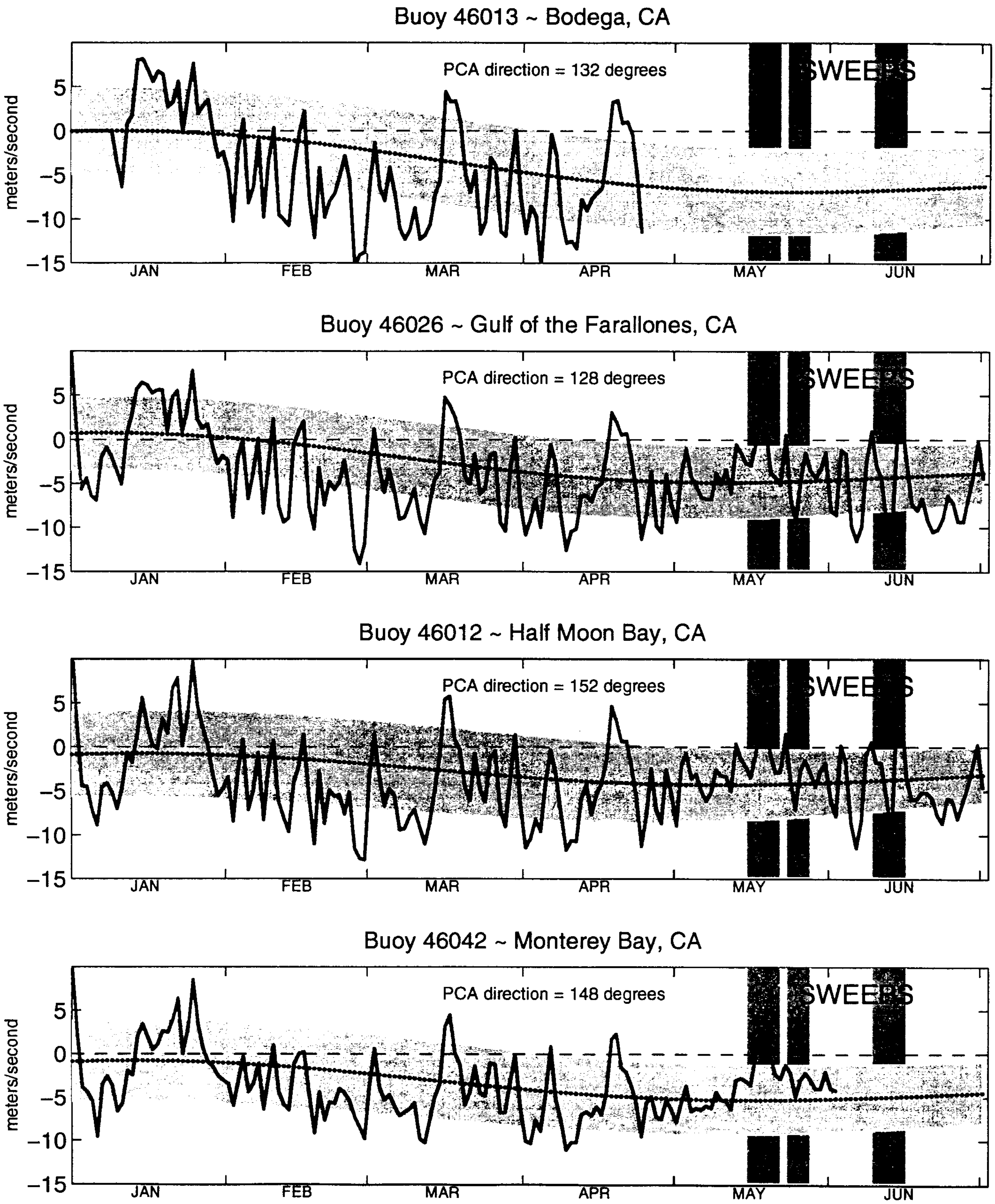
Buoy 46012 ~ Half Moon Bay, CA



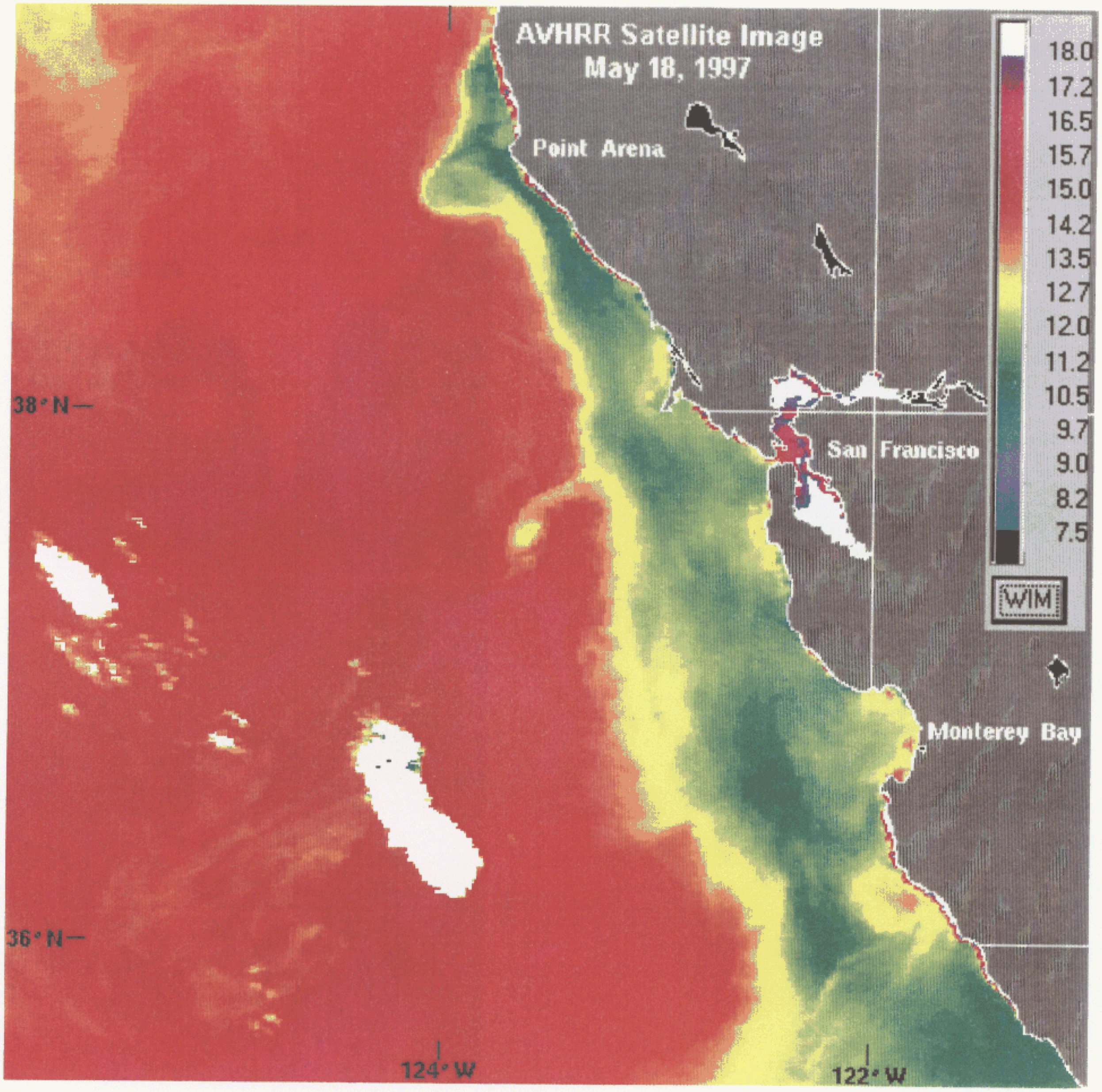
Buoy 46042 ~ Monterey Bay, CA



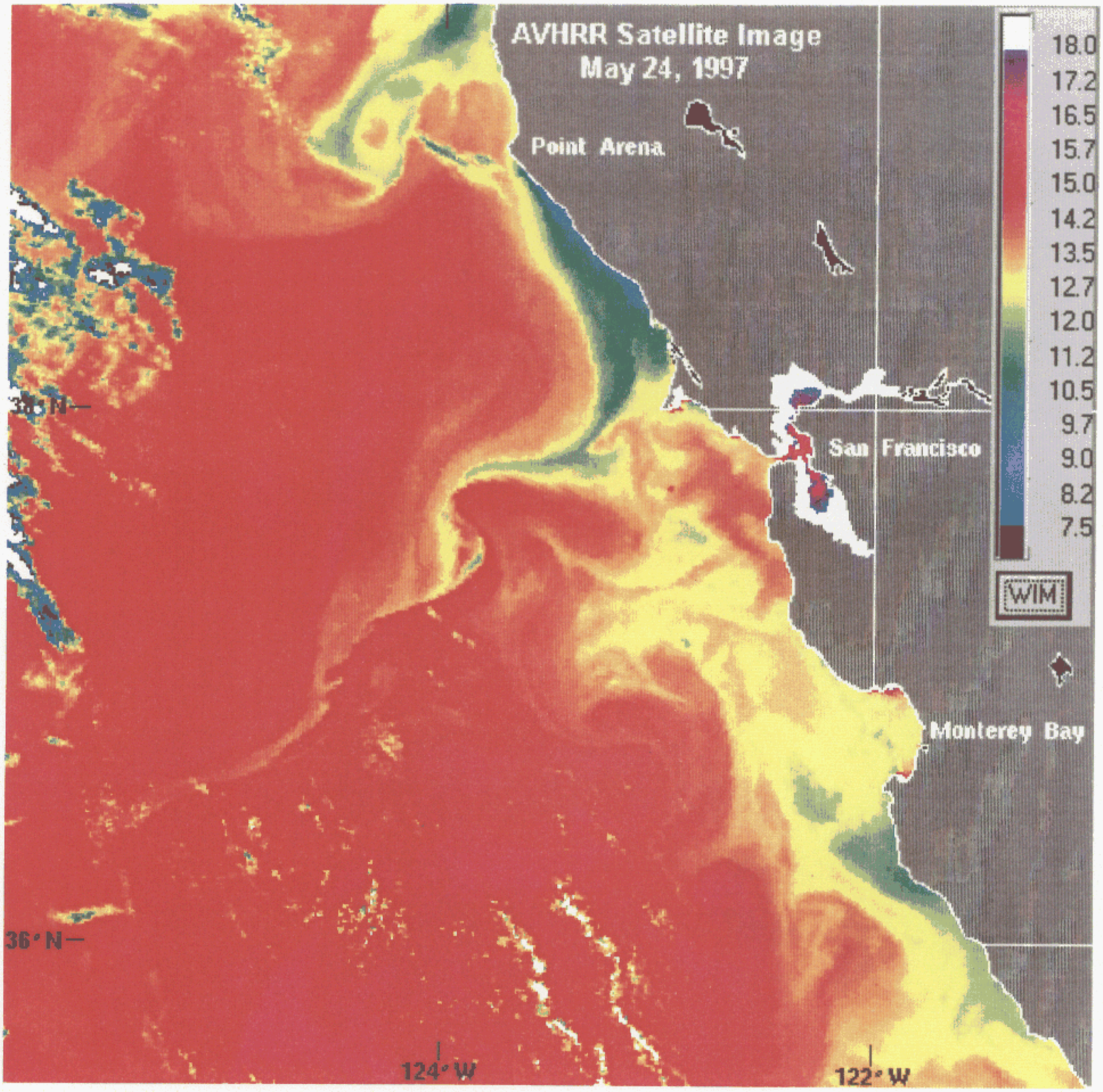
Alongshore Winds from NOAA NDBC Buoys ~ 1997

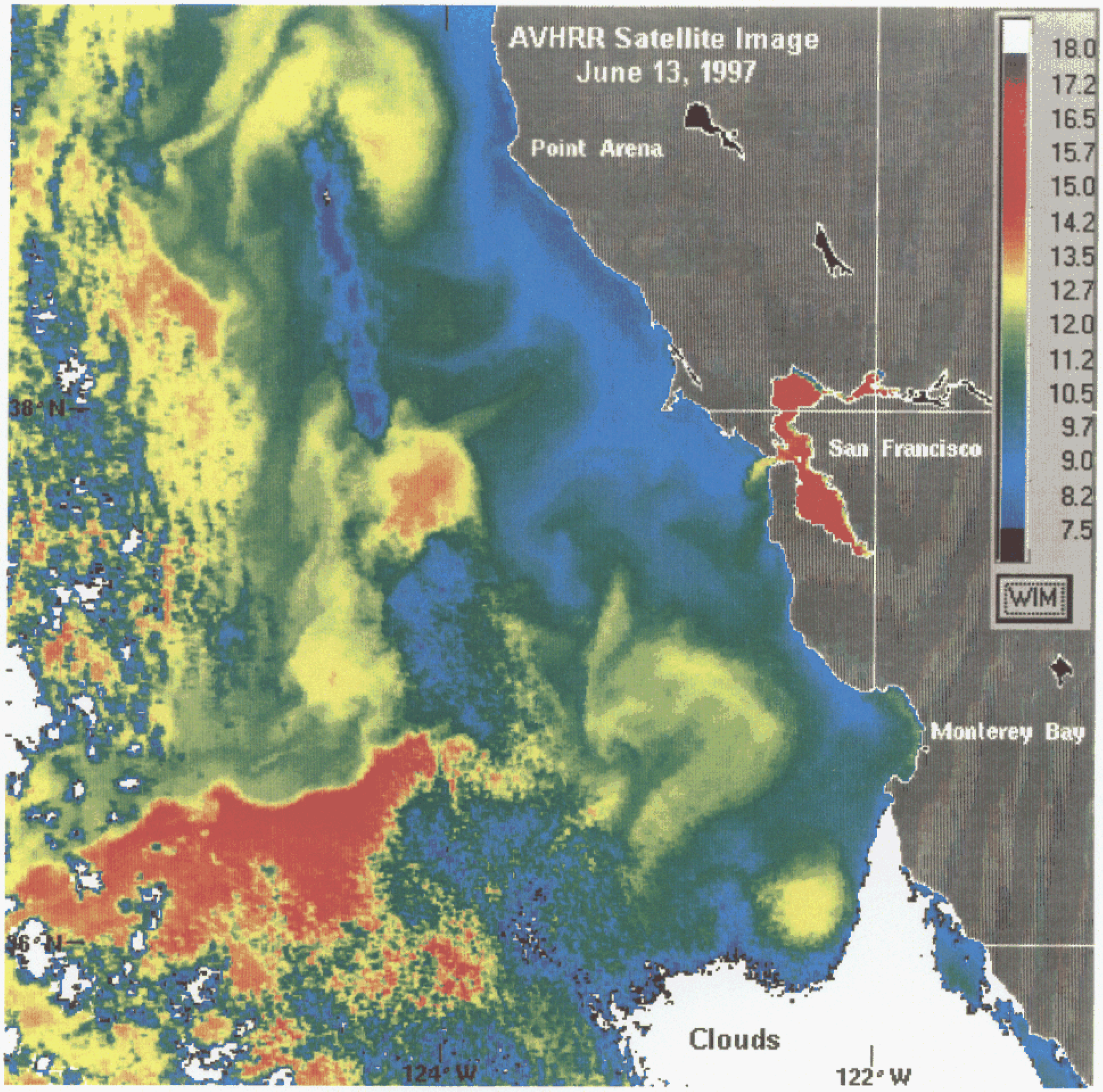


APPENDIX 4: AVHRR SATELLITE IMAGES OF SST



AVHRR Satellite Image
May 18, 1997
Point Arena
San Francisco
Monterey Bay
38° N
36° N
124° W
122° W
18.0
17.2
16.5
15.7
15.0
14.2
13.5
12.7
12.0
11.2
10.5
9.7
9.0
8.2
7.5
WIM

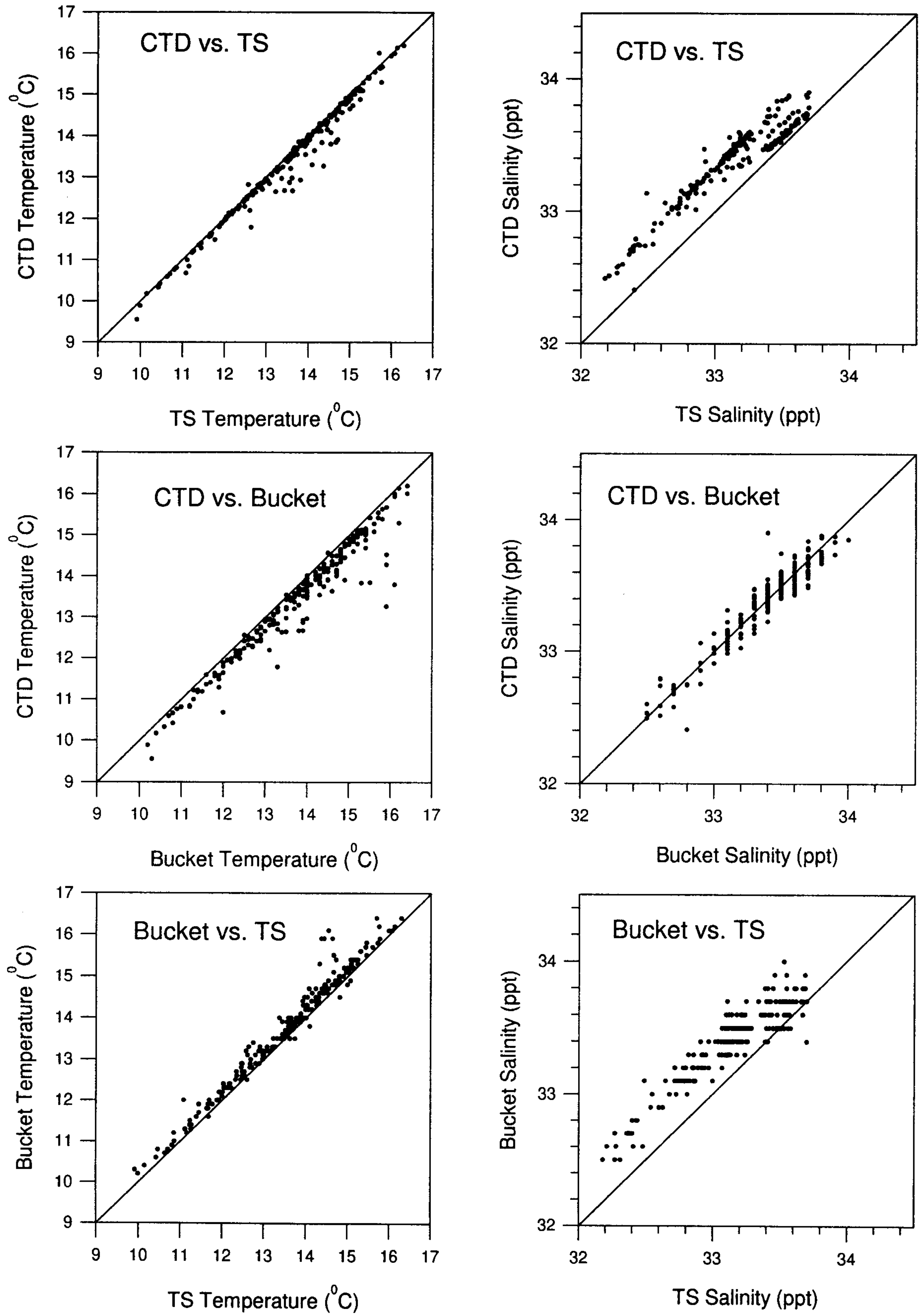

AVHRR Satellite Image
May 24, 1997
Point Arena
San Francisco
Monterey Bay
36° N
124° W
122° W
18.0
17.2
16.5
15.7
15.0
14.2
13.5
12.7
12.0
11.2
10.5
9.7
9.0
8.2
7.5
WIM



