DETAILED REPORTS

1. Physical oceanography; submitted by Anthony F. Amos (Shakedown, Leg I), Andrea Wickham (Shakedown, Legs I and II), and Charles Rowe (Leg II).

1.1 Objectives: The physical oceanography component of the AMLR program provided the means to identify contributing water masses and environmental influences within the AMLR study area, as well as to log meteorological and sea surface conditions annotated by the ship's position. The instrumentation and data collection programs served as host to the other scientific components of the program. AMLR 96 is the seventh field season for the collaboration of physical measurements with biological studies.

1.2 Accomplishments:

CTD/Rosette Stations: Ninety-one CTD/rosette casts were made on Leg I and 112 on Leg II. The major effort on each leg was the large-area survey, designated Survey A on Leg I (Stations A1-A91) and Survey D on Leg II (Stations D1-D91). Three cross-shelf transects were conducted during Leg II, consisting of twenty-one CTD/rosette stations (Stations X1-X21). Four hundred and seventy water samples were collected from the rosette bottles for salinity analysis during Leg I (out of a total of 988 water samples collected), and 597 water samples were collected for salinity analysis during Leg II (out of 1206 water samples collected). Water from these samples were analyzed for micronutrient concentration, phytoplankton, and chlorophyll by the phytoplankton group; for salinity by the Russian scientific team; and for dissolved oxygen by the phytoplankton team.

Salinity samples were analyzed aboard (using a Guildline Autosal) to verify the depth that each bottle tripped and to provide calibration data for the CTD conductivity sensor. The difference between the salinity measured by the Autosal and the CTD sensor was about 0.008, confirming the high accuracy of the CTD. Comparisons between oxygen sensor data from the CTD and samples run aboard (by Winkler titration method) showed lower absolute values for the sensor (see Section 2, Phytoplankton). This difference will be accounted for in the final analysis by applying a correction to the coefficients used in the calculation of dissolved oxygen from the raw oxygen current and temperature data provided by the sensor.

Underway Environmental Observations: Thirty and 29 days of continuously acquired weather, sea temperature, salinity, water clarity, chlorophyll, and solar radiation data were collected during Legs I and II, respectively. Augmented with the ship's navigational data, these data provided complete coverage of surface environmental conditions encountered in the AMLR study area.

1.3 Methods:

CTD/Rosette: Water profiles were collected with a Sea-Bird model SBE-9 PLUS CTD/rosette. CTD profiles were limited to 750 meter (m) depth (or to within a few meters of the ocean floor when the depth was 750m, or less). During the cross-shelf transects, sensors with depth limitations were removed allowing the CTD to be operated to 2000m. An ORE 12kHz pinger was attached to the rosette frame replacing bottle number 12. No difficulties were experienced in obtaining a good bottom return from the pinger; the CTD routinely went to within 10m of the ocean floor in shallow water. A Sea-Bird dissolved oxygen sensor, Seatech 25-centimeter beam transmissometer, Biospherical Instruments PAR sensor, and a Seatech *in situ* fluorometer (interfaced with the CTD/rosette unit) provided additional water column data on each station. Downtrace and uptrace CTD data for each station were recorded separately on Bernoulli drive removable cartridges. Data were collected at 24 scans/sec on the downtrace and 6 scans/sec on the up. All rosette bottles were fired during the upcast.

Raw CTD data were corrected for time-constant differences in the primary and oxygen sensors. Parameters were then derived and binned to produce 1-meter by depth averaged files for analysis. A sorted printout of the rosette bottle tripping sequence was produced so that sampling strategies could be adjusted immediately after the CTD/rosette unit was retrieved on deck. At each station, the current underway data were recorded to a disk and then transferred to the CTD computer; a log sheet was printed containing all the current meteorological and surface-water conditions. The log sheet included a diagram of the ship's heading and wind direction on-station and a map inset showing the location of the station.

Underway Data: Data from various environmental sensors were collected, multiplexed, and combined with the Global Positioning System (GPS) navigational information. A Data World computer equipped with a GTEK multiple serial port card was used to acquire, display, and store the data at one-minute intervals throughout Legs I and II. Several RS-232 interfaces were installed, allowing ASCII data to be sent from the ship's various systems to the Data World computer. Ship's position data were obtained using a Magellan GPS system. Ship's course was acquired from the gyro compass; relative wind speed, direction, and air temperature from the R.M. Young weather system; and sea temperature and salinity from the Sea-Bird SBE-21 Thermosalinograph. Using a Weathermeasure signal conditioning unit, barometric pressure, air temperature, and relative humidity data were sent to a HP 3421A data acquisition unit, where they were multiplexed and sent to the Data World computer via an IEEE-488GPIB interface.

A single optical sensor (Biospherical Instruments PAR sensor) was mounted on the ship’s mast to sense solar radiation. These data were fed to the GTEK port from the PAR sensor deck unit located in the phytoplankton lab. Finally, a plumbed seawater flow-through system provided bubble-free water for a Seatech 25cm transmissometer and a Turner Designs Fluorometer to monitor sea surface water clarity and chlorophyll fluorescence. These inputs were also fed to the HP 3421A. Throughout the cruise, a HP 7475A plotter was used to provide real-time graphical representation of environmental conditions.

1.4 Results and Tentative Conclusions:

Oceanography: As in past years, we classified and grouped stations with similar vertical temperature/salinity (T/S) characteristics. We have identified five water types, designated I through V. It should be noted that the water types are based on the T/S curves from the surface to 750m (or to the bottom in water shallower than 750m). For example, water type I has the following characteristics: warm, low salinity surface water; a strong sub-surface temperature minimum (called "Winter Water" at approximately -1°C and a salinity of 34.0 ppt.); and a distinct T/S maximum near 500m (called "Circumpolar Deep Water" or CDW). We have defined the oceanic water of the Drake Passage as water type I. In the Bransfield Strait and south of Elephant Island, water type IV dominates. Water type IV has the following characteristics: bottom waters around -1°C; and subsurface extrema that are far less prominent, although a slight "crook" in the curve is characteristic. In between, there are transition zones where adjacent water types mix.

The composite T/S scatter diagram for all stations of the large-area surveys (Surveys A and D) are shown in Figures 1.1a and 1.1b, respectively. T/S data are presented in Figures 1.2a-1.2e for each water type in Survey A and in Figures 1.2f-1.2j for each water type in Survey D. For each figure, the gray area is the T/S envelope of all stations identified as having the water type characteristics, and the dark black curve is the mean T/S curve for the water type. The map insets show the location and numbers of stations belonging to each water type. In this way, the locations of the five water masses in the AMLR study area can be envisioned. Although considerable care has been taken to classify each station by water type, these data are still preliminary as some stations are transitional. This particularly applies to water type II, which is characterized by the evidence of isopycnal mixing of the CDW with shelf water. Stations A76 and A91 of Survey A are typical of this transition. In Figures 1.3a and 1.3b, T/S curves have been plotted for each individual station in the AMLR study area for Survey A (Leg I) and Survey D (Leg II), respectively. From these "worm diagrams", the two major water divisions can clearly be seen for both legs. A dashed line is shown to delineate the border of water type I from the other water types, which is the approximate boundary of the major front in the AMLR study area.

The dynamic topography of the region is shown in Figures 1.4a and 1.4b. The implied flow at the surface relative to 500dbar is illustrated by streamlines with arrows pointing in the direction of flow. As usual, the major feature was the prevailing SW to NE flow across the entire AMLR study area. Like previous years, this flow was intensified in three zones: north of Elephant Island, roughly following the topographic trend of the shelf-break; in a narrow band paralleling the northern boundary of the Bransfield Strait south of King George Island; and a more northerly trend between Elephant and Clarence Islands. Another intensification was seen north of King George Island. The eddy-like feature in the northwest was prominent this year on Leg I, with the strongest flow in the area along the topographic boundary to the west of Elephant Island. This dynamic topographic high was a quasi-permanent feature of the flow in the AMLR study area and has been present on all AMLR cruises on both legs. A similar pattern was revealed by referencing the surface to 200m. Thus, it is assumed that these patterns are reasonably representative of the mean flow in the upper water column.

The near-surface (10m) temperature, salinity, density, and dissolved oxygen fields for Surveys A and D are contoured in Figures 1.5a-1.5h. During Leg I, the 2 °C contour was in the same position as last year, but there was no water >3 °C or < 0 °C in the AMLR study area. Overall warmer surface water temperatures were experienced during Leg II, and nine stations showed >3 °C at the surface. Surface salinity distribution was similar to that of 1995. Surface density contours this year showed the density front penetrating the Bransfield Strait from the north in a finger-like lobe. The oxygen data plotted in Figure 1.5d and 1.5h have not been corrected to account for differences between the values from the oxygen sensor on the CTD and those determined by the Winkler method by the phytoplankton group.

