UNITED STATES
AMLR ANTARCTIC MARINE LIVING RESOURCES PROGRAM

AMLR 1999/2000 FIELD SEASON REPORT

Objectives, Accomplishments and Tentative Conclusions

Edited by
Jessica D. Lipsky

March 2001

NOAA-TM-NMFS-SWFSC-302

Southwest Fisheries Science Center
Antarctic Ecosystem Research Group

The National Oceanic and Atmospheric Administration (NOAA), organized in 1970, has evolved into an agency which establishes national policies and manages and conserves our oceanic, coastal, and atmospheric resources. An organizational element within NOAA, the Office of Fisheries is responsible for fisheries policy and the direction of the National Marine Fisheries Service (NMFS).

In addition to its formal publications, the NMFS uses the NOAA Technical Memorandum series to issue informal scientific and technical publications when complete formal review and editorial processing are not appropriate or feasible. Documents within this series, however, reflect sound professional work and may be referenced in the formal scientific and technical literature.

The U.S. Antarctic Marine Living Resources (AMLR) program provides information needed to 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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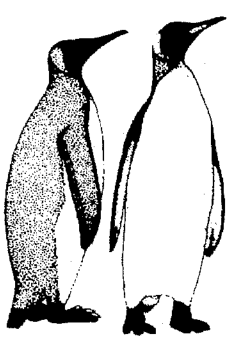

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P.O. Box 271
La Jolla, California, U.S.A. 92038

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BACKGROUND

The long-term objective of the U.S. AMLR field research program is to describe the functional relationships between Antarctic krill (*Euphausia superba*), 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. To refine these hypotheses a study area was designated in the vicinity of Elephant, Clarence, and King George Islands, and a field camp was established at Seal Island, a small island off the northwest coast of Elephant Island. From 1989-1996, shipboard studies were conducted in the study area to describe variations within and between seasons in the distributions of nekton, zooplankton, phytoplankton, and water zones. Complementary reproductive and foraging studies on breeding pinnipeds and seabirds were also accomplished at Seal Island.

Beginning in the 1996/97 season, the AMLR study area was expanded to include a large area around the South Shetland Islands, and a new field camp was established at Cape Shirreff, Livingston Island (Figure 1). Research at Seal Island was discontinued due to landslide hazards. Shipboard surveys of the pelagic ecosystem in the expanded study area are accomplished each season, as are land-based studies on the reproductive success and feeding ecology of pinnipeds and seabirds at Cape Shirreff. During the 1999/2000 season, the AMLR program also participated in a multi-nation, multi-ship survey of krill throughout the Scotia Sea, known as the CCAMLR 2000 survey.

SUMMARY OF 2000 RESULTS

The Russian R/V *Yuzhmorgeologiya* was chartered to support the U.S. AMLR Program during the 1999/2000 field season. This was the first year of a new 5-year charter with the vessel operators after four successful previous seasons. Shipboard operations included: 1) participation in a multi-nation, multi-ship survey of Antarctic krill across the Scotia Sea; 2) a joint Zodiac/ship inshore survey of krill and oceanographic conditions near Cape Shirreff; 3) a region-wide survey of krill and oceanographic conditions in the vicinity of the South Shetland Islands; 4) calibration of acoustic instrumentation at the beginning and end of survey operations; and 5) shore camp support. Land-based operations at Cape Shirreff included: 1) observations of chinstrap and Adélie penguin breeding colony sizes, foraging locations and depths, diet composition, breeding chronology and success, and fledging weights; 2) instrumentation of adult penguins to determine winter-time migration routes and foraging areas; 3) observations of fur seal pup production and growth rates, adult female attendance behavior, diet composition, foraging locations and depths, and metabolic rates; 4) collection of female fur seal milk samples for determination of fatty acid signatures; 5) collection of fur seal teeth for age determination and other demographic studies; 6) tagging of penguin chicks and fur seal pups for future demographic studies; and 7) establishment of a weather station for continuous recording of meteorological data.

The CCAMLR 2000 Survey was conducted in collaboration with vessels from Japan, Russia and the UK (Figure 2). Sampling protocols, survey design, analysis procedures, and detailed results are presented elsewhere (SC-CAMLR-XVIII, Annex 4, Appendices D and E; SC-CAMLR-XIX, Annex 4, Appendix G). Marine mammal and bird observers from the International Whaling Commission also participated on the survey. Oceanographic fronts located at the central axis (SACCF) and southern boundary of the Antarctic Circumpolar Current were evident at all major transects across the Scotia Sea. Chlorophyll concentrations were highest north of the SACCF, with lower values south of the SACCF that increased toward the southern boundary. Lowest chlorophyll concentrations and highest krill densities were observed in the vicinity of the South Orkney Islands. Three geographically distinct size clusters of krill were also mapped across the Scotia Sea. Very large krill (52mm modal length) were sampled in the western Scotia Sea and Drake Passage. Another cluster (48mm modal length, but also containing several samples of intermediate size krill) was mapped in the inshore waters adjacent to the Antarctic Peninsula and extended across the northeastern part of the survey area. Small krill (26mm modal length) were found in the eastern portion of the Scotia Sea in a broad tongue extending from the southern part of the survey area between the South Orkney and South Sandwich Islands north to the eastern end of South Georgia. A preliminary examination of the oceanographic data suggested the small krill may have been transported into the Scotia Sea from the Weddell Sea. Similar biogeographic patterns were apparent in salp demographics and macro-zooplankton species composition mapped from samples collected aboard the *Yuzhmorgeologiya* (approximately one-third of the total number of samples). Krill densities (estimated from the combined data sets) were highest over the continental shelves surrounding the South Shetland, South Orkney, South Georgia and South Sandwich archipelagos. Overall krill density was estimated to be 21.3 g/m^2 over a survey area of 2,065 x 10^3 km^2 for a total biomass of 44.3 million tons (CV 11.4%).

The inshore survey near Cape Shirreff (Figure 3) was accomplished using a 5-m Zodiac configured with a 120kHz echo sounder, an underwater video camera, a CTD, several continuously recording sea surface and meteorological sensors, two GPS receivers, a radar, and emergency equipment. The Zodiac was used to map krill within 15 nautical miles of the Cape while the ship surveyed further offshore. The survey was staged from the field camp and conducted over a 5-day period. Substantial amounts of krill were mapped inshore of the region surveyed by the ship and the feasibility of using a small boat to conduct inshore surveys in Antarctica was demonstrated.

An oceanic frontal zone was mapped along the north side of the South Shetland Islands, running parallel to the continental shelf break and separating Drakes Passage water to the north from Bransfield Strait water to the south (Figure 4). The prevailing flow was southwest to northeast; however, both the front and geostrophic flow lines diverged to the north in the vicinity of Elephant Island. Chlorophyll concentrations were above average and highest south of the frontal zone. Highest densities of krill were mapped between King George, Elephant and Clarence Islands and along the shelf break north of the archipelago. Mean krill biomass density in the Elephant Island area was estimated to be 37.5 g/m^2, higher than that observed in 1999, and in conformance with a long-term cyclic trend. Sampled krill were predominately large and sexually mature; the few immature krill caught were large and probably post-spawning; and only two out of 2,100 specimens processed were juveniles. Virtually all of the sampled krill represented the 1994/95 and 1995/96 year classes. High densities of late krill larval stages suggest an active and prolonged 1999/2000 spawning season. Demographic analysis of sampled *Salpa thompsoni* suggested the population may have initiated seasonally early production of the over-wintering form. Copepods and larval krill dominated the zooplankton assemblage, although salps were widespread and relatively abundant as well. This, and other aspects of the zooplankton assemblage, suggested that 1999 and 2000 may be classified as transition years between a salp-dominated community and a copepod-dominated community. Acoustically detected layers of myctophid fish were mapped north of the frontal zone and appeared to be associated with the southern boundary of the ACC.

The numbers of chinstrap and gentoo breeding pairs were higher than the previous season and above the three-year mean for the Cape Shirreff monitoring site. Overall reproductive success for chinstrap penguins was lower than average, but fledging weight was slightly higher than average. Conversely, overall reproductive success for gentoo penguins was higher than average, and fledging weight lower than average. Large krill (41 – 55mm) were present in 100% of the sampled diets from both species, while fish were evident in 3% of chinstrap and 80% of gentoo penguin samples. The distribution of foraging trip durations for chinstrap parents were bimodal. Shorter trips (8-hr mode) were initiated between dawn and noon; longer trips (12-hr mode) began later in the day and included the dark period. The median birth date of fur seal pups was two days earlier and total pup production was 5.8% higher than the previous season. Return rates of adult females were comparable to last year, although the return rate for yearlings was lower. Foraging trip duration for lactating females was significantly less than the last two years. As in previous years, an increase in fish and squid in the diet was observed as the season progressed. Teeth were extracted from 80 fur seals for age determination and other demographic studies; operations proceeded according to approved protocols and no adverse reactions were noted.

References:

SC-CAMLR-XVIII. 1999. CCAMLR Synoptic Planning Meeting. Appendix D to Report of the Working Group on Ecosystem Monitoring and Management. In: *Report of the Eighteenth Meeting of the Scientific Committee* (SC-CAMLR-XVIII), Annex 4. CCAMLR, Hobart, Australia: 191-202.

SC-CAMLR-XVIII. 1999. CCAMLR 2000 Krill Synoptic Survey: A Description of the Rationale and Design. Appendix E to Report of the Working Group on Ecosystem Monitoring and Management. In: *Report of the Eighteenth Meeting of the Scientific Committee* (SC-CAMLR-XVIII), Annex 4. CCAMLR, Hobart, Australia: 203-225.

SC-CAMLR-XIX. 2000. Report of the B_0 Workshop. Appendix G to Report of the Working Group on Ecosystem Monitoring and Management. In: *Report of the Nineteenth Meeting of the Scientific Committee* (SC-CAMLR-XVIII), Annex 4. CCAMLR, Hobart, Australia.

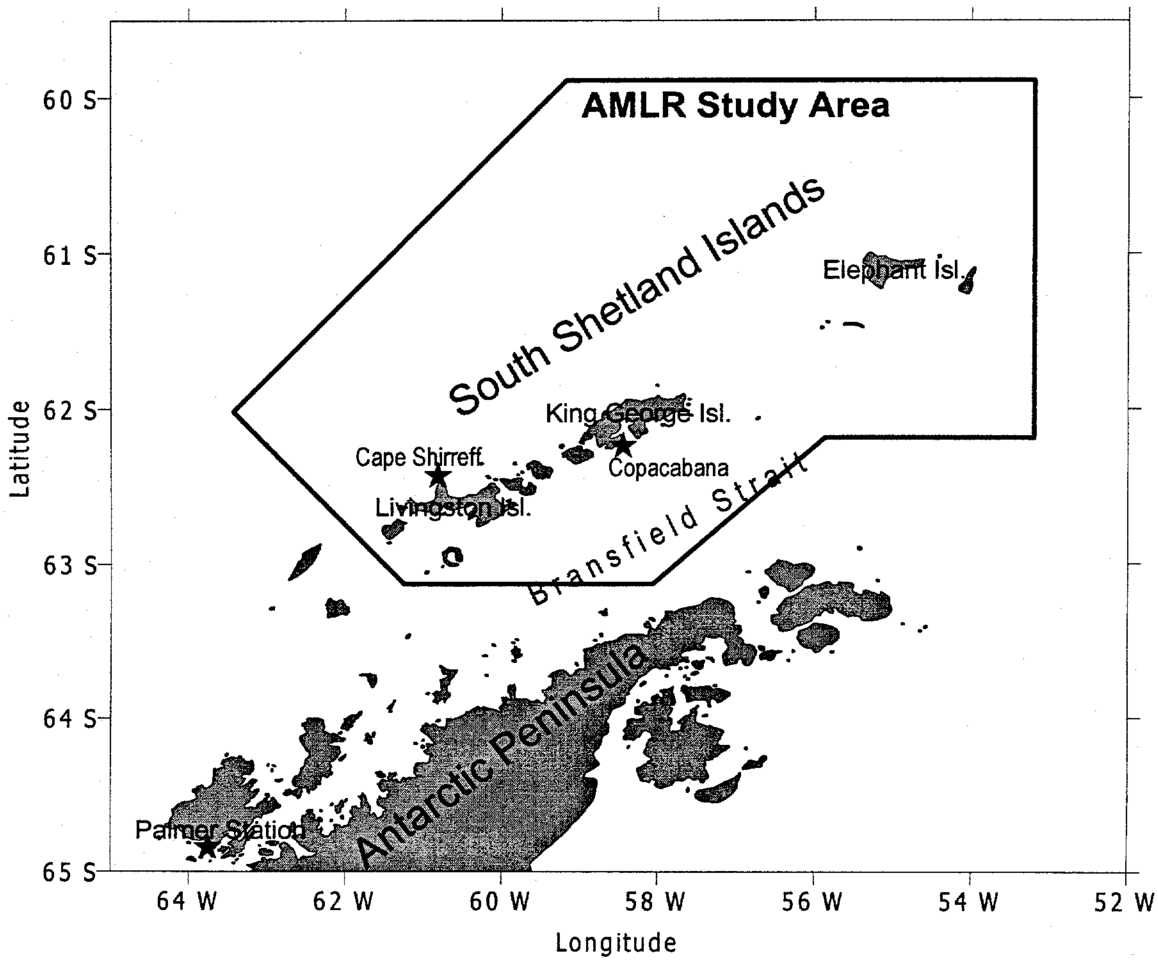

Figure 1. Locations of the U.S. AMLR field research program: AMLR study area, Cape Shirreff and Copacabana.

OBJECTIVES

Shipboard Research:

1. Conduct the portion of the CCAMLR 2000 survey for Antarctic krill in the Scotia Sea that is assigned to the U.S. survey ship (R/V *Yuzhmorgeologiya*).
2. Conduct a high-resolution survey for krill in the vicinity of Cape Shirreff using a specially-equipped Zodiac for the inshore areas and the *Yuzhmorgeologiya* for the offshore areas.
3. Calibrate the shipboard acoustic system in Leigh Harbor, South Georgia near the beginning of Leg I, at Cape Shirreff near the beginning of Leg II, and again at Admiralty Bay near the end of Leg II.
4. Conduct a survey in the vicinity of the South Shetland Islands during Leg II to map meso-scale features of the dispersion of krill, water mass structure, and zooplankton constituents.
5. Collect continuous measurements of the research ship□s position, sea surface temperature, salinity, turbidity, fluorescence, air temperature, barometric pressure, relative humidity, and wind speed and direction.
6. Provide logistical support to two land-based field sites: Cape Shirreff (Livingston Island), and Copacabana field camp (Admiralty Bay, King George Island).

Land-based Research:

<u>Cape Shirreff</u>

1. Estimate chinstrap and gentoo penguin breeding population size.
2. Band 1000 chinstrap and 200 gentoo penguin chicks for future demographic studies.
3. Record at sea foraging locations for chinstrap penguins during their chick-rearing period using ARGOS satellite-linked transmitters (PTTs).
4. Determine chinstrap and gentoo penguin breeding success.
5. Determine chinstrap and gentoo penguin chick weights at fledging.
6. Determine chinstrap and gentoo penguin diet composition, meal size, and krill length/frequency distributions via stomach lavage.
7. Determine chinstrap and gentoo penguin breeding chronologies.
8. Deploy time-depth recorders (TDRs) on chinstrap and gentoo penguins during chick rearing for diving studies.
9. Collect data on foraging locations (using PTTs) and foraging depths (using TDRs) of chinstrap penguins while concurrently collecting acoustically derived krill biomass and location data during the inshore survey.
10. Deploy PTTs on chinstrap penguins following adult molt to determine migration routes and winter foraging areas in the Scotia Sea region.
11. Document Antarctic fur seal pup production for Cape Shirreff and assist Chilean colleagues with censuses of fur seal pups for the entire Cape and the San Telmo Islands.

12. Monitor female Antarctic fur seal attendance behavior.
13. Assist Chilean researchers in collecting Antarctic fur seal pup length, girth, and mass for 100 pups every two weeks through the season.
14. Collect 10 Antarctic fur seal scat samples every week for diet studies.
15. Collect a milk sample at each female Antarctic fur seal capture for fatty acid signature analysis and diet studies.
16. Record at-sea foraging locations for female Antarctic fur seals using PTTs.
17. Deploy TDRs on female Antarctic fur seals for diving studies.
18. Measure at-sea metabolic rates and foraging energetics of lactating Antarctic fur seals using doubly-labeled water.
19. Tag 500 Antarctic fur seal pups for future demographic studies.
20. Measure metabolic rates and thermo-neutral zones of pups and juvenile Antarctic fur seals using a metabolic chamber.
21. Collect teeth from selected Antarctic fur seals for age determination and other demographic studies.
22. Deploy a weather station for continuous recording of wind speed, wind direction, ambient temperature, humidity, and barometric pressure.

DESCRIPTION OF OPERATIONS

Shipboard Research:

For the fifth consecutive year, the cruise was conducted aboard the chartered Russian research vessel R/V *Yuzhmorgeologiya*.

Itinerary

Leg I:	Depart Punta Arenas	08 January 2000
	Calibrate in Leith Harbor, South Georgia	12 January
	CCAMLR 2000 survey	13 January-04 February
	Resupply Cape Shirreff camp	05 February
	Cape Shirreff survey	06-10 February
	Recover personnel from Copacabana camp	12 February
	Arrive Punta Arenas	15 February
Leg II:	Depart Punta Arenas	18 February
	Transfer personnel and supplies at Cape Shirreff	21 February
	Calibrate at Cape Shirreff	21 February
	Large-area survey (Survey D)	22 February-07 March
	Calibrate at Admiralty Bay	07 March
	Close Copacabana camp	08 March
	Close Cape Shirreff	09 March
	Arrive Punta Arenas	12 March

Leg I.

1. The R/V *Yuzhmorgeologiya* departed Punta Arenas, Chile en route to South Georgia.

2. The acoustic transducers were calibrated in Leith Harbor, South Georgia. 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. In addition, a specially-outfitted Zodiac was launched and acoustic sensors, navigation systems, and safety equipment were tested in preparation for a survey off Cape Shirreff later in the cruise.

3. A multi-national, multi-ship survey of Antarctic krill and whales organized by CCAMLR and the International Whaling Commission (IWC), known as the CCAMLR 2000 survey, was conducted across the Scotia Sea (Figure 2). Other vessels participating in the survey were the R/V *James Clarke Ross* (United Kingdom), the R/V *Kaiyo Maru* (Japan), and the R/V *Atlantida* (Russia). Survey components included acoustic mapping of zooplankton, direct sampling of zooplankton, Antarctic krill demographics, and marine mammal and bird observations. Also, physical oceanography and phytoplankton observations were obtained.

4. Continuous environmental data were collected throughout Leg I, which included measurements of ship□s position, sea surface temperature and salinity, fluorescence, air temperature, barometric pressure, relative humidity, wind speed, and wind direction.

5. The ship visited the Cape Shirreff field camp to deliver provisions and supplies.

6. A high-resolution survey for krill and oceanographic conditions was conducted in the vicinity of Cape Shirreff (Figure 3). A specially-outfitted Zodiac conducted a series of acoustic transects, CTD deployments and underwater video observations within 15 miles of Cape Shirreff. The ship complemented these measurements on a coarser grid further offshore, deploying an Isaacs-Kidd Midwater Trawl (IKMT).

7. The ship rendezvoused with the R/V *James Clark Ross* near Deception Island; zooplankton samples collected during the CCAMLR 2000 survey were passed to British Antarctic Survey colleagues for permanent archiving in Cambridge.

8. The ship visited the Copacabana field camp at Admiralty Bay, King George Island to retrieve four personnel.

Leg II.

1. The R/V *Yuzhmorgeologiya* departed Punta Arenas, Chile via the eastern end of the Strait of Magellan and arrived at Cape Shirreff to deliver supplies and personnel to the field camp.

2. The acoustic transducers were calibrated while the ship was at anchor near Cape Shirreff.

3. A large-area survey of 97 Conductivity-Temperature-Depth (CTD) and net sampling stations, separated by acoustic transects, was conducted in the vicinity of Elephant, Clarence, King George, and Livingston Islands (Survey D, Figure 4). Stations are located in three areas: stations to the west of Livingston and King George Islands are designated the "West area," those to the south of King George Island are designated the "South area," and those around Elephant Island are called the "Elephant Island area". Acoustic transects were conducted at 10 knots, using hull-mounted 38kHz, 120kHz, and 200kHz down-looking transducers. Operations at each station included: (a) vertical profiles of temperature, salinity, and oxygen, and measurements of chlorophyll at 5 meters depth; and (b) deployment of an IKMT to obtain samples of zooplankton and micronekton.

4. Optical oceanographic measurements were conducted, which included weekly SeaWiFS satellite images of surface chlorophyll distributions and *in-situ* light spectra profiles.

5. As on Leg I, continuous environmental data were collected throughout the second leg.

6. Following the completion of Survey D, the acoustic transducers were calibrated in Ezcurra Inlet, Admiralty Bay, and King George Island. The Copacabana field camp was closed and field personnel were retrieved. The ship then transited to Cape Shirreff to embark personnel and close the field camp.

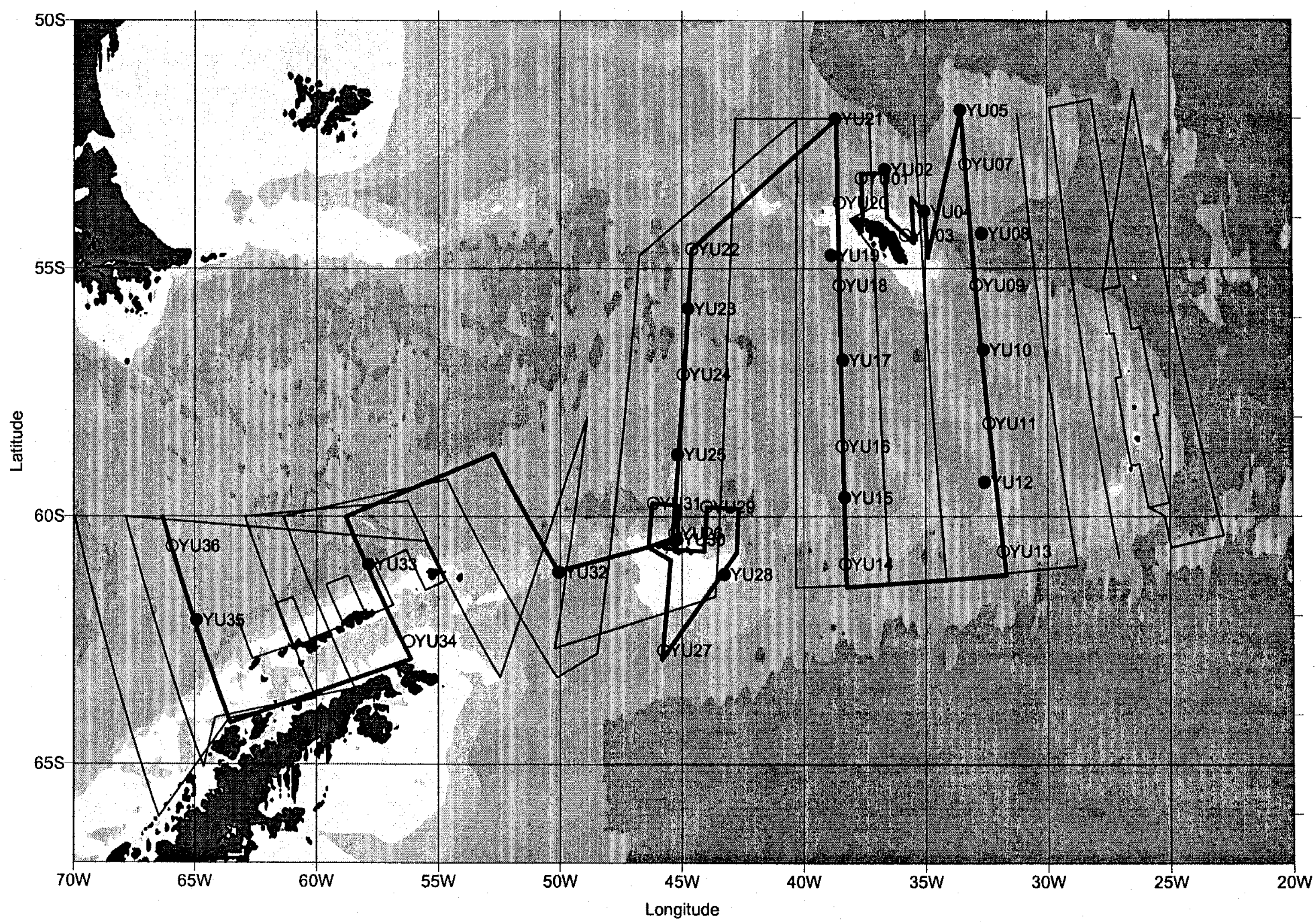

Figure 2. CCAMLR 2000 Survey. Heavy line describes trackline of R/V *Yuzhmorgeologiya*. Open circles represent day-time stations; closed circles represent night-time stations. Light lines represent tracklines of other ships involved in the CCAMLR 2000 Survey (British R/V *James Clark Ross*, Japanese R/V *Kaiyo Maru*, and Russian R/V *Atlantida*). See Report of Bo Workshop, SC-CAMLR-XIX, 2000, CCAMLR, Hobart, Australia for more details. Depth shading is 0-500m, 500-2000 m, 2000-4000m, and greater than 4000 m.

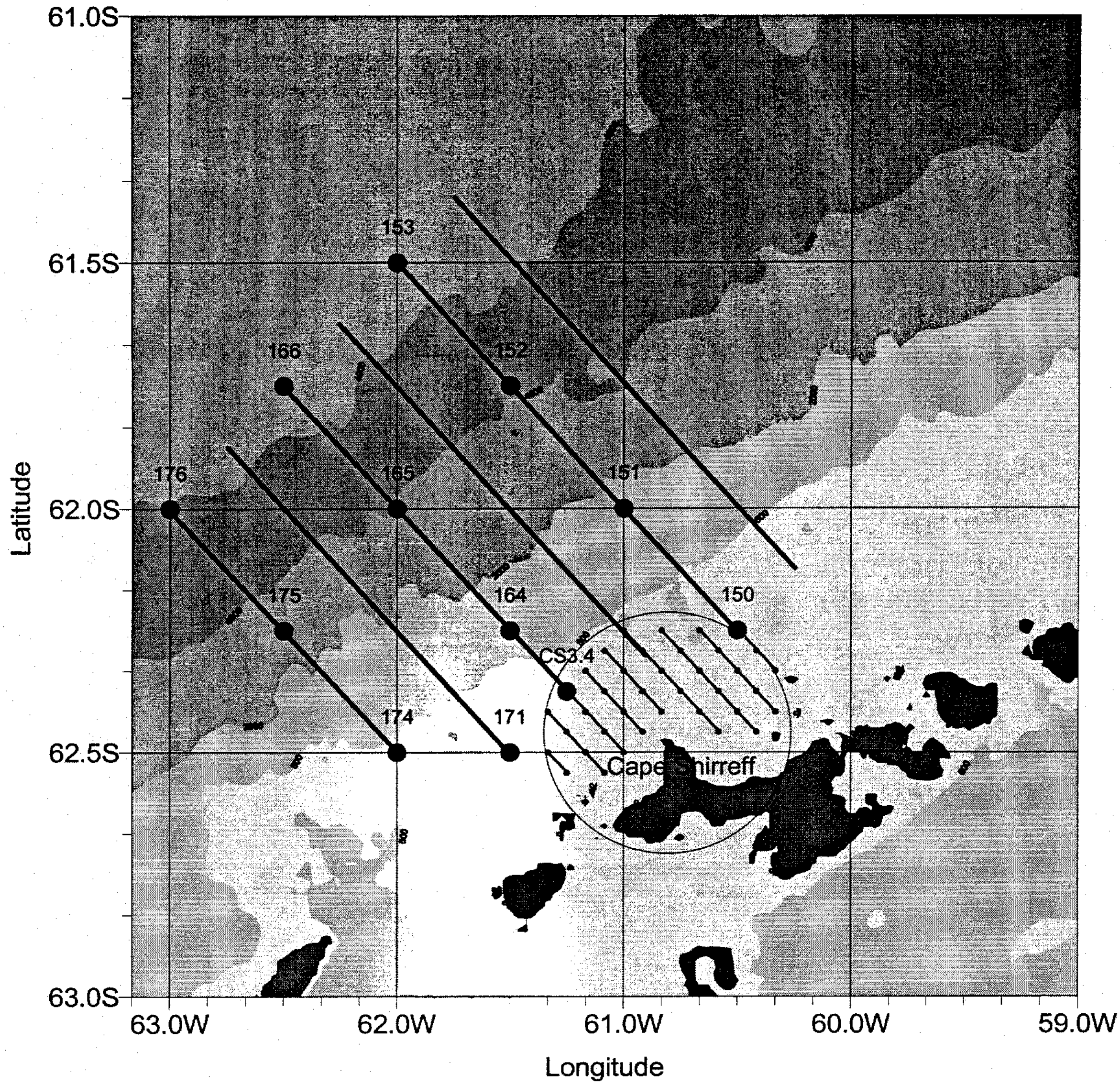

Figure 3. Cape Shirreff inshore survey area. Depth shading is 0-500m, 500-2000m, 2000-4000m and greater than 4000m.

Land-based Research:

Cape Shirreff

1. A four-person field team (M. Goebel, T. Carten, M. Rutishauser, and M. Taft) arrived at Cape Shirreff, Livingston Island, on 31 October 1999 via the R/V *Lawrence M. Gould*. Equipment and provisions were also transferred from the R/V *Lawrence M. Gould* to Cape Shirreff.

2. Two additional personnel (R. Holt and B. Parker), along with supplies and equipment, arrived at Cape Shirreff via the R/V *Lawrence M. Gould* on 22 December 1999. D. Costa arrived at Cape Shirreff via the Aurora Expeditions tour ship, M/V *Prof. Molchanov* on 29 January 2000. Two personnel (D. Demer and A. Jenkins) from the R/V *Yuzhmorgeologiya* visited Cape Shirreff from 5 to 10 February 2000 while they conducted an inshore acoustic survey. N. Gales arrived via the R/V *Yuzhmorgeologiya* on 21 February 2000.

3. Camp maintenance at Cape Shirreff included painting of interior and exterior of camp structures, interior construction of the emergency shelter/bird observation blind, construction of a deck on the storeroom and main hut, and upgrades to electrical fixtures.

4. The annual census of active gentoo penguin nests was conducted on 26 November 1999, and a similar census of chinstrap penguin nests was completed on 30 November 1999. Reproductive success was studied by following a sample of 100 chinstrap penguin pairs and 50 gentoo penguin pairs from egg laying to crèche formation.

5. Radio transmitters were attached to 18 chinstrap penguins on 2 and 3 January 2000; these instruments were used to determine foraging trip duration during the chick-rearing phase. All data were received and stored by a remote field computer set up at the bird observation blind.

6. Five satellite-linked transmitters were deployed on adult chinstrap penguins on 8 January to determine foraging location.

7. Diet studies of chinstrap and gentoo penguins during the chick-rearing phase were initiated on 4 January 2000 and continued through 8 February 2000. Chinstrap and gentoo adult penguins were captured upon returning from foraging trips, and their stomach contents were removed by lavaging.

8. A count of all gentoo penguin chicks was conducted on 4 February 2000, and for chinstrap penguin chicks on 8 February 2000. Fledging weights of chinstrap penguin chicks were collected 16-24 February 2000. Two hundred gentoo penguin chicks were also weighed on 10 February 2000.

9. One thousand chinstrap penguin chicks and 200 gentoo penguin chicks were banded for future demographic studies.

10. Reproductive studies of brown skuas and kelp gulls were conducted around the Cape.

11. Time-depth recorders (TDRs) were deployed on chinstrap and gentoo penguins for 10-12 day foraging periods to study diving behavior.

12. Antarctic fur seal pups and female fur seals were counted at four main breeding beaches every other day from 2 November 1999 through 9 January 2000.

13. Attendance behavior of female Antarctic fur seals was measured using radio transmitters. Twenty-four lactating female seals were instrumented 5-12 December 1999, and their pups were captured, weighed, and measured.

14. U.S. researchers assisted Chilean scientists in collecting data on Antarctic fur seal pup growth. Measurements of mass, length, and girth for 100 pups were begun on 16 December 1999 and continued every two weeks until 5 March 2000.

15. Information on Antarctic fur seal diet was collected using three different methods: scat collection, enemas of captured animals, and fatty-acid signature analyses of milk.

16. Antarctic fur seals were instrumented with TDRs for diving behavior studies.

17. Antarctic fur seal females were instrumented with ARGOS satellite-linked transmitters for studies of foraging locations and energetics. Some of these fur seals also received injections of doubly-labeled water for measurements of metabolic rate, water flux, and energy expended.

18. Five hundred Antarctic fur seal pups were tagged at Cape Shirreff by U.S. and Chilean researchers for demography studies.

19. Weather data recorders were set up at Cape Shirreff for wind speed, wind direction, barometric pressure, temperature, humidity, and rainfall.

20. One team member (T. Carten) left Cape Shirreff via a Chilean Navy vessel on 23 February 2000. Two personnel (D. Costa and N. Gales) were retrieved from Cape Shirreff via the M/V *Prof. Molchanov* on 24 February 2000.

21. The Cape Shirreff field camp was closed for the season on 9 March 2000; all personnel (M. Goebel, M. Rutishauser, M. Taft, R. Holt, and B. Parker), garbage, and equipment were retrieved by the R/V *Yuzhmorgeologiya*.

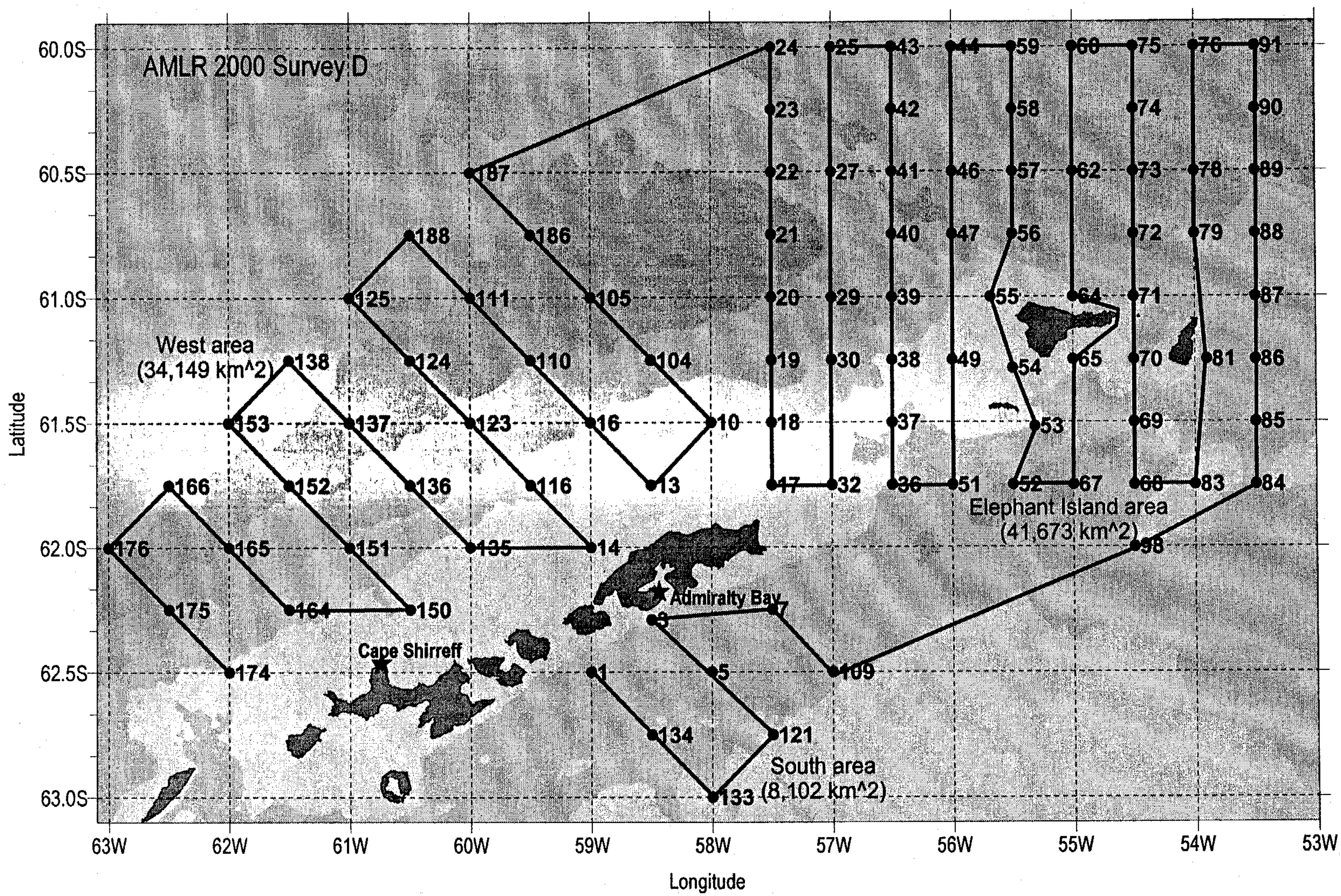

Figure 4. The large-area survey for AMLR 2000 (Survey D) in the vicinity of Elephant, Clarence, King George and Livingston Islands. Stations located to the west of Livingston and King George Islands are designated the “West area”, those to the south of King George Island are designated the “South area” and those around Elephant Island are designated the “Elephant Island area”. Depth shading is 0-500m, 500-2000m, 2000-4000m and greater than 4000m.