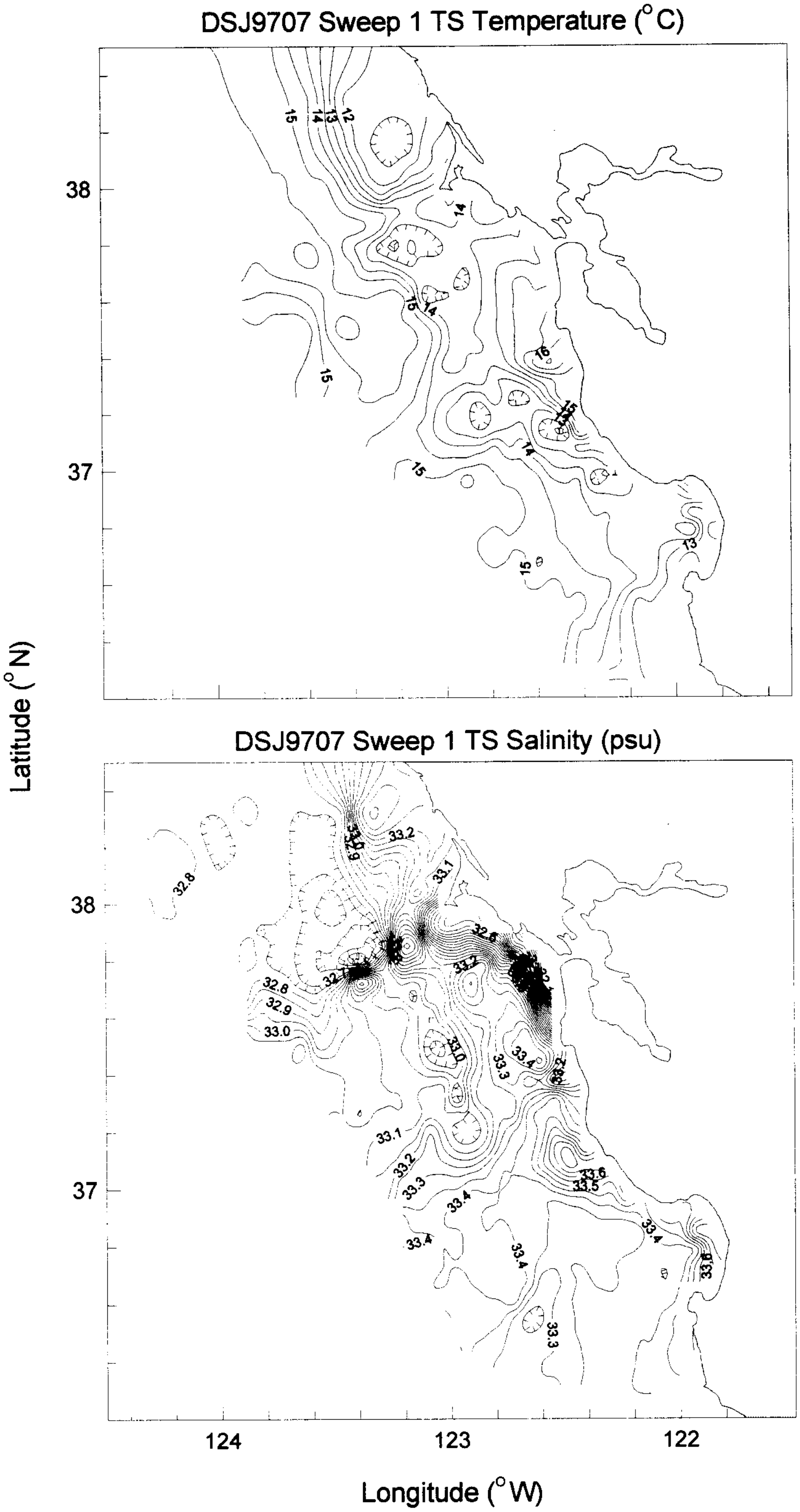
AVHRR Satellite Image
June 13, 1997
Point Arena
San Francisco
Monterey Bay
Clouds
38° N
36° N
124° W
122° W
18.0
17.2
16.5
15.7
15.0
14.2
13.5
12.7
12.0
11.2
10.5
9.7
9.0
8.2
7.5
WIM

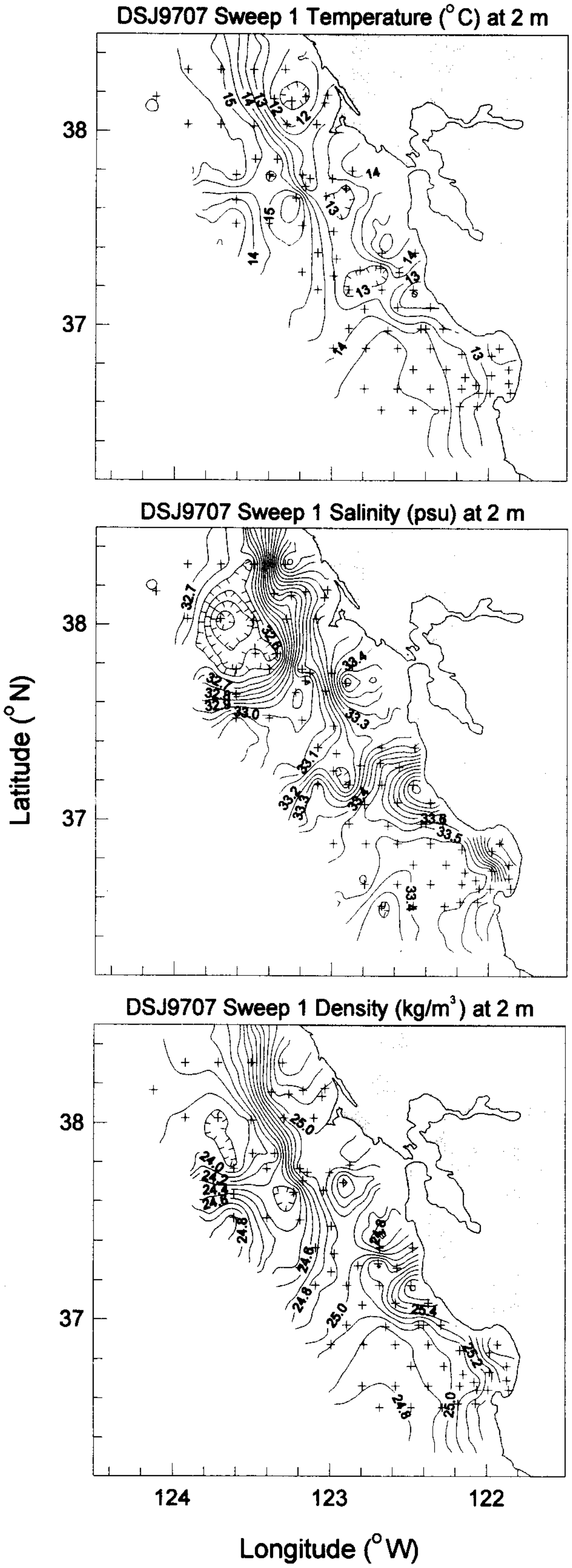
APPENDIX 5: REGRESSION COMPARISONS OF CTD, TS, AND BUCKET FOR DSJ9707

DSJ9707

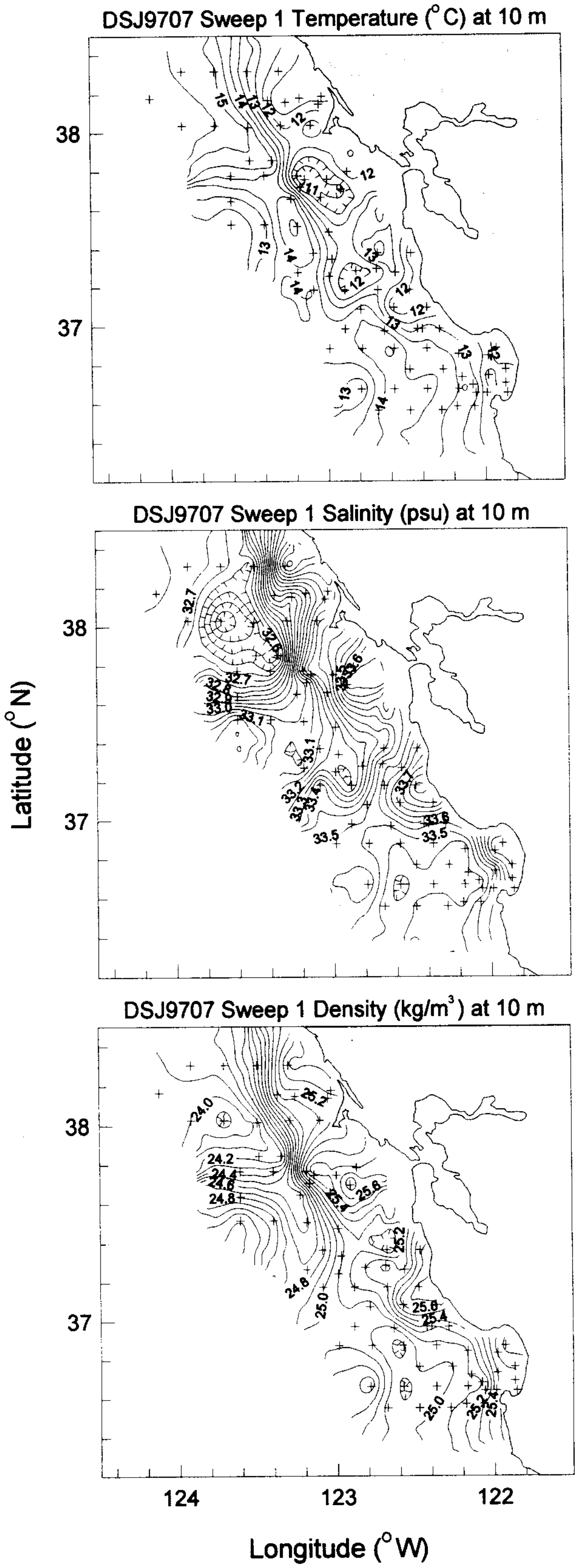

CTD vs. TS
CTD Temperature (°C)
TS Temperature (°C)
CTD vs. TS
CTD Salinity (ppt)
TS Salinity (ppt)
CTD vs. Bucket
CTD Temperature (°C)
Bucket Temperature (°C)
CTD vs. Bucket
CTD Salinity (ppt)
Bucket Salinity (ppt)
Bucket vs. TS
Bucket Temperature (°C)
TS Temperature (°C)
Bucket vs. TS
Bucket Salinity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

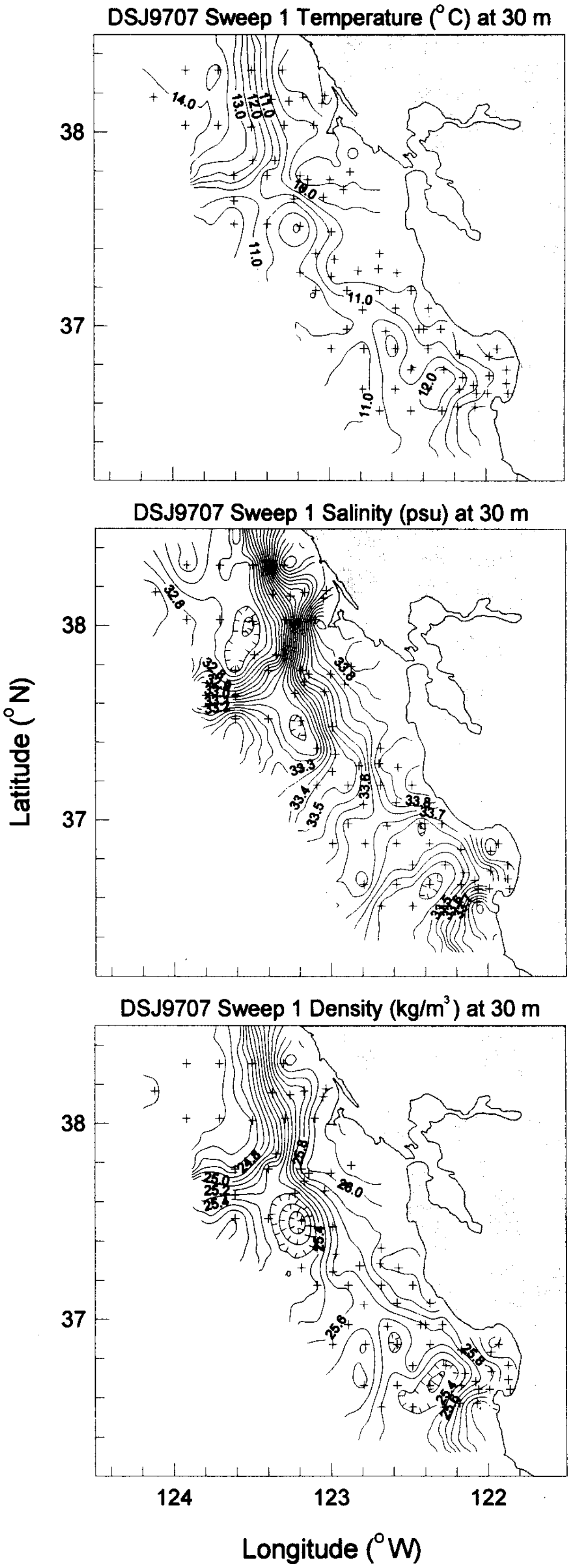
APPENDIX 6.1: HORIZONTAL MAPS OF CTD AND TS FOR DSJ9707, SWEEP 1

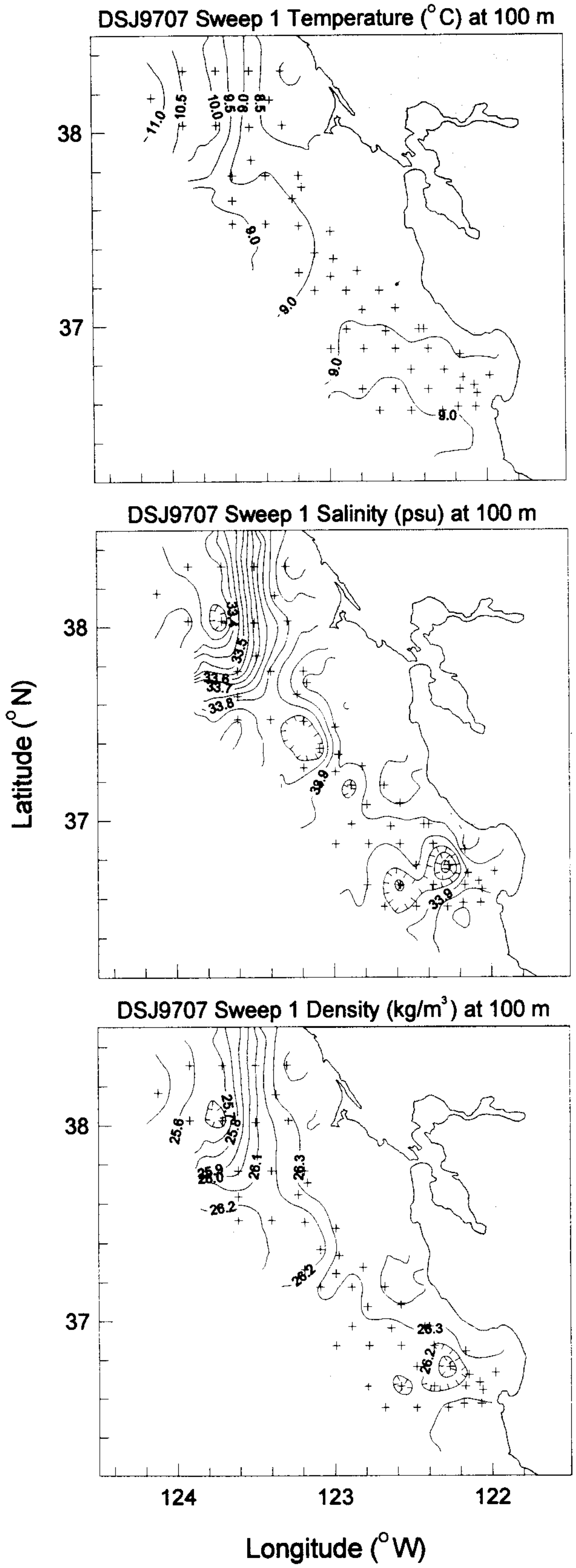

DSJ9707 Sweep 1 TS Temperature (°C)
DSJ9707 Sweep 1 TS Salinity (psu)
Latitude (°N)
Longitude (°W)
38
37
124
123
122

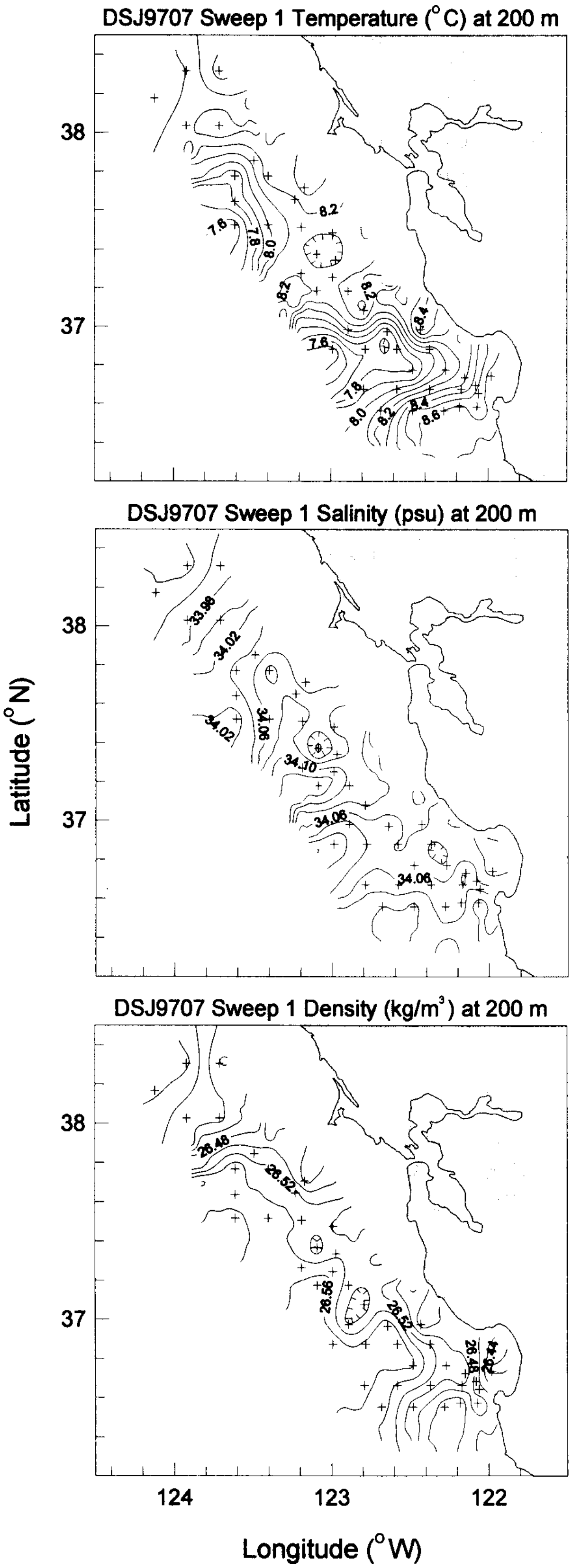


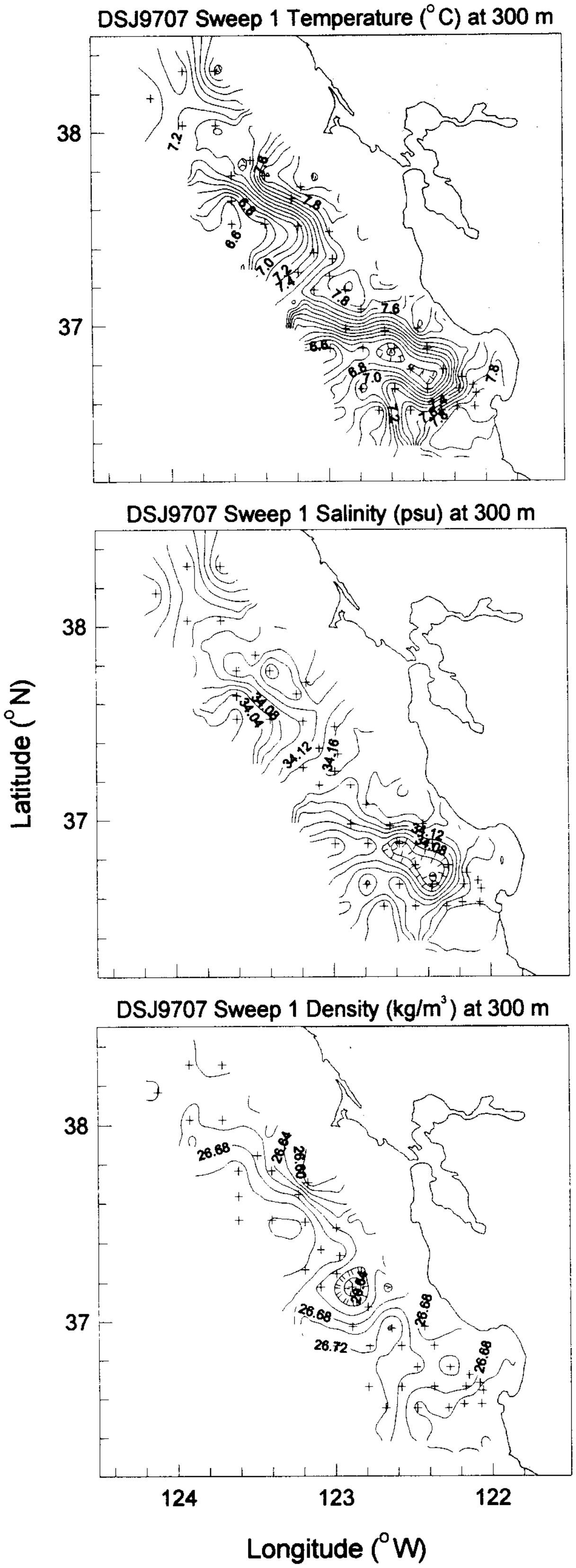
DSJ9707 Sweep 1 Temperature (°C) at 2 m
DSJ9707 Sweep 1 Salinity (psu) at 2 m
DSJ9707 Sweep 1 Density (kg/m³) at 2 m
Latitude (°N)
Longitude (°W)
38
37
124
123
122

