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UNITED STATES
AMLR ANTARCTIC MARINE LIVING RESOURCES PROGRAM

AMLR 1995/96 FIELD SEASON REPORT

Objectives, Accomplishments and Tentative Conclusions

Edited by
Jane Martin

October 1996

ADMINISTRATIVE REPORT LJ-96-15

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION NOAA U.S. DEPARTMENT OF COMMERCE

Southwest Fisheries Science Center
Antarctic Ecosystem Research Group

The U.S. Antarctic Marine Living Resources (AMLR) program provides information neededto formulate U.S. Policy on the conservation and international management of resources living in the oceans surrounding Antarctica. The program advises the U.S. delegation to the Convention for the Conservation of Antarctic Marine Living Resources (CCAMLR), part of the Antarctic treaty system. The U.S. AMLR program is managed by the Antarctic Ecosystem Research Group located at the Southwest Fisheries Science Center in La Jolla.

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BACKGROUND

The long-term objective of the U.S. AMLR field research program is to describe the functional relationships between krill, their predators, and key environmental variables. The field program is based on two working hypotheses: (1) krill predators respond to changes in the availability of their food source; and (2) the distribution of krill is affected by both physical and biological aspects of their habitat. In order to refine these hypotheses, a study area was designated in the vicinity of Elephant, Clarence, and the eastern end of King George Islands, hereinafter called the AMLR study area (Figure 1). A field camp was established at Seal Island, a small island off the northwest coast of Elephant Island.

Shipboard studies have been conducted in the AMLR study area for eight consecutive austral summers to describe variations within and between seasons in the distributions of nekton, zooplankton, phytoplankton, and water types. Complementary reproductive and foraging behavior studies on breeding seals and penguins have been accomplished each austral summer at Seal Island. However, because Seal Island was recently found to be geologically unstable and possibly unsafe due to landslide hazards, research at the field camp was significantly abbreviated during the 1996 season. Research on the ecology of Adelie penguins has been conducted at Palmer Station during each austral spring and summer.

SUMMARY OF 1996 RESULTS

Shipboard surveys were conducted during two 30-day legs in the AMLR study area between mid-January and mid-March 1996. Two major water types were identified: Drake Passage and Bransfield Strait. A prevailing southwest to northeast water flow was seen across the AMLR study area. The 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. High phytoplankton biomass values were found in waters over the continental shelf northeast of Elephant Island during Leg I, while during Leg II the richest areas were found east of King George Island. Relatively high phytoplankton biomass was found south of Elephant Island during both legs. The lowest phytoplankton concentrations were found in the northwest portion of the study area, in Drake Passage waters. During both legs, areas of high krill density were mapped in wide bands along the north side of King George and Elephant Islands where water depth was greater than 200m. The mean krill abundance value from the Elephant Island area in January 1996 was the highest observed there since March 1983 and is mostly due to the large numbers of juvenile krill. The krill recruitment index, based on the relative proportion of total krill comprised by the 1-year old age group during Leg I's survey, was 0.622 (s.e. = 0.849). This value was one of the highest recorded over the past 18 years and indicates strong recruitment of the 1994/95 year class. Strong recruitment results from good spawning success and survival of early stages spawned during the previous year. This was associated with large proportions of advanced female maturity stages during January-March 1995 and extensive sea-ice conditions in the Antarctic Peninsula region during winter 1995. These results support hypothesized relationships between krill recruitment success, krill spawning seasonality, and winter sea-ice conditions. Similar to 1995, salp abundance was relatively low this year, which seems to be correlated with the extensive sea-ice cover of the previous winter. On Seal Island, the highest count of male fur seals hauled out was substantially larger than the number recorded during the same period in the previous season. Fur seal pup production was considerably higher compared to the previous season. Breeding numbers of chinstrap penguins this season were lower than average. Estimates from this year may indicate the lowest breeding population recorded. However, penguins that nested produced chicks whose survival and growth appeared to be normal. The macaroni penguin population appeared to be near normal compared to historical averages. At Palmer Station, most of the measured parameters related to breeding biology of Adelie penguins exhibited a slight decrease between the 1994/95 and 1995/96 seasons, including breeding population size, percent two-chick broods, total chick production, and chick fledging weights. The exception to this trend was breeding success, which exhibited an increase.

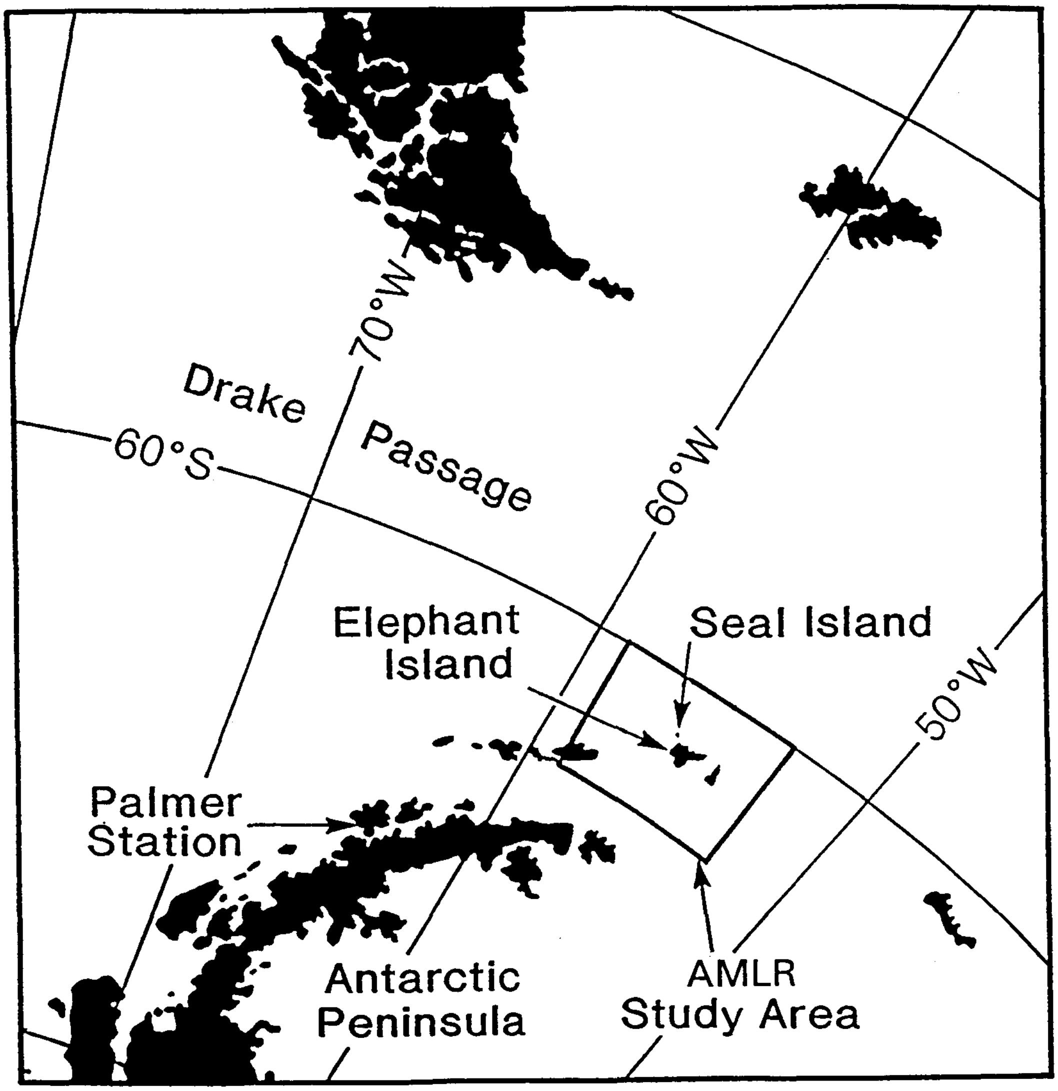


Figure 1. Locations of the U.S. AMLR field research program: AMLR study area, Seal Island, and Palmer Station.

OBJECTIVES

Shipboard Research:

1. Map meso-scale (10's to 100's of kilometers) features of water mass structure, phytoplankton biomass and productivity, and zooplankton constituents (including krill) in the AMLR study area.

2. Estimate the abundance and dispersion of krill in the AMLR study area.

3. Conduct acoustic and net sampling surveys in Admiralty Bay, King George Island to describe krill abundance and distribution.

4. Conduct a census of Antarctic fur seal pups at selected sites in the South Shetland Islands.

5. Identify newly-established or previously unknown fur seal colonies in the South Shetland Islands.

6. Resight tagged Antarctic fur seals in the South Shetland Islands.

7. Record presence of marine debris at sites in the South Shetland Islands, and remove any easily carried debris.

8. Conduct cross-shelf transects north of King George Island, and northwest and south of Elephant Island to describe water mass structure across the shelf-break.

9. Conduct directed net tows in these areas using a Multiple-Opening-Closing-Net-Environmental-Sampling-System (MOCNESS) to correlate acoustic data with species and target sizes.

10. Collect continuous measurements of ship's position, sea surface temperature, salinity, turbidity, fluorescence, air temperature, barometric pressure, relative humidity, wind speed and direction, and solar irradiance.

11. Provide logistical support to Seal Island field camp.

Land-based Research:

<u>Seal Island</u>

1. Monitor the abundance of pinnipeds and seabirds on Seal Island.

2. Record presence of known-aged and previously instrumented or handled pinnipeds and seabirds.

3. Weigh Antarctic fur seal pups at a standard time during the field season.

4. Weigh and measure fledging chinstrap penguin chicks.

5. Dismantle and remove camp structures no longer in use.

<u>Palmer Station</u>

1. Determine Adelie penguin breeding population size.

2. Determine Adelie penguin breeding success.

3. Obtain information on Adelie penguin diet composition and meal size.

4. Determine Adelie penguin chick weights at fledging.

5. Determine adult Adelie penguin foraging trip durations.

6. Band 1000 Adelie penguin chicks for future demographic studies.

7. Determine Adelie penguin breeding chronology.

DESCRIPTION OF OPERATIONS

Shipboard Research:

In previous seasons, the AMLR program's shipboard research was conducted aboard the NOAA Ship *Surveyor*. Due to the decommissioning of *Surveyor* in the fall of 1995, this year's cruise was conducted aboard the chartered Russian research vessel (R/V) *Yuzhmorgeologiya.*

<u>Itinerary</u>

Shakedown Cruise:	Depart Punta Arenas, Chile	14 January 1996
	Arrive Punta Arenas	16 January
Leg I:	Depart Punta Arenas	18 January
	Drop off Seal Island Team	21 January
	Transect AB1	22 January
	Acoustic Transducer Calibration	22 January
	Transect AB2	22 January
	Large-area Survey (Survey A)	23 January - 4 February
	Recover Seal Island Team/Materials	5 February
	Fur seal Survey	6-12 February
	Drop off Seal Island Team	12 February
	Arrive Punta Arenas	16 February
Leg II:	Depart Punta Arenas	19 February
	Recover Seal Island Team/Materials	22-23 February
	Large-area Survey (Survey D)	24 February - 8 March
	Acoustic Transducer Calibration	8 March
	Cross-shelf Transects/MOCNESS	9-14 March
	Arrive Punta Arenas	17 March

Shakedown Cruise.

1. Sea trials of acoustic, oceanographic, and net sampling equipment were conducted for three days in the Strait of Magellan aboard the R/V *Yuzhmorgeologiya*.

Leg I.

1. The R/V *Yuzhmorgeologiya* departed Punta Arenas, Chile via the eastern end of the Strait of Magellan. Land fall was made at Seal Island, and personnel and cargo were transferred to the field camp. In addition, one of the existing camp structures was removed from the camp and loaded aboard the ship.

2. Three acoustic transducers were calibrated in Ezcurra Inlet, King George Island. The transducers, operating at 38 kilohertz (kHz), 120kHz, and 200kHz, were hull-mounted and down-looking. Standard spheres were positioned beneath the transducers via outriggers and monofilament line. The beam patterns were mapped, and system gains were determined for all three transducers.

3. Acoustic data and four net samples were collected along transects (Transect AB1, Stations X1 and X2; Transect AB2, Stations X3 and X4) when entering and leaving Admiralty Bay to complement diet studies on Adelie penguins in the area (Figure 2).

4. A large-area survey of 91 Conductivity-Temperature-Depth (CTD)/rosette and net sampling stations, separated by acoustic transects, was conducted in the vicinity of Elephant, Clarence, and the eastern end of King George Islands (Survey A, Stations A1-A91, Figure 3). Acoustic transects were conducted at 10 knots, using hull-mounted 38kHz, 120kHz, and 200kHz down-looking transducers. Operations at each station included: (1) measurement of temperature, salinity, oxygen, light, transmissometer, and fluorescence profiles; (b) collection of discrete water samples at standard depths for analysis of chlorophyll-a content, particulate absorption spectra, particulate organic carbon and nitrogen concentrations, primary production, size fractionation, floristics, and inorganic nutrient content; and (c) deployment of an Isaacs-Kidd Midwater Trawl (IKMT) to obtain samples of zooplankton and micronekton.

5. The field team was recovered from Seal Island, along with 14 boat loads of building materials. During the visit, Antarctic fur seal pups were counted at several colonies in the Seal Island archipelago.

6. An Antarctic fur seal census was conducted throughout the South Shetland Islands (Figure 4). During these surveys fur seal pups were counted; newly-established or previously unknown colonies were identified; sightings of previously-tagged fur seals were recorded; presence of debris was recorded; and easily carried debris was removed.

7. The field team was disembarked at Seal Island, and the ship returned to Punta Arenas for a two day portcall.

Leg II.

1. The R/V *Yuzhmorgeologiya* departed Punta Arenas, Chile via the eastern end of the Strait of Magellan and arrived at Seal Island. The field team and several boat loads of building materials were recovered from the island.

2. A large-area survey, similar to Survey A, was conducted around Elephant, Clarence, and the eastern end of King George Islands (Survey D, Stations D1-D91, Figure 3). Acoustic transects were again conducted at 10 knots, using the hull-mounted 38kHz, 120kHz, and 200kHz down-looking transducers.

3. Following the completion of Survey D, the three hull-mounted transducers were calibrated again in Ezcurra Inlet, King George Island using similar methods to the first calibration.

4. Three cross-shelf transects were conducted: north of King George Island, northwest of Elephant Island, and south of Elephant Island (Figure 5). During each transect, acoustic data were recorded and seven CTD/rosette stations were completed (a total of 21 CTD/rosette stations, X1-X21). Twenty-three directed net tows (MOCX1 - MOCX23) were also accomplished in these areas using a MOCNESS.

5. The R/V *Yuzhmorgeologiya* returned to Punta Arenas, completing Leg II.

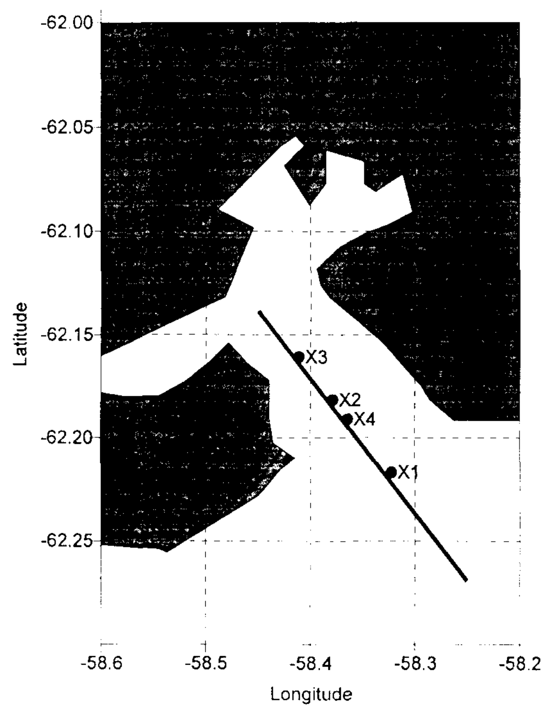


Figure 2. Admiralty Bay transects (Transect AB1, Stations X1 and X2; Transect AB2, Stations X3 and X4).

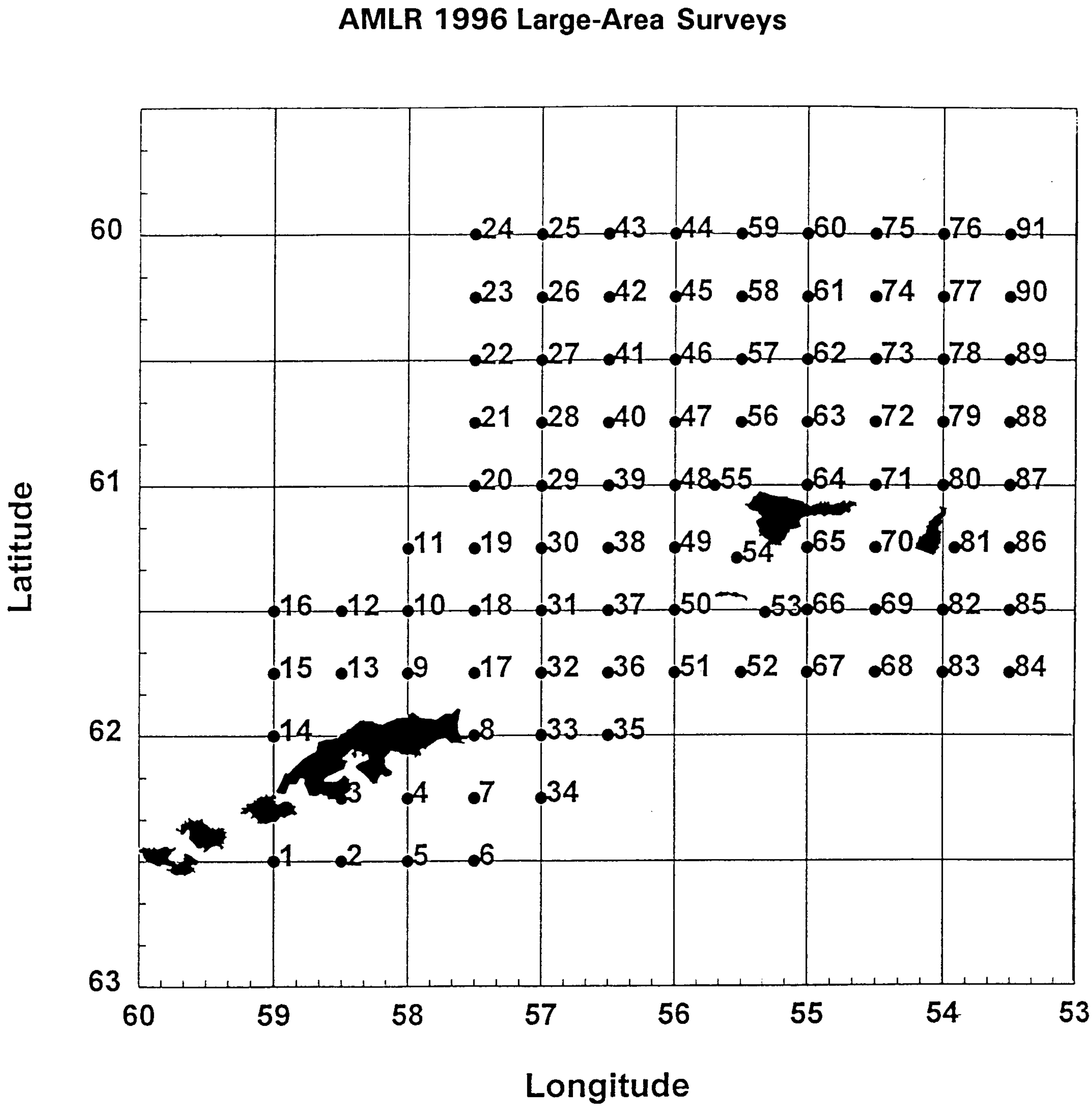


Figure 3. The large-area surveys for AMLR 96 (Surveys A and D) in the vicinity of Elephant, Clarence, and the eastern end of King George Islands (AMLR study area).

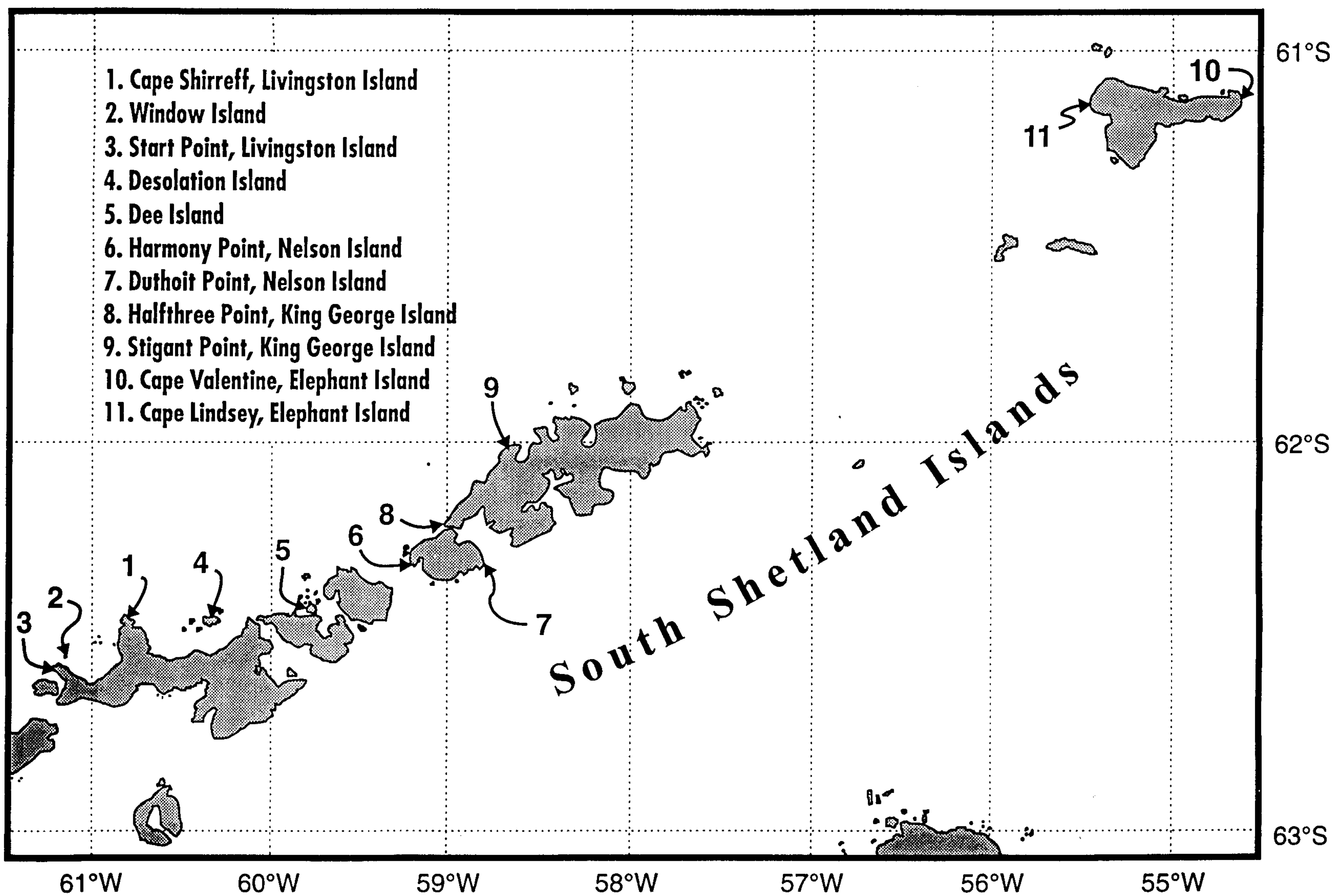


Figure 4. Fur seal census conducted throughout the South Shetland Islands.

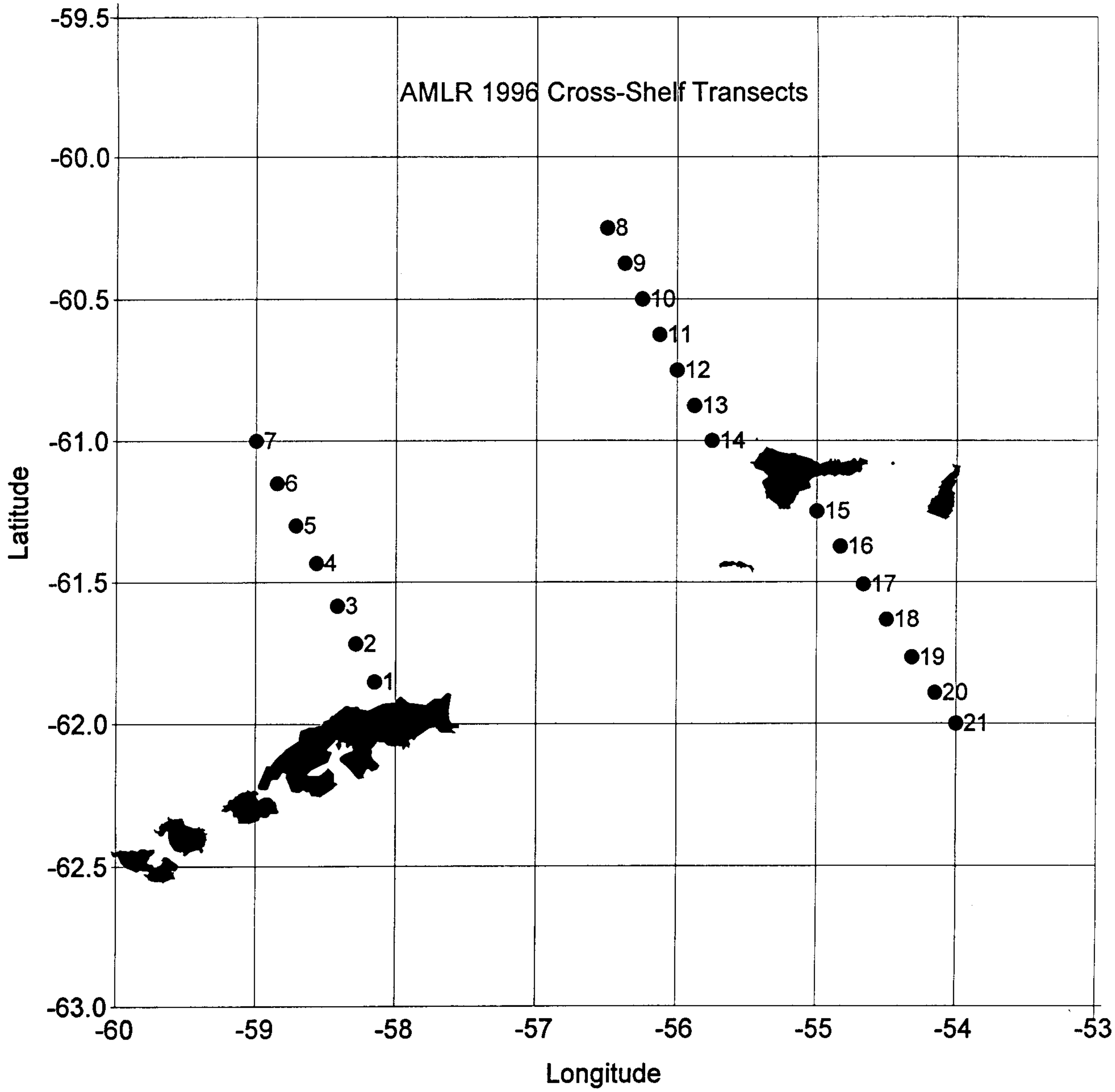


Figure 5. Cross-shelf transects on Leg II; twenty-one CTD/rosette stations (Stations X1-X21).

Land-based Research:

Seal Island

1. A four-person field team (R. Holt, W. Cobb, B. Walker, and W. Meyer) arrived at Seal Island on 21 January. The team disassembled a weatherport structure at the camp and prepared the materials for transport to the ship.

2. Resights of banded penguins and seals were conducted, fur seal pups were counted and weighed, and chinstrap and macaroni penguin chicks were counted at selected colonies on the island.

3. The field team was recovered from the island on 5 February to conduct a fur seal survey throughout the South Shetland Islands.

4. A three-person field team (R. Holt, W. Cobb, and W. Armstrong) was disembarked at Seal Island on 12 February. The team continued to conduct fur seal pup counts and to identify banded seals and penguins. Fledged penguin chicks were weighed and measured.

5. The field camp was closed on 23 February, and the team returned to the ship for the remainder of Leg II.

Palmer Station

1. Field work at Palmer Station was initiated on 10 October 1995 and terminated on 27 March 1996.

2. One hundred Adelie penguin nests on Humble Island were observed from clutch initiation to creche to determine breeding success.

3. Breeding population size was determined by censusing the number of breeding pairs of Adelie penguins at 54 sample colonies during the peak egg-laying period (21-23 November).

4. The proportion of 1 and 2 Adelie penguin chick broods was assessed at 49 sample colonies between 5 and 6 January. Chick production was determined by censusing Adelie penguin chicks on 18 and 20 January at 54 sample colonies when approximately 2/3 of them were in the creche stage.

5. Fledging weights of Adelie penguin chicks were obtained at beaches near the Humble Island rookery between 4 and 23 February.

6. One thousand Adelie penguin chicks were banded as part of continuing demographic studies at selected AMLR colonies on Humble Island.

7. In conjunction with diet studies, adult Adelie penguins were captured and lavaged as they approached their colonies to feed chicks on Torgersen Island.

8. Thirty-three Adelie penguins breeding at the Humble Island rookery were fitted with radio transmitters; radio receivers and automatic data loggers recorded presence/absence data for these animals.

SCIENTIFIC PERSONNEL

Cruise Leader:
- Roger P. Hewitt, Southwest Fisheries Science Center (Shakedown Cruise, Leg I)
- Rennie S. Holt, Southwest Fisheries Science Center (Leg II)

Physical Oceanography:
- Anthony F. Amos, University of Texas at Austin (Shakedown, Leg I)
- Charles Rowe, University of Texas at Austin (Leg II)
- Andrea Wickham, University of Texas at Austin (Shakedown, Legs I and II)

Phytoplankton:
- Osmund Holm-Hansen, Scripps Institution of Oceanography (Shakedown)
- T. Carolina Calvete, Universidad Católica de Valparaíso (Shakedown, Legs I and II)
- E. Walter Helbling, Scripps Institution of Oceanography (Shakedown, Legs I and II)
- Marcelo P. Hernando, Centro Austral de Invest. Cientificas (Shakedown, Legs I and II)
- Virginia E. Villafañe, Scripps Institution of Oceanography (Shakedown, Legs I and II)

Krill and Zooplankton Sampling:
- Valerie Loeb, Moss Landing Marine Laboratories (Shakedown, Legs I and II)
- Wesley Armstrong, Southwest Fisheries Science Center (Shakedown, Legs I and II)
- William T. Cobb, Southwest Fisheries Science Center (Shakedown, Legs I and II)
- Michael Force (Legs I and II)
- Dawn Outram, Moss Landing Marine Laboratories (Shakedown, Legs I and II)
- Charles F. Phleger, San Diego State University (Leg I)
- Volker Siegel, Sea Fisheries Research Institute (Leg I)
- Guiomar Silva-Azevedo, Western Administrative Support Center (Leg II)
- Ruth Yender, NOAA Hazardous Materials Division (Leg I)

Bioacoustic Survey:
- David Demer, Southwest Fisheries Science Center (Shakedown, Leg II)
- David Greene (Shakedown)
- Elizabeth Mitchell, Northwest Observers (Leg I)
- Gabriela V. Chavez, Universidad Autonoma de Baja California Sur (Leg II)

Seal Island Field Team:
- William R. Meyer
- Brian G. Walker

Palmer Station:
- William R. Fraser, Montana State University
- Donna L. Patterson, Montana State University
- Eric J. Holm, Montana State University
- Karen M. Carney, Montana State University
- John Carlson, Montana State University

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.

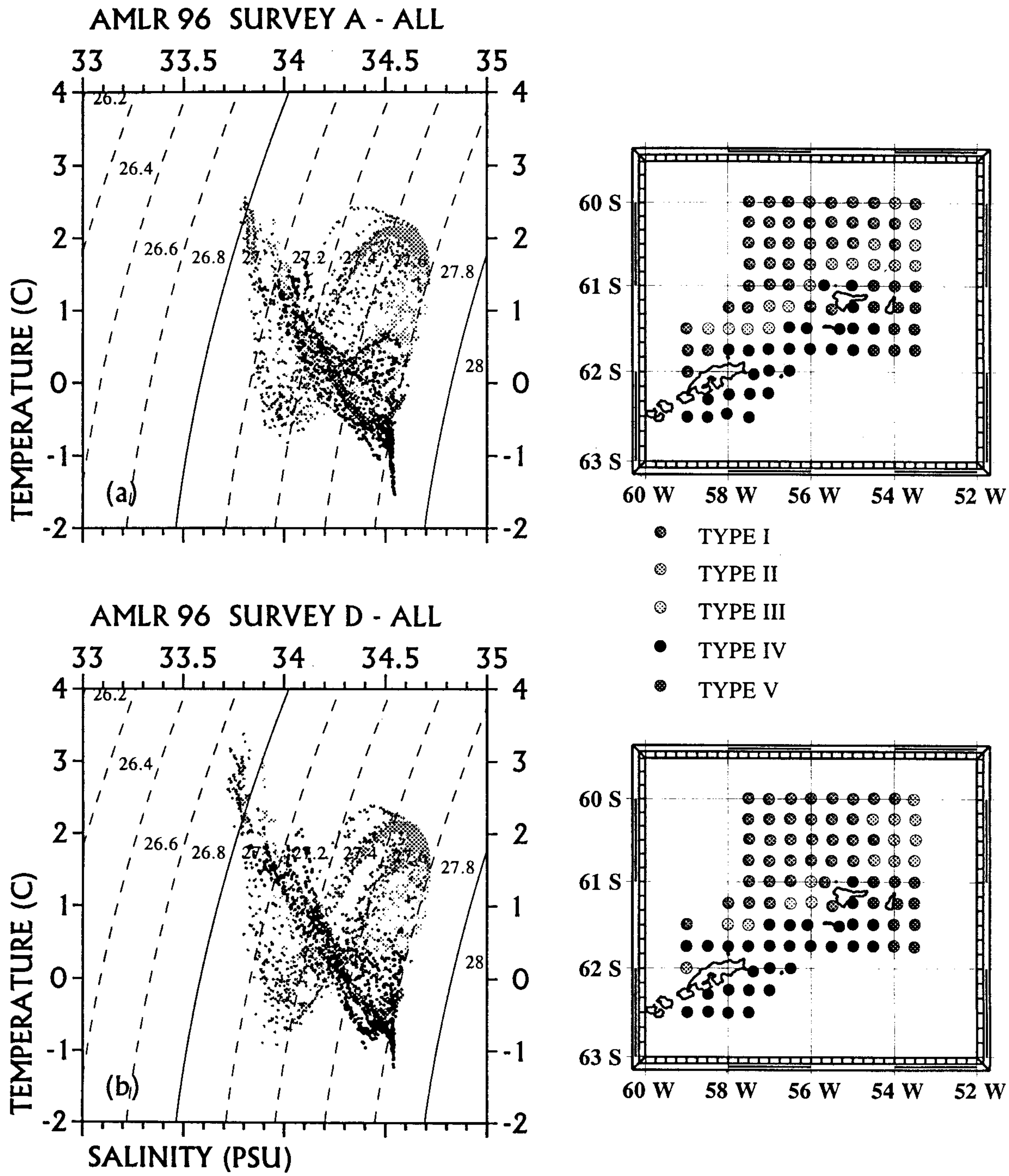


Figure 1.1 Composite Temperature/Salinity diagram for all stations from the large-area surveys. (a) Survey A, Leg I; (b) Survey D, Leg II. Symbols on inset maps show station locations shaded by water types.

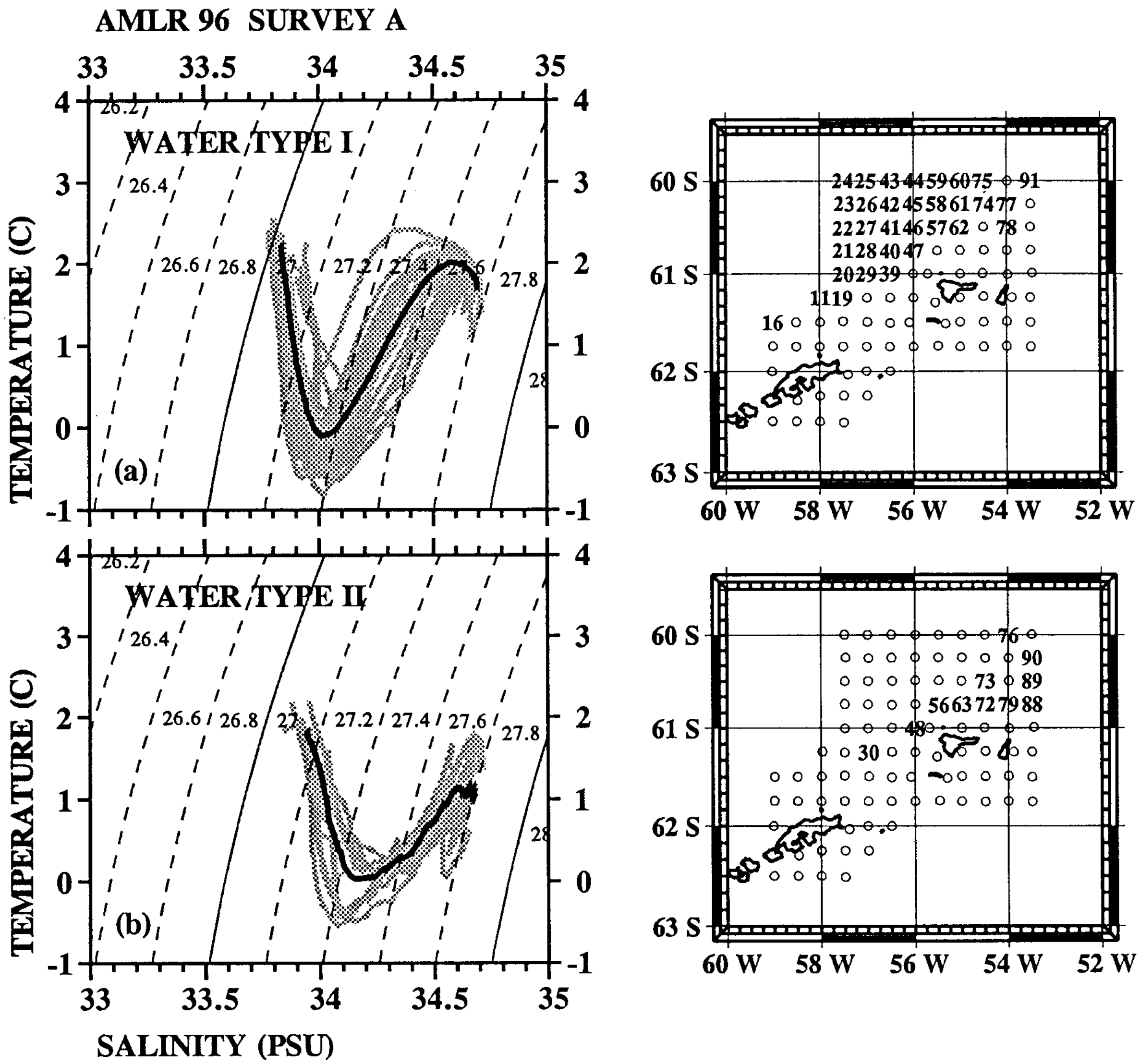


Figure 1.2 Temperature/Salinity curves for various water types in the AMLR study area. The gray area is the T/S envelope of all stations identified as having the water type characteristics. The heavy black curve is the mean T/S curve for each type. Inset maps show the location and numbers of stations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

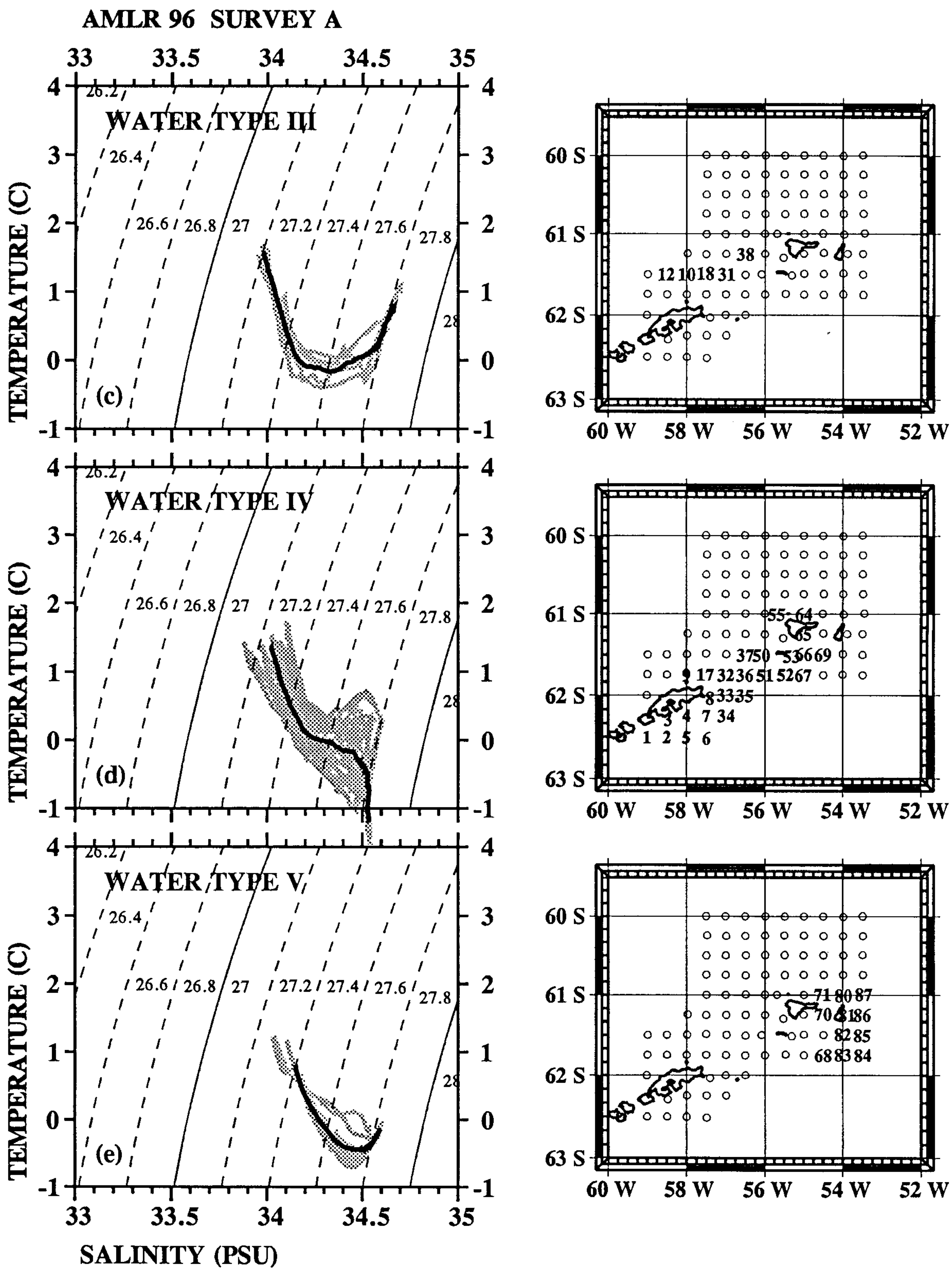


Figure 1.2 (cont.) (c) Survey A, water type III; (d) Survey A, water type IV; (e) Survey A, water type V.