Vertical CTD profiles along the 57°W meridional line for Survey A (Stations A25-A34) and Survey D (Stations D25-D34) are shown in Figures 1.6a-1.6f and Figures 1.7a-1.7f, respectively. Compared with last year, the front was in approximately the same location (Stations A30, A31). However, the contrast between surface and subsurface winter water temperatures was greater in 1995, with the winter water being colder and the surface water warmer in that year. In general, profiles of all parameters show less vertical contrast in the upper waters this year than last, especially in the beam attenuation coefficient (light transmission) and chlorophyll fluorescence (see Section 2, Phytoplankton). It is interesting to note that just visible in the beam attenuation coefficient (BAC) profile, is an area of high BAC in the upper few meters (Figures 1.6e and 1.7e). This is likely due to bubbles from the ship's propeller streaming past the CTD, which was deployed from the stern. The oxygen and chlorophyl maxima in the winter water temperature minimum were also not as prominent as last year. Fluorometry values for stations D25, D26, and D27 are missing in Figure 1.7f because these stations were re-occupied at the end of Leg II due to earlier mechanical failures. The fluorometer values from those stations are useable but are not plotted here because of the time difference between the replicate and original stations.

Underway Data: Data were recorded at 1-minute intervals covering over 8000 nautical miles (n.mi.) of cruise track. We did have several periods of data loss due to GPS, thermosalinograph, and wind measurement problems on Leg I and several hours on Leg II due to unplanned repositioning of the underway equipment . During Leg I, the mean wind was 13.8 knots, which was significantly calmer than on any previous AMLR cruise leg. The maximum wind on Leg I was 31.4 knots, which was also considerably lower than on other cruises. The maximum wind on Leg II was 45.9 knots. Leg II had a mean wind of 15.9 knots and an average maximum wind of 30.1 knots. There were no storms during Leg I, and no stations were missed due to weather. Leg II experienced many stormy days and several stations were delayed due to the bad weather. Air temperatures were below freezing for only a few hours during Leg I, but there were several days of freezing temperatures on Leg II with a low of -2.2°C.

1.5 Disposition of Data: The CTD/rosette, underway, and weather station data have been stored on 150 Mbyte Bernoulli disks. The raw data will be taken to the University of Texas Marine Science Institute in Port Aransas, Texas for backup. Final analysis will be under the direction of Anthony F. Amos. Copies of the CTD/rosette 1-meter averages and modified 1-minute underway data have been distributed on diskettes to the phytoplankton and acoustics groups. Copies of the printed log sheets and plots were provided daily to the phytoplankton group. Special logs listing time, position and weather conditions for each scientific event were provided to cruise participants.

1.6 Acknowledgments: Special mention must go to the Russian crew who prepared, launched, and recovered the CTD and also operated the pinger. We would like to acknowledge them by name because they did such an excellent job: Shift 1, Oleg Pivovarchuk, Andrey Mikhaylov, Evgeniy Dolgovskiy, Vladimir Stukanov, Victor Paramov, Sergey Matral; Shift 2, Valeriy Kazachonok, Anatoliy Miller, Alexey Karpenko, Oleg Liaskovskiy, Slava Sinyavskiy, and Igor Telenkevich. We also are most grateful to Oleg Pivovarchuk (Chief of Expeditions) for his overall leadership and attention to our needs and rapid response to our problems. Oleg and Valeriy also did double duty running hundreds of salinity samples for the physical oceanography group. Mark May (Electronic Technician) was a great help in setting up the laboratory, the salinometer, thermosalinograph, and CTD/rosette; he also attended to numerous repairs, not failing in one (except the PAR sensor which was irreparable). We also thank the phytoplankton group for collecting salinity samples from each station. In general, the cruise aboard the R/V *Yuzhmorgeologiya* was a great success.

1.7 Problems and Suggestions: The major problem experienced with the CTD involved the PAR sensor, which malfunctioned after Station A06 with an operational amplifier failure. Mark May worked hard to repair it by inventing another amplifier, but the logarithmic output was not reproducible. After purchasing a part in Punta Arenas, the PAR sensor was repaired by the beginning of Survey D. The rosette sampler experienced many problems, which lessened confidence in the depth at which some bottles actually tripped. The phytoplankton group relies on the rosette sampler operating properly, and although the combination of salinity sample and chlorophyll comparisons have reduced the possibility of error to a minimum, a more reliable rosette sampler is essential.

The Magellan GPS unit generally functioned well, but the underway system experienced problems when messages from the GPS inexplicably stopped. Because the Magellan unit was required during seal surveys away from the ship, we had to use the simpler Meridian system. This system also had unexplained problems with its output.

Towards the end of Leg I, spikes started appearing on the salinity output from the thermosalinograph. It was discovered that the pump was introducing bubbles which caused the spikes. Some mathematical filtering will need to be done to recover the last several days of salinity data. This problem was never corrected, and all data from Leg II will have to be filtered in the same manner. The R.M.Young wind vane and anemometer produced erroneous data for several days at the beginning of the cruise. After rectifying some problems with a grounded cable, reliable data collection began on 25 January.

There was almost complete lack of general tools, hardware, electronic connectors, spares and test instruments. Also, there were not enough 220V/110V converters. We recommend the following equipment: an oscilloscope, a ratchet wrench set, resistors, capacitors, hook-up wire, coax and other cable, connectors (BNC, RS232, banana plug, etc.), test leads, vice, 12V battery charger, glues, epoxies, electrical tapes, and shrink tubing. We also recommend an antenna cable of 150 feet to allow use of the Trimble GPS unit.