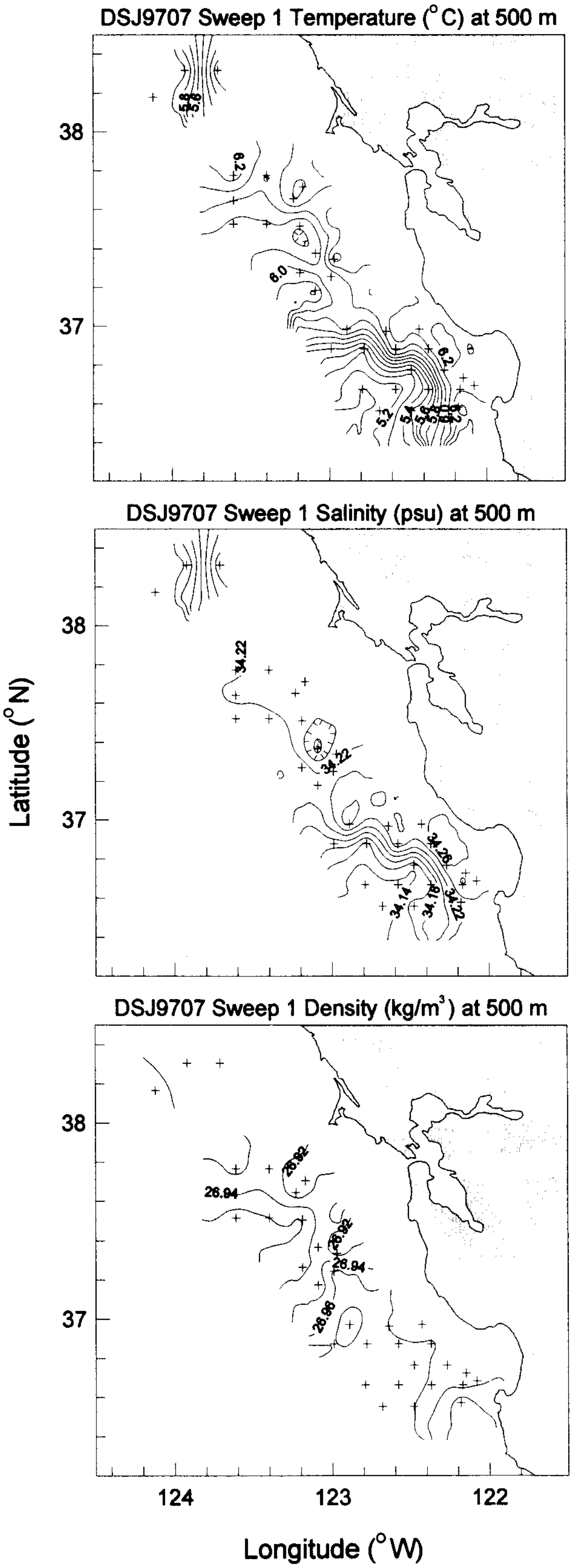

DSJ9707 Sweep 1 Temperature (°C) at 10 m
DSJ9707 Sweep 1 Salinity (psu) at 10 m
DSJ9707 Sweep 1 Density (kg/m³) at 10 m
Latitude (°N)
38
37
124
123
122
Longitude (°W)


DSJ9707 Sweep 1 Temperature (°C) at 30 m
DSJ9707 Sweep 1 Salinity (psu) at 30 m
DSJ9707 Sweep 1 Density (kg/m³) at 30 m
Latitude (°N)
38
37
Longitude (°W)
124
123
122

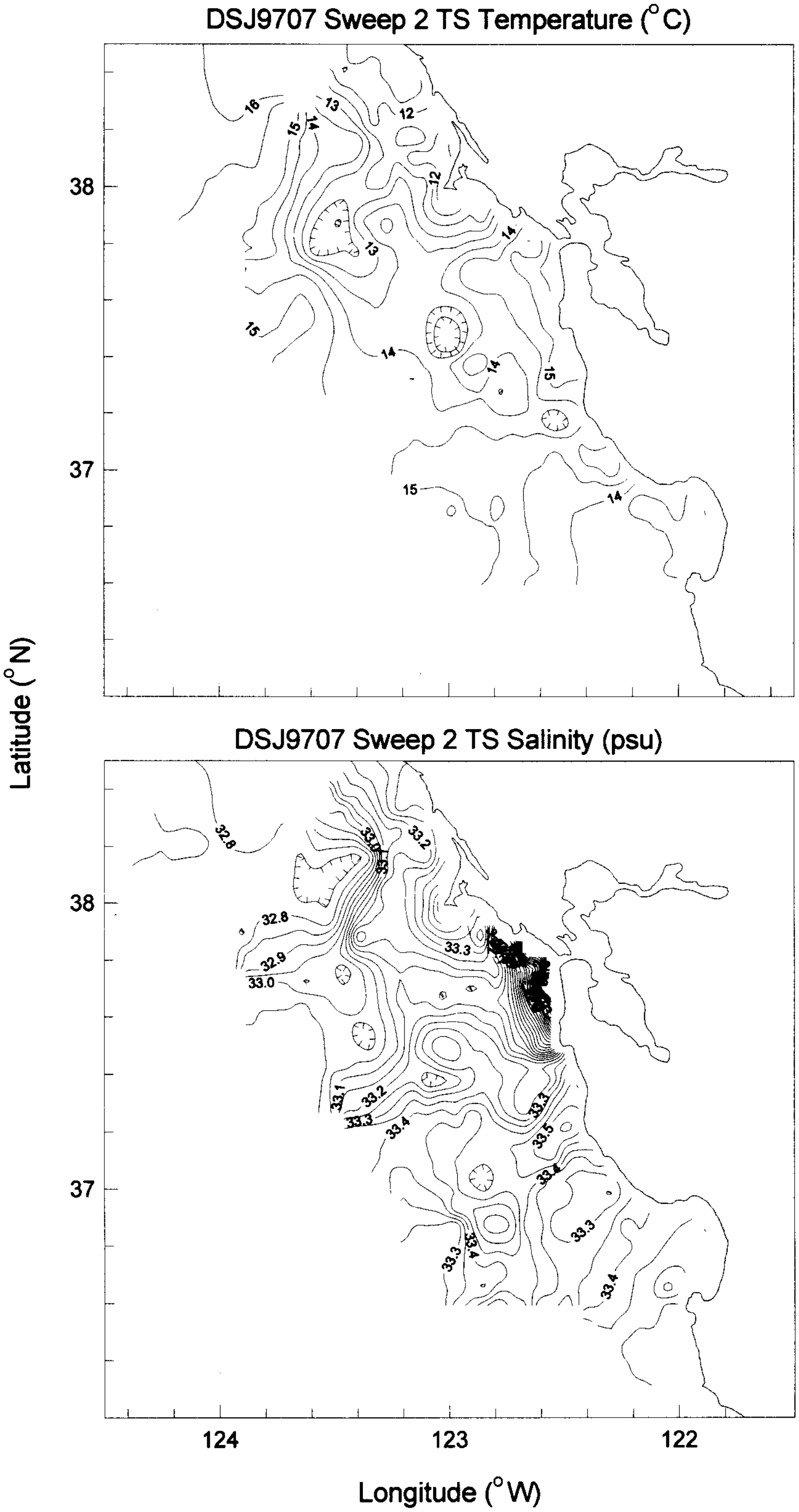

DSJ9707 Sweep 1 Temperature (°C) at 100 m
11.0
10.5
10.0
9.5
9.0
8.5
DSJ9707 Sweep 1 Salinity (psu) at 100 m
33.5
33.6
33.7
33.8
33.9
DSJ9707 Sweep 1 Density (kg/m³) at 100 m
25.6
25.8
26.1
26.2
26.3
38
37
Latitude (°N)
124
123
122
Longitude (°W)

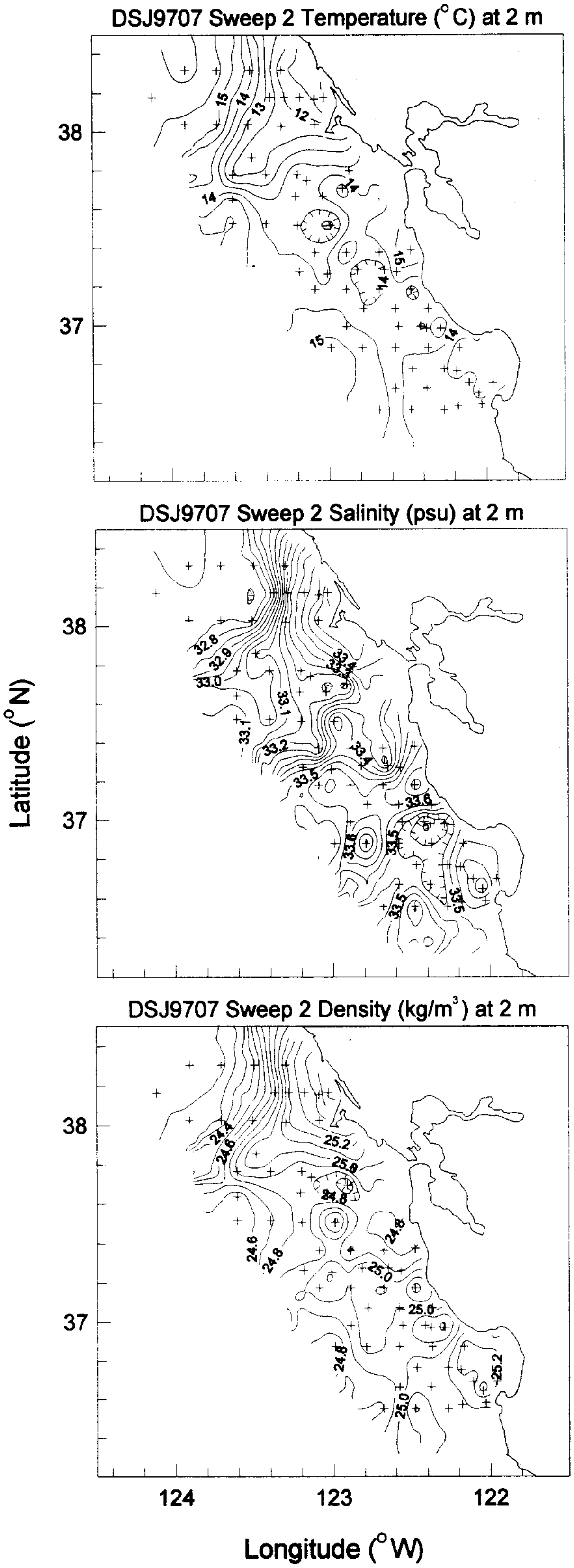

DSJ9707 Sweep 1 Temperature (°C) at 200 m
DSJ9707 Sweep 1 Salinity (psu) at 200 m
DSJ9707 Sweep 1 Density (kg/m³) at 200 m
Latitude (°N)
38
37
124
123
122
Longitude (°W)

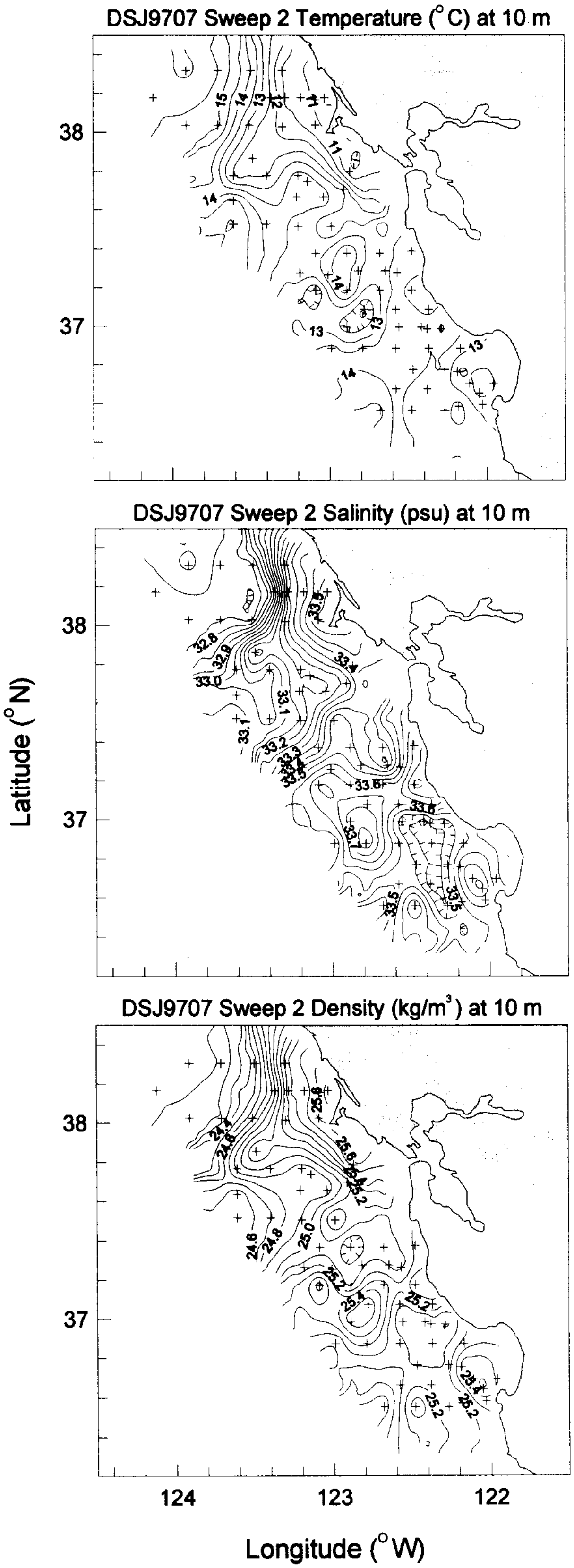

DSJ9707 Sweep 1 Temperature (°C) at 300 m
DSJ9707 Sweep 1 Salinity (psu) at 300 m
DSJ9707 Sweep 1 Density (kg/m³) at 300 m
Latitude (°N)
38
37
124
123
122
Longitude (°W)
7.2
7.6
7.8
7.0
34.12
34.18
26.68
26.72

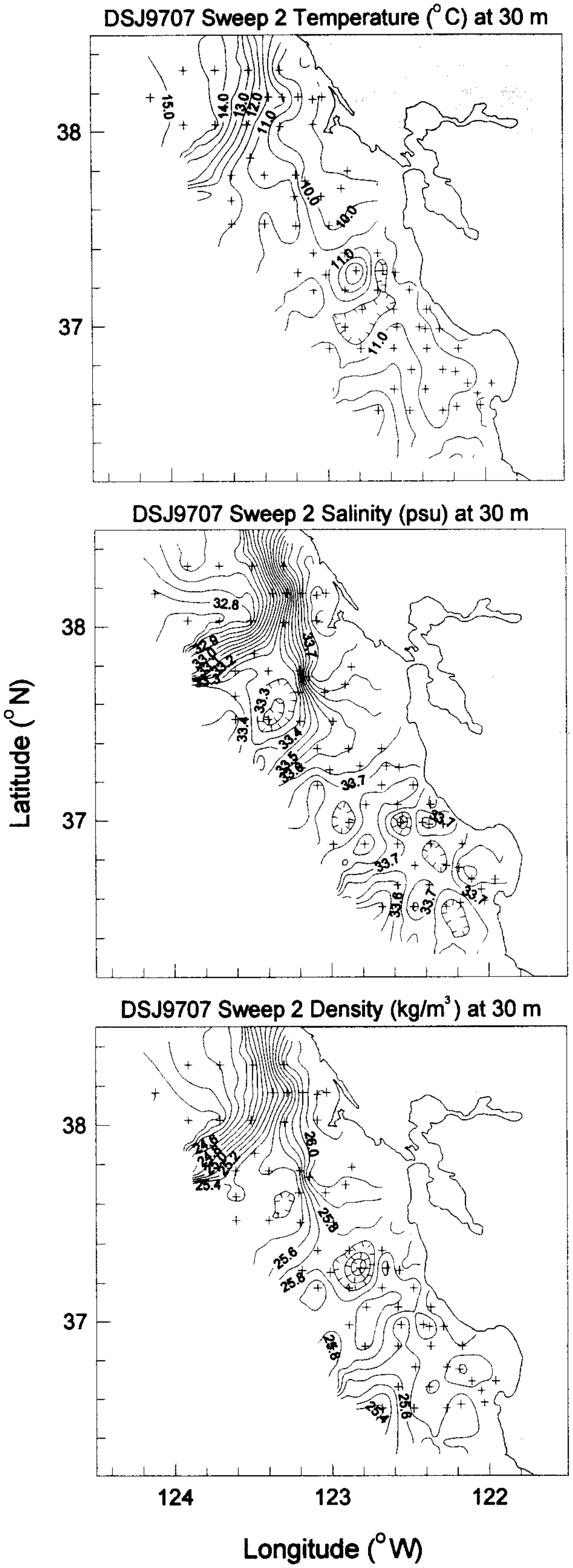

DSJ9707 Sweep 1 Temperature (°C) at 500 m
DSJ9707 Sweep 1 Salinity (psu) at 500 m
DSJ9707 Sweep 1 Density (kg/m³) at 500 m
38
37
Latitude (°N)
124
123
122
Longitude (°W)
6.2
6.0
5.2
5.4
34.22
34.28
34.14
34.18
26.92
26.94
26.96

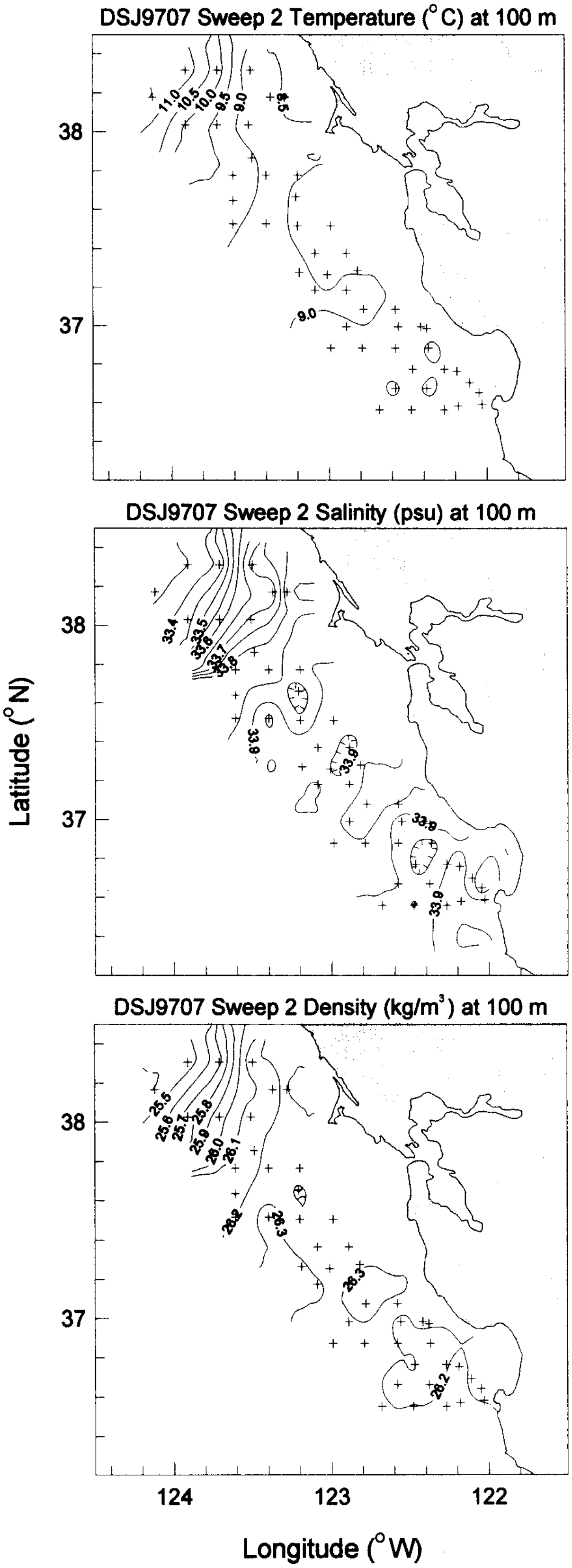
APPENDIX 6.2: HORIZONTAL MAPS OF CTD AND TS FOR DSJ9707, SWEEP 2

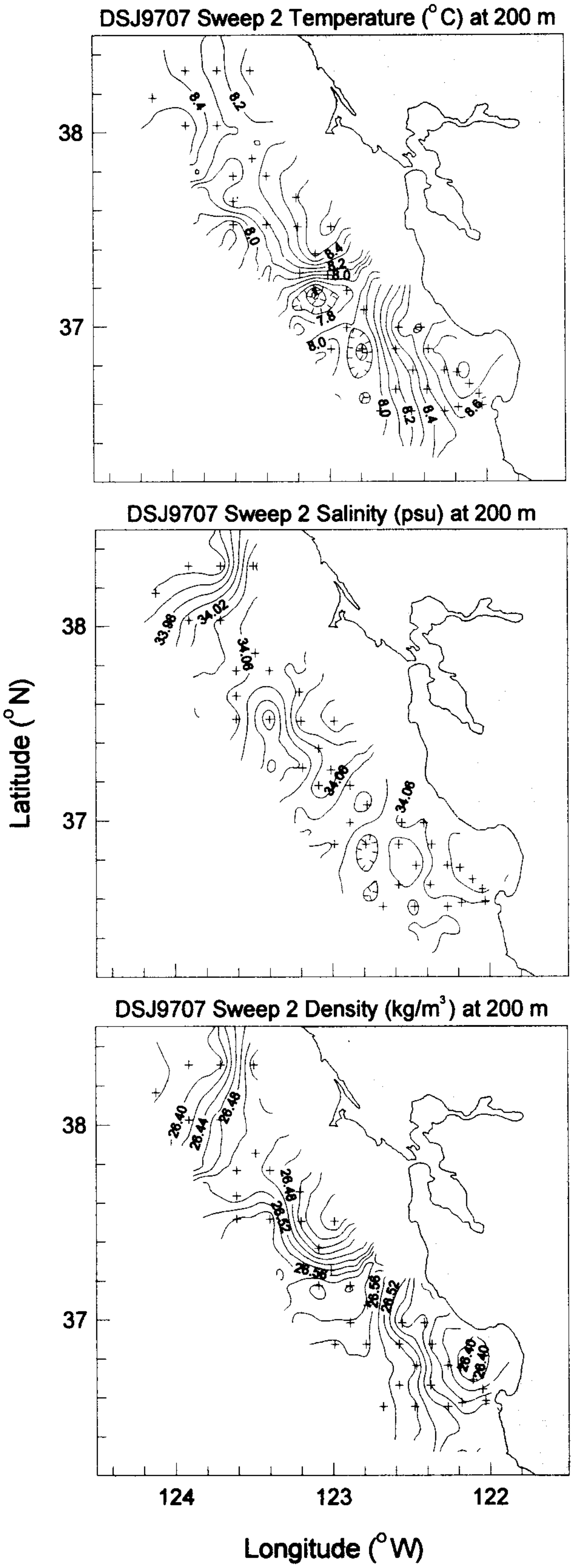

DSJ9707 Sweep 2 TS Temperature (°C)
DSJ9707 Sweep 2 TS Salinity (psu)
Latitude (°N)
Longitude (°W)
38
37
124
123
122
16
15
14
13
12
32.8
32.9
33.0
33.1
33.2
33.3
33.4
33.5