SCIENTIFIC PERSONNEL

Cruise Leader:
    Roger P. Hewitt, Southwest Fisheries Science Center (Legs I and II)

Physical Oceanography:
    David A. Demer, Southwest Fisheries Science Center (Leg I)
    Roger P. Hewitt, Southwest Fisheries Science Center (Leg II)
    Pierre Malan, Sea Fisheries Research Institute (Leg I)
    Rob Rowley, Moss Landing Marine Laboratories (Legs I and II)

Phytoplankton:
    Christopher D. Hewes, Scripps Institution of Oceanography (Leg II)
    John Wieland, Scripps Institution of Oceanography (Leg II)
    Roger P. Hewitt, Southwest Fisheries Science Center (Leg I)

Bioacoustic Survey:
    Roger P. Hewitt, Southwest Fisheries Science Center (Legs I and II)
    David A. Demer, Southwest Fisheries Science Center (Leg I)
    Dale Roberts, NMFS, Tiburon Laboratory (Legs I and II)
    Jennifer Emery, University of California at Santa Cruz (Leg II)

Krill and Zooplankton Sampling:
    Valerie Loeb, Moss Landing Marine Laboratories (Legs I and II)
    Rob Rowley, Moss Landing Marine Laboratories (Legs I and II)
    Jenna Borberg, Moss Landing Marine Laboratories (Legs I and II)
    Kim Dietrich (Leg II)
    Nancy Gong, University of California at Santa Cruz (Leg II)
    Adam Jenkins, Southwest Fisheries Science Center (Legs I and II)
    Pierre Malan, Dept of Environmental Affairs, South Africa (Leg I)
    Dorothee Stübing, Universität Bremen (Leg II)

Fur Seal Energetics Studies:
    Alison R. Banks, University of California at Santa Cruz (Legs I and II)

Krill Genetic Studies:
    Bo Bergstrom, Swedish Academy of Sciences (Leg I)

IWC Whale Survey:

Steve Reilly, Southwest Fisheries Science Center (Leg I)
Deborah Thiele, Deakin University, Australia (Leg I)
Paula Olson, Southwest Fisheries Science Center (Leg I)
James Cotton, Southwest Fisheries Science Center (Leg I)
Simon Berrow, British Antarctic Survey (Leg I)
Amy Williams, Northeast Fisheries Science Center (Leg I)

Film Maker:

Judy Rhee, NYU (Leg I)

Cape Shirreff Personnel:

Michael E. Goebel, Southwest Fisheries Science Center (10/31/99 to 3/9/00)
Terence Carten (10/31/99 to 2/23/00)
Daniel P. Costa, University of California at Santa Cruz (1/29/00 to 2/24/00)
Nick Gales, Dept. of Conservation and Land Management, Australia (2/21/00 to 2/24/00)
Rennie S. Holt, Southwest Fisheries Science Center (12/22/99 to 3/9/00)
Brian Parker, Southwest Fisheries Science Center (12/22/99 to 3/9/00)
Matthew R. Rutishauser, University of California at Santa Cruz (10/31/99 to 3/9/00)
Michael Taft (10/31/99 to 3/9/00)

DETAILED REPORTS

1. Physical Oceanography and Underway Environmental Observations; submitted by David A. Demer (Leg I), Roger Hewitt (Leg II), Pierre Malan (Leg I), Rob Rowley (Legs I and II).

1.1 Objectives: Objectives were to 1) collect and process physical oceanographic data in order to identify and map oceanographic frontal zones; and 2) collect and process environmental data underway in order to describe sea surface and meteorological conditions experienced during the conduct of the surveys. These data may be used to describe the physical circumstances associated with various biological observations as well as provide a detailed record of the ship's movements and encountered environmental conditions.

1.2 Accomplishments: Two series of observations were collected. The first included vertical profiles of temperature, depth, and oxygen as well as discrete water samples from fixed stations. The second included underway measurements of sea surface temperature, salinity and fluorescence as well as air temperature, pressure, relative humidity, wind speed and direction, indexed to date, time and ship's position.

During the CCAMLR-2000 survey on Leg I, 35 CTD/carousel stations were conducted (Figure 2 in Introduction section). Another 12 CTD/carousel stations were conducted later in Leg I in support of the inshore survey near Cape Shirreff (Figure 3 in Introduction and Section 5). During the AMLR survey (AMLR00D) on Leg II, 98 CTD/carousel stations were conducted (Figure 4 in Introduction). During the CCAMLR-2000 survey, five water samples were collected at each station for salinity checks using a calibrated Guildline Autosal; four water samples were collected at each station for determination of chlorophyll concentrations. During both Legs I (39 days) and II (26 days), underway data were collected and archived. Augmented with GPS navigational information and output from the ship's gyro compass, these data provided complete coverage of surface environmental conditions encountered throughout the CCAMLR and AMLR study areas.

All CTD/carousel casts were made with a Sea-Bird SBE-9/11 PLUS CTD/carousel water sampler. During the CCAMLR-2000 survey CTD profiles extended to 1000m (or to within a few meters of the ocean floor when the depth was less than 1000m); during the AMLR survey CTD profiles extended to 750m water depth. A Data Sonics altimeter was used to guide the CTD/carousel to within 5m of the bottom on the shallow stations. Downtrace (24 scans/second) and uptrace (6 scans/second) CTD data for each station were recorded separately. All carousel 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 depth-averaged profiles for analysis. Ocean Data View (version 5.0 developed by Dr. Reiner Schlitzer, Alfred Wegener Institut, and reviewed by Brown, 1998) was used to visualize the data and support tentative conclusions.

The underway data collection system consisted of 1) digital outputs from a Seabird SBE21 thermosalinograph, a Coastal Environmental Systems WeatherPak 2000, a Furuno GPS Navigator GP-30-35, the ship's GPS system, and the ship's gyro compass; 2) analog outputs from a Turner Designs Model 10-005R fluorometer; 3) a Fluke Data Bucket used for analog to digital signal conversion; 4) a Digi 16-port serial adapter; and 5) a Windows NT computer running the Shipboard Computer System (SCS) Version 2.3 software developed by the Software Engineering Division of NOAA's Marine and Aviation Operations, Silver Spring, Maryland.

1.3 Results and Tentative Conclusions:

CCAMLR-2000 survey. Oceanographic fronts located at the central axis and southern boundary of the Antarctic Circumpolar Current were evident on all three major transects across the Scotia Sea conducted by the R/V *Yuzhmorgeologiya* (Figure 1.1). These data will be combined with that collected by observers on the other ships participating in the CCAMLR-2000 survey in order to generate a more detailed description of the physical oceanography of the Scotia Sea during January-February 2000.

Cape Shirreff survey. A portion of the oceanographic front described below was evident on the three cross-sections observed near Cape Shirreff.

AMLR survey. As in past years, the dominant physical feature mapped in the vicinity of the South Shetland Islands during the AMLR00D survey was the oceanographic frontal region running parallel to the continental shelf break north of the archipelago. Stations with similar temperature/salinity (T/S) relationships were grouped and classified into five water zones, designated I through V. The frontal region marks the merge of coastal water flowing through the Bransfield Strait and the Antarctic Circumpolar Current flowing through Drakes Passage. The water zones, defined by characteristic T/S curves (Figure 1.2), may consist of more than one water mass. Thus, Water Zone I is the oceanic water of the Drake Passage and is defined by the following characteristics: warm, low salinity surface water; strong sub-surface temperature minimum (called "Winter Water" at approximately –1°C and salinity of 34.0ppt.); and a distinct T/S maximum near 500m (called "Circumpolar Deep Water" or CDW). In the Bransfield Strait, Water Zone IV is found with bottom waters around –1°C, and subsurface extremes that are far less prominent. In between, there are transition zones where adjacent water zones mix. The water zones were operationally defined as:

	T/S Relationship		
	Left	**Middle**	**Right**
Water Zone I (ACW)	**Pronounced V shape with V at ≤0°C**		
Warm, low salinity water, with a strong subsurface temperature minimum, Winter Water, approximately -1°C, 34.0ppt salinity) and a temperature maximum at the core of the CDW near 500m.	2 to >3°C at 33.7 to 34.1ppt	≤0°C at 33.3 to 34.0ppt	1 to 2°C at 34.4 to 34.7ppt (generally >34.6ppt)
Water Zone II (Transition)	**Broader U-shape**		

Water with a temperature minimum near 0°C, isopycnal mixing below the temperature minimum and CDW evident at some locations.	1.5 to >2°C at 33.7 to 34.2ppt	-0.5 to 1°C at 34.0 to 34.5ppt (generally >0°C)	0.8 to 2°C at 34.6 to 34.7ppt
Water Zone III (Transition)	**Backwards broad J-shape**		
Water with little evidence of a temperature minimum, mixing with Type 2 transition water, no CDW and temperature at depth generally >0°C	1 to >2°C at 33.7 to 34.0ppt	-0.5 to 0.5°C at 34.3 to 34.4ppt (note narrow salinity range)	≤1°C at 34.7ppt
Water Zone IV (Bransfield Strait)	**Elongated S-shape**		
Water with deep temperature near -1°C, salinity 34.5ppt, cooler surface temperatures.	1.5 to >2°C at 33.7 to 34.2ppt	-0.5 to 0.5 °C at 34.3 to 34.45ppt (T/S curve may terminate here)	<0°C at 34.5ppt (salinity < 34.6ppt)
Water Zone V (Weddell Sea)	**Small fish-hook shape**		
Water with little vertical structure and cold surface temperatures near or < 0°C.	1°C (+/- some) at 34.1 to 34.4ppt	-0.5 to 0.5°C at 34.5ppt	<0°C at 34.6ppt

The frontal region was narrow and distinct north of Livingston and King George Islands, broader between King George and Elephant Islands, and extended to the northern edge of the survey grid north of Clarence Island (Figure 1.3). This is consistent with observations on previous AMLR surveys. Water Zone I, indicative of the Antarctic Circumpolar Current, was mapped to the north of the frontal region and extended as far east as 54.4 W, where the frontal region appeared to be curved to the north and west thus enclosing a tongue of Water Zone I. This is more evident on the February 2000 SeaWiFS imagery (Figure 2.5, phytoplankton section) where a tongue of blue (low chlorophyll) water extends across the northern side of the South Shetland Islands as far east as Elephant Island, and is enclosed by an area of green and yellow (higher chlorophyll) water further to the east and north. Because the prevailing flow direction is southwest to northeast, it is hypothesized that the area of higher chlorophyll was entrained in a counter-clockwise eddy north of Elephant Island, and that this eddy was sustained by northward flow of eastern Bransfield Strait water (Water Zone IV) between Elephant and Clarence Islands and by northward flow of Weddell Sea water (Water Zone V) east of Clarence Island.

Cross sections of temperature and salinity also describe the location and intensity of the frontal region (Figure 1.4). Winter water, with a core at approximately 100m depth, and CDW, with a core at approximately 400m depth, are also apparent in the cross-sections. Maps of temperature at 100m depth and 400m depth indicate that cold Winter Water was most evident north of Livingston and King George Islands, and that the southern edge of warmer CDW diverged offshore north of Elephant Island (Figure 1.5).

1.4 Disposition of Data: Data are available from David A. Demer, Southwest Fisheries Science Center, 8604 La Jolla Shores Drive, La Jolla, CA, 92037; phone/fax (858) 546-5603/(858) 546-5608; email: ddemer@ucsd.edu.

1.5 Acknowledgments: The assistance of Dave Benigni and Dennis Shields of NOAA's Marine and Aviation Operations is gratefully acknowledged. The high level of skill among the scientific support staff on the R/V *Yuzhmorgeologiya* allowed the deployment of the instruments in a variety of conditions without mishap.

1.6 References:

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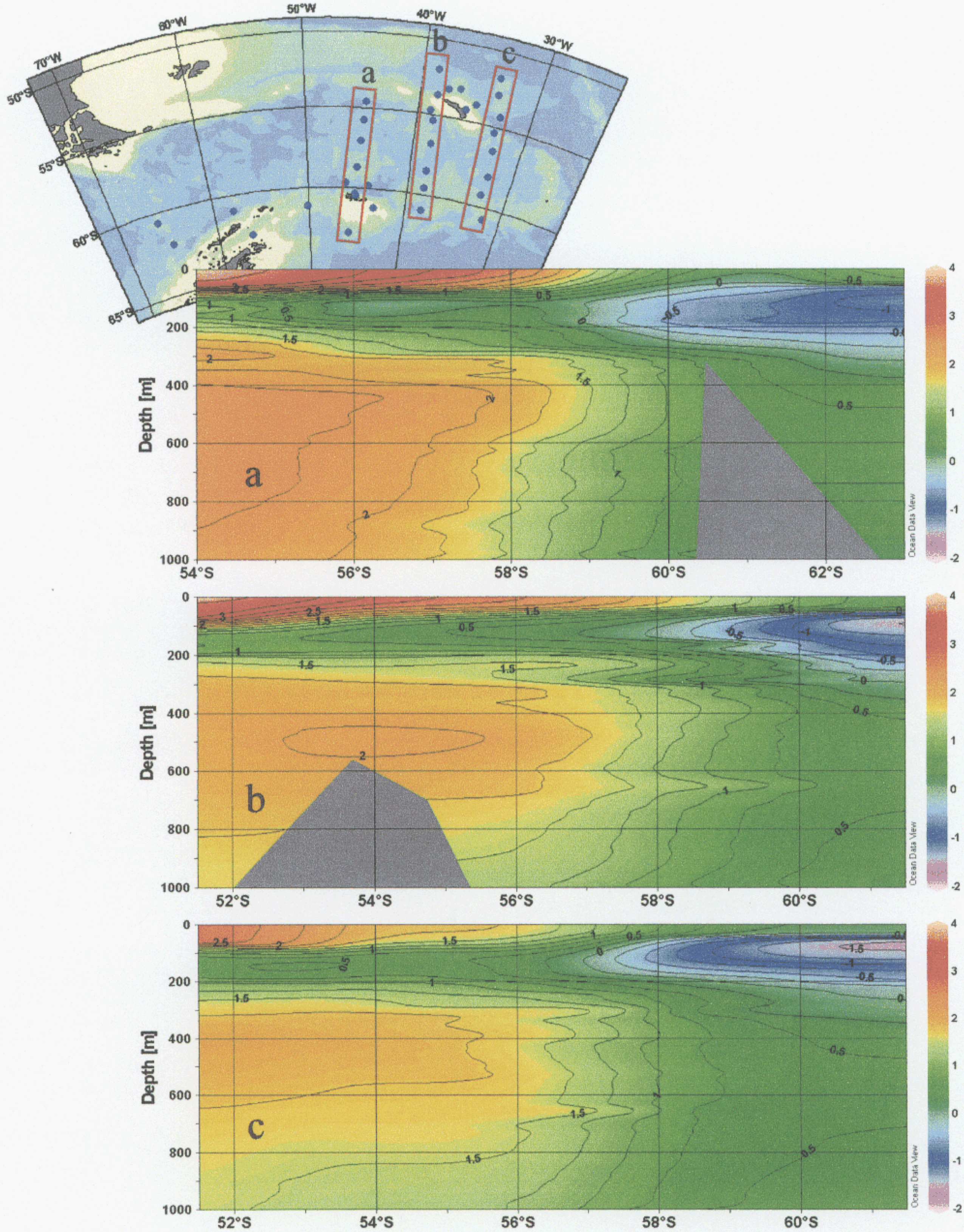

Figure 1.1 CCAMLR-2000 survey temperature cross-sections (Leg I).

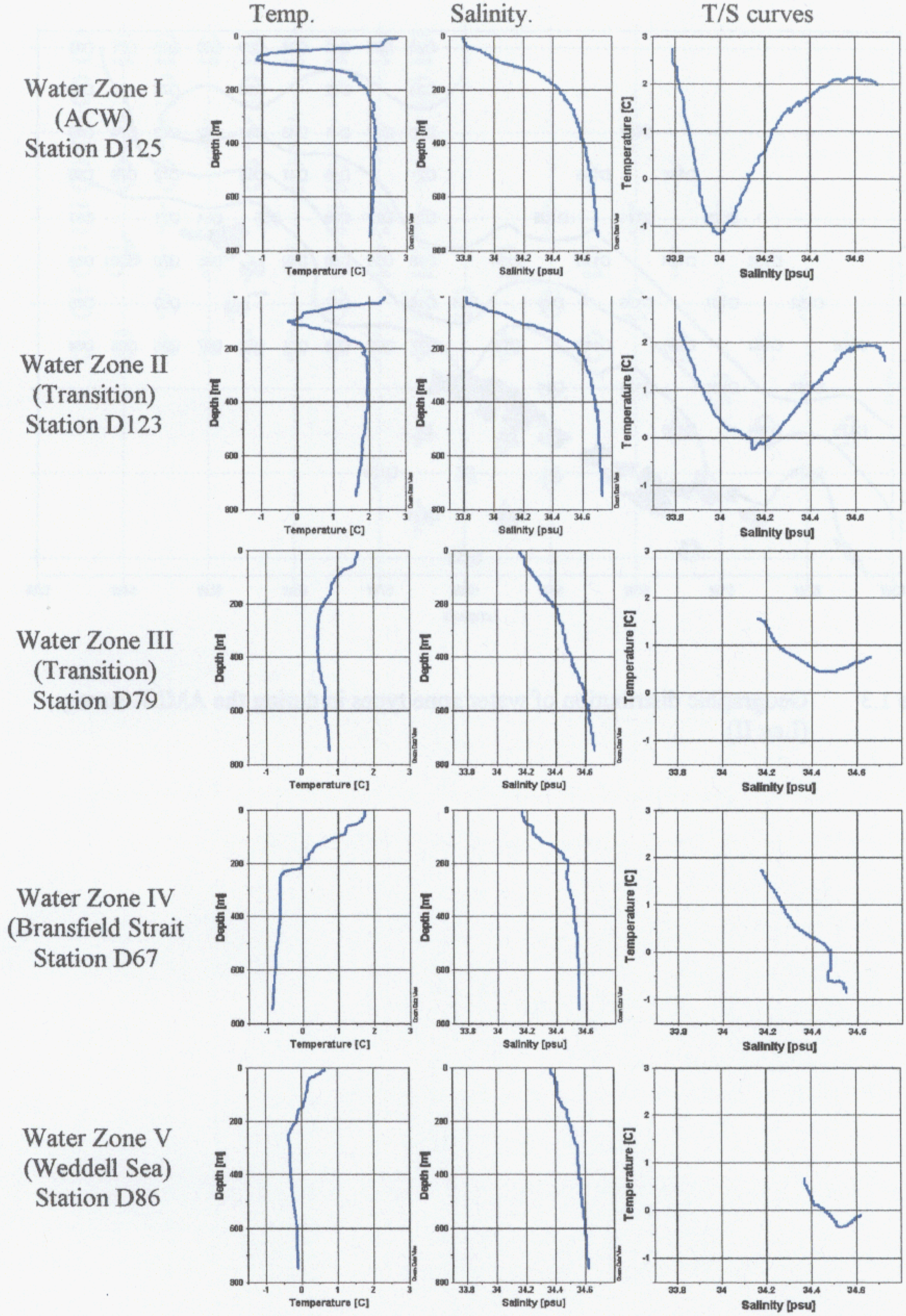

Figure 1.2 T/S curves for selected stations designated as Water Zones I through V during the AMLR survey (Leg II).

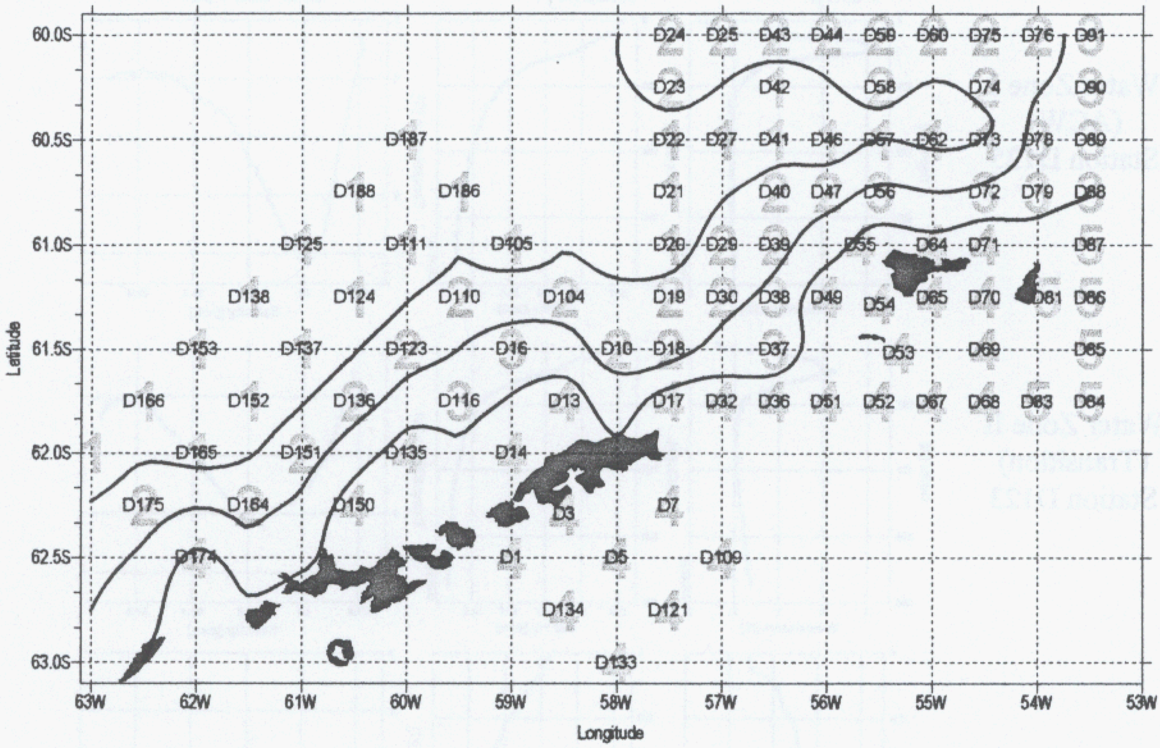

Figure 1.3 Geographic distribution of water zone types in during the AMLR survey (Leg II).

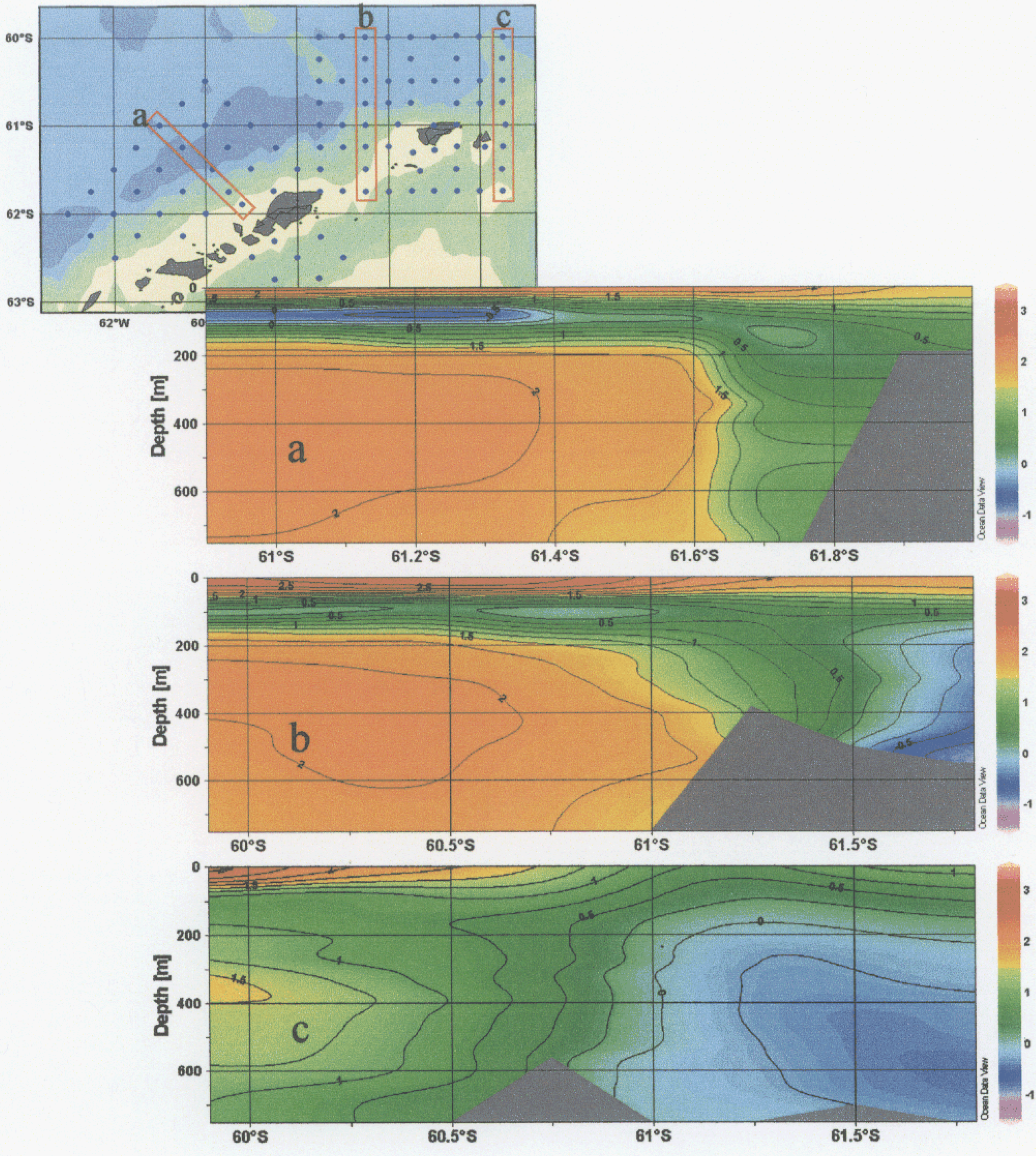

Figure 1.4 Selected temperature cross-sections during the AMLR survey (Leg II).

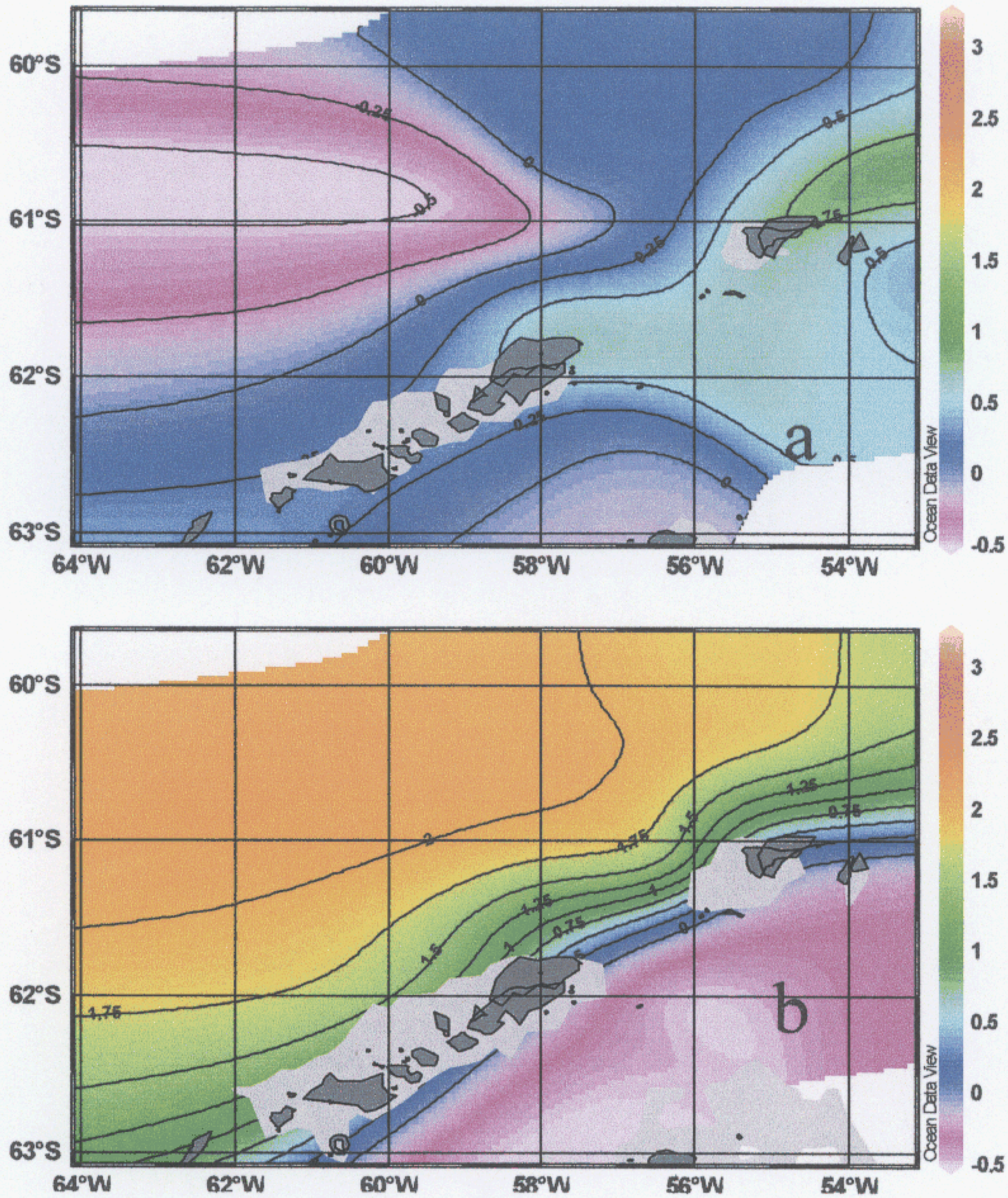

Figure 1.5 Temperature at 100m (a) and 500m (b) depths during the AMLR survey (Leg II).

2. Phytoplankton; submitted by Christopher D. Hewes (Leg II), Roger Hewitt (Leg I), John Wieland (Leg II), B. Greg Mitchell (SIO) and Osmund Holm-Hansen (SIO).

2.1 Objectives: The overall objective of our research project was to assess the distribution and concentration of food reservoirs available to the herbivorous zooplankton populations throughout the AMLR study area during the austral summer. Specific objectives of our work included: (1) to determine the distribution and biomass of phytoplankton in the upper water column (surface to 750m), with emphasis on the upper 100m; (2) to measure pigment-specific absorption by total particulates, detritus and phytoplankton; (3) to measure the spectral attenuation of light with depth (4) to coordinate these activities with SeaWiFS satellite pass overs; (5) to calibrate satellite imagery of spectral reflectance to surface chlorophyll concentrations.

2.2 Methods and Accomplishments: The major types of data acquired during these studies are listed below, together with an explanation of the methodology employed.

(A) Sampling Strategy:

Protocols are to obtain water samples for analyses or to acquire data from various sensors are described below: (1) During Leg I, water samples were obtained from 10-liter Niskin bottles (with Teflon covered springs) which were closed at four standard depths (5, 30, 100, and 150m) from every upcast of the CTD/rosette unit. During Leg II, 5m samples were obtained from 10-liter Niskin bottles at all stations except for three stations in the Bransfield Strait where 9 depths (5, 10, 20, 30, 40, 50, 75, 100, and 150m) were sampled. Leg I occupied 41 stations and Leg II occupied 98 stations. These water samples were used for measurements described below. (2) During Leg II, two transmissometers (488 and 660nm wavelengths) were used to determine the attenuation of collimated light (by both scattering and absorption) during CTD-casts. The methodologies employed in our studies are described below. (3) For both legs, SeaWiFS satellite images were processed for monthly averaged chlorophyll concentration.

(B) Measurements and Data Acquired:

(1) Chlorophyll-*a* concentrations: Chl-*a* concentrations in the water samples (5, 30, 100, 150m Leg I; 5m Leg II except for three stations where profiles were obtained) from the Niskin bottles at every CTD station were determined by measurement of chl-*a* fluorescence after extraction in an organic solvent. Sample volumes of 100 - 250ml were filtered through glass fiber filters (Whatman GF/F, 25mm) at reduced pressure (maximal differential pressure of 1/3rd atmosphere). The filters with the particulate material were placed in 10ml of either 90% acetone (Leg I) or absolute methanol (Legs I and II) in 15ml tubes and the photosynthetic pigments allowed to extract at 4°C for at least 12 hours. The samples were then shaken, centrifuged, and the clear supernatant poured into cuvettes (13 x 100mm) for measurement of chl-*a* fluorescence before and after addition of two drops of 1.0 N HCl. Fluorescence was measured using two Turner Designs Fluorometers (model #10-005R for Leg I and model #700) both having been calibrated using spectrophotometrically determined chl-*a* concentrations of a prepared standard (Sigma). Stability of the fluorometers was verified daily by use of a fluorescence standard.

Furthermore, 5m samples were also filtered onto glass fiber filters, wrapped in aluminum foil, and placed in liquid nitrogen until Leg II, at which time extraction in methanol (MeOH) and analysis using the Turner Designs #700 was done. This allowed the different methods used for each leg to be compared.

(2) For 31 stations during Leg II, discrete samples were obtained between 1000 and 1600 GMT (corresponding with the SeaWiFS satellite pass over) for pigment analyses. Although water bottle samples obtained at 5m depth were the standard protocol, at 3 stations it was possible to obtain an additional 7 different depths (10, 20, 30, 40, 50, 75, 100m). For each analysis, except where noted 1-2 liters were filtered on 25mm Whatman GF/F filters.

- Particulate Absorption (a_p) and Soluble Absorption (a_s). Spectral absorption coefficients of particulate and soluble material were performed on a CARY 100 dual beam spectrophotometer.

- High Pressure Liquid Chromatography (HPLC). HPLC will be used for the analysis of (1) various chlorophylls and associated pigments, and (2) Microsporine-like Amino Acids (MAAs). Samples were frozen and stored in liquid nitrogen until their analyses can be made at SIO. Chlorophyll and associated pigments will be used to determine the proportions of algal classes contained in the phytoplankton community. MAAs absorb ultraviolet-B radiation and are thought to protect phytoplankton against photo-oxidative damage by UV damage to the photosystem.

- Particulate Organic Carbon and Nitrogen (POC/PON). Whatman GF/F filters used for sample preparation were combusted at 450°C prior to the cruise. Samples were frozen and will be analyzed by standard gas chromatography methods at the analytical facility at UC Santa Barbara.

- Phycoerythrins (PE). Cryptomonads are a common phytoflagellate in the AMLR study region and are distinguished from other phytoplankton in the area by PE. The filtered water samples were frozen and stored in liquid nitrogen until their analysis at SIO. PE will be measured using a Spex Fluoromax spectrofluorometer.

- Cell size spectrum. Two ml of water was frozen and stored in liquid nitrogen until analysis. A Coulter Epics flow-cytometer will be used to size cells and classify them in relation to chlorophyll and phycoerythrin fluorescence as well as forward light scatter.

(3) Measurement of beam attenuation: During Leg II, two single wavelength (488 and 660nm) C-star transmissometers (Wetlabs, Inc.) were placed on the Seabird Inc. CTD rosette for deployment at each station. Previous studies have shown that beam attenuation (660nm) coefficients can be used to estimate total particulate organic carbon in Antarctic waters (Villafañe *et al.*, 1993). This calculation assumes that there is a negligible load of inorganic sediment in the water, a condition that is apparently satisfied throughout the study area.

(4) Corresponding approximately in time with the SeaWiFS satellite pass over (26 stations), a Satlantic free-fall SeaWiFS Profiling Multispectral Radiometer (SPMR) was deployed. The SPMR measured spectral downwelling irradiance and upwelling radiance at 13 wavelengths continuously from the surface to the bottom of the profile. Profile depths ranged from 50-150 meters depending on the station. Spectral values of normalized water-leaving radiance will be computed from the SPMR data and used to validate SeaWiFS data, as well as to develop Southern Ocean regional ocean color algorithms.

(5) SeaWiFS chlorophyll images were obtained for 8-day and monthly average composites from NASA archives. These data will be sufficient to evaluate the time-dependence and distribution of chl-*a* within our study region.

2.3 Results and Tentative Conclusions: An optical oceanography component was incorporated to the program this year (funds from NASA to Dr. Greg Mitchell, SIO), providing satellite (SeaWiFS) images of surface chlorophyll distributions, as well as *in-situ* light spectra profiling during Leg II and spectrophotometry of pigments.

(A) Although different methods for chlorophyll analysis were done for each Leg, the two yielded similar results (Figure 2.1). Phytoplankton biomass at 5m depth during Leg I averaged 1.17 ± 1.19 mg chl-*a* m^{-3}, and Leg II chl-*a* concentrations averaged 1.4 ± 1.1 mg m^{-3}. During Leg I, chl-*a* concentrations were estimated from discrete water samples and integrated over the upper 200m. Chl-*a* patterns followed hydrographic boundaries with highest values north of Southern Antarctic Circumpolar Current Front (SACCF). Lower values were observed to the south of the SACCF, increasing toward the southern boundary of the Antarctic Circumpolar Current. Integrated chl-*a* values were highest along the middle and northern portions of Transects SS05 and SS08 and lowest in the vicinity of the South Orkney Islands. During Leg II, the west section mean 5m chl-*a* was 0.95 ± 1.15 mg m^{-3}. This is higher than found for the mean of the same area in 1999, then having 0.6 ± 0.7 mg m^{-3}. Highest chl-*a* concentrations (3.0 - 4.7 mg m^{-3}) were found at the near coastal stations along King George Island, while lowest concentrations were found in the northern region of the survey (Type I waters, averaging 0.2 mg m^{-3}). Phytoplankton biomass measured for 5m samples in the Elephant Island area was 1.50 ± 1.07 mg chl-*a* m^{-3} (58 stations). These values compare to 1.64 ± 1.50 mg chl-*a* m^{-3} from Leg II of last year, and to the mean (1990-1999) February 5m values of 1.06 ± 1.23 mg chl-*a* m^{-3}. Therefore, although not the richest year observed, February 2000 had an above average phytoplankton crop in the Elephant Island sector. The highest value observed was 4.1 mg chl-*a* m^{-3} at Station A065 (just south of Elephant Island).

(B) Chl-*a* concentrations in the upper water column differ in various regions of the sampling grid as described in past reports. Since chl-*a* profiles were not possible at all stations this year, we can only present transmissometer data (Figure 2.3). Previously, stations with the lowest surface chl-*a* concentrations generally had a deep chl-*a* maximum at approximately 80m depth and are found in Drake Passage waters (e.g., Zone 1A water). Stations in the other water zones generally have higher chl-*a* values in the upper 20-30m of the water column, and no deep chl-*a* maximum. For the Drake Passage waters (Figure 2.3A), a small bulge in the C_t at the temperature minimum (arrow 1) corresponds with where the chl-*a* maximum is usually found. A maximum C_t was recorded near the base of the upper mixed layer (arrow 2). This maximum C_t was also observed at Station D104 (Figure 2.3B), and was a blend of Drake Passage and Bransfield Strait waters (e.g., Zone 1B water). Bransfield Strait water (Figure 2.3C) demonstrates a C_t profile that is more typical for a chlorophyll concentration profile for this type of water.

(C) Spectrophotometric particulate absorption data were obtained at 31 stations, and spectrophotometry of MeOH and acetone extracts done at 14 stations. Spectra from station 91 are shown in Figure 2.2. The UV-B absorbing mycosporine-like-amino acids (MAA) compounds were present as indicated by the peak in the spectrum below 350nm. Acetone absorbs wavelengths around this region (arrow in Figure 2.2) and therefore is not appropriate for the analysis of MAA compounds.

(D) Too few data were obtained during Leg I to obtain a good description of the horizontal 5m chlorophyll distribution. The horizontal distribution for Leg II is shown in Figure 2.4A. This compares well to the medium resolution SeaWiFS monthly composite of surface chl-*a* in the region (Figure 2.4B). During Leg II, phytoplankton biomass measured for 5m samples in the Elephant Island area was 1.50 +/- 1.07 mg chl-*a* m^{-3} (58 stations). For the same region, SeaWiFS monthly composite gave an estimate (using the SeaWiFS algorithm) of only 0.6 mg chl-*a* m^{-3}. Bio-optical algorithms for either ocean color remote sensing or diffuse attenuation coefficients are different in temperate and polar regions (Mitchell and Holm-Hansen, 1991; Mitchell, 1992; Arrigo *et al.*, 1998). For US JGOFS data, Moore *et al.*, (1999) have shown that SeaWiFS underpredicts chl-*a* by about 30% compared to *in situ* estimates. Previously, we hypothesized that pigment package effects and a relative lack of detrital and soluble absorption were responsible for the relationships found for the Antarctic Peninsula region (Mitchell and Holm-Hansen, 1991; Mitchell, 1992). It is important to extend our regional understanding of these algorithms and to assess their implications for remote sensing of pigments, diffuse attenuation coefficients and application of optical-based models of primary production. In particular, no detailed optical measurements have been made in the AMLR survey region prior to this year. Bio-optical relationships and parameterizations will be used to improve applications of both ocean color satellite data and models of primary production in the AMLR survey region.