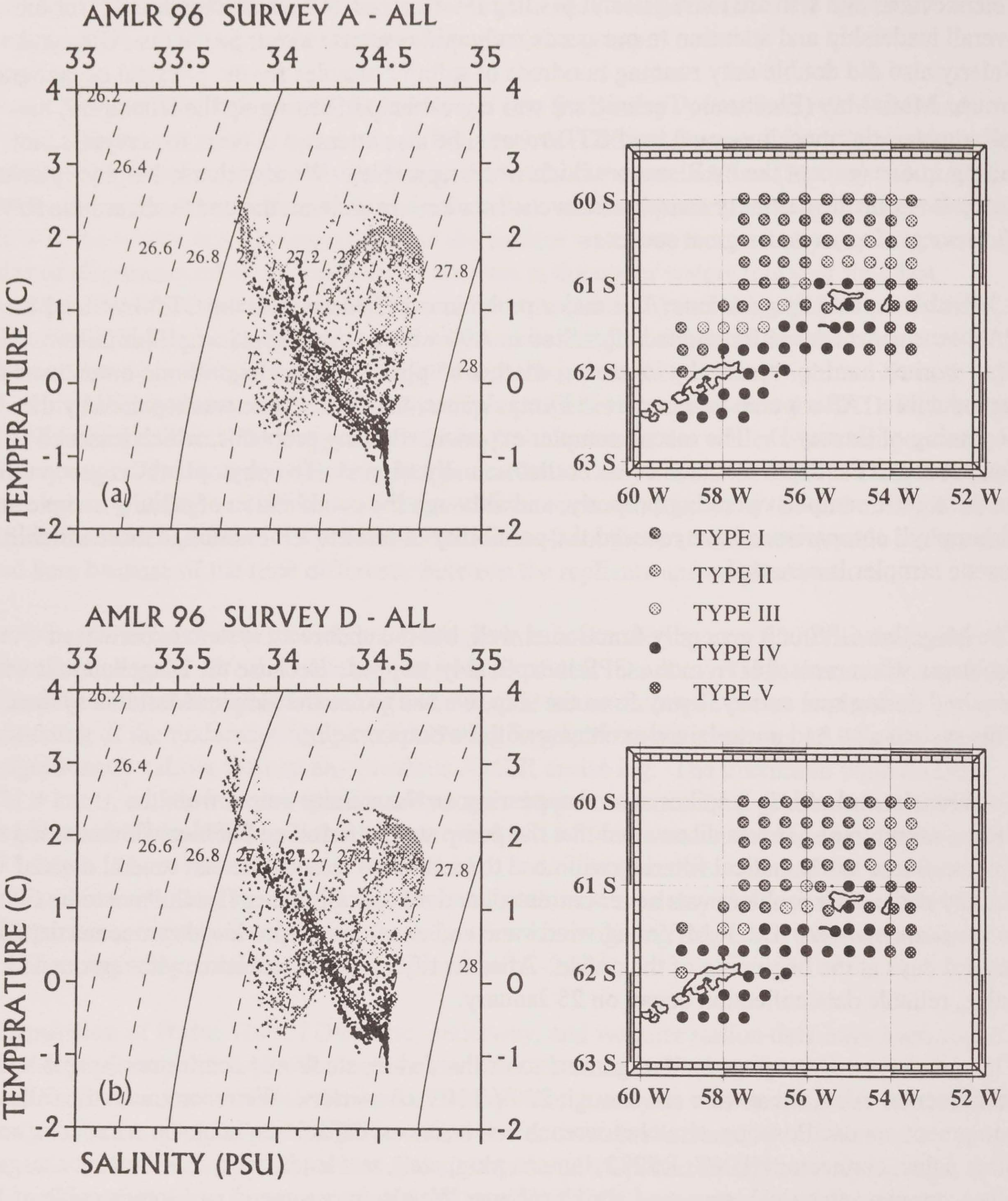


Figure 1.1 Composite Temperature/Salinity diagram for all stations from the large-area surveys. (a) Survey A, Leg I; (b) Survey D, Leg II. Symbols on inset maps show station locations shaded by water types.

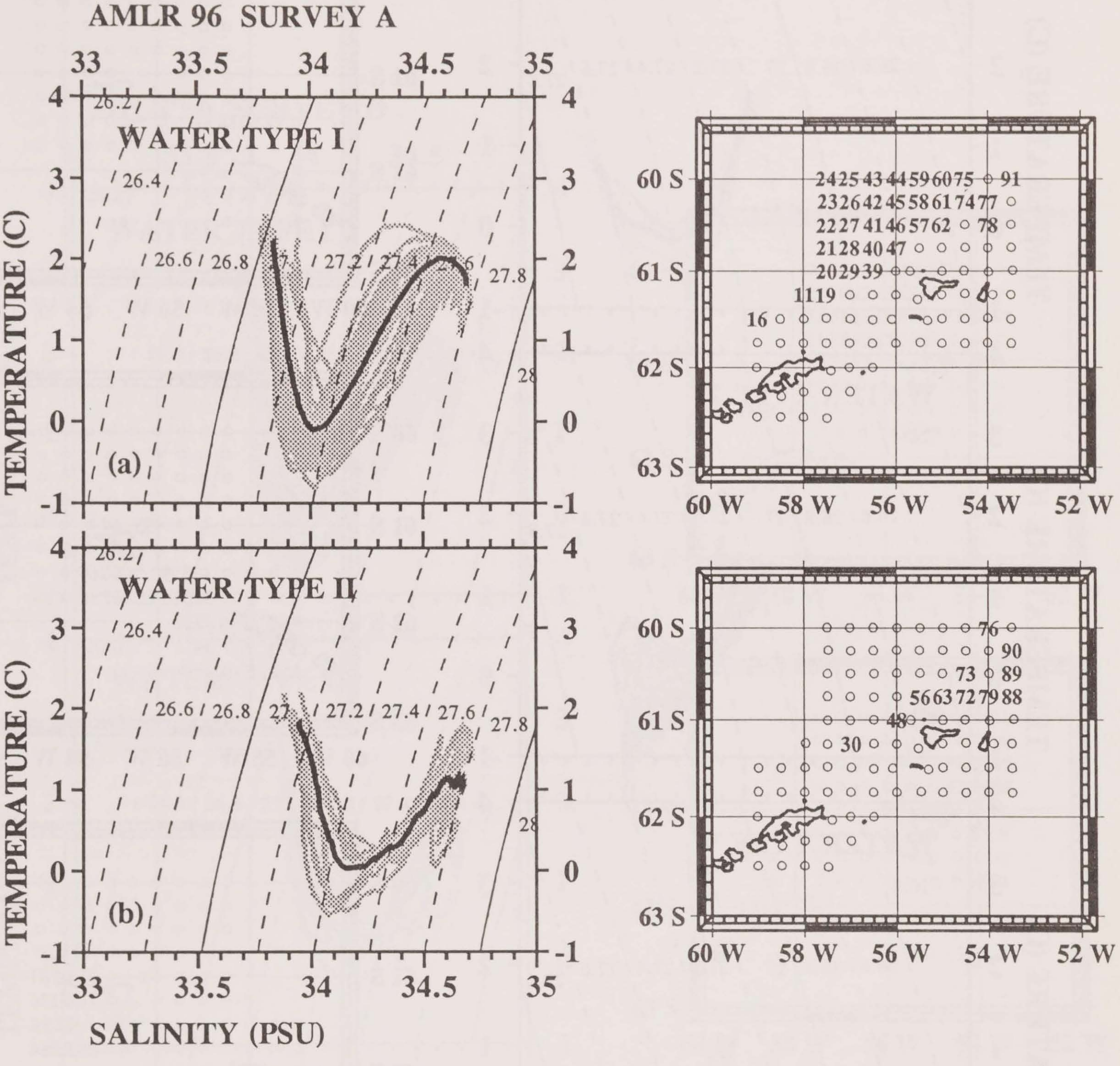


Figure 1.2 Temperature/Salinity curves for various water types in the AMLR study area. The gray area is the T/S envelope of all stations identified as having the water type characteristics. The heavy black curve is the mean T/S curve for each type. Inset maps show the location and numbers of stations belonging to each type. (a) Survey A, water type I; (b) Survey A, water type II.

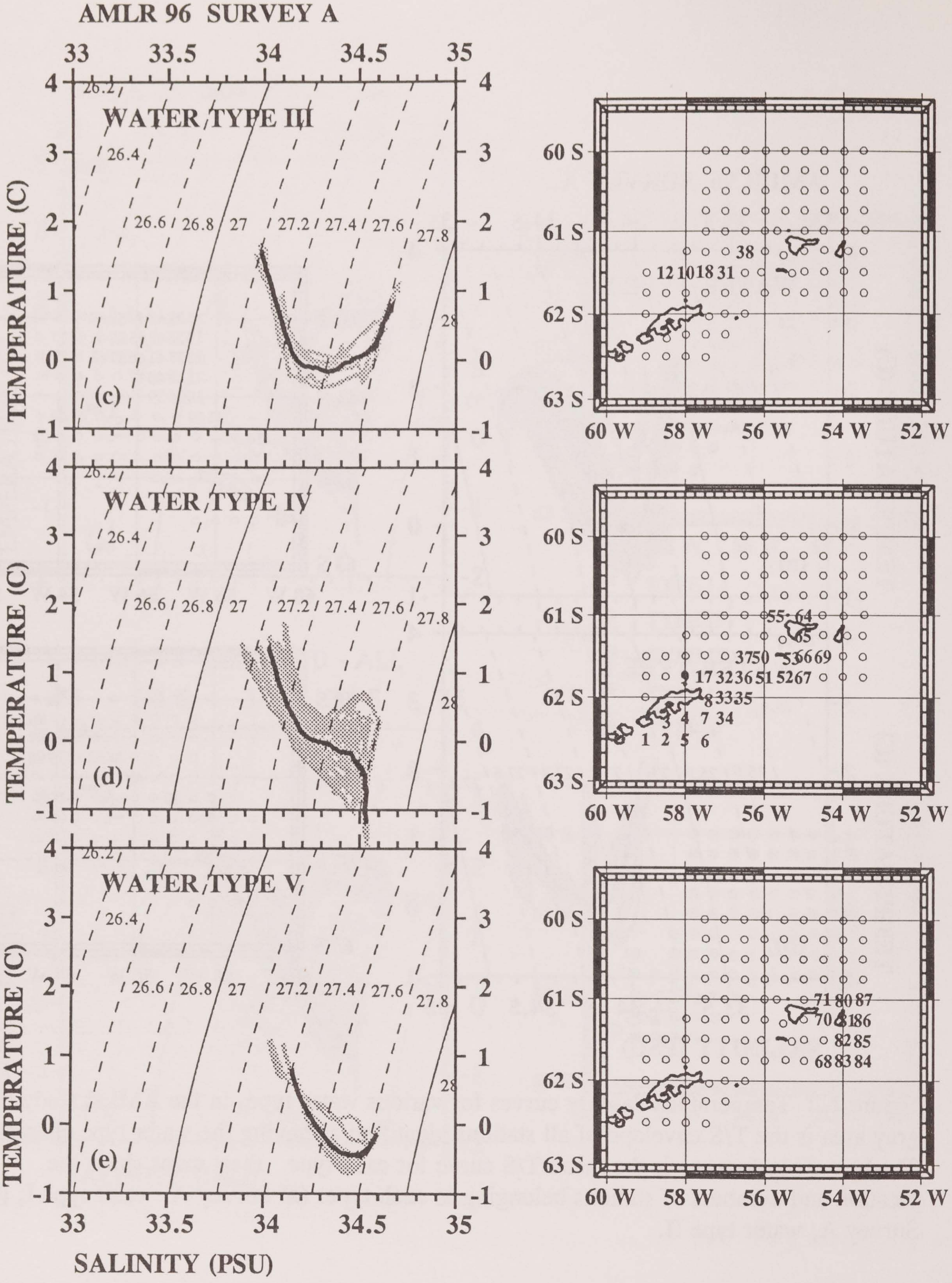


Figure 1.2 (cont.) (c) Survey A, water type III; (d) Survey A, water type IV; (e) Survey A, water type V.