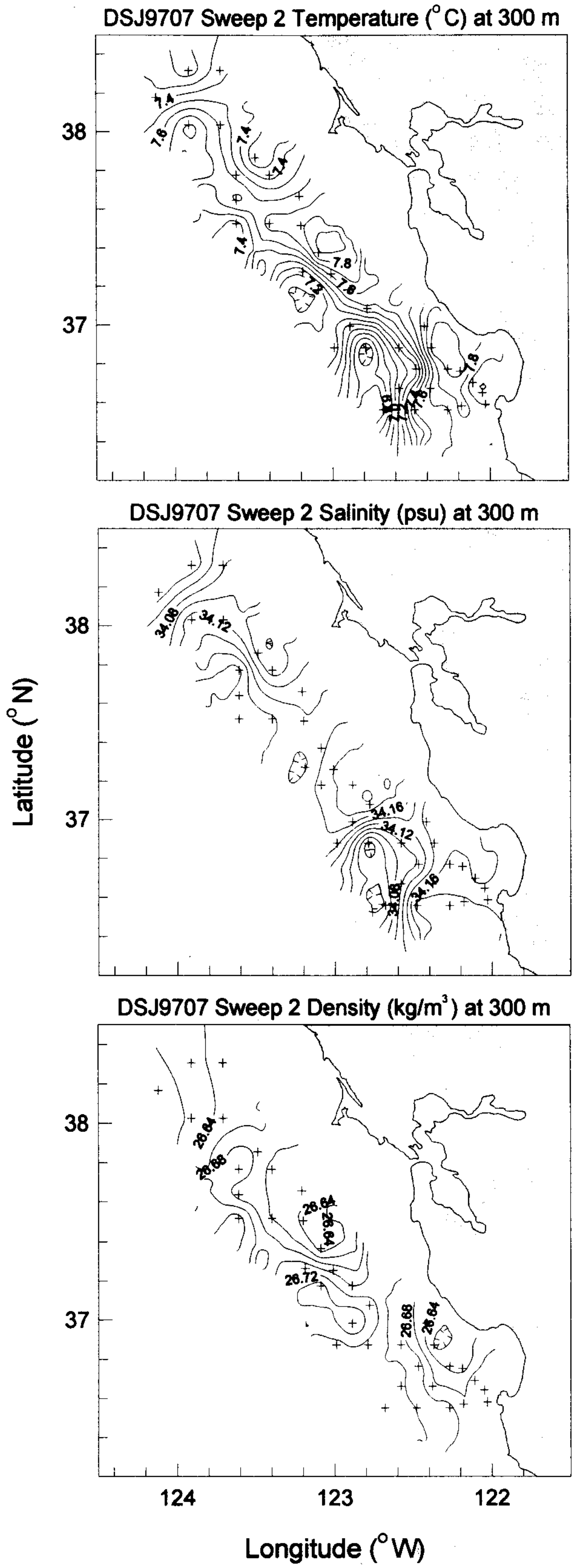

DSJ9707 Sweep 2 Temperature (°C) at 2 m
DSJ9707 Sweep 2 Salinity (psu) at 2 m
DSJ9707 Sweep 2 Density (kg/m³) at 2 m
38
37
Latitude (°N)
124
123
122
Longitude (°W)

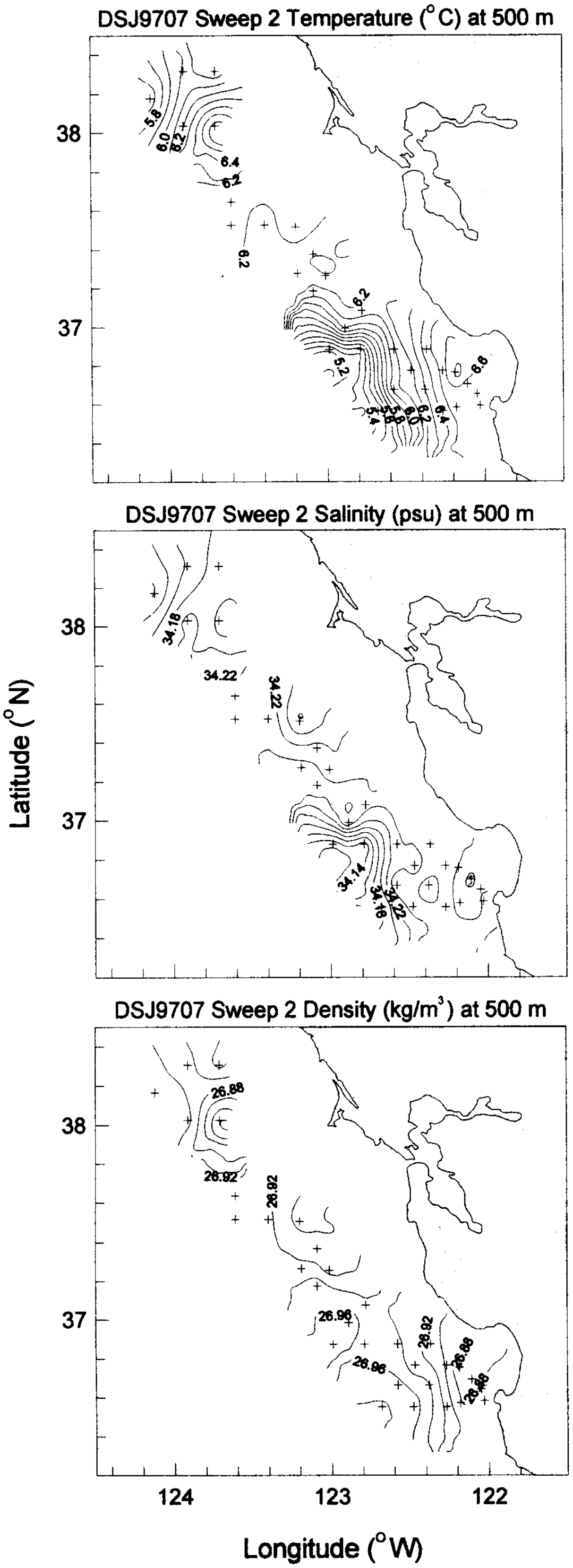

DSJ9707 Sweep 2 Temperature (°C) at 10 m
DSJ9707 Sweep 2 Salinity (psu) at 10 m
DSJ9707 Sweep 2 Density (kg/m³) at 10 m
38
37
Latitude (°N)
124
123
122
Longitude (°W)


DSJ9707 Sweep 2 Temperature (°C) at 30 m
DSJ9707 Sweep 2 Salinity (psu) at 30 m
DSJ9707 Sweep 2 Density (kg/m³) at 30 m
Latitude (°N)
38
37
124
123
122
Longitude (°W)

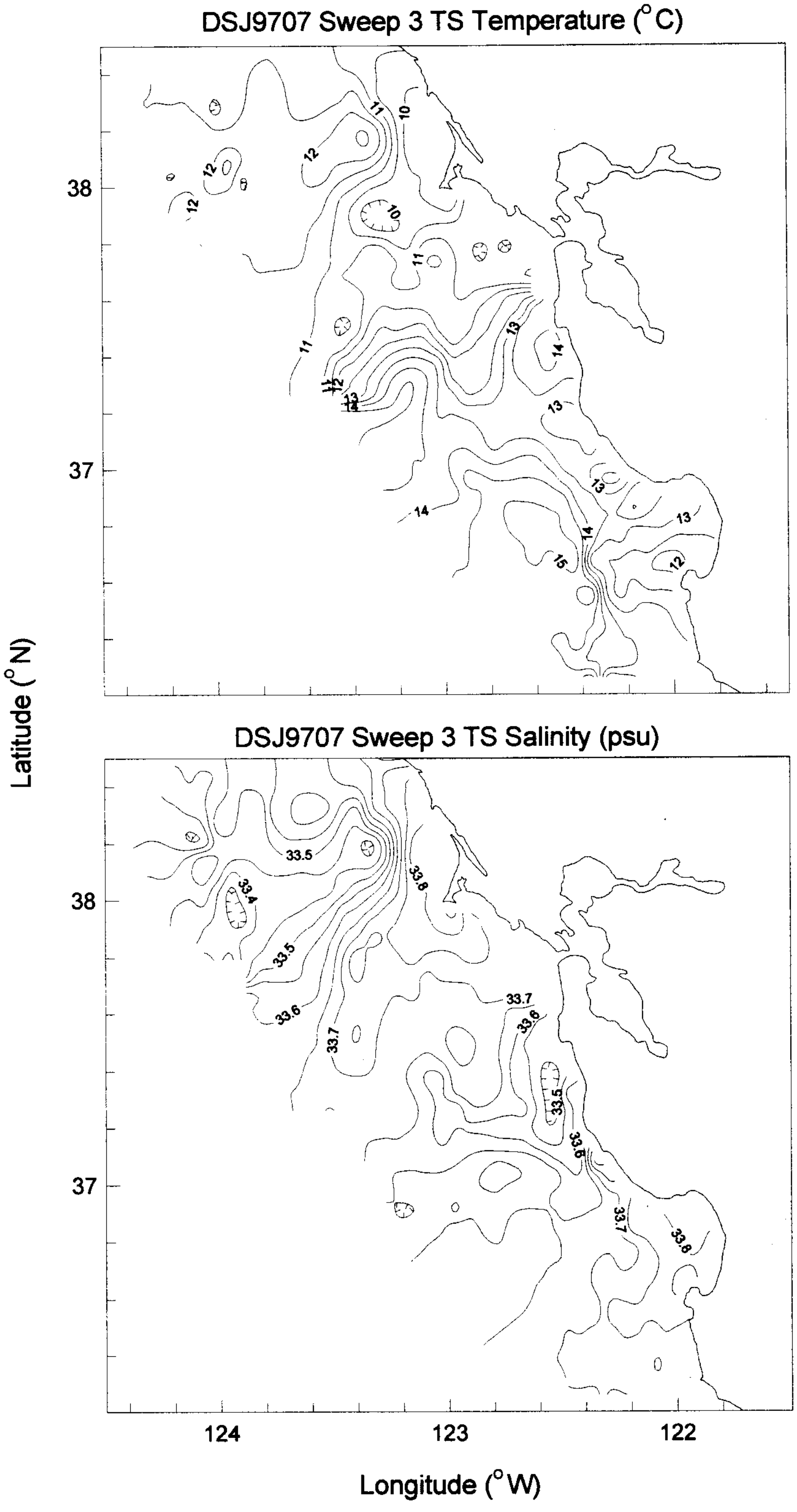

DSJ9707 Sweep 2 Temperature (°C) at 100 m
DSJ9707 Sweep 2 Salinity (psu) at 100 m
DSJ9707 Sweep 2 Density (kg/m³) at 100 m
Latitude (°N)
Longitude (°W)
38
37
124
123
122

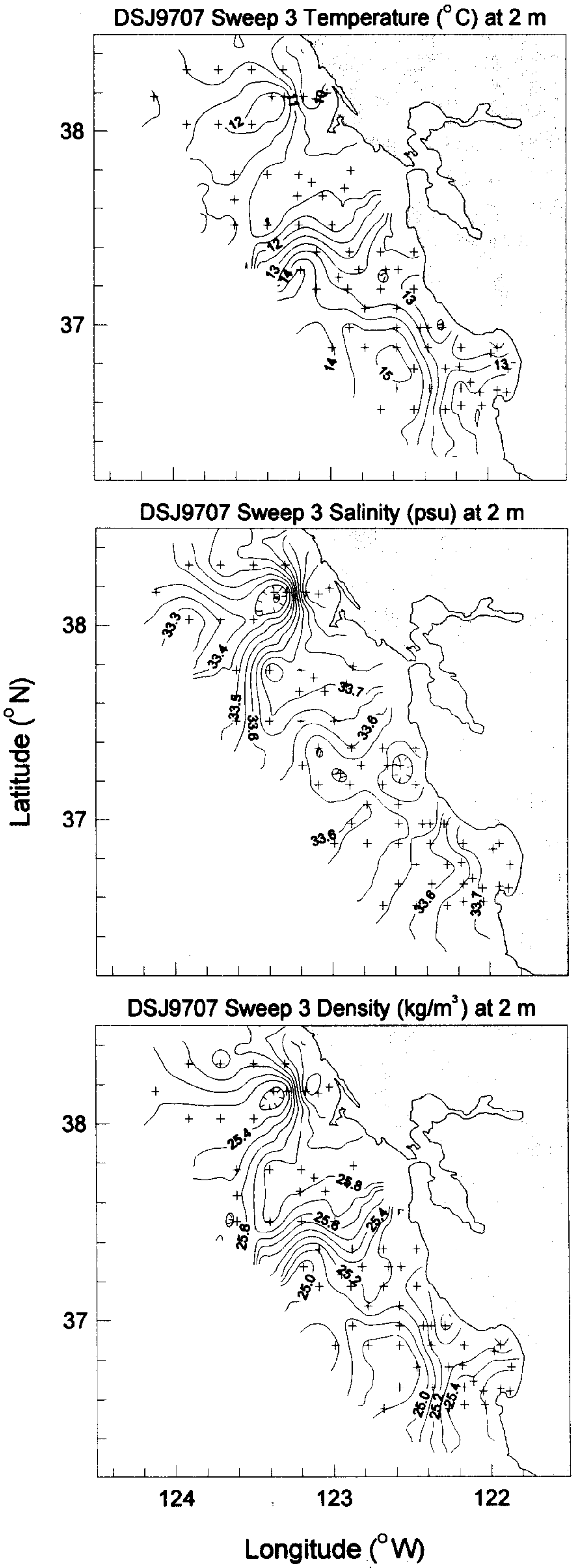

DSJ9707 Sweep 2 Temperature (°C) at 200 m
DSJ9707 Sweep 2 Salinity (psu) at 200 m
DSJ9707 Sweep 2 Density (kg/m³) at 200 m
Latitude (°N)
38
37
124
123
122
Longitude (°W)

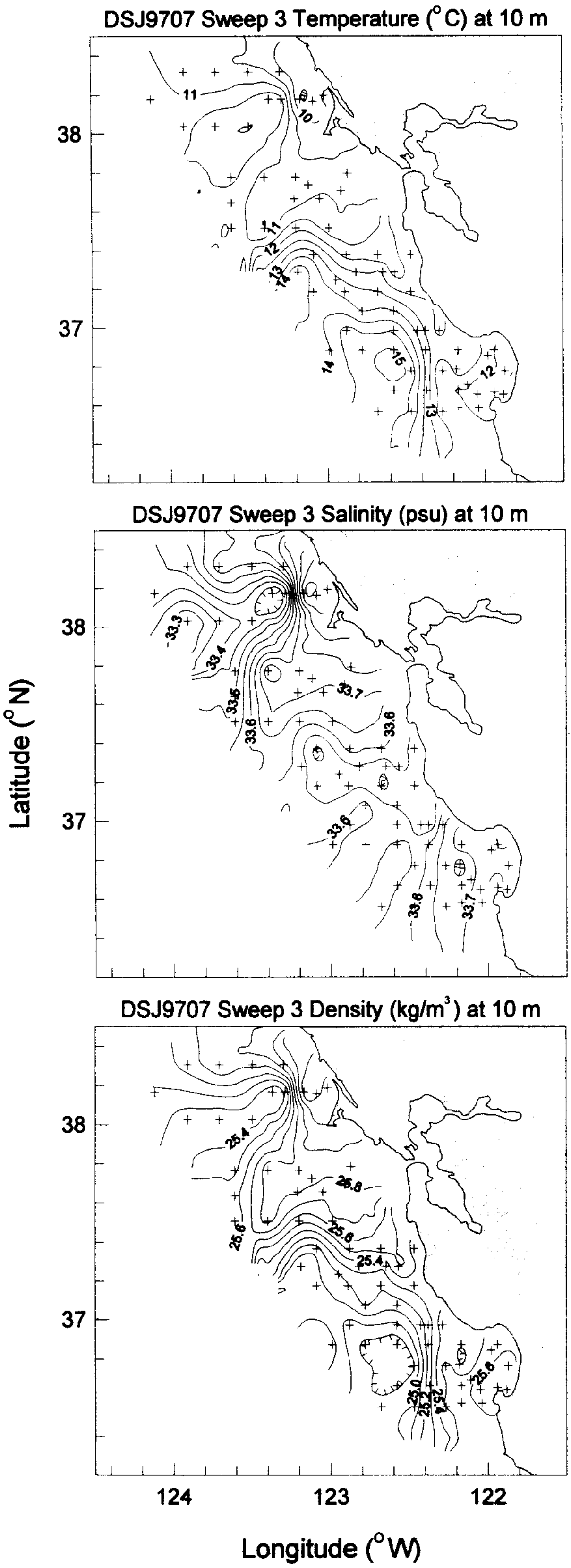

DSJ9707 Sweep 2 Temperature (°C) at 300 m
DSJ9707 Sweep 2 Salinity (psu) at 300 m
DSJ9707 Sweep 2 Density (kg/m³) at 300 m
Latitude (°N)
Longitude (°W)
38
37
124
123
122

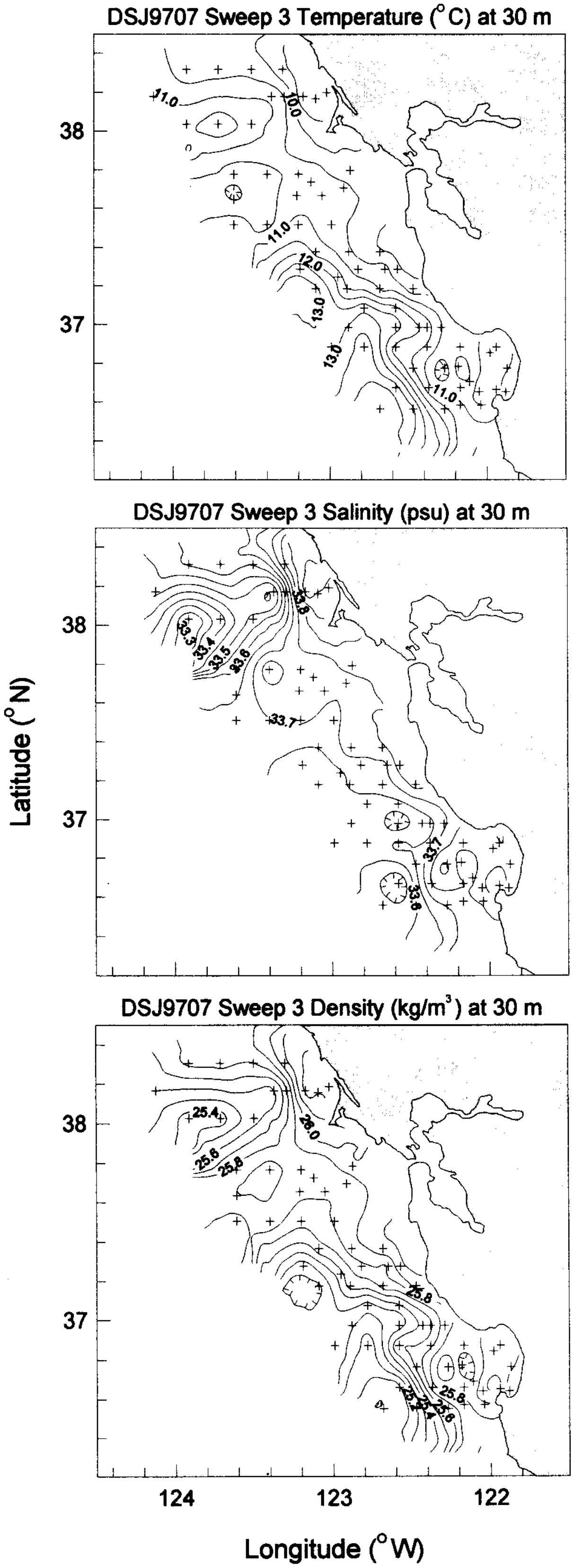

DSJ9707 Sweep 2 Temperature (°C) at 500 m
DSJ9707 Sweep 2 Salinity (psu) at 500 m
DSJ9707 Sweep 2 Density (kg/m³) at 500 m
Latitude (°N)
38
37
124
123
122
Longitude (°W)