(E) Monthly composite chlorophyll distributions from SeaWiFS images for January and February of the region covered during the synoptic survey (Leg I) are shown as Figure 2.5. A belt of blue water (Water Zone 1A) lies between South America and the Antarctic Peninsula, and high chlorophyll concentrations appear to reach from the Bransfield Strait region to South Georgia. For the Leg I survey area, highest chlorophyll concentrations were indicated along the western shore of South Georgia (note the bloom development during February). High chlorophyll concentrations are also indicated on the southern shores of the South Orkney Islands during January. In this regard, it appears that the two stations south of South Orkney Islands (Leg I) missed this bloom. The greatest density of surface chlorophyll for the Antarctic Peninsular region occurred on the Weddell Sea side, and is probably an ice-edge related bloom.

(F) One of the key parameters obtainable from satellite measurements is the spectral reflectance, or ocean color, which contains information about optically significant constituents of seawater. The AMLR survey region is a complex system with significant internal gradients in forcing and biogeochemical properties. There remains a critical need to generalize bio-optical properties for bio-geographic provinces of this region and their relation to photosynthesis, biomass, carbon and production.

(G) Apparent optical properties of water including the diffuse attenuation coefficient (K) that specifies the rate of light attenuation of the ocean and the reflectance (R) which is the "ocean color" depend on inherent optical properties (absorption and scattering) of the medium. Water may contain variable amounts of particulates or soluble material, which affect inherent and apparent optical properties (Morel and Prieur, 1977; Smith and Baker, 1978; Morel, 1988; Mitchell and Holm-Hansen, 1991; Arrigo *et al.*, 1998). R and K have been shown to correlate well with the phytoplankton pigments biomass (e.g. chl-*a*) because absorption by pigments dominates variability in these properties. Significant correlations have been reported between POC and the particulate beam attenuation in the AMLR region (Villafañe *et al.*, 1993), the northeast Atlantic Ocean (Marra, 1995) and the Pacific Ocean (Bishop, 1999). This good correlation will allow us to interpret beam attenuation data in terms of POC distributions and in relation to physical mixing.

2.4 Disposition of the Samples and Data: All data obtained during the cruises have been stored on CD-ROM. After compilation of the final data sets, a copy of all data will be deposited with the AERG office in La Jolla, CA. Copies of any of our data sets are available to all other AMLR investigators upon request.

2.5 Problems and Suggestions: There were several serious shortcomings this year in regard to facilities and equipment needed on the ship to satisfactorily carry out phytoplankton studies for the AMLR program. Lack of funding greatly restricted both the personnel required on board ship to process samples (previous years we have had four compared to only two persons this year) and restricted the number of analyses that could be accomplished. This year, an optical oceanography program required to develop satellite ocean color algorithms in the AMLR region was initiated. Although much data were collected, it is not known how much will be processed due to lack of funds. In this report, we demonstrate the potential usefulness of synoptic satellite images to describe the large-scale distribution of phytoplankton in the AMLR region. As shown here, and published previously, Southern Ocean regional ocean color algorithms are essential for quantitative application of these satellite data sets. This requires a significant *in situ* phytoplankton and bio-optics effort to provide critical data.

2.6 Acknowledgements: We want to express our gratitude and appreciation to the entire complement of the R/V *Yuzhmorgeologiya* for their generous and valuable help during the entire cruise. They not only aided immeasurably in our ability to obtain the desired oceanographic data, but they also made the cruise most enjoyable and rewarding in many ways. We also thank all other AMLR personnel for help and support which was essential to the success of our program. This work was supported in part by NASA SIMBIOS Project awards to B. Greg Mitchell (NAS5-97130 and S-35780-G).

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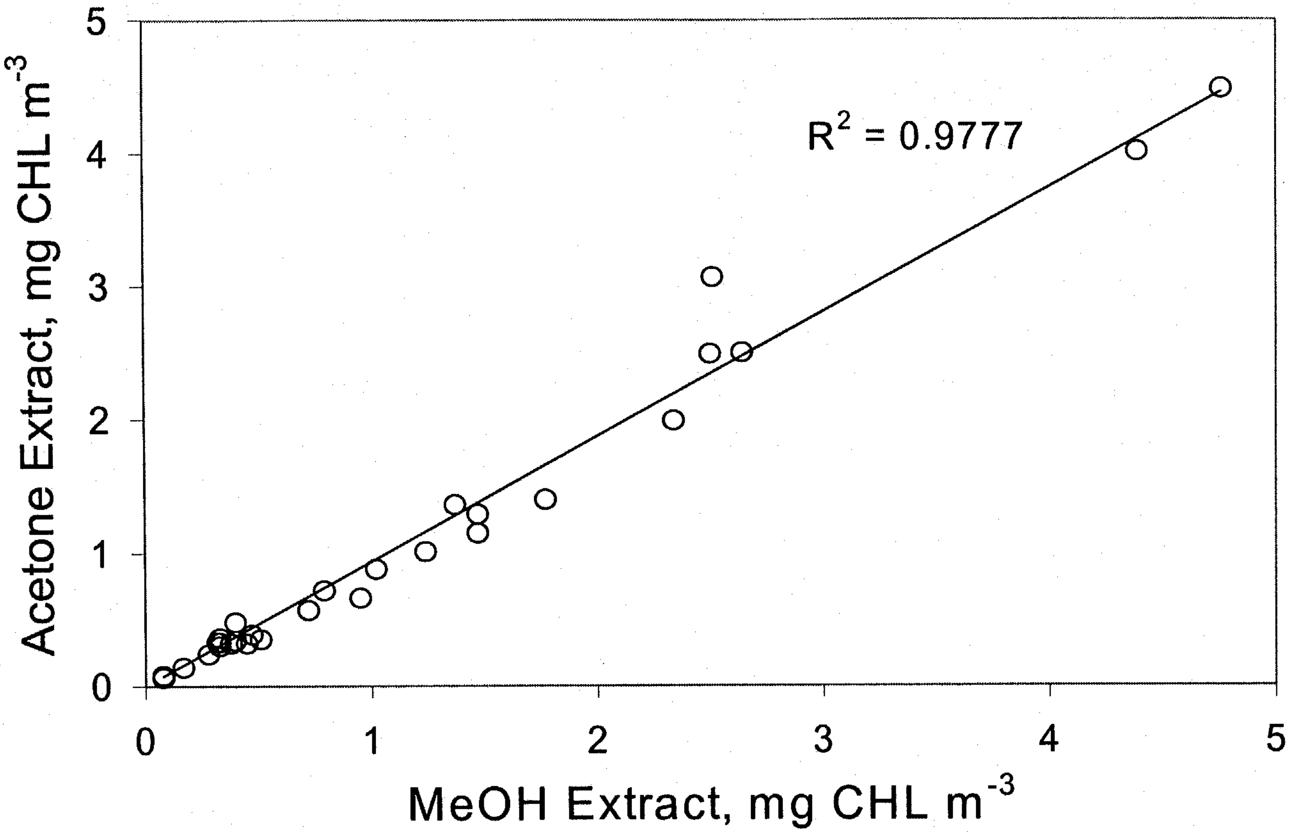


Figure 2.1 Comparison between estimates of chlorophyll concentrations using methanol (MeOH) and 90% acetone. Chl-*a* was extracted using acetone during Leg I, whereas MeOH was used during Leg II (and has been the solvent used for this in all previous years). Additionally, different fluorometers were used for chl-*a* analysis during each leg. Because of differences in methodologies, during Leg I samples for chl-*a* analysis were also frozen in liquid nitrogen until Leg II when MeOH extraction and analysis using the other fluorometer was possible. These data indicate that the two methods were comparable.

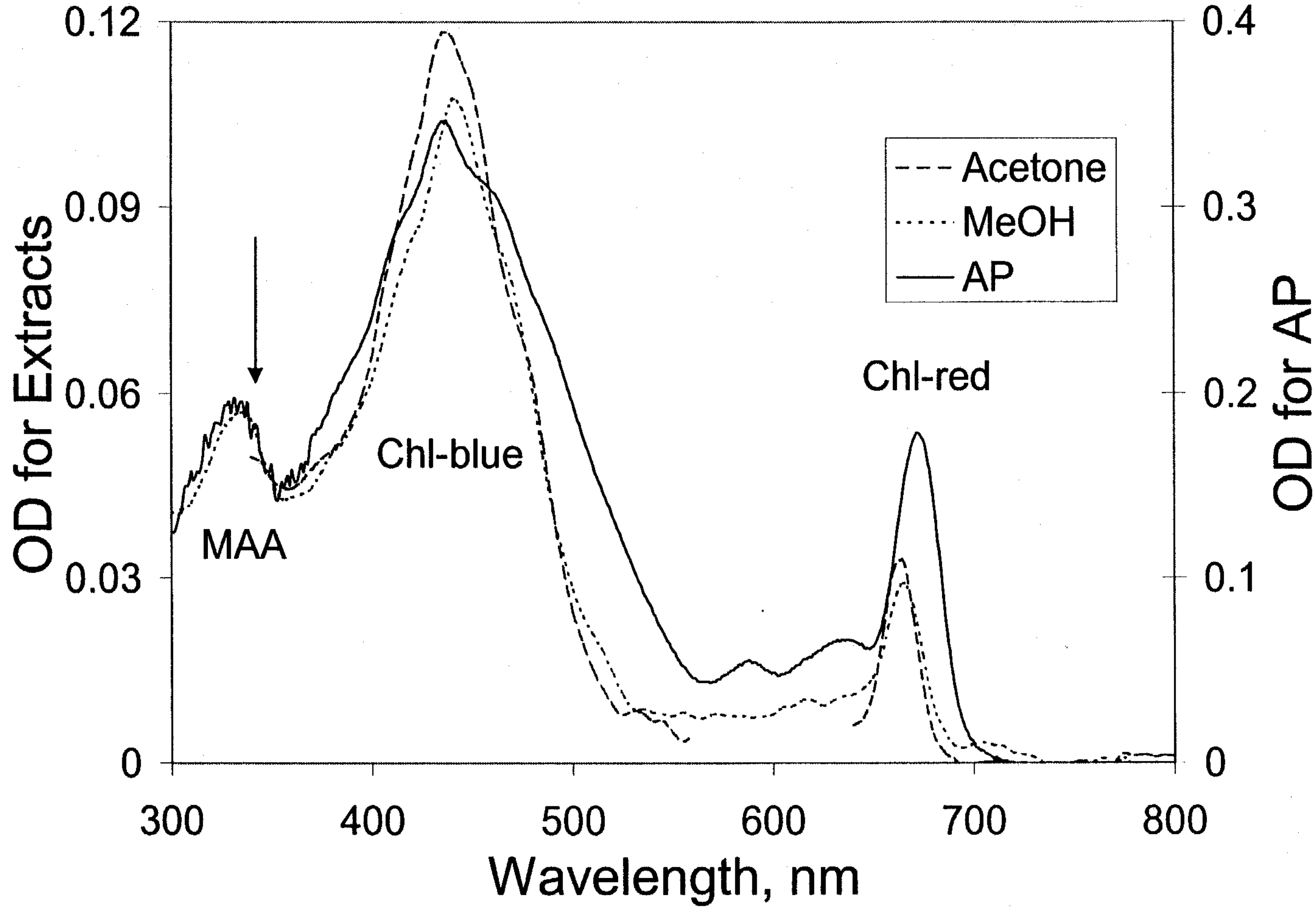
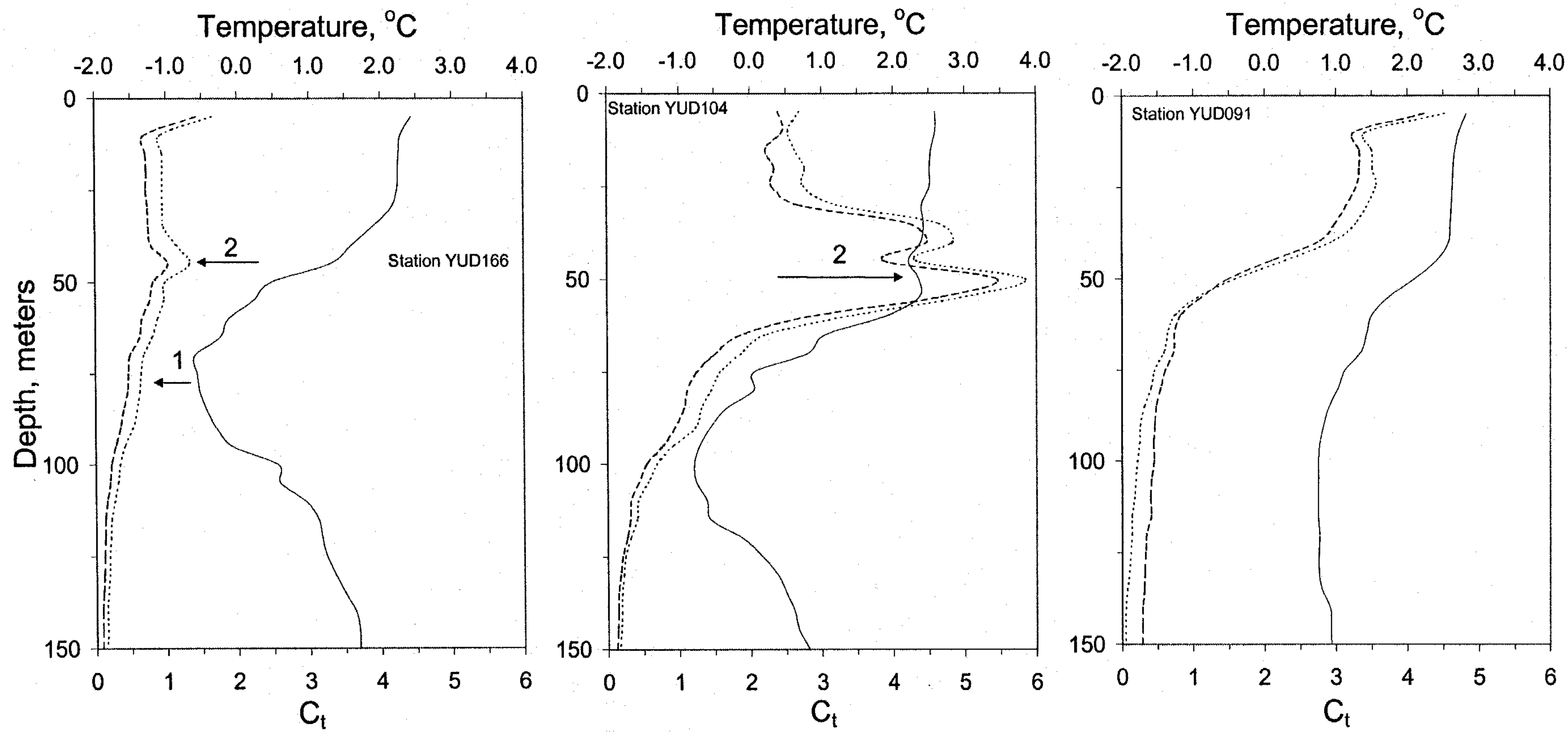


Figure 2.2 Absorption (optical density, OD) spectra for acetone and MeOH extracts and particulates (AP). Chlorophyll absorbs wavelengths in both red (Chl-red) and blue (Chl-blue) wavelengths, and corresponds with the wavelengths used for the two transmissometers (see Figure 2.3). The absorption spectra of UV-B protection MAA compounds is also indicated.



A) Drake Passage (Type 1A water)

B) Type 1B water

C) Bransfield Strait (Type 1C water)

Figure 2.3 Depth profiles for transmissometers (C_t) of 488nm (stippled line) and 660nm (dashed line) and temperature (solid line) from three stations during Leg II. A) Drake Passage (Type1A) water typically has a chl-*a* maximum and a temperature minimum at 75-100m (1), however transmissometer indicated a chl-*a* maximum at the bottom of the upper mixed layer (2). B) Type 1B water differs from 1A water by having a higher chl-*a* concentration in the upper mixed layer. Again, a C_t maximum (2) was observed at the base if the upper mixed layer. C) Bransfield Strait water showing a more classical profile of C_t in the upper mixed layer.

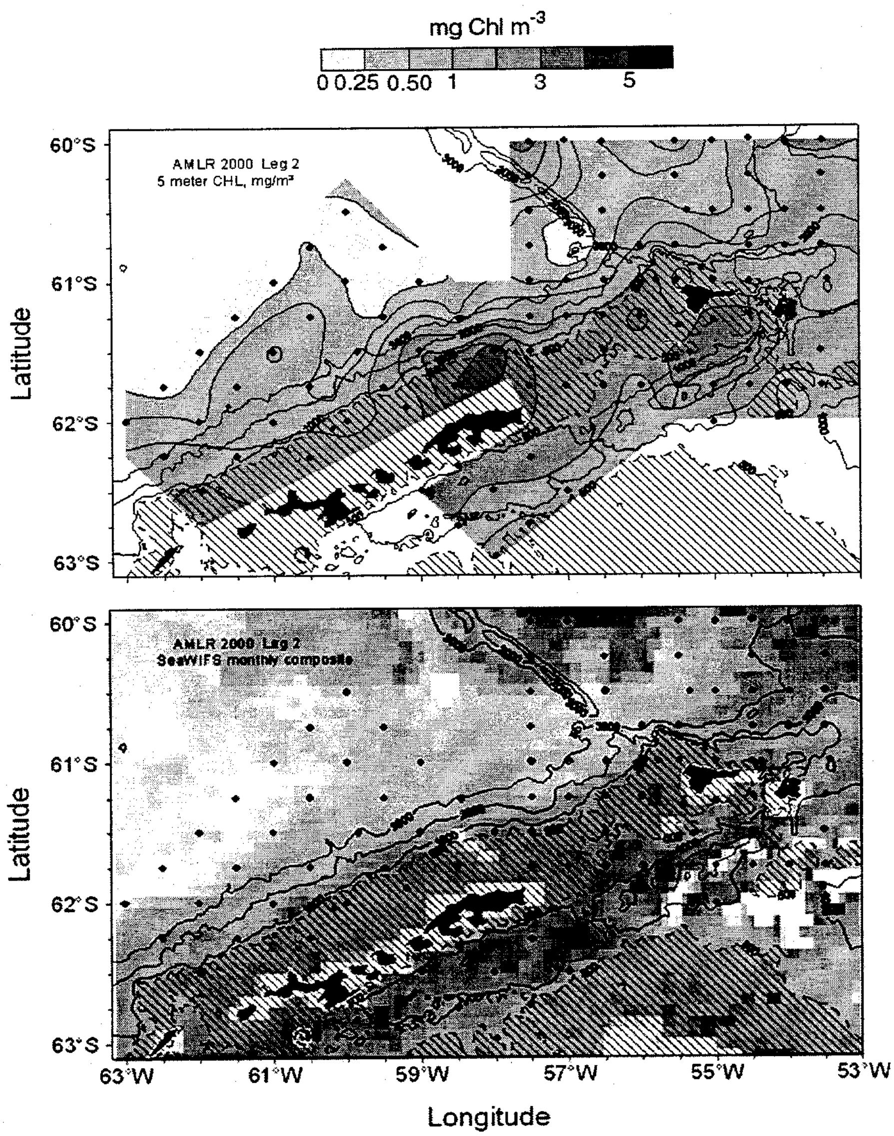


Figure 2.4 Distribution of surface chlorophyll in the AMLR survey area during Leg II. A) Top panel, concentrations estimated from extracted chl-*a* sampled by Niskin bottles at 5m depth. B) Bottom panel, surface concentrations estimated by SeaWiFS algorithms as a February monthly average. Chl-*a* estimated by SeaWiFS algorithm is considered an underestimate (Mitchell and Holm-Hansen, 1991; Moore *et al.*, 1999) therefore gray scaling has been adjusted (by eye) to correspond with the range of values from the extractions.

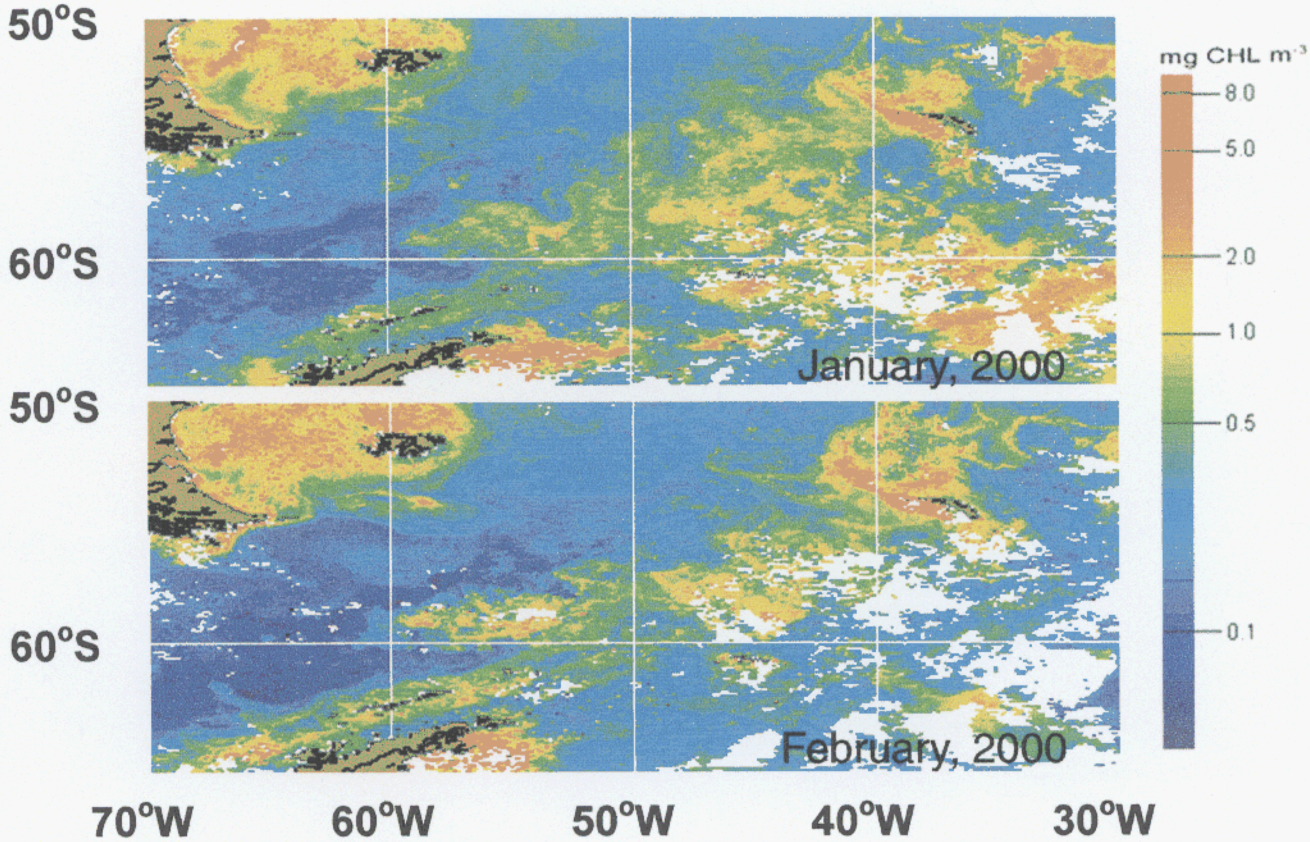


Figure 2.5 January (top panel) and February (bottom panel) of surface chl-*a* distributions (SeaWiFS algorithm) encompassing the area covered during Leg I. Highest chl-*a* (red) occurred on the Weddell Sea side of the Antarctic Peninsula and South Georgia, with moderate (yellow) concentrations spreading as a discontinuous band between them. The lowest concentrations (blue) were found in the Drake Passage between the Antarctic Peninsula and the tip of South America.

3. Bioacoustic survey; submitted by Jennifer H. Emery (Leg II), Roger P. Hewitt (Legs I and II), David A. Demer (Leg I) and Dale Roberts (Legs I and II).

3.1 Objectives: During Leg I a multinational effort sponsored by CCAMLR was undertaken to estimate the krill (*Euphausia superba*) standing stock in the Scotia Sea by conducting both large-scale and meso-scale acoustic surveys (see Report of the Bo workshop, SC-CAMLR-XIX, 2000, CCAMLR, Hobart, Australia). The primary objectives during Leg II were to map the meso-scale dispersion of krill in the vicinity of the South Shetland Islands; to estimate their biomass; and to determine their association with predator foraging patterns, water mass boundaries, spatial patterns of primary productivity, and bathymetry. In addition, efforts were made to map the distribution of myctophids and determine their relationship with water mass boundaries and zooplankton distribution.

3.2 Methods and Accomplishment: Acoustic data were collected using a multi-frequency echo sounder (Simrad EK500) configured with down-looking 38, 120, and 200 kilohertz (kHz) transducers mounted in the hull of the ship. System calibrations were conducted before and after the surveys using standard sphere techniques while the ship was at anchor in Stromness Bay, South Georgia and Admiralty Bay, King George Island. During the surveys, pulses were transmitted every 2 seconds at 1 kilowatt for 1 millisecond duration at 38kHz, 120kHz, and 200kHz. Geographic positions were logged every 60 seconds. Ethernet communications were maintained between the EK500 and two Windows NT workstations. Both Windows NT workstations were running SonarData EchoLog and EchoView software. One unit was used for primary system control, and data logging, processing and archiving while the other ran in parallel for back-up logging and archiving.

Leg I (CCAMLR Synoptic survey)

An acoustic survey of the Scotia Sea was conducted on Leg I. This survey was divided into two large-scale and two meso-scale areas (see Figure 2): (1) a 473,318 km^2 area north of the Antarctic Peninsula sampled with three northwest-southeast transects; (2) a 1,109,789 km^2 area of the Scotia Sea beginning north of South Georgia sampled with three north-south transects; (3) a 24,409 km^2 area north of the South Orkney Islands sampled with four north-south transect; and (4) a 25,000 km^2 area on the north side of South Georgia sampled with four north-south transects. It should be noted that the two large-scale surveys included a total of 19 transects (Antarctic Peninsula) and 10 transects (Scotia Sea) with the remaining transects completed by other CCAMLR participants (Report of Bo workshop, SC-CAMLR-XIX, 2000, CCAMLR, Hobart, Australia).

Leg II (Survey D)

An acoustic survey of the waters surrounding the South Shetland Islands was conducted on Leg II. This survey was divided into three areas (see Figure 4): (1) a 41,673 km^2 area centered on Elephant Island (Elephant Island Area) was sampled with nine north-south transects; (2) a 34,149 km^2 area along the north side of the southwestern portion of the South Shetland archipelago (West area) was sampled with seven transects oriented northwest-southeast; and (3) a 8,102 km^2 area south of King George Island in the Bransfield Strait (South area) was sampled with three transects oriented northwest-southwest.

Two methods of krill delineation for estimating biomass were use: (1) the visual classification method (Leg II) and (2) the two frequency method (Legs I and II). These methods were also used for myctophid delineation on Leg II.

Visual Classification Method

This method involved visual comparison of scattering layers at the three different frequencies.

Three main rules were applied for krill classification:

(1) Aggregations that were horizontally continuous and contained well-defined edges when above 250m were classified as krill.
(2) Continuous aggregations with less defined edges found below 250m during daylight hours were classified as krill if intensity was highest at 200kHz and lowest and 38kHz.
(3) At dawn and dusk, dense vertically continuous aggregations most intense at 200kHz and least intense at 38kHz were classified as krill.

A conservative approach was used to classify the structures of the aggregations as krill and, as such, a bias may exist toward underestimation of krill biomass density based on visual classification of this data.

Myctophid visual classification was based on the following rules:

(1) Aggregations that were equally or more intense at 38kHz than at 120kHz and 200kHz were classified as myctophids.
(2) Small, dense, and slightly vertically elongated swarms forming a horizontal chain of scatterers were classifies as myctophids.
(3) Continuous horizontally elongated scattering layers lacking well defined edges, with a cloud-like appearance were classified as myctophids if most intense or equally intense at 38kHz. These layers were usually much more dispersed than krill swarms.

Two Frequency Method

Past research has focused on the delineation of krill using a ΔMVBS (mean volume backscattering strength) window of 2-12dB, where ΔMVBS (dB) = MVBS 120kHz – MVBS 38kHz (Madureira *et al.*, 1993). However, recent studies have shown that the 2-12dB window omits a considerable amount of smaller krill (Watkins and Brierley, 2000). Therefore, it was decided during the CCAMLR Bo workshop that a range of 2-16dB would be more appropriate. This method was then employed for acoustic data from both Legs I and II.

Although this approach is more objective than the visual classification method, it is also more liberal because of the window range. Some bias may exist for slight overestimation of krill biomass density. The 2-16dB window allows smaller krill to be included in the analysis, but it may also allow the smaller euphausiid species to be included as well.

A window of –5 to 2dB was applied to the two frequency method for the purpose of delineating myctophids. This range was chosen based on observed differences in myctophid backscattering values between 38kHz and 120kHz. The results were compared with the visual classification of myctophids and found to be nearly identical.

Abundance Estimation and Map Generation

Backscattering values were averaged over 5m by 100s bins. Time varied gain (TVG) noise was subtracted from the echogram, and in the case of the two-frequency method, the ΔMVBS window was applied. TVG values were based on levels required to erase the rainbow effect plus 2dB. The remaining volume backscatter classified as krill or myctophids was integrated over depth (500 m) and averaged over 1852.0m (1 nautical mile) distance intervals. These data were processed using SonarData Echoview software.

Integrated krill 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, both expressed as a function of body length and summed over the sampled length frequency distribution for each survey (Hewitt and Demer, 1993):

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

Where

$$S_A = 4\pi (1852)^2 \int_0^{500} S_v \qquad (\text{m}^2/\text{n.mi.}^2)$$

And f_i = the relative frequency of krill of standard length l_i.

For each area in each survey, mean biomass density attributed to krill and its variance were calculated by assuming that the mean density along a single transect was an independent estimate of the mean density in the area (Jolly and Hampton, 1990).

No myctophid biomass estimates were made because of the lack of target strength data and length frequency distributions. The nautical area scattering coefficient (S_A) attributed to myctophids was integrated using SonarData EchoView software and then used to map their distribution.

3.3 Tentative Conclusions: During survey D, the highest concentration of krill was mapped east of Elephant Island between Elephant Island and Clarence Island (Figure 3.1). High concentrations of krill were also found northeast of King George Island/southwest of Elephant Island and along the shelf break north of the South Shetlands, with a high density pocket along the shelf northeast of King George Island. Krill scattering layers were typically found between 50m and 250m. Similarities and differences in krill density estimates between the two methods can be observed both visually and numerically (Figure 3.1, Table 3.2) Visual comparison of echograms indicated that these differences may be attributed to the inclusion of smaller euphausiid species by the two frequency method, or the exclusion of smaller, more dispersed, *E. superba* by the visual classification method. However, no small *E. superba* were collected in the net samples. The two-frequency window was thus set at 2 to 12db. In spite of this change, the results were consistent with the previous two-frequency analysis.

Mean krill biomass densities within the eight years of the AMLR surveys were highest in 1997 and lowest in 1999. The 2000 survey results indicate a slight increase in krill density since 1999 (Table 3.1) and a model of the variability of acoustic estimates of krill in the Elephant Island area predicts increasing krill density in 2001 (Figure 3.4, Hewitt and Demer, in press).

Scatterers attributed to myctophids were found seaward of the shelf break. Areas of highest myctophid backscattering volume were mapped northeast of Elephant Island, northwest of King George Island, northwest of Livingston Island, and due north of the eastern edge of King George Island (Figure 3.2). Myctophids were found predominantly at depths greater than 150m.

Myctophid aggregations of greatest volume backscattering were found on transect 6 of the West area and transect 7 of the Elephant Island area. Cross sectional representation of these scattering layers and sea water temperature indicates a relationship between the myctophids and the Circumpolar Deep Water (Figure 3.3). These aggregations are typically found between approximately 1.5 and 2.0 °C at the boundary between cold winter water and the deeper, but warmer, Circumpolar Deep Water.

There appeared to be little indication of krill/myctophid interaction. Few areas of overlap between the two occurred and where they did, krill were detected at more shallow depths than myctophids.

3.4 Disposition of Data: All integrated acoustic data will be made available to other U.S. AMLR investigators in ASCII format files. The analyzed echo-integration data consume approximately 10 Mbytes. The data are available from Jennifer H. Emery, Southwest Fisheries Science Center, 8604 La Jolla Shores Drive, La Jolla, CA 92037; phone/fax – (858) 546-5609/546-5608; e-mail: jhemery@ucsd.edu

3.5 References:

Hewitt, R.P. and D.A. Demer. 1993. *Mar. Ecol. Prog. Ser.* 99:29-39.
Hewitt, R.P. and D.A. Demer. In press. *U.S. Antarctic Jour.*
Jolly, G.M. and I. Hampton. 1990. *Can. J. Fish Aquat. Sci.* 47:1282-1291.
Madureira, L.S.P., P. Ward, and A. Atkinson. 1993. *Mar. Ecol. Prog. Ser.* 99:17-24.
Watkins, J.L. and A.S. Brierley. 2000. *ICES J. Mar. Research*: (in press).

Survey	Area	Mean Density (g/m^2)	Area (km^2)	Biomass (10^3 tons)	CV %
1992 A (late January)	Elephant Island	61.20	36,271	2,220	15.8
D (early March)	Elephant Island	29.63	36,271	1,075	9.2
1994 A (late January)	Elephant Island	9.63	41,673	401	10.7
D (early March)	Elephant Island	7.74	41,673	323	22.2
1995 A (late January)	Elephant Island	27.84	41,673	1,160	12.0
D (early March)	Elephant Island	35.52	41,673	1,480	24.2
1996 A (late January)	Elephant Island	80.82	41,673	3,368	11.4
D (early March)	Elephant Island	70.10	41,673	2,921	22.7
1997 A (late January)	Elephant Island	100.47	41,673	4,187	21.8
1998 A (late January)	Elephant Island	82.26	41,673	3,428	13.6
	West	78.88	34,149	2,694	9.9
	South	40.99	8,102	332	16.3
D (late February)	Elephant Island	47.11	41,673	1,963	14.7
	West	73.32	34,149	2,504	16.6
	South	47.93	8,102	388	12.2
1999 A (late January)	Elephant Island	23.72	41,673	988	20.3
	West	27.13	34,149	927	28.7
	South	19.68	8,102	159	9.4
D (late February)	Elephant Island	15.37	41,673	641	26.0
	West	11.85	34,149	405	30.0
	South	N/A	8,102	N/A	N/A
2000 D (late February)	West	37.54*	34,149	1,282	14.1
	Elephant Island	36.19*	41,673	1,508	21.1
	South	22.75*	8,102	184	29.2

Table 3.1 Mean krill biomass density for surveys conducted from 1992 to 2000. Coefficients of variation (CV) are calculated by the methods described in Jolly and Hampton, 1990, and describe measurement imprecision due to the survey design. 1993 estimates were omitted due to system calibration uncertainties; only one survey was conducted in 1997; 1999 south area values are not available due to lack of data. See Figure 1 in the Introduction Section for description of each survey.

*Data values are based on the two-frequency krill delineation method.

Elephant Island Area			
		visual	2-16dB window
	n	krill density	krill density
Transect 1	111	9.22	38.04
Transect 2	118	55.85	59.46
Transect 3	116	13.11	14.71
Transect 4	109	38.29	48.52
Transect 5	128	7.16	15.61
Transect 6	126	33.95	73.56
Transect 7	125	42.37	49.91
Transect 8	115	19.42	22.73
Transect 9	112	2.05	10.40

South Area			
		visual	2-16dB window
	n	krill density	krill density
Transect 1	20	0.34	1.51
Transect 2	44	30.53	31.06
Transect 3	40	26.28	24.21

West Area			
		visual	2-16dB window
	n	krill density	krill density
Transect 1	41	52.09	71.07
Transect 2	40	33.72	32.21
Transect 3	66	30.09	38.33
Transect 4	71	37.86	40.60
Transect 5	73	28.70	32.73
Transect 6	89	28.73	44.77
Transect 7	99	7.47	20.13

Table 3.2 Krill density estimates by area and transect for Survey D, Leg II.

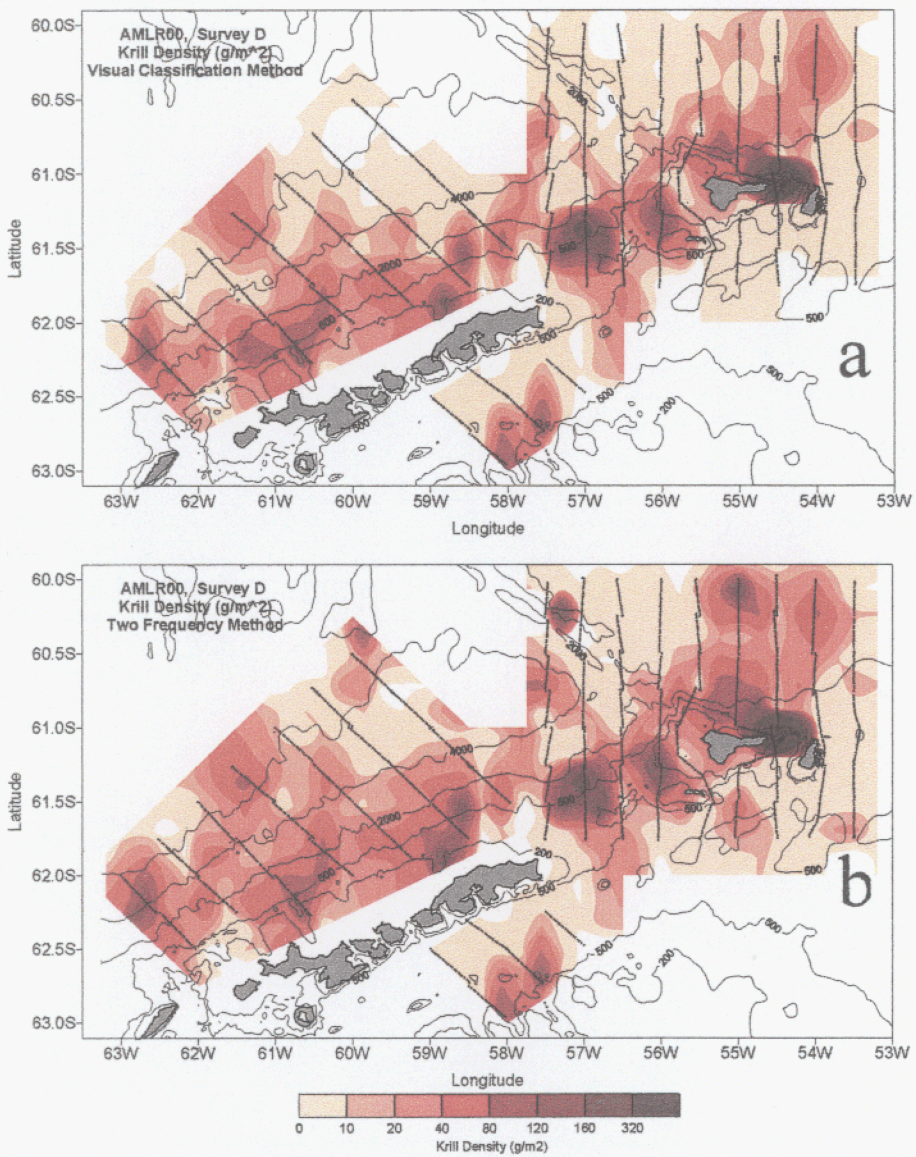


Figure 3.1 Mean krill density (g/m^2) for Survey D at 120 kHz as determined using the visual classification method (a) and the two-frequency method (b).