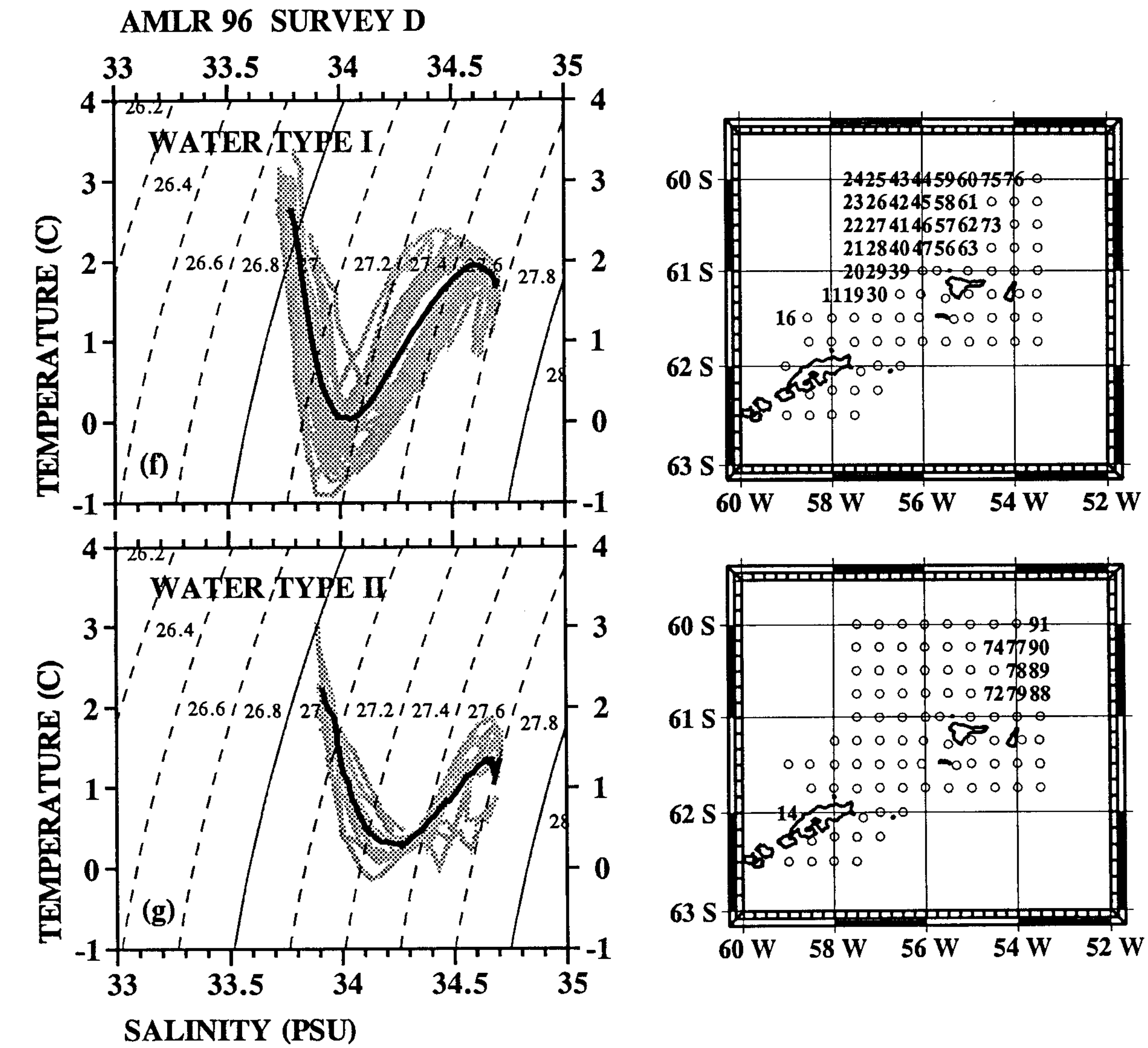


Figure 1.2 (cont.) (f) Survey D, water type I; (g) Survey D, water type II.

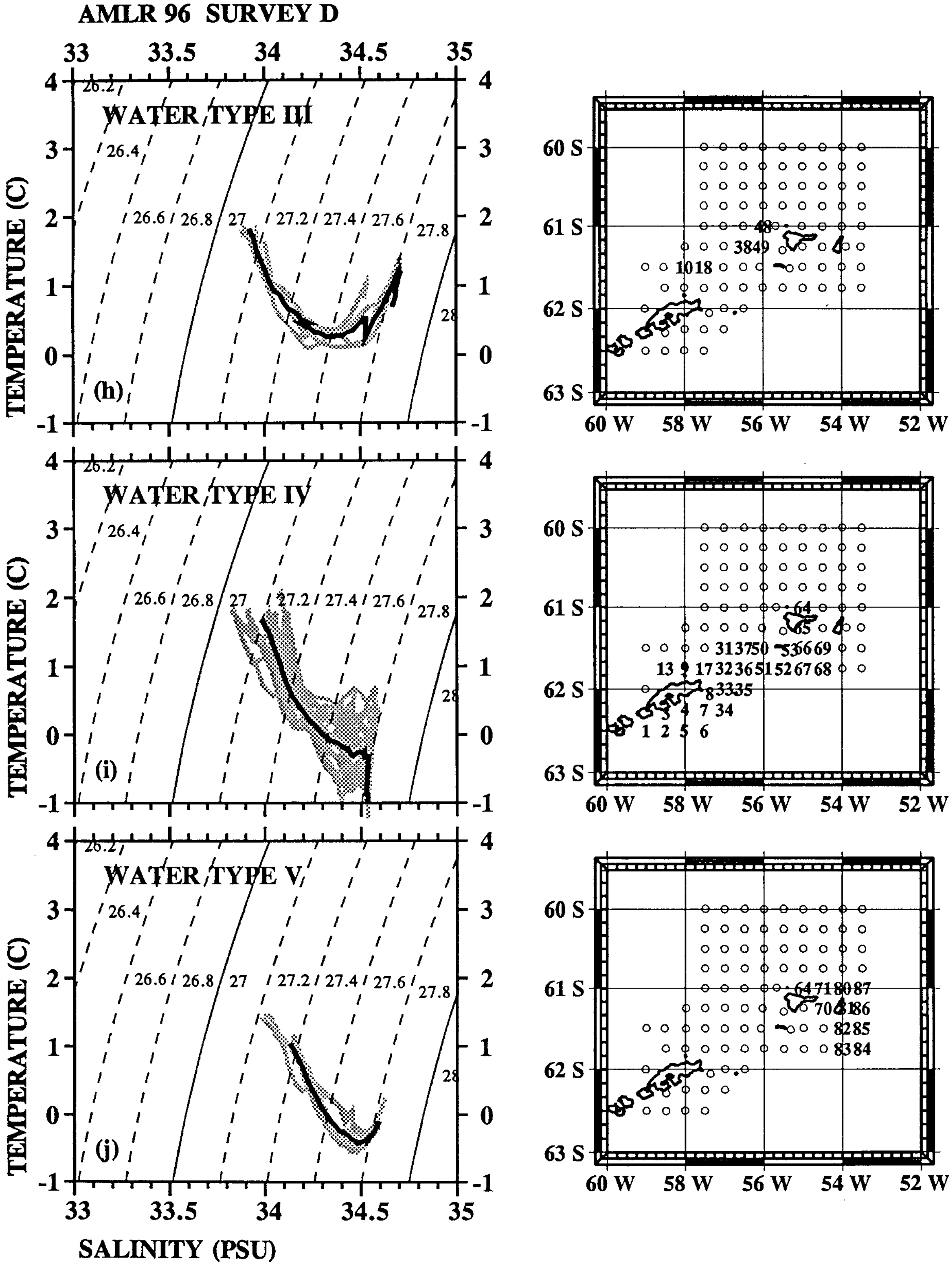


Figure 1.2 (cont.) (h) Survey D, water type III; (i) Survey D, water type IV; (j) Survey D, water type V.

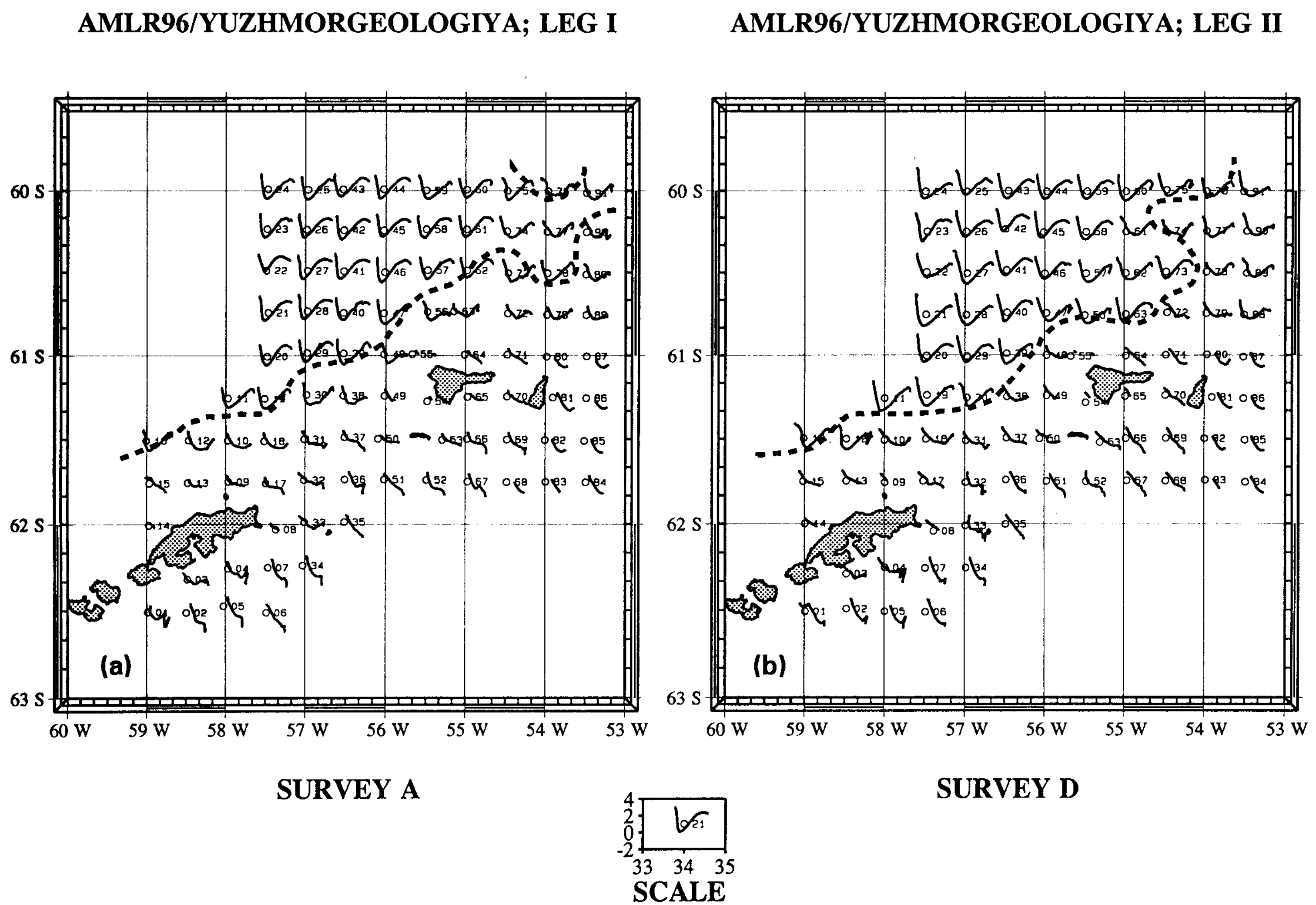


Figure 1.3 "Worm diagram" showing Temperature/Salinity curves for individual stations plotted at the station location. The circle representing station location is plotted at S=34, T=+0.5 (see scale inset). Dashed lines show divisions between water type I and the rest of the water types. (a) Survey A,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

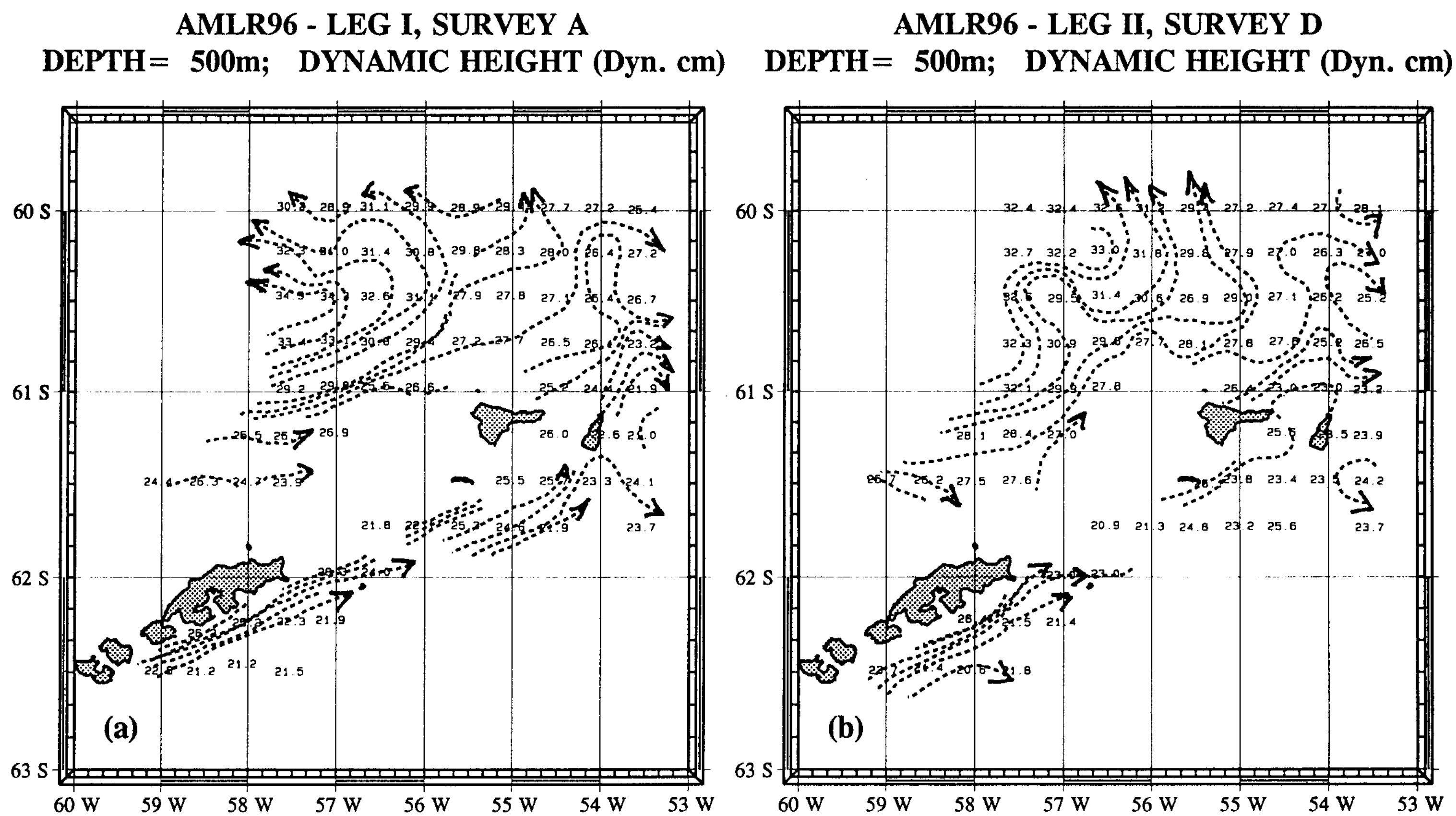


Figure 1.4 Dynamic topography of AMLR study area. Dynamic height with respect to 500db at the surface (dyn. cm.). (a) Survey A, Leg I; (b) Survey D, Leg II.

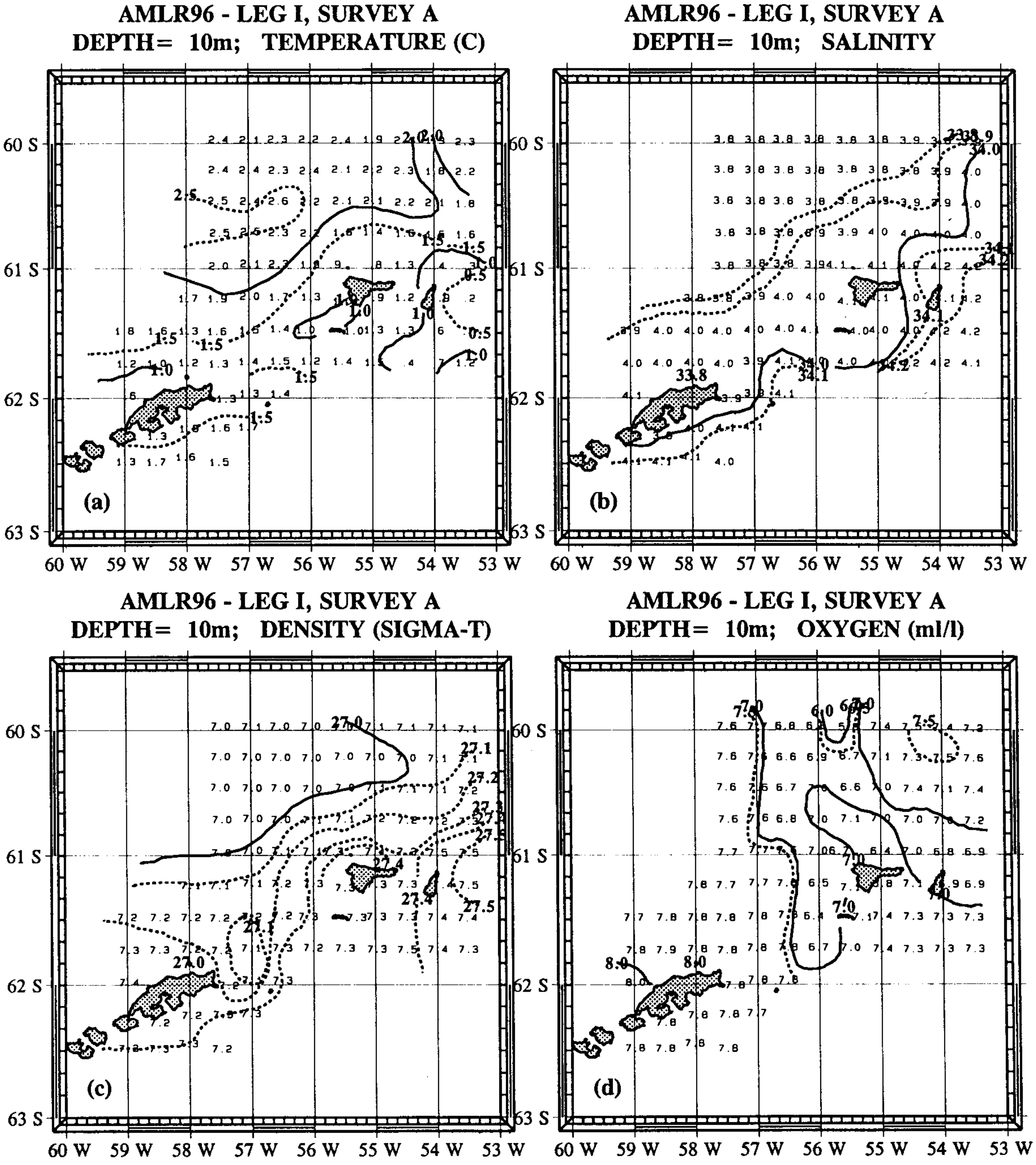


Figure 1.5 Horizontal maps of near surface oceanographic conditions in the AMLR study area during Survey A. (a) Temperature, contour interval 0.5C; (b) Salinity, contour interval 0.1; (c) Density (Sigma-T), contour interval 0.1; (d) Dissolved oxygen, contour interval .5 ml/liter.

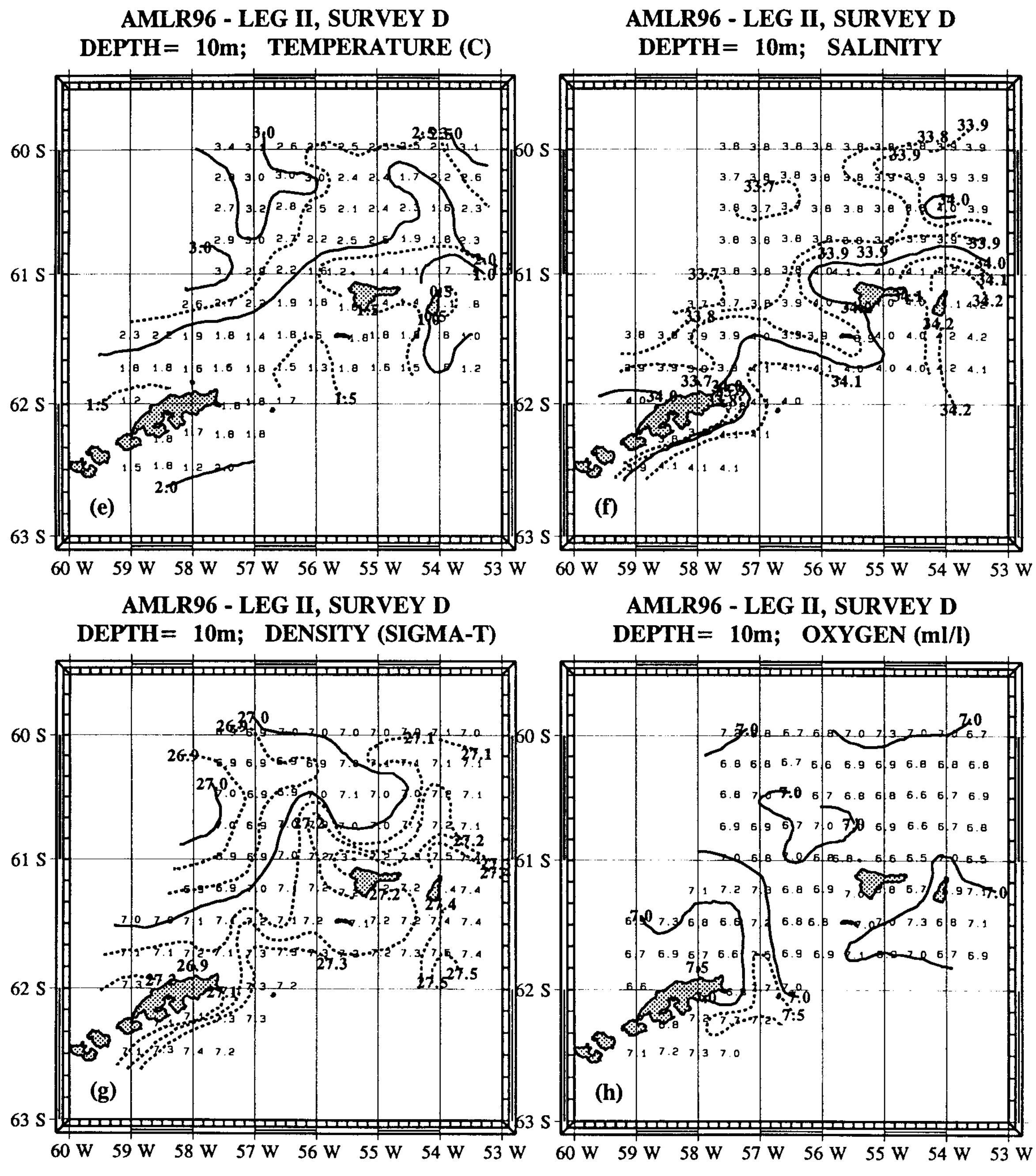


Figure 1.5 (cont.) Horizontal maps of near surface oceanographic conditions in the AMLR study area during Survey D. (e) Temperature, contour interval 0.5C; (f) Salinity, contour interval 0.1; (g) Density (Sigma-T), contour interval 0.1; (h) Dissolved oxygen, contour interval .5 ml/liter.

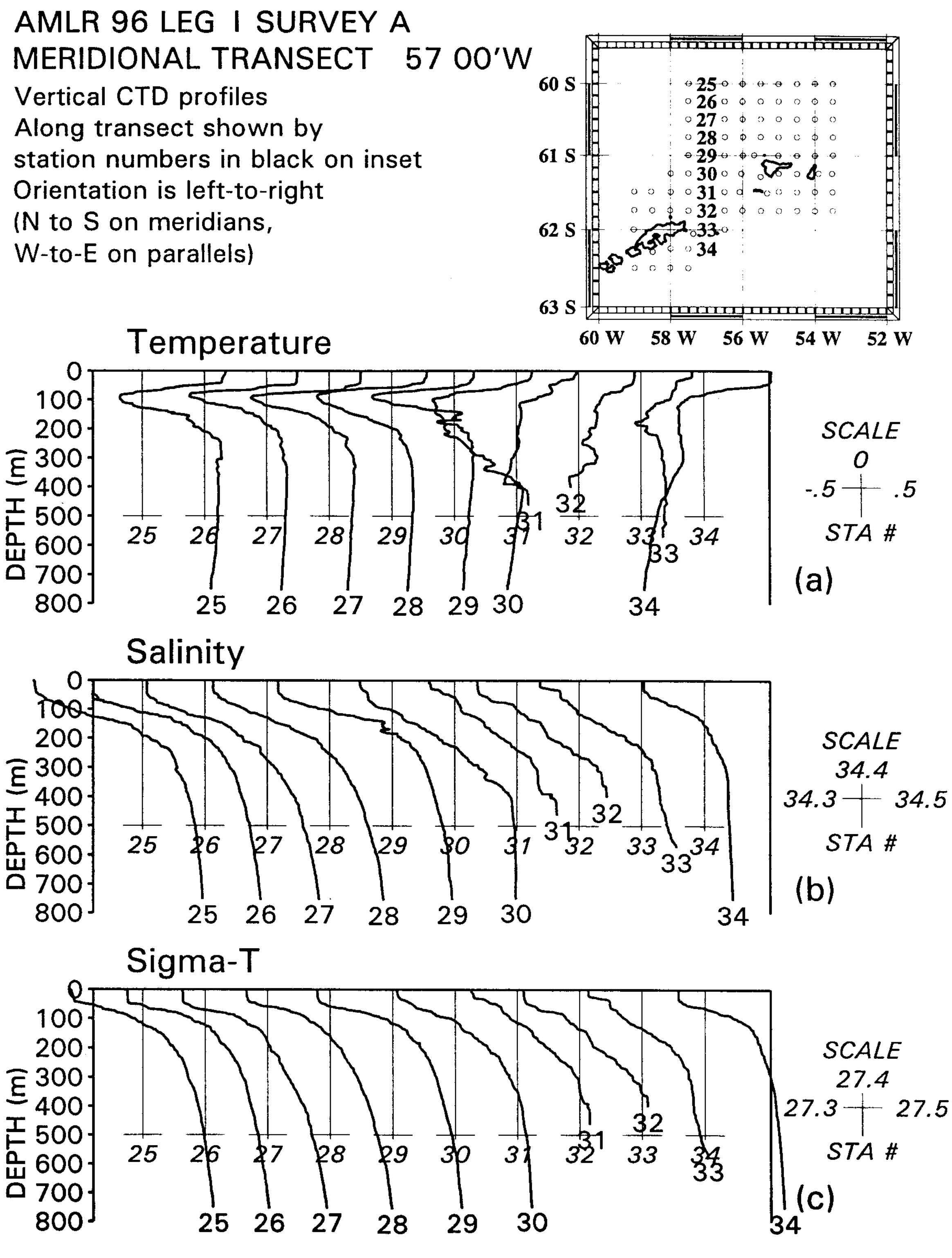


Figure 1.6 Vertical profiles of oceanographic parameters along selected meridians and parallels in the AMLR study area during Survey A. (a) Temperature; (b) Salinity; (c) Sigma-T.

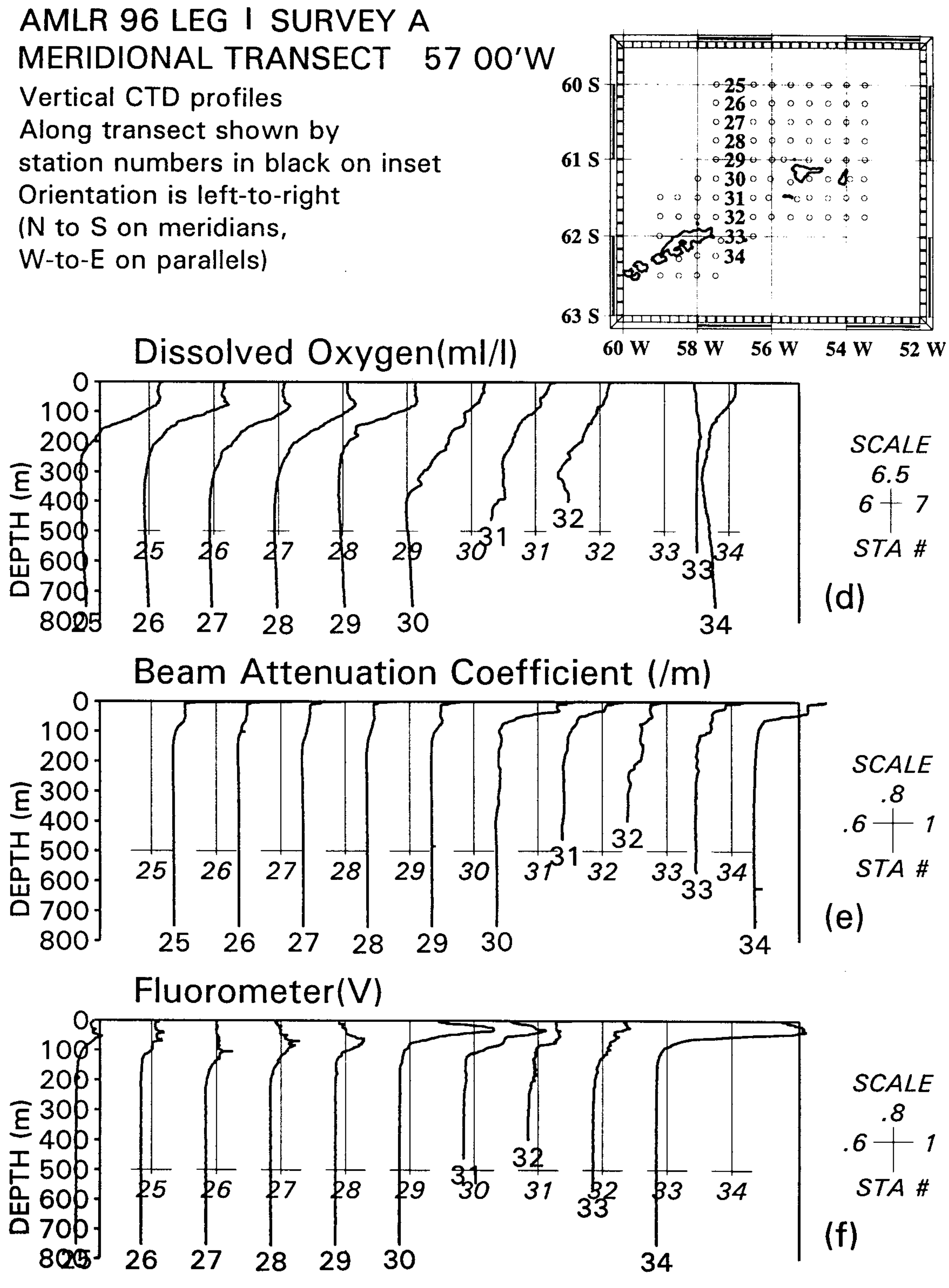


Figure 1.6 (cont.) Vertical profiles of oceanographic parameters along selected meridians and parallels in the AMLR study area during Survey A. (d) Dissolved oxygen; (e) Beam Attenuation Coefficient; (f) Fluorometer.

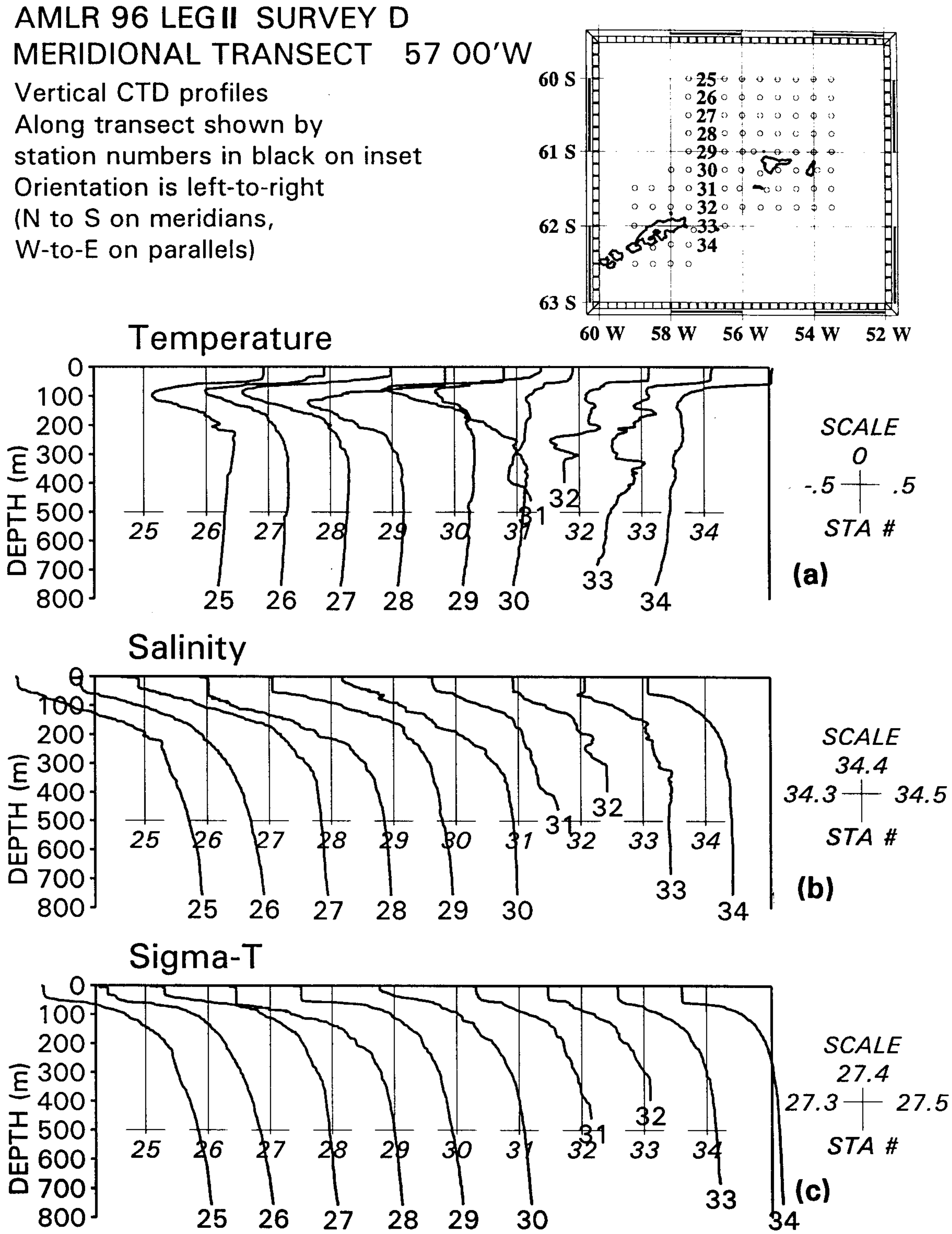


Figure 1.7 Vertical profiles of oceanographic parameters along selected meridians and parallels in the AMLR study area during Survey D. (a) Temperature; (b) Salinity; (c) Sigma-T.

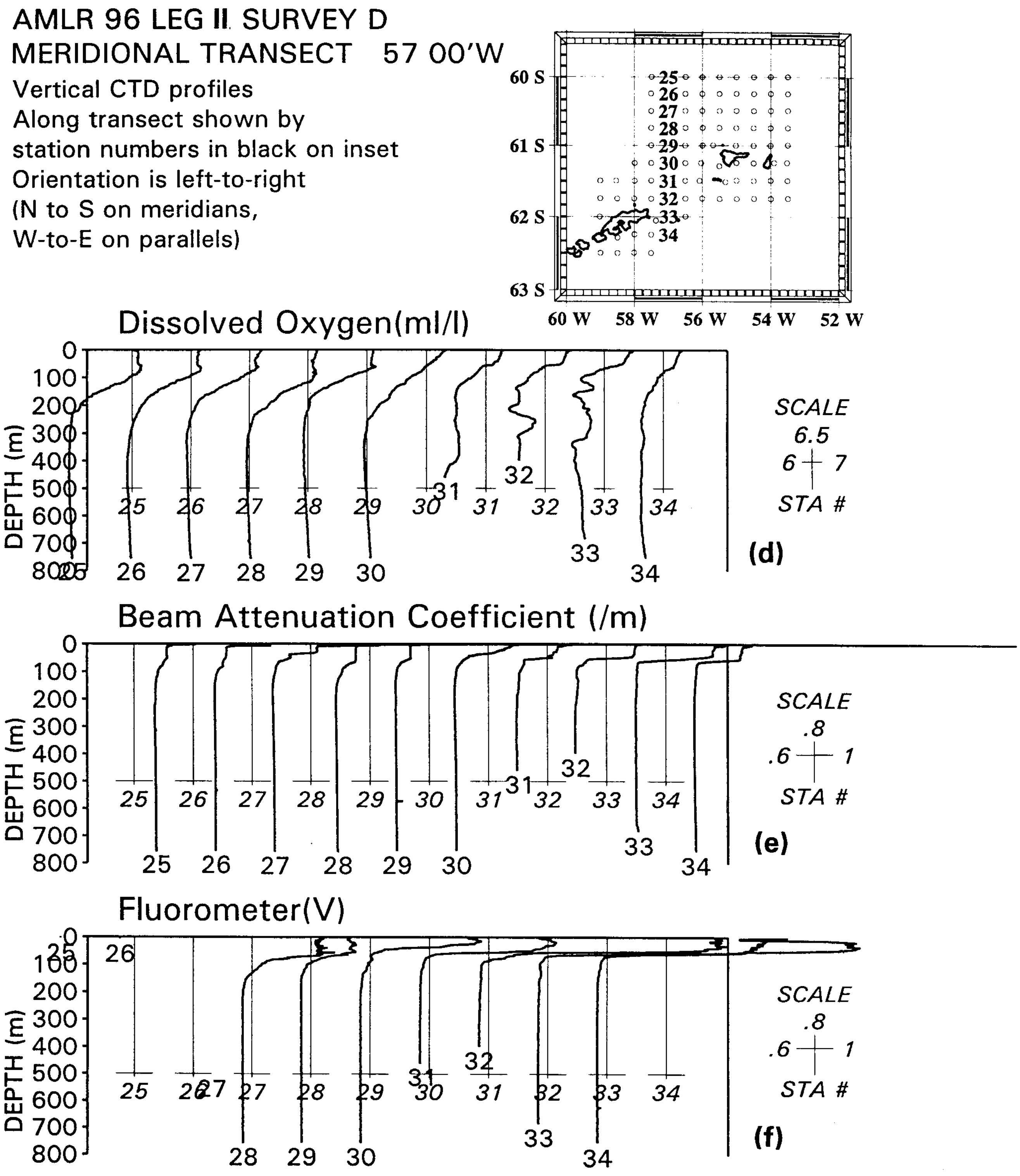


Figure 1.7 (cont.) Vertical profiles of oceanographic parameters along selected meridians and parallels in the AMLR study area during Survey D. (d) Dissolved Oxygen; (e) Beam Attenuation Coefficient; (f) Fluorometer.

2. Phytoplankton; submitted by E. Walter Helbling (Shakedown, Legs I and II), Virginia E. Villafañe (Shakedown, Legs I and II), T. Carolina Calvete (Shakedown, Legs I and II), Marcelo P. Hernando (Shakedown, Legs I and II), and Osmund Holm-Hansen (Shakedown).

2.1 Objectives: The overall objective of this research project was to assess the distribution, concentration, and rate of production of organic food reservoirs available to the herbivorous zooplankton populations throughout the AMLR study area during the austral summer. Specific objectives of our work included: (1) documentation of the distribution and biomass of phytoplankton in the upper water column (0 to 750m), with emphasis on the upper 100m; (2) determination of the concentrations of total particulate organic carbon (POC) and nitrogen (PON); (3) determination of the rate of primary production, as well as the photo-adaptational state of the phytoplankton; (4) determination of the species composition of phytoplankton, in addition to determination of cell sizes and numbers; and (5) analysis of the importance of physical, chemical, and optical characteristics in the upper water column as controlling factors for the distribution and photosynthetic activity of phytoplankton.

2.2 Methods and Accomplishments: The major types of data acquired during our studies are listed below, together with a brief statement regarding the methodology employed.

(A) Sampling Strategy:

The protocol relied on the following methods to obtain water samples or data from various sensors: (1) Water samples were obtained from 10-liter Niskin bottles (with teflon covered springs) at eleven standard depths (5, 10, 15, 20, 30, 40, 50, 75, 100, 200, and 750m or within 10m of the bottom at the shallow stations) from the CTD/rosette stations conducted during the large-area surveys. Ninety of 91 stations were sampled during the large-area survey on Leg I (Survey A) and during the large-area survey on Leg II (Survey D). Samples were also taken at variable depths at 21 stations in three cross-shelf transects during Leg II, when CTD/rosette casts were done down to 2000m or within 10m of the bottom at shallower stations. These water samples were used for measurements described below. (2) The ship's clean water intake line from approximately 5m depth was used to monitor phytoplankton distributions continuously during the entire cruise and also to obtain water samples for extraction of chlorophyll-a (chl-a). (3) A phytoplankton net was deployed at every odd-numbered CTD/rosette station to obtain a sample of the larger phytoplankton. (4) A variety of automatic sensors, either mounted on the ship or on the rosette, were used to obtain data as described below.