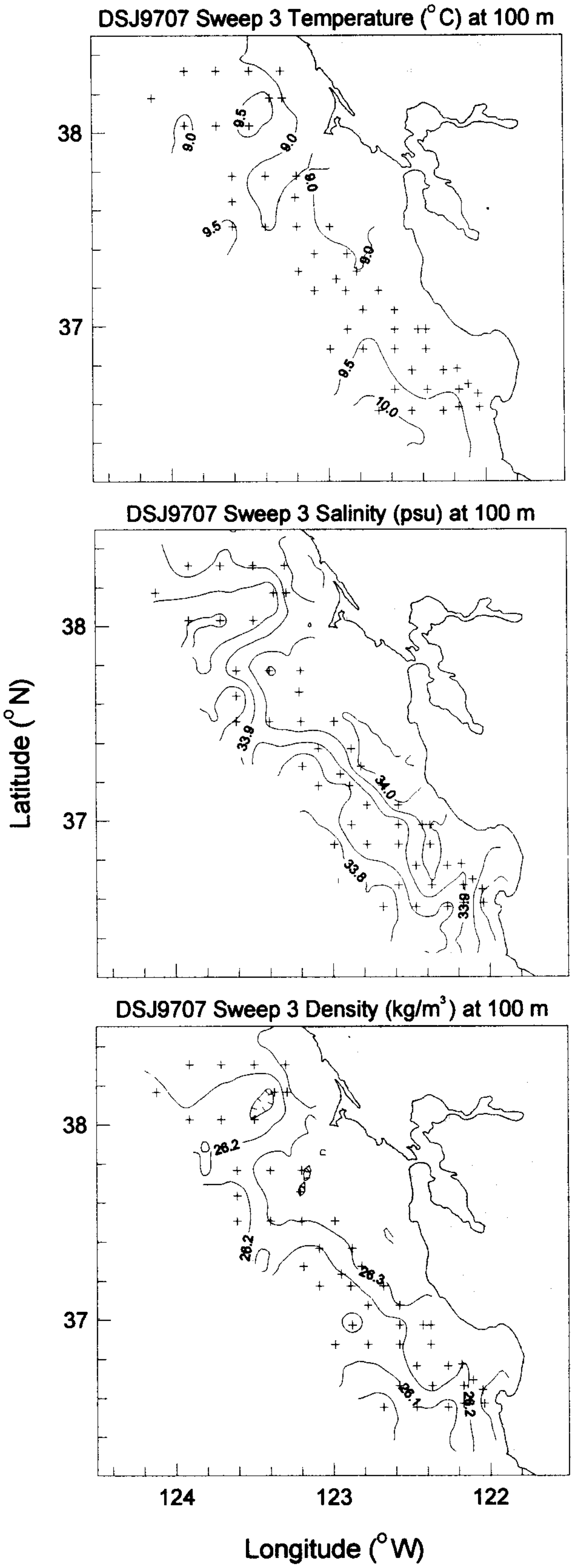
APPENDIX 6.3: HORIZONTAL MAPS OF CTD AND TS FOR DSJ9707, SWEEP 3


DSJ9707 Sweep 3 TS Temperature (°C)
38
37
12
11
10
13
14
15
Latitude (°N)
DSJ9707 Sweep 3 TS Salinity (psu)
38
37
33.4
33.5
33.6
33.7
33.8
124
123
122
Longitude (°W)

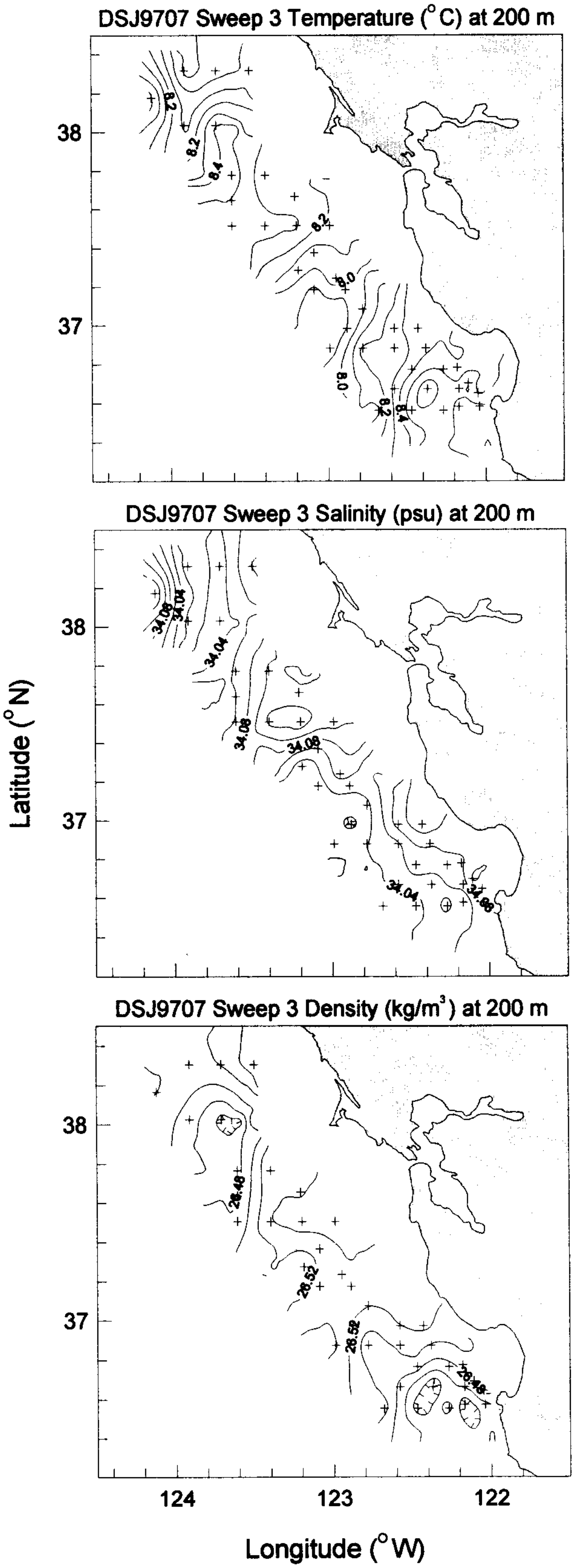

DSJ9707 Sweep 3 Temperature (°C) at 2 m
DSJ9707 Sweep 3 Salinity (psu) at 2 m
DSJ9707 Sweep 3 Density (kg/m³) at 2 m
Latitude (°N)
38
37
Longitude (°W)
124
123
122

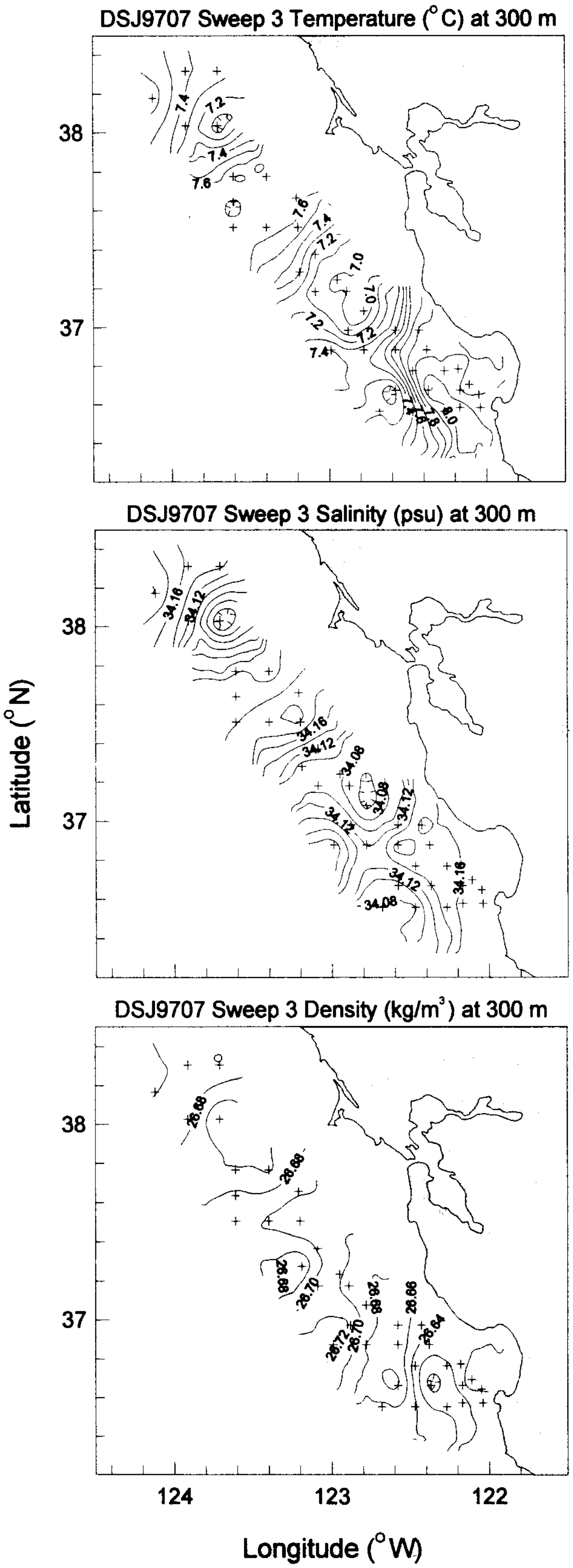

DSJ9707 Sweep 3 Temperature (°C) at 10 m
DSJ9707 Sweep 3 Salinity (psu) at 10 m
DSJ9707 Sweep 3 Density (kg/m³) at 10 m
Latitude (°N)
38
37
124
123
122
Longitude (°W)

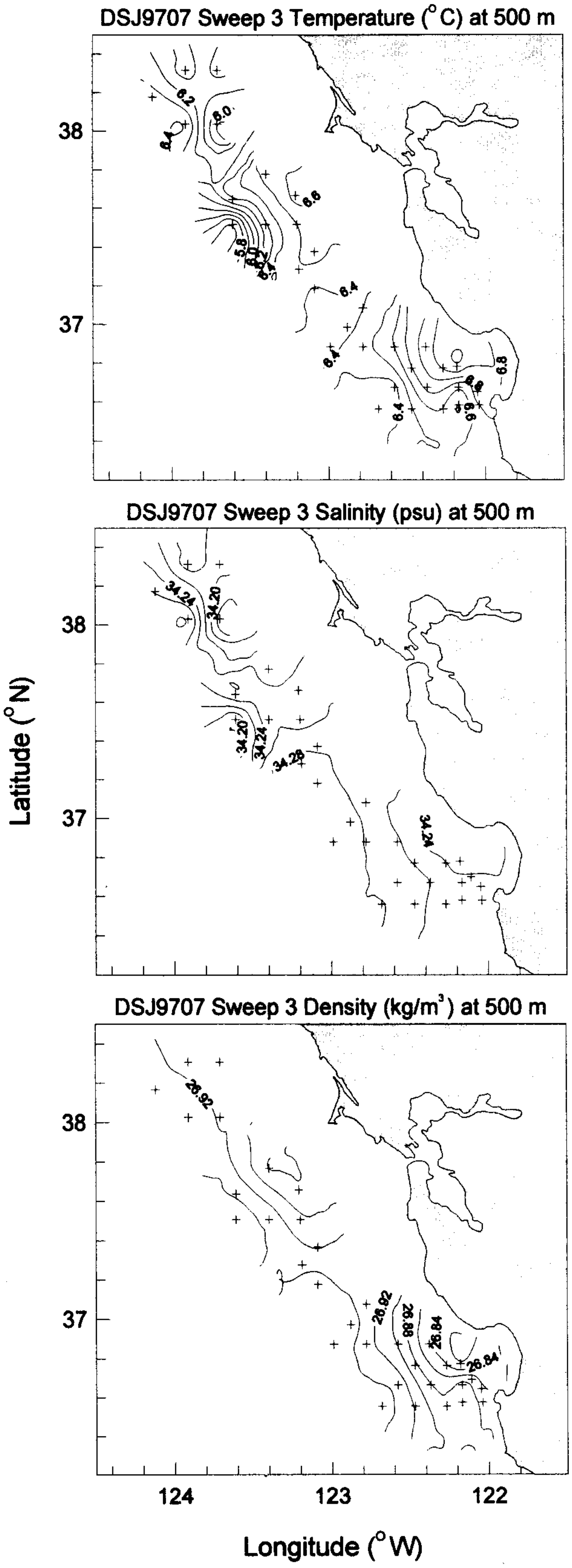

DSJ9707 Sweep 3 Temperature (°C) at 30 m
DSJ9707 Sweep 3 Salinity (psu) at 30 m
DSJ9707 Sweep 3 Density (kg/m³) at 30 m
38
37
Latitude (°N)
124
123
122
Longitude (°W)
11.0
10.0
12.0
13.0
33.4
33.5
33.6
33.7
33.8
25.4
25.6
25.8
26.0



DSJ9707 Sweep 3 Temperature (°C) at 100 m
9.5
9.0
9.0
9.0
9.5
9.0
9.5
10.0
DSJ9707 Sweep 3 Salinity (psu) at 100 m
33.9
34.0
33.8
33.9
DSJ9707 Sweep 3 Density (kg/m³) at 100 m
26.2
26.2
26.3
26.1
26.2
38
37
Latitude (°N)
124
123
122
Longitude (°W)

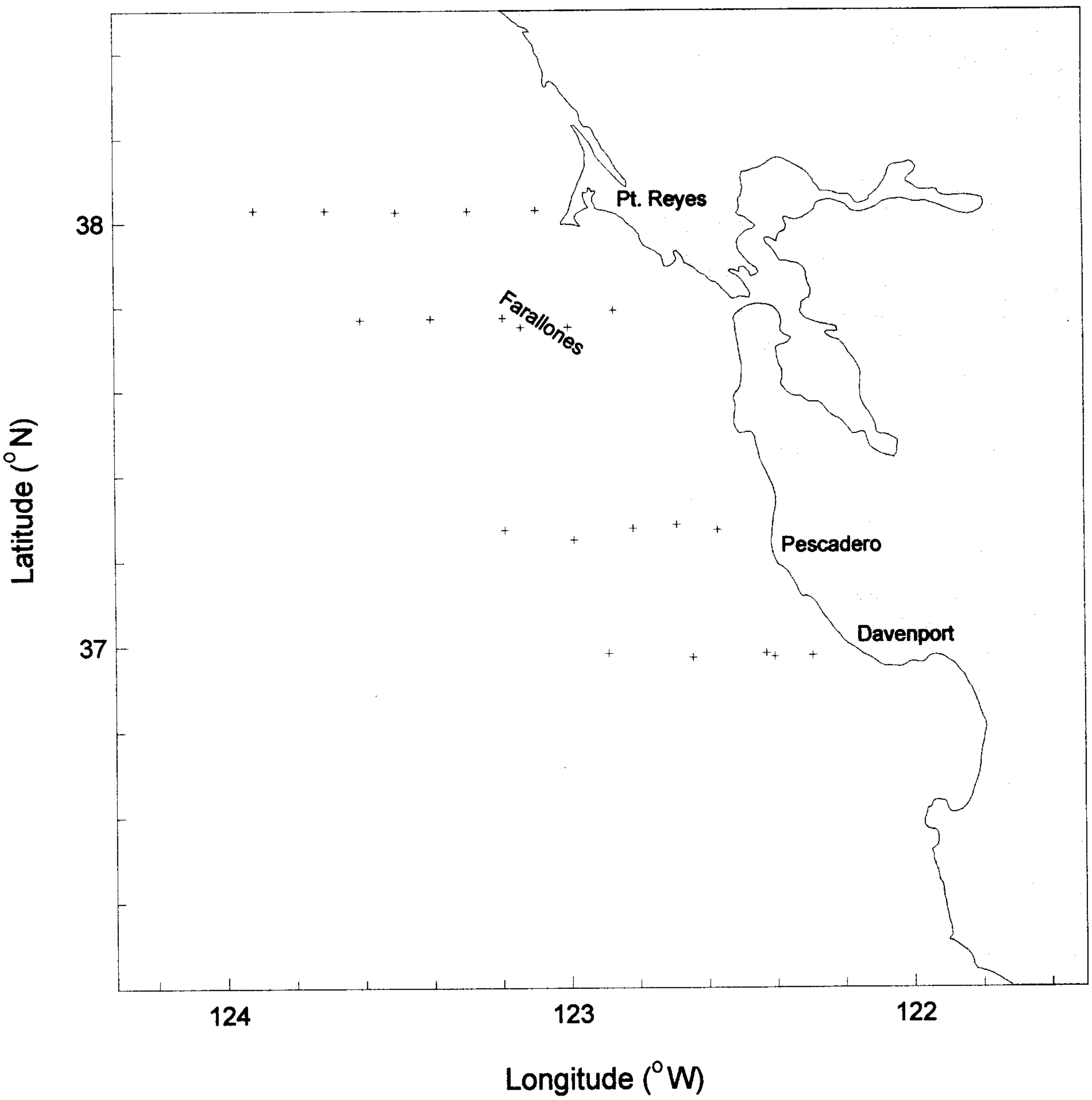

DSJ9707 Sweep 3 Temperature (°C) at 200 m
8.2
8.4
8.0
DSJ9707 Sweep 3 Salinity (psu) at 200 m
34.08
34.04
DSJ9707 Sweep 3 Density (kg/m³) at 200 m
26.48
26.52
Latitude (°N)
38
37
124
123
122
Longitude (°W)

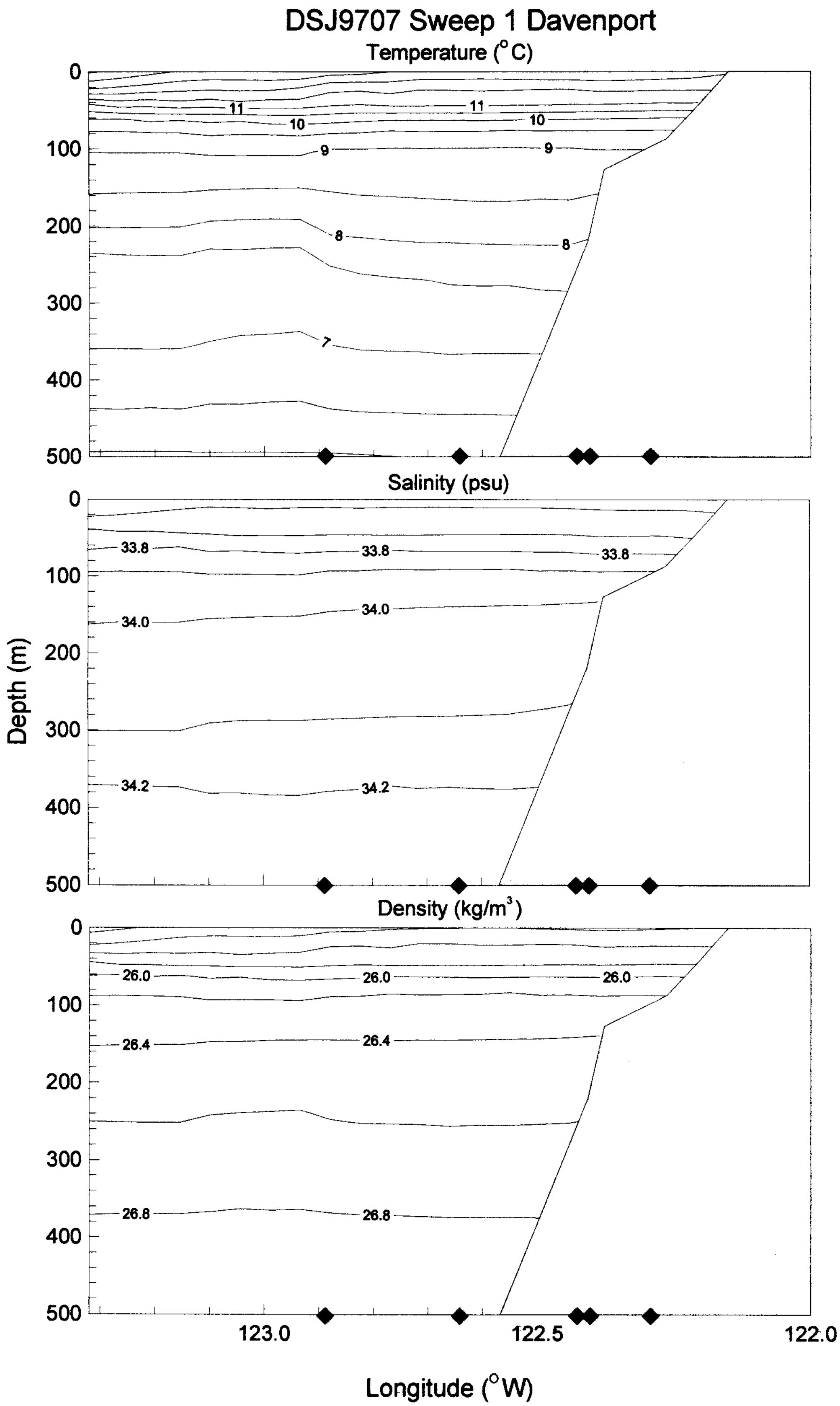

DSJ9707 Sweep 3 Temperature (°C) at 300 m
DSJ9707 Sweep 3 Salinity (psu) at 300 m
DSJ9707 Sweep 3 Density (kg/m³) at 300 m
Latitude (°N)
38
37
124
123
122
Longitude (°W)


DSJ9707 Sweep 3 Temperature (°C) at 500 m
DSJ9707 Sweep 3 Salinity (psu) at 500 m
DSJ9707 Sweep 3 Density (kg/m³) at 500 m
Latitude (°N)
38
37
124
123
122
Longitude (°W)