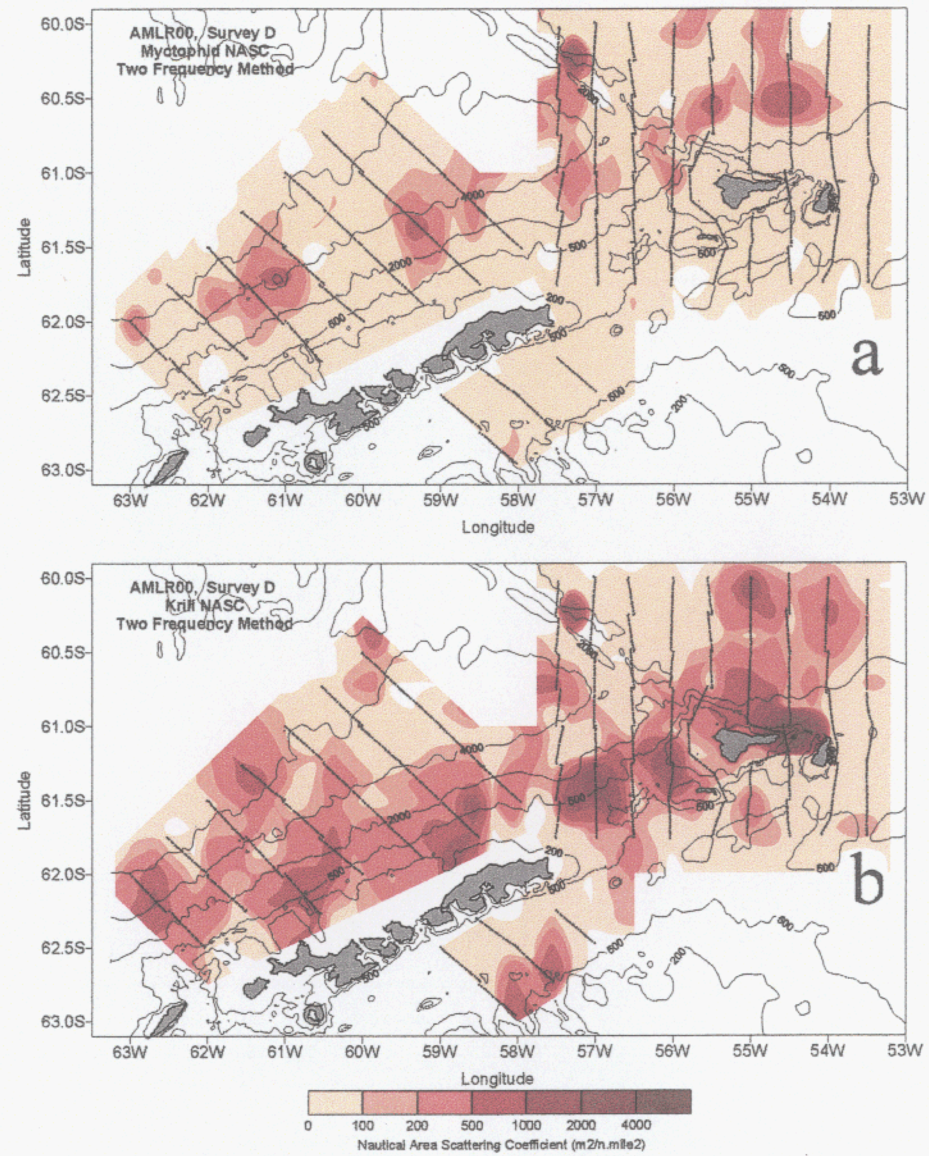


Figure 3.2 Integrated nautical area scattering coefficient (NASC, m^2/n.mile^2) for myctophids (a) and krill (b) at 120 kHz.

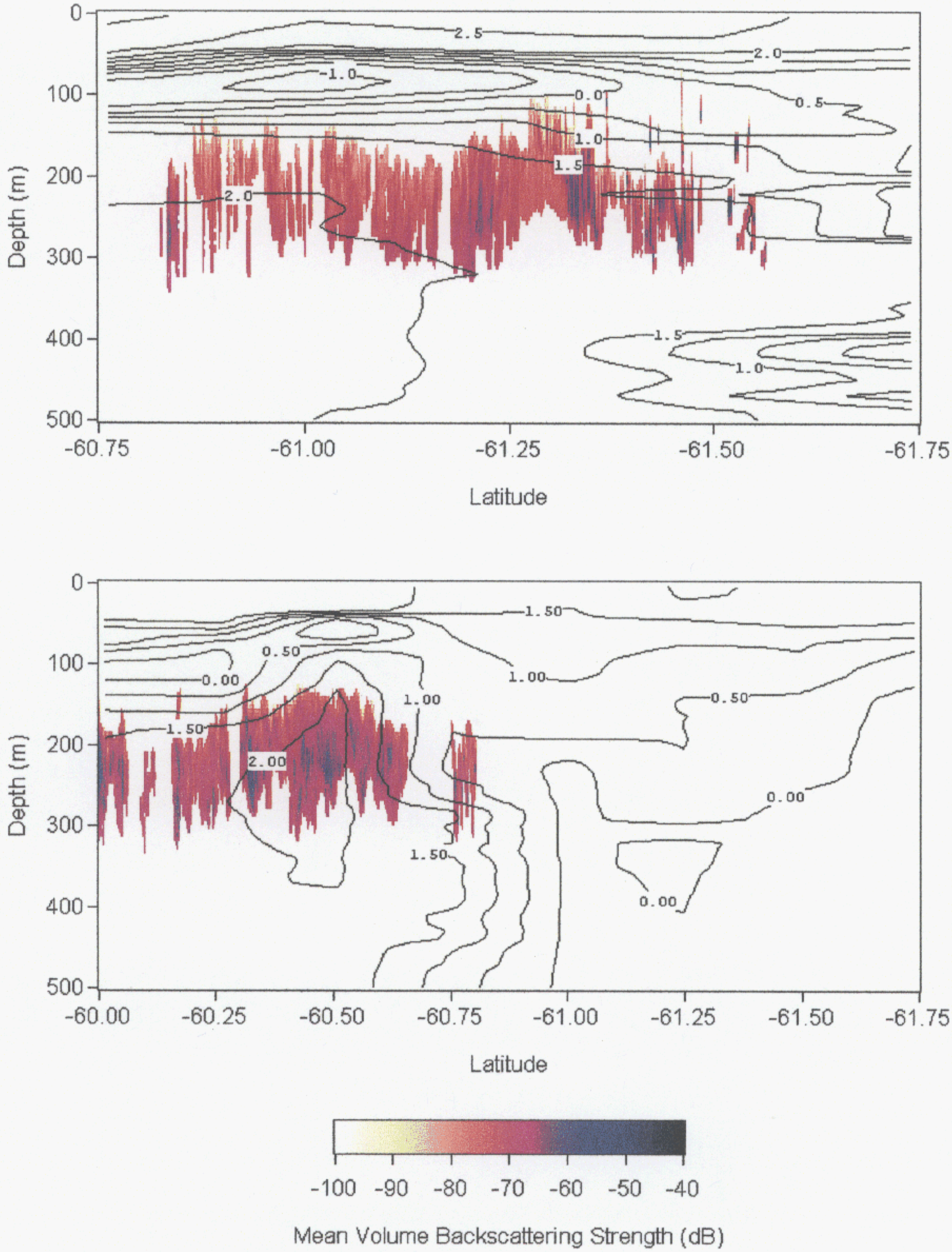


Figure 3.3 Integrated myctophid backscattering volume for Elephant Island area transect 7 (upper image) and West area transect 6 (lower image) and corresponding temperature.

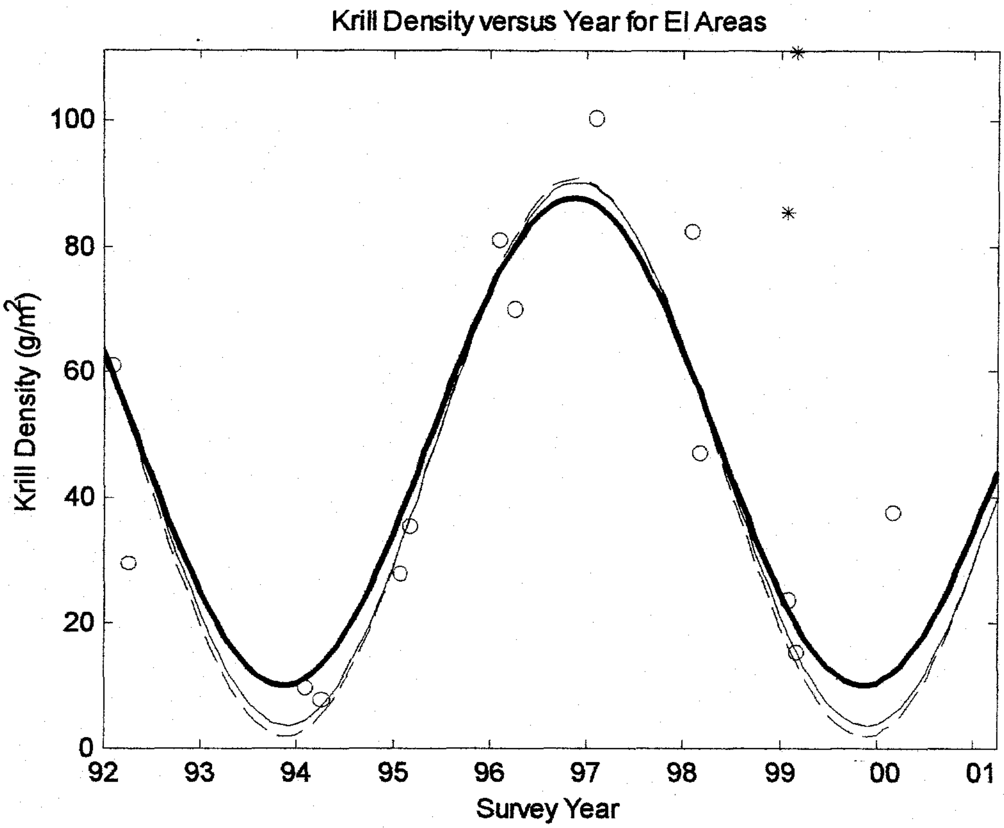


Figure 3.4 Times series of krill density in the Elephant Island area from austral summer 1991/92 to 1999/2000. The curves were fitted according to $\rho(t) = A + B\cos\left(\frac{2\pi t}{6yrs} + \phi_1\right)$ where t is time (years) and A is the mean values of the series and B and ϕ_1 are the amplitude (g/m^2) and the phase (radians) of the 6-year cyclical component. The thick solid line represents the curve fitted to the 1992-2000 data; the thin solid line represents the curve fitted to the 1992-1999 data; the dashed line represents the curve fitted to the 1992-1998 data. From 1992 to 1998, krill biomass estimates were obtained using total volume backscattering. For 1999, circles indicate krill biomass density estimates as determined by visual classification of krill and asterisks indicate krill biomass density estimates assuming all volume backscattering is from krill. For 2000, circles indicate krill biomass density estimates determined by the two-frequency method.

4. Net sampling: krill and zooplankton; submitted by Valerie Loeb (Legs I and II), Jenna Borberg (Legs I and II), Kimberly Dietrich (Leg II), Nancy Gong (Leg II), Adam Jenkins (Legs I and II), Pierre Malan (Leg I), Rob Rowley (Legs I and II) and Dorothee Stübing (Leg II).

4.1 Objectives: Here we provide information on the demographic structure of Antarctic krill (*Euphausia superba*) and the abundance and distribution of *Salpa thompsoni* and other zooplankton taxa sampled during the January-February 2000 field season. Three data sets are presented. These were derived from net samples collected during: (a) the CCAMLR 2000 krill stock assessment survey in the South Atlantic Sector of the Southern Ocean; (b) a limited survey area offshore of Cape Shirreff; and (c) the standard AMLR large-area survey in the Elephant-Livingston Island area.

Essential krill demographic information includes length, sex ratio, maturity stage composition, and reproductive condition. These data are used for determination of acoustic target identity and strength and to describe large-scale distribution patterns and regional recruitment indices. Information on krill demography obtained from the Cape Shirreff and AMLR surveys are also used in predator foraging studies. The salp *Salpa thompsoni*, receives special attention because of its hypothesized influence on the distribution, behavior and recruitment success of krill. Emphasis is also placed on copepods in the AMLR survey area as interannual variations in copepod abundance and species composition may reveal underlying hydrographic processes influencing the Antarctic Peninsula ecosystem.

Information derived from net samples taken at CTD/phytoplankton stations is useful for determining the relationships between krill and zooplankton distribution patterns and ambient environmental conditions. The CCAMLR 2000 sample data are to be combined with those from British, Japanese and Russian collaborators for an overall assessment of krill, salp and other zooplankton species abundance and distribution patterns relative to water mass influences and transport in the South Atlantic sector of the Southern Ocean. Results from AMLR 2000 Survey D are compared to results from 1992-1999 to assess between-year differences in krill demography and salp, copepod and other zooplankton composition and abundance.

4.2 Accomplishments:

CCAMLR Survey Samples.

Standard techniques established by the CCAMLR Working Group were adopted for this survey. Sampling was done with an opening-closing RMT8+1 (Rectangular Midwater Trawl; Baker *et al.*, 1973). This paired net system utilized an $8m^2$ net of 4.5mm mesh and a $1m^2$ net of 333µm mesh. The larger net was intended to more adequately sample krill and other active nektonic organisms, while the smaller net was intended to adequately sample small zooplankton such as copepods. A calibrated General Oceanics flowmeter was used to estimate filtered water volume; fishing depth was monitored using a real-time depth recorder. Two net tows were generally taken within a 24-hour period, one around local midnight and one around local noon. Sampling times were logged as GMT (+3 local time). Midnight tows were double oblique, fished between 0 and 200m (or within 10m of the bottom in shallower water). Due to the paucity of acoustic targets, most midday tows were also double oblique, 0-200m. However, when acoustic targets were present the nets were opened and closed at appropriate depths to sample them. Water volume filtered during those tows could not be estimated because the flowmeter was located above the net system. Tows were made at ship speeds of ca. 2kts. CCAMLR survey data are considered according to four regions: South Georgia (SG); South Shetlands (SS); South Orkney Islands (SOI); and Antarctic Peninsula (AP). Data from three north-south transects within the South Shetlands region (SS02, SS05 and SS08) are also considered separately.

AMLR Survey Samples.

Krill and zooplankton were obtained from a 6' Isaacs-Kidd Midwater Trawl (IKMT) fitted with a 505µm mesh plankton net. Flow volumes were measured using a calibrated flowmeter mounted on the frame in front of the net. All tows were fished obliquely from a depth of 170m or ca. 10m above bottom in shallower waters. Real time tow depths were derived from a depth recorder mounted on the trawl bridle. Tow speeds were ca. 2kts.

Samples were collected at Cape Shirreff survey stations during Leg I and at standard AMLR survey stations during Leg II (Hewitt *et al.*, this volume). Three regionally distinct groups of stations are considered within the large survey area. "Elephant Island Area" stations represent the historically sampled area used for long-term analyses of the Antarctic Peninsula marine ecosystem. "West Area" stations, north of King George and Livingston Islands, form a database with which to examine the abundance and age/maturity/length composition of krill stocks to predator populations at Cape Shirreff and to the krill fishery that operates in this area during summer months. "South Area" stations, located in Bransfield Strait, are used to monitor krill supplies available to predator populations in Admiralty Bay, King George Island.

Shipboard Analyses.

All samples were processed on board. With a few exceptions the same techniques were used during the CCAMLR and AMLR surveys. The exceptions were that (a) during the CCAMLR survey only freshly caught krill were analyzed while freshly caught, live-refrigerated and frozen specimens were used for demographic analyses during the AMLR surveys and (b) sample displacement volumes were measured only during the CCAMLR survey. In both surveys, analyses of the other zooplankton were with fresh material within 2 hours of sample collection. Abundance estimates of krill, salps and other taxa are expressed as numbers per $1000m^3$ water filtered.

(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 (mm); stages were based on the classification scheme of Makarov and Denys (1981).

(2) Salps: All salps were removed from samples of 2 liters or less and enumerated. For larger catches the numbers of salps in 1- to 2-liter subsamples were used to estimate abundance. For samples with ≤100 individuals, the two salp life stages (aggregate/sexual and solitary/asexual) were enumerated and internal body length (Foxton, 1966) was measured to the nearest mm. Representative subsamples of ≥ 100 individuals were analyzed in the same manner for larger catches.

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

(4) Zooplankton: After krill, salps, and adult fish were removed from samples, the remaining zooplankton fraction was analyzed. With large salp catches, all salps were carefully washed and removed; the remaining zooplankton from the entire sample was then retained for analysis. All of the larger organisms (e.g., other euphausiids, amphipods, pteropods, polychaetes) were sorted, identified to species if possible, and enumerated. Following this the smaller constituents (e.g., copepods, chaetognaths, euphausiid larvae) were enumerated using dissecting microscopes. Larval stages of *E. superba* (calyptopis 1-3 and furcilia 1 and 2) were identified based on the description by Fraser, 1936. The small zooplankton fraction typically represented 5-20% of the total sample. After analysis the zooplankton samples (without salps and adult fish) were preserved in 10% buffered formalin for long term storage.

4.3 Results and Preliminary Conclusions:

(A) Leg I, CCAMLR 2000 Krill Stock Assessment Survey, 13 January-4 February 2000

(1) RMT8 Net Catches:

Krill Abundance

A total of 33 RMT tows were made; these included 28 quantitatively useful open oblique tows from ca. 200m (Table 4.1A) and 5 tows directed at specific acoustics targets within the upper 400m (Table 4.1B). Krill were collected by 20 of the 28 quantitative tows (71%), but three tows yielded over 93% of the total ca. 47,890 individuals in the RMT8 samples. The largest catch, containing an estimated 21,677 krill, occurred at station YU30 over the eastern shelf of the South Orkneys (Figure 4.1). The two next largest catches of 11,433 and 11,680 krill occurred, respectively, over the eastern shelf of South Georgia (YU03) and east of the South Orkneys (Transect Line SS05, station YU15). Because of these large catches overall, mean krill abundance was greatest in the South Orkney Island area (SOI; 517.0 per 1000m3) followed by the South Georgia area (SG; 576.1 per 1000m3) and South Shetland transect line 5 (SS05; 133.4 per 1000m3). Two moderately sized catches (1,724 and 1,114 krill) were made along the SSO2 transect at stations YU08 and YU12 (Figure 4.1) yielding a relatively high mean abundance value (31.5 per 1000m^3). Krill was least abundant along the SS08 transect line (6 samples, 20 krill) and in the Antarctic Peninsula area (AP; 5 samples, 20 krill); mean abundance was <1.0 per 1000m^3 in these areas. Median krill abundance values were generally low for the survey areas

(0-2.5 per $1000m^3$ for all but SG) due to extreme patchiness and rare encounters with more than a dozen krill at the sampling sites.

Krill Size and Maturity Stage Composition

There were obvious regional differences in krill length/maturity/age composition across the survey area (Figures 4.2, 4.3). Small juveniles (65% 29-32mm lengths) dominated the South Georgia area samples. Mixtures of juveniles and immature stages dominated catches along easternmost transect lines SS02 (67% 29-37mm lengths) and SS05 (78% 34-42mm lengths). In contrast, large sexually mature krill dominated catches around the South Orkneys (77% 47-55mm) and to the north (SS08; 65% 49-53mm) and west (AP; 85% 45-52mm). Females outnumbered males in the SOI samples; these females were mostly in advanced maturity stages and spent individuals comprised 52% of the catch.

(2) Salps:

Salp Abundance

Salpa thompsoni were collected at all but three of the 28 stations (Table 4.1A; Figure 4.4). They were least abundant around South Georgia and along transect lines SS02 and SS08 (median values 0.8-1.3 per $1000m^3$). They were most abundant in the South Orkney Island and Antarctic Peninsula areas (median values 22.8-27.7 per $1000m^3$). The mean and median salp abundance estimates in the Antarctic Peninsula area were comparable to those observed during "copepod years", and one to two orders of magnitude lower than observed during "transition periods" or "salp years" in that area. The other Southern Ocean salp species *Ihlea racovitzai* was collected in only two samples (6 individuals total) in the South Orkney Island area (Stations YU28 and YU32).

Salp Maturity, Size and Age

The vast majority of salps (98%) were the aggregate (sexual) form; internal lengths were 4-65mm (Figure 4.5). Cluster analysis applied to samples with >20 salps yielded three groups with significantly different size frequency distributions (Kolmogorov-Smirnov tests, $P<0.01$ in all cases; Figures 4.5, 4.6). Cluster 1, represented at 7 stations, was primarily composed of small salps; 60% were 10-20mm (13mm size mode) and 90% were <28mm. Somewhat larger Cluster 2 salps occurred at 5 stations; 60% of these were 20-30mm (25mm mode) and 90% were <33mm. Cluster 3 salps, present at 4 stations, were largest, ranging up to 42mm; 66% were 27-37mm (29mm mode). Cluster 1 salps occurred north of the Weddell Sea between the South Orkneys and eastern shelf of South Georgia (Figure 4.6). Cluster 2 salps were distributed between the offshore and northern shelf area of the Antarctic Peninsula islands to north of the South Orkneys and also northeast of the Weddell Sea. Cluster 3 salps were primarily distributed in oceanic water southwest of South Georgia; similarly sized salps were also collected in Bransfield Strait. The different salp lengths most likely reflect regional differences in seasonal production periods; their distribution patterns appear to reflect water mass source areas and circulation patterns. In this respect, Cluster 1 salps had the most recent onset of production (e.g., from mid-December), probably associated with Weddell Sea dynamics. Cluster 2 salps had a somewhat earlier onset of production, possibly associated with a Bellingshausen Sea source area and transport in the Westwind Drift. Seasonal production of Cluster 3 salps began earliest (e.g., mid-November) possibly as a consequence of their distribution in lower latitude waters not directly affected by seasonal sea ice.

(3) Nekton and Zooplankton Assemblages:

Distribution and Abundance Relations of Dominant Taxa

A total of 61 taxa were identified in the RMT8 samples (Table 4.2). Krill was the overall dominant in terms of numbers of individuals and mean abundance. However *Thysanoëssa* spp., *S. thompsoni* and *Themisto gaudichaudii* occurred more frequently (82-89% vs. 71% of samples) and had greater median abundance than krill (0.8-5.5 vs. 0.2 per 1000m^3). *Euphausia frigida* was similar to krill in frequency of occurrence, but had greater median abundance (1.1 per 1000m^3). Other frequent and/or abundant taxa included the siphonophore *Diphyes antarctica*, *Euphausia triacantha,* chaetognaths and polychaete *Tomopteris spp.*

Cluster analysis applied to abundance (Log [n+1]) of taxa other than krill yielded three distinct groupings (Table 4.3). These nekton/zooplankton assemblages had distribution patterns similar to those of the salp clusters (Figure 4.7). Cluster 1, the largest, was represented at 12 stations all but one of which extended from south of the South Orkneys to east of South Georgia. Clusters 2 and 3 were each represented by 8 stations. Cluster 2 occurred from north of the Antarctic Peninsula to east of the South Orkneys while Cluster 3 was located around South Georgia. These distribution patterns, as with those of salps, indicated marked spatial and temporal variability over island shelf areas, especially at the South Orkneys.

Although taxonomic richness of the three clusters was similar (13-15 taxa per tow), their overall abundance and species abundance relations differed somewhat (Table 4.3). Cluster 1, characterized by relatively low mean and median zooplankton abundance, was numerically dominated by *Thysanoëssa* spp. and *Diphyes antarctica.* While frequent (92% of samples), *S. thompsoni* was not abundant (median catch 0.7 per 1000m^3). Frequent occurrence of *Diphyes,* other siphonophores and the hydromedusa *Euphysora gigantea* are unique to, and characterize, this cluster. *Thysanoëssa* spp., *S. thompsoni, Euphausia frigida* and *Vibilia antarctica* were always present and had maximum abundance in Cluster 2 samples; the pteropods *Clio pyramidata* and *Clione limacina* were also relatively frequent and abundant. *Themisto gaudichaudii* was present in all Cluster 3 samples and contributed over 55% of the mean zooplankton abundance; its median abundance here was quite high (41 per 1000 m^3). This cluster was also characterized by relatively high occurrence and abundance of *Euphausia triacantha* and larval squid.

Interspecific Relationships

Distribution of the clusters roughly conforms to three "faunistic divisions" described by Mackintosh (1934): the eastern Scotia Sea (Cluster 1); Graham Land (Cluster 2); and transition belt (Cluster 3). According to Mackintosh (1934), the transition belt included South Georgia and the boundaries of Bellingshausen and Weddell Sea waters. This zone contained a mixture of species with the warmest (e.g., *Euphausia vallentini*) and coldest (e.g., *Diphyes antarctica*) water mass affiliations at their respective southern and northern distribution limits. The eastern Scotia Sea, bracketed by the South Shetlands, South Orkneys and South Georgia, was characterized as having uniformly distributed, but seasonally and annually variable, taxa. The Graham Land (Antarctic Peninsula) area was characterized by typically cold-water species (e.g., *Salpa thompsoni, Euphausia superba*) and extremely patchy plankton distributions. As with the present study, Mackintosh (1934) noted hydrographically related faunal complexity around the South Orkneys.

Despite between-cluster abundance differences of various taxa, Analyses of variance (ANOVA) indicated significant differences for only two species: salps (Cluster 2 abundance greater than Clusters 1 and 3; P=0.001 in both cases) and *T. gaudichaudii* (Cluster 3 abundance greater than Clusters 1 and 2; P=0.000 in both cases). Mackintosh (1934) described large differences in macrozooplankton abundance between the three faunal divisions (high abundance in the Transition Zone around South Georgia, low abundance in the Graham Land area), however, this is not supported by the present data set (ANOVA, P>0.20 for significant differences between total zooplankton abundance of the three clusters).

(4) RMT1 Net Catches

Nekton and Zooplankton Assemblages

Only 53 taxonomic categories were identified in the RMT1 samples compared to 61 in the RMT8 samples. Four of these (copepods, larval krill, larval *Thysanoëssa* spp. and chaetognaths) were the overwhelming dominants. Copepods were present in all but one sample and were by far the most abundant (Table 4.4). Larval *Thysanoëssa* spp. followed in frequency of occurrence (93%) and median abundance while larval krill ranked second in mean abundance. Chaetognaths were relatively frequent (86% of samples) and abundant (rank 4). *Tomopteris* spp., *Thysanoëssa* spp. and *Euphausia frigida* were common in the samples.

Larval krill were represented from early calyptopis (C1) to early furcilia (F2) stages. Calyptopis stages were the most abundant, contributing 91% of the larvae (C1, 44.3%; C2, 15.5%; C3, 31.2%); most of the furcilia larvae were F1 (5.7%). The larvae had a highly patchy distribution (Figure 4.8). Relatively large concentrations occurred across the eastern half of the survey area (50^{o}W eastward) but greatest concentrations (5,603-6,797 per $1000m^{3}$) were over shoal areas west, adjacent to and east of the South Orkneys (stations YU15, YU29 and YU32; Fig. 4.8). The most advanced larval stages (C3 to F2) primarily occurred at those three stations. Relatively low abundance of larval krill in the Antarctic Peninsula region may be an artifact resulting from the low sampling density and sampling locations there. Presence of ca. two-month old furcilia stages (Ross *et al.*, 1988) during mid- to late January suggests an early onset of the spawning season, possibly mid- to late November. Exceptionally active spawning, especially over the past month, is indicated by the high frequency of occurrence and abundance of calyptopis larvae.

Unlike the RMT8 data, cluster analysis applied to RMT1 zooplankton data did not produce meaningful biogeographic patterns. This most likely results from pooling species of abundant taxonomic categories (especially copepods and *Thysanoëssa*), which obscures the distribution patterns described by Mackintosh (1934). In order to further compare regional zooplankton abundance patterns with those he reported, the RMT1 data were segregated according to the RMT8 station clusters (Table 4.5). As before, despite large between-region differences in species abundance and abundance relations, only two were significant. Salps again were significantly more abundant in Cluster 2 than Clusters 1 and 3 (ANOVA, P=0.03 in both cases). *Euphausia frigida* was also most abundant in Cluster 2 (P=0.02). This latter result, establishing higher abundance in the cold Antarctic Peninsula region, is in contrast to Mackintosh's (1934) description of *E. frigida* as a "warm water" species. As with the RMT8 data, there were no significant differences between total zooplankton abundances or between taxonomic richness of the three clusters.

(B) Leg I, Cape Shirreff Survey, 6-10 February 2000

(1) Krill

<u>Krill Abundance</u>

Krill were present in 10 of 12 IKMT samples collected off Cape Shirreff in the West area of the AMLR survey grid (Table 4.6). All catches were small (1-67 individuals) and yielded a total of 183 krill. Largest concentrations (10.7-31.8 per 1000m^3) occurred in the mid-shelf area (Figure 4.9). Overall mean and median abundance values were 7.4 and 5.4 per 1000m^3, respectively. Mean and median abundance values in the West area during January 1998 and 1999 were, respectively, 56.0 and 15.1 per 1000m^3 (n=28) and 5.0 and 0.0 per 1000m^3 (n=27), therefore the 2000 values were most like those of 1999.

<u>Size Distribution, Maturity Stage Composition and Distributional Attributes</u>

Most of the krill were large and sexually mature. Sizes ranged from 33-58mm, but 86% were 45-55mm (Figure 4.10a). These lengths correspond to animals that are probably 4 and 5 years old (Siegel, 1987; i.e., the 1995/96 and 1994/95 year classes). Males and females were fairly equally represented; 46% were sexually mature males and 42% were sexually mature females (Figure 4.10b). Almost all of the animals were sexually active: males were predominantly stage 3b; 52% of the females were gravid (stage 3d) and 17% spent (3e). Only calyptopis stage larvae were collected here.

(2) *Salpa thompsoni*

Abundance, Size Distribution, Maturity Stage Composition and Distributional Attributes

Salps were present in all 12 samples with abundance ranging from 14.8 to 2,204 individuals per $1000m^3$ (Table 4.6). Greatest concentrations occurred over and beyond the outer shelf (Figure 4.11). Median abundance was 64.3 per $1000m^3$. Corresponding median values in the West area during January 1998 and 1999 were, respectively, 194.4 and 70.6 per $1000m^3$. Like krill, salp abundance in early February 2000 most resembled that of the preceding "transition" year.

Although the majority of individuals were aggregates (77%), a substantial proportion (23%) was composed of small solitary stages. The aggregates were relatively large; only 10% were <20mm in length and over half were 30-40mm, centered around 32 and 36mm modes (early December production peak). In contrast, almost all of the solitaries (95%) were ≤20mm and 80% were <14mm. The overall length frequency distribution reflects these stage-related differences (Figure 4.11). This length frequency distribution is quite different from those of the various clusters in the CCAMLR survey area (Figure 4.5). Presumably these salps were advected into the area from the west and resulted from an earlier production period. The stage and size composition is unusual for January, which typically is the season of aggregate production and growth (Foxton, 1966). The large size of aggregates and recent production of substantial numbers of the overwintering solitary stage suggests an early end to the production cycle.

(3) The Zooplankton and Nekton Assemblage:

Distribution and Abundance Relations of Dominant Taxa

A total of 32 taxa were represented in the Cape Shirreff survey samples (Table 4.7). Copepods, larval *T. macrura*, *S. thompsoni* and chaetognaths were present in all 12 samples and together made up 94.5% of the total mean zooplankton abundance. Copepods were the overall dominant with mean and median abundance values of 5,332.6 and 2,175.0 per $1000m^3$; this taxon alone comprised 60% of the total abundance. Copepods were followed in mean abundance by larval *T. macrura* (15.5%), *S. thompsoni* (13.5%) and chaetognaths (5.6%). Although krill larvae ranked 5 in terms of mean abundance (82.1 per $1000m^3$), they were present in only 5 samples and had a 0.0 median abundance value. These abundance values are 2-3 orders of magnitude smaller than those estimated for the CCAMLR survey area (Table 4.4).

(C) Leg II, Survey D, 22 February-7 March

(1) Krill

Krill Abundance

Krill were broadly distributed across the large survey area and occurred in 75 of 97 samples (77%). They were present in all 8 of South area samples compared to 49 of 60 (82%) Elephant Island area and 23 of 37 (62%) West area samples. Most catches were ≤ 25 individuals. The two largest, 1,594 and 799 krill (606 and 304 per 1000m^3), were north of Cape Shirreff; another relatively large catch of 657 krill (253 per 1000m^3) was located northeast of Clarence Island (Figure 4.13). Accordingly, mean krill abundance was highest in the West (38.5 per 1000m^3) vs. Elephant Island and South areas (14.4 and 6.7 per 1000m^3, respectively; Table 4.8). Median krill abundance in the three areas was similar (2.3 to 3.9 per 1000m^3), reflecting their broad, predominantly low density distribution.

Length and Maturity Stage Composition

Like the population sampled near the South Orkneys during January, virtually all post-larval krill were large, mature individuals (Figures 4.14, 4.15; Table 4.9). Although lengths ranged from 30 to 58 mm, 99% were >41mm and 75% were 47-52mm, centered around a mode of 49-50mm. This length mode corresponds to 5-year old krill, remainders of the highly successful 1994/95 year class. Only 2 of >2,100 krill analyzed were juveniles. Most of the immatures (2% of total krill) were large, probably undergoing post-spawn regression. Most mature males were reproductively active (stage 3b) and 79% of mature females were in advanced reproductive stages (gravid and spent, stages 3d, 3e). As with the CCAMLR 2000 survey, large larval concentrations (Table 4.11) and occurrence of developmental stages up to furcilia 3 suggest an active and prolonged spawning season.

Krill length composition was quite uniform across the survey area and the overall size frequency distribution (Figure 4.14) was similarly represented in all three subareas (Kolmogorov-Smirnov tests, P>0.05). Unlike previous years, cluster analysis applied to length frequency distributions did not yield groups with spatially coherent distribution patterns (e.g., large, mature stages in the north, small juvenile stages in the south, and intermediate forms in between these). Krill comprising the three resultant clusters had the same overall length distribution with only minor composition differences within the 43-48 mm size range. In contrast, sex ratio and maturity stage composition differed somewhat between the three subareas (Table 4.9). Males outnumbered females by ca. 2:1 in the West, females outnumbered males by ca. 3:1 in the South, and the sexes were equally represented in the Elephant Island area. While gravid and spent females predominated in the Elephant Island area, females in the West and South areas were primarily undergoing ovarian development or were gravid (3c and 3d) suggesting somewhat delayed or prolonged spawning activity in those subareas.

The absence of small juvenile and immature krill in the Antarctic Peninsula region suggests recruitment failure there from the past two years (i.e., 1997/98 and 1998/99 year classes). Presence of large, mature stages across the entire area instead of their typical distribution within the northern portion (Siegel, 1988) could be related to absence of younger krill in the island shelf regions and Bransfield Strait (i.e., altered migratory behavior).

(2) *Salpa thompsoni*

Abundance, Size and Maturity Stage Composition and Distribution

Salps were ubiquitous and relatively abundant during Survey D (Table 4.8; Figure 4.16). They were present in all but two samples (98%) and had a median abundance of 232 per $1000m^3$. Two extremely large salp samples, estimated to contain 31,223 and 53,603 individuals (12,319 and 24,050 per $1000m^3$), were collected in Bransfield Strait south of Elephant Island. The latter catch, with a volume of 120l, was the largest ever made during the 12-year series of AMLR surveys. Ten other relatively large concentrations were sampled (1,000 to 8,600 per $1000m^3$): three offshore in the West; three in the east Elephant Island area; and four in Bransfield Strait, south of King George Island. Overall, salps were least abundant in the West where mean and median values were 313 and 82 per $1000m^3$, respectively. Salps were an order of magnitude more abundant in the South (mean and median values 2,283 and 1,291 per $1000m^3$); intermediate concentrations (969 and 275 per $1000m^3$) occurred in the Elephant Island area. As usual the aggregate (sexual) stage dominated. However, the abundance of solitary (asexual) forms (8.3%) was relatively high (Figure 4.17). Proportions of solitary salps were greatest in the West (13.2%), least in the South (5.7%) and intermediate (7%) in the Elephant Island area.

Aggregate individuals were up to 75mm in length but the bulk of the population was ≤65mm and the majority (57%) were 25-45mm, centered about a 34-3 mm length mode (Figure 4.17). This size distribution reflects initiation of seasonal production in late October-early November. Solitary stage salps ranged in length from 4 to 118mm, but half of the individuals were ≤16mm (9-10mm mode) and 70% were <27mm. These small solitaries result from sexual reproduction by aggregates produced the preceding spring. A number of 21mm length mode solitaries were observed still within the parents, which were slightly over twice their length (50-55mm). Assuming similar growth rates for solitaries and aggregates, these individuals could have begun developing ca. six weeks earlier (i.e., mid- to late January). As noted in the Cape Shirreff survey, relatively large numbers and sizes of solitaries during this time of year suggest an unusually early production of the overwintering form.

Cluster analysis applied to length frequency distributions in samples represented by a minimum of 60 measured aggregates yielded three groups with more or less coherent spatial distributions (Figures 4.17, 4.18a). Cluster 1 salps were mostly 22-40mm (60%) with sizes fairly evenly distributed around a 30mm mode (early January production peak); only a small proportion (7%) were <10mm. This was the largest group represented at 57 stations mainly in the West area and southwest portion of the Elephant Island area. Cluster 3 had an irregular length frequency distribution: 45% of individuals were 23-45mm (39-40mm mode, mid-December production peak) and 42% were ≤15mm (10mm mode) resulting from a recent pulse of new production. This group was limited to 12 stations, all but 2 of which were in Drake Passage north of Elephant Island. Most of the Cluster 2 salps (62%) were 40-55mm distributed around a 45mm peak (early December production); only 10% were <30mm. All but one of 17 stations represented by these salps were adjacent to or downstream of King George and Elephant Island shelves. This length frequency distribution was significantly different from those of Clusters 1 and 3 (Kolmogorov Smirnov tests, D_{max} values 43.9 and 53.9; $P<0.05$). Interestingly, the length frequency distribution of Cluster 2 most resembles that of the salps sampled north of Cape Shirreff three weeks earlier (Figure 4.19b). When that size distribution is moved to the right 10mm to accommodate estimated growth, the resulting D_{max} value is relatively small (19.7). This suggests that the large aggregates off Cape Shirreff three weeks earlier were advected eastward and replaced by individuals from a different source area and growth history. However, relatively large numbers of small aggregates and solitaries, which characterized the catches off Cape Sheriff in early February, were not associated with Cluster 2.