(B) Measurements and Data Acquired:

(1) Photosynthetic pigments: Chl-a concentrations, which are used to estimate phytoplankton biomass, were measured in all water samples at ten depths (0-200m) obtained from the CTD/rosette casts and also from the ship's flow-through system at each CTD/rosette station. Chl-a concentrations were determined on samples filtered through glass fiber filters (GF/F, 25

millimeter), extracted in absolute methanol, and the fluorescence of the extract measured in a Turner Designs fluorometer. In addition, chl-a concentrations were estimated by *in vivo* chl-a fluorescence measurements from the ship's clean seawater intake throughout the entire cruise. *In situ* chl-a fluorescence, obtained with a pulsed fluorometer attached to the rosette, was also used to estimate phytoplankton biomass throughout the upper water column at all stations throughout the entire cruise.

(2) Biomass and organic carbon concentrations: The following measurements were made to determine phytoplankton biomass in terms of organic carbon content: (a) At the complete stations (12 stations per leg; the first station occurring after 0700 each day was designated a "complete" station; also where samples for primary productivity measurements were taken), water samples from 5, 20 and 50m depth were filtered through combusted GF/F glass fiber filters for determination of POC and PON, which will be done by gas chromatographic techniques at Scripps Institution of Oceanography. (b) Data on particulate beam attenuation coefficients (c_p) will be used to estimate POC by use of an algorithm that we have developed from data previously obtained in the AMLR program. The c_p values were obtained from two transmissometers, one attached to the CTD/rosette unit for obtaining continuous variation of c_p with depth, and the other connected to the ship's clean seawater intake line to provide data at 5m depth throughout the entire cruise. (c) Approximately 100 water samples were preserved with buffered formalin for later determination of phytoplankton cell numbers, sizes and shapes, from which total cellular volumes and organic carbon can be estimated.

(3) Phytoplankton cell size and numbers, and species composition: The following samples were obtained at every CTD/rosette station: (a) Samples from 5m depth were filtered through Nitex nylon mesh with 20 micrometer (μm) pore size to obtain a suspension of nanoplankton, defined as cells having a mean cellular diameter of < 20μm. Measurement of chl-a in the original water sample and in the fractionated sample provides an estimate of the relative abundances of nanoplankton (< 20μm) and microplankton (> 20μm) sized phytoplankton. (b) At every other station water samples from 5m depth were preserved with borate-buffered formalin (final concentration of 0.4%) for identification and quantification of phytoplankton species; at all complete stations samples for microscopic examination were taken at 5, 20, 50, and 100m. Inverted microscope techniques will be used to determine species composition, cell numbers, and cell volumes in these preserved samples. (c) A plankton net with 15μm mesh size was deployed (horizontal tow, 5 minutes) at 46 stations during each leg to obtain a sample of the larger specimens for floristic examination.

(4) Rates of primary production: Water samples, obtained from eight depths (from 5 to 75m) at all 24 complete CTD/rosette stations, were poured into 50 milliliter (ml) polycarbonate screw-cap tubes and inoculated with 5 microcuries (μCi) of ^{14}C-labeled bicarbonate. Duplicate tubes were used for each depth, in addition to one tube with water from 5m and one from 75m which were kept in darkness. These tubes were attached to a Plexiglas frame with sections of neutral density screening to simulate the irradiance at the depths from which the phytoplankton had been sampled. The tubes were exposed to solar radiation for 6-8 hours in the incubators mounted on

the upper deck; flowing surface seawater was used as temperature control. The irradiance incident upon the samples varied from 95% to 0.5% of incident solar radiation. Data from these experiments will be used to calculate the rates of primary production occurring in the AMLR study area.

(5) Photoadaptational state of the phytoplankton: Simultaneous with the primary production measurements, water samples from 5 and 50m were treated in a similar fashion except that replicate water samples from each of these two depths were exposed to the eight different irradiances (95 to 0.5% of incident solar radiation). These data will be used to determine the Photosynthesis - Irradiance (P-I) characteristics of the phytoplankton at 5 and 50m, which will be indicative of the rate of mixing in the upper water column.

(6) Inorganic nutrients: Water samples were taken from 5m depth at every other station in the survey grid for measurements of nitrite, nitrate, phosphate and silicic acid. At the complete stations, nutrient samples were taken at 5, 20, 50 and 100m depth. In addition, nutrient samples were collected at six depths (5, 20, 50, 100, 400 and 750m) at all stations in two north-south lines (Stations 25-34 and 76-83), and at three to eleven depths (variable sampling according to water depth) at 21 cross-shelf stations. All nutrient samples (total of 556) were frozen (-20°C) until later analysis using an autoanalyzer at the Universidad Católica de Valparaíso (Chile).

(7) Dissolved oxygen: Concentrations of dissolved oxygen were determined in triplicate in water samples collected from 20 and 200m depth (eleven stations on Leg I, ten stations on Leg II). These oxygen determinations were made by the standard Winkler titration procedure and were done to calibrate the data from the oxygen sensor on the CTD/rosette system.

(8) Solar radiation measurements: The following data on incident solar radiation were collected throughout the entire cruise: (a) continuous recording (every minute) of Photosynthetic Available Radiation (PAR) using a 2-pi sensor, which was mounted in a shade-free location on the ship's superstructure; (b) attenuation of solar radiation in the water column was recorded (at six CTD/rosette stations during Leg I, and at all stations during Leg II) with a PAR sensor (cosine response), which was mounted on the CTD/rosette unit.

2.3 Results and Tentative Conclusions:

(A) Phytoplankton distributions at 5m depth throughout the AMLR study area, as indicated by chl-a concentrations [milligrams chl-a per cubic meter (mg m^{-3})], are shown for Legs I and II in Figures 2.1A and 2.1B, respectively. The patterns of phytoplankton distribution during both legs were quite similar, but there was an increase of phytoplankton biomass from Leg I to Leg II. During both legs, relatively high phytoplankton biomass was found in general south of Elephant Island. During Leg I, high values were also found in waters over the continental shelf to the northeast of Elephant Island, while during Leg II the richest areas were found to the east of King George Island. These phytoplankton rich areas are found mostly in waters of Bransfield Strait origin or in the area of the Surface Bransfield-Drake Boundary Front (SBDBF), which is a zone that runs from the southwest to the northeast corner of the survey grid. The lowest phytoplankton concentrations were found in the northwest portion of the grid, in Drake Passage waters.

(B) Phytoplankton distribution as indicated by integrated chl-a values (0-100m) throughout the AMLR study area was quite similar to the pattern shown by chl-a concentrations in surface waters (Figures 2.2A and 2.2B). Data in Figures 2.2A and 2.2B show that: (1) Integrated chl-a concentrations in the upper 100m of the water column in Drake Passage waters were very low [less than 30 milligrams of chl-a per square meter (mg m^{-2})]; (2) The greatest phytoplankton concentrations were found to the east of King George Island, with maximum values of 100 and 210mg m^{-2} during Legs I and II, respectively, and to the southeast of Elephant Island during Leg II; (3) The phytoplankton biomass in the confluence zone of Drake Passage and Bransfield Strait waters had intermediate values of integrated chl-a (generally between 40-80mg m^{-2}); and (4) Integrated concentrations of chl-a also indicated the increase of phytoplankton biomass from Leg I to Leg II.

(C) The mean chl-a concentrations at 5m depth throughout the study area during Legs I and II were 0.29 and 1.5mg m^{-3}, respectively. The mean integrated values (0 to 100m) for chl-a during Legs I and II were 52.7 and 78.1mg m^{-2}, respectively.

(D) In general, the concentration and distribution of phytoplankton biomass (which is directly related to the rate of primary production) with depth in the water column is correlated with the different water structures found in the study area. The northern stations in the survey (in Drake Passage waters) had low phytoplankton concentrations in the upper 40m of the water column, and higher concentrations between 50 to 100m. This distribution of phytoplankton in deep pelagic waters north of Elephant island is probably related to a physiological limitation by iron or some other essential micro-nutrient in the upper 50m of the water column. The stations in Bransfield waters had different depth distributions of phytoplankton biomass, as these stations usually had a deep and stable upper mixed layer in which chl-a concentrations were relatively high and uniform. Stations between these two main geographical areas had intermediate depth distributions in both physical and biological parameters.

(E) The proportion of nanoplanktonic cells ($< 20\mu m$), as determined by chl-a analysis, was high during both legs, in general more than 80% for all the study area (Figures 2.3A and 2.3B). However, during Leg II there was a trend towards an increase in the relative concentration of microplanktonic cells ($>20\mu m$ in diameter), especially in the area to the northwest of Elephant Island.

(F) Data for dissolved oxygen (as determined with the Winkler titration method) are in good relative agreement with the oxygen sensor mounted on the CTD/rosette unit, but it should be noted that the oxygen sensor showed lower absolute values. The concentrations of our solutions used in the Winkler method will be verified in the laboratory so that the difference between our data and the data from the oxygen electrode can be brought into agreement.

(G) The surface radiation conditions for the study area are shown in Figure 2.4. The mean daily PAR radiation was 38 Einsteins m^{-2} day^{-1} (624 μEinsteins m^{-2} s^{-1}) during Leg I; while during Leg II, it was lower at 28 Einsteins m^{-2} day^{-1} (573 μEinsteins m^{-2} s^{-1}).

2.4 Disposition of the Samples and Data: The nutrient samples will be processed at the Universidad Católica de Valparaíso (Chile). All other samples (for radiocarbon measurements, CHN analysis, floristic determinations) will be returned to SIO for processing. All data obtained during the cruise have been stored on duplicate 230 Mbytes Bernoulli disks. Copies of any of our data sets are available to all other AMLR investigators upon request to Osmund Holm-Hansen.

2.5 Problems and Suggestions: All shipboard operations proceeded very well throughout both legs without any loss of equipment. All living conditions on the ship were excellent. The only major problem was the malfunctioning of the CTD/rosette system, with bottles not firing or closing at unknown depths, especially during Leg II. This is a serious problem for the phytoplankton studies because it is essential to get samples from the desired depths. We would like in the future to have a backup system with spare parts.

2.6 Acknowledgments: We want to express our appreciation to the crew of the R/V *Yuzhmorgeologiya* for their generous and valuable help during the entire cruise. We also thank all other AMLR personnel for help and support which was essential to the success of our program, especially to the Physical Oceanographic group who meshed some of our instruments and sensors with their data acquisition systems. A special thanks to the Electronic Technician (Mark May) for solving many instrument problems so efficiently.

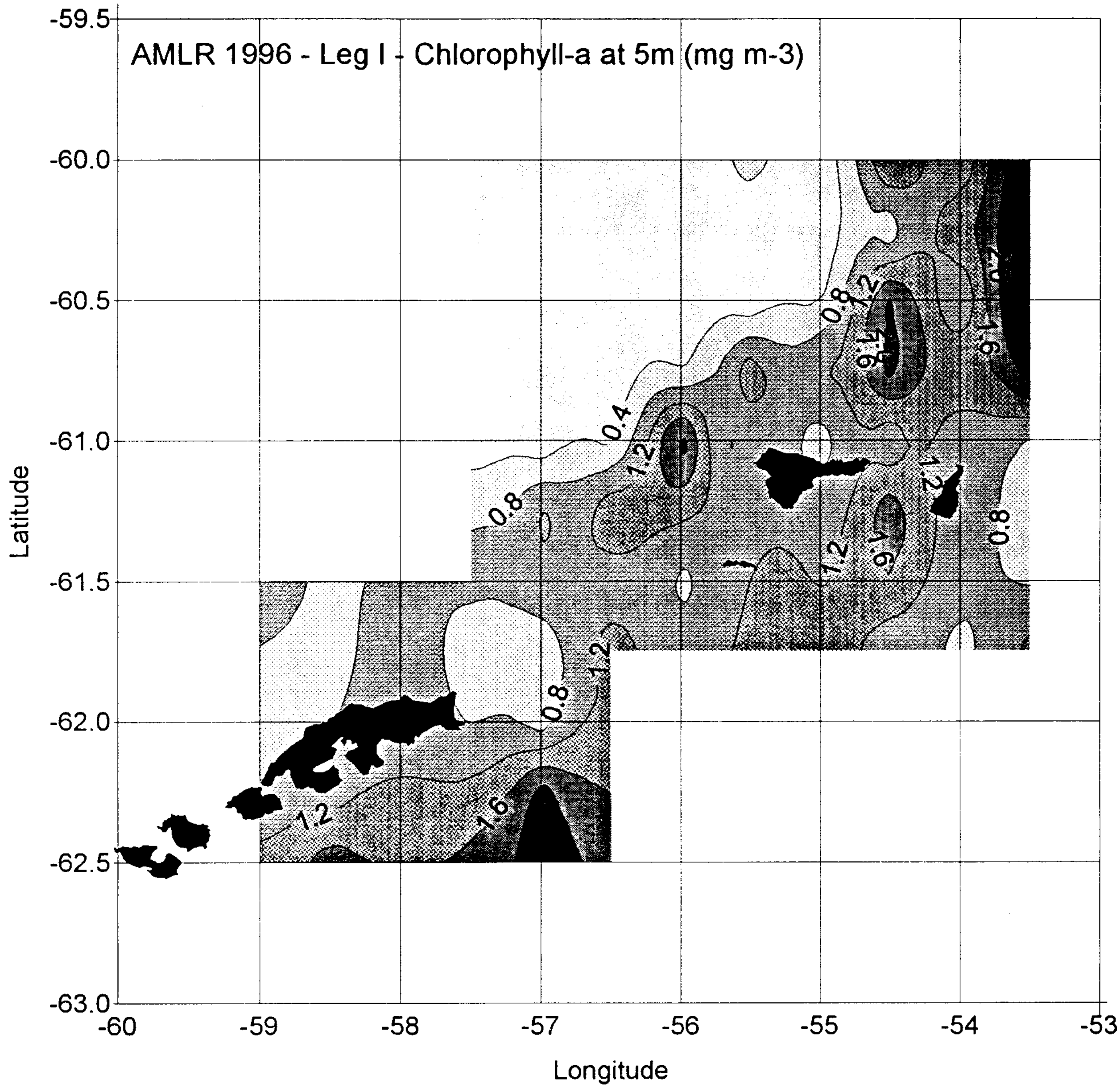


Figure 2.1A Distribution of chlorophyll-a concentrations (mg m^{-3}) at 5m depth throughout the large-area survey grid during Leg I (Survey A).

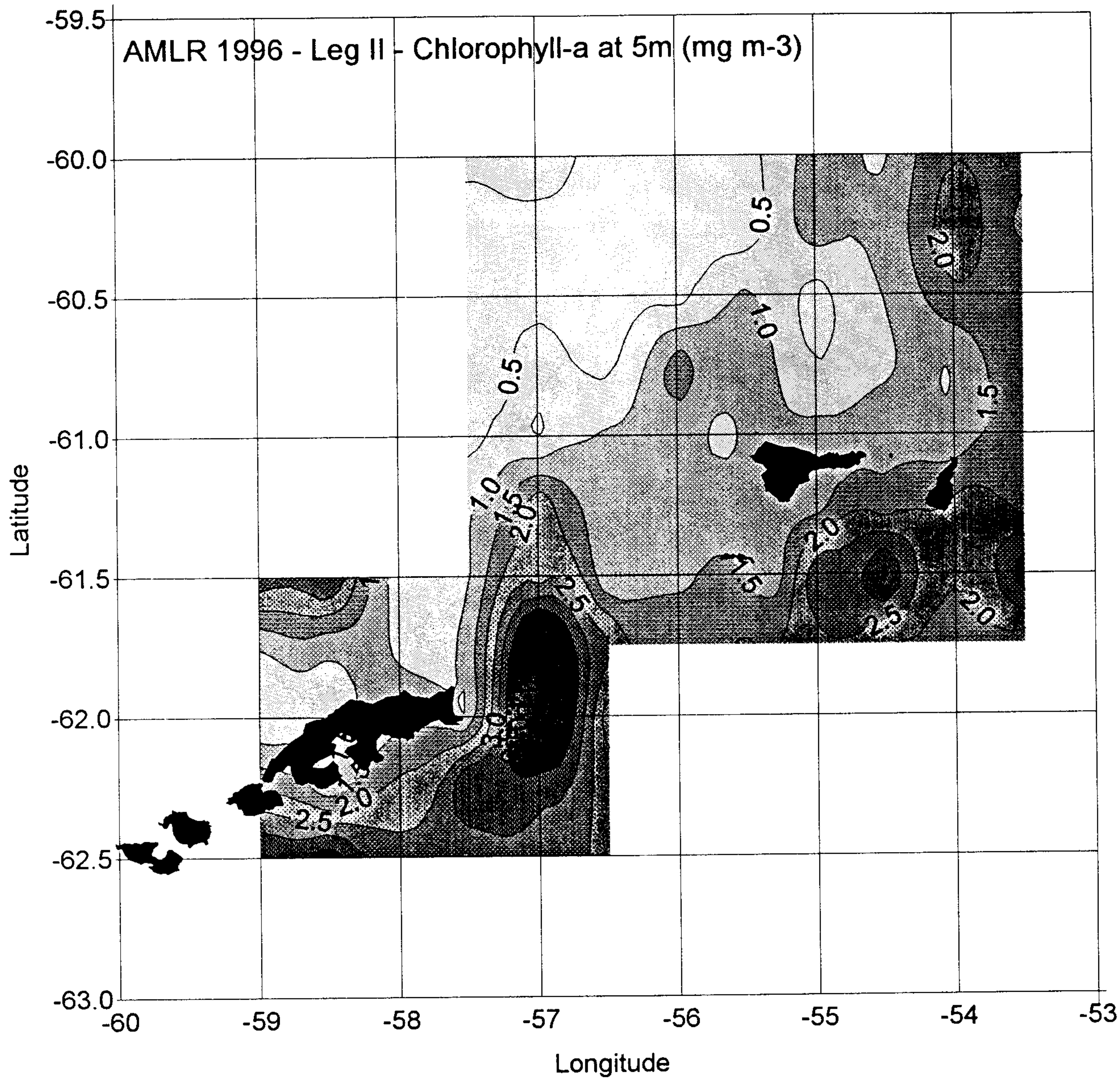


Figure 2.1B Distribution of chlorophyll-a concentrations (mg m^{-3}) at 5m depth throughout the large-area survey grid during Leg II (Survey D).

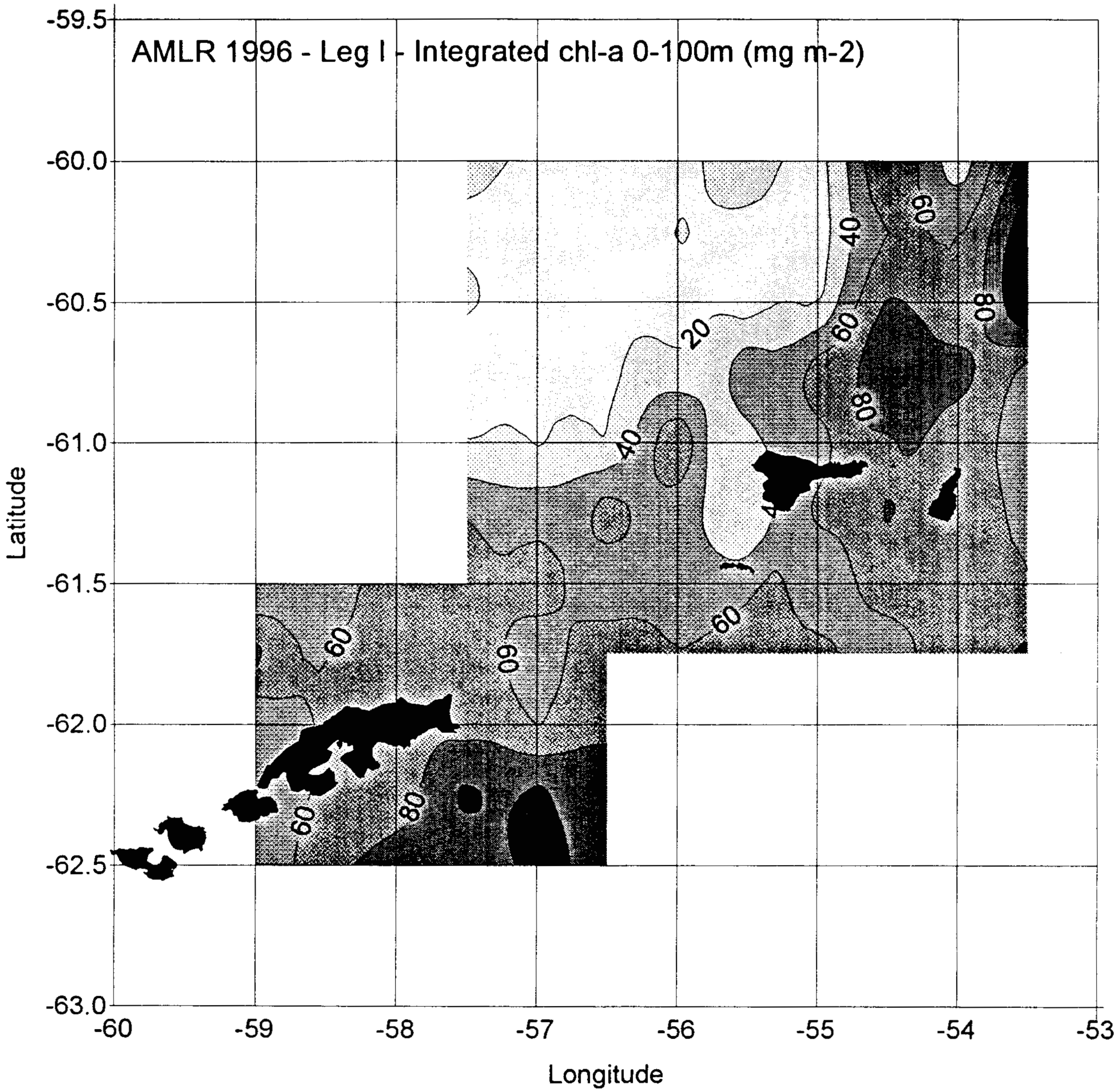


Figure 2.2A Distribution of integrated chlorophyll-a concentrations (mg m^{-2}, 0 to 100m) throughout the large-area survey grid during Leg I (Survey A).

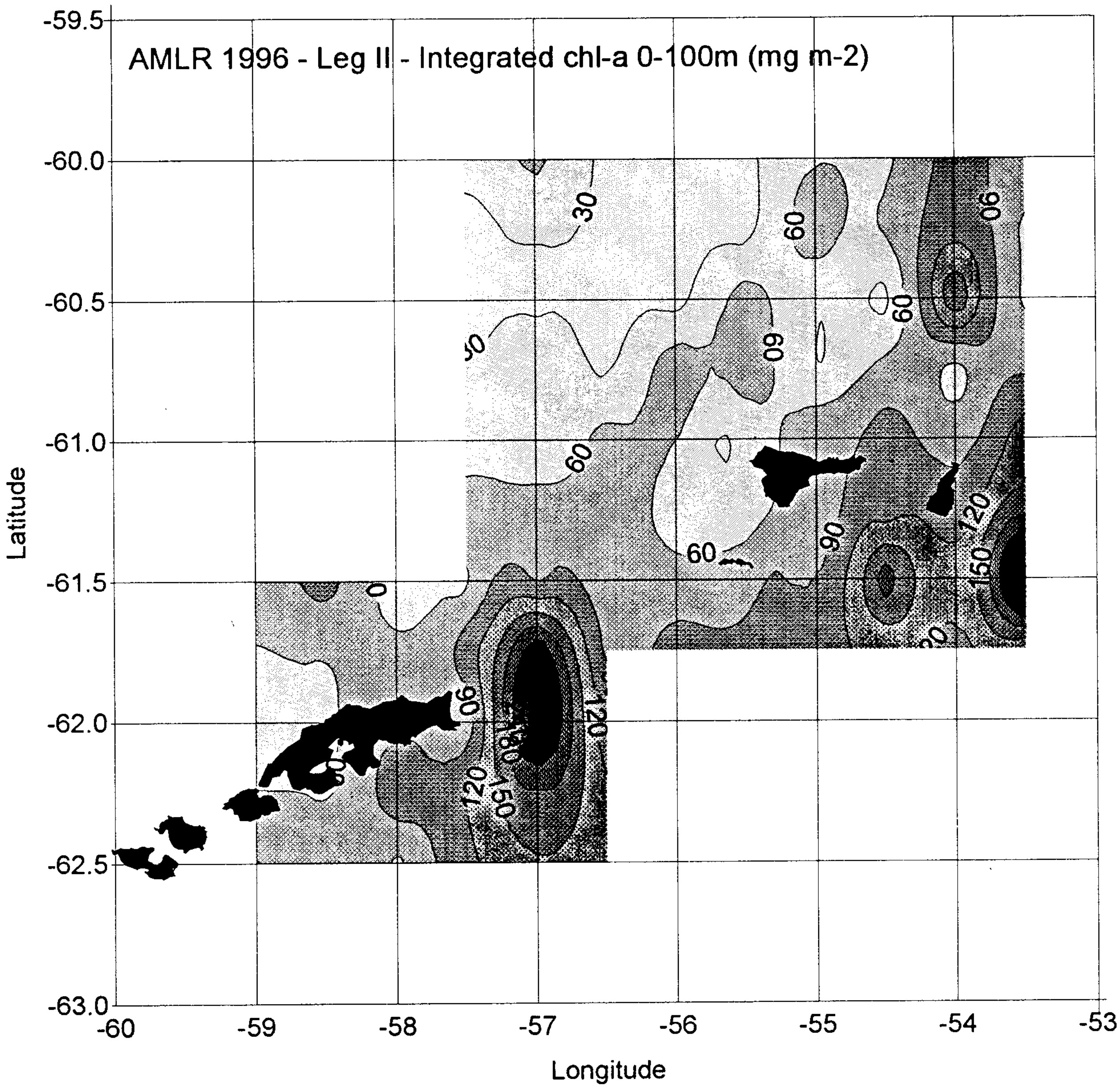


Figure 2.2B Distribution of integrated chlorophyll-a concentrations (mg m^{-2}, 0 to 100m) throughout the large-area survey grid during Leg II (Survey D).

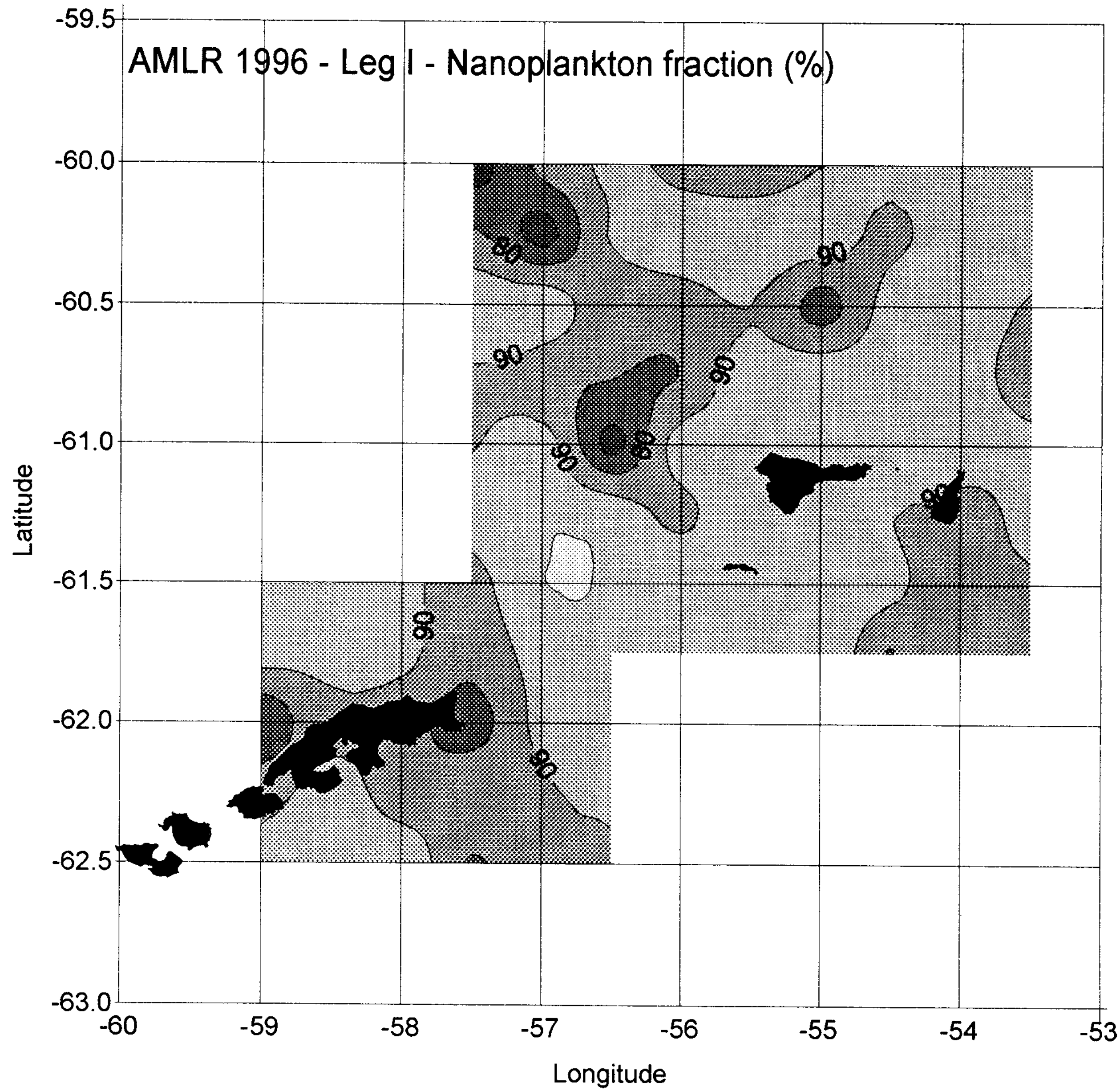


Figure 2.3A Distribution of nanoplankton (in % of total chl-a) at 5m depth throughout the large-area survey grid during Leg I (Survey A).

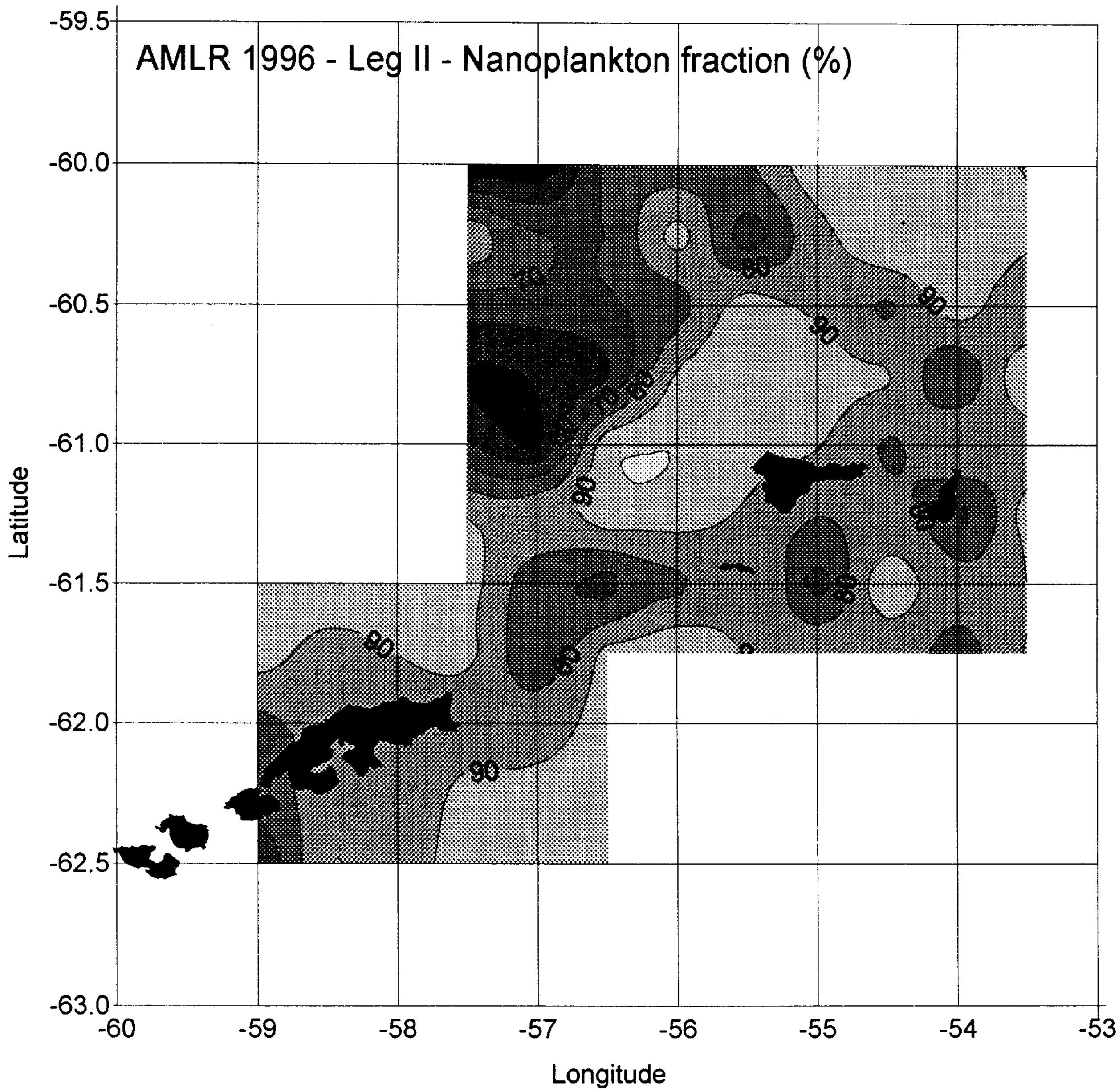


Figure 2.3B Distribution of nanoplankton (in % of total chl-a) at 5m depth throughout the large-area survey grid during Leg II (Survey D).

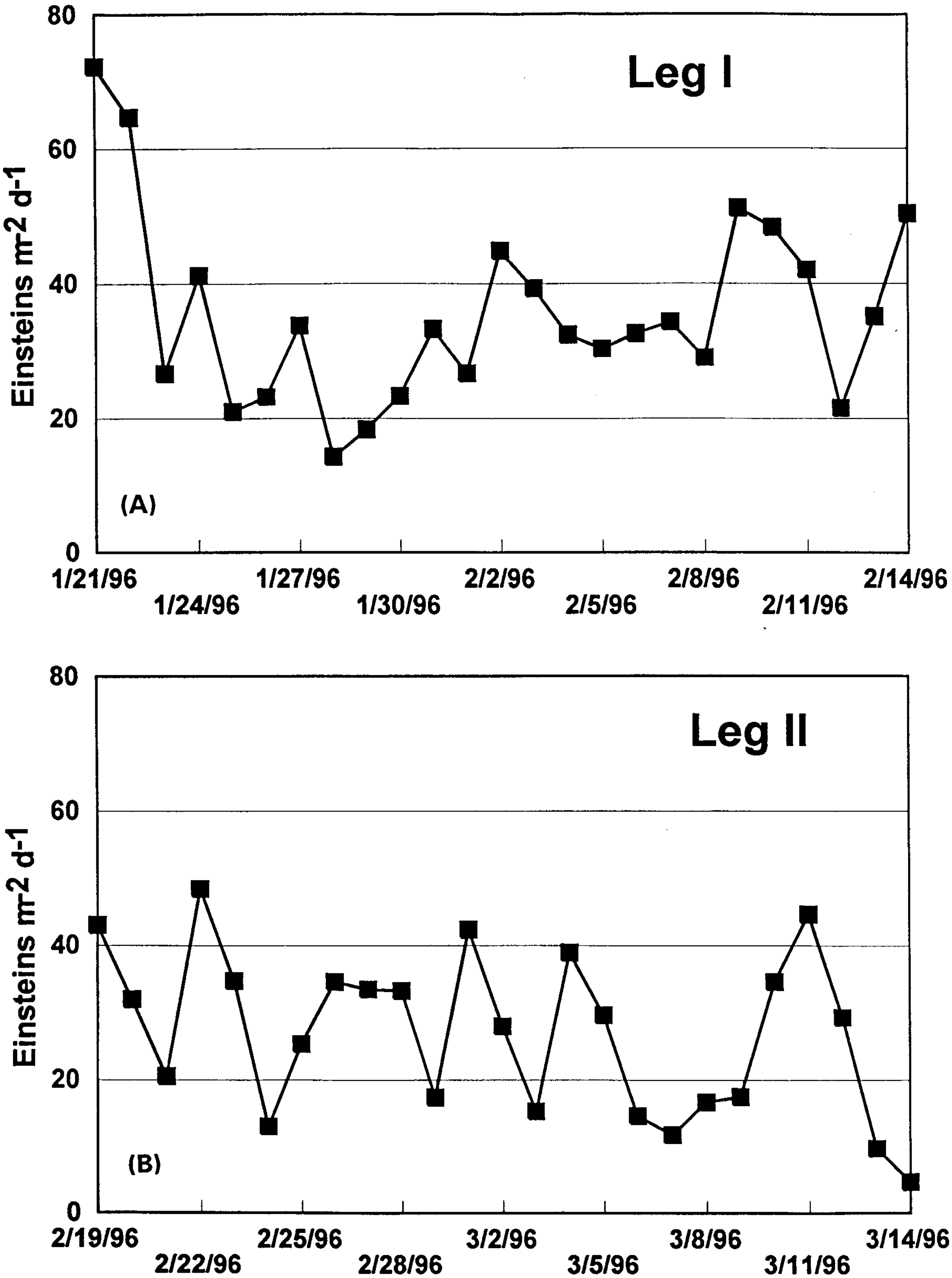


Figure 2.4 Daily irradiance of Photosynthetic Available Radiation (PAR, 400-700nm; in Einsteins m^{-2} day^{-1}) during the AMLR cruise. (A) Leg I (period of January 21 to February 14, 1996). (B) Leg II (period of February 19 to March 15, 1996).

3. Bioacoustic survey; submitted by Roger Hewitt (Shakedown, Leg I), Elizabeth Mitchell (Leg I), David Demer (Shakedown, Leg II), Gabriela V. Chavez (Leg II), and Rennie Holt (Leg II).

3.1 Objectives: The primary objectives of the bioacoustic sampling program were to map the meso-scale (10's to 100's of kilometers) dispersion of krill (*Euphausia superba*) in the vicinity of Elephant Island; to estimate their biomass; and to determine their association with predator foraging patterns, water mass boundaries, spatial patterns of primary productivity, and bathymetry. Secondary objectives were to describe cross-sections of volume backscattering strength along transects through Admiralty Bay, across the shelf-break to the north and south of the South Sheltand Islands, and across the Antarctic Convergence in the Drake Passage. Directed net sampling was also conducted to verify classification of acoustic targets.

3.2 Methods and Accomplishments: An echo integration system was used to map krill dispersion patterns and to estimate krill biomass. Acoustic data were collected using a multi-frequency echo sounder (Simrad EK500) configured with downlooking 38, 120, and 200kHz transducers mounted in the hull of the ship. Pulses were transmitted every two seconds at 1 kilowatt (kW) for 1.0 milliseconds (ms) duration at 38kHz, 0.3ms duration at 120kHz, and 0.6ms at 200kHz. Geographic positions were logged every 60 seconds. Ethernet communications were maintained between the EK500, two UNIX workstations, and a Windows-95 workstation. The UNIX workstations were used for system control, data logging, and data post-processing, including interpretation of echograms, echo-integration, and target strength analyses. Processed data were passed to a Windows-95 PC for gridding and contouring of integrated volume backscattering strength using Krigging methods, assuming a linear variogram model. All data sets, both raw and derived, were archived on 8.0 Gbyte digital audio tapes and 650 Mbyte magneto-optical disks. System calibrations were conducted before and after the surveys using standard sphere techniques while the ship was at anchor in Ezcurra Inlet, King George Island. For the purposes of generating distribution maps and biomass estimates, 120kHz volume backscattering strength attributed to krill was integrated over depth from 10m to 250m and averaged over 0.1 n.mi. (185m) distance intervals.

Integrated volume backscattering strength per unit sea surface area (s_A) was converted to estimates of krill biomass density (ρ) by applying a factor equal to the quotient of the weight of an individual krill and its backscattering cross-sectional area, summed over the sampled length frequency distribution for each survey (Hewitt and Demer, 1993). The relationship of krill wet weight as a function of standard length (l) was taken from Siegel (1986) for krill caught in March. The relationship of backscattering cross-sectional area as function of standard length was derived from the definition of krill target strength as proposed by Greene et al. (1991) at 120kHz. Substituting these relationships into the expression for density:

$$\rho = 0.249 \sum_{i=1}^{n} f_i (l_i)^{-0.16} s_A \qquad (g/m^2)$$

(Hewitt and Demer, 1993), where s_A is expressed in units of $m^2(n.mi.)^{-2}$ and f_i = the relative frequency of krill of standard length l_i such that

$$\sum_{i=1}^{n} f_i = 1$$

where *i* refers to the *i*th length class and *n* is the number of length classes.

Total biomass was estimated by treating the mean biomass density on each transect as an independent estimate of the mean density over the survey area (Hewitt and Demer, 1993). The entire survey area was treated as a single stratum.

Large-Area Surveys: Survey A (23 January - 4 February) and Survey D (24 February - 6 March) were conducted to map the meso-scale dispersion and to estimate the biomass of krill in 15,000 $n.mi.^2$ in the vicinity of Elephant, Clarence and King George Islands (see Introduction Section, Figure 3). Each survey consisted of 12 north-south transects with 15 n.mi. spacing between lines. Stations were 15 n.mi. apart and included a CTD/rosette cast and an IKMT plankton tow. Measurements of volume backscattering strength were recorded continuously, integrated from 10 to 250m in depth, and averaged over 0.1 n.mi. track-line increments. The resulting data were considered to be proportional to krill biomass densities. In-situ target strength (TS) measurements of individual zooplankton were made during each IKMT. These data will be used to develop or enhance TS models for various macro-zooplankton and nekton.

Admiralty Bay Surveys: Acoustic data were collected along transects through Admiralty Bay during the approach (Transect AB1) and departure (Transect AB2) from the anchorage at Ezcurra Inlet (see Introduction Section, Figure 2). Four IKMT tows were conducted along these transects as well, two tows during the approach and two tows during the departure. The diets of chinstrap, Adelie and gentoo penguins were sampled concurrently at colonies along the shores of Admiralty Bay by Nina Karnovski at the Copacabana field camp. Volume backscattering strength was averaged over 5m vertically and 185m horizontally and plotted as cross-sections along the transects.

Cross-Shelf Transects: Three cross-shelf transects were conducted: north of King George Island, northwest of Elephant Island, and south of Elephant Island (see Introduction Section, Figure 5). In addition, a transect was conducted across the Antarctic Convergence in the Drake Passage.

Directed Sampling: Twenty-three MOCNESS tows were conducted north of King George and Elephant Islands to obtain verification of acoustic target classification. Four echogram types were defined corresponding to *Euphausia superba, Euphausia frigida, Salpa thompsoni,* and myctophid fish. See Section 4 (Zooplankton) for description of catches from vertically stratified tows.