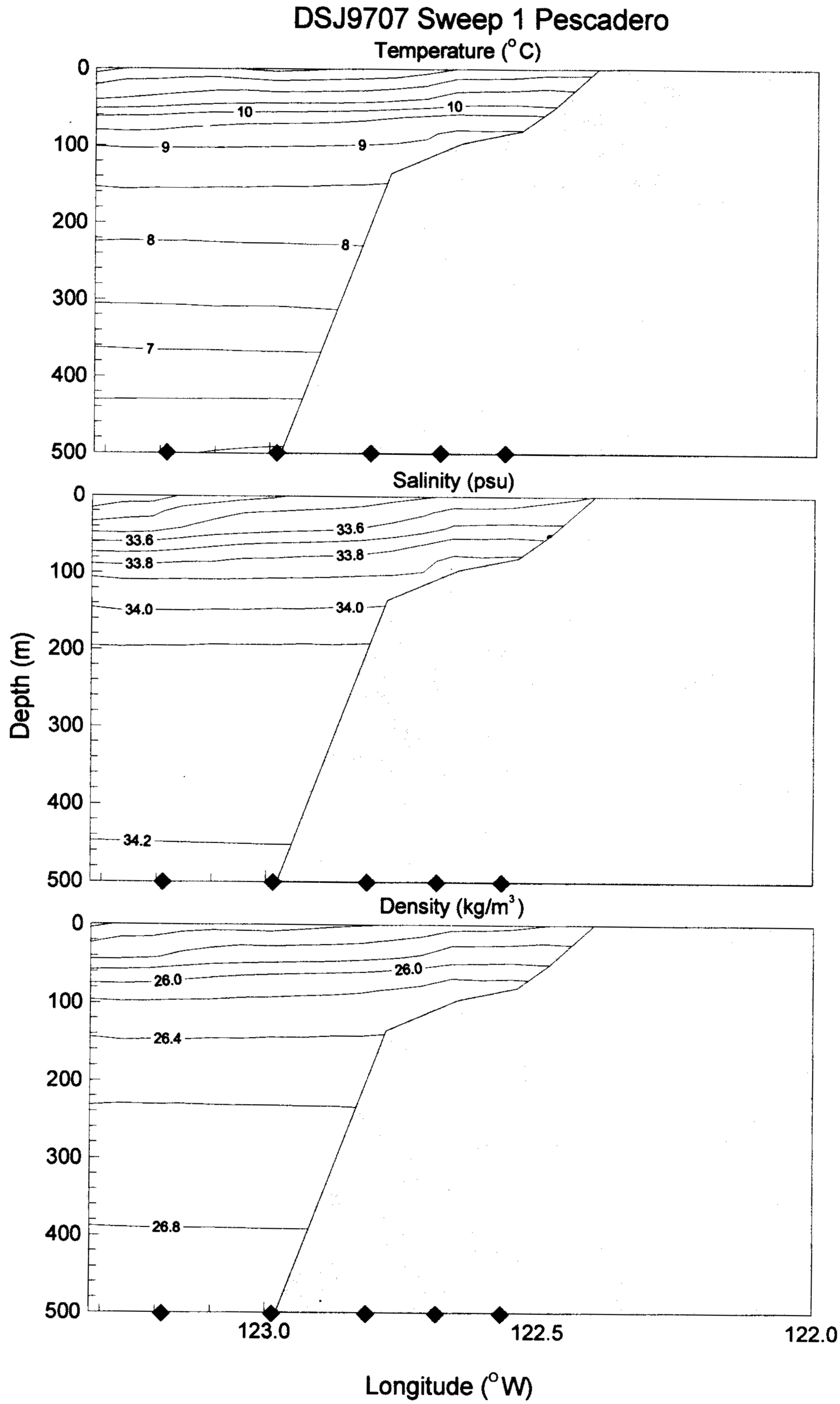
APPENDIX 7: VERTICAL SECTIONS FOR DSJ9707

DSJ9707 Sweep 1 Vertical Transect Stations

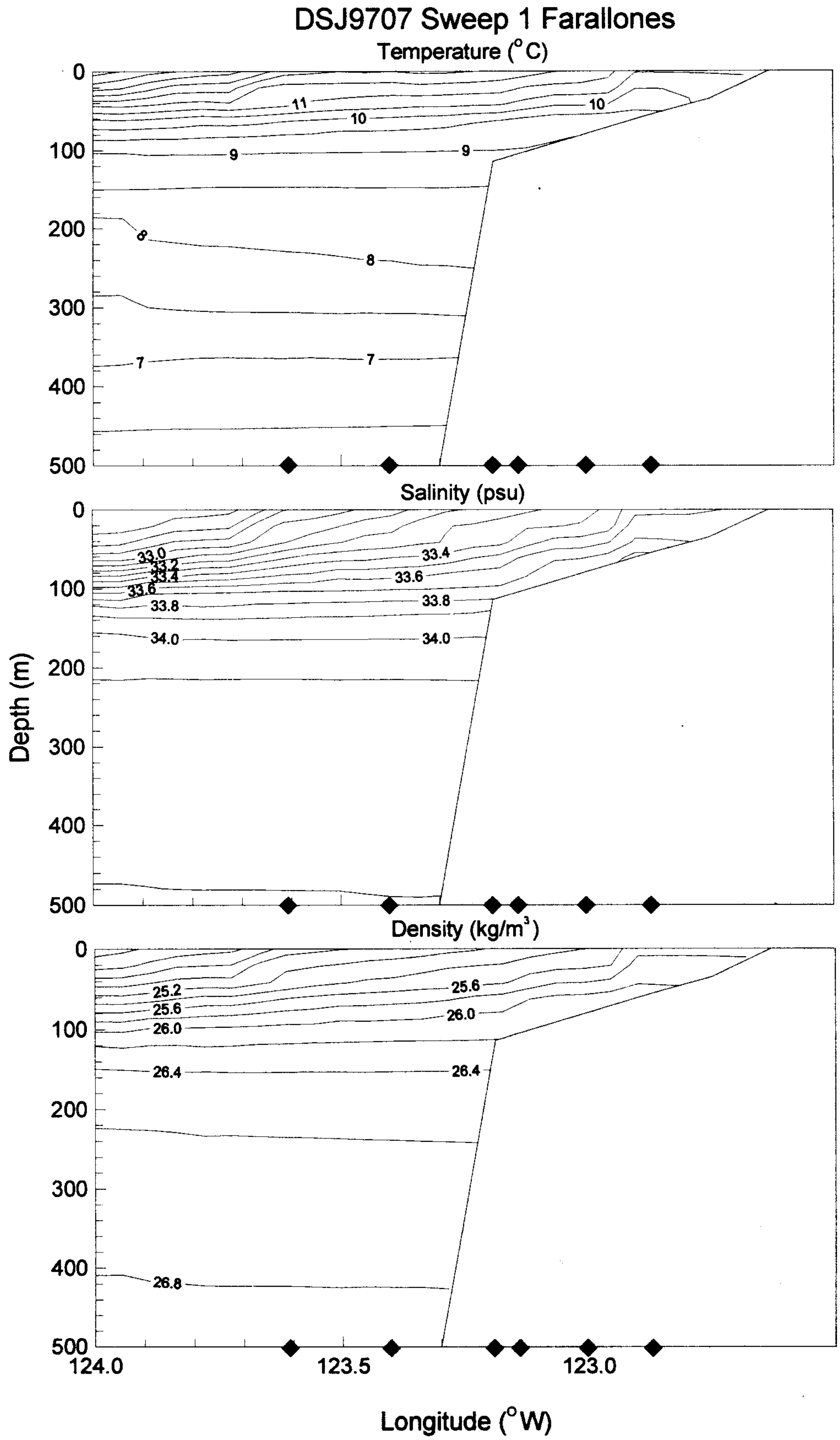




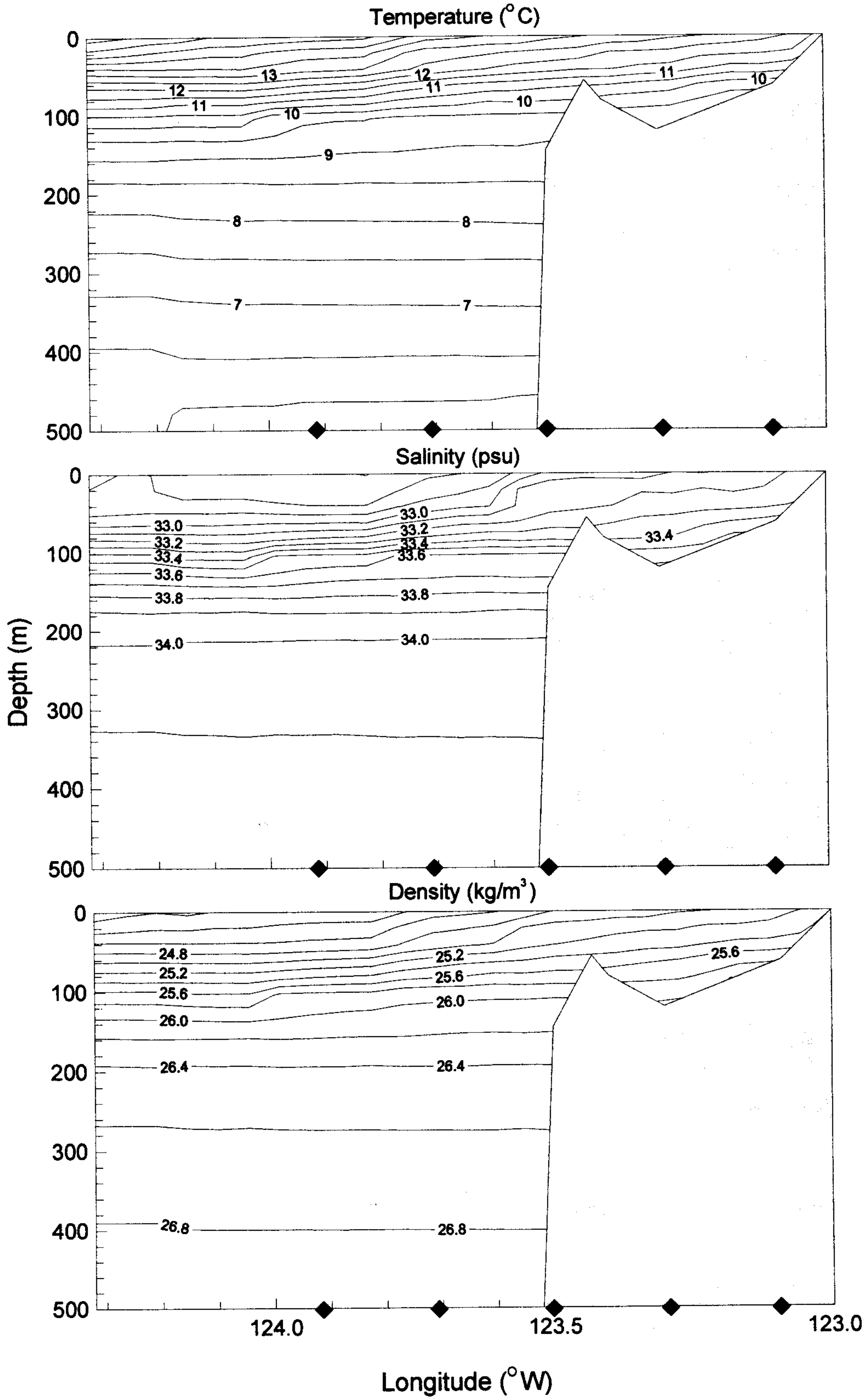
DSJ9707 Sweep 1 Davenport
Temperature (°C)
Salinity (psu)
Density (kg/m³)
Depth (m)
Longitude (°W)
0
100
200
300
400
500
123.0
122.5
122.0
11
10
9
8
7
33.8
34.0
34.2
26.0
26.4
26.8



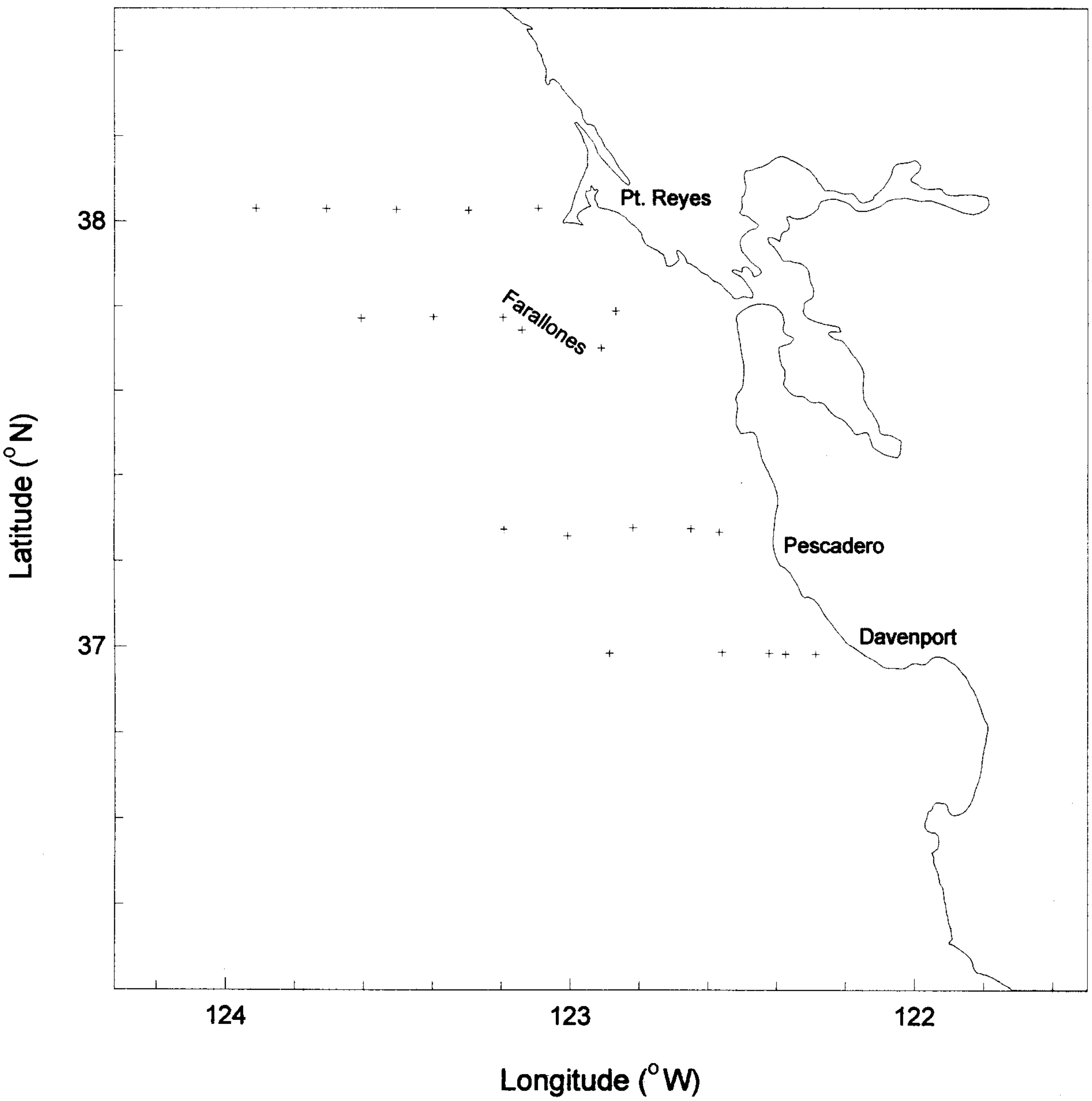
DSJ9707 Sweep 1 Pescadero
Temperature (°C)
0
100
200
300
400
500
10
10
9
9
8
8
7
Salinity (psu)
0
100
200
300
400
500
33.6
33.6
33.8
33.8
34.0
34.0
34.2
Depth (m)
Density (kg/m³)
0
100
200
300
400
500
26.0
26.0
26.4
26.8
123.0
122.5
122.0
Longitude (°W)

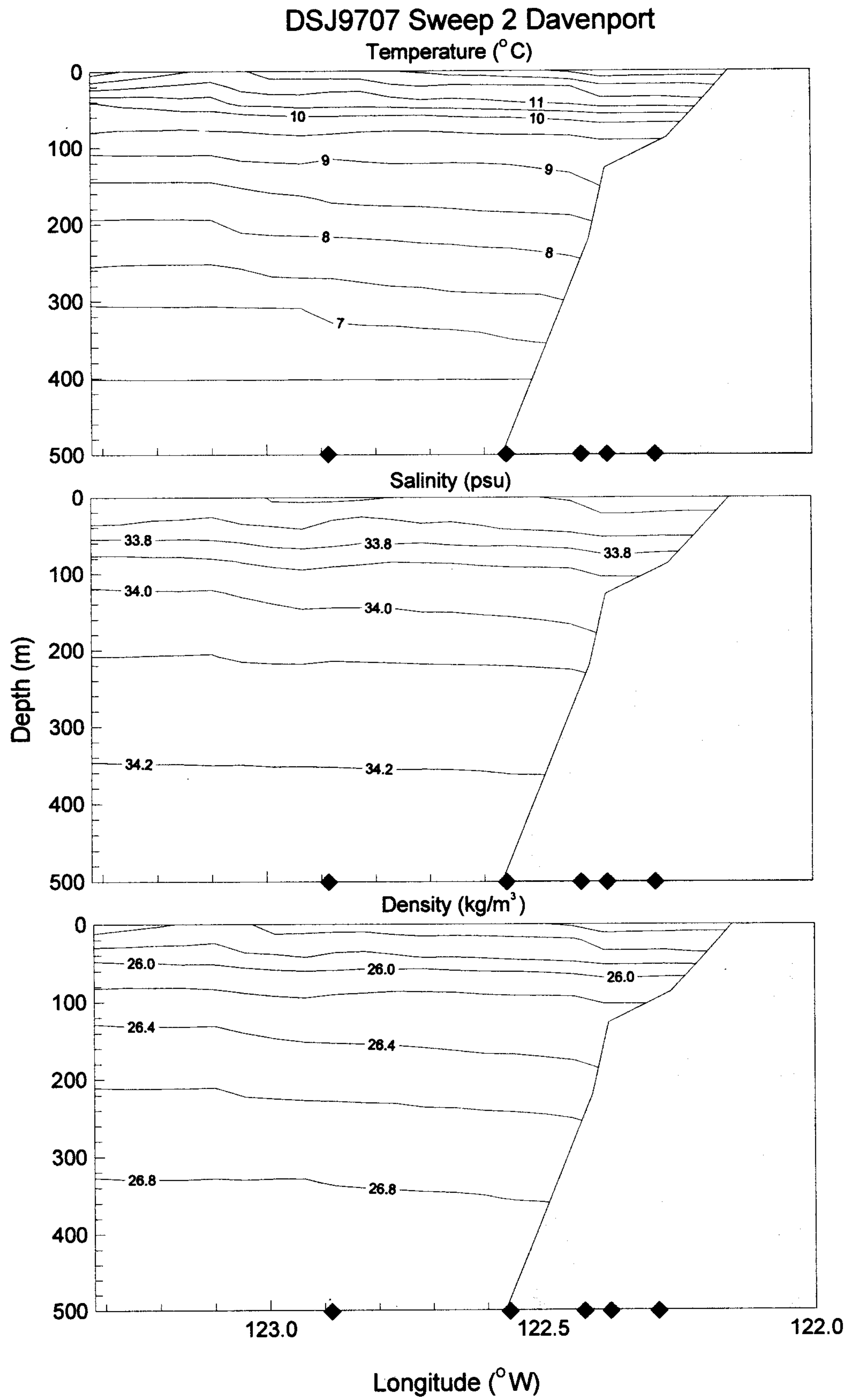

DSJ9707 Sweep 1 Farallones
Temperature (°C)
11
10
10
9
9
8
8
7
7
Salinity (psu)
33.0
33.2
33.4
33.6
33.8
34.0
33.4
33.6
33.8
34.0
Density (kg/m³)
25.2
25.6
26.0
25.6
26.0
26.4
26.4
26.8
Depth (m)
0
100
200
300
400
500
124.0
123.5
123.0
Longitude (°W)