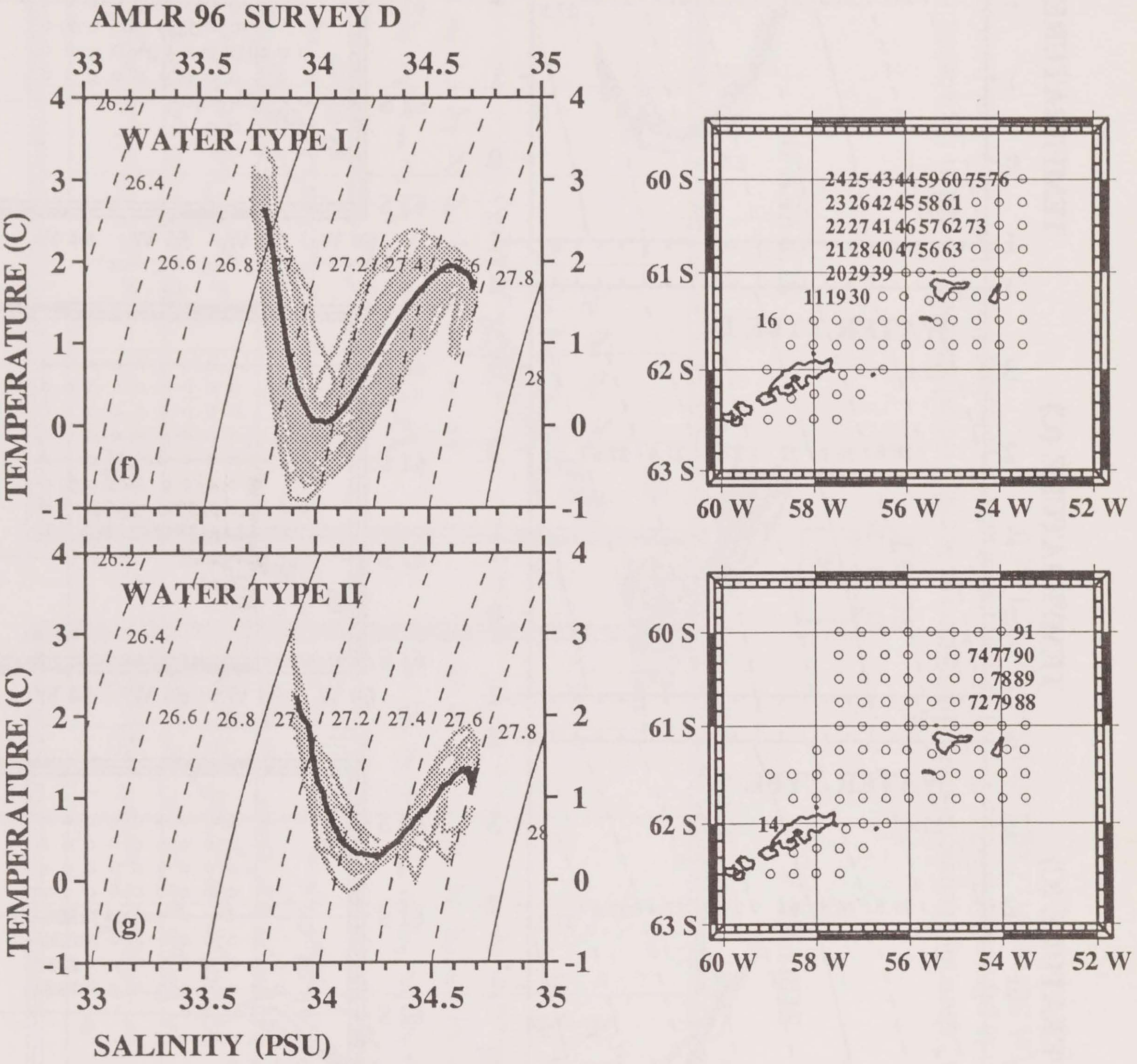


Figure 1.2 (cont.) (f) Survey D, water type I; (g) Survey D, water type II.