3.3 Tentative Conclusions:

Large-Area Surveys: During both surveys, areas of high krill density were mapped in wide bands along the north side of King George and Elephant Islands where water depth was greater than 200m (Figures 3.1 and 3.2). The bands widened north of Elephant Island where water flowing north from Bransfield Strait impinged on the general northeast flow along the north side of the South Shetland Islands (see Section 1, Physical Oceanography). This distribution pattern is similar to that observed during previous surveys.

Krill biomass, estimated from the acoustic data for the area outlined in the box on Figures 3.1 and 3.2, was the highest estimated since 1992 (Tables 3.1 and 3.2). High biomass estimates during Survey A represent large numbers of juvenile krill that were spawned in 1995; high biomass estimates during Survey D represent moderate numbers of sexually mature adults (see Section 4, Zooplankton).

Admiralty Bay Surveys: The acoustic and IKMT data indicate a layer of dense swarms existed between 50 and 150m depth throughout the extent of Admiralty Bay, but not extending into Bransfield Strait (Figure 3.3). Krill length-frequency distributions from the IKMT tows indicate that the krill in the area were comprised of two modal size groups centered around 26 and 48mm. These modes are similar to those observed last year in Admiralty Bay, except that the larger mode is about 5mm longer. The krill length frequency distributions from penguin diet samples indicate no significant differences between penguin species, and also that the penguins may have been feeding selectively on larger krill. The IKMT tow samples from Admiralty Bay were combined with other samples in the Bransfield Strait and discussed in Section 4 (Zooplankton).

Krill aggregations encountered during Transect AB2 appear to be slightly higher in the water column than during Transect AB1, particularly during the latter portion of Transect AB2. This is likely due to the vertical movement of krill into shallower waters beginning at dusk. It has been suggested that krill reflect less sound during times of vertical migration when their body orientation with respect to the vertical is steeper; this may be an alternate explanation to the apparent decrease in krill between the two transects.

3.4 Disposition of Data: Integrated volume backscattering data will be made available to other investigators in MS-DOS or UNIX (Sun-OS) format ASCII files. The analyzed echo-integration data, averaged over 0.1 n.mi. intervals, consumes approximately 10 Mbyte. The data are available from Roger Hewitt or David Demer, Southwest Fisheries Science Center, 8604 La Jolla Shores Drive, La Jolla, CA 92037 USA; phone/fax - (619) 546-5602/546-7003; internet: rhewitt@ucsd.edu, ddemer@ucsd.edu.

3.5 References:

Greene, C.H., T.K. Stanton, P.H. Wiebe, and S. McClatchie. 1991. *Nature*, 349:110.
Hewitt, R.P. and D.A. Demer. 1993. *Mar. Ecol. Prog. Ser.* 99:29-39.
Siegel, V.1986. Arch. FischWiss. 37:51-72.

Table 3.1 Estimates of krill biomass for Surveys A and D.

	Survey A		Survey D	
	n	mean s_A	n	mean s_A
Transect 1	1096	491.59	1235	123.52
Transect 2	833	549.53	1058	222.03
Transect 3	1159	328.57	939	381.61
Transect 4	1031	634.17	1309	683.02
Transect 5	1288	738.13	1215	475.64
Transect 6	1255	820.85	1089	622.22
Transect 7	1096	791.55	976	1160.81
Transect 8	1199	395.04	985	200.14
Transect 9	842	197.28	1157	212.66
Total n	9799		8728	
weighted mean		563.26		512.31
weighted var.		4096.24		13522.23
$0.249 * \sum f_i(l_i)^{-0.16}$		0.1435		0.1368
Area (x10^6 m^2)		41,673		41,673
Biomass (mton)		3,367,941		2,921,357
CV		0.11		0.23

Table 3.2 Mean krill biomass density for surveys conducted during 1992 through 1996. ** Previously reported biomass density values for 1993 are suspicious because of problems with equipment performance and possible misinterpretation of backscatter from salps; these values are omitted here.

Year and Survey	**Mean Krill Biomass Density (g/m^2)**
1992 Survey A (January)	61.20
Survey D (Feb-Mar)	29.63
1993 Survey A (January)	**
Survey E (Feb-Mar)	**
1994 Survey A (January)	9.63
Survey D (Feb-Mar)	7.74
1995 Survey A (January)	28.78
Survey D (Feb-Mar)	35.52
1996 Survey A (January)	76.26
Survey D (Feb-Mar)	69.37

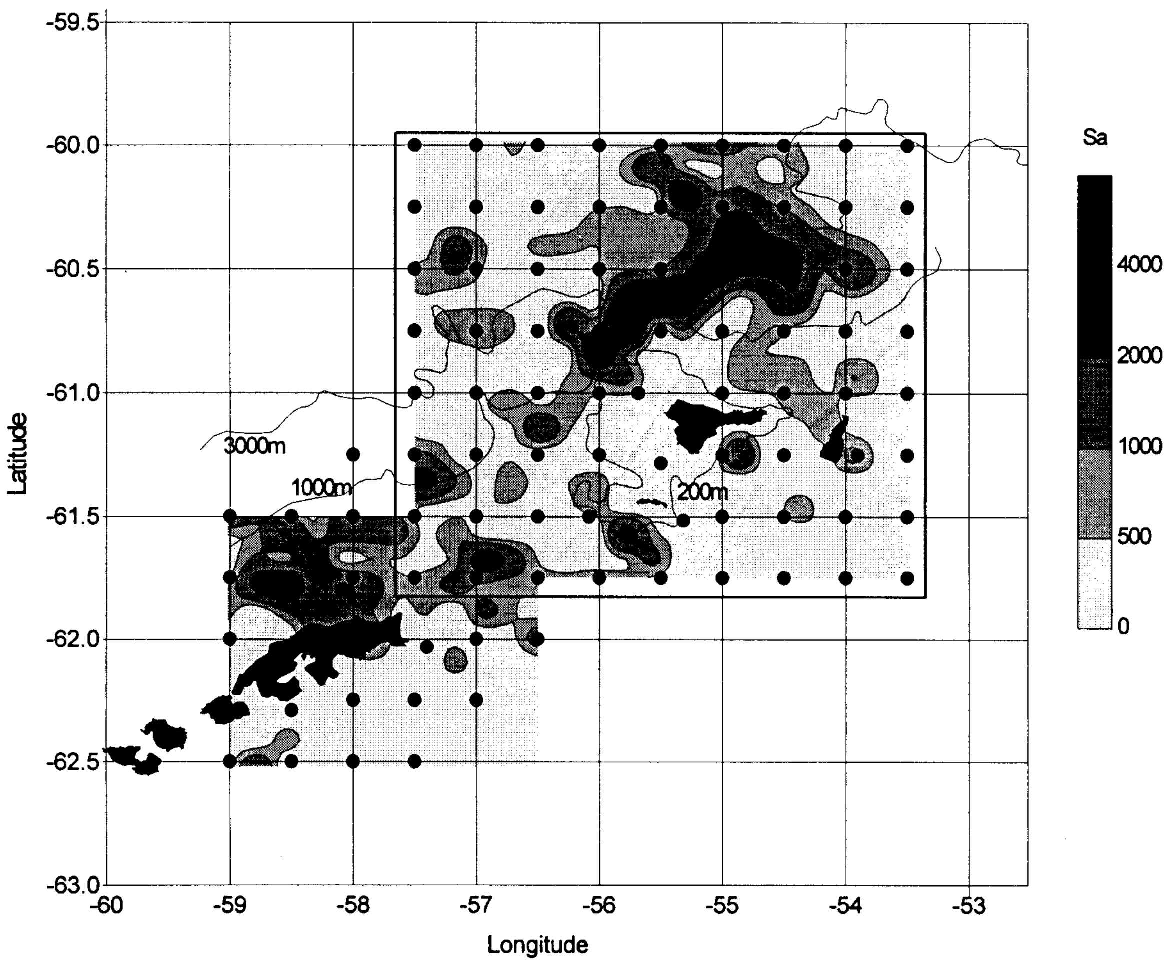


Figure 3.1 Distribution of integrated volume back-scattering strength during Survey A (23 January - 4 February).

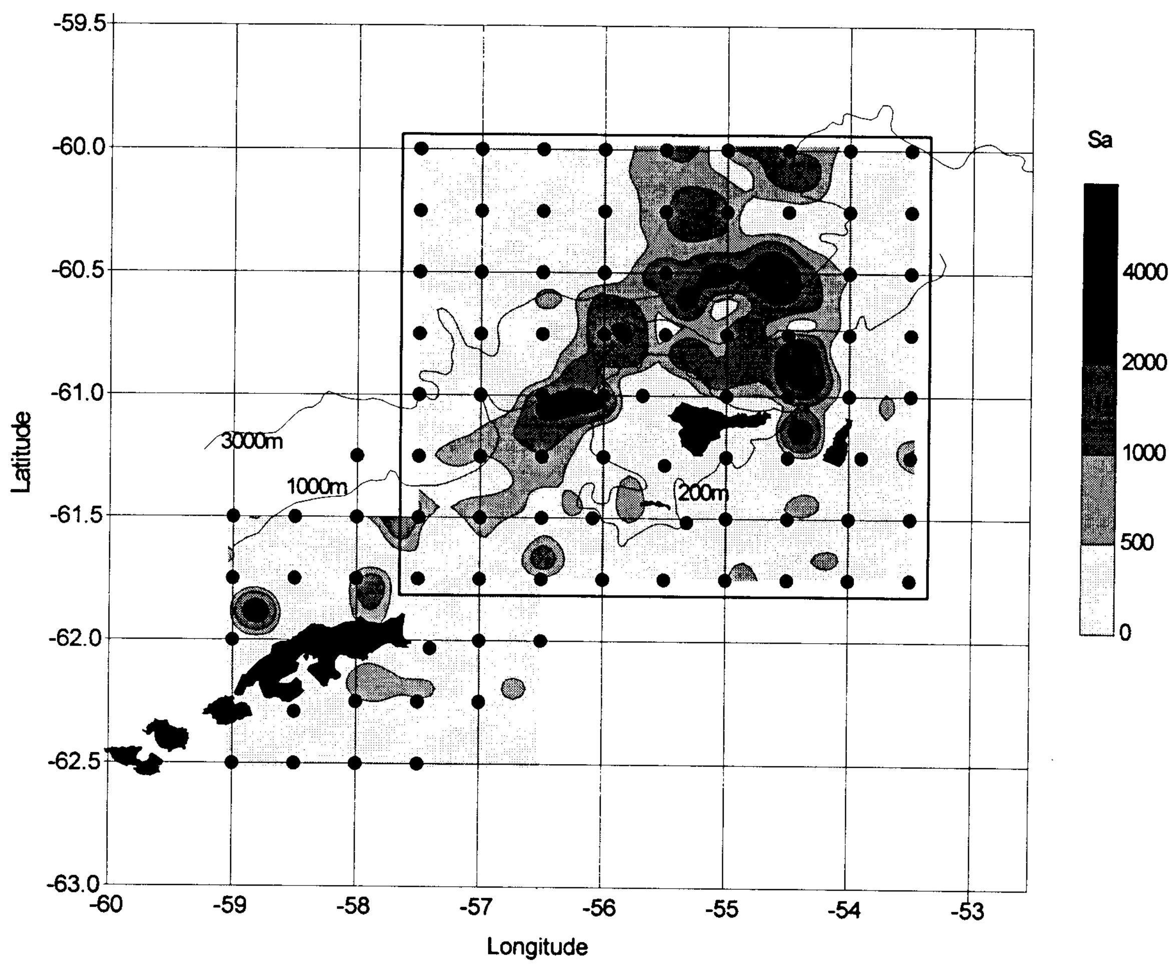
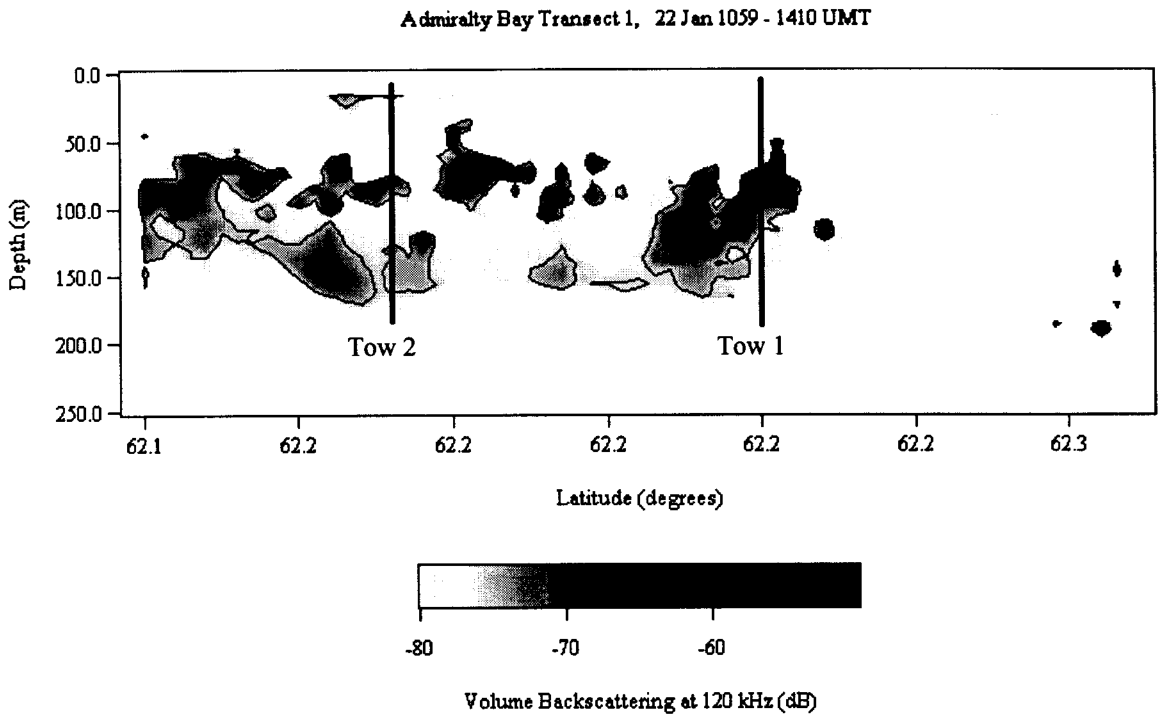


Figure 3.2 Distribution of integrated volume back-scattering strength during Survey D (24 February - 8 March).



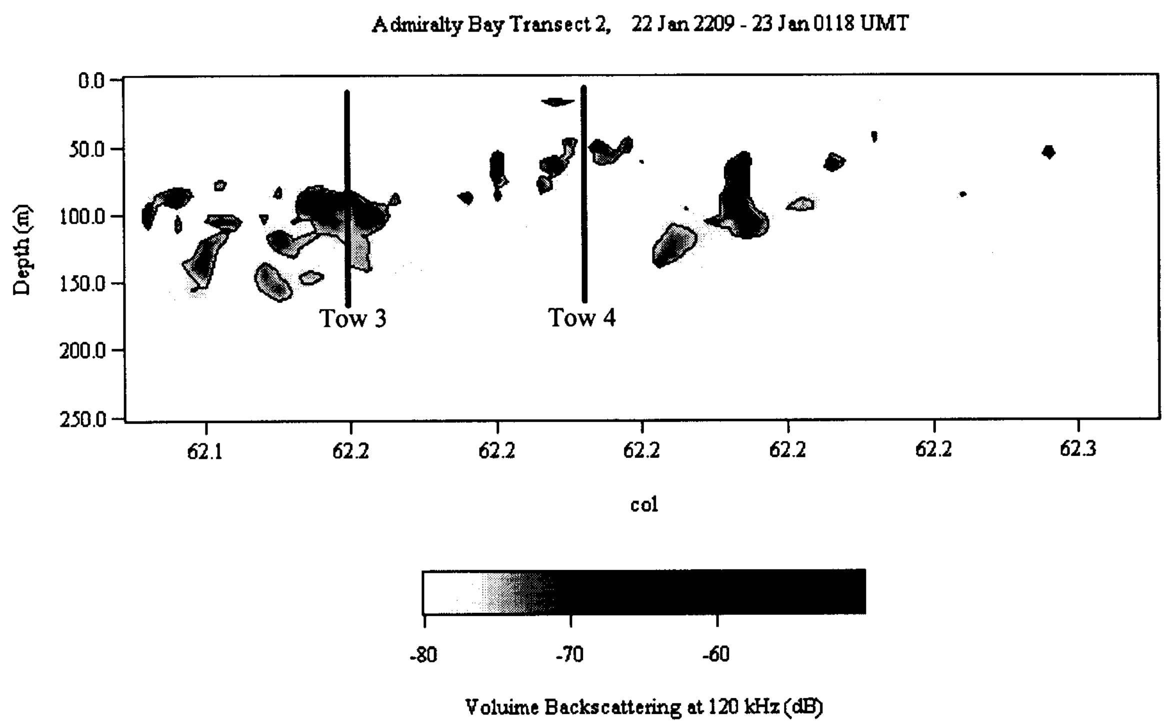


Figure 3.3. Vertical cross-sections of volume backscattering strength at 120 kHz on Admiralty Bay transects. Transect 1 was conducted from 1059 to 1410 UMT, 22 January, and Transect 2 was conducted from 2209 UMT 22 January to 0118 23 January.

4. Direct krill and zooplankton sampling; submitted by Valerie Loeb (Shakedown, Legs I and II), Dawn Outram (Shakedown, Legs I and II), Volker Siegel (Leg I), Wesley Armstrong (Shakedown, Legs I and II), William T. Cobb (Shakedown, Leg II), Michael Force (Legs I and II), Charles F. Phleger (Leg I), Guiomar Silva-Azevedo (Leg II), and Ruth Yender (Leg I).

4.1 Objectives: The objective of this work was to provide information on the demographic structure of Antarctic krill (*Euphausia superba*) and the abundance and distribution of macrozooplankton components in the AMLR study area. Essential demographic information for krill includes length, sex ratio, reproductive condition, and maturity stage composition. Information useful for determining the relationship between krill distribution and population structure and ambient environmental conditions was derived from net tows conducted at each CTD/rosette station within the large-area surveys (Survey A on Leg I, Stations A1-A91; Survey D on Leg II, Stations D1-D91). Information on the size distribution of krill available for predators was obtained from survey stations and ancillary tows made in the vicinity of penguin colonies in Admiralty Bay, King George Island. Information on the abundance and distribution of other zooplankton components was obtained from the large-area survey samples. Additional attention was focused on salps (*Salpa thompsoni*) because of their inclusion in acoustical biomass assessment and potential influence on the distribution and behavior of krill. Specific information useful for determining acoustic target identity and size distributions was derived from directed tows made at various locations within the large-area survey grid.

4.2 Accomplishments:

Large-Area Survey Samples.

Krill and zooplankton were obtained from a 6-foot Isaacs-Kidd Midwater Trawl (IKMT) fitted with a 505μm mesh plankton net. Flow volumes were measured using a calibrated General Oceanics flow meter mounted on the frame in front of the net mouth opening. All tows were fished obliquely to a depth of 170m or to about 10m above bottom in shallower waters. Tow depths were derived from a real time depth recorder mounted on the trawl bridle and monitored in the acoustics lab. Tow speeds were ca. 2 knots.

Targeted Sampling.

During Leg II, a series of directed net tows were conducted to sample acoustically detected swarms and layers within the upper 300m of the water column. These targeted tows were made using a Multiple Opening Closing Net and Environmental Sampling System (MOCNESS). The 1 m^2 nets were fitted with 505μm mesh. Tow depth, duration, water filtered, and ancillary hydrographic data were electronically logged onboard. Tow speeds were ca. 2 knots. Sampling locations were based on the presence of different categories of scattering layers identified during Survey A and consistently observed during Survey D. Vertically stratified sampling was done at each location using four nets; these were fished alternately with nets lacking cod ends to permit discrete samples from the targeted depth intervals. Sampling depths were dependent on the depth and thickness of acoustically monitored organisms; the nets were generally towed horizontally or "yo-yoed" within the targeted layer and closed after filtering ca. $200m^3$.

Shipboard Analyses.

All net samples were processed onboard using fresh material. Krill demographic analyses were made using fresh or freshly frozen specimens. The other zooplankton analyses were made within one hour of sample collection.

Abundance estimates of krill are expressed as numbers per m^2 sea surface and/or numbers per 1000 m^3 of water filtered. Abundance estimates of salps and other zooplankton taxa are expressed as numbers per 1000 m^3 of water filtered. Data are presented for the large-area surveys and for the more restricted "Elephant Island Area" (a box around Elephant Island, see Figure 4.3) to allow comparison with previous AMLR cruises.

(A) Large-Area Survey Samples

(1) Krill: Krill were removed and counted prior to other sample processing. All krill from samples containing <150 individuals were analyzed. For larger samples, 100-200 individuals were measured, sexed, and staged. Measurements were made of total length [millimeters (mm)]; stages were based on the classification scheme of Makarov and Denys (1981).

(2) Salps: All salps were removed from the samples. For entire samples of ≤100 individuals, the two forms (aggregate/sexual and solitary/asexual) were enumerated and the internal body length (Foxton, 1966) was measured to the nearest mm. Representative subsamples of 50-150 individuals were analyzed for larger catches.

(3) Fish: All adult myctophids were removed, identified, measured to the nearest mm SL, and frozen.

(4) Zooplankton: After krill, salps, and adult fish were removed, the remaining zooplankton samples were analyzed; these zooplankton samples typically were <500ml in volume. All of the larger organisms (e.g., other euphausiids, amphipods, pteropods, polychaetes) were sorted from the samples, identified to the lowest taxon possible, and enumerated. The smaller constituents (e.g., copepods, chaetognaths, euphausiid larvae) in representative aliquots were then enumerated using dissecting microscopes; these aliquots generally accounted for 5-20% of the total small fraction. After analysis the zooplankton samples (minus krill, salps, and adult fish) were returned to sample jars and preserved in 10% buffered formalin for long-term storage.

(B)Targeted Samples

All vertically stratified MOCNESS samples were thoroughly analyzed. Species suspected to be important acoustic scatterers because of their size and abundance were enumerated and measured. These included post-larval stages of krill, the euphausiids *Thysanoessa macrura* and *Euphausia frigida*, myctophids, and salps. Measurements were as described for the large-area surveys, but with the addition of salp nucleus diameter associated with internal body length (Foxton 1966). Other macrozooplankton taxa were enumerated as multispecies groupings (e.g., amphipods, pteropods, polychaetes). The smaller zooplankton taxa in representative aliquots were enumerated as described for the large-area survey samples.

4.3 Results and preliminary conclusions:

(A) Leg I, Admiralty Bay Survey

On 22 January, four IKMT tows (Stations X1-X4) were made in the vicinity of Admiralty Bay to assess the size composition of resident krill stocks in relation to the krill being fed upon by penguins in nearby colonies. Krill catches ranged from 1-154 per tow with a combined total of 225 individuals. These data were augmented by catches made at four large-area survey stations adjacent to Admiralty Bay (Stations A1-A4) on 23 January (Figure 4.1). The resulting krill length frequency distribution based on 448 individuals was bimodal with dominant length categories at 24-29mm and 46-49mm, reflecting the primarily juvenile (32%) and mature (52%) stage composition (Figure 4.2). Stomach contents of penguins sampled by Nina Karnovski at the Admiralty Bay Copacabana Station on 22 January (733 krill) indicated a krill size structure similar to that represented in the IKMT samples (Figure 4.2). Kolmogorov-Smirnov test comparison yields a significant difference between the cumulative length frequency distributions in the stomach contents and net samples ($P < 0.01$) due to slightly lower proportions of small krill in the penguin diets. However, this difference could result from various sampling artifacts rather than selective predation upon large-sized krill. Replicated net sampling within the immediate foraging area of radio-tagged penguins is probably required to adequately assess any size selective feeding.

(B) Leg I, Survey A

(1) Krill: IKMT tows were made at all 91 stations during Survey A, 23 January - 4 February (Table 4.1A). Krill were collected at all but three stations (97%), yielding an estimated total of 46,831 individuals; 5811 of these were measured, sexed, and staged for demographic analyses. Relatively high krill densities were distributed in waters over and adjacent to the northern and southeastern shelves of King George and Elephant Islands (Figure 4.3). Two of the three largest catches (17,156 and 6295 krill) occurred to the southeast of these islands (Stations A7 and A70, respectively); the other catch occurred northwest of Elephant Island (6680 krill, Station A48). The relatively high mean krill abundance of 18.9 per m^2 was largely due to the influence of these three catches (233.4 to 579.6 per m^2); the median abundance was 2.0 per m^2.

Krill lengths ranged from 15-59mm. The overall length frequency distribution was bimodal and numerically dominated (71.3%) by small krill 22-33mm long; large krill of 44-53mm lengths comprised the second mode (18.6%) (Figure 4.4). The small length mode was due to large numbers of juveniles (63.2%) and immature males (2a stage, 11.8%; Table 4.2) and represents a relatively abundant 1-year old age class (i.e., the 1994/95 year class resulting from last year's spawning season). The large size mode included primarily mature stages >4 years of age. Mature forms contributed 22.5% of the total. Relatively small proportions of intermediate-sized (34-43mm, 7.5%) and immature krill other than small 2a males result from poor recruitment of the 1992/93 and 1993/94 year classes. Males outnumbered females by 2.3:1, but this seemingly disproportionate number of males is in part due to the ability to identify young males (2a stage), but not young females, within 1-year old age class. Almost all of the mature females were in advanced stages: 24.6% had developing gonads (3c); 7.4% were gravid (3d); and 66.0% were spent (3e). The common occurrence of spent forms, which still had numerous eggs remaining in the ovaries, suggests that a substantial proportion of the females were undergoing batch spawning during the survey period.

Cluster analysis applied to the length frequency distributions from all stations represented by >20 krill resulted in two groups with distinctly different size and maturity stage composition, which together result in the overall bimodal distribution pattern (Figures 4.5 and 4.6). Cluster 1, the small size group, was composed of predominantly juveniles and 2a stage immature males with lengths centered around a mode of 28mm; 85.4% of these krill had lengths of 21-33mm. The large predominantly mature krill (87.4%) of Cluster 2 had lengths centered around 47-50mm; 78.7% of these krill were between 44-54mm. Within this cluster males out-numbered females by only 1.6:1. Virtually all of the females (96.5%) were in advanced maturity stages, and 49.0% were spent. As during other years, these two clusters had different spatial distribution patterns with the small-sized Cluster 1 krill occurring to the south of the larger sizes (Figure 4.7).

(2) Zooplankton: Seventy zooplankton species and taxonomic categories were identified (Table 4.3). Copepods were present in all 91 net samples and comprised the most frequent and abundant category (mean abundance 794.4 per 1000 m^3).

(a) *Thysanoessa macrura*: Larval stages of the euphausiid *T. macrura* were second in abundance (308.5 per 1000 m^3) and occurred in 90% of the samples. Among the larger zooplankton constituents, *T. macrura* post-larvae were most frequent (99% of tows) and ranked fourth in abundance (106.9 per 1000 m^3). Larval *T. macrura* were most abundant in Drake Passage water offshore of Elephant Island, while post-larval *T. macrura* were most abundant in the Bransfield Strait and waters adjacent to and between King George and Elephant Islands (Figures 4.8a and 4.8b). These distributions are almost diametrical, as indicated by a highly significant negative correlation (Spearmans $R = -0.40$, $P << 0.001$) between the larval and post-larval abundance values at each station.

(b) Krill: Post-larval krill comprised the third most frequent taxon (97% of tows) and were slightly more abundant (112.5 per 1000 m^3) than *T. macrura* post-larvae. Early calyptopis stages of krill larvae were present in 22% of the samples and indicated that successful spawning had occurred ca. 3-4 weeks earlier (Ross et al., 1988). Although their frequency of occurrence in samples was similar to that during the January 1995 survey, they were two orders of magnitude less abundant (2.7 vs. 135.8 per 1000 m^3). Nearly all of the catches were in Drake Passage water and mixed water to the east; the largest catch occurred northeast of Elephant Island during the latter part of the survey (Figure 4.9). This overall distribution pattern was also observed during the 1995 survey.

(c) Salps: Salps occurred in 65% of the samples and were the sixth most abundant taxon (20.4 per 1000 m^3). They were most frequent and abundant in Drake Passage water, although some relatively large catches were also made southeast of Elephant Island (Figure 4.10). Lengths ranged from 4-135mm, with a median length of 30mm; the majority (74%) were between 22-50mm. Virtually all of the salps (98%) were the aggregate form.

(d) Other taxa: Although chaetognaths were relatively frequent (68% of samples), they were not numerous (12.5 per 1000 m^3) and ranked seventh in mean abundance; *Themisto gaudichaudii,* an amphipod, followed this in abundance. The polychaete worm *Tomopteris carpenteri* and pteropods *Limacina helicina* and *Clione limacina* were also relatively frequent and abundant in the samples.

(C) Leg I, Between Year Comparisons

The median and mean krill abundance values within the Elephant Island area were, respectively, ca. 4X and 9X higher than those recorded during January 1992-1995 (Table 4.4). These differences can largely be attributed to the large proportions of 1-year old krill (Cluster 1 juveniles and stage 2a males), which were distributed across the southern and central portions of the Elephant Island area and formed the majority of larger catches within the area (Figures 4.3 and 4.7). The large contribution of this age class (75% of total krill) signifies exceedingly good recruitment from the 1994/95 spawning season.

During January of 1995 and 1996, the vast majority of the female krill were in advanced maturity stages suggesting an early spawning season. Discrepancies between the proportions of females in the 3c (developing ovaries), 3d (gravid), and 3e (recently spent) stages result from difficulties in establishing whether the females were truly spent or undergoing multiple spawning events (Table 4.2). The comparatively low numbers of krill larvae collected during January 1996 suggest later initiation of spawning than during the previous year. Earlier initiation of spawning, recovery of the ovary, and development of additional eggs (i.e., resumption of the 3c stage) associated with batch spawning by some of the females in January 1995 is one possible explanation of the discrepancies. The early spawning seasons of 1994/95 and 1995/96 differ substantially from the previous three years when the majority of the females were in early stages of gonadal development (i.e., 3a and 3b) during January.

Although the median salp abundance during January 1996 was an order of magnitude higher than during the previous year, the mean abundance values were quite similar (Table 4.4). Mean and median salp abundance values during both years were two to three orders of magnitude lower than during the 1993 and 1994 "salp years," and the mean values were significantly lower than those observed during 1992 (Z tests, P<0.01). The overall length frequency distribution of salps was similar to that observed during January 1994 but differed significantly from that in 1995 (Kolmogorov-Smirnov test P<0.01; Figure 4.11). During 1994 and 1996 the populations were dominated by relatively large aggregate forms with internal body lengths >20mm, while aggregate forms <25mm predominated in 1995. These observations suggest that: (1) environmental conditions during both 1994/95 and 1995/96 were not favorable for explosive salp population growth as during 1992/93 and 1993/94; and (2) salp populations within the Elephant Island area had different sources during summer 1995 and 1996. The predominately small-sized salps of 1995 were most abundant in the southern portion of the survey area and, based on drifter tracks (Amos et al., 1995), were probably derived from Bransfield Strait waters to the southwest. The small sizes suggest a relatively short growth period in the source waters. In contrast, the larger salps collected during 1996 were most abundant in Drake Passage water and possibly were transported into the Elephant Island area after a comparatively prolonged growth period in the West Wind Drift. The widespread occurrence and high abundance of large salps across the Elephant Island area during 1994 most likely resulted from rapid population growth and an extended growing season both within Bransfield Strait and Drake Passage.

Overall zooplankton species richness in the survey samples (70 taxa) was similar to that monitored in January 1995 (76 taxa); both were high compared to January 1994 (46 taxa; Table 4.3). As with the 1995 samples, the marked increase could in part result from sampling artifacts. The extreme salp dominance in 1994 necessitated subsampling for salp abundance estimates and analysis of the other zooplankton taxa; at times these subsamples were small relative to the total sample volume. As a consequence, relatively uncommon and rare taxa were undoubtedly under-represented during those years. This is probably reflected in the increased frequency of occurrence of most taxa in the 1995 and 1996 samples. In addition, increased use of the dissecting microscope for shipboard zooplankton analyses starting in 1995 resulted in the identification and enumeration of smaller taxa such as ostracods, larval krill, and small larval fish. The use of entire zooplankton samples and more accurate enumeration could also explain some of the vastly increased abundances of smaller zooplankton (e.g., copepods) in 1995 and 1996. However, it is also quite likely that substantially increased abundance of these taxa within the 0-170m water column sampled was a real phenomenon.

Copepods, post-larval *T. macrura,* and *T. gaudichaudii* had similar mean abundance values during January 1996 vs. 1995. However, abundance of *T. macrura* larvae in 1996 was 19X greater than in 1995. All pteropod species, except *Clio pyramidata*, showed an increase in abundance in 1996 over the two previous years. The most prevalent of these, *L. helicina*, ranked fifth in mean abundance in 1996 (33.7 per 1000 m^3); this species' mean abundance was ranked fourteenth (1.9 per 1000 m^3) in 1995 and fifhteenth (0.3 per 1000 m^3) in 1994. Chaetognaths were less frequent and 1/6th as abundant in January 1996 relative to 1995. *Vibilia antarctica,* a hyperiid amphipod species known to associate with salps, was two orders of magnitude less abundant in January 1995 and 1996 than in 1994 due to the dramatic abundance decrease of *S. thompsoni.* Typically common larval fish species *Lepidonotothen larseni, Notolepis coatsi, N.*

annulata and *Electrona antarctica* were absent or infrequently collected in January 1996 compared to 1995. Larval *L. kempi* differed from these in that they were much more broadly distributed across the survey area in 1996.

(D) Leg II, Survey D

(1) Krill: A total of ca. 33,795 krill were collected at 79 (87%) of the 91 stations during Survey D, 24 February - 8 March (Table 4.1B); 3523 of these were analyzed for use in demographic analyses. The larger krill samples generally occurred in the area extending from northeast of King George Island to south and east of Elephant Island. The largest catch, estimated to be ca. 26,650 krill, was at Station D80 to the northeast of Clarence Island (Figure 4.12). This sample represented 79% of the krill collected during Survey D. The largest catches of salps (2380), copepods (69000), and krill larvae (1330) also occurred at Station D80. These dense concentrations may have resulted from retention within a gyral or frontal system "downstream" of Clarence Island. Large numbers of adult *Electrona antarctica* (42) in the sample suggest that elevated plankton concentrations may have persisted in this area for some time and that these were favorable for their predators. The extremely large catches at this station overwhelm those from the other survey stations and are at times omitted to describe conditions more characteristic of the broader survey area. For example, the mean krill abundance for all Survey D stations was 16.9 per m^2 ($\pm$ 130.7 per m^2), while that after excluding Station D80 was 3.1 per m^2 ($\pm$ 7.0 per m^2). The median abundance estimates with and without D80 were similar, 0.6 and 0.5 per m^2, respectively, reflecting the relatively low abundance of krill across the survey area during this time.

The overall krill length frequency distribution from the survey area (excluding Station D80) was bimodal with most of the krill within 25-33mm and 45-53mm length categories (Figure 4.13). In contrast to Survey A, large mature forms numerically dominated (71%), while juveniles and young immature males $\leq$33mm (the 1-year old age class) constituted only 23% of the total (Table 4.2). Males again outnumbered females (2.4:1), but in this case the relationship was due to substantially more mature males than females and not to the differential ability in identifying the sex of small individuals. As during Survey A, most of the mature females were in advanced maturity stages: 57.6% were gravid (3d) and 22.1% spent (3e).

Cluster analysis applied to krill catches with $\geq$20 individuals again yielded two groups that conformed to the overall bimodal length frequency and maturity stage composition represented in the survey area (Figures 4.14 and 4.15). Juveniles and 2a males $\leq$33mm in length (1-year old) comprised 85% of Cluster 1, while mature stages $\geq$45mm in length (the 4+ age group) comprised 87% of Cluster 2. In contrast to Survey A the distribution of Cluster 1 krill was quite limited, occurring only in waters adjacent to and south of Elephant Island, while Cluster 2 krill were distributed over most of the remaining survey area (Figure 4.16).

(2) Zooplankton: The number of zooplankton taxa identified in the Survey D samples was similar to that of Survey A (67 vs. 70; Table 4.5). Copepods again numerically dominated the catches; they were present in 90 samples and their mean and median abundance values (1387 and 921 per 1000 m^3) were, respectively, 1.7 and 2.9X larger than during January. Chaetognaths showed a marked increase in frequency of occurrence (37%) and median abundance (10X) over the previous month and displaced *T. macrura* as the second most frequent taxon.

(a) *Thysanoessa macrura*: The frequency of occurrence as well as estimated and relative abundance values of larval and post-larval stages of *T. macrura* were similar to those observed during Survey A. During both surveys the mean abundance of larval *T. macrura* was second to that of copepods; the mean abundance of post-larvae ranked third in Survey D. The distribution patterns of these stages were also similar to those observed during January, with largest concentrations of larvae in Drake Passage water and largest concentrations of post-larvae in the Bransfield Strait and waters adjacent to King George and Elephant Islands (Figures 4.17a and 4.17b). Again, these distribution patterns are diametrical, and the overall station abundance values of the different stages are negatively correlated (Spearmans $R = -0.44$; $P \ll 0.001$).

(b) Krill: The mean krill abundance value (106.7 per 1000 m^3, ranked fourth) was similar to that during Survey A, but as indicated above is strongly biased by the catch at Station D80. Excluding this station, both the mean (25.9 per 1000 m^3) and median (3.1 per 1000 m^3) values are ca. 25% of those during the previous month. The decreased abundance in conjunction with the large shift in length and maturity stage composition indicates that much of the krill, especially the juvenile stages, had left the area between the two surveys. Although krill larvae were encountered with greater frequency and abundance than during Survey A, they were not among the dominant taxa, ranking seventh in mean abundance. Calyptopis stages were the most common (57% of stations and 85% of total larvae); early furcilia stages occurred at 18% of the stations. The larvae demonstrated no obvious distribution pattern (Figure 4.18).

(c) Salps: The mean salp abundance value (28.2 per 1000 m^3), like that of krill, is inflated by the large catch at Station D80. Excluding this station, the mean value (21.2 per 1000 m$^{3)}$ is similar to that during Survey A (20.4 per 1000 m^3). However, the median catch of 0.9 per 1000 m^3 was only 20% of that observed during January indicating an overall abundance decrease across the area. Salps were again most frequent and abundant in Drake Passage water (Figure 4.19). Solitary stages made up 21% of the total, a considerably larger proportion than during Survey A. The overall size distribution was complex and quite different from that of Survey A (Figure 4.20). Although a broad size range was again represented, there were substantially greater proportions of small and large individuals than during the previous month. A strong mode was centered around 7-12mm lengths and accounted for 25% of the total salp abundance. This was composed mostly of aggregate stages, although solitary forms accounted for 18% of these individuals. Salps of this size are <1 month old (Foxton 1966) and reflect recent bud release by the solitary stages and spawning by the aggregate stages. Large salps $\geq$55mm made up 15% of the total abundance; 70% of these were solitary forms. The 37-50mm central size mode was due primarily to aggregate stages (88%), which probably were released the previous spring. Cluster analysis applied to the salp length frequency distributions at each station with $\geq$19 individuals resulted in two spatially separated groups (Figures 4.21 and 4.22). While the stage composition of these groups was similar (78-82% aggregate forms), Cluster 2 was numerically dominated (75%) by the small individuals. These occurred mostly in Drake Passage waters in the western portion of the survey area. Cluster 1 also included small individuals (10%), but half of the individuals were between 35-55mm; these were distributed to the south and east of Cluster 2.

The overall abundance decrease and size composition change between Surveys A and D are associated with the seasonal reproductive cycle and ontogenetic vertical migrations of *S. thompsoni* (Foxton, 1966; Casareto and Nemoto 1986). The February-March period covers the late summer production peak of aggregates through asexual budding by the solitary form, and initiation of peak autumnal production of solitary forms through spawning by the aggregate form; the newly released individuals of both forms are 5-10mm in length. Increased numbers and proportions of large (>50mm), budding solitary forms in the upper 100m at this time are associated with their upward ontogenetic migration from greater depths. Conversely, lower numbers of mature aggregate forms >20mm in the upper water column, due to ontogenetic migration to greater spawning depths, are responsible for the overall salp abundance decrease at this time. The results of the cluster analysis indicates that spawning activity was earlier and/or more intense in Drake Passage and upstream waters to the northwest of the survey area.

(d) Other taxa: Among the other zooplankton, the frequency of occurrence and abundance of *T. gaudichaudii* was similar to that of Survey A, but those of the amphipod *Primno macropa* (primarily small individuals), larval fish *Notolepis coatsi,* euphausiid *Euphausia frigida,* adult *Electrona antarctica,* and small squid were notably greater than during Survey A. Increased catches of the latter three taxa may be related to the longer periods of darkness during February-March influencing the diel vertical migrations and distributions of *E. frigida* and *E. antarctica,* as well as decreased visually aided net avoidance by *E. antarctica* and cephalopods. The pteropods *L. helicina* and *Clione limacina* were notably less frequent and abundant during Survey D compared to Survey A.

(E) Leg II, Between Year Comparisons

The mean and median abundance of krill in the Elephant Island area during February-March were the highest observed there since 1992 (Table 4.4). However, if the large catch from Station D80 is ignored these values, 31.3 (± 111.1) per 1000 m^3 and 4.1 per 1000 m^3, respectively, are similar to those observed in the area during 1992 and 1993. The ca. 50% decrease in mean krill abundance over the January survey estimates was also observed in February-March 1994 and 1995, and most likely represents a seasonal migration out of the area. These years differ from 1992 and 1993 when krill abundance was similar or increased somewhat across the summer survey periods. Although decreased proportions of juveniles in January vs. February-March sampling periods have been observed each year from 1992 to present (Table 4.2), this decrease was most dramatic during 1996 (55% to 21% of the total krill). The overall maturity stage composition during February-March 1996 most resembles that in 1992 when juveniles resulting from good recruitment of the previous year class contributed >30% of the total krill (Table 4.2).

Both 1995 and 1996 were characterized by large proportions of advanced female maturity stages during February-March compared to the other years, indicating a dramatically earlier spawning season. However, the smaller proportions of spent females this year confirm the speculation resulting from Survey A that the major spawning effort in 1995/96 was later than in 1994/95. This is supported by the exceedingly low numbers of krill larvae collected during Survey D in 1996 relative to 1995 (Table 4.6)

As with the previous survey, salp concentrations in the Elephant Island area during February-March were similar to those the previous year and both were radically lower than during the 1993 and 1994 "salp years." The broad size distribution is similar to that observed in 1994 and both differ from the relatively restricted size distribution, dominated by 15-25mm individuals, observed in 1995. The ca. 50% decrease in median abundance relative to the earlier survey period was similar to the seasonal abundance changes of 1994 and 1995 (Table 4.4); 1993 differed from these years in that median salp abundance more than doubled between January and February-March sampling periods.