(3) Zooplankton and Nekton

Distribution and Abundance Relations of Dominant Taxa

A total of 80 taxa were identified in Survey D samples. Copepods were by far the most frequent and abundant category, present in 96 of 97 samples and comprising 59.5% of total mean abundance (Table 4.12). Median copepod abundance (3,689 per 1000m^3) was an order of magnitude greater than that of any other taxon. Greatest copepod concentrations (>10,000 per 1000m^3) occurred offshore (Figure 4.20a). Larval krill were second in overall mean abundance but, due to their extremely patchy distribution, ranked 5 in median abundance after chaetognaths, salps and larval *Thysanoëssa macrura*. Krill larvae were present in all but two Elephant Island area samples but were absent or in low numbers at West and South area stations. Greatest concentrations (>10,000 per 1000m^3) were northwest and southeast of Elephant Island (Figure 4.20b). This distribution pattern relative to the CCAMLR 2000 transect lines could explain the paucity of larval krill collected here during January (Figure 4.8). Developmental stages to mid-furcilia (F3) were found, but early calyptopis stages (primarily C1 and C2) made up 97% of the total. *Thysanoëssa macrura* larvae followed larval krill in mean abundance. Salp and chaetognath abundance values were similar to one another; these ranked 4 and 5 in mean, and 2 and 3 in median, abundance. Postlarval *T. macrura* and krill ranked 8 and 10 in mean abundance. *Ihlea racovitzai* was present in small numbers in 13% of samples. While abundance relations of dominant taxa differed somewhat between the three subareas (Table 4.12) these differences were significant only for *I. racovitzai*; it was most frequent (4 of 8 samples) and abundant in the South (ANOVA, $P< 0.01$ in both comparisons).

Diel Abundance Differences

Seven taxa exhibited marked diel abundance variations. Among the euphausiids significantly larger night vs. day catches occurred for postlarval krill, *E. triacantha* and *T. macrura*, while both night and twilight catches of *E. frigida* were greater than those during day. Among the copepods, both night and twilight abundance of *Metridia gerlachei* were significantly higher than during day, and night abundance values of *Pleuromamma robusta* and "other" species exceeded those during day and twilight (ANOVA, $P = 0.000$ to 0.002 in all cases).

Interspecific Relationships

Cluster analysis of zooplankton taxa (Log [N+1]) defined two distinct assemblages whose distributions more or less conformed to the northern island shelf contour (Figure 4.21; Table 4.13). Cluster 1 was largest (58 stations) and occurred in the southern portion of the survey area, its northern limit associated with the mid- to outer shelf. Cluster 2 (39 stations) occurred seaward of this in Drake Passage. These "coastal" and "oceanic" assemblages differed greatly in their species abundance relationships as indicated by a low Percent Similarity Index (PSI) value of 45.2. *Calanoides acutus, Calanus propinquus, Rhincalanus gigas, Pleuromamma robusta, Paraeuchaeta sp.* and "other" copepods were an order of magnitude and significantly more abundant at the offshore Cluster 2 stations (ANOVA, P = 0.000 to 0.003). Chaetognaths, larval *T. macrura,* and most of the other taxa considered were also significantly more abundant offshore (ANOVA, P <0.05). Notable exceptions were larval and postlarval krill, the copepod *Metridia gerlachei*, *S. thompsoni* and *Euphausia frigida* which were more evenly distributed across the survey area, and *Thysanoëssa macrura* postlarvae, *Ihlea racovitzai* and *Dimophyes arctica* which were significantly more abundant at Cluster 1 stations.

(4) Leg II, Between Year Comparisons

Krill

The low mean and median krill abundance values during February-March 2000 were similar to those observed during 1994, 1995 and 1999 (Table 4.14) and similarly resulted from a succession of years with low recruitment success. A history of poor recruitment was also reflected by predominance of large mature krill across the entire survey area. While the 1996/97 spawning season yielded a relatively low proportional recruitment index (0.168), the past two seasons had zero recruitment success as indicated by the virtual absence of one-year-old juveniles. Failure of the 1997/98 year class was attributed to unfavorably late seasonal spawning. Although "normal" spawning seasonality occurred during 1998/99, no substantial increases in larval abundance or development were observed over the two-month field season. We speculated that this may have been due to high larval mortality and/or advection of young krill out of the survey area (i.e., to South Georgia) and advised guarded optimism for subsequent year class success. During the CCAMLR 2000 survey, observations of juvenile and immature stages only near South Georgia and along eastern transect lines (Figures 4.2, 4.3) support these hypotheses. With the paucity of young stages in the Antarctic Peninsula region during both 1999 and 2000 summers, reproductive adults occurred further south than typical (Siegel, 1988). This distribution change could result from decreased necessity for offshore migration to avoid competition with, and/or predation upon eggs and larvae by, juvenile and immature krill.

The onset of spawning during 1999/2000 was apparently earlier than last year (mid- to late November vs. mid- to late December). However, extremely large larval concentrations and presence of mid-furcilia stages during February-March 2000 suggest greatly enhanced production, survivorship and/or retention of eggs and larvae within the Antarctic Peninsula region this year. Larval krill concentrations within the Elephant Island area were almost as high as those during February-March 1995 (Table 4.14) which led to the very successful 1994/95 year class. Given favorable overwintering conditions for these larvae the 1999/2000 year class success may approach that level.

Salpa thompsoni

Median salp abundance in the Elephant Island area was similar to February-March 1994 and 1999 values (Table 4.14) and characteristic of transition periods that separate salp years and copepod years. The aggregate length frequency distribution was most like that of February-March 1994 (Figure 4.22; Kolmogorov-Smirnov D_{max}=5.3). During both years aggregate production began around late October-early November, increased gradually to an early January peak, then declined gradually through summer with no indication of a late-season pulse. Median salp carbon biomass values (mgC per m^2) also most resembled those of February-March 1994 and 1999; because of the relatively large krill median biomass value, the salp:krill ratio was relatively small (5.6:1; Table 4.15).

Zooplankton and Nekton

Copepod and chaetognath abundance in the Elephant Island area during February-March 2000 (Table 4.14) were both significantly higher than any of the values from February-March AMLR surveys since 1994 (ANOVA, P all <0.010). The significant abundance increase over 1999 was primarily due to *M. gerlachei* (P<0.01), *R. gigas* and "other" species (P<0.05 for both). Among the other dominant taxa, significantly elevated abundances were observed for *E. frigida* (vs. 1996 and 1998; P=0.01 in both cases) and larval *T. macrura* (vs. 1994 and 1998 (P=0.02). In contrast, abundance of postlarval *T. macrura* in 2000 was significantly lower than during February-March 1997 and 1998 (P<0.05). Interestingly, abundance of the salp-associated amphipods *Cyllopus magellanicus* and *Vibilia antarctica* in 2000 were significantly higher than during most other years (P≤0.05 for all but 1998 for *C. magellanicus* and 1997 for *V. antarctica*). The affiliation of these species with offshore Cluster 2 as well as decreased salp abundance relative to 1997 and 1998 (Tables 4.11 and 4.14) suggests that their increases are due to factors other than just salp abundance.

The zooplankton composition of Elephant Island area samples during 2000 most resembled those from February-March 1999 and 1995 (Table 4.15; PSI=76.9 and 72.0, respectively); it was least like the 1998 salp year (PSI=15.5). Given numerical dominance by copepods and a salp:krill carbon biomass ratio >1 (Table 4.16) this year is considered a continuation of the transition period initiated in 1999. In this respect transition periods have formed the dominant ecological regime, prevailing here over four of the last 8 years:

(a) Copepod years (1995 and 1996):
(b) Salp years (1993 and 1998):
(c) Transition periods (1994, 1997, 1999 and 2000):

Overall similarity between the 2000 and 1995 zooplankton assemblages is in part due to their large larval krill concentrations and suggests that this may presage good krill recruitment and a major copepod year in 2001.

Although the 1999 sea ice index is not presently available, daily satellite images produced from May through December indicated that sea ice development was not particularly extensive and the index will most likely be like that of 1997 and about average for the past 10 years. Despite only moderate winter sea ice, the krill obviously had an early and active spawning season, probably starting in mid- to late November 1999. This indicates that optimal feeding conditions were present during early spring for krill to develop resources necessary for reproduction. Additionally, copepod abundance was the highest observed in the past 8 years and salp abundance was relatively high and characteristic of a transition period rather than a copepod year. The coincidental elevated abundance of copepods, larval krill and salps during summer 2000 is unique and is at odds with the concept of copepod years, salp years and hypothesized sea ice-related fluctuations between krill spawning seasonality and salp bloom production (Loeb *et al.*, 1997). Everything seems to indicate that there was widespread abundant primary production in early spring, which provided ample food supplies for potential competitors. The relatively high Chl-*a* values during February-March (See Phytoplankton section) suggest that high primary productivity persisted though summer months. The causes for this elevated productivity can only be speculative at this time.

(D) CCAMLR and AMLR 2000 Cruise Summaries

CCAMLR 2000 Survey

In addition to providing information on krill stock demography and abundance in the Atlantic Sector of the Southern Ocean, the CCAMLR survey permitted an extremely valuable overview of salp and other zooplankton distribution and abundance in this area.

1. Krill were highly patchy and not very abundant. Largest concentrations occurred in proximity to South Georgia and South Orkney Island shelf areas; overall abundance was low in the Antarctic Peninsula region.

2. There were major differences in the distribution of krill length/maturity stages: juvenile and immature krill (1997/98 and 1998/99 year classes) were found only around South Georgia and the easternmost portion of the survey area; large reproductively active adults were found primarily in the South Orkney area.

3. Larval krill were encountered across the survey area; largest concentrations were over shoal areas west, adjacent to and east of the South Orkneys. Presence of ca. 2-month old larval stages suggests an early onset of the 1999/2000 spawning season, possibly mid- to late November. High abundance of early larval stages indicated very active spawning during the past month.

4. Zooplankton taxa and salp length groups demonstrated similar distribution patterns across the survey area, suggesting three ecological regions:

(a) South Georgia and waters to the west were characterized by high abundance of the amphipod *Themisto gaudichaudii*;

(b) Area extending from the Antarctic Peninsula to South Orkneys were characterized by high abundance of *Salpa thompsoni*;

(c) Area north of the Weddell Sea between the South Orkneys and eastern shelf of South Georgia was characterized by high abundance of *Euphausia triacantha* and larval squid.

These roughly conform to three "faunistic divisions" reported from the "Discovery Expeditions" of 1925-1936. However, statistical analyses did not support major differences in total zooplankton abundance reported for the regions. These results may be altered when our relatively small data set is combined with data from the three other collaborative survey efforts.

AMLR 2000 Large Area Survey

1. Predominantly low densities of krill were distributed across the large survey area during February-March. Virtually all of the krill were large, mature individuals, remnants of the 1994/95 and 1995/96 year classes. Absence of juvenile and immature stages indicated recruitment failure of the last two year classes (1997/98 and 1998/99) in this region. Observations of these stages around South Georgia and in the eastern CCAMLR survey area may support hypothesized advection of young out of the area during 1999. Overall low krill abundance values were similar to those of 1994, 1995 and 1999 and similarly reflect a succession of years with poor recruitment success.

2. Large numbers and advanced developmental stages of krill larvae in the Elephant Island area confirm an early initiation and prolonged and active spawning season during 1999/2000. Given adequate retention of early stages within the area and optimal winter sea ice conditions, the 1999/2000 year class success may approach that of 1994/95. This is extremely important because of the advanced age of the current krill population.

3. In addition to larval krill, other zooplankton taxa were extremely abundant compared to previous AMLR surveys. Notable are copepods and chaetognaths which had the highest concentrations monitored in the past 8 years. Abundance of *Euphausia frigida*, larval *Thysanoëssa macrura* (euphausiids), *Cyllopus magellanicus* and *Vibilia antarctica* (amphipods) were also comparatively high. Although salps were ubiquitous and at times exceedingly abundant, their median abundance and carbon biomass values were characteristic of transition periods rather than salp years.

4. The coincidental elevated abundance of copepods, larval krill and salps during summer 2000 is unique and suggests that there may have been abundant wide spread primary production across the region during early spring. High chl-a values and chaetognath abundance during the AMLR survey suggest that elevated productivity persisted into summer. The underlying causes of this high productivity are unknown.

4.4 Disposition of Data and Samples: All of the krill, salp, other zooplankton and fish data have been digitized and are available upon request from Valerie Loeb. These data have been submitted to Roger Hewitt (Southwest Fisheries Science Center). Alcohol preserved salp specimens were provided to Linda Holland (SIO) for genetic studies. Frozen myctophids were provided to Allison Banks and Dan Costa (UCSC) for chemical analyses. Dorothee Stübing used larval and post larval krill for onboard experiments and post cruise lipid analyses.

4.5 Problems and Suggestions: Because of the wealth of information that is coming together about ecological change in the Elephant Island area and possible forcing mechanisms, it is imperative that we continue the historical survey effort here. The usefulness of two Elephant Island survey efforts during January-March has become obvious: the magnitude of within-summer variability is often as great as interannual variability. The trends observed across the summer season are essential for understanding the underlying forcing processes and for continued predictive abilities, which have become the hallmark of the AMLR Program.

1. Major changes in copepod and salp abundance observed over 4-6 week periods indicate a physical rather than a biological cause. These abundance shifts between January and March appear to presage conditions that will be encountered the following year. For example:

   - The large increase of copepod abundance, and coincidental decrease in salp abundance, between the two 1994 surveys marked a major transition between the 1993 salp and 1995-1996 copepod years;
   - The large influx of salps between the two 1997 cruises marked a transition to the 1998 salp year;
   - Constant salp abundance across summer the 1999 was associated with a continuation of a transition period in 2000.

2. Observations of biological conditions across the three-month period are extremely useful for understanding and/or predicting ecological variations. For example:

   - Observations that there were no significant increases in larval krill abundance or developmental stages over January-March 1999 suggested that there may have been losses due to mortality or advection of the young krill from the area. We therefore advised guarded optimism about 1998/99 year class success; this was supported by the 2000 survey results;
   - Salp size distributions observed during both cruises reflect the onset of their production in spring and summer months. Solitary and aggregate salp size modes indicate variable production across the summer period and are essential for determining their seasonal production cycles. This information is essential for assessing the size of next summers seed population.

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Table 4. 1. CCAMLR 2000 Survey RMT tows and krill and salp catch information, R/V *Yuzhmorgeologiya*

A. QUANTITATIVE TOWS

		TIME						KRILL			SALPS	
STATION	DATE	START (GMT)	END	DIEL	TOW DEPTH	WATER DEPTH	VOLUME	TOTAL	$\#/m^2$	$\#/1000m^3$	TOTAL	$\#/1000m^3$
YU03	14/01/00	1511	1537	D	191	225	15330.4	11433	142.4	745.8	0	0.0
YU04	15/01/00	0359	0432	N	201	3560	18049.0	117	1.3	6.5	29	1.9
YU05	16/01/00	0320	0349	N	201	1920	17216.0	51	0.6	3.0	14	0.9
YU08	17/01/00	0325	0357	N	206	4400	17315.2	1724	20.5	99.6	1	0.1
YU10	18/01/00	0322	0352	N	208	3400	15867.8	33	0.4	2.1	9	0.6
YU11	18/01/00	1519	1552	D	204	2000	18838.6	3	0.0	0.2	15	1.0
YU12	19/01/00	0257	0324	N	202	3000	13233.6	1114	17.0	84.2	8	0.5
YU13	19/01/00	1651	1719	D	200	2400	12142.9	0	0.0	0.0	94	6.1
YU14	21/01/00	1544	1612	D	200	2400	12142.9	0	0.0	0.0	83	5.4
YU15	21/01/00	0348	0415	N	201	2870	14609.2	11680	160.7	799.5	1600	104.4
YU17	22/01/00	0347	0415	N	200	3200	13066.7	3	0.0	0.2	34	2.2
YU19	23/01/00	0340	0408	N	202	700	15320.6	14	0.2	0.9	73	4.8
YU20	23/01/00	1519	1546	D	202	700	14008.0	0	0.0	0.0	0	0.0
YU21	24/01/00	0343	0415	N	200	3600	16863.4	1	0.0	0.1	17	1.1
YU22	25/01/00	1659	1721	D	203	4880	10657.4	0	0.0	0.0	25	1.6
YU23	26/01/00	0411	0438	N	201	3800	7896.8	0	0.0	0.0	115	7.5
YU24	26/01/00	1403	1429	D	200	3400	13235.0	0	0.0	0.0	7	0.5
YU25	27/01/00	0407	0440	N	201	2400	15311.2	11	0.1	0.7	618	40.3
YU26	27/01/00	1621	1647	D	201	2770	12556.8	9	0.1	0.7	14	0.9
YU27	28/01/00	1614	1638	D	201	1920	7265.4	0	0.00	0.00	2	0.1
YU28	29/01/00	0407	0437	N	201	480	14195.2	3	0.04	0.21	1449	94.5
YU29	29/01/00	1752	1816	D	200	4400	11771.0	1	0.02	0.08	212	13.8
YU30	30/01/00	0328	0357	N	202	300	13976.1	21673	313.25	1550.7	349	22.8
YU32	31/00/00	0434	0505	N	202	2880	16386.5	11	0.14	0.67	425	27.7
YU33	02/02/00	0517	0547	N	201	4880	13748.0	3	0.04	0.22	903	58.9
YU34	02/02/00	1632	1657	D	200	434	13442.3	0	0.00	0.00	564	36.8
YU35	04/02/00	0511	0539	N	202	2840	14547.6	3	0.04	0.21	425	27.7
YU36	04/02/00	1740	1804	D	·200	2000	11956.6	3	0.05	0.25	0	0.0

	KRILL		KRILL		SALPS
AREA	TOTAL		$\#/m^2$	$\#/1000m^3$	$\#/1000m^3$
SG	11550	Mean	71.9	376.1	0.9
(n=2)		STD	70.6	369.6	0.9
		Median	71.9	376.1	0.9
SS02	2925	Mean	6.4	31.5	1.5
(n=6)		STD	8.8	42.9	2.1
		Median	0.5	2.5	0.8
SS05	11698	Mean	26.8	133.4	19.6
(n=6)		STD	59.9	297.9	37.9
		Median	0.0	0.1	3.5
SS08	20	Mean	0.0	0.2	8.5
(n=6)		STD	0.1	0.3	14.4
		Median	0.0	0.0	1.3
SOI	21677	Mean	104.4	517.0	43.7
(n=3)		STD	147.7	730.9	36.1
		Median	0.0	0.2	22.8
AP	20	Mean	0.1	0.3	30.2
(n=5)		STD	0.0	0.2	18.9
		Median	0.0	0.2	27.7
TOTAL	47890	Mean	23.5	117.7	16.5
(n=28)		STD	68.0	339.6	27.4
		Median	0.0	0.2	2.1

Table 4.1. CCAMLR 2000 Survey RMT tows and krill and salp catch information, R/V *Yuzhmorgeologiya* (Contd.)

B. TARGETED TOWS

STATION	DATE	TIME START (GMT)	END	DIEL	TOW DEPTH	WATER DEPTH	VOLUME	KRILL TOTAL
YU06	16/01/00	0922	0938	D	100-126	1500	NA	240
YU09	17/01/00	1332	1535	D	356	2800	NA	182
YU16	21/01/00	1224	1234	D	90-225	2800	NA	1
YU18	22/01/00	1802	1819	D	295-373	3600	NA	1
YU31	30/01/00	1410	1441	D	80-150	1002	NA	0
TOTAL	(n=5)							424

Table 4.2. Nekton and zooplankton taxa collected by RMT 8 nets during the CCAMLR 2000 survey. N is total number of individuals. F and F(%) are frequency of occurrence in 28 samples. Abundance is numbers per 1000 m^3. (L) and (J) indicate larval and juvenile stages. Mean, median and max. abundance expressed as numbers per 1000m^3.

TAXON	N	F	F(%)	MEAN	STD	MEDIAN	MAX
Thysanoessa spp.	14677	25	89.3	40.9	131.0	5.5	713.6
Salpa thompsoni	5689	25	89.3	20.4	32.7	2.5	109.5
Themisto gaudichaudii	4741	23	82.1	11.9	22.8	0.8	94.2
Euphausia frigida	3232	20	71.4	8.1	23.8	1.1	124.8
Euphausia superba	37378	20	71.4	117.7	339.6	0.2	1550.7
Tomopteris spp.	175	20	71.4	0.5	1.1	0.2	5.2
Chaetognaths	312	19	67.9	1.0	1.5	0.4	6.7
Diphyes antarctica	655	17	60.7	1.7	2.9	0.1	10.2
Spongiobranchaea australis	51	13	46.4	0.1	0.3	0.0	1.2
Larval Squid	35	12	42.9	0.1	0.3	0.0	1.5
Electrona antarctica	51	12	42.9	0.1	0.2	0.0	0.8
Euphausia triacantha	528	12	42.9	1.2	3.0	0.0	14.4
Clione limacina	46	11	39.3	0.1	0.2	0.0	0.9
Vibilia antarctica	83	11	39.3	0.2	0.7	0.0	3.7
Clio pyramidata	57	11	39.3	0.2	0.3	0.0	1.5
Euphysora gigantea	30	9	32.1	0.1	0.1	0.0	0.5
Gymnoscopelus braueri	76	8	28.6	0.2	0.4	0.0	1.8
Electrona spp. (L)	18	8	28.6	0.0	0.1	0.0	0.3
Primno macropa	25	7	25.0	0.1	0.2	0.0	1.2
Electrona carlsbergi	21	7	25.0	0.0	0.1	0.0	0.3
Acanthophyra pelagica	21	6	21.4	0.1	0.1	0.0	0.4
Unid. Jellies	58	6	21.4	0.1	0.4	0.0	2.2
Vanadis antarctica	6	6	21.4	0.0	0.0	0.0	0.1
Muraenolepis microps (L)	10	5	17.9	0.0	0.1	0.0	0.3
Unid. Siphonophores	99	5	17.9	0.3	0.7	0.0	3.6
Cyllopus magellanicus	19	5	17.9	0.1	0.1	0.0	0.5
Rhynchonereella bongraini	8	4	14.3	0.0	0.1	0.0	0.2
Unid. Gastropods	11	4	14.3	0.0	0.1	0.0	0.3
Cyllopus lucasii	16	4	14.3	0.0	0.2	0.0	0.9
Pasiaphaea sp.	31	3	10.7	0.1	0.3	0.0	1.9
Notolepis coatsi (L)	4	3	10.7	0.0	0.0	0.0	0.2
Bathylagus sp.	4	3	10.7	0.0	0.0	0.0	0.1
Periphylla periphylla	5	3	10.7	0.0	0.0	0.0	0.2
Hyperiella dilatata	3	3	10.7	0.0	0.0	0.0	0.1
Hyperoche medusarum	2	3	10.7	0.0	0.0	0.0	0.1
Cyllopus spp.	2	2	7.1	0.0	0.0	0.0	0.1
Unid. Larval Fish	2	2	7.1	0.0	0.0	0.0	0.1
Eusirus antarcticus	4	2	7.1	0.0	0.0	0.0	0.2
Euphausia vallentini	2	2	7.1	0.0	0.0	0.0	0.1
Hyperiella spp.	4	2	7.1	0.0	0.1	0.0	0.3
Krefftichthys anderssoni	8	2	7.1	0.0	0.1	0.0	0.6
Orchomene plebs	6	2	7.1	0.0	0.1	0.0	0.3
Dimophyes arctica	14	2	7.1	0.0	0.2	0.0	0.8
Pleuragramma antarcticum (J)	7	2	7.1	0.0	0.1	0.0	0.4
Ihlea racovitzai	5	2	7.1	0.0	0.1	0.0	0.4
Beroe cucumis	1	1	3.6	0.0	0.0	0.0	0.1
Calycopsis borchgrevinki	1	1	3.6	0.0	0.0	0.0	0.1
Scina spp.	1	1	3.6	0.0	0.0	0.0	0.1
Notothenia neglecta (L)	1	1	3.6	0.0	0.0	0.0	0.1
Pogonophryne marmorata (L)	1	1	3.6	0.0	0.0	0.0	0.1
Notolepis annulata (L)	1	1	3.6	0.0	0.0	0.0	0.1
Vanadis longissima	1	1	3.6	0.0	0.0	0.0	0.1
Artedidraco sp. (L)	1	1	3.6	0.0	0.0	0.0	0.1
Thysanoessa spp. (L)	3	1	3.6	0.0	0.0	0.0	0.3
Lensia meteori	7	1	3.6	0.0	0.1	0.0	0.6
Beroe forskalii	5	1	3.6	0.0	0.1	0.0	0.4
Gymnoscopelus nicholsi	4	1	3.6	0.0	0.1	0.0	0.3
Marus antarctica	11	1	3.6	0.0	0.1	0.0	0.8
Unid. Polychaetes	1	1	3.6	0.0	0.0	0.0	0.1
Limacina helicina	2	1	3.6	0.0	0.0	0.0	0.2
Unid. Decapods	2	1	3.6	0.0	0.0	0.0	0.2
TOTAL	68274	389	1389.3	205.8	475.2	63.2	2424.6
NO. TAXA	61			13.9	4.7	13.5	30

Table 4.3 Taxonomic composition of nekton/zooplankton clusters derived from CCAMLR 2000 survey RMT 8 samples. F(%) is the frequency of occurrence; % is the contribution of each taxon to total mean abundace (all taxa). R is rank order of abundance for the 10 most abundant taxa in each cluster. Clusters roughly conform to three biogeographic regions ("faunistic divisions") defined by Mackintosh (1934) and included here. Mean, median and max. abundance is expressed as numbers per 1000m^3.

	CLUSTER 1 "EASTERN SCOTIA SEA" N=12						CLUSTER 2 "GRAHAM LAND" N=8						CLUSTER 3 "TRANSITION ZONE" N=8					
TAXON	F(%)	R	%	MEAN	STD	MED	F(%)	R	%	MEAN	STD	MED	F(%)	R	%	MEAN	STD	MED
Thysanoessa spp.	91.7	1	41.9	7.8	9.6	3.7	100.0	1	62.7	96.7	233.5	5.6	75.0	2	26.5	18.5	21.1	5.8
Diphyes antarctica	83.3	2	16.6	3.1	3.6	1.6	62.5	5	0.7	1.1	1.9	0.1	25.0	9	0.3	0.2	0.4	0.0
Salpa thompsoni	91.7	3	9.0	1.7	2.3	0.7	100.0	2	29.0	44.8	33.6	33.1	75.0	4	4.6	3.2	4.4	1.7
Themisto gaudichaudii	75.0	4	5.1	1.0	1.3	0.4	75.0	9	0.4	0.5	0.7	0.3	100.0	1	56.8	39.6	27.2	41.4
Chaetognaths	66.7	5	5.0	0.9	1.8	0.3	50.0	8	0.4	0.6	1.1	0.1	87.5	6	1.1	0.8	0.7	0.6
Unid. Siphonophores	41.7	6	3.3	0.6	1.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Euphausia frigida	41.7	7	1.9	0.4	0.7	0.0	100.0	3	15.1	23.3	40.4	5.0	87.5	3	6.4	4.5	3.9	4.0
Tomopteris spp.	75.0	8	1.8	0.3	0.5	0.1	62.5	6	0.5	0.8	1.7	0.2	75.0		0.3	0.2	0.2	0.2
Gymnoscopelus brauer	16.7	9	0.9	0.2	0.4	0.0	25.0		0.0	0.0	0.1	0.0	50.0	8	0.5	0.3	0.6	0.0
Clione limacina	50.0	10	0.8	0.1	0.2	0.0	62.5		0.1	0.2	0.3	0.1	0.0		0.0	0.0	0.0	0.0
Euphysora gigantea	58.3		0.8	0.1	0.2	0.1	25.0		0.0	0.1	0.1	0.0	0.0		0.0	0.0	0.0	0.0
Clio pyramidata	41.7		0.7	0.1	0.2	0.0	50.0	10	0.2	0.3	0.5	0.1	25.0		0.1	0.0	0.1	0.0
Larval Squid	33.3		0.2	0.0	0.1	0.0	37.5		0.0	0.1	0.1	0.0	62.5	10	0.3	0.2	0.5	0.1
Euphausia triacantha	25.0		0.2	0.0	0.1	0.0	37.5	4	0.7	1.1	2.0	0.0	75.0	5	4.5	3.1	4.6	0.7
Vibilia antarctica	8.3		0.1	0.0	0.0	0.0	100.0	7	0.5	0.7	1.2	0.1	25.0		0.1	0.0	0.1	0.0
Unid. Jellies	8.3		0.1	0.0	0.0	0.0	25.0		0.1	0.1	0.2	0.0	37.5	7	0.5	0.4	0.7	0.0
Total Zooplankton				18.6	12.4	15.4				154.2	273.4	48.9				69.7	33.1	58.0
Total No. Taxa				13.3	3.3	13.0				15.0	6.2	13.0				13.6	4.4	15.5

Table 4.4. Nekton and zooplankton taxa collected by RMT 1 nets during the CCAMLR 2000 survey. N is total number of individuals. F and F(%) are frequency of occurrence in 28 samples. Abundance is numbers per 1000 m3. (L) and (J) indicate larval and juvenile stages. Mean, median and max. abundance is expressed as numbers per 1000m3.

TAXON	F	F(%)	MEAN	STD	MED	MAX
Copepods	27	96.4	3983.3	4359.8	1924.0	15163.3
Thysanoessa spp. (L)	26	92.9	405.3	574.2	164.5	2188.4
Chaetognaths	24	85.7	289.0	765.3	47.8	4078.0
Thysanoessa spp.	23	82.1	4.1	6.8	0.6	29.8
E. superba (L)	22	78.6	835.3	1861.1	83.0	6797.3
Themisto gaudichaudii	20	71.4	1.0	2.4	0.2	12.6
Euphausia frigida	19	67.9	0.8	1.2	0.3	4.5
Tomopteris spp.	19	67.9	60.6	146.9	0.1	652.0
Salpa thompsoni	16	57.1	1.9	4.7	0.1	19.9
Spongiobranchaea australis	15	53.6	0.7	3.0	0.1	16.2
Ostracods	13	46.4	17.0	34.5	0.0	150.5
Electrona spp. (L)	11	39.3	0.2	0.5	0.0	2.3
Euphausia superba	10	35.7	4.0	15.0	0.0	80.6
Vibilia antarctica	10	35.7	0.0	0.1	0.0	0.3
Clio pyramidata	9	32.1	0.6	1.7	0.0	8.0
Dimophyes arctica	9	32.1	0.1	0.1	0.0	0.5
Hyperiella dilatata	8	28.6	0.6	2.3	0.0	11.5
Hyperiids	8	28.6	1.4	2.8	0.0	12.2
Diphyes antarctica	8	28.6	0.1	0.1	0.0	0.4
Euphausia triacantha	7	25.0	0.1	0.1	0.0	0.6
Primno macropa	6	21.4	0.0	0.1	0.0	0.4
Clione limacina	6	21.4	0.0	0.1	0.0	0.5
Polychaetes	6	21.4	3.8	8.9	0.0	35.5
Rhynchonereella bongraini	6	21.4	6.4	28.4	0.0	153.3
Electrona antarctica	5	17.9	0.0	0.0	0.0	0.1
Muraenolepis microps (L)	4	14.3	0.0	0.1	0.0	0.6
Cyllopus lucasii	3	10.7	0.0	0.1	0.0	0.5
Hyperoche medusarum	3	10.7	0.0	0.0	0.0	0.1
Limacina helicina	3	10.7	57.5	298.4	0.0	1608.2
Pleuragramma antarcticum (J)	2	7.1	0.0	0.0	0.0	0.1
Vanadis spp.	2	7.1	4.5	21.5	0.0	115.5
Acanthophyra pelagica	2	7.1	0.0	0.0	0.0	0.1
Bathylagus sp. (L)	2	7.1	0.0	0.0	0.0	0.1
Notolepis coatsi (L)	2	7.1	0.0	0.0	0.0	0.1
Larval fish	2	7.1	0.1	0.2	0.0	1.1
Periphylla periphylla	1	3.6	0.0	0.0	0.0	0.1
Pelagobia longicirrata	1	3.6	0.0	0.0	0.0	0.1
Vanadis antarctica	1	3.6	0.0	0.0	0.0	0.1
Notothenia spp. (L)	1	3.6	0.0	0.0	0.0	0.1
Maupasia coeca	1	3.6	0.0	0.0	0.0	0.0
Electrona carlsbergi	1	3.6	0.0	0.0	0.0	0.0
Euphausia vallentini	1	3.6	0.0	0.0	0.0	0.1
Calycopsis borchgrevinki	1	3.6	0.0	0.0	0.0	0.1
Notolepis annulata (L)	1	3.6	0.0	0.0	0.0	0.1
Orchomene plebs	1	3.6	0.0	0.1	0.0	0.3
Larval squid	1	3.6	0.0	0.0	0.0	0.2
Sipunculids	1	3.6	0.3	1.5	0.0	8.0
Cyllopus spp.	1	3.6	0.0	0.2	0.0	0.9
Lepidonotothen larseni (L)	1	3.6	0.0	0.0	0.0	0.1
Krefftichthys anderssoni (L)	1	3.6	0.0	0.0	0.0	0.1
Pasiphaea sp.	1	3.6	0.0	0.0	0.0	0.1
Hyperiella macronyx	1	3.6	0.0	0.0	0.0	0.1
Vanadis longissima	1	3.6	0.0	0.0	0.0	0.1
NO. TAXA	53		13.4	3.1	14	19

Table 4.5. Zooplankton from RMT1 samples organized according to clusters based on RMT8 station data. R is rank order of abundance for the 10 most abundant taxa in each group. N(%) is the contribution of each taxon to total mean abundance (all taxa pooled). Clusters roughly conform to three biogeographic regions ("faunistic divisions") defined by Mackintosh (1934).

	CLUSTER 1 "EASTERN SCOTIA SEA" N=12					CLUSTER 2 "GRAHAM LAND" N=8					CLUSTER 3 "TRANSITION ZONE" N=8				
TAXON	R	N(%)	MEAN	STD	MED	R	N(%)	MEAN	STD	MED	R	N(%)	MEAN	STD	MED
Copepods	1	72.1	4657.3	4881.0	5696.5	1	54.5	2210.6	3318.3	882.0	1	77.4	4745.2	4642.6	2850.6
E. superba (L)	2	10.4	674.2	139.9	184.3	2	37.1	1502.4	2441.0	15.6	3	6.7	409.7	606.9	204.8
Chaetognaths	3	8.7	559.9	198.4	207.3	5	1.1	45.0	80.3	6.9	4	2.1	126.6	131.8	71.9
Thysanoessa spp. (L)	4	4.9	316.8	1023.3	1165.1	3	3.9	157.2	203.7	90.5	2	12.8	786.0	882.7	208.0
Limacina helicina	5	2.1	134.0	0.0	0.0		0.0	0.1	0.2	0.0		0.0	0.0	0.0	0.0
Tomopteris spp.	6	1.0	64.4	81.0	81.1	4	2.3	95.1	211.5	9.4	6	0.3	20.3	53.6	0.0
Rhynchonereella bongraini	7	0.2	13.8	0.0	0.0	10	0.0	1.8	3.8	0.0		0.0	0.0	0.0	0.0
Vanadis spp.	8	0.1	9.6	0.0	0.0		0.0	1.5	3.9	0.0		0.0	0.0	0.0	0.0
Euphausia superba	9	0.1	7.9	0.5	0.5		0.0	1.4	3.7	0.0		0.0	0.6	1.6	0.0
Ostracods	10.5	0.1	6.1	39.4	41.6	6	0.5	20.3	49.3	0.0	5	0.5	30.2	34.0	14.9
Polychaetes	10.5	0.1	6.1	0.0	0.0		0.0	0.4	0.9	0.0	7	0.1	3.7	7.7	0.0
Thysanoessa spp.		0.0	3.2	0.3	0.3	7	0.2	7.4	9.7	2.8	10	0.0	2.1	2.7	0.6
Spongiobranchaea australis		0.0	1.4	0.4	0.4		0.0	0.1	0.2	0.0		0.0	0.3	0.3	0.2
Hyperiids		0.0	1.3	1.1	1.1		0.0	0.9	1.7	0.0	9	0.0	2.2	4.2	0.0
Clio pyramidata		0.0	1.2	0.0	0.0		0.0	0.4	0.6	0.1		0.0	0.0	0.0	0.0
Salpa thompsoni		0.0	0.6	0.1	0.1	8	0.1	5.8	7.4	1.5		0.0	0.0	0.1	0.0
Euphausia frigida		0.0	0.4	0.0	0.0	9	0.0	1.8	1.8	0.9		0.0	0.2	0.3	0.2
Hyperiella dilatata		0.0	0.4	0.0	0.0		0.0	1.4	3.8	0.0		0.0	0.0	0.0	0.0
Electrona spp. (L)		0.0	0.4	0.2	0.2		0.0	0.0	0.0	0.0		0.0	0.3	0.2	0.3
Muraenolepis microps (L)		0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0		0.0	0.1	0.2	0.0
TOTAL			6460.4	6362.1	7380.4			4054.5	4029.6	2413.8			6131.0	5445.7	4034.3
NO. TAXA			14.2	1.5	13.5			13.5	3.1	15.0			12.3	3.2	11.5

Table 4.6. Cape Shirreff survey IKMT tow data.

STATION #	DATE	TIME START (Local)	TIME END	DIEL	TOW DEPTH (m)	FLOW VOLUME (m^3)	KRILL ABUNDANCE TOTAL	KRILL ABUNDANCE #/m^2	KRILL ABUNDANCE #/1000m^3	SALP ABUNDANCE TOTAL	SALP ABUNDANCE #/1000m^3
YCS03.4	06/02/00	1327	1349	D	170	2104.6	67	5.4	31.8	80	38.0
YCS164	06/02/00	1608	1631	D	170	2273.6	22	1.6	9.7	53	23.3
YCS165	06/02/00	1946	2012	D	171	2523.0	20	1.4	7.9	1207	478.4
YCS166	06/02/00	2338	0003	N	172	2542.3	2	0.1	0.8	1827	718.6
YCS171	07/02/00	1328	1343	D	111	1469.6	1	0.1	0.7	40	27.2
YCS174	07/02/00	1530	1550	D	171	1687.7	12	1.2	7.1	80	47.4
YCS175	07/02/00	1901	1926	D	171	2431.7	26	1.8	10.7	36	14.8
YCS176	07/02/99	2230	2257	T	170	2579.7	0	0.0	0.0	5686	2204.1
YCS150	08/02/00	1306	1322	D	121	1392.1	21	1.8	15.1	113	81.2
YCS151	08/02/00	1633	1657	D	171	2498.3	9	0.6	3.6	86	34.4
YCS152	08/02/00	2007	2038	T	170	2748.8	0	0.0	0.0	2627	955.7
YCS153	08/02/00	2340	0008	N	170	2474.6	3	0.2	1.2	868	350.8
						12 TOWS	183	KRILL		12703	SALPS
							MEAN	1.2	7.4		414.5
							STD	1.5	8.8		618.5
							MED	0.9	5.4		64.3

Table 4.7. Zooplankton taxa collected by Cape Shirreff survey IKMT tows. F and F(%) are frequency of occurrence in 12 samples. N(%) is the proportion of total mean zooplankton abundance contributed by each taxon.