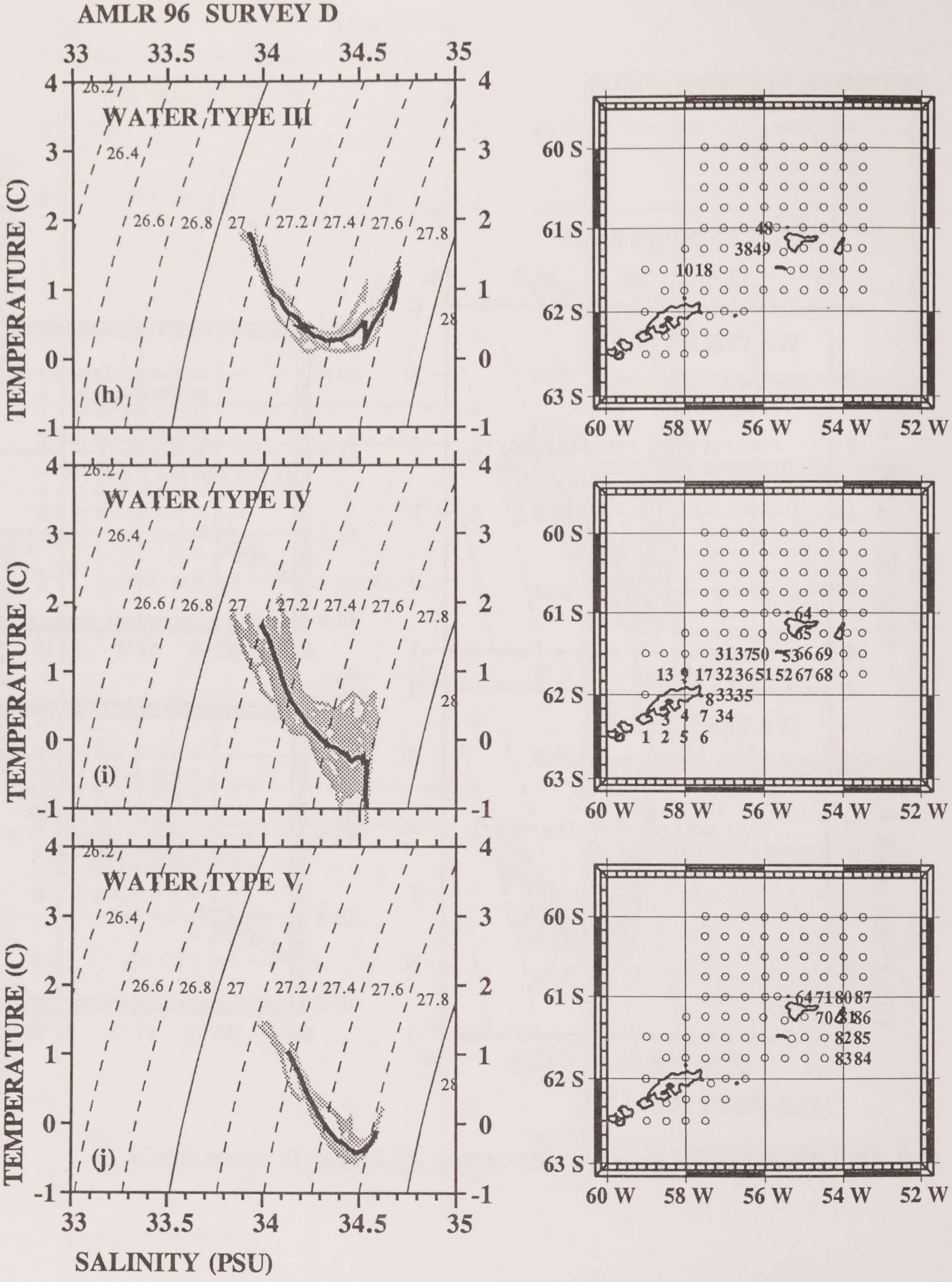
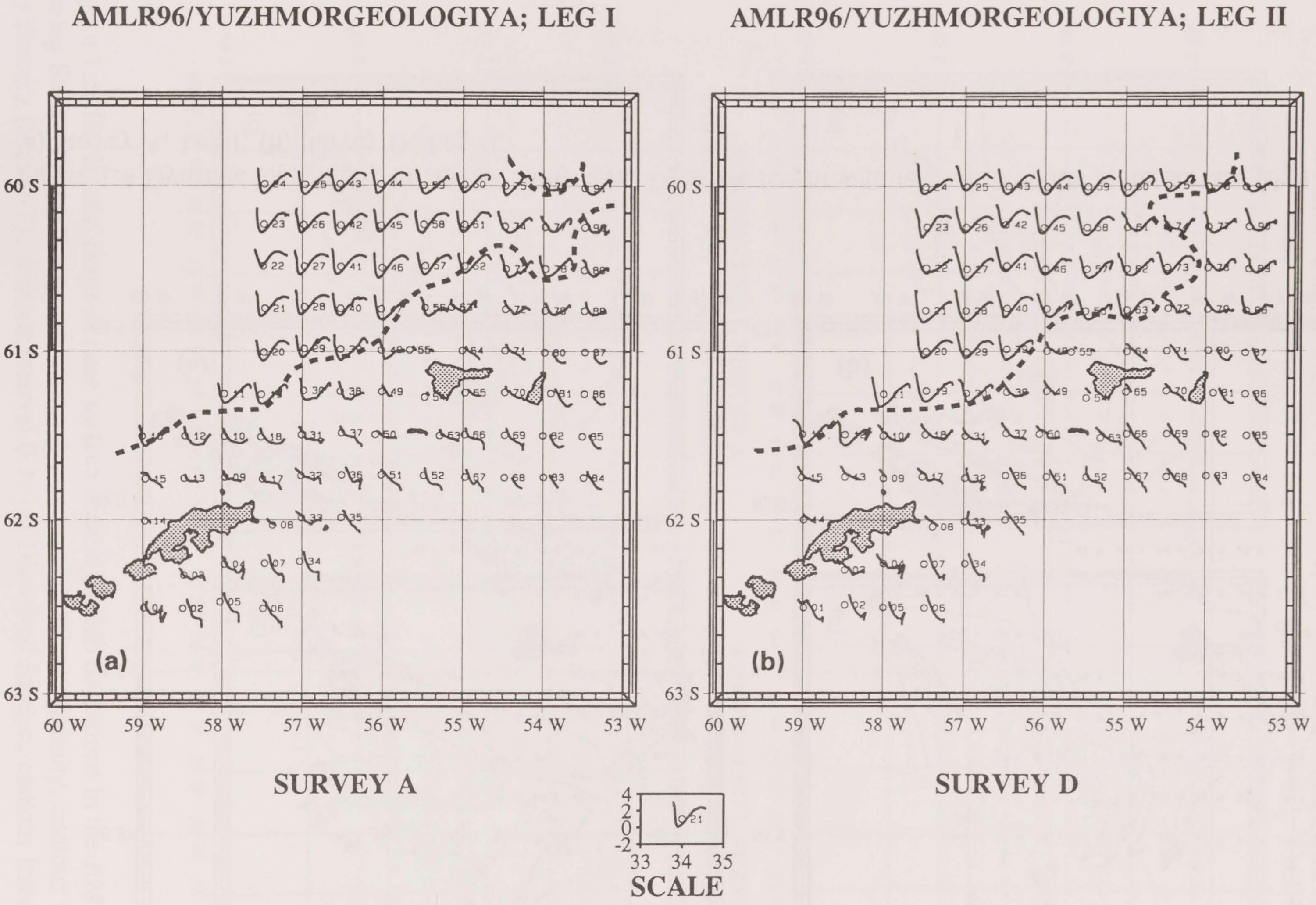


Figure 1.2 (cont.) (h) Survey D, water type III; (i) Survey D, water type IV; (j) Survey D, water type V.


AMLR96/YUZHMORGEOLOGIYA; LEG I

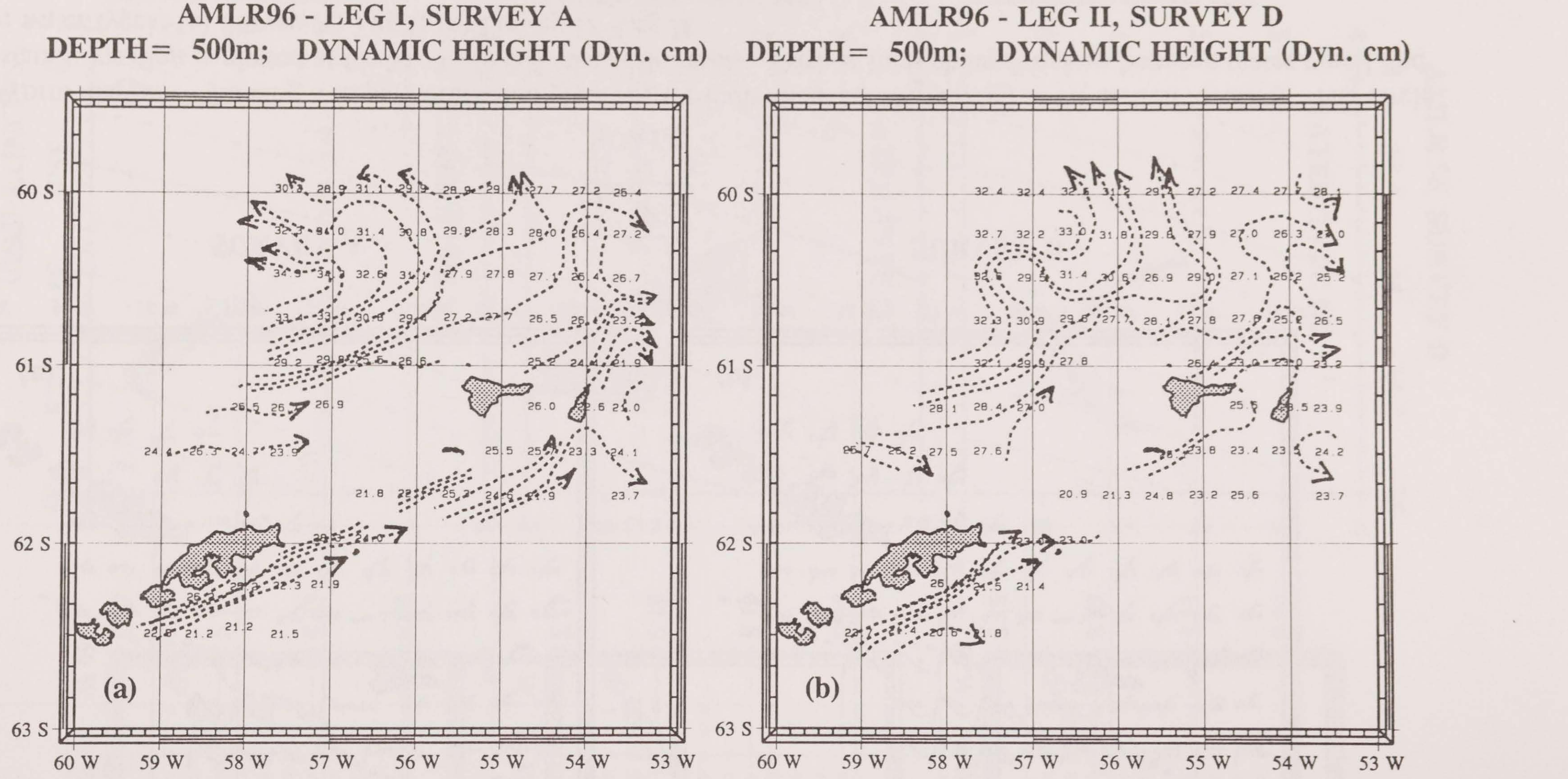
AMLR96/YUZHMORGEOLOGIYA; LEG II

SURVEY A

SURVEY D

SCALE

Figure 1.3 "Worm diagram" showing Temperature/Salinity curves for individual stations plotted at the station location. The circle representing station location is plotted at S=34, T=+0.5 (see scale inset). Dashed lines show divisions between water type I and the rest of the water types. (a) Survey A, Leg I; (b) Survey D, Leg II.