Copepod, chaetognath, and *E. frigida* mean abundance values in the 1996 Survey D area were ca. 25%-50% lower than during 1994 and 1995 (Table 4.6). Abundance of post-larval *T. macrura* was similar to the previous two years. In contrast to Survey A, the larval *T. macrura* abundance value was only ca. 50% larger than during the previous years. This suggests an earlier seasonal spawning period as well as increased larval production during 1996. The distinctly different larval and post-larval distribution patterns observed during both large-area surveys were previously reported for the February-March 1990 survey (Nordhausen, 1991). As noted during Survey A, all pteropod species (except *Clio pyramidata)* were more frequent and abundant in 1996 relative to the previous two years; these differences were most notable for *L helicina* and *C. limacina*. Also noted during Survey A, the low mean abundance of *Vibilia antarctica* during both 1994 and 1995 was associated with relatively low salp abundance. The frequency and mean abundance of small *P. macropa* during Survey D were quite high relative to the previous years.

(F) Targeted Sampling

A total of 23 directed MOCNESS tows were made during 10-14 March (Table 4.7). The first series of four tows (three night, one day) was made north of King George Island; four other series consisting of 3-6 day tows were made in the Elephant Island area (Figure 4.23). The vertical distribution patterns of suspected acoustic target species demonstrated both day-night and regional differences. Day-night differences due to vertical migration were obvious for krill, *E. frigida*, salps, and the myctophids *E. antarctica* and *G. opisthopteris*. Krill were collected within the upper 130m, but were most abundant at 0-15m at night and generally at 30-60m during the day. An exception was the final series (MOCX 21-23) where krill were relatively abundant in the targeted layer at depths >100m. *Euphausia frigida* were present in all but the second series (MOCX 5-10); at night they were most abundant at 30-63m, while greatest daytime concentrations occurred at 150-250m. Salps were present only in the first two series (MOCX 1-10), where they occurred at 35-63m at night and in greatest abundance at 95-190m during the day. Myctophids were collected only at night (63m and 100m); there is no evidence that these fish are important components of daytime scattering layers at 200-300m within the survey area. Non-migratory *T. macrura* post-larvae were collected throughout the upper 300m and their depth of maximum abundance varied regionally. Maximum concentrations were generally within the upper 25m northwest of Elephant Island (MOCX 5-16), but were at 100-200m north of King George Island (MOCX 1-4) and southeast of Elephant Island (MOCX 17-23). Elevated concentrations also occurred at 40-70m southeast of Elephant Island (MOCX 19-20).

(G) AMLR 96 Cruise Summary

The mean krill abundance value from the Elephant Island area in January 1996 was the highest observed there since March 1983 (Siegel and Loeb, 1995) and is mostly due to the large numbers of juveniles. The krill recruitment index (R1), based on the relative proportion of total krill comprised by the 1-year old age group during Survey A, was 0.622 (s.e. = 0.849). This value was one of the highest recorded over the past 18 years and indicates relatively strong recruitment of the 1994/95 year class. Strong recruitment results from good spawning success and survival of early stages spawned during the previous year. This was associated with large proportions of advanced female maturity stages during January-March 1995 (Table 4.2) and extensive sea ice conditions in the Antarctic Peninsula region during winter 1995. These results support the hypothesized relations between krill recruitment success, krill spawning seasonality, and winter sea-ice conditions presented in Siegel and Loeb (1995). In accordance with the apparent relationship between early spawning and good recruitment, strong year class success may result from the relatively large proportions of advanced female stages during 1996.

From comparisons of the 1996 results with those from previous years, it is obvious that summertime salp population size and composition characteristics in the Elephant Island area are extremely variable. Overall salp abundance here reflects conditions affecting population growth during early spring and, like krill abundance, is correlated with winter sea-ice conditions in the Antarctic Peninsula region (Siegel and Loeb 1995). Summers with relatively low salp abundance, such as 1996 and 1995, followed winters with extensive sea-ice development. The 1993 and 1994 "salp years" followed winters with little or no sea-ice development, which apparently favored explosive salp population growth in spring. However, there are major between-year differences within periods of similar salp population sizes. Size composition differences between 1995 and 1996 apparently result from differences in source areas (e.g., Bransfield Strait vs. Drake Passage) and length of the growing season. The prolonged seasonal abundance peak in 1993 possibly resulted from elevated production of aggregate forms throughout the spring and summer, which would maintain large numbers of intermediate-sized immature individuals in the upper water column. However, reproductive stage and size composition data are not available for that year to support this speculation.

4.4 Disposition of Data and Samples: All of the krill, salp, other macrozooplankton, and fish data have been digitized and are available upon request from Valerie Loeb. These data have been submitted to Dave Demer and Roger Hewitt (Southwest Fisheries Science Center). Frozen krill, salp, other macrozooplankton, and myctophid specimens were provided to Rick Phleger (San Diego State University) for use in lipid analyses. The processed zooplankton samples (minus salps) are stored at the Southwest Fisheries Science Center. Myctophids collected by the IKMT were frozen and will be stored until requested for use by an interested researcher.

4.5 Problems and Suggestions: The RV *Yuzhmorgeologiya* proved to be an extremely satisfactory ship for the AMLR field work. The ship's stability in conjunction with the large, protected fan tail area and stern A-frame permitted easy deployment and recovery of the IKMT and MOCNESS net systems in winds up to 40 knots. The ability to work during predominantly rough weather conditions of Leg II permitted us to complete the entire large-area survey within the allocated time period. The good ride of the ship also allowed us to perform microscope zooplankton analyses around the clock even during the roughest sea conditions. Onboard sample processing is essential for the krill/macrozooplankton component of the AMLR program. We strongly recommend continued use of this ship in future AMLR field seasons. If this is not possible, we recommend that the stability and ride of alternative research vessels be high priority considerations.

A new shipboard survey area will undoubtedly be established in conjunction with the planned relocation of AMLR land-based mammal and bird research. However, the large-area survey around Elephant Island must not be totally abandoned as this has unparalleled importance in contributing to an historical data set for the Antarctic marine environment. By pooling German and US AMLR data sets from the Elephant Island area, Siegel and Loeb (1995) established large variability of krill recruitment and salp abundance over a 16 year period that were correlated with winter sea-ice conditions. This long term data set also indicated decreased overall krill abundance since the early 1980's that most likely is related to climate change and has implications for the supply of krill to the seal, penguin, and other seabird predator populations in the Elephant Island area (Loeb et al., in prep.). Continued annual survey efforts in the Elephant Island area are essential to further refine our understanding of variations in the Antarctic Peninsula marine ecosystem, especially with regards to krill abundance fluctuations and krill availability to their predators. Given the typical pattern of seasonal krill abundance decreases in the Elephant Island area, especially of juvenile stages, we strongly recommend that the January survey be continued there to provide the most representative data on krill abundance and maturity stage composition.

4.6 References:

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TABLE 4.1 AMLR 1996 Large-area survey IKMT station information.

A. SURVEY A

STATION #	DATE	START TIME	END TIME	DIEL	TOW DEPTH (m)	BOTTOM DEPTH (m)	VOLUME (m3)	KRILL ABUNDANCE TOTAL	#/m2	#/1000m3
A01	23/01/96	0330	0352	N	169	1500	2874.2	1	0.1	0.3
A02	23/01/96	0636	0658	D	170	1600	3728.6	1	0.0	0.3
A03	23/01/96	0915	0949	D	173	470	5719.8	70	2.1	12.2
A04	23/01/96	1252	1319	D	170	1500	4284.6	152	6.0	35.5
A05	23/01/96	1648	1717	D	170	1800	4538.1	5	0.2	1.1
A06	23/01/96	2108	2133	D	169	1800	4534.2	37	1.4	8.2
A07	24/01/96	0052	0121	N	170	1930	5032.4	17156	579.6	3409.1
A08	24/01/96	0336	0351	T	64	88	2655.4	47	1.1	17.7
A09	24/01/96	0948	1012	D	172	264	4008.0	161	6.9	40.2
A10	24/01/96	1301	1329	D	170	950	4284.1	849	33.7	198.2
A11	24/01/96	1624	1653	D	181	2380	4936.5	39	1.4	7.9
A12	24/01/96	2144	2218	T	171	850	5204.4	81	2.7	15.6
A13	25/01/96	108	137	N	170	274	4214.4	1492	60.2	354.0
A14	25/01/96	0514	545	D	159	168	4870.9	4	0.1	0.8
A15	25/01/96	0818	0851	D	170	317	6390.9	279	7.4	43.7
A16	25/01/96	1155	1218	D	176	2020	3280.4	269	14.4	82.0
A17	25/01/96	1748	1813	D	170	347	3793.2	1629	73.0	429.5
A18	25/01/96	2252	2321	N	170	620	4446.3	137	5.2	30.8
A19	26/01/96	0228	0255	N	171	2629	4624.0	984	36.4	212.8
A20	26/01/96	0542	0610	D	170	3880	4366.4	1	0.0	0.2
A21	26/01/96	0913	0944	D	170	4440	5188.2	2	0.1	0.4
A22	26/01/96	1243	1317	D	170	3650	4309.0	56	2.2	13.0
A23	26/01/96	1618	1648	D	178	3510	4112.6	5	0.2	1.2
A24	26/01/96	1932	2002	D	170	3750	4564.9	20	0.7	4.4
A25	26/01/96	2317	2349	N	171	3470	5626.3	5	0.2	0.9
A26	27/01/96	0229	0255	N	170	4050	3490.3	18	0.9	5.2
A27	27/01/96	0534	0605	D	169	1070	4576.8	76	2.8	16.6
A28	27/01/96	0842	0915	D	171	3630	5743.2	91	2.7	15.8
A29	27/01/96	1154	1226	D	170	2800	5883.7	61	1.8	10.4
A30	27/01/96	1520	1553	D	172	1650	5491.8	45	1.4	8.2
A31	27/01/96	1816	1845	D	170	472	4637.5	54	2.0	11.6
A32	27/01/96	2105	2135	T	170	410	5300.1	221	7.1	41.7
A33	28/01/96	0002	0028	N	170	550	3908.6	287	12.5	73.4
A34	28/01/96	0315	0342	T	169	1560	4002.2	31	1.3	7.7
A35	28/01/96	0704	0728	D	169	1707	3486.4	55	2.7	15.8
A36	28/01/96	1008	1036	D	170	535	4043.1	67	2.8	16.6
A37	28/01/96	1312	1337	D	171	500	4181.0	2	0.1	0.5
A38	28/01/96	1559	1630	D	170	395	4918.8	795	27.5	161.6
A39	28/01/96	1915	1942	D	171	2160	4056.5	12	0.5	3.0
A40	28/01/96	2221	2251	N	168	2660	4780.8	211	7.4	44.1
A41	29/01/96	0145	0223	N	180	3810	5398.3	285	9.5	52.8
A42	29/01/96	0522	0545	T	177	3740	3201.6	6	0.3	1.9
A43	29/01/96	0828	0900	D	170	3540	5290.8	148	4.8	28.0
A44	29/01/96	1144	1222	D	172	3630	6819.2	94	2.4	13.8
A45	29/01/96	1511	1539	D	170	3730	4336.6	117	4.6	27.0
A46	29/01/96	1816	1844	D	171	3775	3946.6	46	2.0	11.7
A47	29/01/96	2125	2157	T	176	2730	4941.6	0	0.0	0.0
A48	30/01/96	0035	0105	N	173	290	4451.5	6680	259.6	1500.6
A49	30/01/96	0321	0344	T	140	159	3357.8	19	0.8	5.7
A50	30/01/96	0614	0641	D	170	350	3733.2	0	0.0	0.0

TABLE 4.1 AMLR 1996 Large-area survey IKMT station information.

A. SURVEY A

STATION #	DATE	START TIME	END TIME	DIEL	TOW DEPTH (m)	BOTTOM DEPTH (m)	VOLUME (m3)	KRILL ABUNDANCE TOTAL	#/m2	#/1000m3
A51	30/01/96	0907	0933	D	169	730	4074.9	15	0.6	3.7
A52	30/01/96	1155	1222	D	170	1950	4136.8	7	0.3	1.7
A53	30/01/96	1459	1526	D	170	480	4573.6	2	0.1	0.4
A54	30/01/96	1739	1746	D	50	56	1089.7	0	0.0	0.0
A55	30/01/96	2036	2047	T	55	66	1758.3	474	14.8	269.6
A56	30/01/96	2331	2359	N	170	3256	4656.5	1441	52.6	309.5
A57	31/01/96	0248	0319	N	170	3530	5268.6	34	1.1	6.5
A58	31/01/96	0611	0635	D	170	3440	3244.6	36	1.9	11.1
A59	31/01/96	959	1032	D	170	3470	5088.6	16	0.5	3.1
A60	31/01/96	1336	1359	D	171	3500	3489.4	2	0.1	0.6
A61	31/01/96	1641	1707	D	170	3290	3963.0	714	30.6	180.2
A62	31/01/96	1934	2009	D	173	3350	5414.4	275	8.8	50.8
A63	31/01/96	2259	2330	N	168	3150	4731.2	64	2.3	13.5
A64	01/02/96	0215	0245	N	170	498	5180.5	804	26.4	155.2
A65	01/02/96	1057	1128	D	170	188	4856.4	14	0.5	2.9
A66	01/02/96	1358	1431	D	170	620	5331.1	3	0.1	0.6
A67	01/02/96	1706	1730	D	170	2030	3788.7	4	0.2	1.1
A68	01/02/96	2011	2035	T	170	620	3315.3	1	0.1	0.3
A69	01/02/96	2316	2344	N	170	1440	3959.8	240	10.3	60.6
A70	02/02/96	0215	0245	N	172	540	4639.5	6295	233.4	1356.8
A71	02/02/96	0527	0557	D	171	590	3555.4	27	1.3	7.6
A72	02/02/96	0833	0857	D	170	2775	3232.8	57	3.0	17.6
A73	02/02/96	1126	1144	D	171	3150	2437.5	148	10.4	60.7
A74	02/02/96	1412	1430	D	170	2994	2242.2	9	0.7	4.0
A75	02/02/96	1707	1726	D	170	3160	3524.5	67	3.2	19.0
A76	02/02/96	2024	2043	T	170	2970	2446.3	12	0.8	4.9
A77	02/02/96	2336	2354	N	171	2710	1990.2	16	1.4	8.0
A78	03/02/96	0237	0256	N	172	2960	2134.7	156	12.6	73.1
A79	03/02/96	0530	0550	D	171	1760	2375.3	34	2.4	14.3
A80	03/02/96	0835	0854	D	170	1035	2288.2	100	7.4	43.7
A81	03/02/96	1217	1250	D	170	1270	5337.5	2423	77.2	454.0
A82	03/02/96	1547	1612	D	170	730	3554.3	38	1.8	10.7
A83	03/02/96	1853	1914	D	170	340	3107.7	47	2.6	15.1
A84	03/02/96	2200	2225	T	169	535	3832.6	3	0.1	0.8
A85	04/02/96	0046	0110	N	171	690	3779.0	69	3.1	18.3
A86	04/02/96	0356	0425	T	170	1060	4156.7	30	1.2	7.2
A87	04/02/96	0702	0724	D	170	1770	3344.1	12	0.6	3.6
A88	04/02/96	0947	1016	D	168	550	4215.0	22	0.9	5.2
A89	04/02/96	1235	1305	D	170	2440	4831.6	124	4.4	25.7
A90	04/02/96	1527	1600	D	169	2350	5406.7	67	2.1	12.4
A91	04/02/96	1821	1848	D	170	3225	3546.4	26	1.2	7.3

SURVEY A AREA	NO.	91	46831			
	MEAN			18.9	112.5	
	STD			70.3	412.2	
	MEDIAN			2.0	12.2	
ELEPHANT ISLAND AREA	NO.	72	25815			
	MEAN			13.6	82.1	
	STD			42.1	245.1	
	MEDIAN			1.9	11.4	

TABLE 4.1 AMLR 1996 Large-area survey IKMT station information.

B. SURVEY D

STATION #	DATE	START TIME	END TIME	DIEL	TOW DEPTH (m)	BOTTOM DEPTH (m)	VOLUME (m3)	KRILL ABUNDANCE TOTAL	#/m2	#/1000m3
D91	23/02/96	2316	2338	N	172	3200	3179.8	43	2.3	13.5
D90	24/02/96	0445	0511	T	170	2390	3887.6	19	0.8	4.9
D89	24/02/96	0754	0818	D	170	2460	3893.9	3	0.1	0.8
D88	24/02/96	1108	1137	D	175	550	3693.6	11	0.5	3.0
D87	24/02/96	1520	1556	D	169	1890	5831.0	151	4.4	25.9
D86	24/02/96	1856	1928	D	171	1066	5510.4	96	3.0	17.4
D85	24/02/96	2213	2244	N	171	704	4762.0	19	0.7	4.0
D84	25/02/96	0146	0216	N	170	530	4483.0	130	4.9	29.0
D83	25/02/96	1332	1352	D	174	325	2378.4	0	0.0	0.0
D82	25/02/96	1729	1754	D	170	740	3281.1	68	3.5	20.7
D81	25/02/96	2107	2132	N	170	1192	3672.8	16	0.7	4.4
D80	26/02/96	0126	0153	N	170	1080	3609.3	26656	1255.5	7385.4
D79	26/02/96	0453	0523	T	169	1710	4567.8	6	0.2	1.3
D78	26/02/96	0819	0847	D	170	2950	4303.0	6	0.2	1.4
D77	26/02/96	1130	1159	D	171	2615	4362.9	1	0.0	0.2
D76	26/02/96	1446	1517	D	168	2950	4682.2	27	1.0	5.8
D75	26/02/96	1818	1852	D	169	3150	5988.3	0	0.0	0.0
D74	26/02/96	2143	2216	N	175	3010	5143.1	112	3.8	21.8
D73	27/02/96	0107	0138	N	171	3130	4638.5	556	20.5	119.9
D72	27/02/96	0435	0505	T	170	2920	4233.6	47	1.9	11.1
D71	27/02/96	0749	0822	D	170	570	6253.2	603	16.4	96.4
D70	27/02/96	1051	1125	D	170	498	5470.6	106	3.3	19.4
D69	27/02/96	1356	1421	D	170	1470	3756.9	1	0.0	0.3
D68	27/02/96	1655	1714	D	171	630	2436.0	0	0.0	0.0
D67	27/02/96	1940	2001	T	171	2050	4251.1	274	11.0	64.5
D66	27/02/96	2248	2324	N	173	780	7043.0	82	2.0	11.6
D65	28/02/96	0135	0202	N	163	180	4155.2	253	9.9	60.9
D64	28/02/96	0643	0709	D	168	430	3324.2	8	0.4	2.4
D63	28/02/96	0948	1019	D	170	3040	5353.7	7	0.2	1.3
D62	28/02/96	1300	1334	D	169	3320	5830.5	4	0.1	0.7
D61	28/02/96	1607	1643	D	199	3400	6218.7	3	0.1	0.5
D60	28/02/96	1903	1928	T	170	3610	3808.1	2	0.1	0.5
D59	28/02/96	2212	2237	N	170	3590	3383.0	44	2.2	13.0
D58	29/02/96	0134	0201	N	170	3440	4309.3	298	11.8	69.2
D57	29/02/96	0503	0529	T	169	3530	4319.8	18	0.7	4.2
D56	29/02/96	0819	0845	D	170	3300	3779.3	25	1.1	6.6
D55	29/02/96	1110	1118	D	41	53	1336.3	1209	37.1	904.7
D54	29/02/96	1403	1414	D	49	62	2130.9	0	0.0	0.0
D53	29/02/96	1652	1718	D	171	492	3552.4	1	0.0	0.3
D52	29/02/96	2002	2029	T	172	3300	4686.8	21	0.8	4.5
D51	29/02/96	2335	0004	N	169	755	4307.2	189	7.4	43.9
D50	01/03/96	0323	0351	N	169	330	4388.4	32	1.2	7.3
D49	01/03/96	0635	0654	D	119	140	3423.0	63	2.2	18.4
D48	01/03/96	1508	1534	D	169	510	2823.1	1	0.1	0.4
D47	01/03/96	1911	1944	T	170	3000	4570.7	8	0.3	1.8
D46	01/03/96	2243	2310	N	169	3880	3331.4	26	1.3	7.8
D45	02/03/96	0152	0214	N	172	3670	2227.6	157	12.1	70.5
D44	02/03/96	0500	0523	T	171	3650	2481.2	3	0.2	1.2
D43	02/03/96	0805	0832	D	170	3600	3975.3	0	0.0	0.0
D42	02/03/96	1134	1200	D	170	3800	3582.0	1	0.0	0.3
D41	02/03/96	1447	1518	D	170	3800	4854.2	19	0.7	3.9
D40	02/03/96	1759	1825	D	170	2890	4018.0	1	0.0	0.2
D39	02/03/96	2130	2156	N	170	2130	3683.7	3	0.1	0.8

TABLE 4.1 AMLR 1996 Large-area survey IKMT station information.

B. SURVEY D

STATION #	DATE	START TIME	END TIME	DIEL	TOW DEPTH (m)	BOTTOM DEPTH (m)	VOLUME (m3)	KRILL ABUNDANCE TOTAL	#/m2	#/1000m3
D38	03/03/96	0051	0115	N	169	360	3257.5	620	32.2	190.3
D37	03/03/96	0347	0413	N	170	510	3280.6	20	1.0	6.1
D36	03/03/96	0639	0705	D	169	533	3654.0	8	0.4	2.2
D35	03/03/96	0958	1023	D	169	1780	3998.2	0	0.0	0.0
D34	03/03/96	1338	1404	D	170	1560	4012.1	261	11.1	65.1
D33	03/03/96	1636	1702	D	170	620	4348.1	2	0.1	0.5
D32	03/03/96	1917	1944	T	175	405	4152.1	7	0.3	1.7
D31	03/03/96	2201	2229	N	174	480	4246.2	848	34.7	199.7
D30	04/03/96	0113	0140	N	169	1620	4118.5	58	2.4	14.1
D29	04/03/96	0426	0454	T	172	2750	4285.3	2	0.1	0.5
D28	04/03/96	0744	0813	D	170	3560	4606.8	0	0.0	0.0
D27	04/03/96	1131	1156	D	170	1572	3380.7	7	0.4	2.1
D26	04/03/96	1515	1539	D	171	4080	3785.9	3	0.1	0.8
D25	04/03/96	1925	1954	T	170	3480	4190.6	0	0.0	0.0
D24	04/03/96	2245	2310	N	171	3760	3641.9	56	2.6	15.4
D23	05/03/96	0333	0357	N	171	2280	3538.6	35	1.7	9.9
D22	05/03/96	0739	0809	D	168	3550	4851.5	0	0.0	0.0
D21	05/03/96	1141	1207	D	169	4490	3950.6	0	0.0	0.0
D20	05/03/96	1537	1605	D	170	3940	4339.3	1	0.0	0.2
D19	05/03/96	1857	1931	T	171	2619	5687.5	2	0.1	0.4
D18	05/03/96	2230	2254	N	171	645	3218.7	169	9.0	52.5
D17	06/03/96	0130	0157	N	180	350	4234.5	40	1.7	9.4
D16	06/03/96	0756	0821	D	170	2010	3857.6	54	2.4	14.0
D15	06/03/96	1104	1132	D	169	322	4626.4	1	0.0	0.2
D14	06/03/96	1349	1408	D	145	162	2416.5	5	0.3	2.1
D13	06/03/96	1709	1733	D	170	276	3541.7	0	0.0	0.0
D12	06/03/96	2010	2043	T	170	950	5600.0	27	0.8	4.8
D11	07/03/96	0017	0041	N	172	2370	3373.2	11	0.6	3.3
D10	07/03/96	0331	0357	N	170	950	3636.9	37	1.7	10.2
D09	07/03/96	0638	0703	D	170	265	4542.8	21	0.8	4.6
D08	07/03/96	1227	1244	D	80	91	2750.7	0	0.0	0.0
D07	07/03/96	1523	1549	D	170	1920	3725.2	5	0.2	1.3
D06	07/03/96	1835	1903	T	170	1460	4746.2	1	0.0	0.2
D05	07/03/96	2129	2156	N	171	1800	4251.9	9	0.4	2.1
D04	08/03/96	0031	0102	N	170	1570	5041.9	37	1.2	7.3
D03	08/03/96	0318	0344	N	175	440	3859.3	16	0.7	4.1
D02	08/03/96	0607	0631	T	191	1640	3696.4	2	0.1	0.5
D01	08/03/96	0901	0921	D	170	1480	2792.0	1	0.1	0.4

SURVEY D AREA		NO.	91	33795		
		MEAN			16.9	106.7
		STD			130.7	773.6
		MEDIAN			0.6	3.3
	WITHOUT D80	NO.	90	7139		
		MEAN			3.1	25.9
		STD			7.0	99.5
		MEDIAN			0.5	3.1
ELEPHANT ISLAND AREA		NO.	72	33305		
		MEAN			21.0	133.2
		STD			146.7	867.7
		MEDIAN			0.7	4.1

Table 4.2 Maturity stage composition of krill collected in the large-area surveys and Elephant Island area during 1996 compared to the Elephant Island area during 1992-1995. February-March 1996 values do not include data from Station D80. Advanced female maturity stages are proportions of mature females that are 3c-3e in January and 3d-3e in February-March.

	E. superba January					
	1996	1996	1995	1994	1993	1992
Area	Survey A	Elephant I.	Elephant I.	Elephant I.	Elephant I.	Elephant I.
	%	%	%	%	%	%
Juveniles	63.2	55.0	4.6	4.0	7.2	37.1
Immature stages	14.3	18.3	4.0	18.8	30.7	19.1
Mature stages	22.5	26.7	91.4	77.2	62.2	43.9
Females:						
F2	0.7	1.1	0.1	2.3	7.8	0.8
F3a	0.0	0.0	0.2	18.0	11.7	0.6
F3b	0.2	0.2	1.2	19.3	14.3	12.3
F3c	2.6	1.9	15.3	20.1	5.1	9.2
F3d	0.8	0.7	17.7	2.3	1.2	0.4
F3e	6.9	11.6	3.7	0.0	0.0	0.0
Advanced Stages	98.0	98.3	96.3	37.5	19.5	42.7
Males:						
M2a	11.8	14.6	0.9	0.3	6.8	8.7
M2b	1.4	2.1	1.5	9.4	11.9	7.3
M2c	0.4	0.5	1.5	6.8	4.2	2.3
M3a	1.3	1.4	4.4	4.3	3.7	2.8
M3b	10.6	10.9	48.9	13.2	26.2	18.7
Male:Female ratio	2.3:1	1.9:1	1.5:1	0.5:1	1.3:1	1.7:1
No. measured	5811	4296	2294	2078	4283	2472

	E. superba February-March					
	1996	1996	1995	1994	1993	1992
Area	Survey D	Elephant I.	Elephant I.	Elephant I.	Elephant I.	Elephant I.
	%	%	%	%	%	%
Juveniles	19.8	20.8	1.1	3.7	3.5	33.6
Immature stages	9.5	9.9	2.5	6.2	51.4	27.1
Mature stages	70.8	69.3	96.4	90.1	45.1	39.2
Females:						
F2	0.5	0.6	0.3	0.7	21.8	0.8
F3a	0.0	0.0	0.0	3.5	12.4	10.3
F3b	0.0	0.0	0.0	7.8	6.2	10.2
F3c	4.6	5.0	2.0	4.3	3.7	4.3
F3d	13.1	10.9	21.8	4.6	1.1	1.2
F3e	5.0	4.9	20.4	0.9	1.2	<0.01
Advanced Stages	79.8	76.0	95.5	26.1	9.3	4.6
Males:						
M2a	6.2	6.5	0.7	0.2	6.9	4.3
M2b	1.2	1.2	0.4	1.2	19.1	19.8
M2c	1.5	1.6	1.1	4.2	3.6	2.2
M3a	5.0	5.3	4.4	24.1	2.1	2.5
M3b	43.0	43.2	47.8	44.7	18.4	10.7
Male:Female ratio	2.4:1	2.7:1	1.2:1	3.4:1	1.1:1	1.5:1
No. measured	3367	2984	1271	1155	3669	3646

Table 4.3 Zooplankton taxa present in the large-area survey samples during January 1996 compared to January 1994 and January 1995. F is the frequency of occurrence (%) in tows. n.a. indicates taxon was not enumerated.

Taxon	Survey A January 1996		Survey A January 1995		Survey A January 1994	
	F(%) (91 tows)	Mean #/1000 m3	F(%) (90 tows)	Mean #/1000 m3	F(%) (81 tows)	Mean #/1000 m3
Copepods	100.0	794.4	98.9	652.7	30.0	41.3
Thysanoessa macrura	98.9	106.9	91.1	96.4	90.0	79.7
Euphausia superba	96.7	112.5	87.8	14.5	77.5	27.1
Themisto gaudichaudii	92.3	4.9	76.7	4.9	83.8	10.6
Thysanoessa macrura (larvae)	90.1	308.5	36.7	15.9	n.a	n.a
Limacina helicina	74.7	33.7	43.3	1.9	6.3	0.3
Chaetognaths	68.1	12.5	98.9	79.7	n.a	n.a
Salpa thompsoni	64.8	20.4	66.7	16.0	100.0	818.3
Tomopteris carpenteri	60.4	0.9	84.4	4.2	37.5	2.5
Clione limacina	56.0	2.1	41.1	0.5	13.8	0.3
Ostracods	53.8	4.9	56.7	9.7	n.a	n.a
Vibilia antarctica	48.4	0.5	22.2	0.2	98.8	11.8
Spongiobranchaea australis	47.3	1.8	64.4	0.5	11.3	0.1
Hyperiella dilatata	41.8	0.6	54.4	0.3	18.7	0.3
Cyllopus magellanicus	41.8	1.6	24.4	0.2	82.5	6.3
Euphausia frigida	30.8	1.9	50.0	9.8	17.5	3.8
Lepidonotothen kempi (larvae)	30.8	0.3	20.0	0.1	6.3	0.3
Electrona antarctica (larvae)	27.5	0.7	61.1	2.5	2.5	0.0
Sagitta gazellae	23.1	0.3	48.9	3.4	20.0	0.4
Lepidonotothen larseni (larvae)	22.0	0.2	40.0	1.1	6.3	0.7
Euphausia superba (larvae)	22.0	2.7	22.2	135.8	n.a	n.a
Primno macropa	20.9	0.1	20.0	0.1	6.3	0.5
Eukrohnia hamata	20.9	0.1	10.0	0.1	21.3	0.2
Diphyes antarctica	17.6	0.1	58.9	1.0	20.0	0.3
Euphausia triacantha	15.4	0.5	33.3	1.5	7.5	1.2
Dimophyes arctica	15.4	0.1	25.6	0.8	7.5	0.0
Electrona antarctica (adults)	13.2	0.0	13.3	0.1	2.5	0.0
Scyphomedusae	13.2	0.1	—	—	1.3	0.0
Radiolaria	12.1	0.1	—	—	—	—
Cyllopus lucasii	11.0	0.1	22.2	0.5	16.3	0.7
Notolepis coatsi (larvae)	8.8	0.0	27.8	0.1	—	—
Sipunculids	7.7	0.0	24.4	0.1	—	—
Beroe cucumis	7.7	0.0	12.2	0.0	15.0	0.1
Clio pyramidata	6.6	0.1	72.2	5.3	40.0	5.4
Hyperiella macronyx	5.5	0.0	23.3	0.1	—	—
Vanadis antarctica	4.4	0.0	15.6	0.1	2.5	0.0
Hydromedusae	4.4	0.0	6.7	0.1	—	—
Thyphloscolex muelleri	4.4	0.0	—	—	—	—
Hyperoche medusarum	3.3	0.0	18.9	0.0	—	—
Lepidonotothen nudifrons (larvae)	2.2	0.0	8.9	0.1	1.3	0.2
Bathylagus antarcticus (larvae)	2.2	0.0	8.9	0.0	—	—
Gymnoscopelus opisthopteris (adults)	2.2	0.0	7.8	0.0	—	—
Rhynchonereella bongraini	2.2	0.0	3.3	0.1	—	—
Hyperiella antarctica	2.2	0.0	2.2	0.0	—	—
Calycopsis borchgrevinki	2.2	0.0	1.1	0.0	1.3	0.0
Decapod larvae	2.2	0.2	—	—	—	—

Table 4.3 Contd.

Taxon	Survey A January 1996		Survey A January 1995		Survey A January 1994	
	F(%) (91 tows)	Mean #/1000 m3	F(%) (90 tows)	Mean #/1000 m3	F(%) (81 tows)	Mean #/1000 m3
Eusirus perdentatus	1.1	0.0	22.2	0.1	—	—
Epimeriella macronyx	1.1	0.0	8.9	0.0	—	—
Atolla wyvillei	1.1	0.0	7.8	0.0	—	—
Orchomene plebs	1.1	0.0	4.4	0.0	1.3	0.0
Fish Eggs	1.1	0.0	4.4	0.0	—	—
Pleuragramma antarcticum (juveniles)	1.1	0.0	2.2	0.0	—	—
Periphylla periphylla	1.1	0.0	1.1	0.0	—	—
Gymnoscopelus nicholsi (adults)	1.1	0.0	1.1	0.0	—	—
Euphausia spp. (larvae)	1.1	0.0	—	—	—	—
Polychaetes	1.1	0.0	—	—	—	—
Cumaceans	1.1	0.0	—	—	—	—
Tomopteris septentrionalis	1.1	0.0	—	—	—	—
Beroe forskalii	1.1	0.0	—	—	—	—
Arctapodema ampla	1.1	0.0	—	—	—	—
Phalacrophorus pictus	1.1	0.0	—	—	—	—
Lepidonotothen larseni (juveniles)	1.1	0.0	—	—	—	—
Pelagobia longicirrata	1.1	0.0	—	—	—	—
Chorismus antarcticus	1.1	0.0	—	—	—	—
Eusirus antarcticus	1.1	0.0	—	—	—	—
Cryodraco antartica	1.1	0.0	—	—	—	—
Gammarids	1.1	0.0	—	—	—	—
Harpagifer antarcticus (larvae)	1.1	0.0	—	—	—	—
Maupasia coeca	1.1	0.0	—	—	—	—
Acanthephyra pelagica	—	—	22.2	0.1	—	—
Notolepis annulata (larvae)	—	—	13.3	0.0	—	—
Ctenophores	—	—	6.7	0.0	—	—
Bylgides pelagica	—	—	5.6	0.0	—	—
Orchomene rossi	—	—	5.6	0.0	—	—
Cyphocaris richardi	—	—	4.4	0.0	—	—
Eusirus microps	—	—	4.4	0.0	—	—
Euphausia crystallorphorias	—	—	4.4	0.0	—	—
Hyperia macrocephala	—	—	3.3	0.0	1.3	0.0
Gosea brachyura	—	—	3.3	0.0	—	—
Cephalopods	—	—	2.2	0.0	—	—
Isopods	—	—	2.2	0.0	—	—
Euphysora gigantea	—	—	2.2	0.0	—	—
Pteropods	—	—	1.1	0.0	2.5	0.0
Notothenia coriiceps (larvae)	—	—	1.1	0.0	1.3	0.0
Botrynema brucei	—	—	1.1	0.0	—	—
Artededraco mirus	—	—	1.1	0.0	—	—
Travisiopsis levinseni	—	—	1.1	0.0	—	—
Tomopteris sp #1	—	—	1.1	0.0	—	—
Notothenia gibberifrons (larvae)	—	—	1.1	0.0	—	—
Pycnogonids	—	—	1.1	0.0	—	—
Gymnodraco acuticeps (juveniles)	—	—	1.1	0.0	—	—
Pegantha martagon	—	—	1.1	0.0	—	—

Table 4.4. Abundance of krill and dominant zooplankton species collected in the Elephant Island area during (A) January and (B) February-March 1996 (all stations) compared to similar sampling periods in 1992-1995. Zooplankton data are not available for February-March 1992.

A.	January Elephant Island Area														
	E. superba					*T. macrura*					*S. thompsoni*				
	1996	1995	1994	1993	1992	1996	1995	1994	1993	1992	1996	1995	1994	1993	1992
No. Tows	72	71	63	70	63	72	71	63	70	63	72	71	63	70	63
Abundance: No./1000 m3															
Median	11.4	3.6	3.1	8.2	5.7	52.3	36.1	25.4	27.5	22.5	10.5	1.6	582.3	245.8	14.0
Mean	82.1	9.5	34.5	28.8	23.7	103.4	104.1	74.6	48.6	48.1	25.5	20.2	931.9	1213.4	94.3
Std. Dev.	245.1	20.6	94.2	64.4	78.0	118.1	231.9	144.3	60.1	57.0	36.3	46.5	950.2	2536.7	192.3
Minimum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.5	6.9	0.0
Maximum	1500.6	146.1	495.9	438.9	594.1	500.1	239.9	901.6	307.1	233.7	161.6	239.9	4781.7	16078.8	1231.1

B.	February-March Elephant Island Area														
	E. superba					*T. macrura* (* includes larval stages)					*S. thompsoni*				
	1996	1995	1994	1993	1992	1996	1995	1994*	1993*	1992	1996	1995	1994	1993	1992
No. Tows	72	71	70	67	67	72	71	70	67		72	71	70	67	
Abundance: No./1000 m3															
Median	4.1	1.2	0.4	3.0	7.1	53.6	22.2	23.8	22.1	n.a.	5.6	0.7	242.6	605.9	n.a.
Mean	133.2	5.2	17.1	35.0	38.0	116.1	79.7	77.1	128.9	n.a.	33.2	20.6	495.1	1585.9	n.a.
Std. Dev.	867.7	12.0	63.5	89.7	77.4	147.4	138.5	132.6	235.1	n.a.	85.7	66.5	579.4	2725.5	n.a.
Minimum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	n.a.	0.0	0.0	5.3	2.2	n.a.
Maximum	7385.4	90.0	371.1	542.0	389.9	679.4	664.9	815.9	1141.5	n.a.	659.4	391.9	2377.5	16662.5	n.a.

Table 4.5 Zooplankton collected in large-area Surveys A and D. Abundance is numbers per 1000 m3. F(%) is percent frequency of occurrence in tows.

	SURVEY A JANUARY 1996				SURVEY D FEBRUARY-MARCH 1996			
TAXON	F(%)	Mean	Std	Median	F(%)	Mean	Std	Median
Copepods	100.0	794.4	1565.5	316.7	98.9	1387.0	2015.6	921.2
Chaetognaths	68.1	12.5	27.0	4.2	93.4	64.1	76.1	41.2
Thysanoessa macrura	98.9	106.9	127.8	58.1	91.2	143.3	183.0	71.3
Themisto gaudichaudii	92.3	4.9	7.7	2.5	91.2	2.5	3.2	1.2
Thysanoessa macrura (larvae)	90.1	308.5	774.9	29.7	87.9	414.4	1289.0	26.1
Euphausia superba	96.7	112.5	412.2	12.2	86.8	106.7	773.6	3.3
Spongiobranchaea australis	47.3	1.8	7.3	0.0	68.1	1.4	2.5	0.3
Primno macropa	20.9	0.1	0.4	0.0	63.7	3.5	10.0	0.9
Salpa thompsoni	64.8	20.4	33.8	4.3	62.6	28.2	77.7	0.9
Euphausia superba (larvae)	22.0	2.7	7.5	0.0	62.6	13.9	40.2	3.0
Euphausia frigida	30.8	1.9	4.9	0.0	54.9	9.0	13.7	1.2
Hyperiella dilatata	41.8	0.6	1.3	0.0	52.7	0.8	1.4	0.2
Vibilia antarctica	48.4	0.5	0.9	0.0	48.4	1.0	2.2	0.0
Ostracods	53.8	4.9	9.8	0.9	47.3	10.1	19.3	0.0
Cyllopus magellanicus	41.8	1.6	3.5	0.0	46.2	2.1	4.8	0.0
Lepidonotothen kempi (larvae)	30.8	0.3	1.0	0.0	39.6	0.4	0.7	0.0
Electrona antarctica (larvae)	27.5	0.7	2.6	0.0	38.5	0.9	2.0	0.0
Tomopteris carpenteri	60.4	0.9	1.6	0.3	38.5	0.9	2.0	0.0
Radiolaria	12.1	0.1	0.4	0.0	34.1	0.9	2.2	0.0
Cyllopus lucasii	11.0	0.1	0.2	0.0	34.1	0.2	0.6	0.0
Sagitta gazellae	23.1	0.3	0.7	0.0	31.9	0.3	0.9	0.0
Limacina helicina	74.7	33.7	90.8	2.0	24.2	1.9	6.4	0.0
Euphausia triacantha	15.4	0.5	2.0	0.0	22.0	0.8	2.5	0.0
Electrona antarctica (adults)	13.2	0.0	0.1	0.0	20.9	0.2	1.2	0.0
Schyphomedusae	13.2	0.1	0.2	0.0	19.8	0.1	0.3	0.0
Eukrohnia hamata	20.9	0.1	0.4	0.0	19.8	0.1	0.2	0.0
Notolepis coatsi (larvae)	8.8	0.0	0.1	0.0	18.7	0.1	0.3	0.0
Clione limacina	56.0	2.1	5.3	0.2	15.4	0.2	0.6	0.0
Lepidonotothen larseni (larvae)	22.0	0.2	0.6	0.0	13.2	0.3	2.3	0.0
Dimophyes arctica	15.4	0.1	0.3	0.0	13.2	0.1	0.5	0.0
Beroe cucumis	7.7	0.0	0.1	0.0	11.0	0.1	0.2	0.0
Cephalopods	0.0	0.0	0.0	0.0	9.9	0.0	0.1	0.0
Sipunculids	7.7	0.0	0.1	0.0	8.8	0.1	0.3	0.0
Diphyes antarctica	17.6	0.1	0.3	0.0	7.7	0.1	0.3	0.0
Hyperiella macronyx	5.5	0.0	0.1	0.0	6.6	0.1	0.3	0.0
Calycopsis borchgrevinki	2.2	0.0	0.0	0.0	6.6	0.0	0.1	0.0
Orchomene rossi	0.0	0.0	0.0	0.0	5.5	0.5	3.9	0.0
Rhynchonereella bongraini	2.2	0.0	0.0	0.0	5.5	0.1	0.8	0.0
Notolepis annulata (larvae)	0.0	0.0	0.0	0.0	5.5	0.0	0.1	0.0
Polychaetes	1.1	0.0	0.2	0.0	3.3	0.1	0.4	0.0
Hydromedusae	4.4	0.0	0.0	0.0	3.3	0.1	0.4	0.0
Gymnoscopelus nicholsi (adults)	1.1	0.0	0.0	0.0	3.3	0.0	0.1	0.0
Clio pyramidata	6.6	0.1	0.5	0.0	3.3	0.0	0.0	0.0
Eusirus microps	0.0	0.0	0.0	0.0	3.3	0.0	0.0	0.0
Gymnoscopelus opisthopteris (adults)	2.2	0.0	0.0	0.0	3.3	0.0	0.0	0.0
Scina spp.	0.0	0.0	0.0	0.0	2.2	0.0	0.3	0.0
Orchomene plebs	1.1	0.0	0.0	0.0	2.2	0.0	0.1	0.0
Hyperoche medusarum	3.3	0.0	0.0	0.0	2.2	0.0	0.0	0.0
Eusirus perdentatus	1.1	0.0	0.0	0.0	2.2	0.0	0.0	0.0
Hyperia spp.	0.0	0.0	0.0	0.0	1.1	0.1	0.5	0.0
Atolla wyvillei	1.1	0.0	0.0	0.0	1.1	0.0	0.3	0.0
Cumacea	1.1	0.0	0.1	0.0	1.1	0.0	0.2	0.0
Gammarids	1.1	0.0	0.0	0.0	1.1	0.0	0.1	0.0
Hyperia macrocephala	0.0	0.0	0.0	0.0	1.1	0.0	0.1	0.0

Table 4.5 Contd.