TAXON	F	F(%)	%	MEAN	STD	MEDIAN
Copepods	12	100.0	59.9	5332.6	10942.5	2175.0
Thysanoessa macrura (L)	12	100.0	15.5	1383.2	2988.6	307.9
Salpa thompsoni	12	100.0	13.5	1201.3	2658.1	81.2
Chaetognaths	12	100.0	5.6	501.0	1046.9	143.0
Euphausia superba (L)	5	41.7	0.9	82.1	142.4	0.0
Spongiobranchaea australis	10	83.3	0.8	75.3	157.5	13.0
Euphausia frigida	5	41.7	0.7	57.9	126.9	0.0
Thysanoessa macrura	11	91.7	0.6	49.6	94.8	17.0
Cyllopus magellanicus	7	58.3	0.5	42.2	81.2	0.7
Themisto gaudichaudii	11	91.7	0.4	34.4	67.3	13.4
Electrona spp. (L)	4	33.3	0.3	23.1	48.3	0.0
Hyperiella spp.	4	33.3	0.2	20.2	38.2	0.0
Euphausia superba	10	83.3	0.2	19.9	37.7	7.9
Radiolarians	1	8.3	0.1	13.1	26.7	0.0
Vibilia antarctica	11	91.7	0.1	11.1	23.6	4.0
Euphausia triacantha	4	33.3	0.1	10.8	21.9	0.0
Clio pyramidata	8	66.7	0.1	9.0	17.9	1.0
Unid.Jelly	3	25.0	0.1	8.7	18.4	0.0
Cyllopus lucasii	1	8.3	0.1	4.8	9.9	0.0
Primno macropa	2	16.7	0.0	4.4	8.9	0.0
Ostracods	1	8.3	0.0	3.5	6.8	0.0
Lepidonotothen larseni (L)	4	33.3	0.0	2.4	4.0	0.0
Lepidonotothen kempi (L)	1	8.3	0.0	2.1	4.2	0.0
Tomopteris spp.	6	50.0	0.0	1.2	2.3	0.0
Dimophyes arctica	1	8.3	0.0	1.2	2.3	0.0
Rhynchonereella bongraini	1	8.3	0.0	0.7	1.4	0.0
Clione limacina	1	8.3	0.0	0.5	1.1	0.0
Diphyes antarctica	2	16.7	0.0	0.3	0.6	0.0
Electrona antarctica	2	16.7	0.0	0.3	0.6	0.0
Notothenia coriiceps (L)	1	8.3	0.0	0.2	0.4	0.0
Beroe forskalii	1	8.3	0.0	0.2	0.4	0.0
Hyperiella dilatata	1	8.3	0.0	0.2	0.4	0.0
TOTAL				8897.3	17886.6	4099.2
NO. TAXA	32			13.9	3.1	13.5

Table 4.8. AMLR 2000 Large-area survey D IKMT station information. Double lines denote subarea divisions. N= night, D= day and T= twilight.

STATION #	DATE	TIME START (Local)	TIME END	DIEL	TOW DEPTH (m)	FLOW VOLUME (m^3)	KRILL ABUNDANCE TOTAL	KRILL ABUNDANCE #/m^2	KRILL ABUNDANCE #/1000m^3	SALP ABUNDANCE TOTAL	SALP ABUNDANCE #/1000m^3
D174	22/02/00	0435	0457	N	171	2302.4	139	10.3	60.4	75	32.6
D175	22/02/00	0754	0820	D	172	2574.5	35	2.3	13.6	8	3.1
D176	22/02/00	1122	1149	D	171	2523.6	0	0.0	0.0	161	63.8
D166	22/02/00	1456	1522	D	170	2504.2	0	0.0	0.0	14	5.6
D165	22/02/00	1910	1935	D	171	2449.4	23	1.6	9.4	365	149.0
D164	23/02/00	2131	2158	T	170	2630.0	40	2.6	15.2	732	278.3
D150	23/02/00	0134	0157	N	120	2495.7	63	3.0	25.2	181	72.5
D151	23/02/00	0455	0527	T	170	2716.5	6	0.4	2.2	398	146.5
D152	23/02/00	0829	0856	D	169	2589.5	0	0.0	0.0	860	332.1
D153	23/02/00	1201	1229	D	169	2633.6	0	0.0	0.0	0	0.0
D138	23/02/00	1548	1610	D	171	2338.5	18	1.3	7.7	59	25.2
D137	23/02/00	1914	1938	D	170	2213.1	0	0.0	0.0	2296	1037.5
D136	23/02/00	2240	2308	N	170	2623.3	799	51.8	304.6	1294	493.3
D135	24/02/00	0202	0231	N	171	2630.8	1594	103.6	605.9	1916	728.3
D014	24/02/00	0528	0553	T	175	2284.0	18	1.4	7.9	177	77.5
D116	24/02/00	0750	0820	D	171	2739.8	17	1.1	6.2	45	16.4
D123	24/02/00	1118	1143	D	170	2154.6	0	0.0	0.0	176	81.7
D124	24/02/00	1441	1509	D	171	2466.1	0	0.0	0.0	548	222.2
D125	24/02/00	1750	1818	D	170	3061.2	17	0.9	5.6	5582	1823.5
D188	24/02/00	2112	2138	T	170	2345.4	0	0.0	0.0	2676	1141.0
D111	25/02/00	0058	0126	N	171	2585.2	10	0.7	3.9	2164	837.1
D110	25/02/00	0440	0502	N	169	2192.4	4	0.3	1.8	1139	519.5
D016	25/02/00	0758	0826	D	171	2558.2	24	1.6	9.4	129	50.4
D013	25/02/00	1105	1133	D	170	2525.8	0	0.0	0.0	16	6.3
D010	25/02/00	1438	1506	D	170	2283.9	4	0.3	1.8	9	3.9
D104	25/02/00	1755	1821	D	170	2674.4	0	0.0	0.0	194	72.5
D105	25/02/00	2220	2246	N	170	2600.0	25	1.6	9.6	1659	638.1
D186	26/02/00	0200	0227	N	171	2618.9	69	4.5	26.3	476	181.8
D187	26/02/00	0543	0610	D	170	2788.2	0	0.0	0.0	94	33.7
D024	26/02/00	1324	1352	D	170	2640.9	0	0.0	0.0	617	233.6
D023	26/02/00	1607	1631	D	171	2294.3	0	0.0	0.0	392	170.9
D022	26/02/00	1844	1908	D	171	2494.4	1	0.1	0.4	888	356.0
D021	26/02/00	2124	2151	N	170	2601.8	1	0.1	0.4	652	250.6
D020	26/02/00	0014	0041	N	168	2825.0	0	0.0	0.0	226	80.0
D019	27/02/00	0325	0353	N	172	2366.1	2	0.1	0.8	671	283.6
D018	27/02/00	0617	0639	D	171	2253.9	8	0.6	3.5	2	0.9
D017	27/02/00	0846	0912	D	170	2174.4	2	0.2	0.9	105	48.3
D032	27/02/00	1116	1144	D	166	2829.0	2	0.1	0.7	0	0.0
D030	27/02/00	1546	1610	D	171	1898.3	2	0.2	1.1	396	208.6
D029	27/02/00	1848	1912	D	170	2476.9	3	0.2	1.2	858	346.4
D027	27/02/00	2320	2345	N	170	2392.1	17	1.2	7.1	317	132.5
D025	27/02/00	0351	0414	N	174	2156.1	38	3.1	17.6	727	337.2
D043	28/02/00	0701	0726	D	170	2345.6	7	0.5	3.0	1117	476.2
D042	28/02/00	0957	1024	D	170	2470.7	10	0.7	4.0	537	217.3
D041	28/02/00	1258	1323	D	170	2253.3	1	0.1	0.4	43	19.1
D040	28/02/00	1606	1629	D	171	2426.2	102	7.2	42.0	199	82.0
D039	28/02/00	1857	1924	D	170	2418.0	0	0.0	0.0	415	171.6
D038	28/02/00	2134	2157	N	170	2099.6	93	7.5	44.3	617	293.9
D037	29/02/00	0008	0033	N	168	2290.8	21	1.5	9.2	902	393.8
D036	29/02/00	0244	0310	N	170	2534.5	88	5.9	34.7	31223	12319.2
D051	29/02/00	0542	0607	D	171	2502.5	6	0.4	2.4	284	113.5
D049	29/02/00	0947	1010	D	148	2082.5	2	0.1	1.0	1580	758.7
D047	29/02/00	1403	1431	D	171	2651.0	1	0.1	0.4	182	68.7
D046	29/02/00	1648	1713	D	171	2534.8	0	0.0	0.0	588	232.0
D046	29/02/00	1648	1713	D	171	2534.8	0	0.0	0.0	588	232.0
D044	29/02/00	2109	2135	N	170	2426.7	11	0.8	4.5	1850	762.4
D059	01/03/00	0012	0039	N	173	2503.1	10	0.7	4.0	717	286.4
D058	01/03/00	0305	0332	N	170	2308.3	3	0.2	1.3	405	175.5
D057	01/03/00	0603	0629	D	171	2495.2	25	1.7	10.0	1485	595.1
D056	01/03/00	0902	0929	D	171	2471.7	17	1.2	6.9	903	365.3

Table 4.8. (Contd.)

STATION #	DATE	TIME START (Local)	END	DIEL	TOW DEPTH (m)	FLOW VOLUME (m^3)	KRILL ABUNDANCE TOTAL	$\#/m^2$	$\#/1000m^3$	SALP ABUNDANCE TOTAL	$\#/1000m^3$
D055	01/03/00	1147	1208	D	163	1955.4	0	0.0	0.0	309	158.0
D054	01/03/00	1516	1543	D	110	1944.9	0	0.0	0.0	394	202.6
D053	01/03/00	1737	1803	D	170	2509.0	0	0.0	0.0	245	97.6
D052	01/03/00	2021	2046	T	168	2268.2	1	0.1	0.4	578	254.8
D067	01/03/00	2316	2341	N	171	2128.9	11	0.9	5.2	664	311.9
D065	02/03/00	0307	0334	N	173	2460.9	188	13.2	76.4	454	184.5
D064	02/03/00	0747	0813	D	170	2298.7	72	5.3	31.3	685	298.0
D062	02/03/00	1223	1250	D	174	2696.3	8	0.5	3.0	210	77.9
D060	02/03/00	1648	1713	D	171	2403.5	26	1.8	10.8	675	280.8
D075	02/03/00	1901	1925	D	170	2280.1	16	1.2	7.0	592	259.6
D074	02/03/00	2257	2324	N	170	2395.6	51	3.6	21.3	494	206.2
D073	03/03/00	0223	0251	N	172	2542.6	34	2.3	13.4	405	159.3
D072	03/03/00	0543	0609	D	172	2352.0	33	2.4	14.0	599	254.7
D071	03/03/00	0842	0908	D	165	2045.5	146	11.8	71.4	908	443.9
D070	03/03/00	1131	1159	D	170	2467.6	1	0.0	0.0	288	116.7
D069	03/03/00	1423	1447	D	171	2411.9	0	0.0	0.0	112	46.4
D068	03/03/00	1702	1729	D	171	2171.9	0	0.0	0.0	804	370.2
D083	03/03/00	1941	2007	D	170	2228.8	0	0.0	0.0	53603	24050.3
D081	04/03/00	0001	0025	N	172	1980.2	2	0.2	1.0	536	270.7
D079	04/03/00	0431	0456	T	170	2284.8	39	2.9	17.1	1092	477.9
D078	04/03/00	0736	0803	D	170	2203.8	55	4.2	25.0	656	297.7
D076	04/03/00	1201	1228	D	170	2393.8	30	2.1	12.5	572	238.9
D091	06/03/00	1507	1531	D	171	2095.0	32	2.6	15.3	522	249.2
D090	04/03/00	1744	1807	D	172	2273.6	55	4.2	24.2	1132	497.9
D089	04/03/00	2023	2049	T	171	2448.7	10	0.7	4.1	5901	2409.8
D088	04/03/00	2300	2329	N	170	2591.9	657	43.1	253.5	2301	887.8
D087	05/03/00	0132	0209	N	171	2428.4	125	8.8	51.5	698	287.4
D086	05/03/00	0423	0449	N	173	2573.8	10	0.7	3.9	685	266.1
D085	05/03/00	0738	0806	D	168	2608.9	4	0.3	1.5	1520	2171.4
D084	05/03/00	1048	1113	D	171	2325.0	3	0.2	1.3	1393	2532.7
D109	06/03/00	0110	0138	N	177	2502.0	89	6.3	35.6	1463	1741.7
D007	06/03/00	0454	0519	N	171	2487.9	4	0.3	1.6	1640	841.0
D003	06/03/00	0909	0935	D	169	2983.9	2	0.1	0.7	47	84.2
D005	06/03/00	1235	1302	D	171	2539.7	1	0.1	0.4	1031	557.3
D121	06/03/00	1559	1623	D	170	2434.3	8	0.6	3.3	1577	3391.4
D133	06/03/00	1903	1929	D	171	2392.7	20	1.4	8.4	2254	2683.3
D134	06/03/00	2206	2231	N	170	2308.9	7	0.1	3.0	7735	8594.4
D001	07/03/00	0152	0220	N	169	2797.5	2	0.1	0.7	518	370.0

		KRILL TOTAL	$\#/m^2$	$\#/1000m^3$	SALP TOTAL	$\#/1000m^3$
SURVEY AREA D		5120			167633	
N = 97	MEAN		3.6	21.0		881.2
	STD		12.4	72.6		2840.2
	MEDIAN		0.4	2.4		232.0
WEST AREA		2905			23443	
N = 29	MEAN		6.5	38.5		312.9
	STD		20.6	120.7		430.0
	MEDIAN		0.7	3.9		81.7
ELEPHANT ISLAND		2082			127925	
N = 60	MEAN		2.5	14.4		969.0
	STD		6.0	35.3		3407.1
	MEDIAN		0.6	3.3		257.2
SOUTH AREA		133			16265	
N = 8	MEAN		1.1	6.7		2282.9
	STD		2.0	11.2		2623.6
	MEDIAN		0.2	2.3		1291.3

Table 4.9. Maturity stage composition of krill collected in the large survey area D and three subareas, February-March 2000. Advanced maturity stages are proportions of mature females that are 3d-3e (Makarov and Denys, 1981).

	E. superba February-March 2000			
Area	Survey D	Elephant I.	West	South
Stage	%	%	%	%
Juveniles	0.1	0.1	0.0	0.0
Immature	1.9	2.3	1.4	4.4
Mature	98.1	97.5	98.6	95.6
Females:				
F2	0.1	0.2	0.0	0.8
F3a	0.6	1.0	0.2	4.2
F3b	0.6	0.7	0.6	0.0
F3c	7.8	6.5	8.3	15.8
F3d	23.0	21.9	22.3	53.3
F3e	11.2	22.0	3.2	5.8
Advanced Stages	79.2	84.2	73.8	74.7
Males:				
M2a	0.1	0.1	0.2	0.0
M2b	0.5	0.7	0.3	2.1
M2c	1.1	1.3	0.9	1.5
M3a	7.6	7.4	8.0	1.5
M3b	47.3	38.0	56.1	15.0
Male:Female	1.3	0.9	1.9	0.3
No. measured	2167	1371	663	133

Table 4.10. Abundance relations of dominant zooplankton taxa in the large survey area and three subareas, February-March 2000. Only the 20 most abundant taxa are considered. F(%) is frequency of occurrence in N samples. Abundance ranks (R) are provided for the 10 most abundant taxa in each subarea. N(%) is proportion of total mean abundance provided by each taxon. (L) indicates larval form.

	SURVEY D N=97						ELEPHANT ISLAND AREA N=60						WEST AREA N=29						SOUTH AREA N=8					
TAXA	F(%)	R	N(%)	MEAN	STD	MED	F(%)	R	N(%)	MEAN	STD	MED	F(%)	R	N(%)	MEAN	STD	MED	F(%)	R	N(%)	MEAN	STD	MED
Copepods	99.0	1	59.5	7038.7	9979.9	3689.2	98.3	1	51.4	8019.1	11824.4	3478.0	100.0	1	76.5	6099.9	5733.8	4516.4	100.0	1	71.3	3088.8	3720.1	1520.7
Euphausia superba (L)	80.4	2	18.0	2129.6	7247.8	34.2	96.7	2	21.9	3423.2	8974.1	248.7	55.2	7	0.5	37.8	75.2	9.5	50.0	7	0.3	11.1	11.2	9.6
Thysanoessa macrura (L)	82.5	3	7.5	883.9	3317.6	47.7	78.3	3	7.0	1084.8	4147.3	26.8	100.0	2	8.9	710.2	950.2	209.7	50.0	9	0.2	7.6	9.9	0.8
Salpa thompsoni	96.9	4	6.1	726.2	2709.5	254.7	98.3	4	5.9	912.8	3395.1	262.9	93.1	4	3.8	306.7	433.2	77.5	100.0	2	19.6	847.8	984.2	616.3
Chaetognaths	91.8	5	5.4	632.8	1251.8	263.0	90.0	5	5.1	792.3	1543.7	229.4	100.0	3	5.5	440.4	379.9	346.4	75.0	4	3.1	133.4	165.1	62.1
Limacina helicina	45.4	6	1.7	205.4	1832.5	0.0	43.3	6	2.1	327.6	2321.4	0.0	51.7		0.1	9.2	36.5	0.4	37.5		0.0	0.2	0.3	0.0
Euphausia frigida	67.0	7	0.4	49.9	80.9	7.5	70.0	7	0.3	43.1	73.0	6.8	58.6	5	0.9	74.1	98.5	17.4	75.0	6	0.3	13.3	18.5	5.9
Thysanoessa macrura	92.8	8	0.4	41.5	75.6	15.3	91.7	8	0.2	35.1	61.5	14.0	93.1	8	0.3	24.7	37.8	6.5	100.0	3	3.5	150.6	150.5	113.0
Ostracods	45.4	9	0.2	25.1	61.0	0.0	46.7	9	0.2	29.6	72.9	0.0	37.9	10	0.2	15.6	30.1	0.0	62.5	5	0.6	25.3	38.6	1.7
Euphausia superba	77.3	10	0.2	21.0	72.6	3.0	81.7	11	0.1	14.4	35.3	3.3	62.1	6	0.5	38.5	120.7	3.9	100.0	10	0.2	6.9	11.4	2.3
Vibilia antarctica	95.9		0.2	20.2	43.7	5.3	98.3	10	0.2	27.1	53.2	6.6	89.7		0.1	8.7	16.6	2.6	100.0	8	0.3	10.8	6.9	10.6
Cyllopus magellanicus	87.6		0.1	10.0	15.0	4.2	91.7		0.1	10.0	11.9	4.7	79.3		0.1	11.5	21.1	3.7	87.5		0.1	4.9	5.5	3.5
Themisto gaudichaudii	83.5		0.1	7.2	15.0	2.5	78.3		0.0	3.4	5.7	1.8	96.6	9	0.2	16.3	23.8	4.6	75.0		0.0	2.0	3.2	1.1
Euphausia spp. larvae	11.3		0.0	4.3	21.7	0.0	15.0		0.0	6.0	26.7	0.0	3.4		0.0	1.7	8.8	0.0	12.5		0.0	0.8	2.1	0.0
Electrona spp. (L)	43.3		0.0	4.0	14.2	0.0	53.3		0.0	4.5	15.0	0.4	27.6		0.0	3.9	14.4	0.0	25.0		0.0	0.2	0.3	0.0
Primno macropa	44.3		0.0	3.2	10.6	0.0	43.3		0.0	3.2	11.0	0.0	55.2		0.1	4.1	10.9	0.4	12.5		0.0	0.0	0.1	0.0
Cyllopus spp.	25.8		0.0	2.9	10.2	0.0	20.0		0.0	0.2	0.5	0.0	41.4		0.1	9.2	17.1	0.0	12.5		0.0	0.2	0.5	0.0
Spongiobranchaea australis	68.0		0.0	2.7	4.2	1.4	60.0		0.0	1.9	3.1	0.6	89.7		0.0	3.8	4.1	2.3	50.0		0.1	5.4	8.1	0.4
Tomopteris spp.	23.7		0.0	2.3	11.7	0.0	18.3		0.0	2.2	13.4	0.0	31.0		0.0	1.5	4.3	0.0	37.5		0.1	6.1	14.9	0.0
Euphausia triacantha	25.8		0.0	1.9	6.3	0.0	25.0		0.0	1.4	4.5	0.0	31.0		0.0	3.4	9.4	0.0	12.5		0.0	0.0	0.1	0.0
Orchomene spp.	1.0		0.0	1.3	12.9	0.0	0.0		0.0	0.0	0.0	0.0	3.4		0.1	4.4	23.4	0.0	0.0		0.0	0.0	0.0	0.0
Orchomene plebs	2.1		0.0	0.8	8.2	0.0	0.0		0.0	0.0	0.0	0.0	6.9		0.0	2.8	14.8	0.0	0.0		0.0	0.0	0.0	0.0
Pasiphea spp.	1.0		0.0	0.8	7.8	0.0	1.7		0.0	1.3	9.8	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Pelagobia longicirrata	5.2		0.0	0.6	4.2	0.0	8.3		0.0	1.0	5.3	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Ihlea racovitzai	13.4		0.0	0.6	2.4	0.0	15.0		0.0	0.6	1.9	0.0	0.0		0.0	0.0	0.0	0.0	50.0		0.1	3.2	5.7	0.4
Dimophyes arctica	15.5		0.0	0.6	2.3	0.0	15.0		0.0	0.6	2.4	0.0	13.8		0.0	0.6	2.1	0.0	25.0		0.0	0.8	1.5	0.0
Rhynchonereella bongraini	5.2		0.0	0.6	3.7	0.0	6.7		0.0	0.4	1.9	0.0	3.4		0.0	1.2	6.2	0.0	0.0		0.0	0.0	0.0	0.0
Diphyes antarctica	21.6		0.0	0.4	1.0	0.0	23.3		0.0	0.4	1.1	0.0	10.3		0.0	0.0	0.1	0.0	50.0		0.0	1.3	1.4	0.8
Hyperiella dilatata	22.7		0.0	0.4	1.8	0.0	10.0		0.0	0.0	0.2	0.0	51.7		0.0	1.1	3.2	0.4	12.5		0.0	0.0	0.1	0.0

Table 4.11. Dominant zooplankton taxa comprising two assemblages in the Survey D area, February-March 2000. R is ranked mean abundance. N(%) is percent contribution to total mean zooplankton abundance by each taxon. Asterisks denote significant abundance differences based on Analysis of Variance: *** P=0.000; ** P <0.01; *P<0.05.

	CLUSTER 1 N=58					CLUSTER 2 N = 39				
TAXA	R	N(%)	MEAN	STD	MEDIAN	R	N(%)	MEAN	STD	MEDIAN
Calanoides acutus	4	4.6	309.8	821.8	64.8	1	19.1	***3713.0	3624.8	2245.2
Metridia gerlachi	2	32.2	2177.1	3662.3	545.9	2	17.1	3330.1	4462.4	1670.5
Other copepods	5	4.2	284.4	390.4	111.8	3	11.5	***2231.2	3324.7	1354.2
Thysanoessa macrura (L)		0.5	33.5	80.4	8.2	4	11.1	**2148.6	4969.0	1025.3
Rhincalanus gigas	8	1.7	112.0	347.9	29.3	5	10.0	***1938.6	2807.5	546.1
Euphausia superba (L)	1	34.3	2322.8	8305.5	24.0	6	9.5	1842.4	5284.5	141.3
Calanus propinquus	7	1.8	119.0	187.0	49.5	7	8.4	***1626.9	1777.8	1062.7
Chaetognaths	6	2.8	189.0	283.6	89.7	8	6.7	***1292.8	1746.1	768.2
Limacina helicina		0.0	1.9	5.6	0.0	9	2.6	508.0	2863.3	0.0
Salpa thompsoni	3	14.6	987.8	3466.7	262.9	10	1.7	337.3	365.5	232.0
Pareucheata sp.		0.4	25.3	62.9	0.0		0.7	**129.8	299.3	0.0
Euphausia frigida	10	0.7	46.5	74.5	10.5		0.3	55.0	89.3	1.5
Ostracods		0.2	11.4	23.2	0.0		0.2	**45.4	88.0	7.2
Vibilia antarctica		0.2	11.2	29.4	4.4		0.2	**33.7	56.2	8.8
Pleuromama robusta		0.0	2.9	14.5	0.0		0.1	**22.9	55.0	0.0
Cyllopus magellanicus		0.1	5.0	9.1	1.9		0.1	***17.3	18.7	13.8
Themisto gaudichaudii		0.0	2.6	3.9	1.3		0.1	***14.0	21.5	5.0
Euphausia superba		0.4	26.8	84.8	4.6		0.1	12.3	48.1	1.3
Thysanoessa macrura	9	0.9	***64.0	90.2	36.6		0.0	8.1	16.0	2.5
Electrona spp. (L)		0.0	1.3	5.4	0.0		0.0	*7.9	20.8	0.0
Primno macropa		0.0	0.8	2.2	0.0		0.0	**6.8	15.8	0.4
Cyllopus spp.		0.0	0.2	0.7	0.0		0.0	**6.8	15.2	0.0
Haloptilus ocellatus		0.0	1.0	6.1	0.0	18	0.0	5.5	23.4	0.0
Euphausia triacantha		0.0	0.3	1.5	0.0		0.0	**4.2	9.3	0.0
Spongiobranchaea australis		0.0	2.0	4.2	0.4		0.0	*3.8	3.9	2.5
Tomopteris spp.		0.0	1.3	6.0	0.0		0.0	3.8	16.8	0.0
Rhynchonereella bongraini		0.0	0.3	1.7	0.0		0.0	1.1	5.4	0.0
Dimophyes arctica		0.0	*1.0	2.9	0.0		0.0	0.0	0.1	0.0
Siphonophores		0.1	3.9	14.5	0.0		0.0	0.0	0.1	0.0
Ihlea racovitzai		0.0	***1.0	3.0	0.0		0.0	0.0	0.0	0.0
TOTAL			6766.4	11869.6	2243.9			19422.8	21009.8	11939.5
NO. TAXA			16.3	4.0	16.0			17.8	3.3	18.0

Table 4.12. Zooplankton taxa present in large survey area samples during February-March 2000 compared to February-March 1994-1999. F (%) is frequenc of occurrence in (N) samples. n.a. indicates taxon was not enumerated. (L) and (J) indicate larval and juvenile stages. Total copepods include listed taxa.

	February-March													
	2000		1999		1998		1997		1996		1995		1994	
Taxon	F(%) (97)	Mean No.	F(%) (67)	Mean No.	F(%) (104)	Mean No.	F(%) (16)	Mean No.	F(%) (91)	Mean No.	F(%) (89)	Mean No.	F(%) (89)	Mean No.
Copepods (Total)	99.0	7038.7	100.0	1454.5	97.1	119.0	100.0	1267.8	98.9	1387.0	100.0	3189.1	89.9	3090.2
Other copepods	99.0	1067.1	100.0	90.3	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Metridia gerlachi	97.9	2640.7	98.5	447.8	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Calanoides acutus	97.9	1678.1	98.5	503.1	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Calanus propinquus	93.8	725.3	100.0	241.5	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Rhincalanus gigas	92.8	846.4	98.5	171.8	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Pareucheata sp.	38.1	67.4	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Pleuromama robusta	12.4	10.9	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Haloptilus ocellatus	7.2	2.8	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Salpa thompsoni	96.9	726.2	100.0	248.1	98.1	689.1	100.0	1245.5	62.6	28.2	59.6	16.5	98.9	523.5
Vibilia antarctica	95.9	20.2	98.5	3.6	96.2	8.0	81.3	8.1	48.4	1.0	23.6	0.2	85.4	6.4
Thysanoessa macrura	92.8	41.5	98.5	93.1	100.0	177.4	100.0	181.3	91.2	143.3	93.3	161.3	91.0	118.9
Chaetognaths	91.8	632.8	91.0	127.4	61.5	10.7	75.0	18.2	93.4	64.1	100.0	296.4	n.a.	n.a.
Cyllopus magellanicus	87.6	10.0	95.5	4.8	81.7	5.6	93.8	3.3	46.2	2.1	25.8	0.7	79.8	4.4
Themisto gaudichaudii	83.5	7.2	32.8	0.2	32.7	0.3	87.5	2.9	91.2	2.5	74.2	3.6	94.4	11.8
Thysanoessa macrura (L)	82.5	883.9	74.6	137.4	13.5	2.6	50.0	10.8	87.9	414.4	79.8	276.9	n.a.	n.a.
Euphausia superba (L)	80.4	2129.6	80.6	49.8	12.5	1.6	37.5	25.0	62.6	13.9	93.3	3690.0	n.a.	n.a.
Euphausia superba	77.3	21.0	61.2	24.4	89.4	133.5	68.8	30.4	86.8	106.7	78.7	5.7	66.3	18.4
Spongiobranchaea australis	68.0	2.7	65.7	1.0	38.5	0.8	43.8	2.8	68.1	1.4	60.7	0.4	14.6	0.1
Euphausia frigida	67.0	49.9	64.2	20.0	29.8	9.3	68.8	44.8	54.9	9.0	60.7	16.7	61.8	25.9
Ostracods	45.4	25.1	80.6	14.0	43.3	5.4	56.3	4.8	47.3	10.1	75.3	43.4	n.a.	n.a.
Limacina helicina	45.4	205.4	26.9	1.9	37.5	0.8	---	---	24.2	1.9	4.5	0.0	---	---
Primno macropa	44.3	3.2	65.7	2.6	49.0	1.9	18.8	0.5	63.7	3.5	31.5	0.4	10.1	0.1
Electrona spp. (L)	43.3	4.0	20.9	0.3	10.6	0.2	12.5	0.1	38.5	0.9	62.9	5.2	11.2	0.2
Lepidonotothen kempi (L)	29.9	0.3	16.4	0.1	22.1	0.2	6.3	0.2	39.6	0.4	48.3	0.4	6.7	0.1
Euphausia triacantha	25.8	1.9	22.4	1.8	11.5	0.6	43.8	0.9	22.0	0.8	28.1	1.6	11.2	1.0
Cyllopus spp.	25.8	2.9	---	---	24.0	0.7	24.0	0.7	---	---	---	---	---	---
Tomopteris spp.	23.7	2.3	55.2	2.8	8.7	0.0	31.3	0.5	38.5	0.9	57.3	1.3	24.7	0.6
Hydromedusae	23.7	0.5	40.3	0.3	12.5	0.2	12.5	0.2	3.3	0.1	5.6	0.0	---	---
Hyperiella dilatata	22.7	0.4	56.7	1.2	34.6	0.4	25.0	0.2	52.7	0.8	24.7	0.1	36.0	0.6
Diphyes antarctica	21.6	0.4	31.3	0.3	29.8	0.4	6.3	0.3	7.7	0.1	23.6	0.4	13.5	0.1
Amphipods (unid)	18.6	7.4	---	---	---	---	---	---	---	---	---	---	---	---
Polychaetes	18.6	2.6	7.5	0.3	13.5	0.3	---	---	3.3	0.1	2.2	0.0	---	---
Electrona antarctica	15.5	0.1	6.0	0.0	8.7	0.0	31.3	0.2	20.9	0.2	15.7	0.1	13.5	0.1
Dimophyes arctica	15.5	0.6	---	---	16.3	0.4	12.5	0.1	13.2	0.1	13.5	0.3	10.1	0.0
Pegantha martgon	13.4	0.2	---	---	---	---	---	---	---	---	---	---	---	---
Ihlea racovitzai	13.4	0.6	26.9	5.1	61.5	51.5	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Beroe forskalii	13.4	0.1	9.0	0.0	2.9	0.0	---	---	---	---	1.1	0.0	3.4	0.1
Calycopsis borchgrevinki	13.4	0.2	19.4	0.4	4.8	0.0	6.3	0.0	6.6	0.0	11.2	0.0	10.1	0.1
Sipunculids	12.4	0.1	11.9	0.0	4.8	0.1	6.3	0.0	8.8	0.1	9.0	0.0	3.4	0.0
Euphausia spp. (L)	11.3	4.3	13.4	1.5	---	---	---	---	---	---	---	---	---	---
Siphonophores	10.3	2.3	---	---	---	---	---	---	---	---	---	---	---	---
Hyperiella spp.	9.3	0.3	9.0	0.1	1.0	0.0	---	---	---	---	---	---	---	---
Gymnoscopelus braueri	8.2	0.1	7.5	0.1	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Hyperiids (unid)	8.2	2.2	---	---	---	---	---	---	---	---	---	---	---	---
Notolepis coatsi (L)	6.2	0.0	---	---	4.8	0.0	---	---	18.7	0.1	36.0	0.2	---	---
Larval fish (unid.)	6.2	0.6	14.9	0.7	1.9	0.1	---	---	1.1	0.0	---	---	---	---
Ctenophores	6.2	0.1	4.5	0.0	---	---	6.3	0.0	1.1	0.0	3.4	0.0	---	---
Clione limacina	5.2	0.0	3.0	0.0	10.6	0.1	12.5	0.0	15.4	0.2	---	---	---	---
Clio pyramidata	5.2	0.0	13.4	0.1	---	---	---	---	3.3	0.0	12.4	0.0	9.0	0.2
Pelagobia longicirrata	5.2	0.6	---	---	---	---	---	---	---	---	---	---	---	---
Rhynchonereella bongraini	5.2	0.6	31.3	2.3	1.0	0.0	----	----	5.5	0.1	20.2	0.1	---	---
Vanadis antarctica	4.1	0.1	1.5	0.0	3.8	0.1	---	---	1.1	0.0	6.7	0.0	7.9	0.1
Gastropods	4.1	17.6	6.0	0.5	1.9	0.0	---	---	---	---	---	---	---	---
Cyllopus lucasii	4.1	0.0	29.9	0.2	57.7	1.6	93.8	2.4	34.1	0.2	23.6	0.5	89.9	6.1
Euphausia spp.	4.1	0.7	---	---	---	---	---	---	---	---	---	---	---	---
Cyphocaris richardi	3.1	0.0	1.5	0.0	---	---	---	---	1.1	0.0	3.4	0.1	---	---
Lepidonotothen larseni (L)	3.1	0.0	11.9	0.0	13.5	0.1	---	---	13.2	0.3	10.1	0.0	---	---
Hyperoche medusarum	3.1	0.0	4.5	0.0	---	---	12.5	0.3	2.2	0.0	12.4	0.0	---	---

Table 4.12 (Contd.)

	February-March													
	2000		1999		1998		1997		1996		1995		1994	
Taxon	F(%)	Mean	F(%)	Mean	F(%)	Mean	F(%)	Mean	F(%)	Mean	F(%)	Mean	F(%)	Mean
Beroe cucumis	2.1	0.0	9.0	0.0	4.8	0.0	---	---	11.0	0.1	4.5	0.0	2.2	0.0
Cephalopods	2.1	0.0	4.5	0.0	1.9	0.0	---	---	9.9	0.0	---	---	---	---
Leusia sp.	2.1	0.0	---	---	---	---	---	---	---	---	---	---	---	---
Larvaceans	2.1	0.3	4.5	0.8	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Bolinopsis infundiluus	2.1	0.0	---	---	---	---	---	---	---	---	---	---	---	---
Epimeriella macronyx	2.1	0.1	---	---	---	---	---	---	1.1	0.0	5.6	0.6	---	---
Orchomene plebs	2.1	0.8	---	---	1.9	0.0	---	---	2.2	0.0	3.4	0.0	2.2	0.1
Gobionotothen gibberifrons (L)	2.1	0.0	---	---	---	---	---	---	---	---	---	---	---	---
Gymnoscopelus nicholsi	1.0	0.0	1.5	0.0	1.0	0.0	12.5	0.1	3.3	0.0	1.1	0.0	---	---
Chionodraco rastrospinosus (L)	1.0	0.0	---	---	---	---	---	---	---	---	---	---	---	---
Harpagifer antarcticus	1.0	0.0	---	---	---	---	---	---	1.1	0.0	---	---	---	---
Eusirus perdentatus	1.0	0.0	---	---	1.0	0.0	---	---	2.2	0.0	6.7	0.1	---	---
Solomondella sp.	1.0	0.0	---	---	---	---	---	---	---	---	---	---	---	---
Champsocephalus gunnari (L)	1.0	0.0	---	---	---	---	---	---	---	---	1.1	0.0	---	---
Promyctophum bolini	1.0	0.0	---	---	---	---	---	---	---	---	---	---	---	---
Mysids	1.0	0.0	1.5	0.0	---	---	---	---	---	---	---	---	---	---
Orchomene spp.	1.0	1.3	---	---	---	---	---	---	---	---	---	---	---	---
Pasiphea sp.	1.0	0.8	---	---	---	---	---	---	---	---	---	---	---	---
Gammarids	1.0	0.0	---	---	---	---	---	---	---	---	---	---	---	---
Eusirus antarcticus	1.0	0.0	1.5	0.0	1.9	0.0	---	---	---	---	---	---	---	---
Scina spp.	1.0	0.0	1.5	0.0	---	---	6.3	0.5	2.2	0.0	1.1	0.0	---	---
Electrona carlsbergi	1.0	0.0	4.5	0.0	1.9	0.0	---	---	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Bylgides pelagica	---	---	---	---	1.0	0.0	---	---	---	---	2.2	0.0	---	---
Hyperia spp.	---	---	---	---	---	---	---	---	1.1	0.1	---	---	---	---
Hyperia macrocephala	---	---	---	---	1.9	0.0	---	---	1.1	0.0	5.6	0.0	---	---
Hyperiella macronyx	---	---	1.5	0.0	---	---	6.3	0.0	6.6	0.1	13.5	0.0	---	---
Lepidonothen larseni (J)	---	---	---	---	---	---	---	---	---	---	1.1	0.0	---	---
Krefftichthys anderssoni (L)	---	---	---	---	1.0	0.0	---	---	---	---	---	---	---	---
Eusirus microps	---	---	---	---	---	---	---	---	3.3	0.0	---	---	---	---
Decapod larvae	---	---	---	---	---	---	---	---	1.1	0.0	---	---	---	---
Fish eggs	---	---	1.5	0.0	1.0	0.0	---	---	---	---	1.1	0.0	7.9	0.1
Gymnoscopelus sp.	---	---	---	---	1.9	0.0	---	---	---	---	---	---	---	---
Gymnoscopelus opisthopteris	---	---	---	---	---	---	---	---	3.3	0.0	10.1	0.0	2.2	0.0
Lepidonotothen nudifrons (L)	---	---	---	---	---	---	---	---	1.1	0.0	3.4	0.0	---	---
Pleuragramma antarcticum	---	---	---	---	2.9	0.0	---	---	1.1	0.0	2.2	0.0	---	---
Periphylla periphylla	---	---	1.5	0.0	---	---	---	---	1.1	0.0	1.1	0.0	3.4	0.0
Rhynchonereella sp.	---	---	---	---	1.0	0.0	---	---	---	---	---	---	---	---
Travisiopsis coniceps	---	---	---	---	---	---	---	---	1.1	0.0	1.1	0.0	---	---
Schyphomedusae	---	---	---	---	1.9	0.0	12.5	0.0	19.8	0.1	13.5	0.1	---	---
Notolepis spp. (L)	---	---	7.5	0.0	---	---	---	---	---	---	2.2	0.0	5.6	0.0
Notolepis annulata (L)	---	---	---	---	---	---	6.3	0.0	5.5	0.0	3.4	0.0	---	---
Orchomene rossi	---	---	1.5	0.0	1.0	0.0	---	---	5.5	0.5	6.7	0.0	---	---
Pagothenia brachysoma	---	---	---	---	1.9	0.0	---	---	---	---	---	---	---	---
Pagetopsis macropterus	---	---	---	---	---	---	---	---	---	---	1.1	0.0	---	---
Atolla wyvillei	---	---	---	---	---	---	---	---	1.1	0.0	---	---	---	---
Cumaceans	---	---	---	---	---	---	---	---	1.1	0.0	---	---	---	---
Bathylagus antarcticus	---	---	3.0	0.0	---	---	---	---	---	---	---	---	---	---
Bathylagus sp.	---	---	---	---	---	---	6.3	0.0	1.1	0.0	14.6	0.0	---	---
Chorismus antarcticus	---	---	1.5	0.0	---	---	---	---	---	---	---	---	---	---
Acanthephyra pelagica (L)	---	---	3.0	0.0	1.0	0.0	---	---	---	---	5.6	0.0	---	---
Artedidraco skottsbergi (L)	---	---	---	---	1.0	0.0	---	---	---	---	---	---	---	---
Chaenodraco wilsoni	---	---	---	---	1.0	0.0	---	---	---	---	---	---	---	---
TOTAL		11855.1		2204.4		1224.1		2853.3		2195.8		7716.6		3813.1
TOTAL TAXA	80		63		60		37		63		62		32	

Table 4.13. Maturity stage composition of krill collected in the Elephant Island area during February-March 2000 compared to 1992-1999. Advanced maturity stages are proportions of mature females that are 3d-3e.