AMLR96 - LEG I, SURVEY A
DEPTH= 500m; DYNAMIC HEIGHT (Dyn. cm)

AMLR96 - LEG II, SURVEY D
DEPTH= 500m; DYNAMIC HEIGHT (Dyn. cm)

Figure 1.4 Dynamic topography of AMLR study area. Dynamic height with respect to 500db at the surface (dyn. cm.). (a) Survey A, Leg I; (b) Survey D, Leg II.

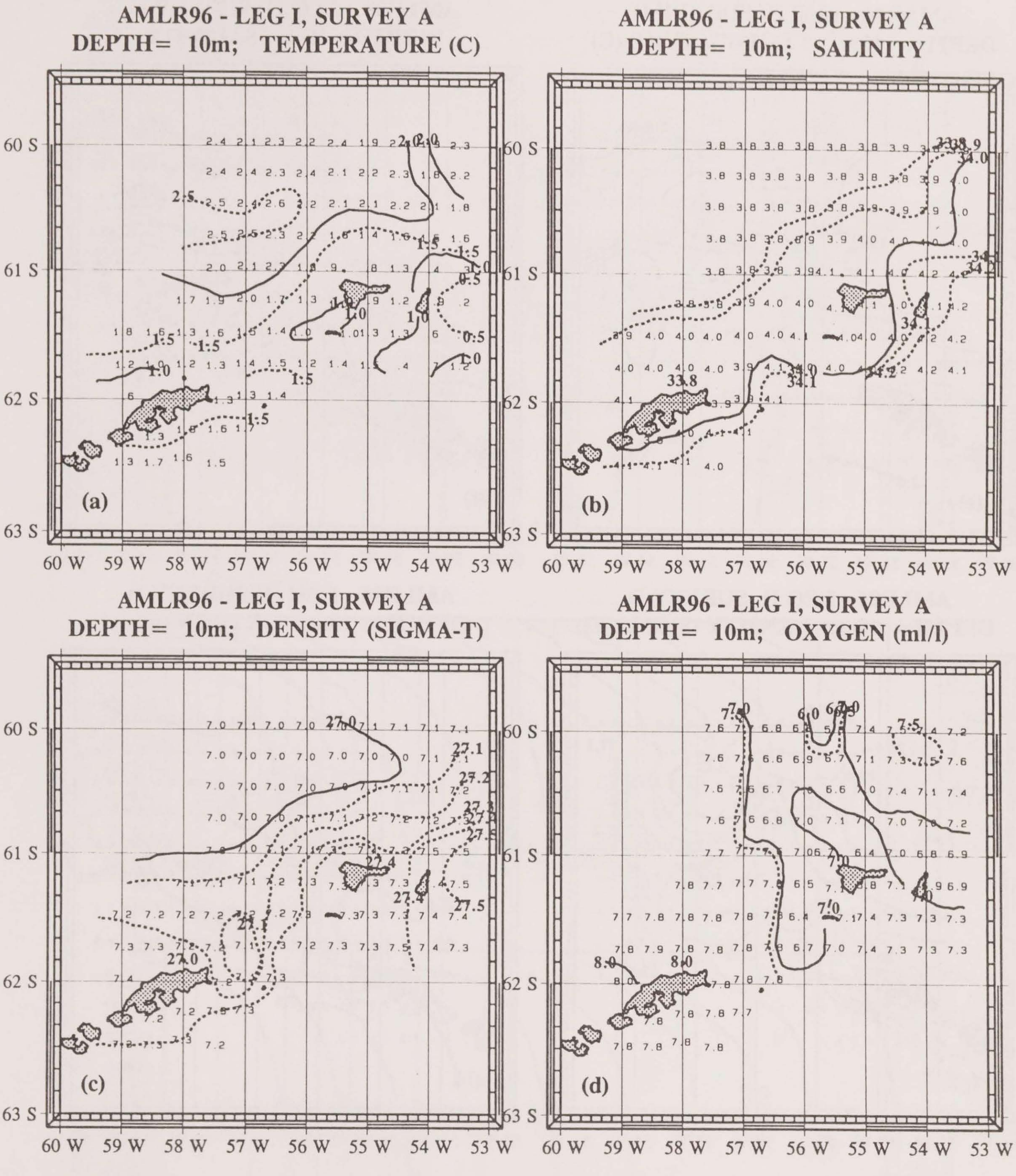


Figure 1.5 Horizontal maps of near surface oceanographic conditions in the AMLR study area during Survey A. (a) Temperature, contour interval 0.5C; (b) Salinity, contour interval 0.1; (c) Density (Sigma-T), contour interval 0.1; (d) Dissolved oxygen, contour interval .5 ml/liter.

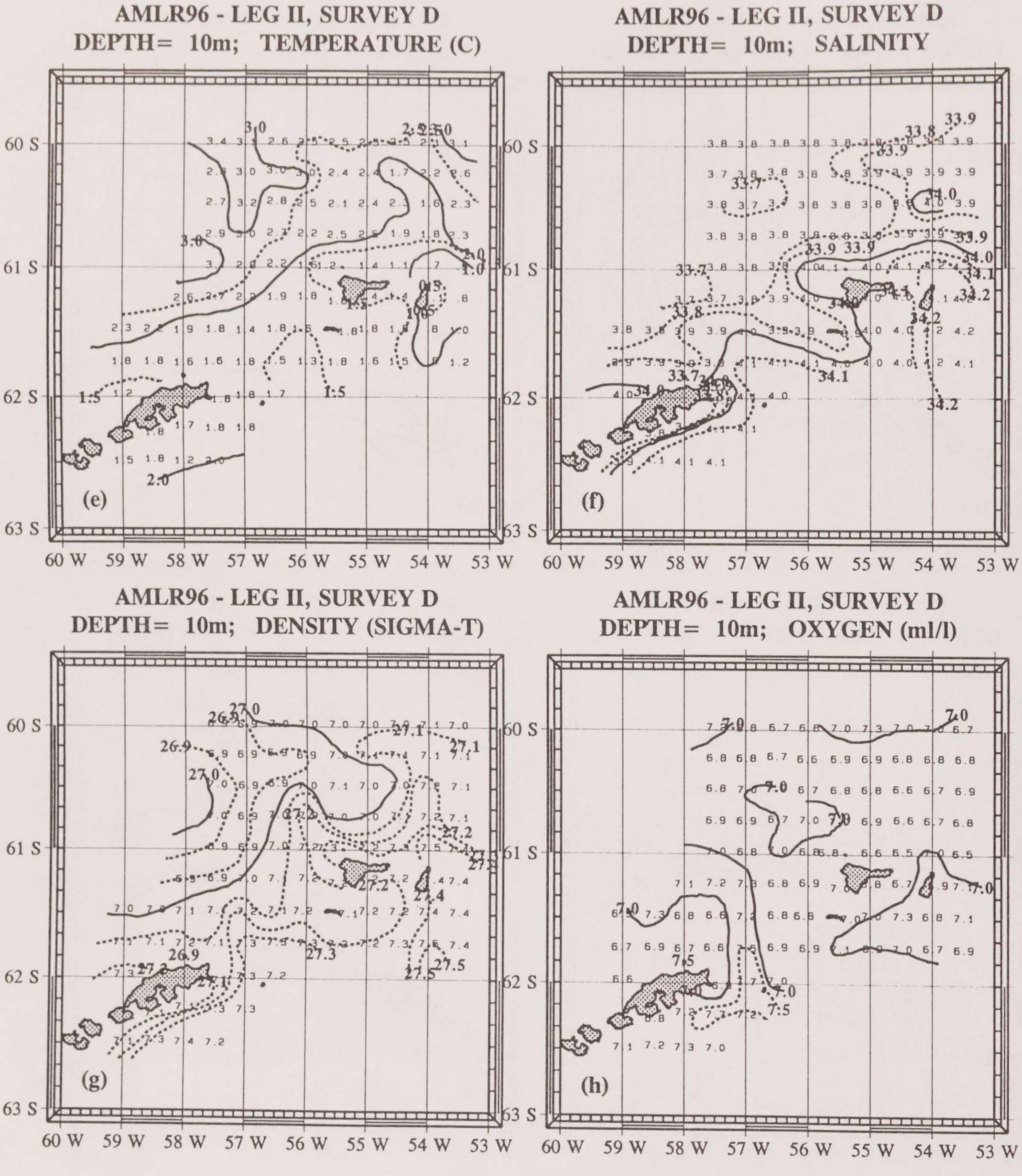


Figure 1.5 (cont.) Horizontal maps of near surface oceanographic conditions in the AMLR study area during Survey D. (e) Temperature, contour interval 0.5C; (f) Salinity, contour interval 0.1; (g) Density (Sigma-T), contour interval 0.1; (h) Dissolved oxygen, contour interval .5 ml/liter.