TAXON	SURVEY A JANUARY 1996				SURVEY D FEBRUARY-MARCH 1996			
	F(%)	Mean	Std	Median	F(%)	Mean	Std	Median
Epimeriella macronyx	1.1	0.0	0.0	0.0	1.1	0.0	0.1	0.0
Travisiopsis coniceps	0.0	0.0	0.0	0.0	1.1	0.0	0.0	0.0
Lepidonotothen nudifrons (larvae)	2.2	0.0	0.1	0.0	1.1	0.0	0.0	0.0
Hyperiids	0.0	0.0	0.0	0.0	1.1	0.0	0.0	0.0
Bathylagus antarcticus (larvae)	2.2	0.0	0.1	0.0	1.1	0.0	0.0	0.0
Harpagifer antarcticus (larvae)	1.1	0.0	0.0	0.0	1.1	0.0	0.0	0.0
Larval fish (unident.)	1.1	0.0	0.1	0.0	1.1	0.0	0.0	0.0
Decapod larvae	2.2	0.2	1.1	0.0	1.1	0.0	0.0	0.0
Cyphocaris richardi	0.0	0.0	0.0	0.0	1.1	0.0	0.0	0.0
Periphylla periphylla	1.1	0.0	0.0	0.0	1.1	0.0	0.0	0.0
Pleuragramma antarcticum (juveniles)	1.1	0.0	0.2	0.0	1.1	0.0	0.0	0.0
Ctenophores	0.0	0.0	0.0	0.0	1.1	0.0	0.0	0.0
Vanadis antarctica	4.4	0.0	0.1	0.0	1.1	0.0	0.0	0.0
Thyphloscolex muelleri	4.4	0.0	0.1	0.0	0.0	0.0	0.0	0.0
Hyperiella antarctica	2.2	0.0	0.1	0.0	0.0	0.0	0.0	0.0
Euphausia spp. (larvae)	1.1	0.0	0.4	0.0	0.0	0.0	0.0	0.0
Tomopteris septentrionalis	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Beroe forskalii	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Arctapodema ampla	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Phalacrophorus pictus	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lepidonotothen larseni (juveniles)	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Fish Eggs	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pelagobia longicirrata	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Chorismus antarcticus	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Eusirus antarcticus	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cryodraco antartica (juveniles)	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Maupasia coeca	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL		1414.2	2156.7	667.2		2196.8	3224.3	1402.9

Table 4.6 Zooplankton taxa present in the large-area survey samples during February-March 1996 compared to February-March 1994 and 1995. F is the frequency of occurrence (%) in tows. n.a. indicates taxon was not enumerated.

	Survey D February-March 1996		Survey D February 1995		Survey D February-March 1994	
TAXON	F(%) (91 tows)	Mean #/1000m3	F(%) (89 tows)	Mean #/1000m3	F(%) (89 tows)	Mean #/1000m3
Copepods	98.9	1387.0	100.0	3189.1	89.9	3090.2
Chaetognaths	93.4	64.1	100.0	296.4	n.a.	n.a.
Thysanoessa macrura (adults)	91.2	143.3	93.3	161.3	91.0	118.9
Themisto gaudichaudii	91.2	2.5	74.2	3.6	94.4	11.8
Thysanoessa macrura (larvae)	87.9	414.4	79.8	276.9	n.a.	n.a.
Euphausia superba	86.8	106.7	78.7	5.7	66.3	18.4
Spongiobranchaea australis	68.1	1.4	60.7	0.4	14.6	0.1
Primno macropa	63.7	3.5	31.5	0.4	10.1	0.1
Salpa thompsoni	62.6	28.2	59.6	16.5	98.9	523.5
Euphausia superba (larvae)	62.6	13.9	93.3	3690.0	n.a.	n.a.
Euphausia frigida	54.9	9.0	60.7	16.7	61.8	25.9
Hyperiella dilatata	52.7	0.8	24.7	0.1	36.0	0.6
Vibilia antarctica	48.4	1.0	23.6	0.2	85.4	6.4
Ostracods	47.3	10.1	75.3	43.4	n.a.	n.a.
Cyllopus magellanicus	46.2	2.1	25.8	0.7	79.8	4.4
Lepidonotothen kempi (larvae)	39.6	0.4	48.3	0.4	6.7	0.1
Electrona antarctica (larvae)	38.5	0.9	62.9	5.2	11.2	0.2
Tomopteris carpenteri	38.5	0.9	57.3	1.3	24.7	0.6
Cyllopus lucasii	34.1	0.2	23.6	0.5	89.9	6.1
Sagitta gazellae	31.9	0.3	59.6	3.0	34.8	3.8
Limacina helicina	24.2	1.9	4.5	0.0	—	—
Euphausia triacantha	22.0	0.8	28.1	1.6	11.2	1.0
Electrona antarctica (adults)	20.9	0.2	15.7	0.1	13.5	0.1
Scyphomedusae	19.8	0.1	13.5	0.1	—	—
Eukronia hamata	19.8	0.1	33.7	0.8	3.4	0.1
Notolepis coatsi (larvae)	18.7	0.1	36.0	0.2	—	—
Clione limacina	15.4	0.2	—	—	—	—
Lepidonothen larseni (larvae)	13.2	0.3	10.1	0.0	—	—
Dimophyes arctica	13.2	0.1	13.5	0.3	10.1	0.0
Beroe cucumis	11.0	0.1	4.5	0.0	2.2	0.0
Cephalopods	9.9	0.0	—	—	—	—
Sipunculids	8.8	0.1	9.0	0.0	3.4	0.0
Diphyes antarctica	7.7	0.1	23.6	0.4	13.5	0.1
Hyperiella macronyx	6.6	0.1	13.5	0.0	—	—
Calycopsis borchgrevinki	6.6	0.0	11.2	0.0	10.1	0.1
Orchomene rossi	5.5	0.5	6.7	0.0	—	—
Rhynchonereella bongraini	5.5	0.1	20.2	0.1	—	—
Notolepis annulata (larvae)	5.5	0.0	3.4	0.0	—	—
Polychaetes	3.3	0.1	2.2	0.0	—	—
Hydromedusae	3.3	0.1	5.6	0.0	—	—
Gymnoscopelus nicholsi (adults)	3.3	0.0	1.1	0.0	—	—
Clio pyramidata	3.3	0.0	12.4	0.0	9.0	0.2
Eusirus microps	3.3	0.0	—	—	—	—
Gymnoscopelus opisthopterus (adults)	3.3	0.0	10.1	0.0	2.2	0.0
Scina spp.	2.2	0.0	1.1	0.0	—	—

Table 4.6 Contd.

TAXON	Survey D February-March 1996 F(%) (91 tows)	Survey D February-March 1996 Mean #/1000m3	Survey D February 1995 F(%) (89 tows)	Survey D February 1995 Mean #/1000m3	Survey D February-March 1994 F(%) (89 tows)	Survey D February-March 1994 Mean #/1000m3
Orchomene plebs	2.2	0.0	3.4	0.0	2.2	0.1
Hyperoche medusarum	2.2	0.0	12.4	0.0	5.6	0.1
Eusirus perdentatus	2.2	0.0	6.7	0.1	—	—
Hyperia spp.	1.1	0.1	—	—	—	—
Atolla wyvillei	1.1	0.0	—	—	—	—
Cumacea	1.1	0.0	—	—	—	—
Gammarids	1.1	0.0	—	—	—	—
Hyperia macrocephala	1.1	0.0	5.6	0.0	—	—
Epimeriella macronyx	1.1	0.0	5.6	0.6	—	—
Travisiopsis coniceps	1.1	0.0	1.1	0.0	—	—
Nototheniops nudifrons (larvae)	1.1	0.0	3.4	0.0	—	—
Hyperiids	1.1	0.0	—	—	—	—
Bathylagus antarcticus (larvae)	1.1	0.0	14.6	0.0	—	—
Harpagifer antarcticus	1.1	0.0	—	—	—	—
Larval fish (unident.)	1.1	0.0	—	—	—	—
Decapod larvae	1.1	0.0	—	—	—	—
Cyphocaris richardi	1.1	0.0	3.4	0.1	—	—
Periphylla periphylla	1.1	0.0	1.1	0.0	3.4	0.0
Pleurogramma antarcticum (juveniles)	1.1	0.0	2.2	0.0	—	—
Ctenophores	1.1	0.0	3.4	0.0	—	—
Vanadis antarctica	1.1	0.0	6.7	0.0	7.9	0.1
Acanthephyra pelagica (larvae)	—	—	5.6	0.0	—	—
Byglides pelagica	—	—	2.2	0.0	—	—
Beroe forskalii	—	—	1.1	0.0	3.4	0.1
Fish eggs	—	—	1.1	0.0	7.9	0.1
Lepidonothen larseni (juveniles)	—	—	1.1	0.0	—	—
Notolepis spp. (larvae)	—	—	2.2	0.0	5.6	0.0
Pagetopsis macropterus	—	—	1.1	0.0	—	—
Champsocephalus gunnari	—	—	1.1	0.0	—	—

Table 4.7 Composition and abundance of selected taxa collected in targeted MOCNESS tows during 10-14 March 1996. Abundance is numbers per 1000 m3. Vertically stratified tows are arranged according to increasing depth of haul. Time is GMT (+3). Shading indicates dusk and night time tows; all others are day tows. Vertical lines separate five tow series.

Tow No.	X001	X002	X003	X004	X005	X006	X007	X008	X009	X010
Date	10/03/96	10/03/96	10/03/96	10/03/96	11/03/96	11/03/96	11/03/96	11/03/96	11/03/96	11/03/96
Net No.	4	4	4	1	4	4	4	4	4	4
Time	0145-0153	0616-0621	0814-0818	1021-1027	1221-1225	1427-1432	1644-1649	1821-1826	2024-2028	2136-2140
Depth Range (m)	63	15	10-12	11-13	2-14	12-17	11-13	0-17	0-12	0-15
Vol. (m3)	687.1	304.9	193.0	193.0	190.8	208.1	205.7	184.6	184.3	197.5
Krill	0.0	347.6	15.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Krill larvae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
T. macrura	0.0	0.0	0.0	0.0	1561.5	9.6	116.7	21.7	10.9	5.1
T. macrura larvae	4912.1	32.8	93.3	0.0	10742.0	322.0	87.5	92.1	0.0	541.7
E. frigida	109.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
E. triacantha	71.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Amphipods	106.2	3.3	0.0	5.2	73.4	0.0	0.0	0.0	21.7	10.1
Copepods	25243.1	983.8	238.3	1580.3	3275.0	288.4	481.2	2600.5	3038.9	440.4
Chaetognaths	545.8	32.8	93.3	331.6	131.0	192.2	87.5	216.7	54.3	0.0
Salps	138.3	0.0	0.0	0.0	36.7	0.0	0.0	0.0	54.3	0.0
Ostracods	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pteropods	74.2	0.0	0.0	0.0	5.2	0.0	0.0	0.0	5.4	0.0
E. antarctica	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
G. opisthopteris	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Net No.	3	3	3	2	3	3	3	3	1	1
Time	0138-0142	0610-0614	0806-0811	1013-1018	1159-1207	1420-1425	1636-1640	1815-1819	1934-1939	2057-2101
Depth Range (m)	96-98	30	35	20-23	141-147	23-36	45-57	40-50	30-35	35-40
Vol. (m3)	193.0	196.9	193.0	189.1	404.9	181.0	197.4	186.2	179.8	186.2
Krill	0.0	25.4	5.2	95.2	0.0	11.0	0.0	0.0	16.7	5.4
Krill larvae	0.0	0.0	0.0	0.0	34.6	0.0	0.0	0.0	0.0	0.0
T. macrura	10.4	20.3	20.7	10.6	0.0	0.0	5.1	10.7	0.0	0.0
T. macrura larvae	155.4	309.9	67.4	26.4	439.7	237.5	1874.7	429.6	1668.5	322.2
E. frigida	0.0	960.1	305.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
E. triacantha	5.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Amphipods	5.2	5.1	0.0	0.0	0.0	5.5	10.1	21.5	16.7	21.5
Copepods	6943.0	4597.2	114.0	26.4	7997.8	331.5	1722.7	2405.9	1724.1	1342.5
Chaetognaths	51.8	0.0	0.0	0.0	123.5	110.5	0.0	128.9	55.6	53.7
Salps	0.0	0.0	5.2	0.0	7.4	0.0	0.0	0.0	5.6	5.4
Ostracods	103.6	0.0	0.0	0.0	34.6	0.0	0.0	0.0	0.0	0.0
Pteropods	114.0	0.0	0.0	0.0	2.5	16.6	50.7	37.6	55.6	16.1
E. antarctica	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
G. opisthopteris	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Net No.	2	2	2	3	1	1	2	2	3	3
Time	0123-0130	0557-603	0755-0758	0948-0953	1127-1136	1352-1356	1618-1623	1800-1804	2009-2012	2122-2126
Depth Range (m)	242	100	100	156-159	178-202	110-112	100-109	145-165	95-100	71-72
Vol. (m3)	193.0	196.9	193.0	193.0	386.1	196.6	196.5	179.7	167.8	171.0
Krill	0.0	15.5	5.2	25.9	0.0	0.0	0.0	0.0	0.0	0.0
Krill larvae	0.0	46.6	0.0	0.0	0.0	0.0	0.0	0.0	59.6	0.0
T. macrura	36.3	212.4	114.0	129.5	0.0	0.0	10.2	0.0	0.0	0.0
T. macrura larvae	0.0	373.1	0.0	0.0	77.7	50.9	76.3	0.0	238.5	315.8
E. frigida	0.0	10.4	5.2	5.2	0.0	0.0	0.0	0.0	0.0	0.0
E. triacantha	5.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Amphipods	15.5	0.0	0.0	5.2	23.3	50.9	30.5	0.0	47.7	52.6
Copepods	5269.4	2072.5	5492.2	0.0	11190.3	12258.4	111.9	5843.4	29031.3	19825.7
Chaetognaths	41.5	0.0	103.6	0.0	0.0	763.0	76.3	389.6	119.2	40.9
Salps	0.0	0.0	0.0	0.0	25.9	0.0	0.0	0.0	417.3	11.7
Ostracods	0.0	0.0	0.0	0.0	233.1	0.0	0.0	0.0	0.0	0.0
Pteropods	57.0	0.0	0.0	0.0	62.2	0.0	20.4	0.0	0.0	17.5
E. antarctica	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
G. opisthopteris	0.0	0.0	5.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Net No.	1	1	1		2	2	1	1	2	2
Time	0114-0120	0539-0545	0740-0744		1136-1149	1359-1404	1607-1612	1753-1757	1957-2001	2112-2117
Depth Range (m)	293	250	200		208-228	150-164	150-170	175-190	146-150	140-150
Vol. (m3)	193.0	193.0	196.9		586.3	223.2	183.2	151.2	172.7	181.9
Krill	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0	0.0
Krill larvae	0.0	0.0	50.8		0.0	0.0	0.0	0.0	29.0	55.0
T. macrura	10.4	25.9	35.6		0.0	4.5	0.0	0.0	0.0	0.0
T. macrura larvae	124.4	36.3	0.0		0.0	26.9	54.6	0.0	57.9	0.0
E. frigida	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0	0.0
E. triacantha	5.2	5.2	5.1		0.0	0.0	0.0	0.0	0.0	0.0
Amphipods	93.3	10.4	111.8		93.8	0.0	0.0	11.7	29.0	98.9
Copepods	16456.0	1399.0	2946.3		4195.2	2970.8	6060.3	13025.7	3387.6	6100.9
Chaetognaths	373.1	699.5	609.6		0.0	591.5	436.8	3563.1	405.4	494.7
Salps	0.0	0.0	0.0		51.2	0.0	103.7	554.9	11.6	450.7
Ostracods	248.7	72.5	50.8		0.0	0.0	0.0	0.0	57.9	0.0
Pteropods	20.7	5.2	0.0		18.8	0.0	16.4	0.0	0.0	0.0
E. antarctica	0.0	5.2	0.0		0.0	0.0	0.0	0.0	0.0	0.0
G. opisthopteris	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0	0.0

Table 4.7 Contd.

Tow No.	X011	X012	X013	X014	X015	X016	X017	X018	X0019	X020
Date	12/03/96	12/03/96	12/03/96	12/03/96	12/03/96	12/03/96	13/03/96	13/03/96	13/03/96	13/03/96
Net No.	4	4	2	4	4	4	4	4	4	4
Time	1232-1237	1443-1447	1549-1552	1757-1801	1940-1952	2138-2143	1415-1419	1615-1619	1840-1843	2019-2022
Depth Range (m)	0-15	40-45	31-37	5-15	0-25	0-15	0-17	0-15	0-15	40-66
Vol. (m3)	247.4	173.9	183.9	173.0	183.9	211.7	160.3	168.2	161.2	150.2
Krill	0.0	40.3	32.6	23.1	5.4	4.7	0.0	0.0	0.0	253.0
Krill larvae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
T. macrura	3783.5	356.5	27.2	884.6	1429.9	944.9	0.0	5.9	0.0	259.7
T. macrura larvae	0.0	0.0	0.0	57.8	793.8	590.5	0.0	178.3	0.0	33.3
E. frigida	0.0	5.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
E. triacantha	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Amphipods	4.0	0.0	0.0	0.0	0.0	4.7	0.0	0.0	68.3	0.0
Copepods	452.7	2127.8	271.9	57.8	570.9	47.2	212.1	772.8	186.2	266.3
Chaetognaths	48.5	172.5	27.2	0.0	38.1	0.0	81.1	5.9	0.0	99.9
Salps	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ostracods	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pteropods	0.0	0.0	0.0	0.0	0.0	4.7	0.0	5.9	0.0	0.0
E. antarctica	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
G. opisthopteris	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Net No.	3	3	1	1	3	3	3	3	3	1
Time	1225-1231	1431-1435	1544-1548	1706-1711	1932-1936	2131-2136	1402-1406	1605-1609	1832-1835	1948-1953
Depth Range (m)	35-50	135-136	35-40	30-35	135-150	25-27	100-132	73-78	50-70	95-105
Vol. (m3)	218.8	205.5	177.2	187.1	173.0	203.0	182.9	201.0	139.4	192.9
Krill	27.4	0.0	11.3	37.4	0.0	14.8	0.0	0.0	0.0	20.7
Krill larvae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
T. macrura	45.7	0.0	33.9	5.3	0.0	54.2	49.2	0.0	322.8	0.0
T. macrura larvae	0.0	0.0	28.2	0.0	0.0	0.0	0.0	0.0	0.0	36.3
E. frigida	0.0	0.0	0.0	0.0	0.0	0.0	16.4	0.0	0.0	0.0
E. triacantha	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Amphipods	4.6	29.2	5.6	0.0	40.5	4.9	5.5	9.9	7.2	36.3
Copepods	2262.8	725.1	90.3	588.0	988.5	123.2	2564.2	278.6	50.2	414.7
Chaetognaths	45.7	58.4	146.8	42.8	133.0	24.6	552.2	199.0	480.6	36.3
Salps	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ostracods	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pteropods	9.1	0.0	5.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
E. antarctica	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
G. opisthopteris	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Net No.	2	1	4	3	2	2	2	2	1	2
Time	1206-1211	1357-1402	1612-1615	1744-1748	1921-1926	2120-2124	1353-1357	1534-1539	1739-1743	1956-2001
Depth Range (m)	115-140	220-225	28-55	135-145	249-265	26-27	135-150	75-100	95-105	100-107
Vol. (m3)	197.0	206.8	151.6	184.1	201.5	195.3	187.2	190.0	179.0	180.3
Krill	0.0	0.0	46.2	0.0	0.0	20.5	0.0	5.3	5.6	0.0
Krill larvae	45.7	0.0	0.0	0.0	148.9	0.0	0.0	0.0	0.0	0.0
T. macrura	0.0	0.0	72.6	0.0	0.0	25.6	16.0	15.8	0.0	38.8
T. macrura larvae	0.0	0.0	33.0	0.0	0.0	0.0	0.0	0.0	0.0	38.8
E. frigida	0.0	125.8	0.0	0.0	0.0	0.0	58.8	0.0	0.0	0.0
E. triacantha	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Amphipods	10.2	0.0	6.6	0.0	9.9	10.2	5.3	0.0	55.6	0.0
Copepods	3065.7	9963.7	428.7	3042.5	7395.3	158.7	1655.7	526.3	1000.9	443.7
Chaetognaths	106.6	203.1	131.9	108.7	546.0	0.0	1554.2	105.3	0.0	110.9
Salps	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ostracods	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pteropods	0.0	19.3	6.6	0.0	5.0	0.0	0.0	0.0	0.0	0.0
E. antarctica	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
G. opisthopteris	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Net No.	1	2	3	2	1	1	1	1	2	3
Time	1127-1153	1409-1413	1601-1605	1722-1727	1912-1916	2100-2105	1348-1353	1517-1522	1821-1825	2006-2011
Depth Range (m)	240-250	265-285	130-150	245-255	295-310	165-175	150-173	160-175	125-130	150
Vol. (m3)	217.1	197.6	195.2	220.6	189.5	192.1	221.5	225.1	183.2	211.4
Krill	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Krill larvae	92.1	50.6	25.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
T. macrura	0.0	10.1	5.1	0.0	0.0	5.2	58.7	164.3	10.9	217.6
T. macrura larvae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	177.7	0.0	94.6
E. frigida	129.0	30.4	0.0	95.2	21.1	1015.4	31.6	111.0	0.0	430.4
E. triacantha	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Amphipods	0.0	0.0	0.0	0.0	0.0	15.6	0.0	0.0	0.0	47.3
Copepods	9581.7	2682.6	1742.2	3582.0	15141.9	4014.6	2889.0	21232.2	218.4	2506.6
Chaetognaths	552.8	404.9	153.7	408.1	1213.5	978.9	993.1	799.5	21.8	945.9
Salps	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ostracods	92.1	0.0	0.0	90.7	369.3	0.0	0.0	0.0	0.0	0.0
Pteropods	13.8	0.0	0.0	0.0	52.8	0.0	45.1	0.0	0.0	0.0
E. antarctica	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
G. opisthopteris	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 4.7 Contd.

Tow No.	X021	X022	X023
Date	14/03/96	14/03/96	14/03/96
Net No.		4	4
Time		1954-1957	2157-2202
Depth Range (m)		100-110	0-15
Vol. (m3)		152.9	195.6
Krill		104.7	0.0
Krill larvae		0.0	20.5
T. macrura		39.2	0.0
T. macrura larvae		32.7	40.9
E. frigida		0.0	0.0
E. triacantha		0.0	0.0
Amphipods		0.0	20.5
Copepods		457.9	409.1
Chaetognaths		0.0	40.9
Salps		0.0	0.0
Ostracods		0.0	0.0
Pteropods		0.0	0.0
E. antarctica		0.0	0.0
G. opisthopteris		0.0	0.0
Net No.		3	3
Time		1951-1954	2151-2156
Depth Range (m)		118-125	15-17
Vol. (m3)		193.0	213.6
Krill		10.4	0.0
Krill larvae		0.0	37.5
T. macrura		51.8	0.0
T. macrura larvae		82.9	74.9
E. frigida		20.7	0.0
E. triacantha		0.0	0.0
Amphipods		0.0	0.0
Copepods		124.4	412.1
Chaetognaths		0.0	42.1
Salps		0.0	0.0
Ostracods		0.0	0.0
Pteropods		0.0	0.0
E. antarctica		0.0	0.0
G. opisthopteris		0.0	0.0
Net No.	2	2	2
Time	1728-1731	1945-1948	2128-2133
Depth Range (m)	125-135	125	98-128
Vol. (m3)	143.0	176.2	202.0
Krill	7.0	0.0	99.0
Krill larvae	0.0	0.0	0.0
T. macrura	7.0	22.7	19.8
T. macrura larvae	0.0	22.7	0.0
E. frigida	0.0	5.7	5.0
E. triacantha	0.0	0.0	0.0
Amphipods	48.9	0.0	0.0
Copepods	328.6	431.2	277.3
Chaetognaths	55.9	68.1	49.5
Salps	0.0	0.0	0.0
Ostracods	0.0	0.0	0.0
Pteropods	48.9	22.7	0.0
E. antarctica	0.0	0.0	0.0
G. opisthopteris	0.0	0.0	0.0
Net No.	1	1	1
Time	1724-1727	1918-1923	2123-2128
Depth Range (m)	150-190	122-130	110-125
Vol. (m3)	139.6	190.4	193.5
Krill	21.5	5.3	5.2
Krill larvae	0.0	0.0	0.0
T. macrura	57.3	15.8	46.5
T. macrura larvae	0.0	26.3	0.0
E. frigida	0.0	0.0	0.0
E. triacantha	0.0	0.0	0.0
Amphipods	0.0	0.0	0.0
Copepods	1389.7	131.3	1110.9
Chaetognaths	143.3	0.0	31.0
Salps	0.0	0.0	0.0
Ostracods	0.0	0.0	0.0
Pteropods	0.0	0.0	5.2
E. antarctica	0.0	0.0	0.0
G. opisthopteris	0.0	0.0	0.0

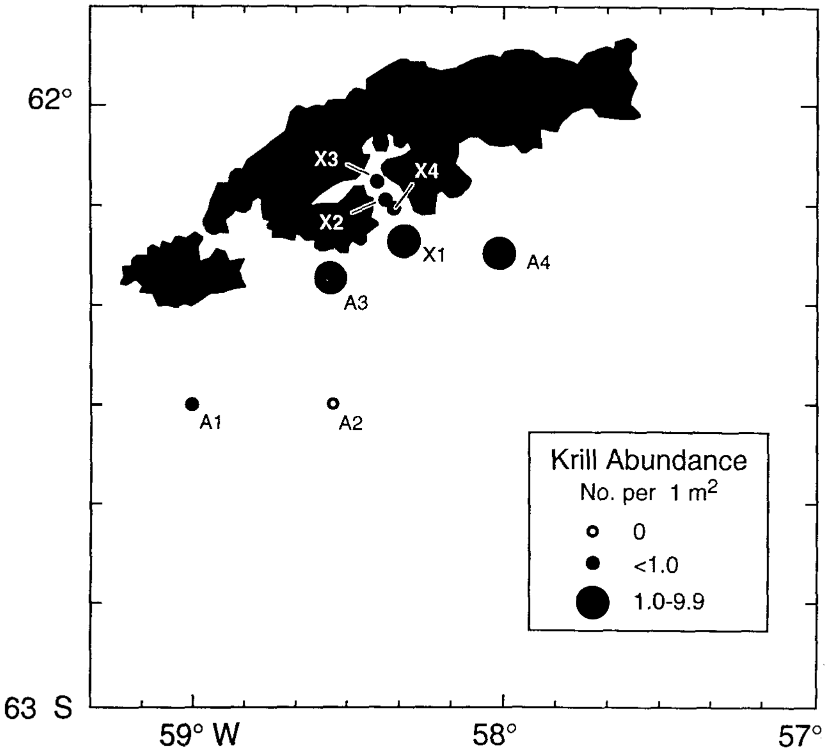

Figure 4.1 Krill abundance in four IKMT tows (Stations X1-X4) conducted on 22 January in Admiralty Bay. Also, krill abundance in four large-area survey stations adjacent to Admiralty Bay (Stations A1-A4) conducted on 23 January.

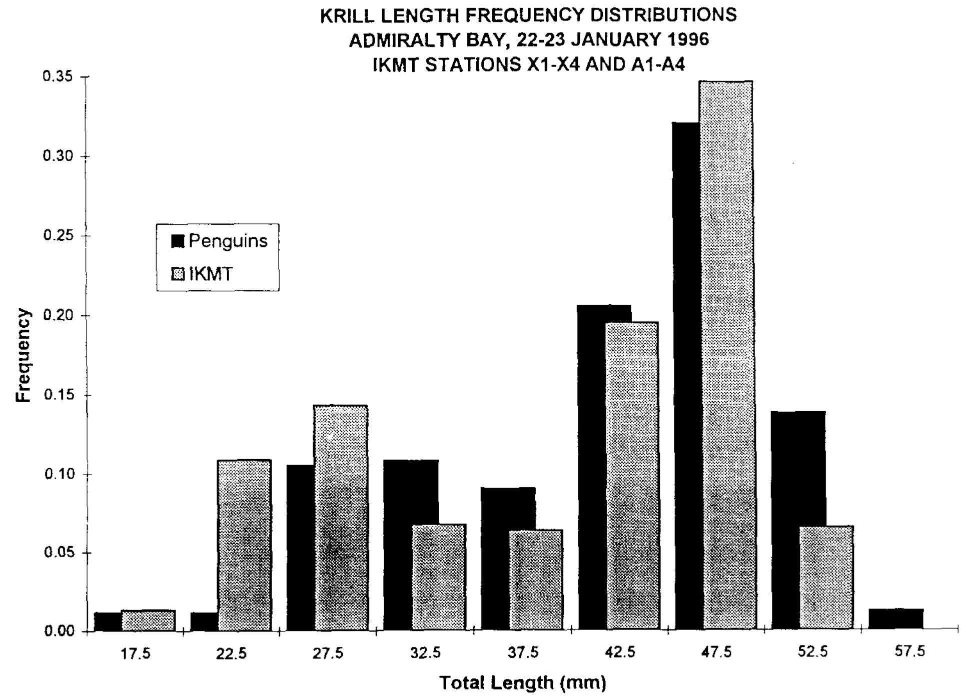

Figure 4.2 Overall length frequency distributions of krill collected at IKMT Stations X1-X4 and A1-A4 and obtained from penguin stomachs, 22-23 January 1996. Length frequencies are based on 5mm size categories.

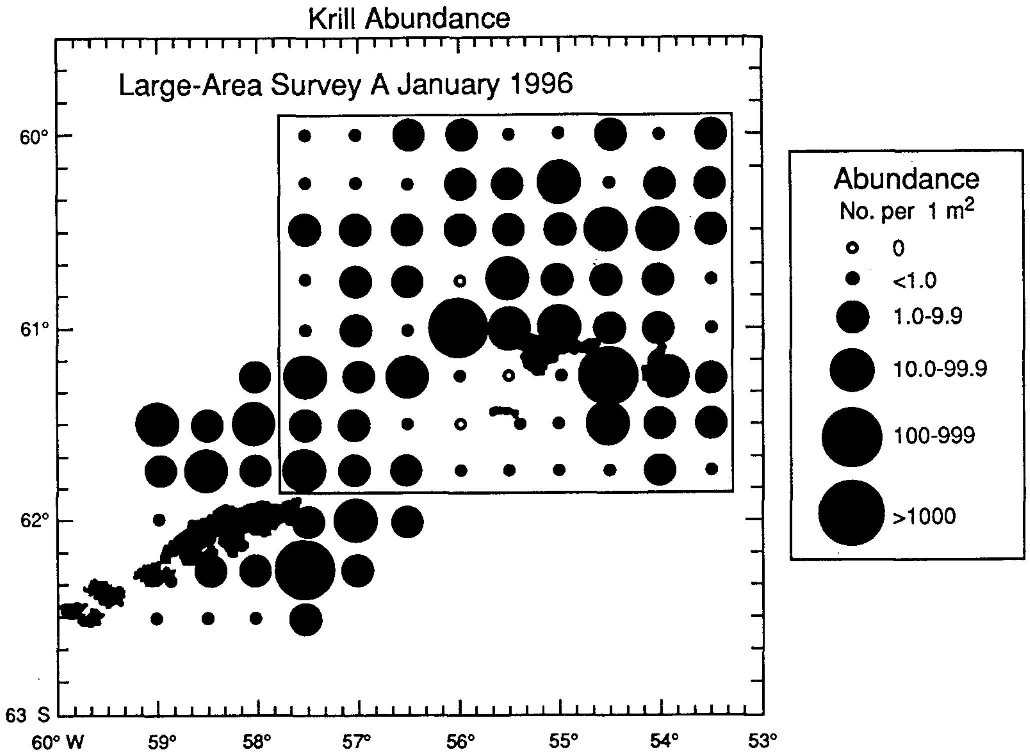

Figure 4.3 Krill abundance in IKMT tows collected during Survey A. The outlined stations are included in the "Elephant Island area" used for between-year comparisons.

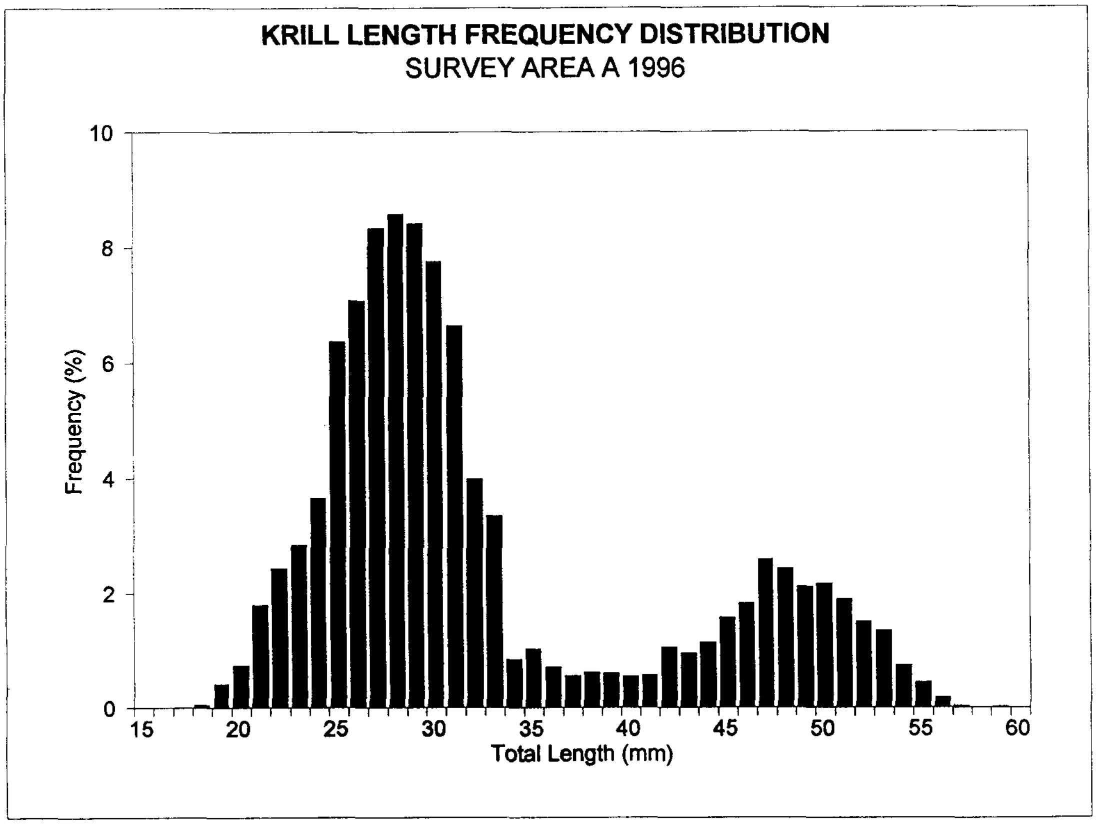

Figure 4.4 Overall length frequency distribution of krill collected during Survey A.

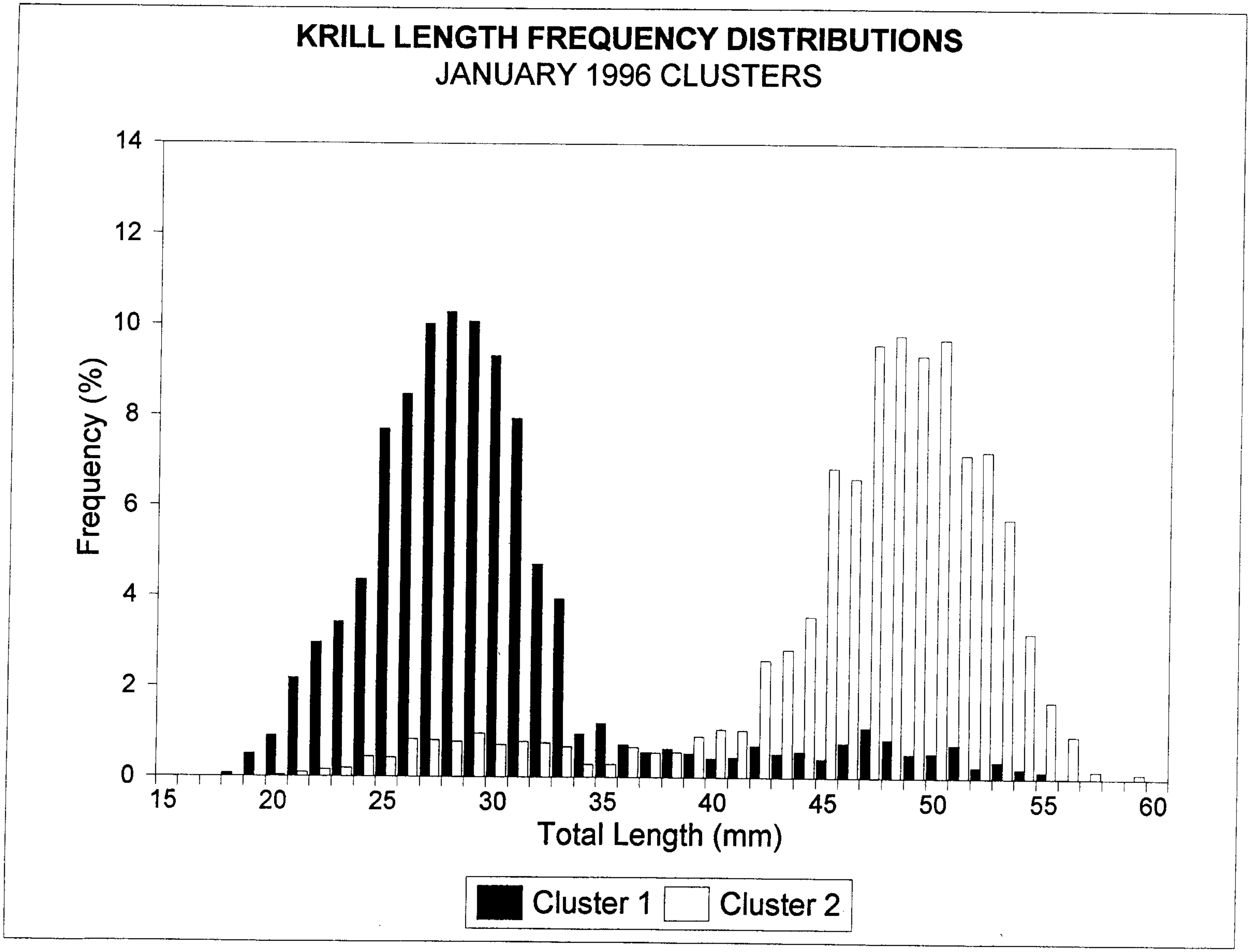

Figure 4.5 Length frequency distributions of krill belonging to two different length categories (Clusters 1 and 2) in the Survey A area.

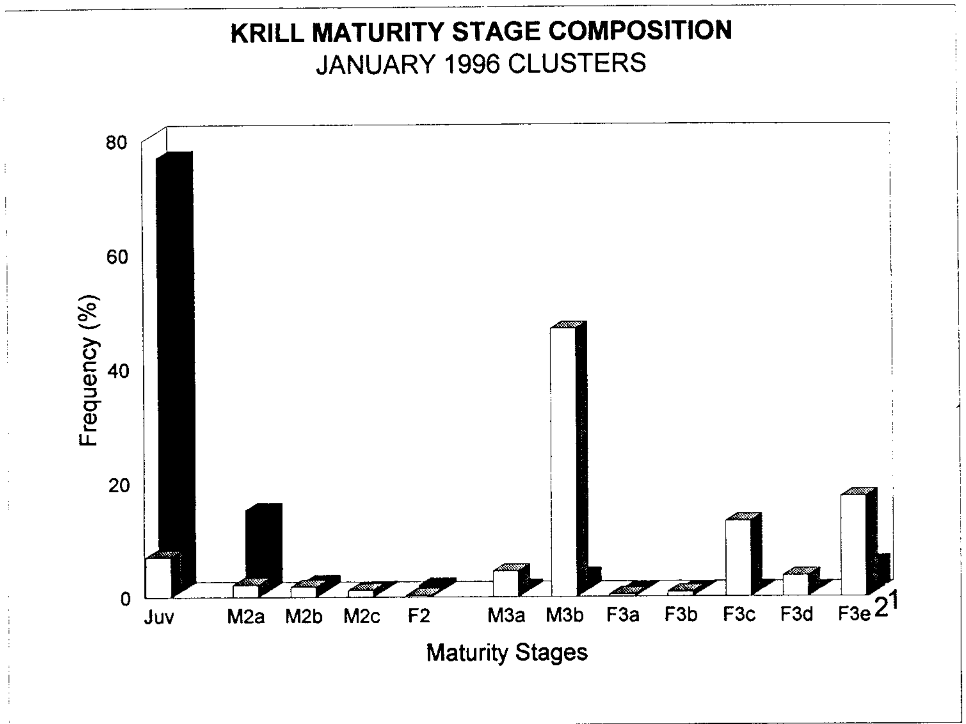

Figure 4.6 Maturity stage composition of krill associated with two different length categories (Clusters 1 and 2) in the Survey A area.