	E. superba February-March								
Stage	1992 %	1993 %	1994 %	1995 %	1996 %	1997 %	1998 %	1999 %	2000 %
Juveniles	33.6	3.5	3.7	1.1	20.8	8.0	3.6	0.0	0.1
Immature	27.1	51.4	6.2	2.5	9.9	19.7	25.4	1.3	2.3
Mature	39.2	45.1	90.1	96.4	69.3	72.3	71.0	98.7	97.5
Females:									
F2	0.8	21.8	0.7	0.3	0.6	1.1	6.9	0.0	0.2
F3a	10.3	12.4	3.5	0.0	0.0	0.1	10.9	0.4	1.0
F3b	10.2	6.2	7.8	0.0	0.0	0.0	11.8	0.0	0.7
F3c	4.3	3.7	4.3	2.0	5.0	1.8	3.0	11.1	6.5
F3d	1.2	1.1	4.6	21.8	10.9	29.1	1.3	47.3	21.9
F3e	<0.01	1.2	0.9	20.4	4.9	7.3	0.1	4.8	22.0
Advanced Stages	4.6	9.3	26.1	95.5	76.0	95.0	5.2	81.8	84.2
Males:									
M2a	4.3	6.9	0.2	0.7	6.5	8.6	1.9	0.0	0.1
M2b	19.8	19.1	1.2	0.4	1.2	8.8	6.6	0.7	0.7
M2c	2.2	3.6	4.2	1.1	1.6	1.2	10.0	0.6	1.3
M3a	2.5	2.1	24.1	4.4	5.3	3.7	17.5	2.6	7.4
M3b	10.7	18.4	44.7	47.8	43.2	30.3	26.2	32.4	38.0
Male:Female ratio	1.5	1.1	3.4	1.2	2.7	1.3	1.9	0.6	0.9
No. measured	3646	3669	1155	1271	2984	560	3153	1176	1371

Table 4.14. Abundance of krill and other dominant zooplankton taxa collected in the Elephant Island area during January-February and February-March surveys, 1992-2000. Zooplankton data are not available for February-March 1992 or January 2000.

	Euphausia superba								
	January-February								
Year	1992	1993	1994	1995	1996	1997	1998	1999	2000
N	63	70	63	71	72	71	61	40	
Mean	23.7	28.8	34.5	9.5	82.1	29.6	27.1	5.3	n.a.
SD	78.0	64.4	94.2	20.6	245.1	80.5	42.3	8.1	n.a.
Med	5.7	8.2	3.1	3.6	11.4	5.6	10.2	1.7	n.a.
Max	594.1	438.9	495.9	146.1	1500.6	483.2	175.0	35.1	n.a.
	February-March								
Year	1992	1993	1994	1995	1996	1997	1998	1999	2000
N	67	67	70	71	72	16	61	39	60
Mean	38.0	35.0	17.1	5.2	133.2	30.4	162.6	35.5	14.4
SD	77.4	89.7	63.5	12.0	867.7	56.4	768.3	155.7	35.3
Med	7.1	3.0	0.4	1.2	4.1	4.6	4.5	.0.8	3.3
Max	389.9	542.0	371.1	90.0	7385.4	204.2	5667.0	978.6	253.5

Thysanoessa macrura								
January-February								
1992	1993	1994	1995	1996	1997	1998	1999	2000
63	70	63	71	72	71	61	40	
48.1	48.6	74.6	104.1	103.4	101.0	135.3	46.6	n.a.
57.0	60.1	144.3	231.9	118.1	127.2	150.8	54.1	n.a.
22.5	27.5	25.4	36.1	52.3	52.8	98.0	23.2	n.a.
233.7	307.1	901.6	1859.0	500.1	616.2	992.3	215.8	n.a.
February-March								
1992	1993	1994	1995	1996	1997	1998	1999	2000
	67	70	71	72	16	61	39	60
n.a.	128.9	77.1	79.7	116.1	181.3	140.6	95.2	35.1
n.a.	235.1	132.6	138.5	147.4	168.0	232.3	131.9	61.5
n.a.	22.1	23.8	22.2	53.6	122.6	70.0	18.0	14.0
n.a.	1141.5	815.9	664.9	679.4	538.9	1638.5	589.2	291.6

	Salpa thompsoni								
	January-February								
Year	1992	1993	1994	1995	1996	1997	1998	1999	2000
N	63	70	63	71	72	71	61	40	
Mean	94.3	1213.4	931.9	20.2	25.5	223.2	939.7	197.5	n.a.
SD	192.3	2536.7	950.2	46.5	36.3	336.4	1556.3	191.6	n.a.
Med	14.0	245.8	582.3	1.6	10.5	87.1	348.9	159.1	n.a.
Max	1231.1	16078.8	4781.7	239.9	161.6	2006.3	8030.4	873.4	n.a.
	February-March								
Year	1992	1993	1994	1995	1996	1997	1998	1999	2000
N	67	67	70	71	72	16	61	39	60
Mean	n.a.	1585.9	495.1	20.6	33.2	1245.5	977.3	309.1	912.8
SD	n.a.	2725.5	579.4	66.5	85.7	1224.6	1496.5	376	3395.1
Med	n.a.	605.9	242.6	0.7	5.6	521.0	553.8	160.7	262.9
Max	n.a.	16662.5	2377.5	391.9	659.4	4348.3	10712.9	1550.2	24031.9

Copepods								
January-February								
1992	1993	1994	1995	1996	1997	1998	1999	2000
63	70	63	71	72	71	61	40	
n.a	73.5	32.4	741.0	897.5	656.4	41.2	928.2	n.a.
n.a	302.7	92.2	1061.3	1726.4	799.1	55.1	1590.8	n.a.
n.a	0.0	0.0	346.0	338.2	399.7	21.5	333.0	n.a.
n.a	2312.6	465.3	7047.5	10598.0	4090.0	276.0	7524.8	n.a.
February-March								
1992	1993	1994	1995	1996	1997	1998	1999	2000
67	67	70	71	72	16	61	39	60
n.a.	n.a.	3453.3	3707.3	1483.7	1267.8	110.4	1558.4	8019.1
n.a.	n.a.	8190.8	5750.3	2209.2	1755.6	170.3	2337.5	11824.4
n.a.	n.a.	172.4	1630.9	970.2	659.8	50.9	621.6	3478.0
n.a.	n.a.	37987.2	40998.5	16621.0	7289.2	901.1	10786.6	57498.5

Table 4.14. (Contd.)

Euphausia superba Larvae

	January-February								
Year	1992	1993	1994	1995	1996	1997	1998	1999	2000
N	63	70	63	71	72	71	61	40	
Mean	n.a.	n.a.	n.a.	172.1	3.4	19.3	0.4	175.1	n.a.
SD	n.a.	n.a.	n.a.	969.4	8.3	27.0	1.6	795.5	n.a.
Med	n.a.	n.a.	n.a.	0.0	0.0	6.4	0.0	4.3	n.a.
Max	n.a.	n.a.	n.a.	8076.1	42.7	96.5	11.4	5083.2	n.a.
	February-March								
Year	1992	1993	1994	1995	1996	1997	1998	1999	2000
N	67	67	70	71	72	16	61	39	60
Mean	n.a.	n.a.	n.a.	4593.4	14.1	25.0	2.5	67.2	3423.2
SD	n.a.	n.a.	n.a.	20117.0	44.0	81.4	18.3	146.0	8974.1
Med	n.a.	n.a.	n.a.	268.6	3.3	0.0	0.0	12.3	248.7
Max	n.a.	n.a.	n.a.	167575.6	368.5	339.0	144.1	692.5	44478.2

Thysanoessa macrura larvae

	January-February								
Year	1992	1993	1994	1995	1996	1997	1998	1999	2000
N	63	70	63	71	72	71	61	40	
Mean	n.a.	n.a.	n.a.	20.2	372.0	21.5	0.0	116.5	n.a.
SD	n.a.	n.a.	n.a.	75.2	858.1	38.4	0.0	348.8	n.a.
Med	n.a.	n.a.	n.a.	0.0	32.1	1.5	0.0	2.8	n.a.
Max	n.a.	n.a.	n.a.	441.5	4961.8	159.9	0.0	1519.6	n.a.
	February-March								
Year	1992	1993	1994	1995	1996	1997	1998	1999	2000
N	67	67	70	71	72	16	61	39	60
Mean	n.a.	n.a.	31.7	344.3	511.5	10.8	0.5	185.9	1084.8
SD	n.a.	n.a.	111.1	594.2	1432.5	24.9	2.0	535.7	4147.3
Med	n.a.	n.a.	0.0	79.9	36.1	1.0	0.0	10.0	26.8
Max	n.a.	n.a.	809.1	3735.5	10875.0	104.7	12.1	2990.8	31132.5

Euphausia frigida

	January-February								
Year	1992	1993	1994	1995	1996	1997	1998	1999	2000
N	63	70	63	71	72	71	61	40	
Mean	5.4	4.2	4.7	12.1	2.0	9.6	0.3	15.9	n.a.
SD	14.9	18.4	14.9	32.1	4.5	21.4	1.4	29.1	n.a.
Med	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	n.a.
Max		143.0	76.7	175.6	22.5	91.4	10.0	116.0	n.a.
	February-March								
Year	1992	1993	1994	1995	1996	1997	1998	1999	2000
N	67	67	70	71	72	16	61	39	60
Mean	n.a.	1.0	28.9	19.7	9.5	44.8	9.0	23.0	43.1
SD	n.a.	4.7	62.0	36.7	12.7	54.2	26.0	38.7	73.0
Med	n.a.	0.0	5.5	2.9	1.2	21.0	0.0	7.6	6.8
Max	n.a.	32.6	439.7	216.1	48.8	176.2	178.4	159.1	307.2

Chaetognaths

	January-February								
Year	1992	1993	1994	1995	1996	1997	1998	1999	2000
N	63	70	63	71	72	71	61	40	
Mean	n.a.	3.1	0.2	84.7	11.9	20.1	3.3	63.9	n.a.
SD	n.a.	7.9	0.5	159.5	25.1	26.1	5.2	159.1	n.a.
Med	n.a.	0.0	0.0	30.0	4.2	10.3	0.9	14.7	n.a.
Max	n.a.	41.3	2.2	781.8	184.9	120.4	24.7	960.2	n.a.
	February-March								
Year	1992	1993	1994	1995	1996	1997	1998	1999	2000
N	67	67	70	71	72	16	61	39	60
Mean	n.a.	0.7	21.8	330.2	58.4	18.4	8.9	147.4	792.3
SD	n.a.	4.2	87.7	404.6	72.3	23.9	23.3	261.4	1543.7
Med	n.a.	0.0	0.0	161.0	31.8	5.5	1.0	48.7	229.4
Max	n.a.	34.9	578.9	1769.9	383.8	77.9	124.7	1146.6	8221.0

Table 4.15. Percent contribution and abundance rank of numerically dominant zooplankton and nekton taxa in the Elephant Island area during January-March surveys, 1994-2000. Includes the 10 most abundant taxa each year. No samples collected during January-February 2000. n.a. indicates that taxon was not enumerated during other surveys. Shaded column is a "salp year".

	January-February Elephant Island Area													
	1994		1995		1996		1997		1998		1999		2000	
Taxon	%	Rank	%	Rank	%	Rank	%	Rank	%	Rank	%	Rank	%	Rank
Copepods	4.08	3	61.54	1	56.18	1	57.16	1	4.80	3	58.05	1		
Salpa thompsoni	80.83	1	1.51	5	1.45	6	17.79	2	68.76	1	12.35	2		
Euphausia superba (L)	n.a.		12.80	2	0.19	10	1.49	7	0.09		10.95	3		
Thysanoessa macrura (L)	n.a.		1.50	6	21.82	2	1.67	6	0.00		7.29	4		
Chaetognaths	0.04		7.84	4	0.90	7	2.28	5	0.92	7	4.00	5		
Thysanoessa macrura	7.87	2	9.09	3	7.56	4	10.24	3	15.38	2	2.92	6		
Euphausia frigida	0.38	9	0.92	8	0.14		1.45	8	0.02		1.00	7		
Euphausia superba	2.68	4	1.37	7	7.95	3	3.96	4	3.13	5	0.33	8		
Vibilia antarctica	1.17	5	0.02		0.04		0.24		1.12	6	0.32	9		
Tomopteris spp.	0.25	10	0.40		0.06		0.19		0.11		0.15	10		
Cyllopus magellanicus	0.62	7	0.02		0.11		0.37		0.16	10	0.15			
Ihlea racovitzai	n.a.		n.a.		n.a.		n.a.		3.53	4	0.15			
Ostracods	n.a.		0.91	9	0.35	8	0.54	9	0.41	9	0.13			
Primno macropa	0.05		0.01		0.01		0.42	10	0.06		0.13			
Spongiobranchaea australis	0.01		0.05		0.13		0.22		0.07		0.09			
Limacina helicina	0.03		0.18		2.38	5	0.28		0.69	8	0.07			
Euphausia triacantha	0.12		0.14		0.04		0.14		0.02		0.03			
Themisto gaudichaudii	1.05	6	0.46		0.34	9	0.35		0.03		0.02			
Clio pyramidata	0.53	8	0.50	10	0.01		0.00		0.02		0.01			
TOTAL	99.69		99.26		99.64		98.79		99.32		98.15			

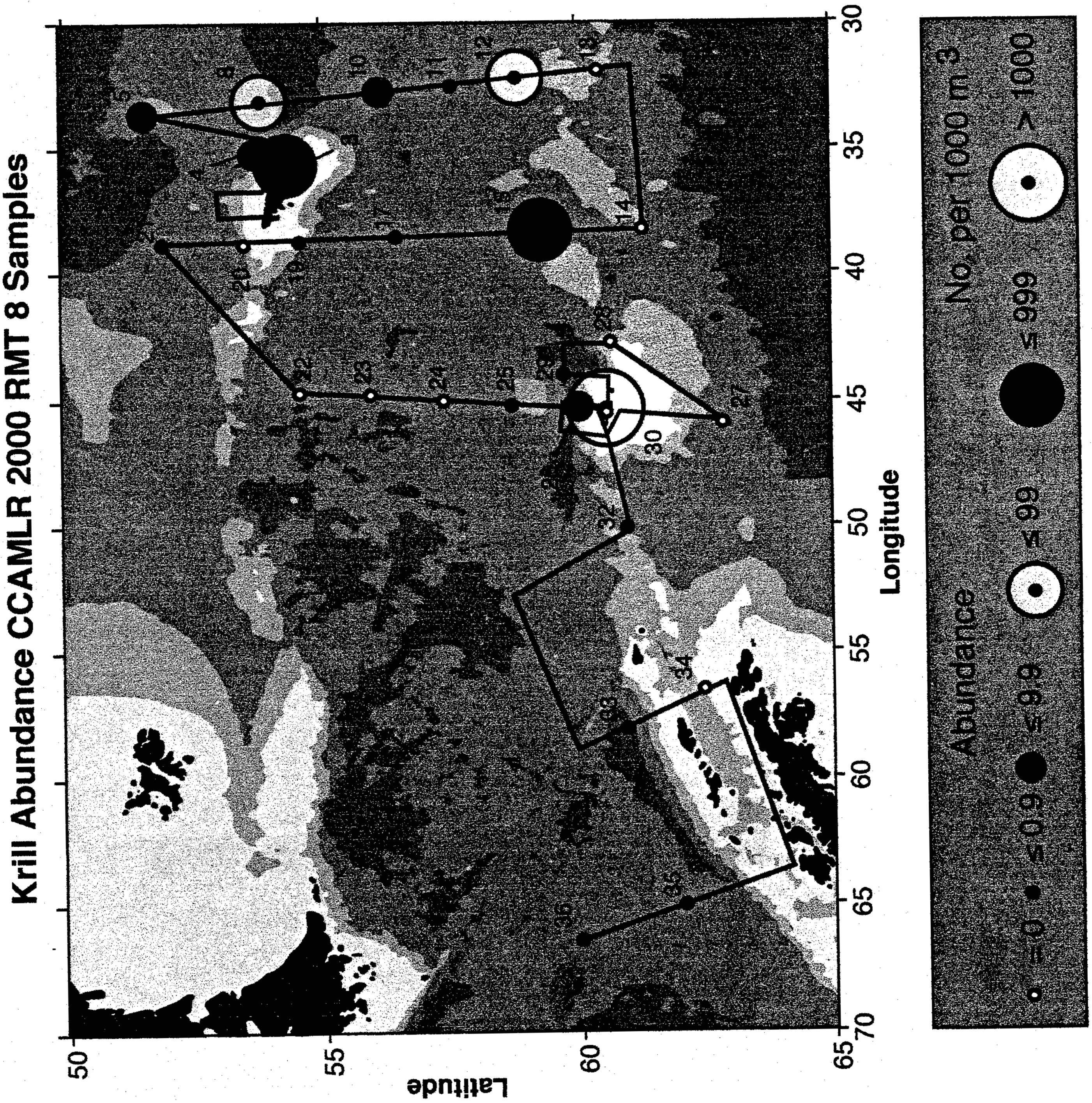
	February-March Elephant Island Area													
	1994		1995		1996		1997		1998		1999		2000	
Taxon	%	Rank	%	Rank	%	Rank	%	Rank	%	Rank	%	Rank	%	Rank
Copepoda	82.15	1	40.49	2	62.07	1	44.46	1	7.38	4	62.77	1	54.20	1
Euphausia superba (L)	n.a.		50.16	1	0.59	7	0.88	6	0.16		2.71	6	23.14	2
Thysanoessa macrura (L))	n.a.		3.76	3	21.40	2	0.38	8	0.03		7.49	3	7.33	3
Salpa thompsoni	11.78	2	0.22	7	1.39	6	43.62	2	65.31	1	12.46	2	6.17	4
Chaetognaths	0.47	6	3.61	4	2.43	5	0.65	7	0.60	8	5.94	4	5.35	5
Limacina helicina	0.00		0.00		0.01		0.00		0.03		0.00		2.21	6
Euphausia frigida	0.69	5	0.21	8	0.40	8	1.57	4	0.60	7	1.00	8	0.29	7
Thysanoessa macrura	1.83	3	0.87	5	4.86	4	6.36	3	9.40	3	3.84	5	0.24	8
Ostracods	n.a.		0.43	6	0.38	9	0.17	10	0.35	10	0.65	9	0.20	9
Vibilia antarctica	0.16	9	0.00		0.05		0.28	9	0.71	6	0.15		0.18	10
Euphausia superba	0.41	7	0.06	10	5.57	3	1.07	5	10.87	2	1.43	7	0.10	
Cyllopus magellanicus	0.12		0.01		0.10		0.12		0.55	9	0.17		0.07	
Euphausia spp. larvae	0.75	4	0.00		0.00		0.00		0.00		0.10		0.04	
Electrona antarctica (L)			0.07	9	0.04		0.01		0.01		0.01		0.03	
Primno macropa	0.00		0.00		0.15	10	0.02		0.11		0.08		0.02	
Themisto gaudichaudii	0.27	8	0.01		0.09		0.10		0.01		0.01		0.02	
Euphausia triacantha	0.03		0.02		0.03		0.03		0.04		0.06		0.01	
Cyllopus lucasii	0.14	10	0.01		0.01		0.08		0.14		0.01		0.00	
Ihlea racovitzai	n.a.		n.a.		n.a.		n.a.		2.77	5	0.34	10	0.00	
TOTAL	98.4		99.89		99.28		99.56		96.00		98.71		98.4	

Table 4.16. Salp and krill carbon biomass (mg C per m^2) in the Elephant Island area during 1994-2000 surveys. N is number of of samples. Salp:Krill ratio is based on median values.

	January-February													
	1994		1995		1996		1997		1998		1999		2000	
Biomass (mg C m^-2)	Salps	Krill	Salps	Krill	Salps	Krill	Salps	Krill	Salps	Krill	Salps	Krill	Salps	Krill
Mean	570.6	314.1	7.8	242.3	20.2	337.3	334.5	229.0	430.8	173.1	151.8	48.6	n.a.	n.a.
SD	563.2	856.4	16.1	201.1	30.9	756.1	1115.6	522.1	565.3	290.6	166.1	66.1	n.a.	n.a.
Median	400.5	25.6	1.3	43.5	10.0	72.2	108.9	45.1	187.0	46.7	93.2	14.5	n.a.	n.a.
Maximum	3277	4971.1	75.3	1545.2	134.2	4721.0	9434.6	3115.5	2699.0	1488.4	882.7	304.4	n.a.	n.a.
N	63	63	57	71	72	72	71	71	61	60	40	40	n.a.	n.a.
Salp:Krill Ratio	15.6		0.03		0.1		2.4		4.0		6.4		n.a.	

	February-March													
	1994		1995		1996		1997		1998		1999		2000	
Biomass (mg C m^-2)	Salps	Krill	Salps	Krill	Salps	Krill	Salps	Krill	Salps	Krill	Salps	Krill	Salps	Krill
Mean	483.7	425.9	13.1	59.2	50.7	1702.3	1139.7	313.1	694.6	1555.8	321.9	451.0	741.2	204.4
SD	469.5	2351.4	47.3	149.1	146.5	12441.6	1269.8	655.2	1121.2	8218.7	335.1	2082.6	2314.9	507.6
Median	285.6	2.8	0.7	13.1	4.6	40.7	504.8	50.0	379.4	31.6	193.5	6.9	239.0	42.8
Maximum	1844	19313.8	325.2	1107.1	954.0	106458.5	4645.4	2639	8543.0	62155.8	1698.1	13133.1	16400.1	3634.6
N	70	70	71	71	72	72	16	16	61	60	39	39	60	60
Salp:Krill Ratio	102.0		0.1		0.1		10.1		12.0		28.0		5.6	

Figure 4.1 Krill abundance in RMT8 samples collected during the CCAMLR 2000 Survey, January 2000.



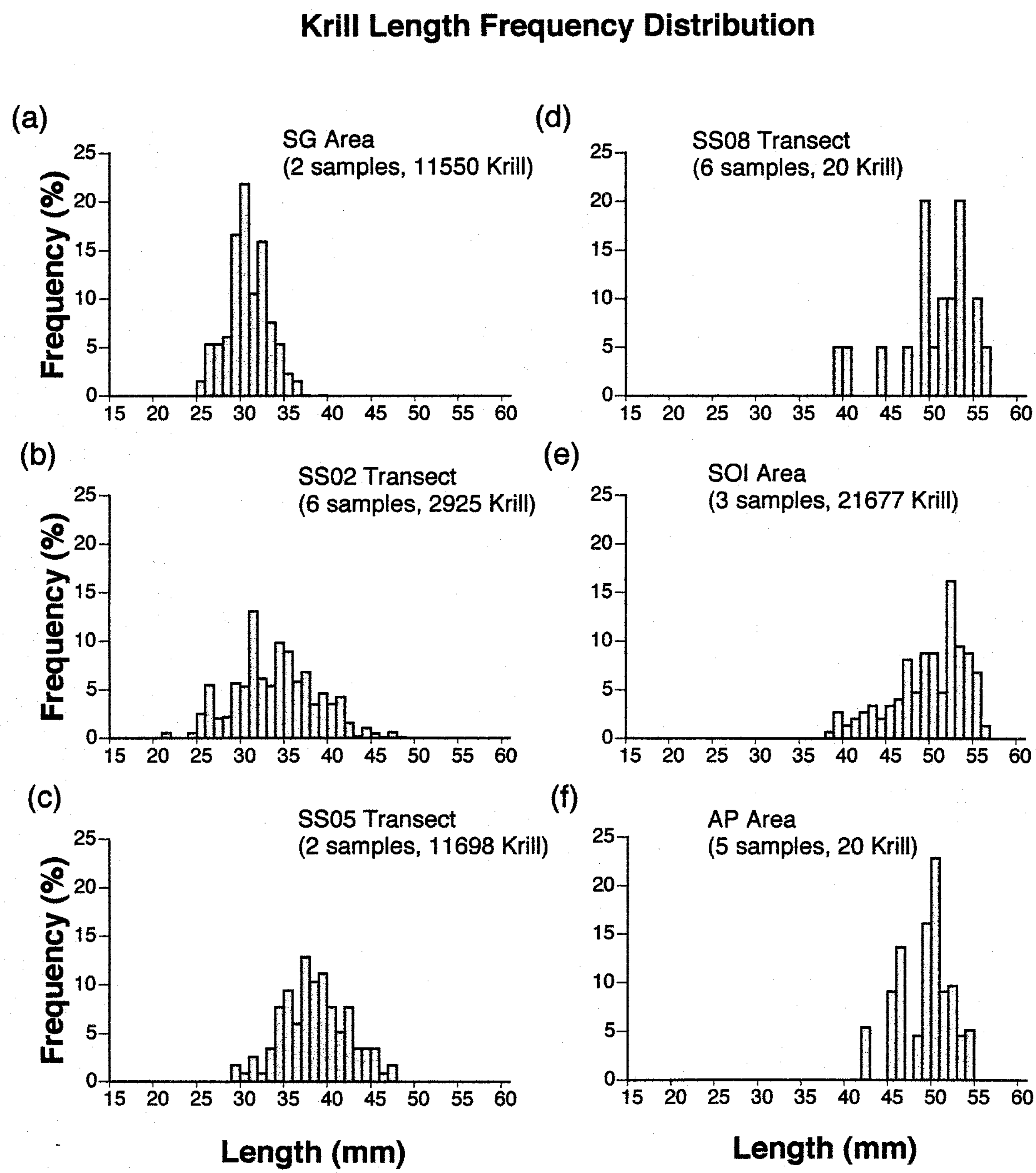


Figure 4.2 Length frequency distribution of krill collected in three areas (South Georgia, South Orkney Islands, Antarctic Peninsula) and along three transect lines (South Shetlands lines 2, 5 and 8) during the CCAMLR 2000 survey.

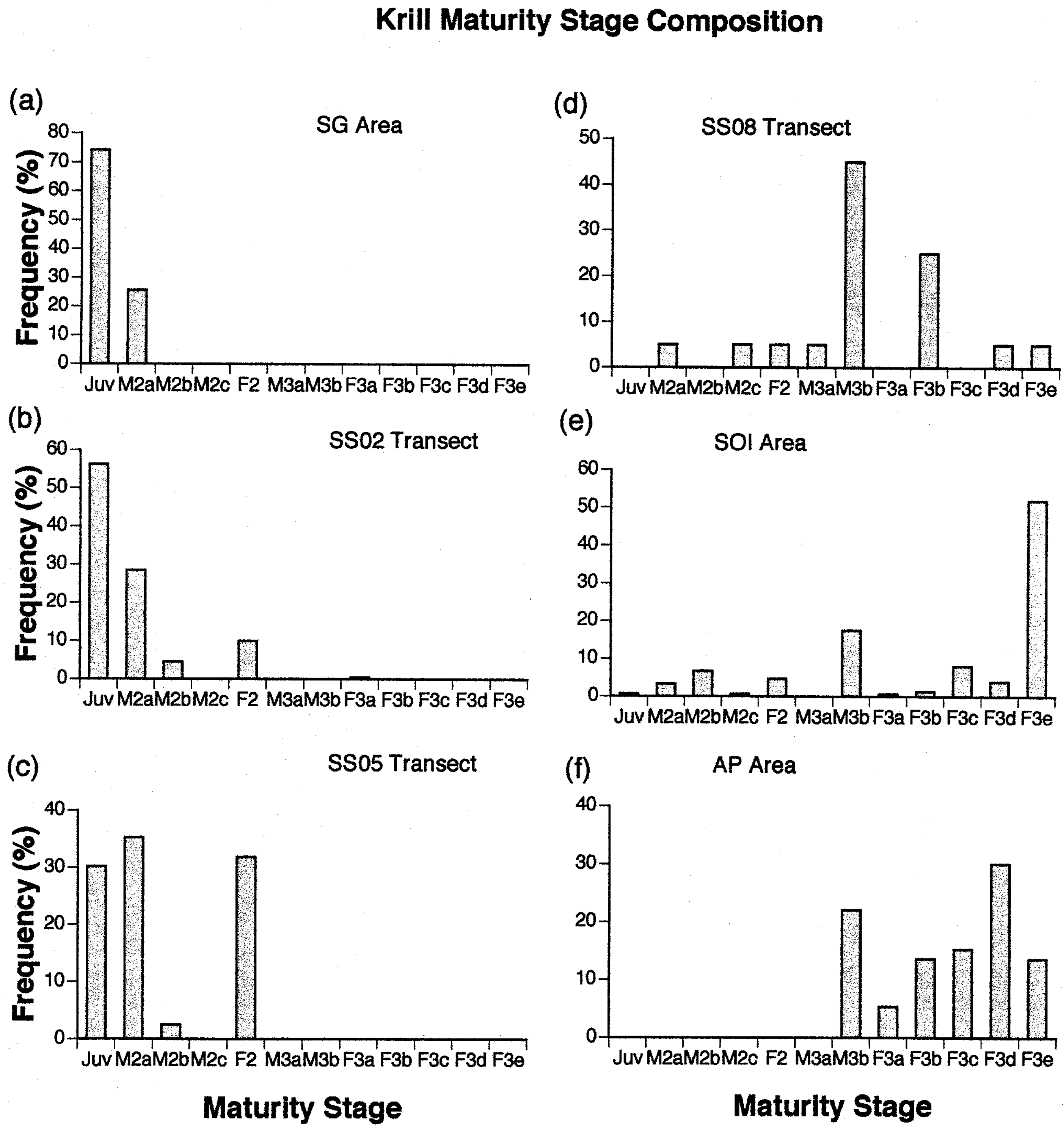


Figure 4.3 Maturity stage composition of krill collected in three areas (South Georgia, South Orkney Islands, Antarctic Peninsula) and along three transect lines (South Shetlands lines 2, 5 and 8) during the CCAMLR 2000 survey.

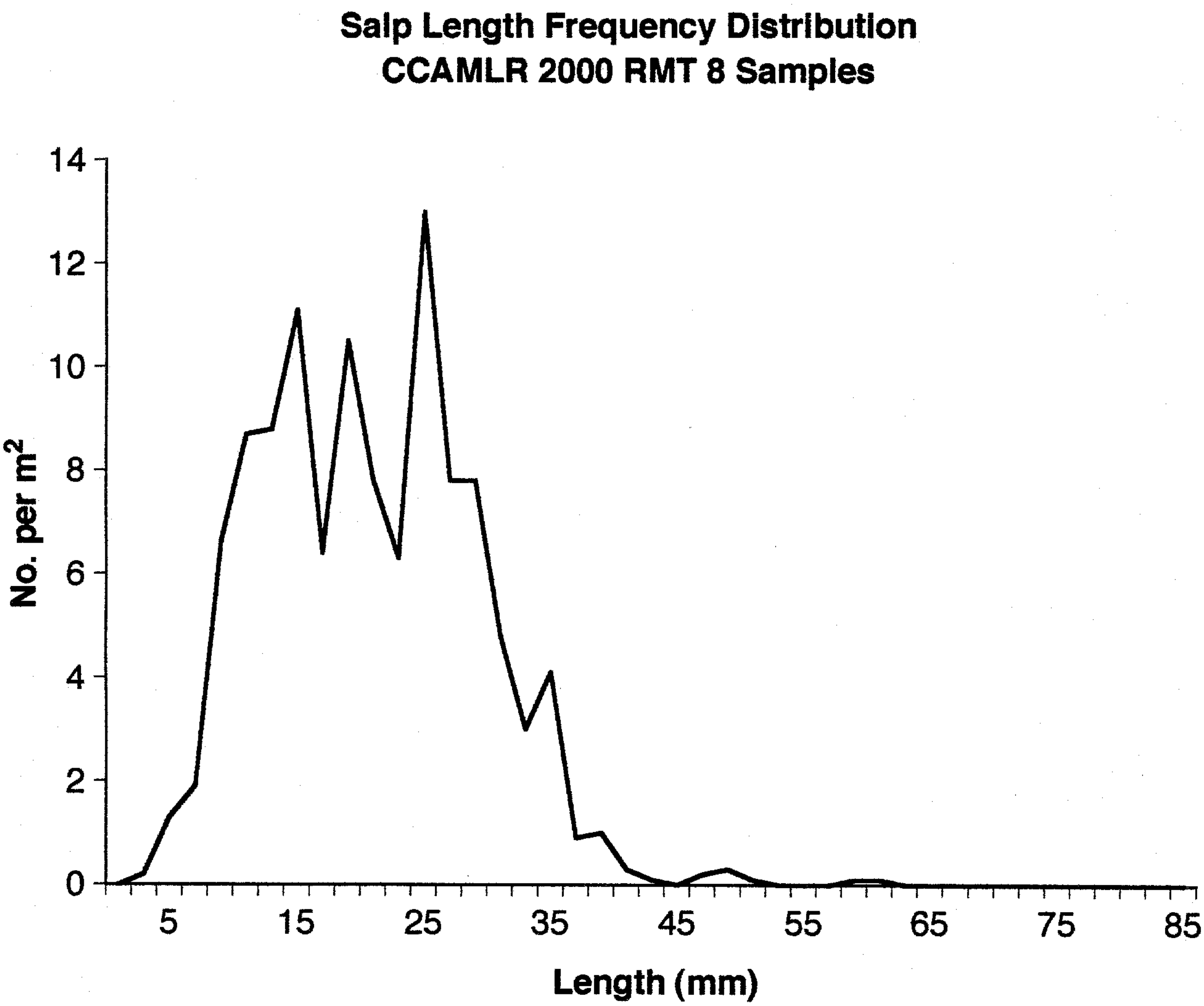


Figure 4.4 Overall length frequency distribution of *Salpa thompsoni* in the CCAMLR 2000 survey area.

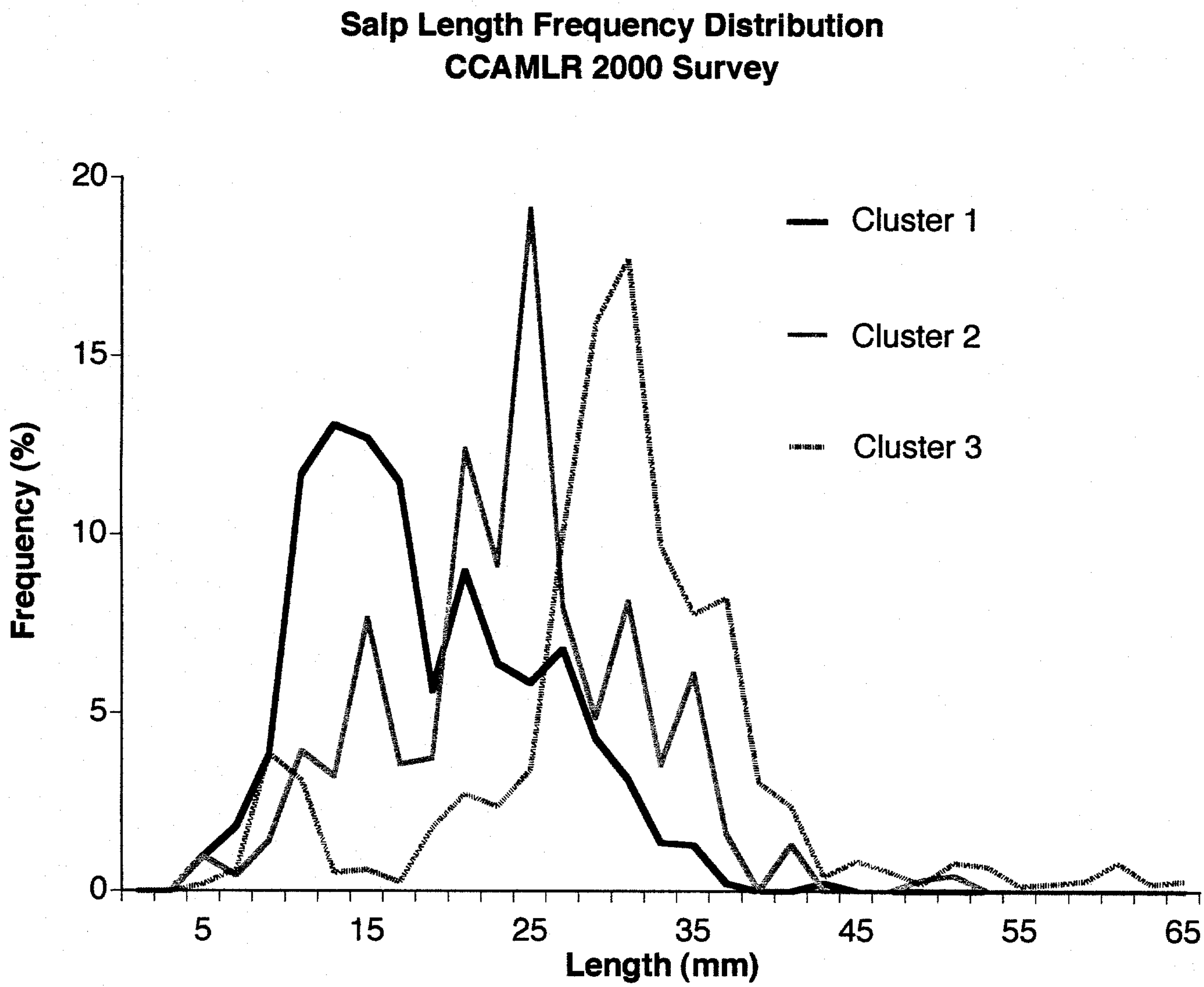


Figure 4.5 Length frequency distribution of *Salpa thompsoni* belonging to three size categories (Clusters 1, 2 and 3) in the CCAMLR 2000 Survey area.