DSJ9707 Sweep 1 Point Reyes

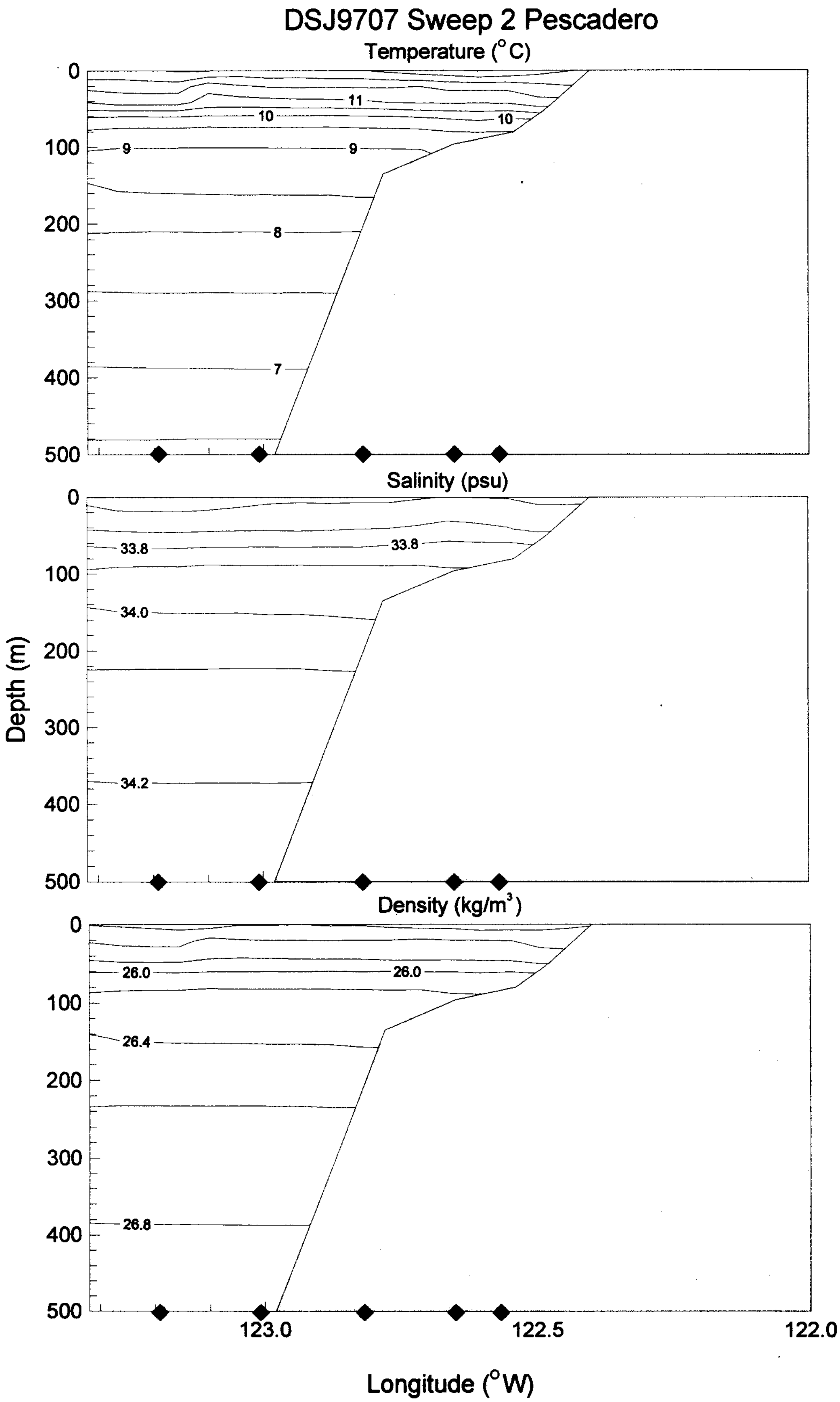


DSJ9707 Sweep 2 Vertical Transect Stations

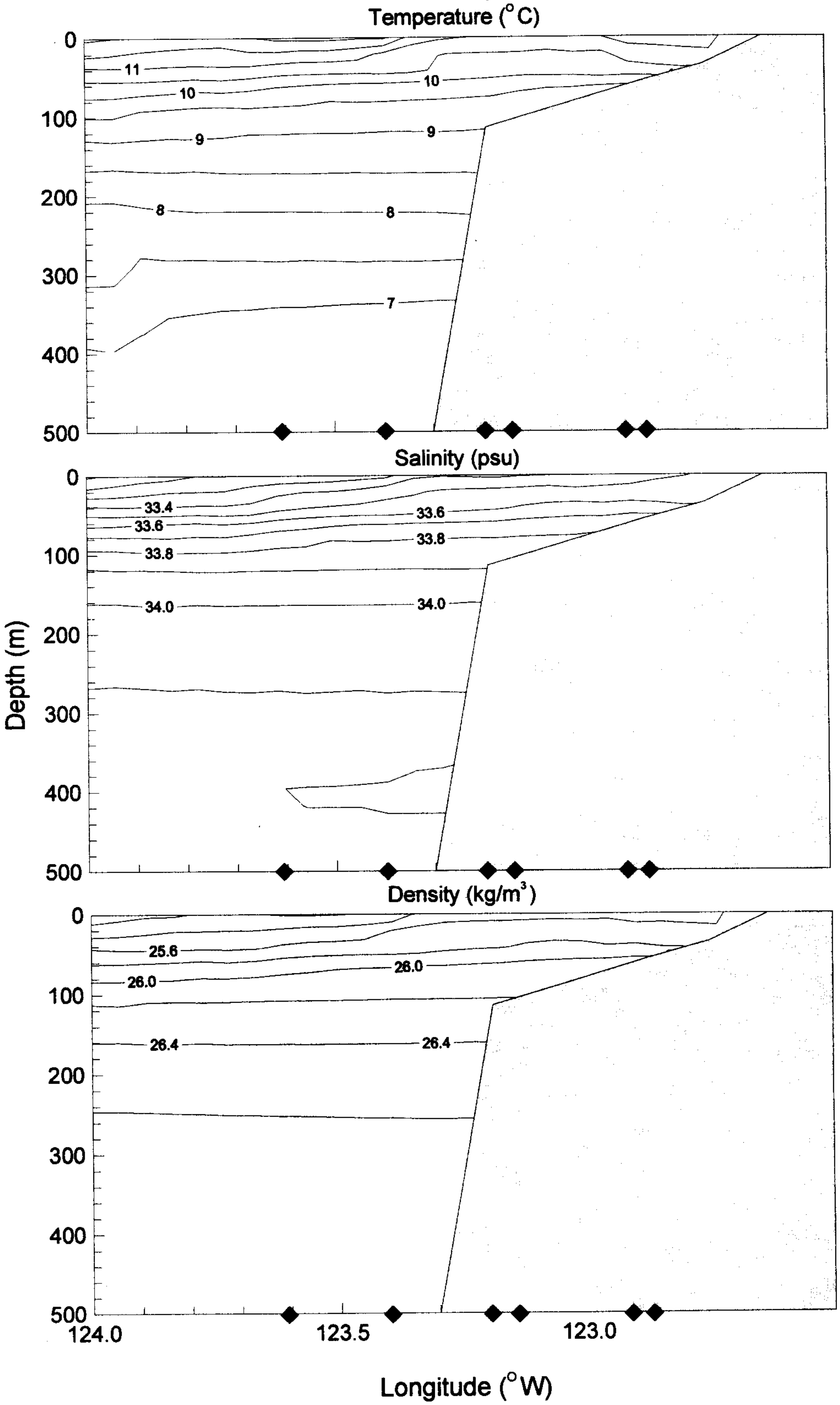


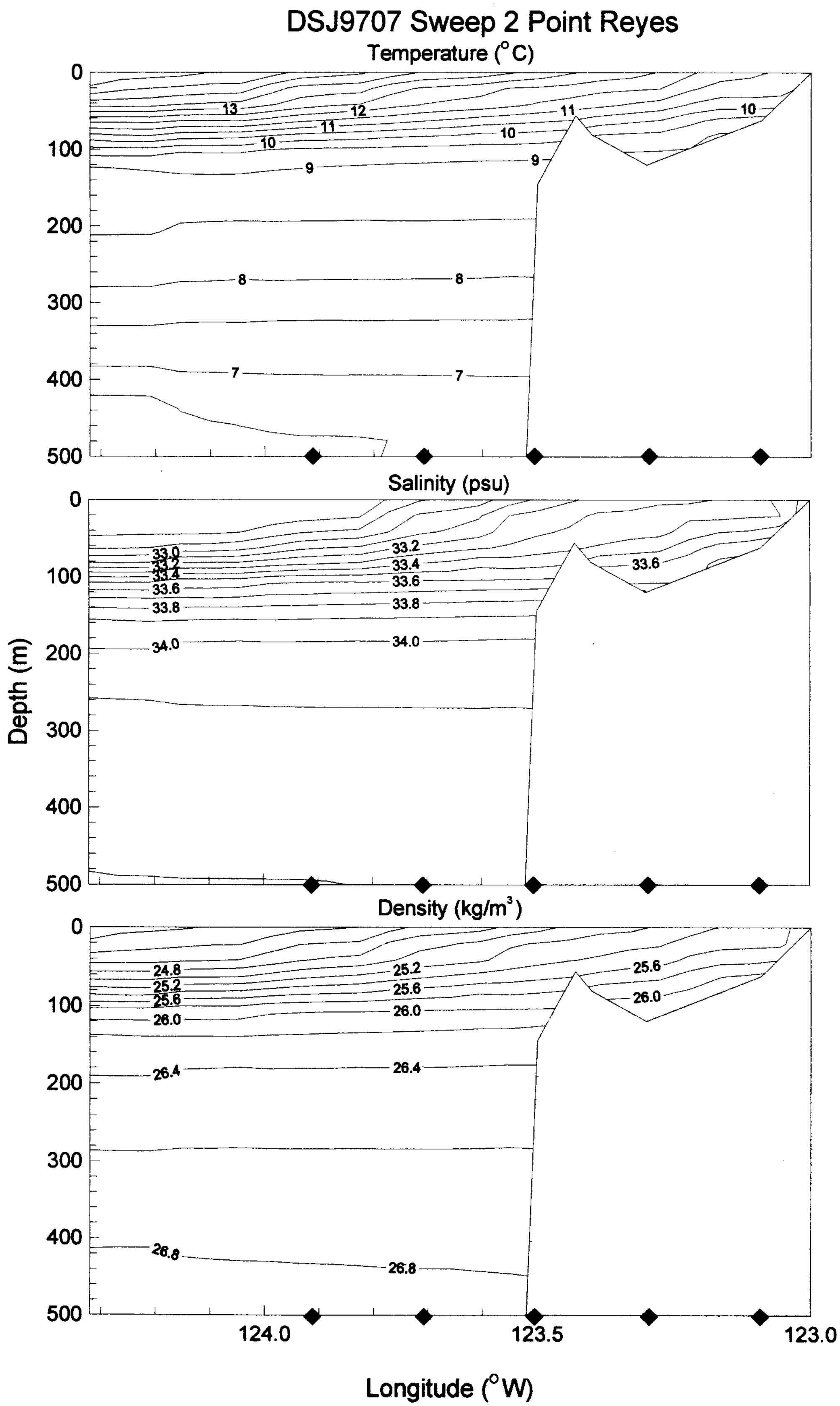


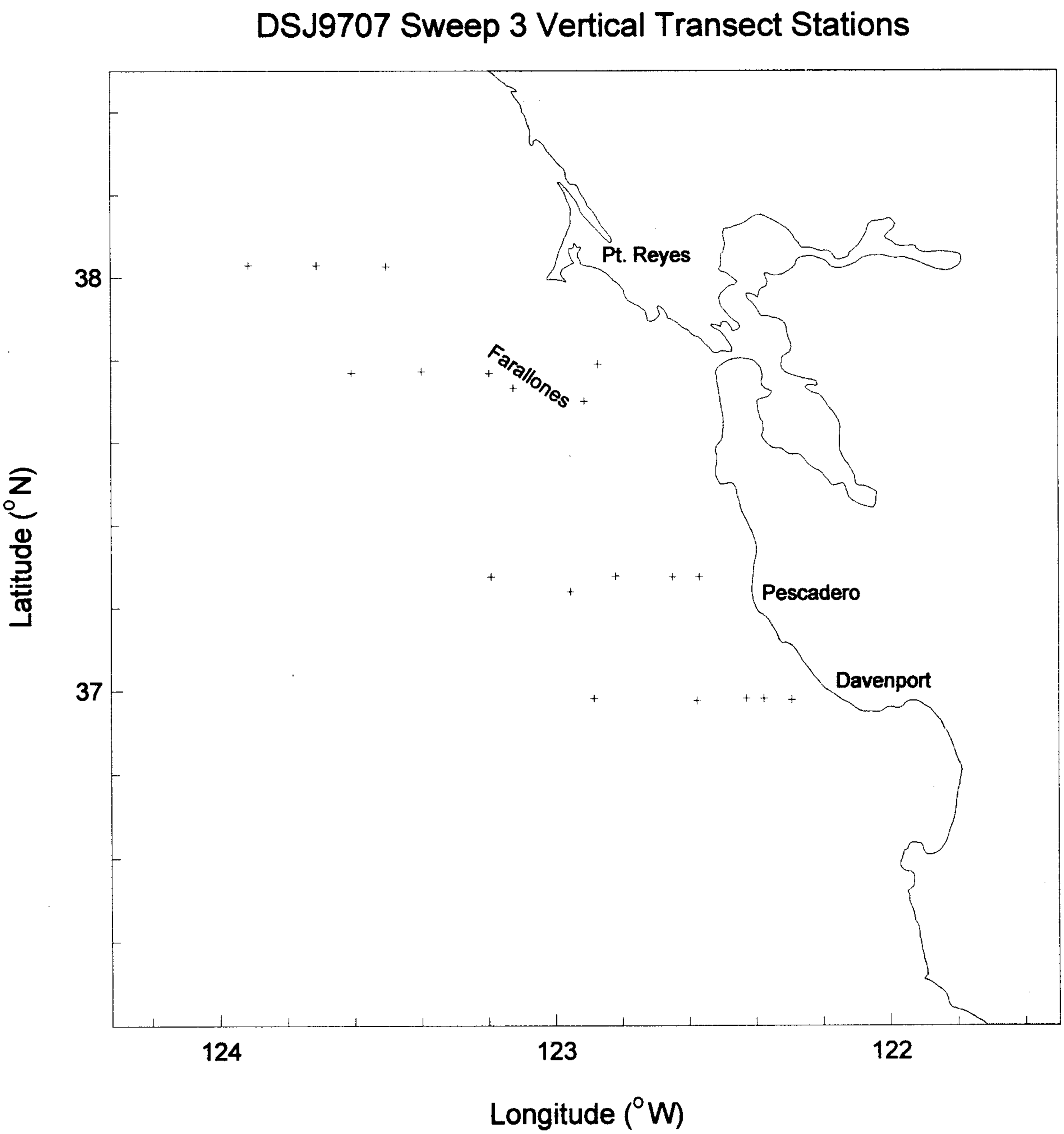
DSJ9707 Sweep 2 Davenport
Temperature (°C)
Salinity (psu)
Density (kg/m³)
Depth (m)
Longitude (°W)
0
100
200
300
400
500
11
10
9
8
7
33.8
34.0
34.2
26.0
26.4
26.8
123.0
122.5
122.0

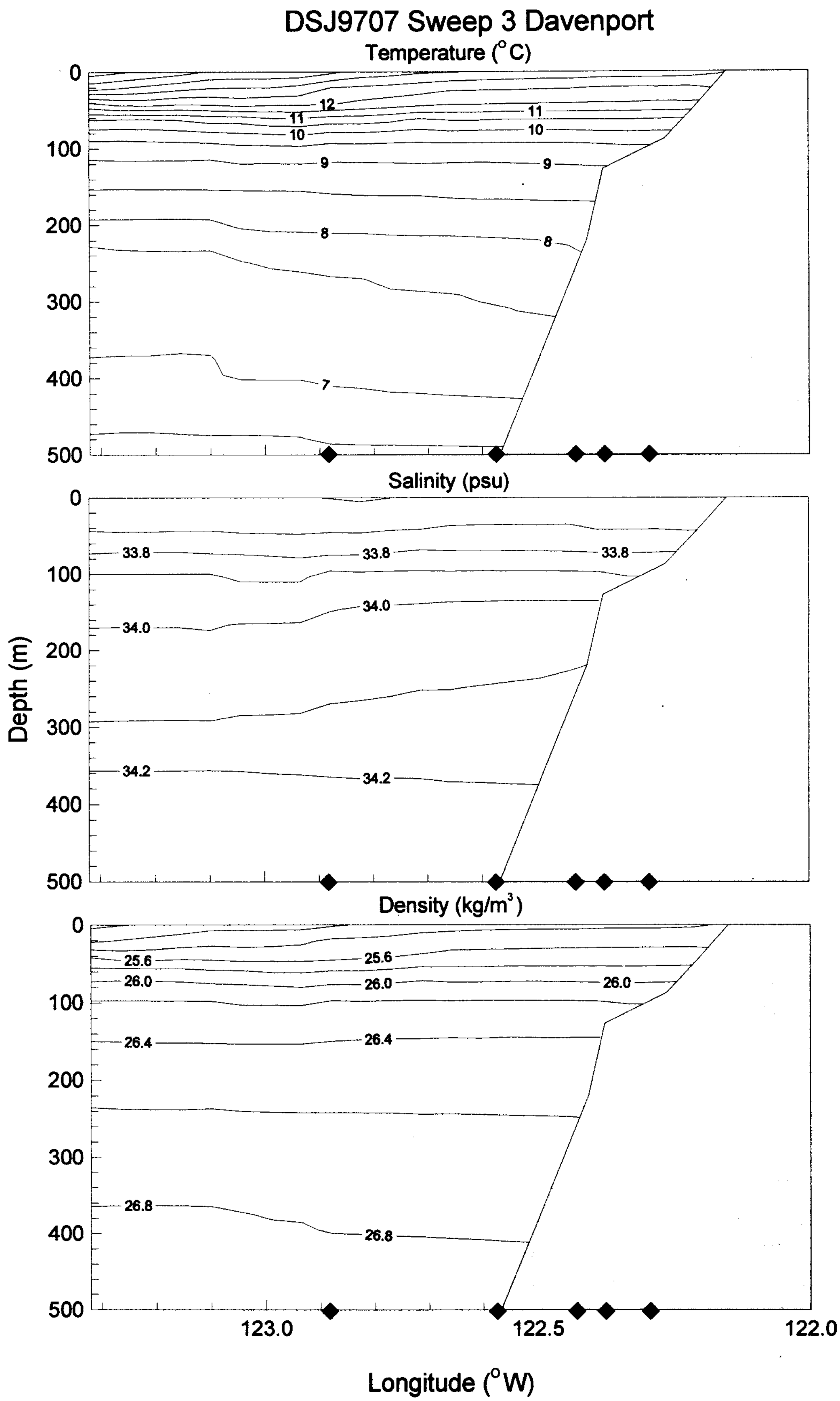

DSJ9707 Sweep 2 Pescadero
Temperature (°C)
Salinity (psu)
Density (kg/m³)
Depth (m)
Longitude (°W)
0
100
200
300
400
500
123.0
122.5
122.0
11
10
9
8
7
33.8
34.0
34.2
26.0
26.4
26.8