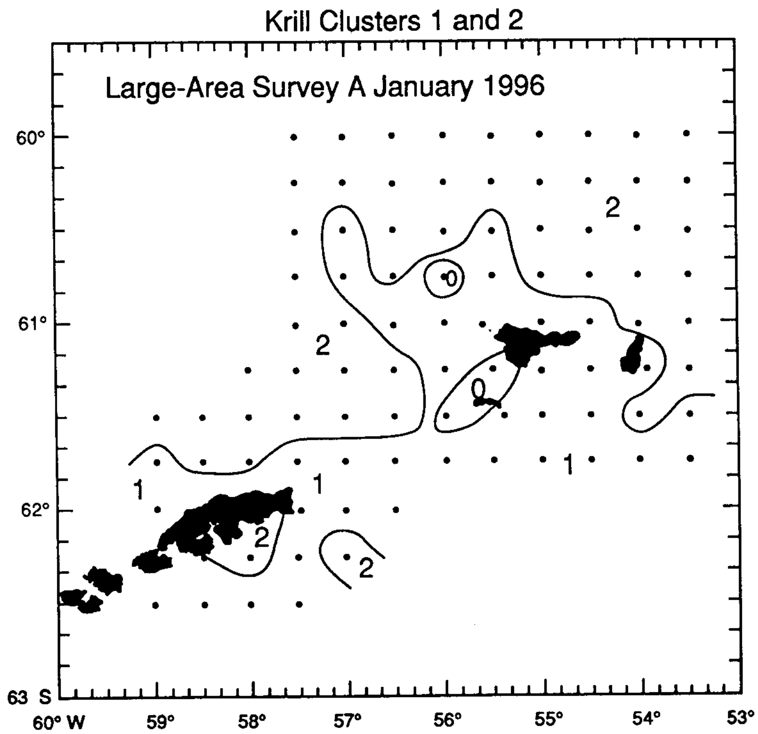

Figure 4.7 Distribution patterns of krill belonging to different length categories (Clusters 1 and 2) within the Survey A area, January 1996. "0" denotes no krill caught at these locations.

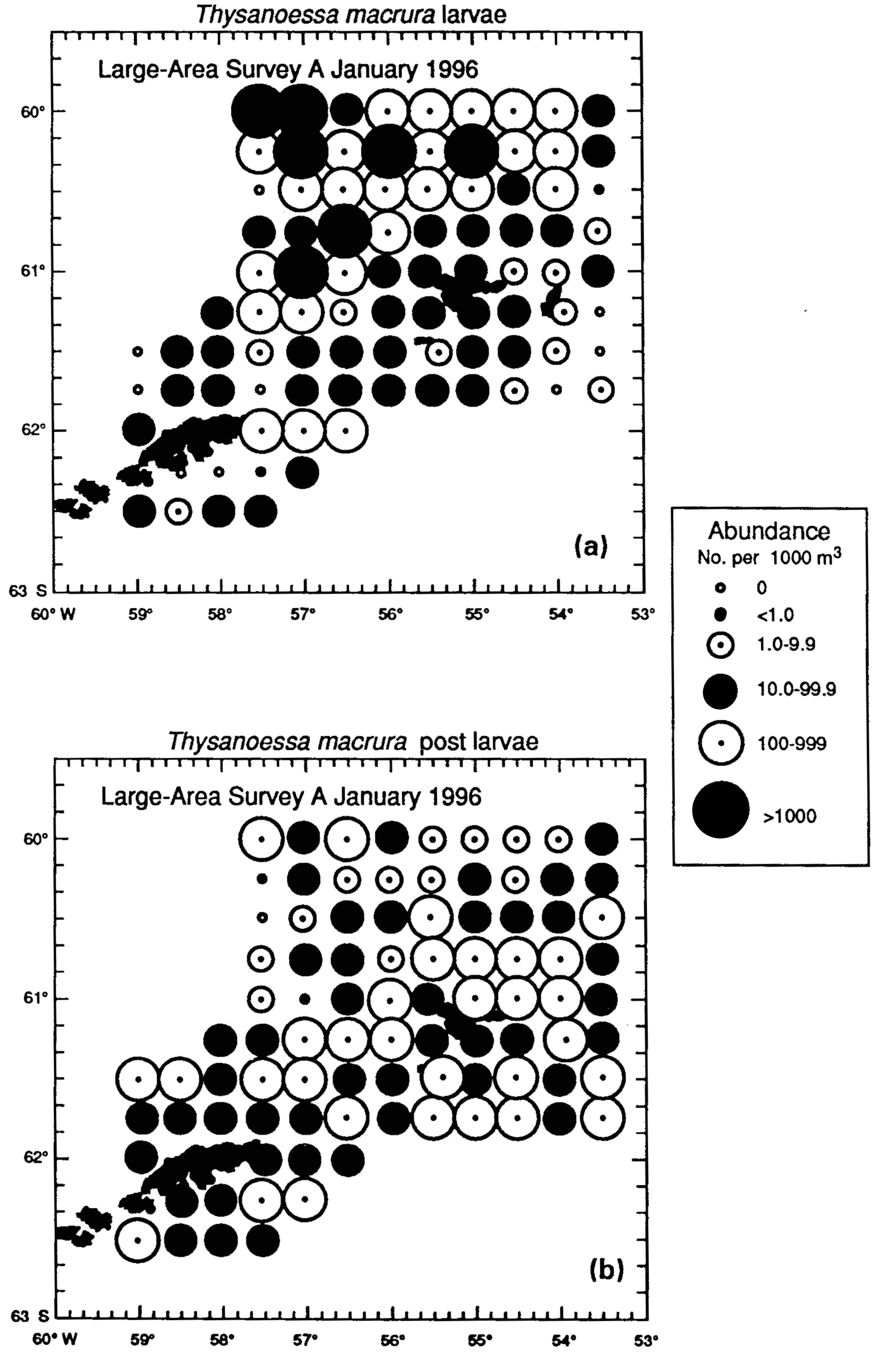

Figure 4.8 Distribution and abundance of (a) larval and (b) post-larval *Thysanoessa macrura* in the Survey A area.

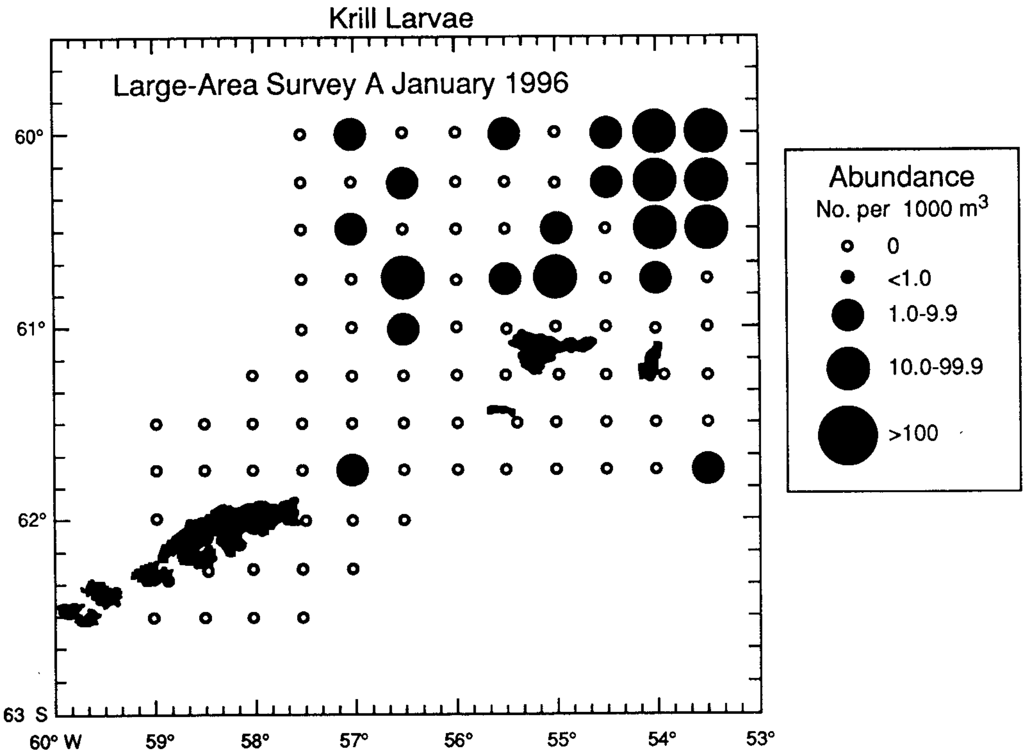

Figure 4.9 Distribution and abundance of krill larvae in the Survey A area.

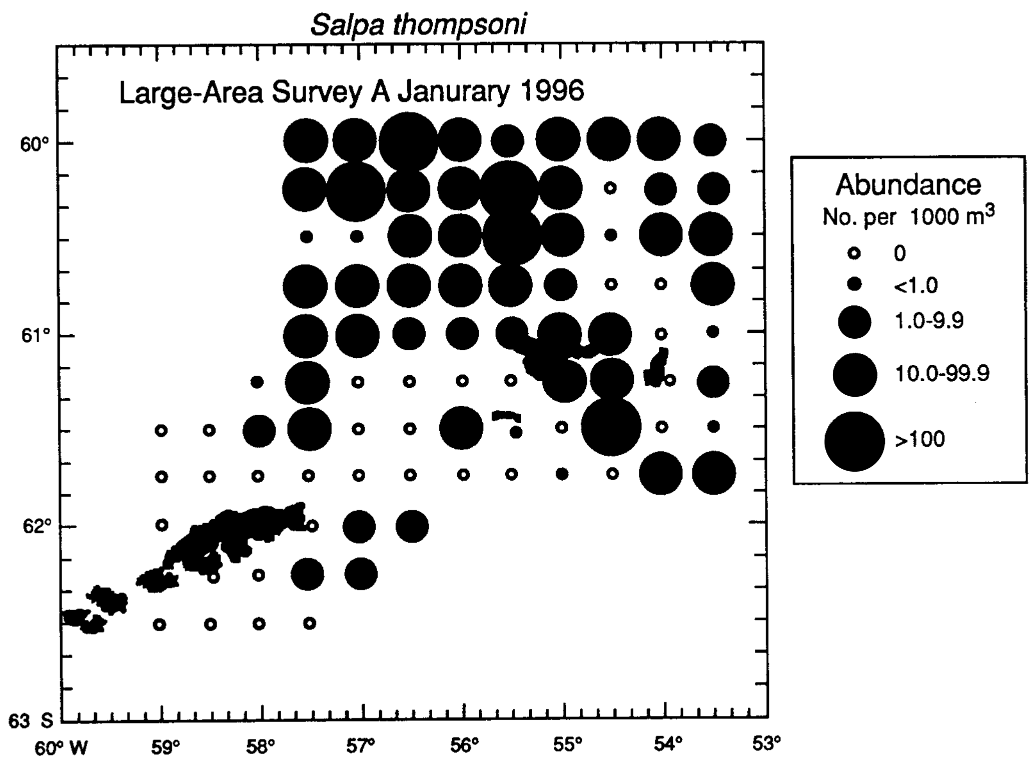

Figure 4.10 Distribution and abundance of *Salpa thompsoni* in the Survey A area.

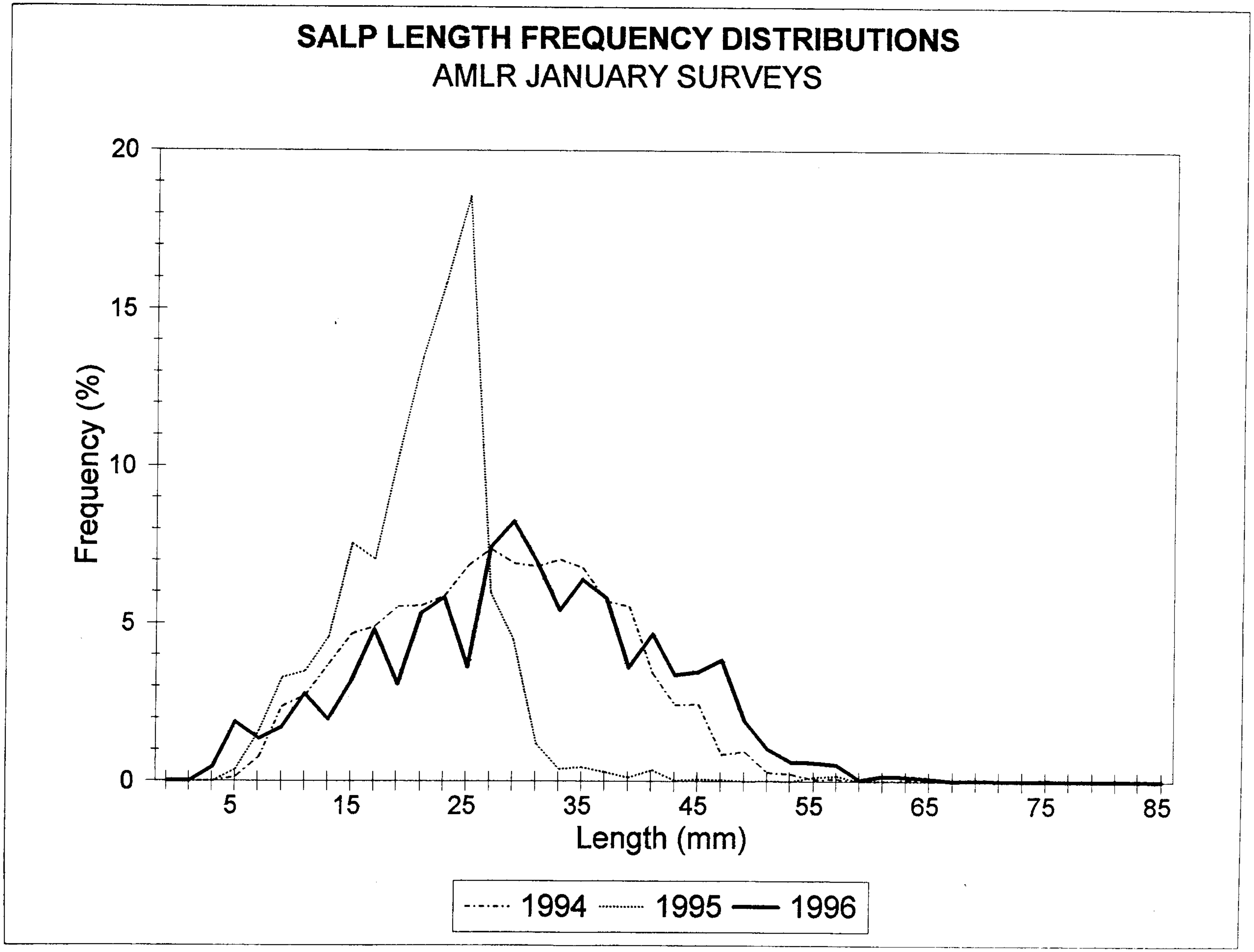

Figure 4.11 Length frequency distribution of salps in the Survey A area, January 1994, 1995 and 1996.

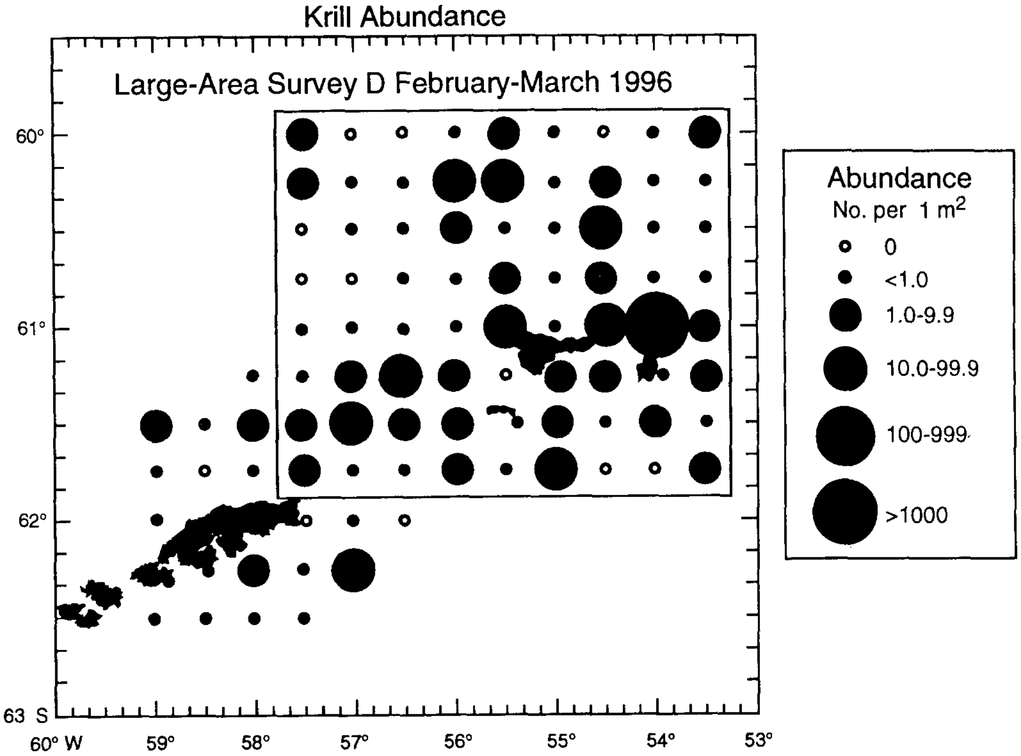

Figure 4.12 Krill abundance in IKMT tows collected during Survey D.

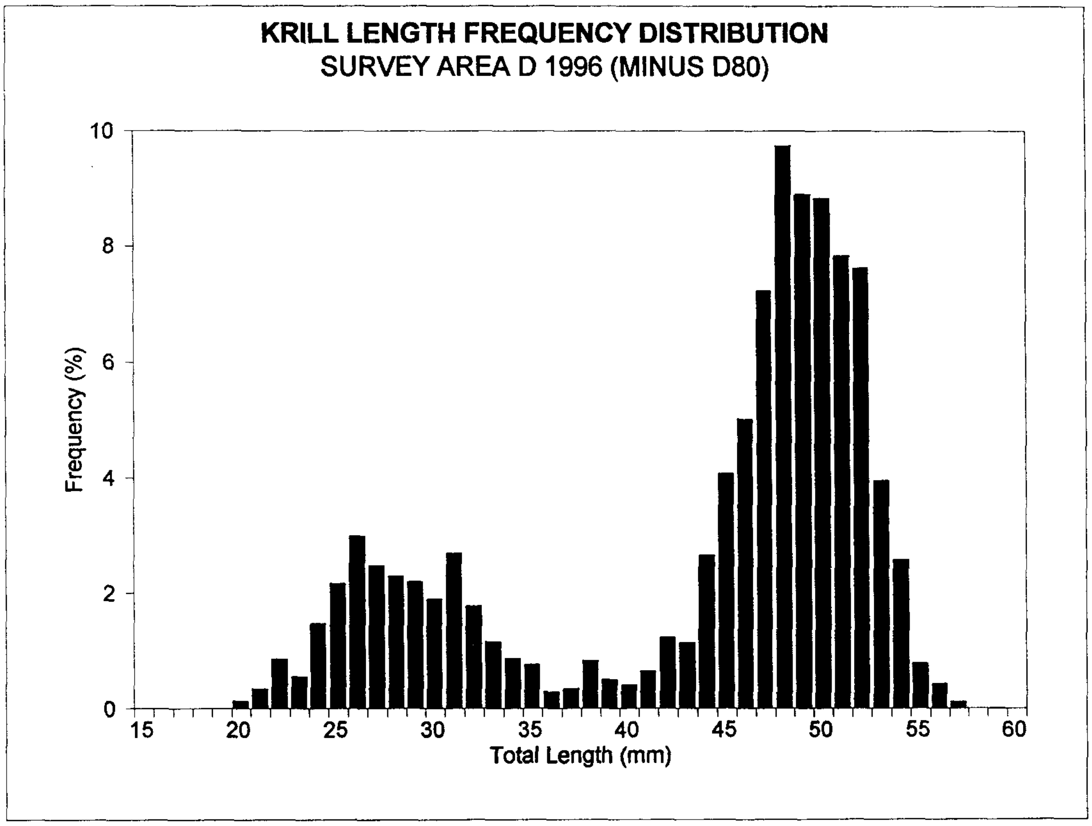

Figure 4.13 Overall length frequency distribution of krill collected during Survey D. Krill collected at Station D80 are excluded.

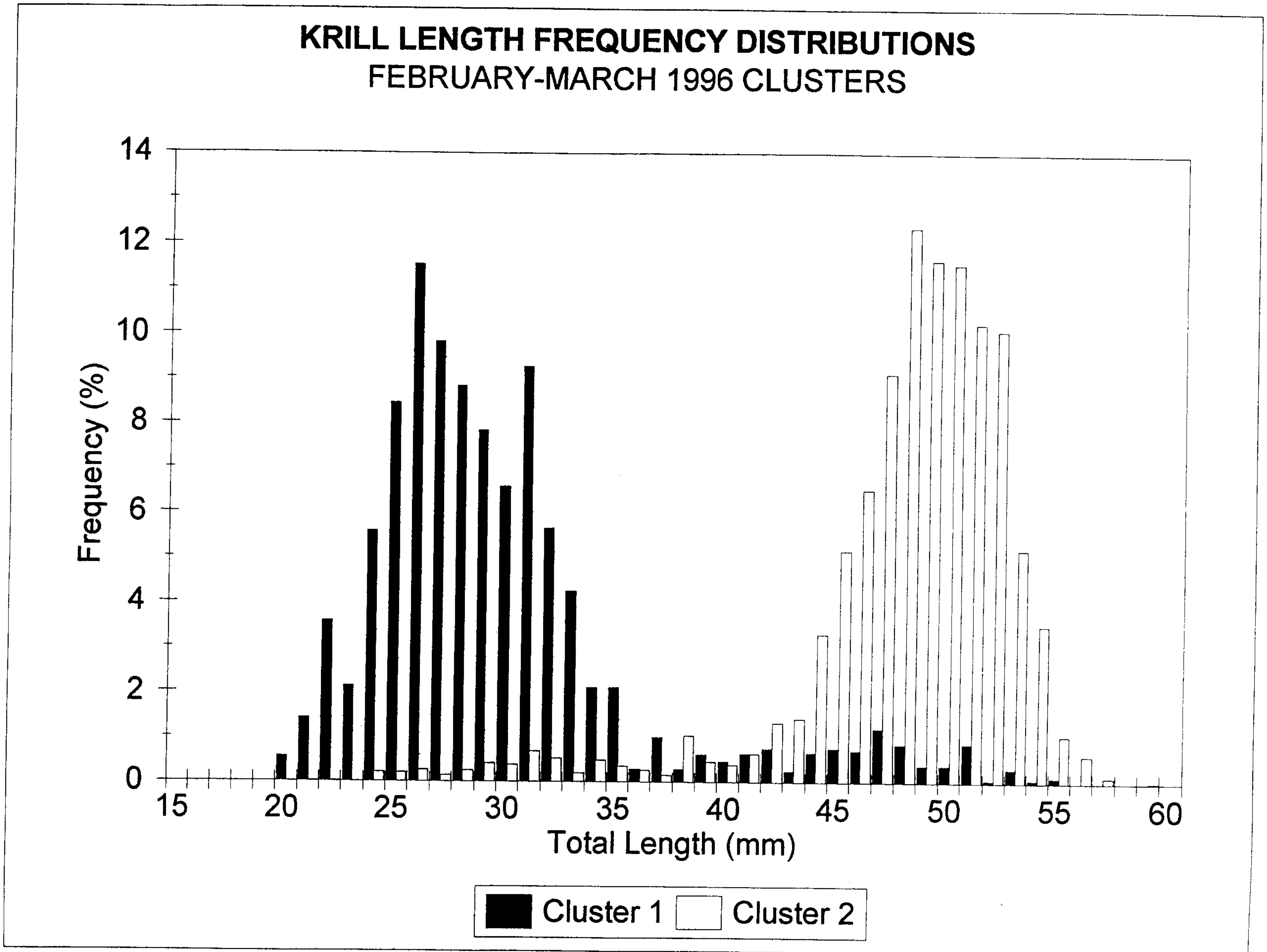

Figure 4.14 Length frequency distributions of krill belonging to two different length categories (Clusters 1 and 2) in the Survey D area, February-March 1996. Krill collected at Station D80 are excluded.

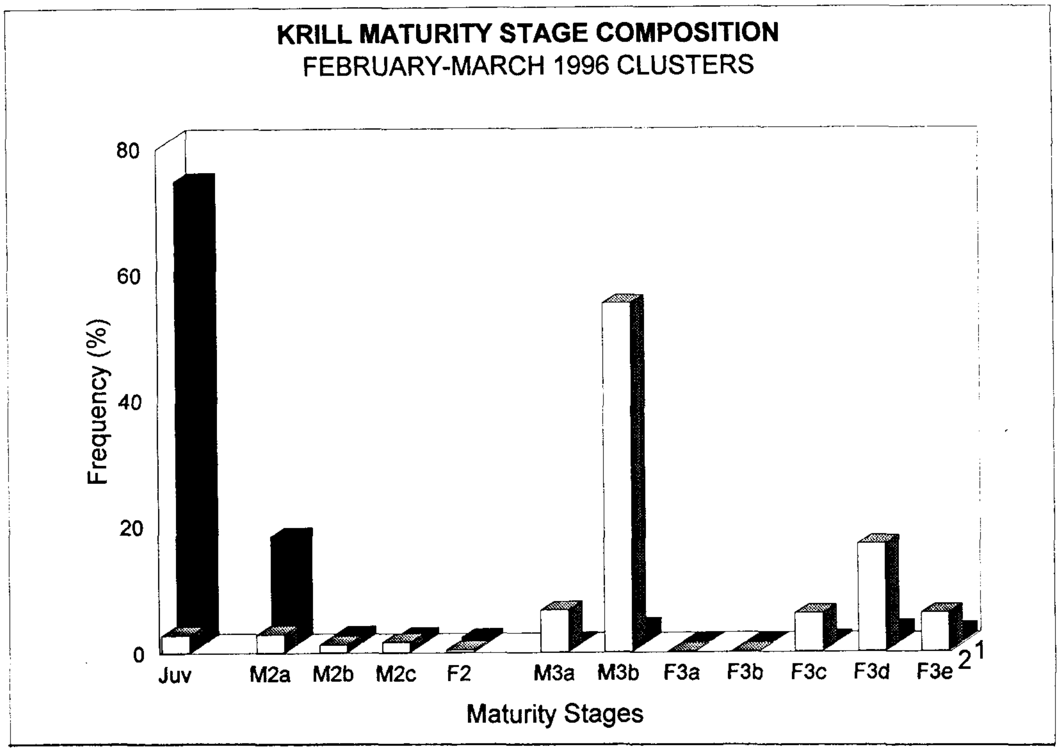

Figure 4.15 Maturity stage composition of krill associated with two different length categories (Clusters 1 and 2) in the Survey D area. Krill collected at Station D80 are excluded.

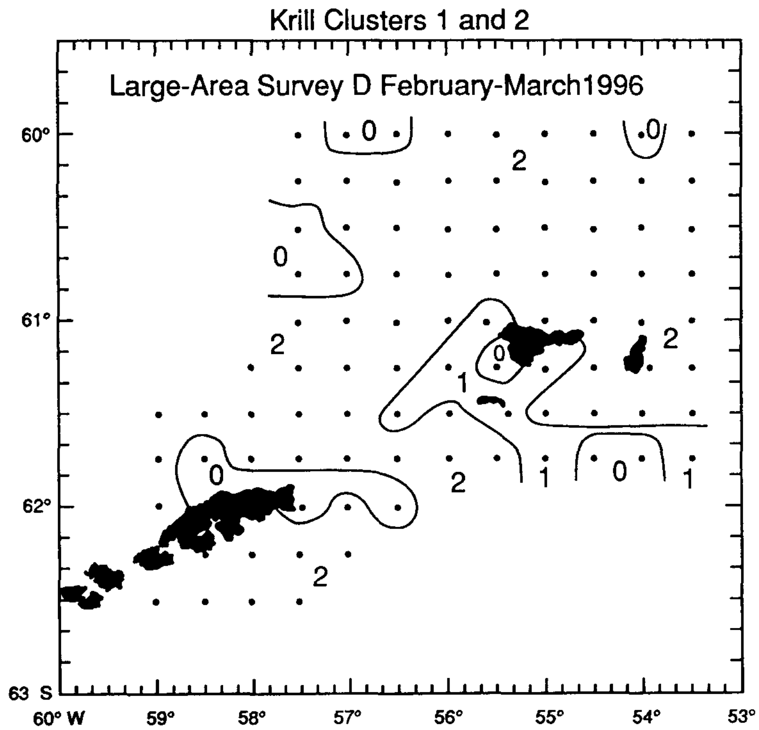

Figure 4.16 Distribution patterns of krill belonging to different length categories (Clusters 1 and 2) within the Survey D area. "0" denotes no krill caught at these locations.

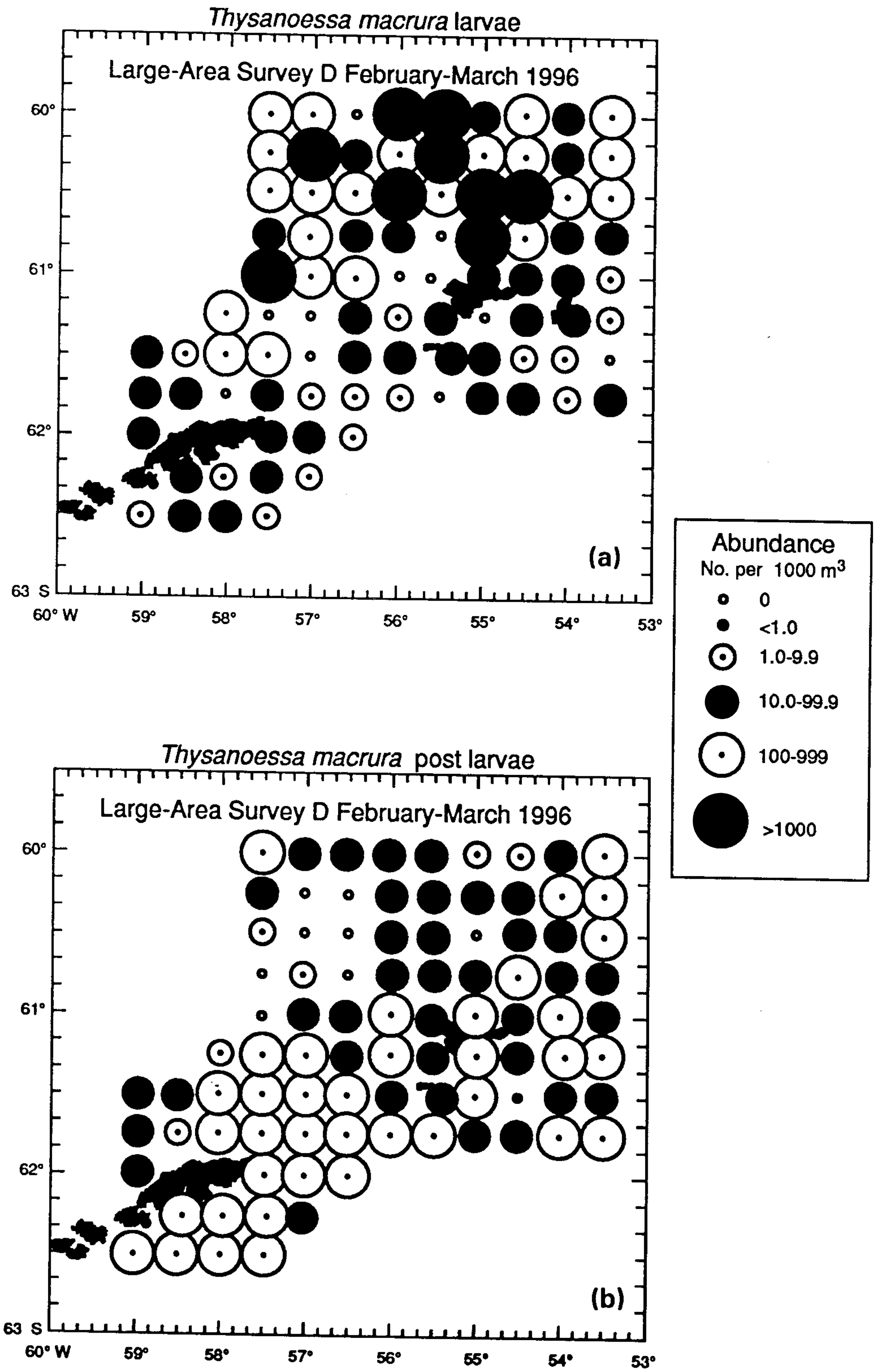

Figure 4.17 Distribution and abundance of (a) larval and (b) post-larval *Thysanoessa macrura* in the Survey D area.

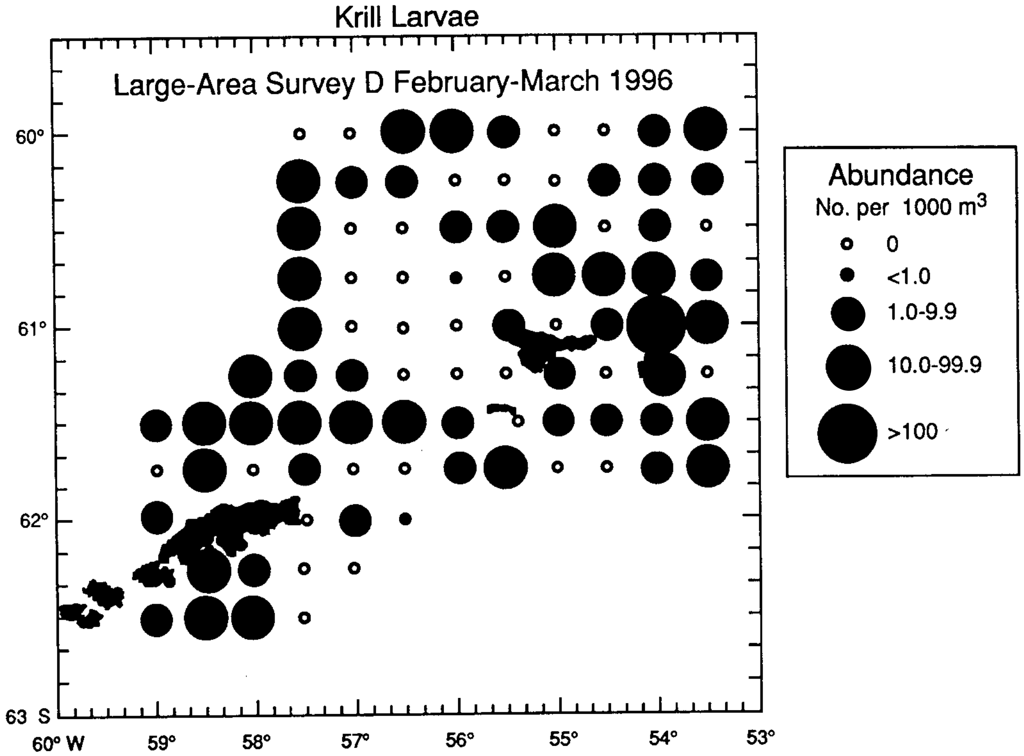

Figure 4.18 Distribution and abundance of krill larvae in the Survey D area.

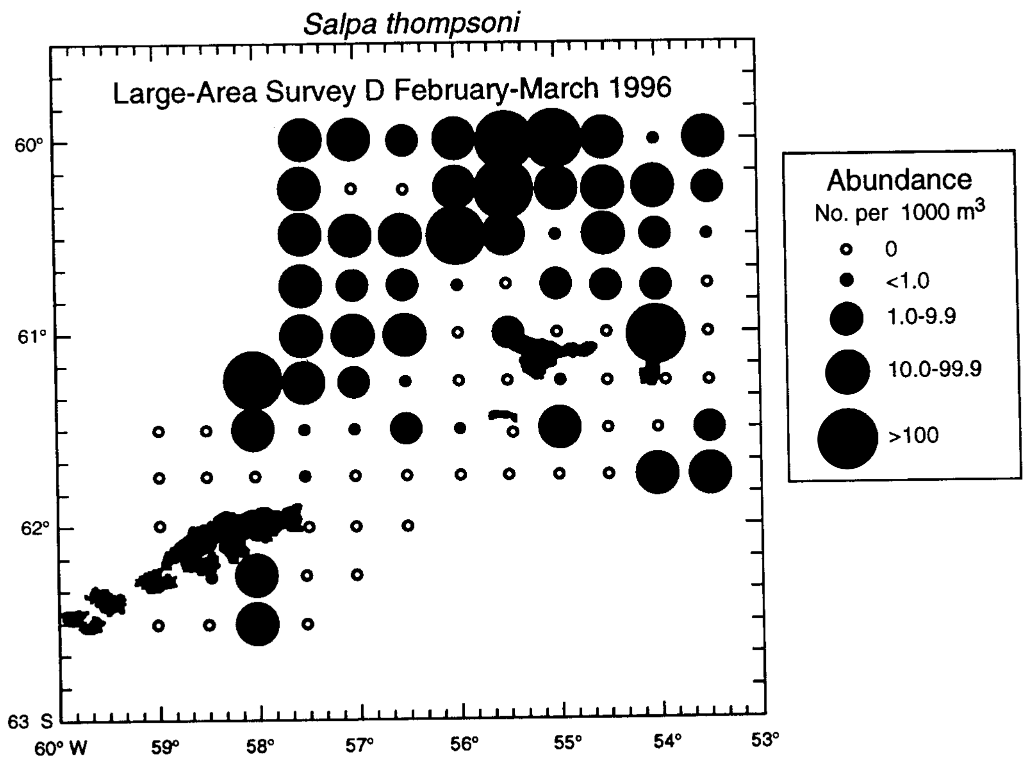

Figure 4.19 Distribution and abundance of *Salpa thompsoni* in the Survey D area.

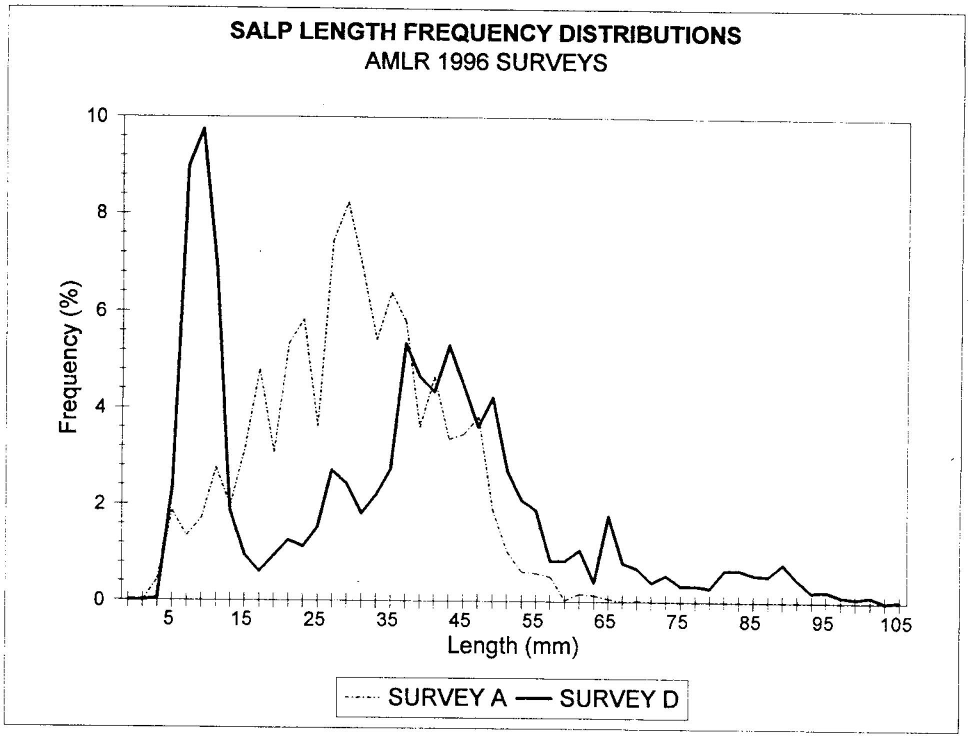

Figure 4.20 Length frequency distribution of *Salpa thompsoni* in the January (Survey A) and February-March 1996 (Survey D) survey areas.

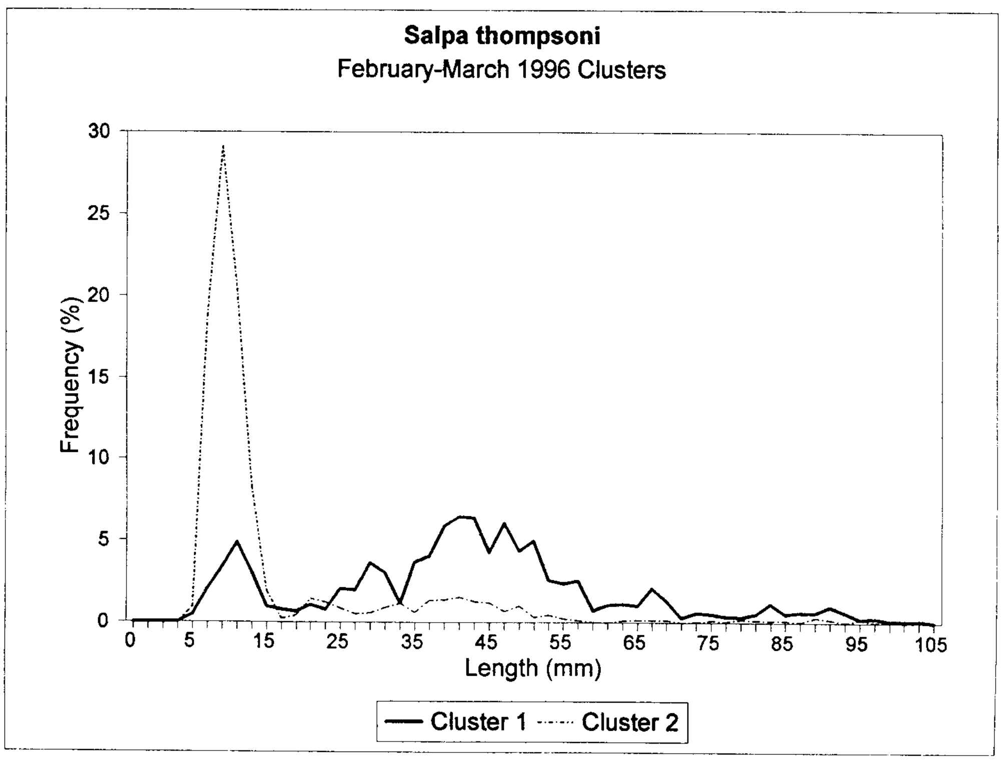

Figure 4.21 Length frequency distribution of *Salpa thompsoni* belonging to two different length categories (Clusters 1 and 2) in the Survey D area.