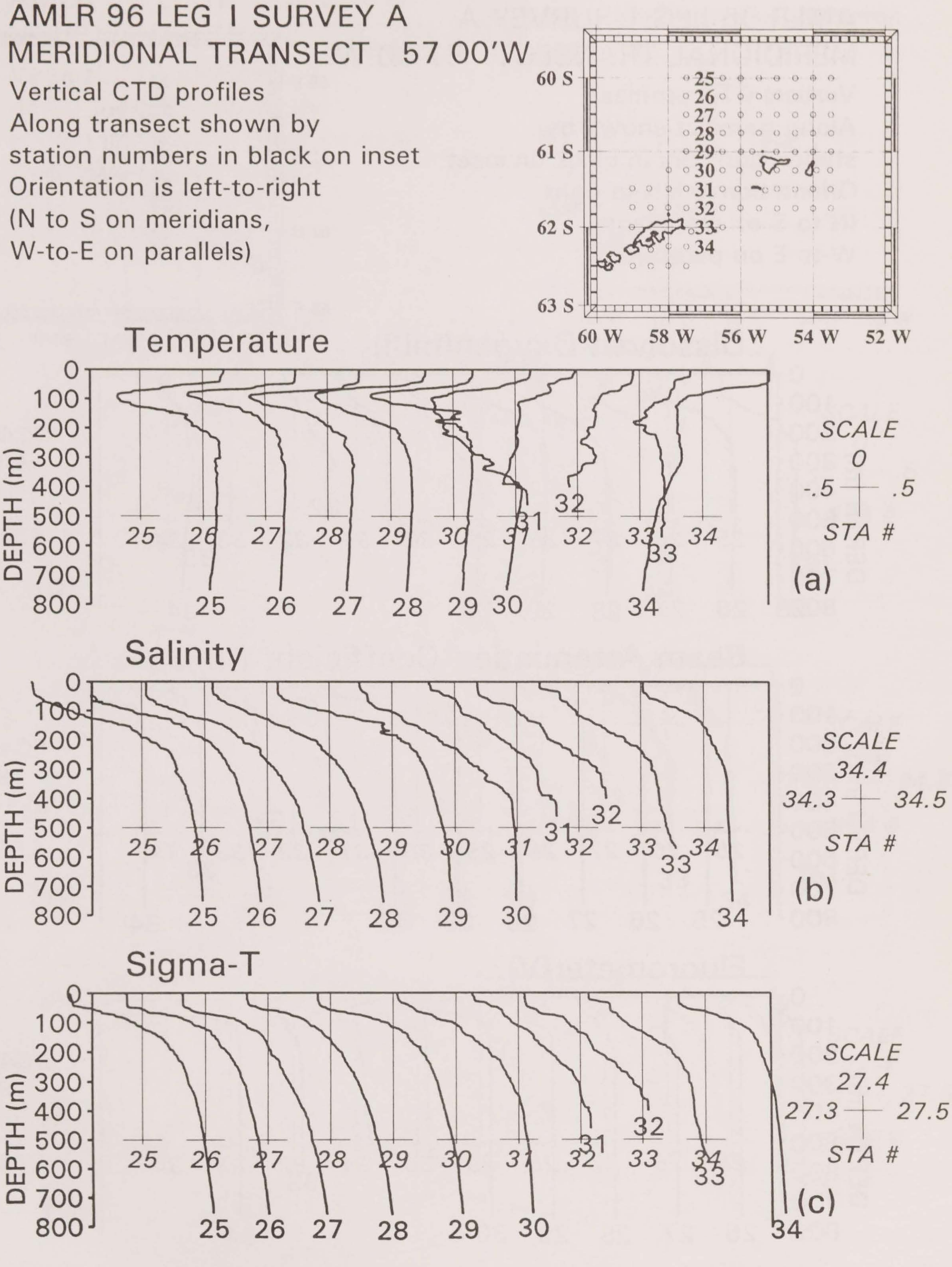


Figure 1.6 Vertical profiles of oceanographic parameters along selected meridians and parallels in the AMLR study area during Survey A. (a) Temperature; (b) Salinity; (c) Sigma-T.

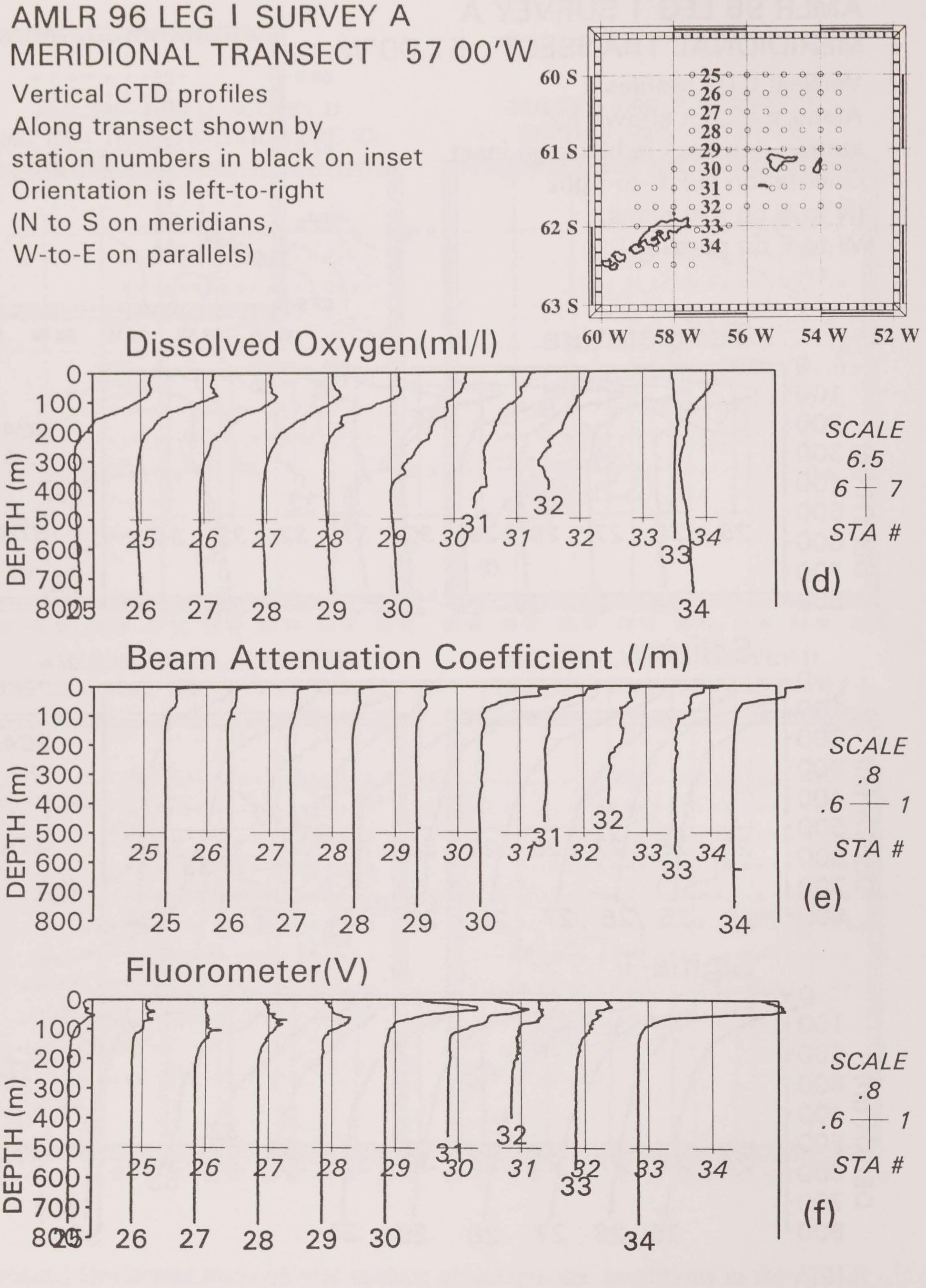


Figure 1.6 (cont.) Vertical profiles of oceanographic parameters along selected meridians and parallels in the AMLR study area during Survey A. (d) Dissolved oxygen; (e) Beam Attenuation Coefficient; (f) Fluorometer.