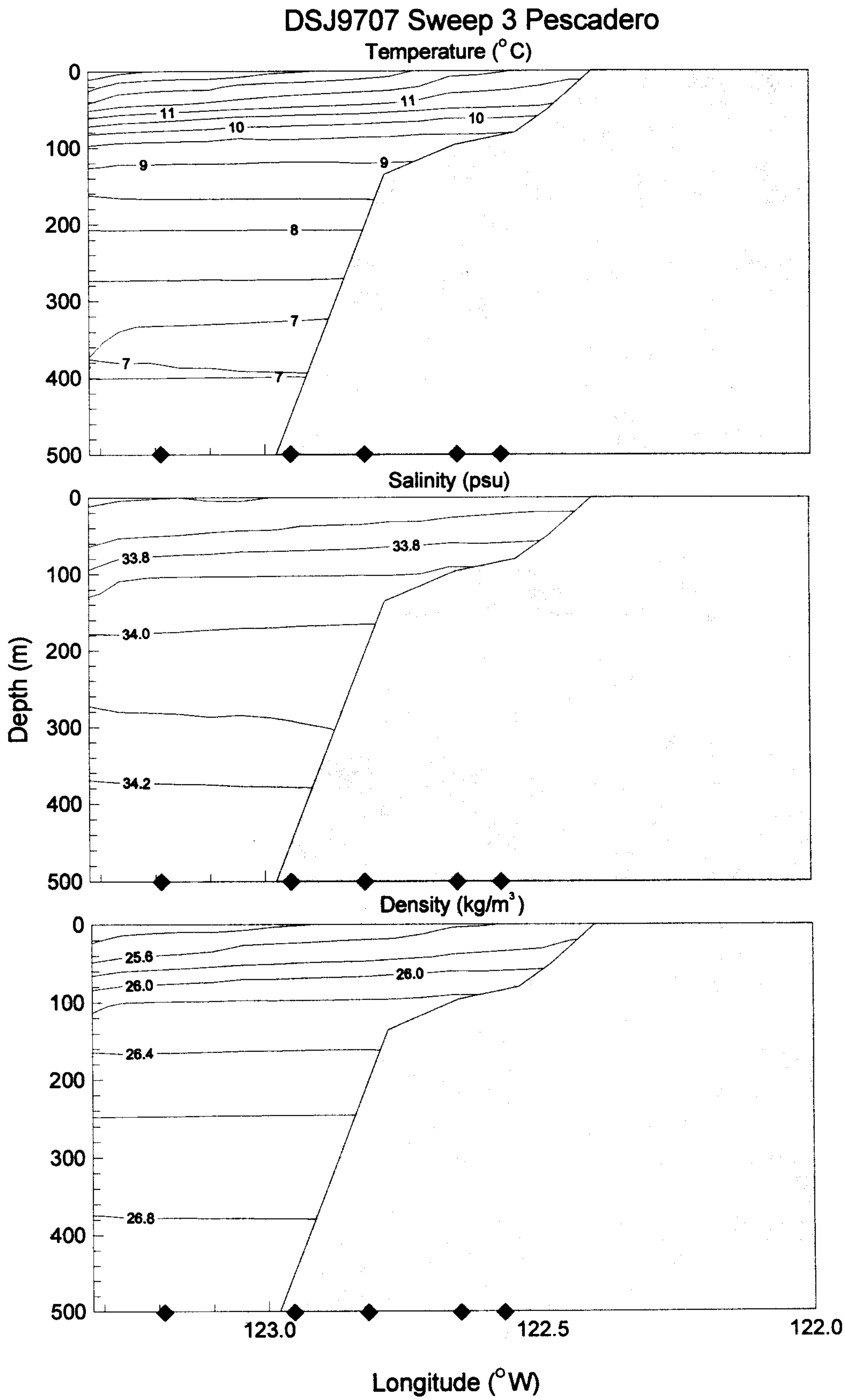
DSJ9707 Sweep 2 Farallones



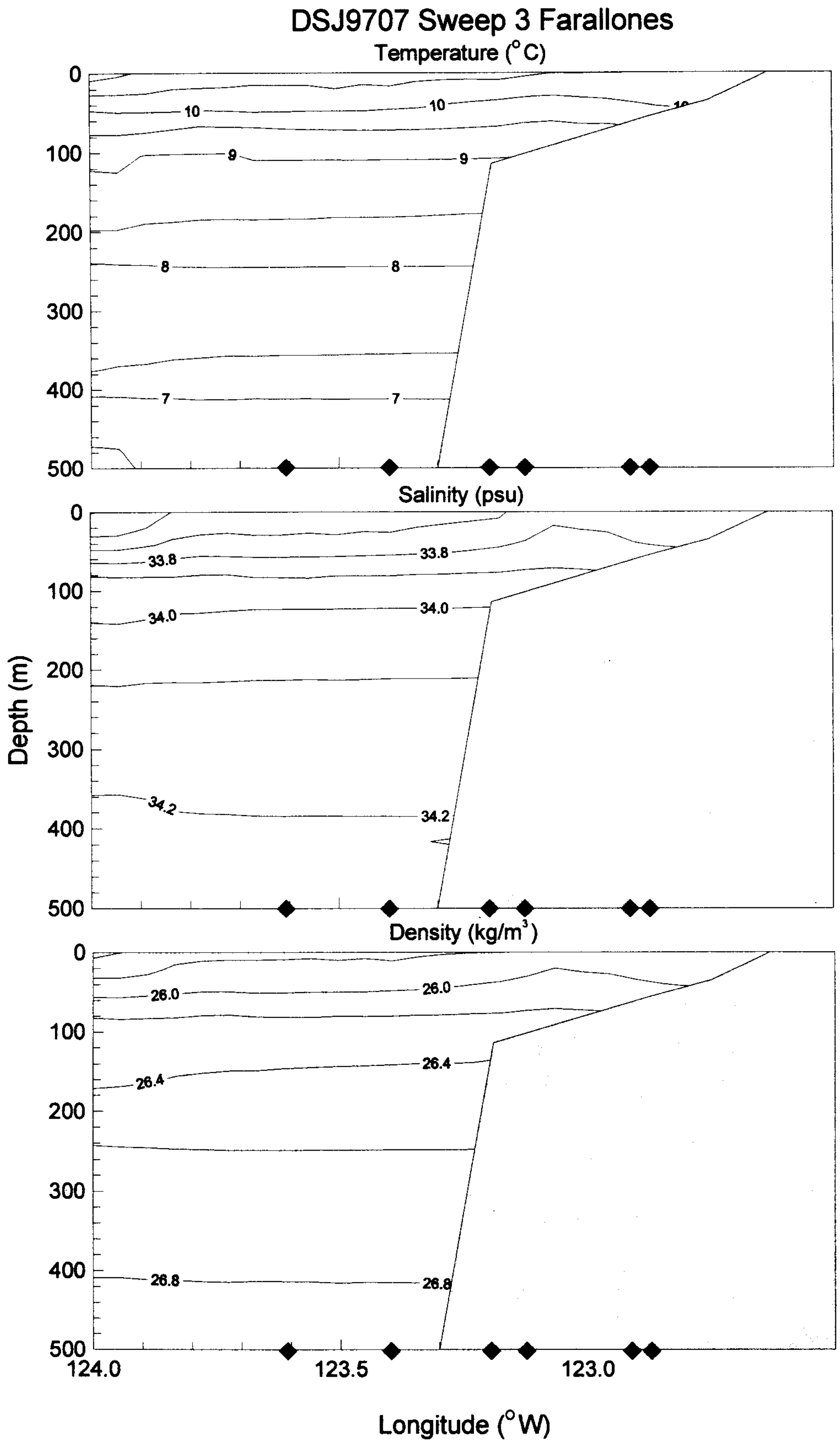

DSJ9707 Sweep 2 Point Reyes
Temperature (°C)
Salinity (psu)
Density (kg/m³)
Depth (m)
Longitude (°W)
0
100
200
300
400
500
124.0
123.5
123.0
13
12
11
10
9
8
7
33.0
33.2
33.4
33.6
33.8
34.0
24.8
25.2
25.6
26.0
26.4
26.8


DSJ9707 Sweep 3 Vertical Transect Stations
Pt. Reyes
Farallones
Pescadero
Davenport
38
37
Latitude (°N)
124
123
122
Longitude (°W)

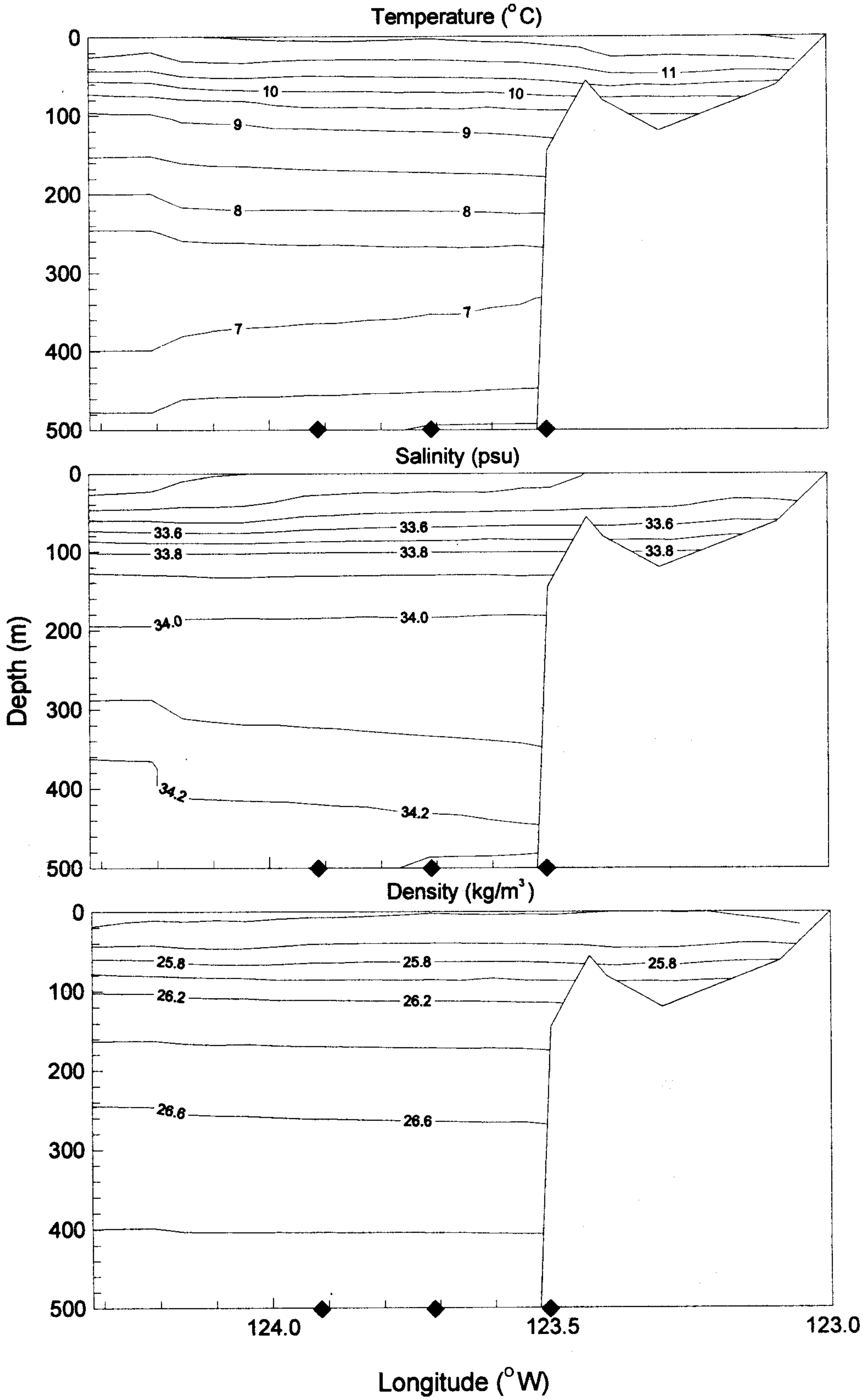

DSJ9707 Sweep 3 Davenport
Temperature (°C)
Salinity (psu)
Density (kg/m³)
Depth (m)
Longitude (°W)
0
100
200
300
400
500
123.0
122.5
122.0
12
11
10
9
8
7
33.8
34.0
34.2
25.6
26.0
26.4
26.8



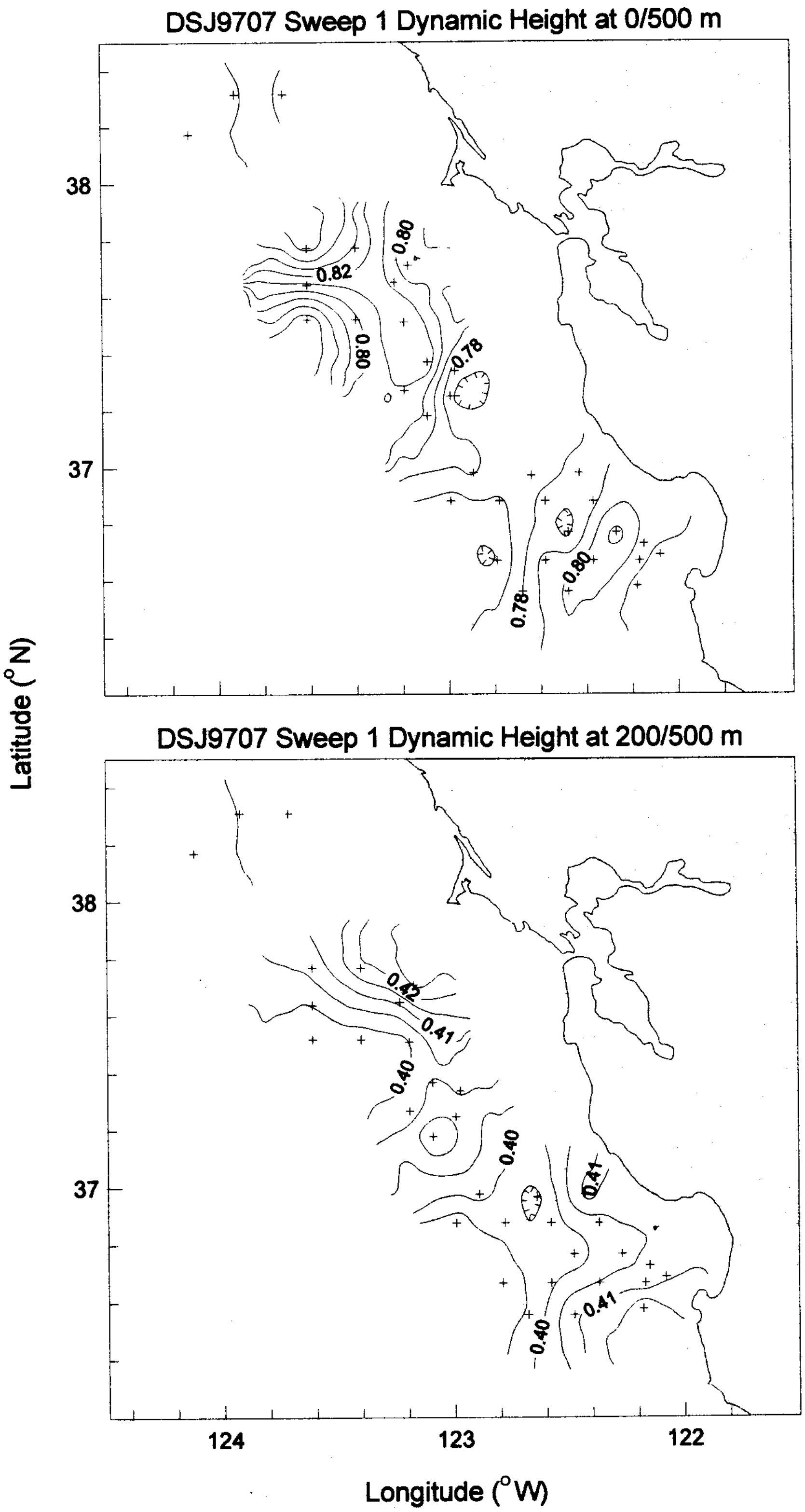
DSJ9707 Sweep 3 Pescadero
Temperature (°C)
11
10
9
8
7
Salinity (psu)
33.8
34.0
34.2
Density (kg/m³)
25.6
26.0
26.4
26.8
Depth (m)
0
100
200
300
400
500
123.0
122.5
122.0
Longitude (°W)

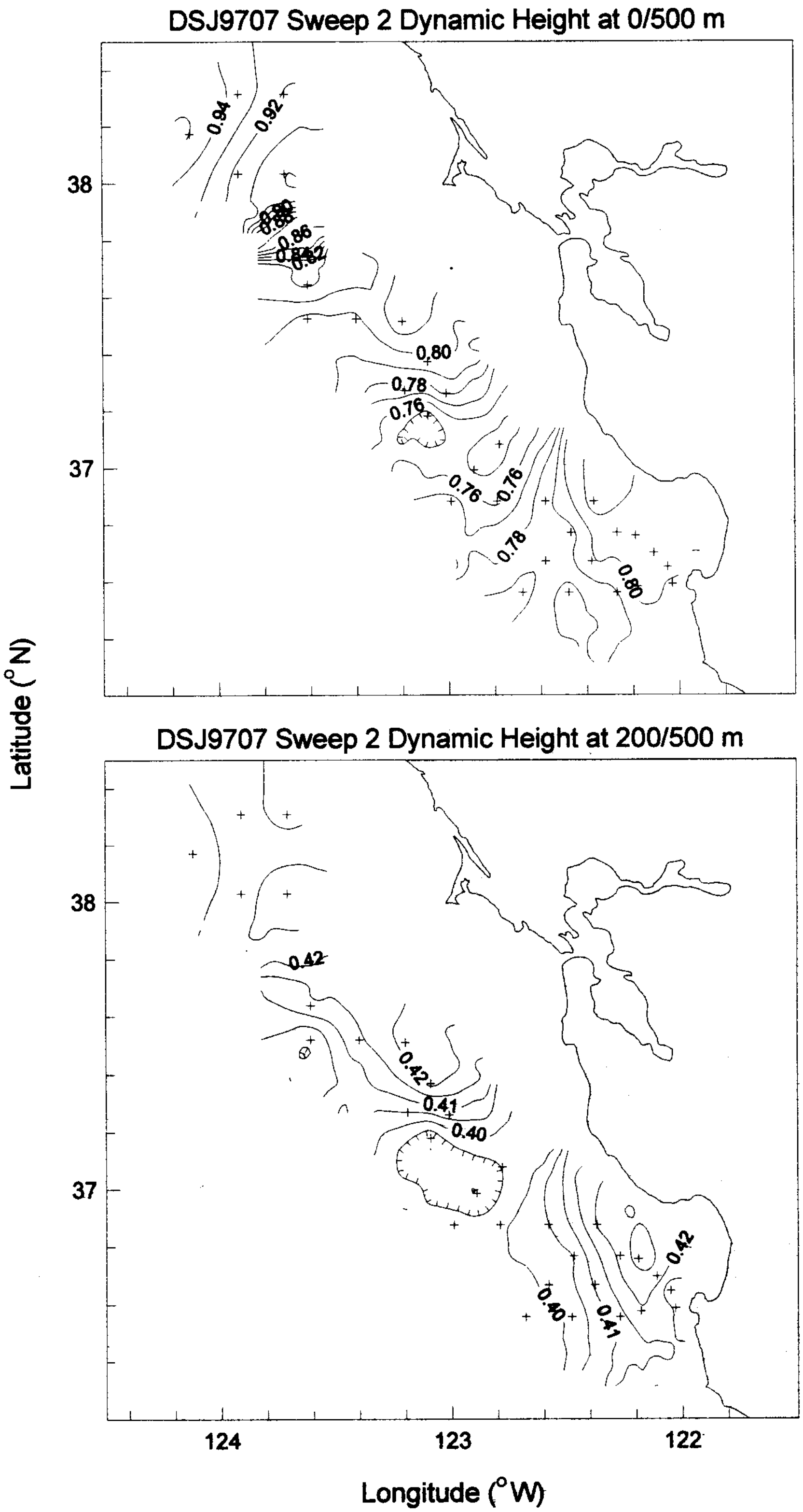

DSJ9707 Sweep 3 Farallones
Temperature (°C)
Salinity (psu)
Density (kg/m³)
Depth (m)
Longitude (°W)
124.0
123.5
123.0
0
100
200
300
400
500
10
9
8
7
33.8
34.0
34.2
26.0
26.4
26.8

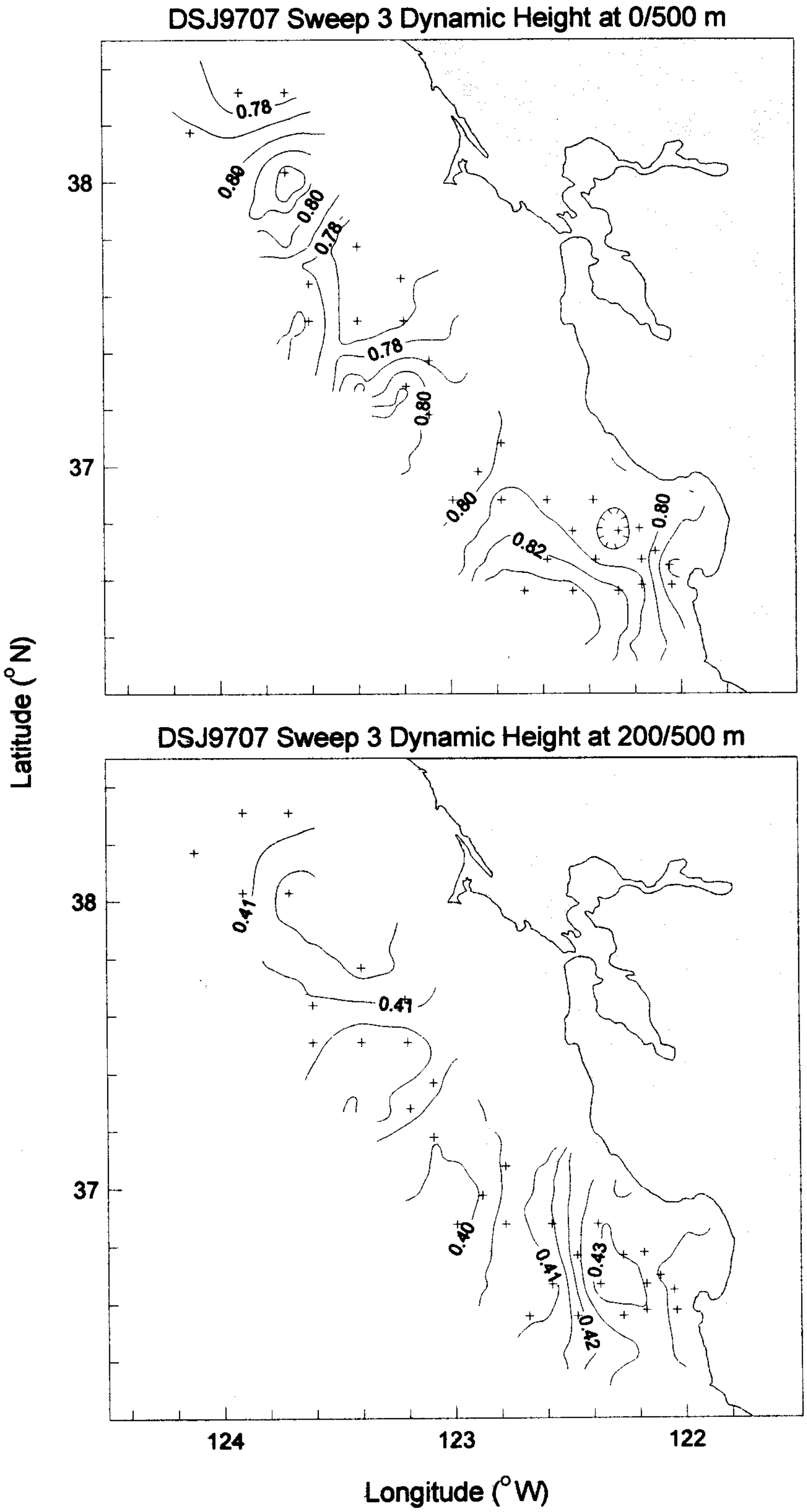
DSJ9707 Sweep 3 Point Reyes



APPENDIX 8: DYNAMIC HEIGHT TOPOGRAPHY FOR DSJ9707


DSJ9707 Sweep 1 Dynamic Height at 0/500 m
0.82
0.80
0.80
0.78
0.80
0.78
38
37
Latitude (°N)
DSJ9707 Sweep 1 Dynamic Height at 200/500 m
0.42
0.41
0.40
0.40
0.41
0.40
0.41
38
37
124
123
122
Longitude (°W)


DSJ9707 Sweep 2 Dynamic Height at 0/500 m
DSJ9707 Sweep 2 Dynamic Height at 200/500 m
Latitude (°N)
Longitude (°W)
38
37
124
123
122
0.94
0.92
0.86
0.80
0.78
0.76
0.42
0.41
0.40



DSJ9707 Sweep 3 Dynamic Height at 0/500 m
0.78
0.80
0.78
0.80
0.82
DSJ9707 Sweep 3 Dynamic Height at 200/500 m
0.41
0.40
0.42
0.43
38
37
124
123
122
Latitude (°N)
Longitude (°W)

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