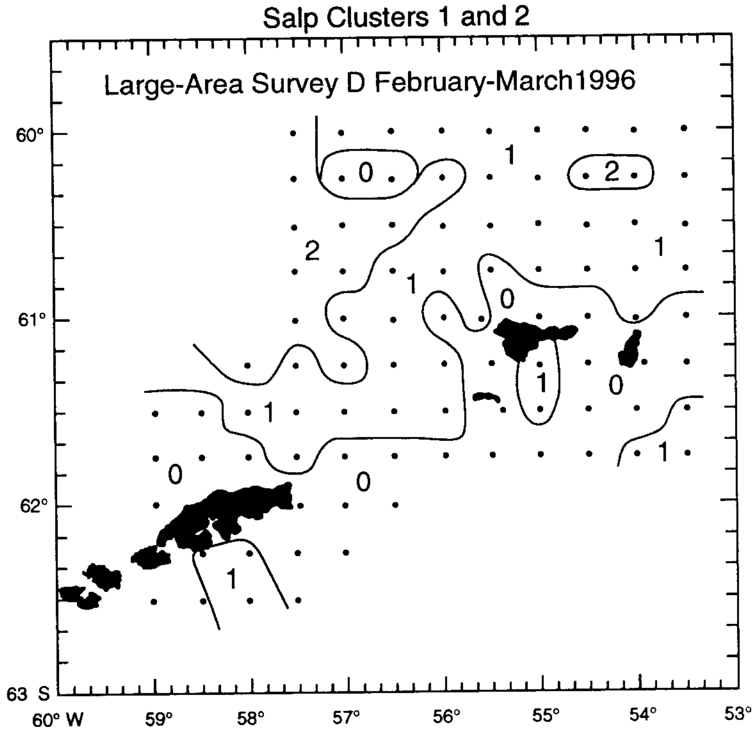

Figure 4.22 Distribution patterns of salps belonging to two different length categories (Clusters 1 and 2) in the Survey D area. "0" denotes no salps caught at these locations.

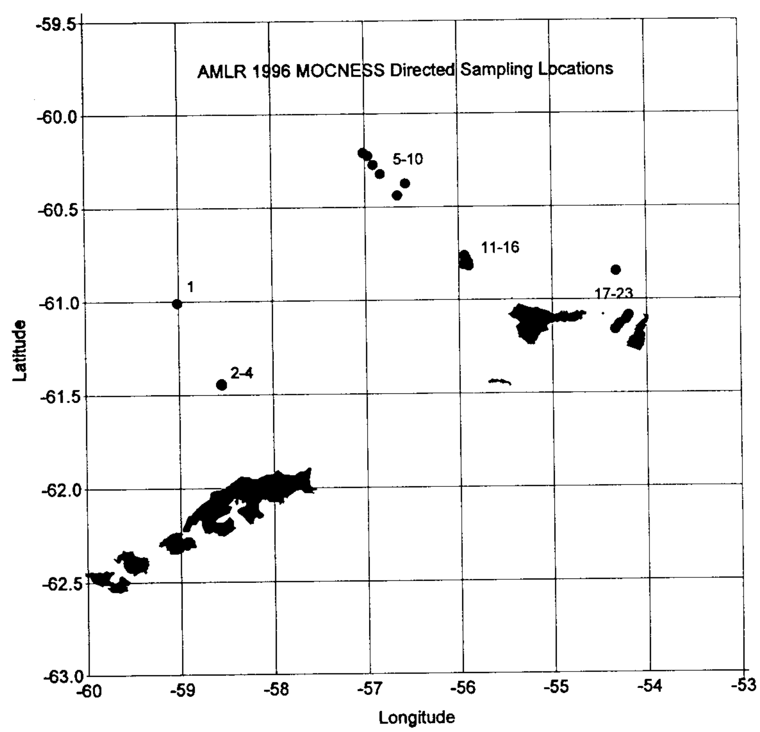

Figure 4.23 Locations of 23 directed MOCNESS tows.

5. Lipids in the Antarctic zooplankton ecosystem; submitted by Charles F. Phleger (Leg I).

5.1 Objectives: The objectives of this study were to clarify and further understand Antarctic marine zooplankton food web interactions and seasonal variability by examining lipids and fatty acids as key biochemical factors. Lipids are important energy reserve molecules as well as being necessary for cell membrane structure and function, particularly the polyunsaturated fatty acids, which are required for reproduction and growth. Selected zooplankton taxa, from IKMT samples collected near Elephant Island, were analyzed for lipids and fatty acids. Analyses were done at CSIRO, Division of Oceanography, Hobart, Tasmania, in the laboratory of Peter D. Nichols. Lipids were extracted with chloroform-methanol, and their classes were determined with an Iatroscan MK III THIO TLC-FID analyzer on silica gel chromarods. After saponification and transmethylation, fatty acids were analyzed on a Hewlett-Packard gas chromatograph mass spectrometer, allowing exact identification. By identifying important tracer components, such as palmitoleic acid omega 10 trans, a better understanding of food chain energy transfer in the Antarctic ecosystem can be obtained.

5.2 Accomplishments: Zooplankton samples from IKMT tows conducted during Leg I were sorted into phylogenetic groups and immediately frozen for analysis (Table 5.1).

5.3 Results: Results of this 1996 study will be compared with those obtained from the same study area near Elephant Island in 1995. In the 1995 study, lipids and fatty acids of *Euphausia superba, Beroe cucumis, Periphylla periphylla, Salpa thompsoni,* and *Chaetoceros* spp. were compared. *Euphausia superba* lipids (2.54%, as percent wet weight) were dominated by triacylglycerols (energy storage lipids) and phospholipids. In contrast, the gelatinous zooplankton (including salps) lipids (0.07-0.12%, as percent wet weight) were dominated by phospholipid and other polar lipids, characteristic membrane components.

5.4 Acknowledgments: I am grateful to Valerie Loeb, Volker Siegel and Dawn Outram for their help with the sorting and identification of specimens. I would also like to acknowledge Mike Force, Wes Armstrong, Ruth Yender, Marcelo Pablo Hernando and the entire crew of the R/V *Yuzhmorgeologiya* for their enthusiasm and hard work in sample collection.

Table 5.1 Zooplankton samples from IKMT tows conducted during Leg I.

Taxon	Survey Station/Location
Cnidaria	
Periphylla periphylla (Scyphomedusae)	A86
Arctopodema ampla (Hydromedusae)	A76
Calycopsis borchgrevinki (Hydromedusae)	A83
Ctenophora	
Beroe cucumis	A74, A81, A85
Chaetognatha	
Sagitta gazellae	A83, A84
Urochordata	
Salpa thompsoni	A18, A23, A28, A29
Benthic Ascidian (floating)	A65, Livingston Island
Polychaeta	
Tomopteris carpenteri	A11, A22, A23
Vanadis antarctica	A89
Pteropoda	
Limacina helicina	X3 (Admiralty Bay)
Clione limacina	A4
Amphipoda	
Themisto gaudichaudii	A9, A12
Euphausiids	
Euphausia superba (adults)	A10, A39, A61
Euphausia superba (juveniles)	A55
Thysanoessa macrura	A5, A52, A81
Teleostei	
Electrona antarctica (adult)	A48, A56, A63, A64, A71, A75
Gymnoscopelus opisthopterus (adult)	A57
Notothenia neglecta (juvenile)	Nelson Island (hook and line)

6. Operations and logistics at Seal Island, Antarctica, 1996; submitted by W.T. Cobb and R.S. Holt.

6.1 Objectives: The AMLR program has maintained a field camp at Seal Island, South Shetland Islands, Antarctica (60°59'14"S, 55°23'04"W) in support of land-based research on marine mammals and birds. The camp was occupied on two separate occasions during the austral summer months of January and February 1996. During past field seasons, the field team occupied the camp continuously from December through March. Due to safety considerations associated with the island, time at the camp was substantially shortened for the 1996 season. The main logistics objectives of the 1996 season were:

1. To deploy the initial four-person field team in mid-January from the R/V *Yuzhmorgeologiya* to Seal Island and then recover this team in early February;

2. To deploy a three-person field team in mid-February from the R/V *Yuzhmorgeologiya* to Seal Island and then recover this team in late February;

3. To resupply the field camp with fresh provisions transported by the R/V *Yuzhmorgeologiya* from Chile;

4. To maintain effective communication systems on the island and to maintain daily radio contact with either Palmer station or R/V *Yuzhmorgeologiya*;

5. To repair, maintain, and improve camp facilities at the Seal Island field camp;

6. To dismantle and retrograde the wooden entryway and weatherport platform where the main tent was previously erected; and

7. To retrograde trash and other cargo from the island.

6.2 Accomplishments: A four-person field team embarked the R/V *Yuzhmorgeologiya* in Punta Arenas, Chile, on 18 January 1996. The ship proceeded directly to Seal Island and disembarked the field team on 21 January 1996. Good weather resulted in an efficient landing at the camp beach. Camp structures over-wintered well and without damage. The field team immediately established living quarters in the laboratory. Due to the shortened season, the tent that served as the main living quarters in past seasons was not erected. Also due to the shortened season, the amount of cargo unloaded on the island was greatly reduced.

Dismantling of the weatherport platform and entryway was undertaken during the first stay on Seal Island. Items stored on the platform for winter were moved and eventually retrograded to the ship, or stored elsewhere in the field camp. All traces of the platform were removed, including underground support columns. The main tent and associated hardware were removed from the island to the R/V *Yuzhmorgeologiya* for transport back to the Southwest Fisheries Science Center.

The R/V *Yuzhmorgeologiya* returned to Seal Island on 5 February and embarked the four-person field team to conduct a fur seal survey. Fourteen Zodiac loads of retrograde cargo were transported from the island to the ship for disposal in Punta Arenas, Chile.

On 12 February the R/V *Yuzhmorgeologiya* returned again to Seal Island and disembarked a three- person field team. One of the MK V Zodiacs was kept on the island for this stay. The camp was closed and the field team embarked the R/V *Yuzhmorgeologiya* on 22 February, using the stored MK V Zodiac. Final island off-loading operations were completed on 23 February and the ship began the Leg II large-area survey. All small boat and cargo loading operations went smoothly in favorable weather conditions. The assistance of the ship's personnel and AMLR scientific personnel both on the island and on the ship expedited supply and retrograde operations. As in past seasons, four swimmers in dry suits were utilized to steady the Zodiacs during beach operations.

Daily radio communications were maintained with Palmer station (U.S.) from 14 February to 20 February when the R/V *Yuzhmorgeologiya* returned to port in Chile. Daily contact was maintained with the R/V *Yuzhmorgeologiya* from 21 January to 5 February, from 12 February to 13 February, and from 20 February to 22 February using SSB or VHF radio. In addition to the regularly scheduled communications, periodic contact was also made with personnel at Copacabana camp, King George Island (U.S.).

Routine maintenance of camp facilities was undertaken as necessary. Obsolete and unneeded equipment was identified and removed from the island for shipment to the U.S. As ice washed ashore, it was gathered and stored for use as drinking water. The solar-tracker array was disassembled and removed from the island for refurbishment and use at another location.

All trash and retrograde cargo were removed from the island and transported to the ship. Retrograded cargo was transported back to the U.S., while all trash was left for proper disposal by the ship.

6.3 Recommendations: Support provided by the R/V *Yuzhmorgeologiya* and the AMLR scientific complement made a significant contribution to the success of the field season at Seal Island. Assistance of the AMLR Electronics Technician aided in establishing radio communications during camp set-up. The continued practice of using four swimmers in dry suits to assist with Zodiac beach operations was invaluable. Reliable radio communications between the Zodiacs and the ship are necessary for safe operations, and need to be improved in future cruises.

7. Antarctic fur seal abundance and distribution in the South Shetland Islands, 1996; submitted by W.M. Meyer, B.G. Walker, and R.S. Holt.

7.1 Objectives: Antarctic fur seals (*Arctocephalus gazella*) were hunted to near extinction during the eighteenth and nineteenth centuries. From a small isolated population near South Georgia, this species has slowly reestablished itself within its previous historical range. Because fur seals were nearly eradicated from the South Shetland Islands, this area is particularly interesting to examine as a model of species recovery after severe exploitation. In addition, due to the importance of the South Shetlands area as an established krill fishery, it is essential to monitor the potential influence of this fishery on fur seal abundance and distribution.

Areas of known fur seal breeding activity and locations thought to be suitable for fur seal breeding have been surveyed at approximately 4-5 year intervals since the austral summer of 1986/87. The objectives of the fur seal census in 1996 were:

1. To count Antarctic fur seal pups at known breeding colonies;

2. To search for and identify newly-established or previously unknown fur seal colonies;

3. To resight tagged animals to better understand fur seal movements; and

4. To record the presence of marine debris in areas inhabited by Antarctic fur seals.

7.2 Accomplishments:

Established Breeding Colonies: Known South Shetland fur seal colonies originally surveyed during the 1986/87 austral summer and surveyed again this season were: Seal Island and the adjacent Large Leap Island; Capes Valentine and Lindsey, Elephant Island; Stigant Point, King George Island; and Desolation Island, Cape Shirreff (including Telmo Island), Window Island and Start Point, all associated with Livingston Island (see Introduction Section, Figure 4). In addition, one new colony in the Seal Island archipelago known as Saddle Rock was discovered in the 1993/94 partial seal census (northern South Shetlands only) and was surveyed this season. Results from the complete South Shetland seal surveys of 1996, 1991/92, and 1986/87 and the partial survey of 1993/94 are presented in Table 7.1.

Potential Colony Areas: Sites of potential seal colonization surveyed this season were: Harmony and Duthoit Points, on Nelson Island; Dee and Aitcho Islands, just north of Greenwich Island; and the coast and offshore islands on the north side of Fildes Peninsula (opposite of Maxwell Bay) on King George Island. No fur seal pups were seen at any of these sites.

Movement of Tagged fur Seals: Data on movements of tagged seals can be useful in studying the recolonization and migration patterns of the species. Three Seal Island-tagged females (unknown aged animals, used in previous instrumentation studies) were seen during the survey:

N244 on Window Island, and N184 and N412 on Cape Valentine, Elephant Island. Also, two known-aged Seal Island seals (U00100, an eight year old female; and U00668, a three year old female) were seen on Large Leap Island. One seal of unknown origin, tagged with a green Allflex tag #37, was seen on Window Island.

Marine Debris: Man-made debris was found periodically in the South Shetland Islands. In conjunction with the fur seal surveys, the presence of any immovable debris was recorded, and any easily transported debris was collected, removed, and recorded. Debris collected from Desolation Island was photo-documented. Items noted and/or removed were as follows:

Seal Island
    collected: 3 small (less than 1 meter) wood pieces, one packing band.
Large Leap
    collected: 1 packing band, approx. 20 meters in length. Note: this band contained remains (one flipper and some intestinal parts) of a fur seal pup entangled in the mass.
Window Island
    collected: 5 packing bands
    uncollected: one 2-liter plastic bottle (in center of the seal colony), moderate large wood debris, including a large ship's mast.
Start Point
    collected: Styrofoam pieces, burlap sack, 2-liter plastic bottle, 8-inch pink float, 1-liter soda bottle, small plastic fish float, collapsible water bag, 2 meters of 2-inch rope, 6 packing bands of various lengths.
    uncollected: 55 gallon barrel, 50 feet of 3-inch ship's rope.
Cape Valentine
    collected: 6-inch metal float, foam pad, Styrofoam pieces.
Stigant Point
    collected: life ring, soda bottle, Styrofoam pieces, 8-inch fish float.
    uncollected: oil barrel, moderate wood debris, large (70 lb.) metal fish float.
Desolation Island
    collected: sandal, 6 plastic bottles, 2 fish plastic floats, plastic lined paper bag, fine fishing net, plastic sheeting, metal pot, numerous packing bands, miscellaneous rope, block of Styrofoam, and broken plastic jug.
Dee Island
    uncollected: 2x3m yellow drum.

7.3 Preliminary Conclusions: Antarctic fur seal numbers at known breeding colonies remained stable or have significantly increased from the period of initial survey (1986/87). Relatively stable colonies, such as Seal Island, Large Leap and Stigant Point, may represent areas of early recolonization and as such, may have reached their maximum sustainable populations. Colonies showing significant increases, such as Start Point and Cape Valentine, may represent areas where recolonization has been more recent and maximum population has not yet been reached. Continued monitoring of both types of colonies and areas of potential breeding will be important in the study of this recolonization process.

Table 7.1 Summary of 1996 and historic Antarctic fur seal pup censuses in the South Shetland Islands, Antarctica. Numbers in parenthesis represent counts of dead pups recorded at the site. "n/c" means no count made.

Location	1996	1993/94	1991/92	1986/87
Seal Island Archipelago:				
Seal Island (incl Big Boote)	281 (2)	297 (2)	300 (5)	241 (8)
Large Leap Island	288 (4)	304 (2)	258	254 (21)
Saddle Rock & Cave	101	63	n/c	n/c
Cape Shirreff	**	3474[1]	2583[2]	673 (45)
Telmo Island	**	2973[1]	2272 (68)	1660 (215)
Window Island	412 (6)	n/c	372 (3)	297
Start Point	129	n/c	43	0
Desolation Island	1	n/c	0	1
Stigant Point	156 (2)	n/c	134	145 (12)
Cape Valentine	185	124	126	42 (3)
Cape Lindsey	325	296	227	191 (12)

** Data collected and will be provided by Daniel Torres to the 1996 Working Group on Ecosystem Monitoring and Management.

[1]Data taken from Aguayo, A. And D. Torres. 1994. Analisis de los censos de *Arctocephalus Gazella* efectuados en el sitio de especial interes cientifico no 32. Isla Livingston, Antarctica. Scientific Committee for the Conservation of Antarctic Marine Living Resources Working Group Paper, WG-CEMP-93/24. 1-9. (Working paper; do not cite data).

[2]Data taken from Torres, D. 1994. Synthesis of CEMP activities carried out at Cape Shirreff. Scientific Committee for the Conservation of Antarctic Marine Living Resources Working Group Paper, WG-CEMP-94/28. 1-4. (Working paper; do not cite data).

8. Pinniped and seabird research at Seal Island, Antarctica, 1996; submitted by B.G. Walker, W.R. Meyer, W.T. Cobb, R.S. Holt, and W.A. Armstrong.

8.1 Objectives: During the austral summer, pinniped and seabird research continued on Seal Island, Antarctica (60°59'14"S, 55°23'04"W) as part of the CCAMLR Ecosystem Monitoring Program (CEMP). This multi-national program is mandated to study the relationship between top predators (pinnipeds, seabirds and cetaceans), their prey (krill and fish), and the environment in the Southern Ocean system. Due to the impending closure of the Seal Island site and selection of an alternative camp site, the objectives for the 1996 field season were abbreviated as follows:

1. To monitor the abundance of pinnipeds and seabirds on Seal Island;

2. To record presence of known-aged and previously-instrumented or handled pinnipeds and seabirds;

3. To weigh Antarctic fur seal pups (*Arctocephalus gazella*) at a standard time in the season; and

4. To weigh and measure fledging chinstrap penguin chicks on Beaker Bay beach.

8.2 Accomplishments:

Pinnipeds.

Seal Surveys: Seal surveys were conducted on 22 and 28 January and 4, 14, and 20 February 1996. Surveys were conducted along Beaker Bay Beach (Table 8.1) and in the North Cove and North Annex study areas (Table 8.2). The presence of Antarctic fur seals (recorded by sex, if known, and maturity state), Southern elephant seals (*Mirounga leonina*), and Weddell seals (*Leptonychotes weddelli*) were recorded. No leopard seals (*Hydrurga leptonyx*) were seen on Seal Island this season. The number of male fur seals hauled out on Beaker Bay increased rapidly from 28 January to 4 February (over 200%; Table 8.1). The highest count of male fur seals hauled out on Beaker Bay for this season (609) was substantially larger than the number recorded during the same period from the 1994/95 season (260).

Fur seal pup numbers remained relatively consistent during the first week period measured this season and then decreased modestly during the next three weeks (Table 8.2). Pup numbers in 1994/95, while showing a similar pattern of stability and then decline during the same four week period, were considerably lower (Table 8.3). During the 1993/94 season, pup population started slightly larger but decreased substantially over the same four week period (Table 8.3). Leopard seal predation is a serious cause of mortality in the North Cove pup population. We were unable to quantify if and when such predation was occurring in the colony this season. Thus, it was impossible to accurately predict maximum pup numbers in the North Cove colony or to compare this year's North Cove pup production and effects of leopard seal predation with data from previous years. In contrast to North Cove, the North Annex and Big Booté colonies are not known to be subjected to leopard seal predation. In previous seasons, maximum pup count numbers have generally been very close to final counts for these two colonies. The maximum number of pups in North Annex this season (103) was considerably higher than in the previous season (76 pups). Also, Big Booté pup production increased from 15 pups in 1994/95 to 25 pups (including one dead pup) this season.

Tagged and Known-Aged Seals: Fur seal pups were tagged each season from 1986/87 - 1993/94; tagging was discontinued when it was determined the Seal Island camp was to be closed. During the 1996 season, 74 known-aged individuals were sighted on Seal Island (Table 8.4), a decrease from the 96 known-aged animals observed during the 1994/95 field season. The sighting decrease is most likely due to the abbreviated 1996 field season. Female seals that do not produce viable offspring often leave early in the season, shortly after copulating. Thus, any non-successful known-aged females were likely to have been missed due to the late arrival of the field team. Likewise, yearling and juvenile seals typically arrive late in the field season and stay for only short periods. These late arrivers were likely missed due to the early departure of the field team. Of the 40 known-aged females observed this season, 16 were seen with pups (Table 8.4).

No seals were instrumented on Seal Island this season. Of the 50 female seals that were instrumented last season, 42 (84%) were seen this season. Of these 42, 20 (48%) were observed with pups.

Only one non-Seal Island tagged pinniped was seen this year. On 3 February 1996, a yearling fur seal was observed in North Cove with a yellow All-Flex style tag (slightly larger than those used on Seal Island) in its left flipper, number 127. There was a tag scar on posterior of the right flipper. The seal also had a "V" shaped mark on its back, from either bleaching or clipping of the guard hairs of the seal's coat.

Pup Weight Measurements: One-hundred and one fur seal pups were weighed on 27 January 1996 (CEMP Standard Method C.2). Average weight of female pups (n=51) was 11.58kg (s.d.=1.57). Male pup (n=50) average weight was 13.51kg (s.d. = 2.00). We were unable to calculate growth rates for pups this field season. However, a comparison of weight measurements taken at the same time of year (26-31 January) in past seasons suggests pups were heavier during late January of this season (Table 8.5, bold text) than in any year except the 1991/92 austral summer (Table 8.5, italic text). This increase in average pup weight around January 26-31 may be due to a shift in the chronology of pupping and subsequent nursing schedules, or alternatively due to an increase in the food available for females foraging around the Seal Island area this season. While the former explanation cannot be quantified due to the shortened Seal Island field season, the latter may be supported by data from the 1996 AMLR large-area survey during Leg I.

Seal Entanglements: A single sub-adult male fur seal was observed on several occasions at Beaker Bay Beach with a loop of synthetic cord around his neck. The cord did not constrict breathing or swallowing, but will become a problem as the seal continues to grow and the loop grows tighter. An unsuccessful attempt was made to remove/cut the cord with a hook and shielded blade on the end of a pole. The animal was unharmed and remained on the beach with little disturbance to surrounding animals (male fur seals).

Seabirds.

Resights of Banded Penguins: Historically, 2000 chinstrap chicks and an average of approximately 70 macaroni chicks have been banded each season from 1987/88 to 1993/94. Known-age banding was discontinued after the 1993/94 season when it was determined the Seal Island camp was to be closed. Resight effort this field season was from 21 January to 5 February and 13 February to 20 February, at colonies where banding took place during previous field seasons. Other areas frequented by penguins from these colonies were scanned periodically for resights. A total of 1836 penguin resights were obtained during the 1996 field season, representing 594 individuals. Of these, 444 were known-age chinstrap penguins (see Figure 8.1), 34 were known-age macaroni penguins, 114 unknown-age chinstrap penguins (banded as adults), and two were unknown-age macaroni penguins. Unknown-age animals were banded as adults in all previous seasons for instrumentation and lavage studies. Chinstrap penguins that were two to four years old comprised 86% of the known-age resights, while only 14% were five to eight years old.

Abundance Estimates: In previous seasons, several censuses were typically conducted at ten CEMP monitoring colonies on Seal Island to assess productivity and survival of offspring from egg laying to creche. Additionally, an island wide count conducted in mid-December has been used to estimate the breeding population. This season, the field team arrived on 21 January after the beginning of the creche phase, a time when chicks are large enough to be left alone in the colonies and both adults have the opportunity to forage simultaneously. During this phase the unguarded chicks form small groups called creches, making it difficult to determine the exact number of nests in a colony. Therefore, the "2/3's creche count" (made when 2/3's of the chicks have creched) measures only the number of chicks in a colony, and not the total number of nests. If the colony's reproductive success is known, an estimate of the number of nests may be back-calculated. Unfortunately, we were unable to measure reproductive success due to the abbreviated season and timing of operations at the island. However, estimates of reproductive success at these colonies from previous seasons may allow a rough estimate of island population during the 1996 season.

The 2/3 creche census of the ten chinstrap CEMP colonies indicated breeding numbers of chinstrap penguins were lower than average (Table 8.6). In fact, for the first time one of the ten CEMP colonies (#32) was non-existent. Estimates from this year's census may indicate the lowest breeding population recorded. However, penguins that nested produced chicks whose survival and growth appeared to be normal. The macaroni penguin population appeared to be near normal compared to historical averages (Table 8.7), with all colony populations remaining stable. During the 1994/95 season a small group of macaroni penguins established a colony at Petrel Pass, but no macaroni penguins were observed there this season.

The most striking observation this season was the reduced number of breeding chinstrap penguins. Island-wide it was observed that the breeding population was reduced from the previous season. The numbers of breeding chinstraps censused in the CCAMLR colonies this season were most similar to those of the 1990/91 season (Table 8.6). Reports of extremely heavy ice conditions prior to the 1995/96 nesting season, similar to high ice levels in the 1990/91 season, suggests that heavy ice may decrease penguin reproductive success (evident as fewer numbers of chicks at creche). This may be caused by either a restriction of breeding bird's access to nesting sites by ice and snow or limited prey availability prior to nesting (decreasing the overall condition of the arriving birds). However, a decreased number of chicks at 2/3 creche may alternatively result from a decline in prey during the breeding season. Specific effects and timing of these factors, or others, are unknown.

Fledging Condition: Following the initiation of chinstrap fledging on 16 February 1996, daily samples of fledglings present on Beaker Bay Beach were weighed (CEMP Standard Method A.7.A.) until 21 February when the field team prepared for departure. A total of 148 fledglings were weighed and measured (Table 8.8). Average (± s.d.) fledgling measurements were: weight 3.1kg (± 0.3); culmen length 42.6mm (± 2.8); culmen depth 15.0mm (± 1.1); and wing chord 115mm (± 5). The timing of fledging and average fledgling weight are normal compared to past seasons. Since the field team departed prior to the completion of fledging, it is difficult to determine when peak fledging occurred.

Other Seabird Observations:

- Nesting cape petrels (*Daption capense*) were abundant this season and seemed to have increased in numbers from the previous season, but no formal census of the population was completed. No banded cape petrels were observed.

- Three seabird bands of foreign origin were recorded this season: Chinstrap C 763 and Skuas T 07364 & T 07429.

Table 8.1 Numbers of seals counted on 22 and 28 January and 4, 14 and 20 February 1996, on Beaker Bay Beach, Seal Island, Antarctica.

	Fur seals							
Date	Adult male	Sub-adult male	Juvenile	Pup	Total	Elephant seals	Weddell seals	Leopard seals
22 Jan		195*	0	1	196	17	4	0
28 Jan	66	142	1	0	209	25	5	0
4 Feb	25	584	0	0	609	20	7	0
14 Feb	62	186	0	1	249	19	5	0
20 Feb	34	198	5	0	237	14	5	0

* During the first survey, no distinction was made between adult and sub-adult male fur seals on Beaker Bay.

Table 8.2 Numbers of seals counted in the North Cove (NC) and North Annex (NA) study areas on Seal Island, Antarctica, 22 and 28 January and 4, 14 and 20 February 1996.

	22 January		28 January		4 February		14 February		20 February	
	NC	NA	NC	NA	NC	NA	NC	NA	NC	NA
Fur Seals: Pups	153	102*	152*	103	146*	99	126	93	131	100
Females	150	44	141	43	66†	35	101	41	181	82
Males - adult, territorial	14	4	17	9	14†	7	27	6	14	3
Males - adult, non-territ	44	0	57	17	75†	29	0	0	0	0
Males - subadult	14	4	6	6	37†	14	48	15	64	16
Juveniles	3	5	7	5	4†	1	6	1	4	2
Weddell seals	0	0	0	0	0	0	0	0	1	0
Elephant seals	1	2	1	0	0	0	0	0	0	0

*Counts do not include one dead pup. † Partial counts due to missing data.

Table 8.3 Comparison of weekly fur seal pup counts in the North Cove and North Annex study areas from the last three study seasons (1993/94, 1994/95 and 1996). Numbers in parenthesis ( ) represent dead pups at time of count.

	Date				
Season	18-22 Jan	25-28 Jan	1-4 Feb	14-16 Feb	20-23 Feb
1996	255(1)	255(1)	245(1)	219	231
1994/95	190(2)	189(1)	186	159(1)	150
1993/94*	275	232	186	177	178

* Number of dead pups not known.

Table 8.4 Numbers of known-aged fur seals, recorded by original tagging season and sex, observed during the 1996 field season on Seal Island, Antarctica. Numbers of females observed with pups are given in parenthesis.

Original tagging season	Males	Females	Females with pups	Total
1986/87	0	1	(1)	1
1987/88	4	4	(2)	8
1988/89	1	6	(4)	7
1989/90	1	1	(0)	2
1990/91	3	5	(3)	8
1991/92	14	12	(6)	26
1992/93	10	11	(0)	21
1993/94	1	0	(0)	1
			Total	74

Table 8.5 Comparison of average fur seal pup weights, standard deviations and sample sizes from the late January pup weight session for seven years of data collected on Seal Island, Antarctica (1989/90 - 1996).

		89/90	90/91	*91/92*	92/93	93/94	94/95	**1996**
MALE:	mean wt. (kg)	13.11	13.19	*14.07*	12.93	12.63	12.91	**13.51**
	std.dev.	2.01	1.76	*1.71*	1.86	1.45	1.98	**2.00**
	n	32	49	*55*	45	62	54	**50**
FEMALE:	mean wt. (kg)	10.66	11.15	*11.73*	10.86	10.94	11.15	**11.58**
	std.dev.	1.31	1.15	*1.25*	1.67	1.64	1.31	**1.57**
	n	50	51	*45*	55	33	46	**51**

Table 8.6 Summary of 2/3 creche censuses of the ten CCAMLR chinstrap penguin colonies from 1990-1996.

Colony	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**Average 1990-96**
9	351	246	352	265	397	265	**184**	294
21	87	53	80	119	105	167	**85**	99
24	1	5	16	9	19	27	**22**	14
31	354	221	273	380	378	346	**259**	316
32	109	50	57	60	41	21	**0**	48
33	182	74	107	126	144	111	**131**	125
42	241	146	186	176	193	156	**67**	166
51	7	28	51	46	52	58	**57**	43
54	147	86	256	182	184	205	**154**	173
66	313	203	253	248	279	184	**138**	231
Total	1792	1112	1631	1611	1792	1540	**1097**	1511
Island Population	38116	31416	45632	41074	44652	34906	N/A	39299

Table 8.7 Summary of the completion of creche censuses, 1990-96, for macaroni penguin colonies on Seal Island, Antarctica.

Colony	1990	1991	1992	1993	1994	1995	1996	Average 1990-96
4	32	27	24	21	26	22	**21**	25
31	46	42	52	51	44	21	**34**	41
61	3	3	4	3	2	4	**3**	3
71	59	48	53	51	58	43	**47**	51
74	87	62	74	96	96	74	**89**	83
Total	227	182	207	222	226	164	**194**	203

Note: A new colony of macaroni penguins formed at Petrel Pass during the 1994/95 season and four chicks reached creche, however no macaronis nested there in 1996.

Table 8.8 Summary of chinstrap fledgling information for 1990 - 1996 field seasons on Seal Island, Antarctica.

	1989/90	1990/91	1991/92	1992/93	1993/94	1994/95	1996
Mean fledging weight (kg)	3.1	2.9	3.1	3.1	2.9	3.1	3.1
Start Fledging	5 Feb	16 Feb	19 Feb	13 Feb	12 Feb	17 Feb	16 Feb

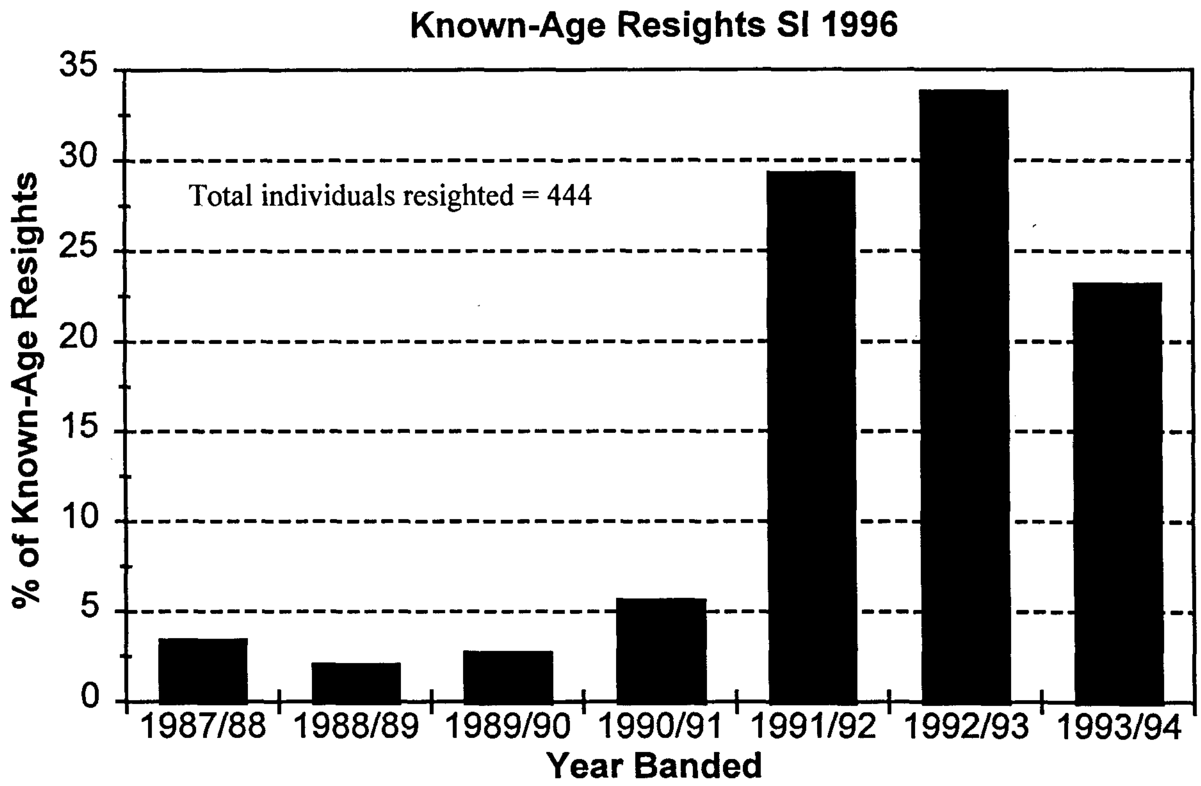

Figure 8.1 Known-age chinstrap resights represented by cohort, 1996. Sightings from 21Jan - 5 Feb, 1996.

9. Seabird research undertaken as part of the NMFS/AMLR ecosystem monitoring program at Palmer Station, 1995/96; submitted by William R. Fraser, Donna L. Patterson, Eric J. Holm, Karen M. Carney, and John Carlson.

9.1 Objectives: The AMLR program of the National Marine Fisheries Service (NMFS) provides information needed to formulate U.S. policy on the conservation and management of resources living in the oceans surrounding Antarctica. The program is in support of U.S. participation in the Convention for the Conservation of Antarctic Marine Living Resources (CCAMLR), which established a program for managing the living resources of the Antarctic ecosystem through international cooperation. The AMLR program emphasizes directed research undertaken for the express purpose of providing for the effective conservation of the marine living resources of the Antarctic ecosystem, which is the primary goal of CCAMLR.

The main objective of U.S. directed research is to provide information needed to detect, monitor, and predict the effects of fishing and associated activities on target, dependent, and related species of the Antarctic marine ecosystem. A key component of this effort involves monitoring seabird populations at Palmer Station, which is one of two sites on the Antarctic Peninsula where long-term research has been undertaken in support of U.S. participation in the CCAMLR Ecosystem Monitoring Program (CEMP). Objectives during 1995/96, the ninth season of field work at Palmer Station on Adelie penguins (*Pygoscelis adeliae*), were:

1. To determine Adelie penguin breeding population size,

2. To determine Adelie penguin breeding success,

3. To obtain information on Adelie penguin diet composition and meal size,

4. To determine Adelie penguin chick weights at fledging,

5. To determine adult Adelie penguin foraging trip durations,

6. To band 1000 Adelie penguin chicks for future demographic studies, and

7. To determine Adelie penguin breeding chronology.

9.2 Accomplishments: Field work at Palmer Station was initiated on 10 October 1995 and terminated on 27 March 1996. The early start date was aided by joint funding from the National Science Foundation's (NSF) Office of Polar Programs. In 1990, NSF selected Palmer Station as a Long Term Ecological Research (LTER) site, and has committed long-term funding and logistics support to an ecosystem study in which Adelie penguins represent one of two key upper trophic level predators selected for research. As a result of this cooperative effort between NMFS and NSF, field season duration at Palmer Station now covers the entire five month Adelie penguin breeding season.

Breeding Biology and Demography.

Adelie penguin breeding population size was determined by censusing the number of breeding pairs at 54 sample colonies during the peak egg-laying period (21-23 November 1995). These colonies contained 5457 pairs, which is a 2.4% decrease in population relative to the 5591 breeding pairs censused 29 November - 2 December 1994.

Breeding success was determined by following a 100-nest sample on Humble Island from clutch initiation to creche. A slight increase in breeding success was recorded this season, with birds creching 1.61 chicks per pair, or 0.12 chicks more than were creched per pair last season. As in past seasons, two other indices of breeding success were also determined. The proportion of one and two chick broods was assessed at 49 sample colonies between 5-6 January 1996. Of the 2844 broods censused, 63.5% (N=1805) contained two chicks, a slight decrease from the 66.5% reported in January 1995.

Chick production was determined by censusing chicks on 18 and 20 January 1996 at 54 sample colonies when approximately 2/3 of them were in the creche stage. Production at these colonies totaled 6532 chicks, a decrease of 2.3% from January 1995 when 6685 chicks were censused.

Chick fledging weights were obtained between 4-23 February 1996 at beaches near the Humble Island rookery. Peak fledging occurred on 10 February, which is one day earlier than in February 1995. Compared to February 1995, the average fledgling weight of the 263 Adelie chicks sampled decreased by less than 50g (2.96 vs 2.92kg). Data specific to the chronology of other breeding events are still under analysis and will be reported later.

As part of continued demographic studies, 1000 Adelie chicks were banded on 4 February 1996 at selected AMLR colonies on Humble Island. The presence of birds banded in previous seasons was also monitored during the entire field season on Humble Island as part of these studies.

Foraging Ecology.

Diet studies were initiated on 11 January 1996 and terminated on 17 February 1996. During each of the eight sampling periods, five adult Adelies were captured and lavaged using a water off-loading method as they approached their colonies to feed chicks on Torgersen Island. All birds (N=40) were released unharmed and the resulting diet samples processed at Palmer Station. The early samples contained a mix of prey items dominated by the presence of the euphausiids *Thysanoesa macrura* and *Euphausia superba.* Of these, only the krill *E. superba* was prevalent in the diets later in the season; fish were also noted in 50% of the diet samples, a marked increase relative to last season. The distribution of krill size-classes was bimodal, with very large (46-55mm) and very small (16-25mm) krill characterizing the samples. This distribution was significantly different from the one observed last season when only large krill were the dominant component of the diet.

Radio receivers and automatic data loggers were deployed at the Humble Island rookery between 9 January 1996 and 24 February 1996 to monitor presence-absence data on 33 breeding Adelie penguins carrying small radio transmitters. These transmitters were glued to adult penguins feeding 10-14 day old chicks. Analysis of the data has not yet been accomplished due to the size of the databases obtained.

9.3 Tentative Conclusions: The 1995/96 season was characterized by the persistence of heavy winter/spring pack ice until December, conditions nearly identical to those encountered last season. Most of the measured parameters related to the breeding biology of Adelie penguins in the Palmer Station vicinity exhibited a slight decrease between the 1994/95 and 1995/96 seasons. This included changes in breeding population size (5591 vs. 5457 pairs), percent two-chick broods (66.5% vs. 63.5%), total chick production at sample colonies (6685 vs. 6532 chicks), and chick weights at fledging (2.96 vs. 2.92kg). The exception to this trend was breeding success, which exhibited an increase (1.49 vs. 1.61 chicks creched per pair). As suggested last season, there is continued evidence that using a 100-nest sample to determine breeding success, as suggested by the CEMP protocols, may not adequately reflect real trends in this parameter from season to season that may be due to changes in the marine environment. The long-term data sets accumulated at Palmer Station are suggesting that breeding success is colony specific, with year-to-year variability within and between colonies being largely determined by environmental features specifically associated with the terrestrial nesting habitat. Variability in snow accumulation, for example, appears to "swamp" the potential effects of changes in the marine system, at least as measured by a 100-nest sample. This continues to suggest that breeding success needs to be measured by including both more nest sites and more colonies to fully account for the effects of changes in the marine system. Despite similar winter/spring pack ice conditions, last season was characterized by a 2-week delay in the timing of the January blooms, a feature not observed during the 1995/96 season.

Relative to last year, changes in the foraging ecology of Adelie penguins during 1995/96 included shorter foraging trip durations (24 vs.13 hours, based on a partial analysis of the data), a bimodal distribution in krill size classes present in the diet samples, and an increased presence of fish in the diets. This pattern exhibits close correspondence with features observed during the 1991/92 season, which also followed a heavy ice year (1990/91) and included relatively "normal" conditions in the timing of the January blooms. These data continue to support the hypothesis that interactions between winter/spring sea ice conditions and the timing of blooms may be the key variables affecting the abundance and distribution of prey in the foraging environment of Adelie penguins in the Palmer Station area. Aspects and implications of this hypothesis are currently being examined in a series of analyses and publications that are either in press or submitted, and which summarize AMLR, LTER and related data for the Palmer area since 1974.

9.4 Disposition of the Data: No diet samples were returned to the U.S. for analysis as all work was successfully completed at Palmer Station. All other data relevant to this season's research are currently on diskettes at the Antarctic Ecosystem Research Group.

9.5 Problems, Suggestions and Recommendations: As suggested last season, it is becoming more apparent that environmental variables such as sea ice extent and snow deposition, among others, may be key determinants of at least some aspects of the annual variability inherent in some of the monitored parameters. However, at the moment, there is no formal requirement in effect by which to standardize the collection and reporting of environmental data. It is our opinion that the development of such standards would greatly aid our interpretive potential within and between CEMP monitoring sites. It is also apparent that some of the CEMP protocols, as they are currently being implemented, may lack the sensitivity to provide the type of information being requested by CEMP. This would argue that these protocols need to be updated, an effort that was instituted at Palmer Station in 1995/96 by a developing a series of experiments to contrast results obtained by using older vs. newer methodologies. This effort is expected to continue next season.