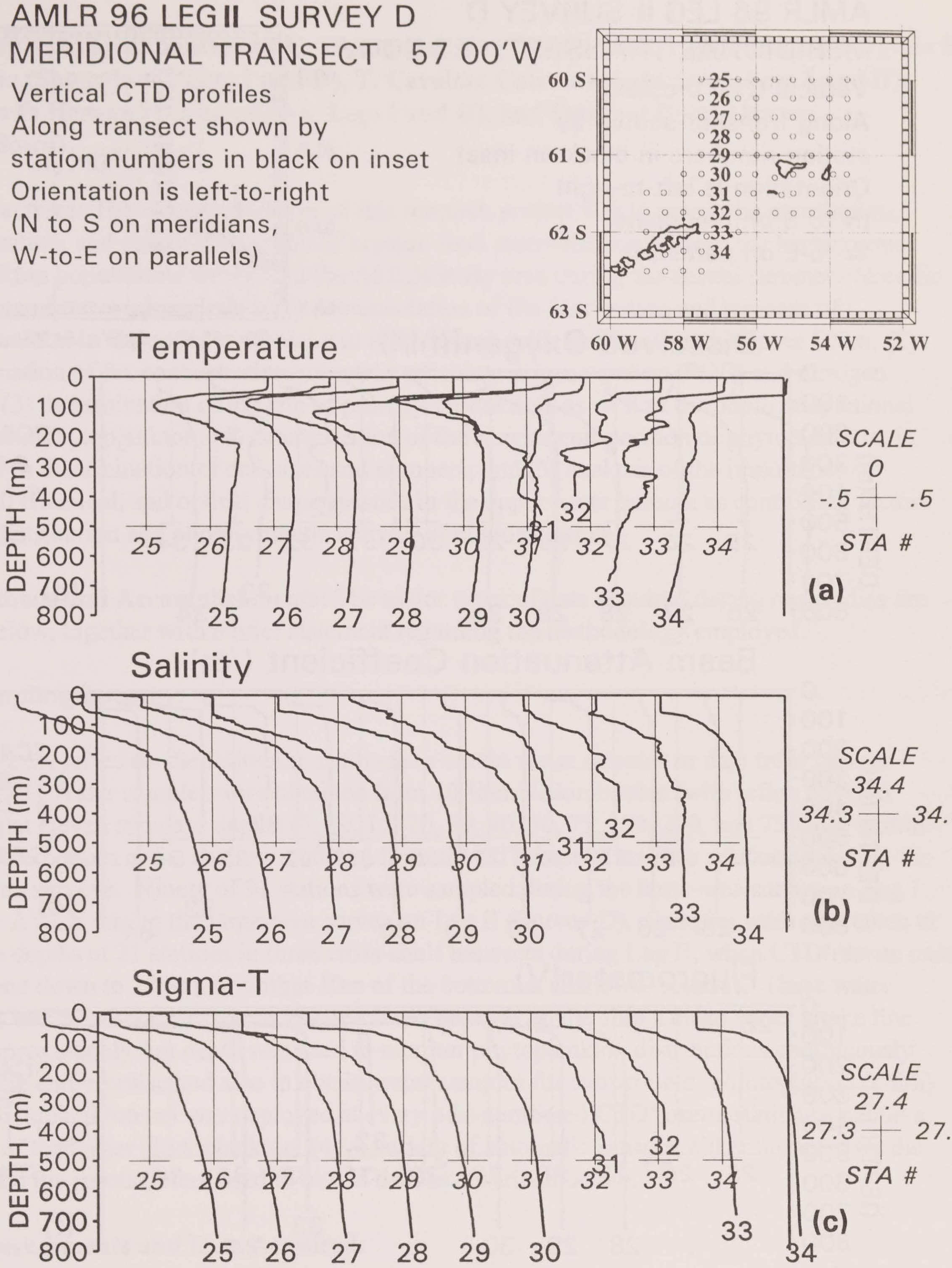


Figure 1.7 Vertical profiles of oceanographic parameters along selected meridians and parallels in the AMLR study area during Survey D. (a) Temperature; (b) Salinity; (c) Sigma-T.

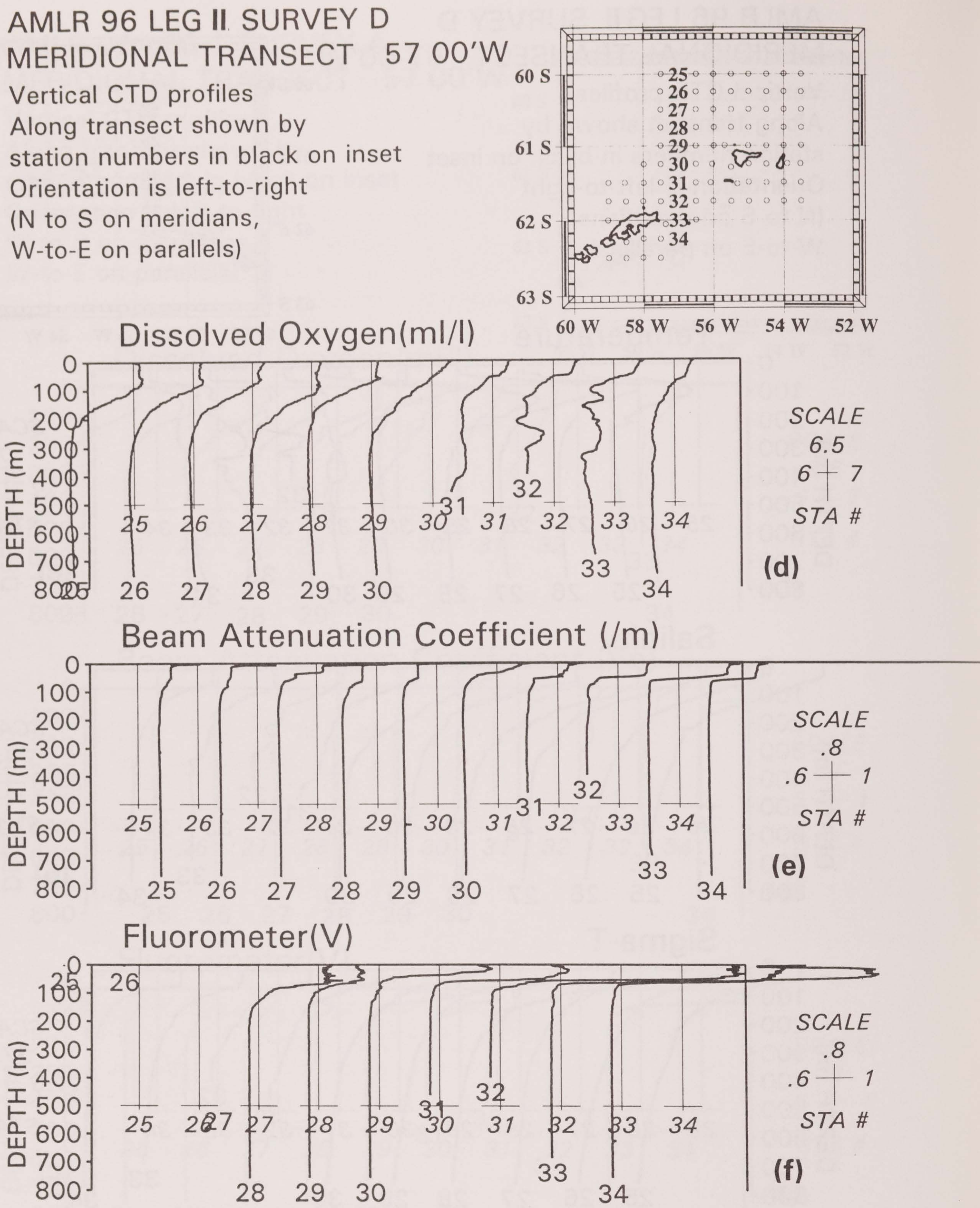


Figure 1.7 (cont.) Vertical profiles of oceanographic parameters along selected meridians and parallels in the AMLR study area during Survey D. (d) Dissolved Oxygen; (e) Beam Attenuation Coefficient; (f) Fluorometer.