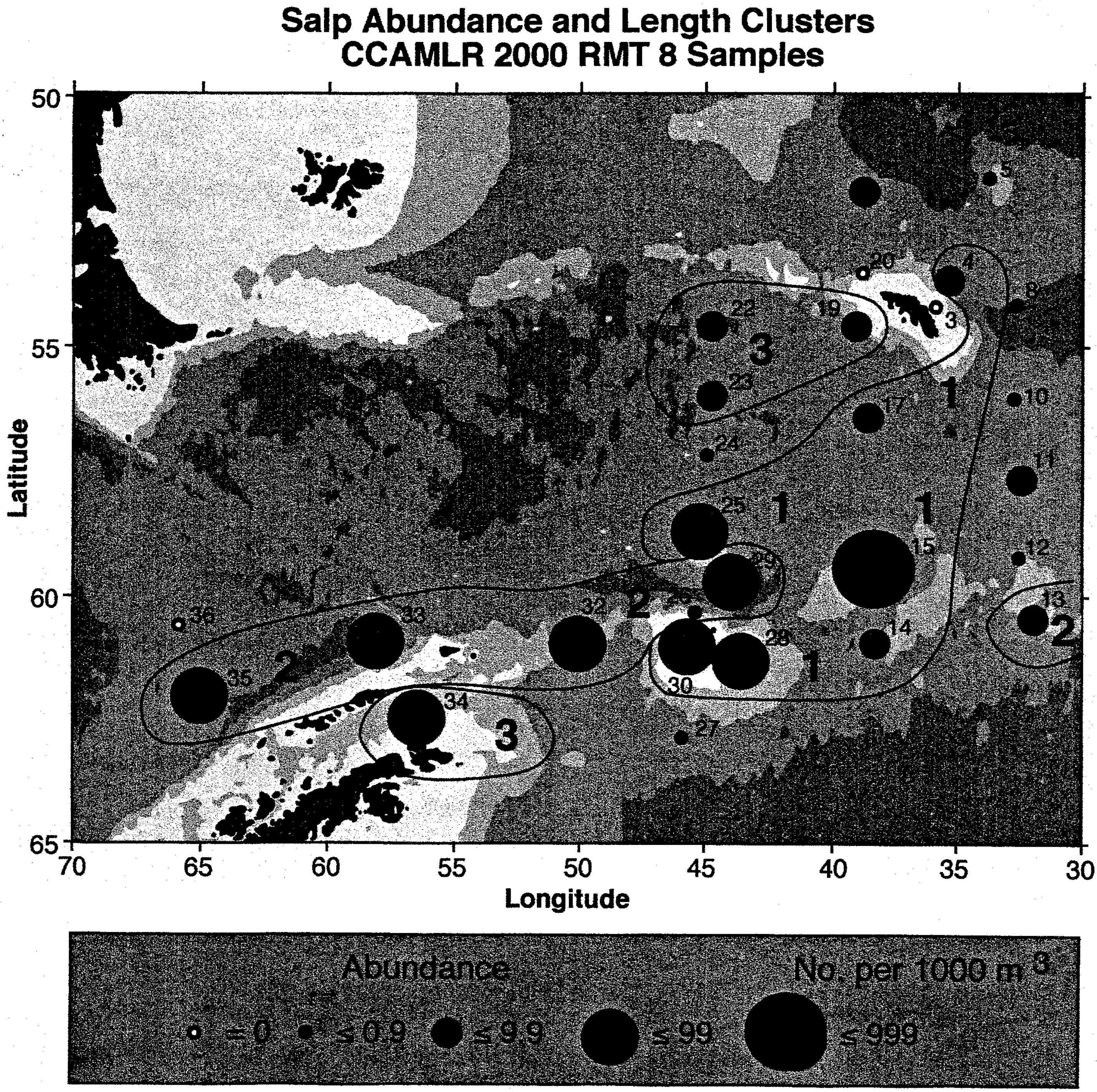


Figure 4.6 Abundance and distribution of *Salpa thompsoni* size categories (Clusters 1, 2 and 3) in the CCAMLR 2000 Survey area.

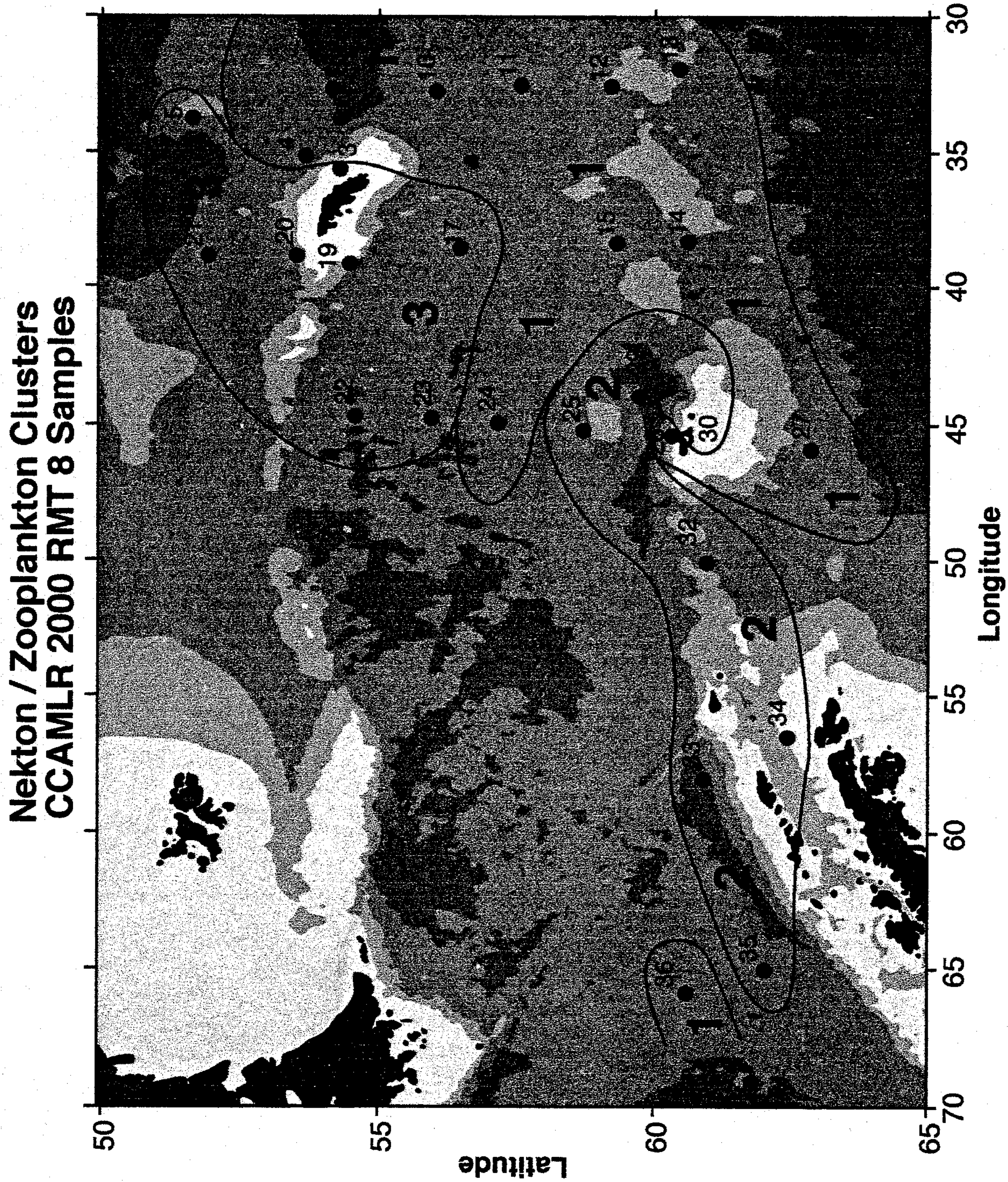


Figure 4.7 Distribution of three zooplankton assemblages (Clusters 1, 2 and 3) noted during the CCAMLR 2000 Survey. These roughly correspond to three "faunistic divisions" described by Mackintosh (1934): the eastern Scotia Sea (Cluster 1); Graham Land (Cluster 2); and transition belt (Cluster 3).

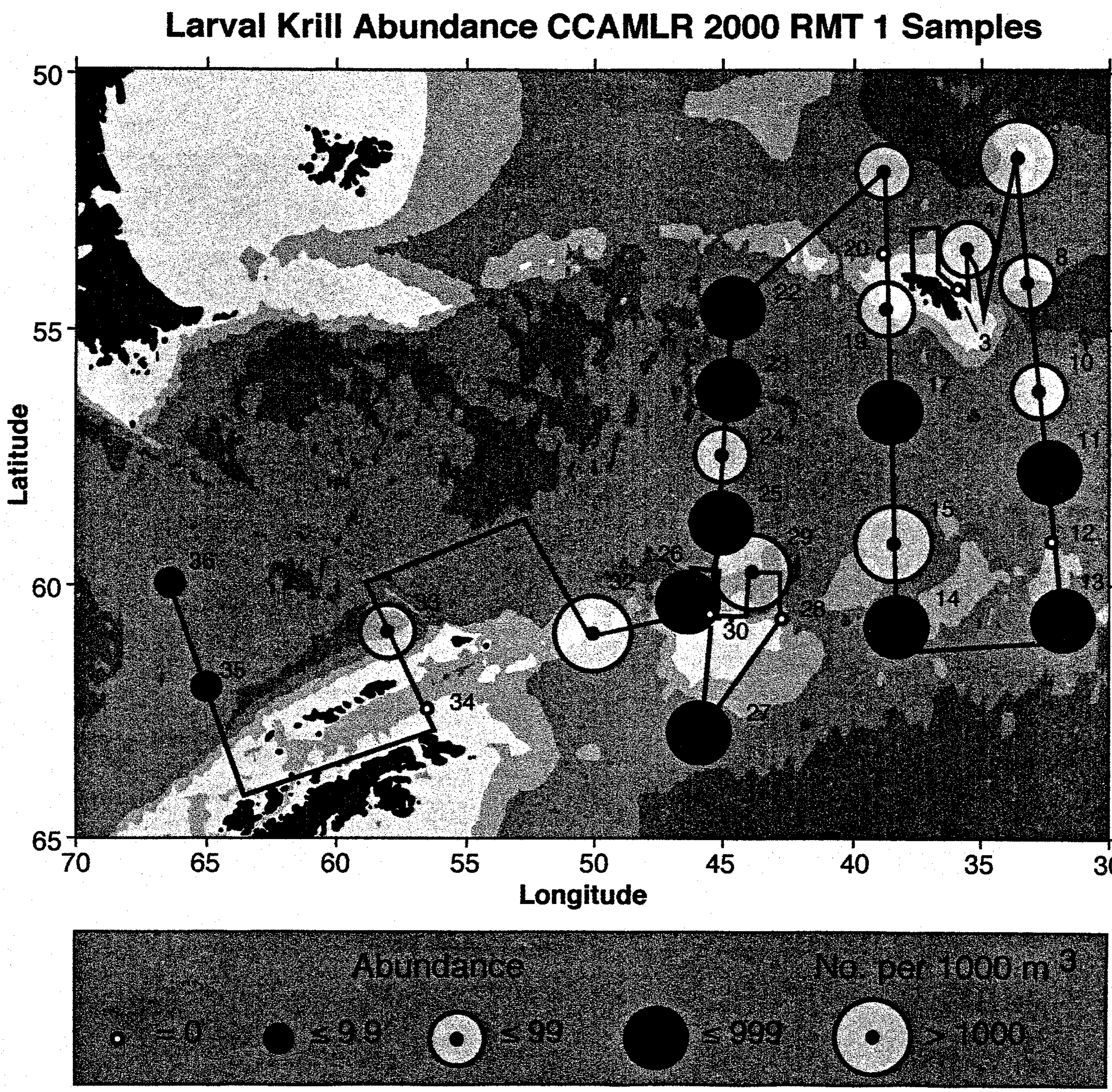


Figure 4.8 Larval krill abundance monitored during the CCAMLR 2000 survey.

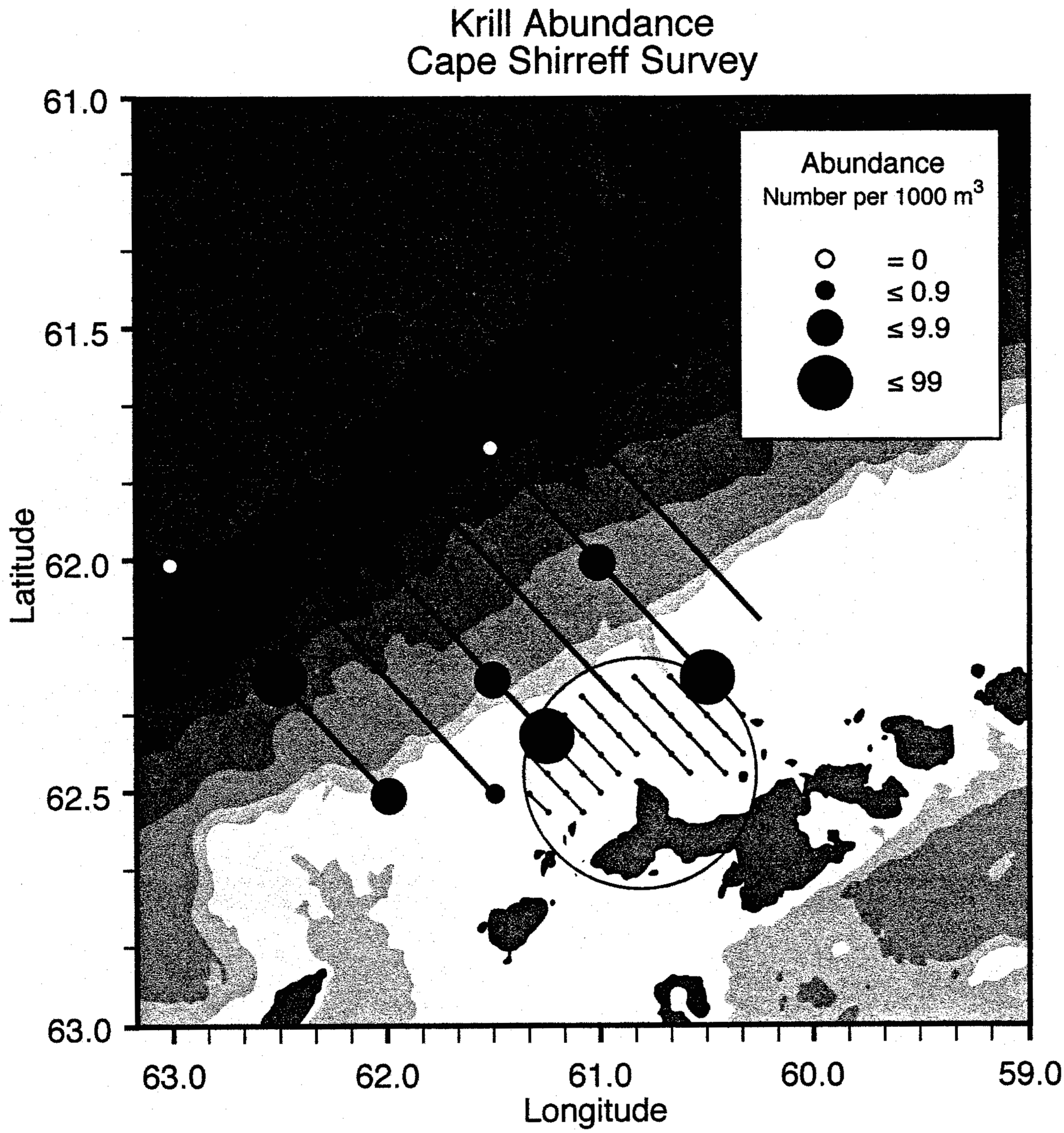


Figure 4.9 Krill abundance in IKMT samples collected during the Cape Shirreff survey, January 2000.

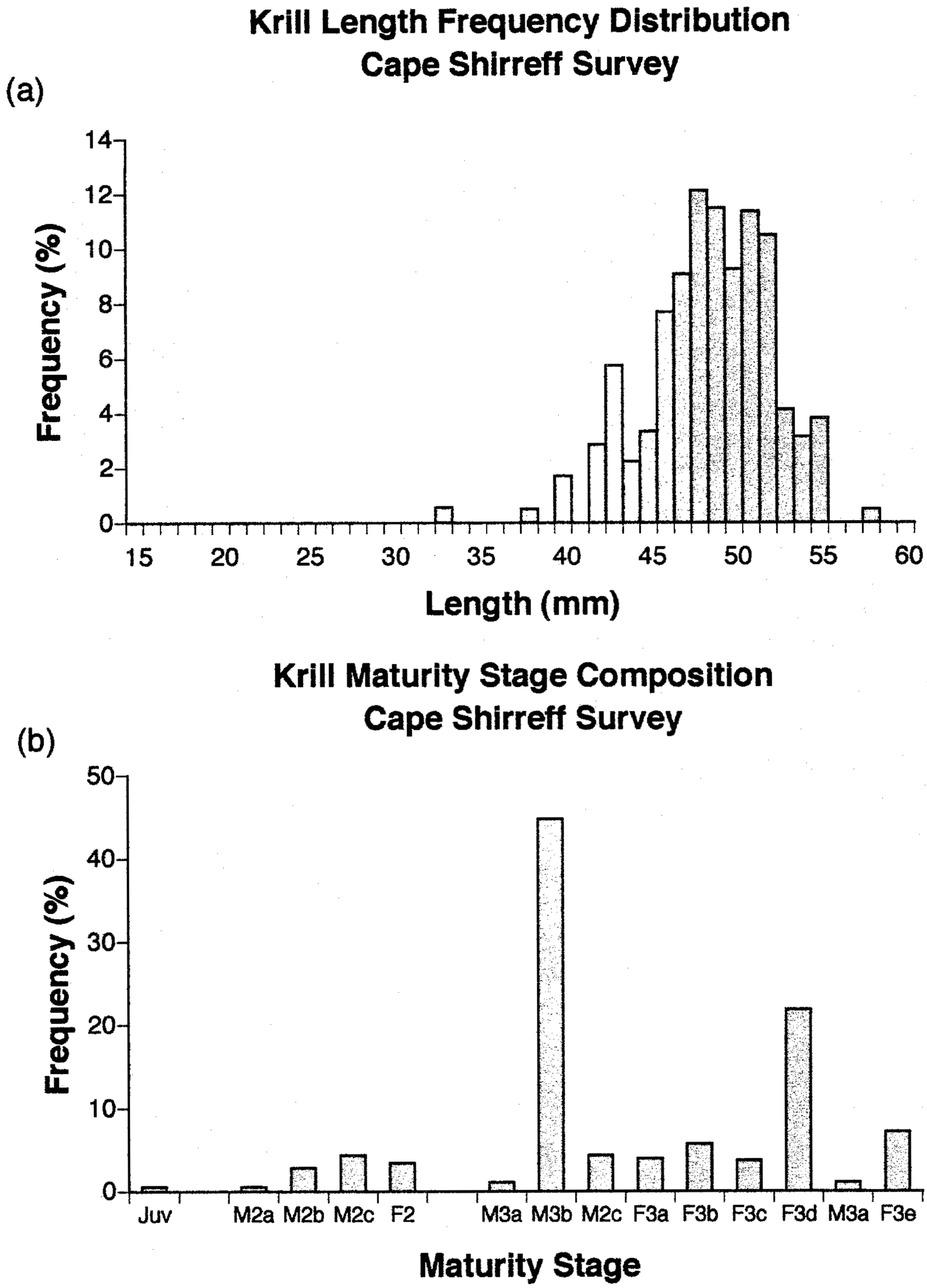


Figure 4.10 (a) Length frequency distribution and (b) maturity stage composition of krill collected during the Cape Shirreff survey, January 2000.

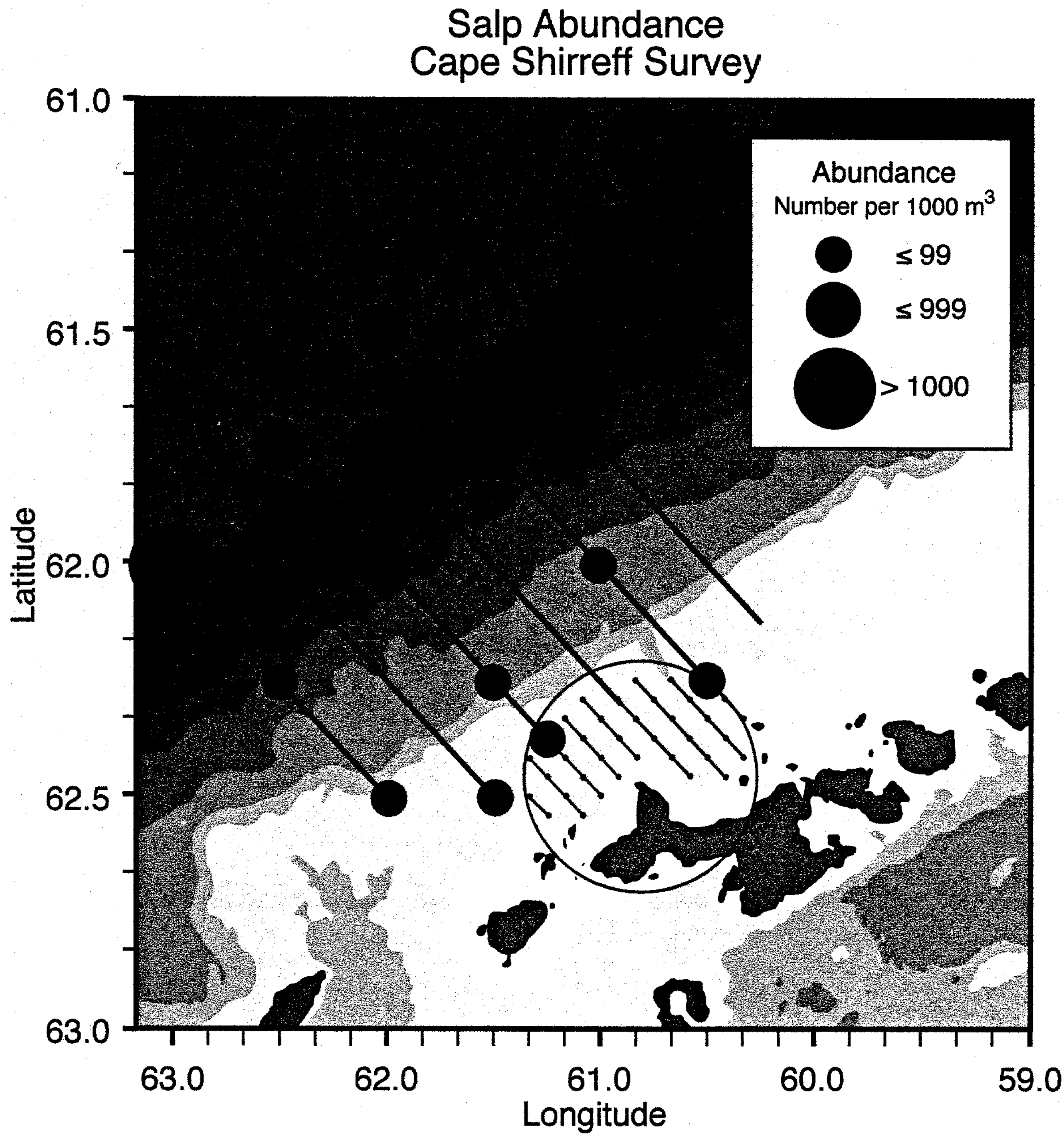


Figure 4.11 Abundance of *Salpa thompsoni* off Cape Shirreff, January 2000.

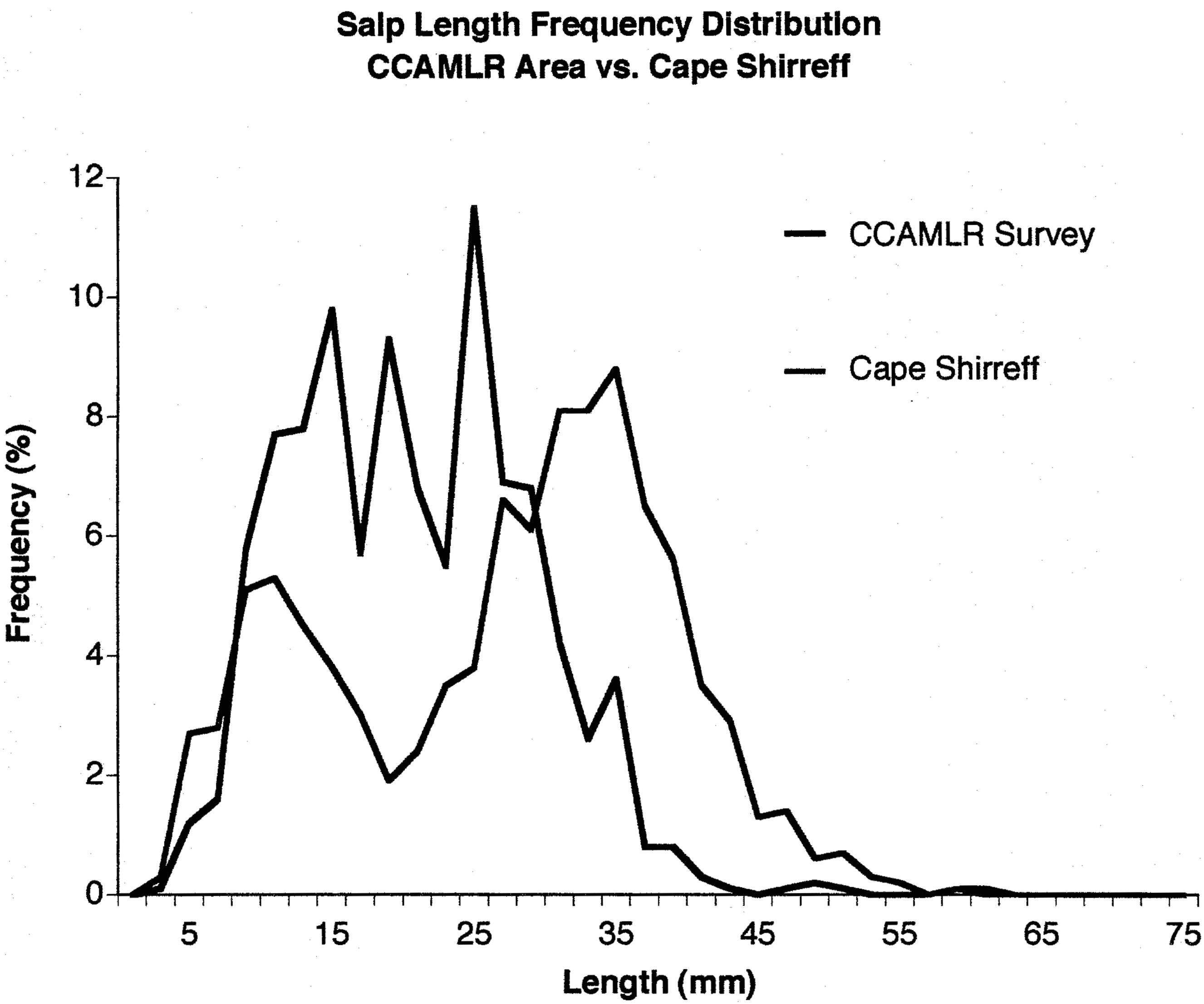


Figure 4.12 Length frequency distribution of salps collected off Cape Shirreff compared to that collected in the CCAMLR survey area, January 2000.

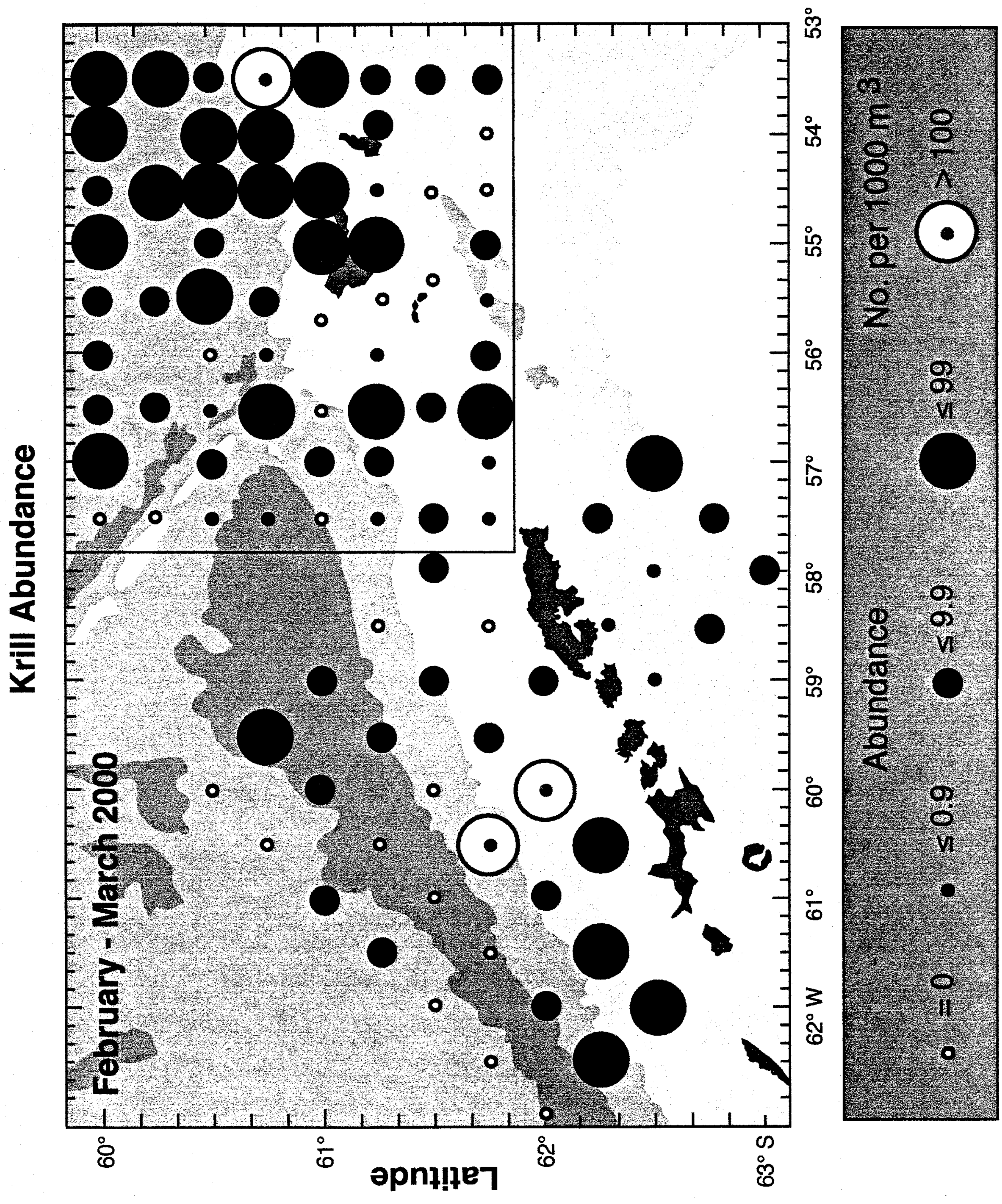


Figure 4.13 Krill abundance in the AMLR survey area, February 2000. The outlined stations are included in the "Elephant Island area" and used for between-year comparisons.

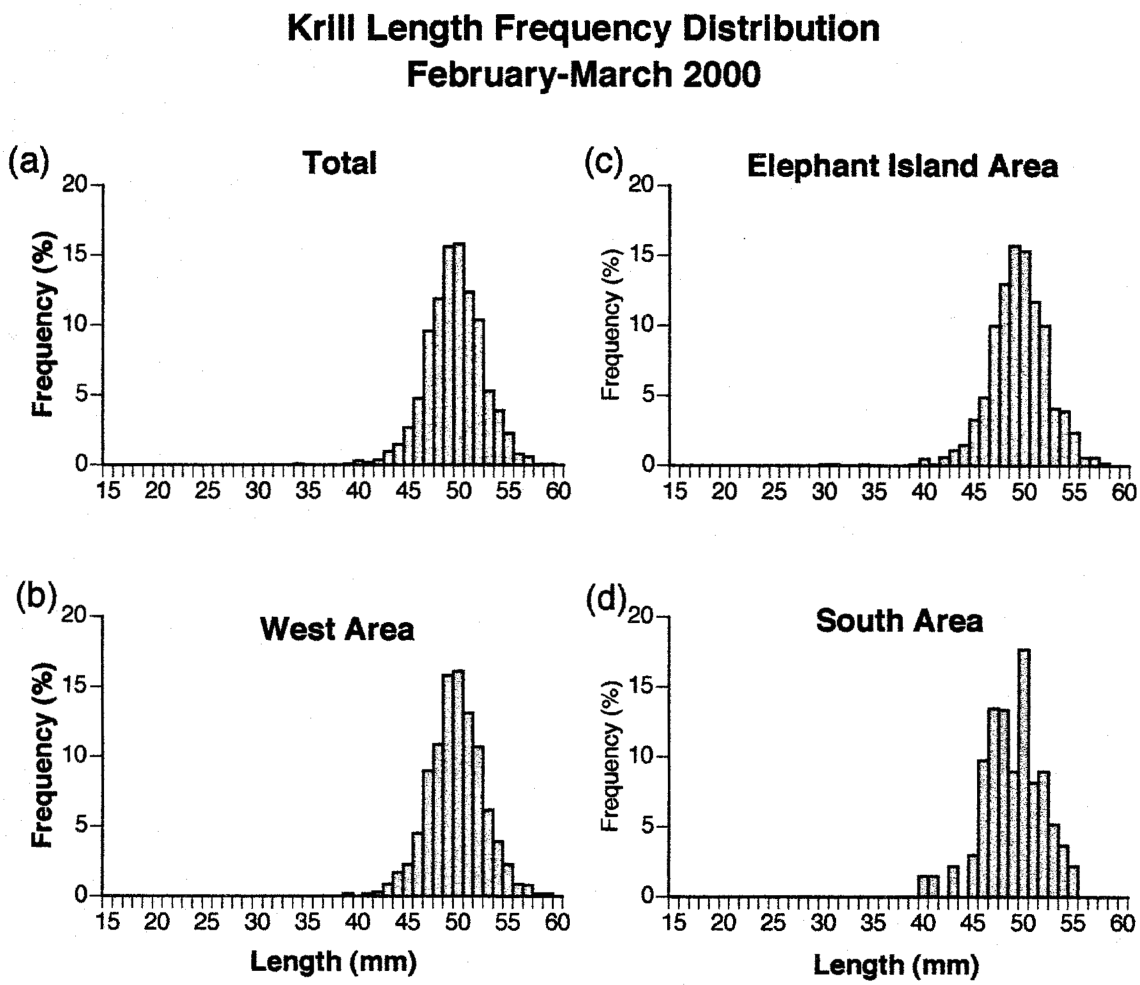


Figure 4.14 Krill length frequency distribution in the (a) total large survey area, (b) West, (c) Elephant Island and (d) South areas, February 2000.

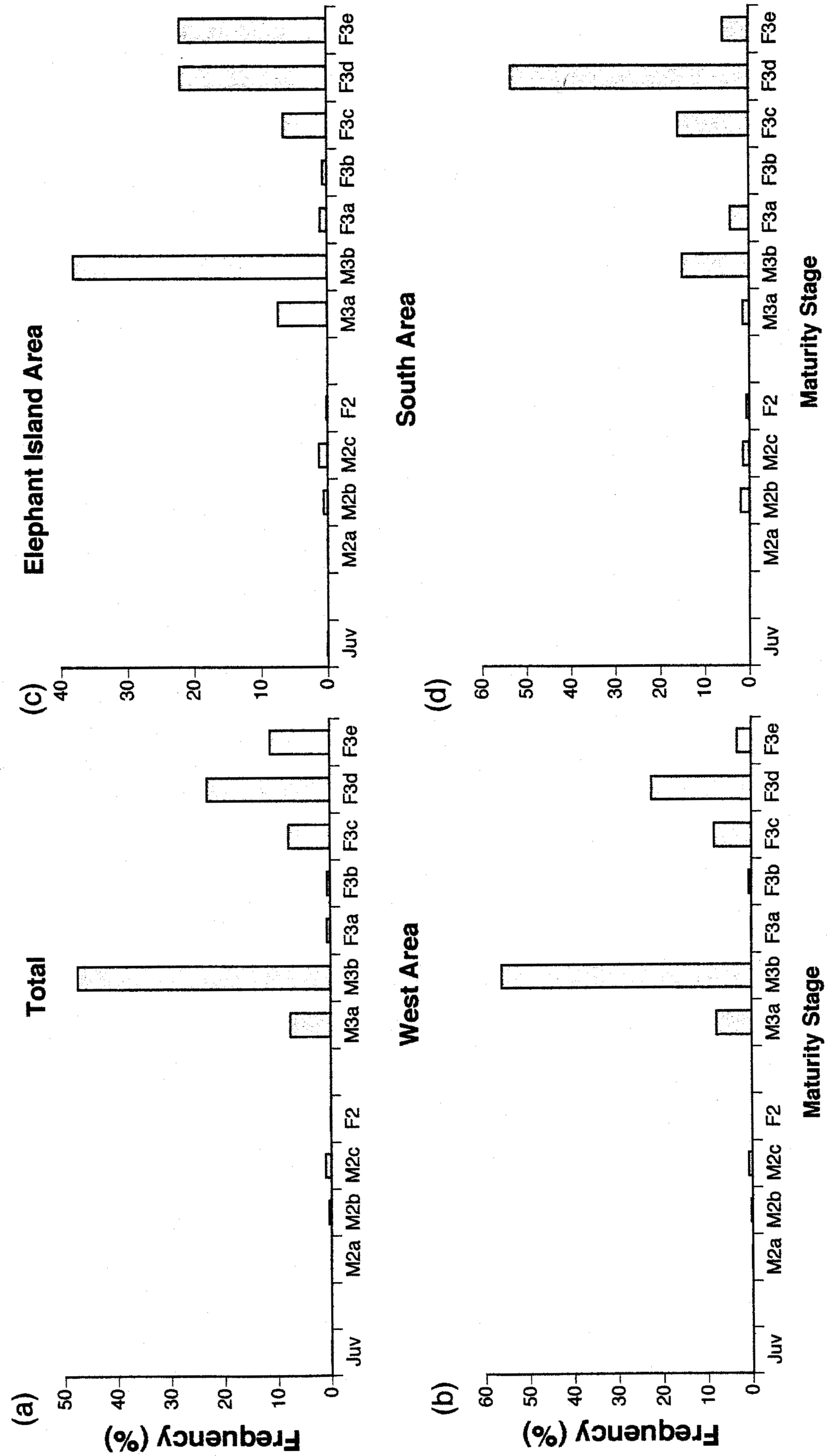


Figure 4.15 Krill maturity stage composition in the (a) total large survey area, (b) West, (c) Elephant Island and (d) South areas, February 2000.

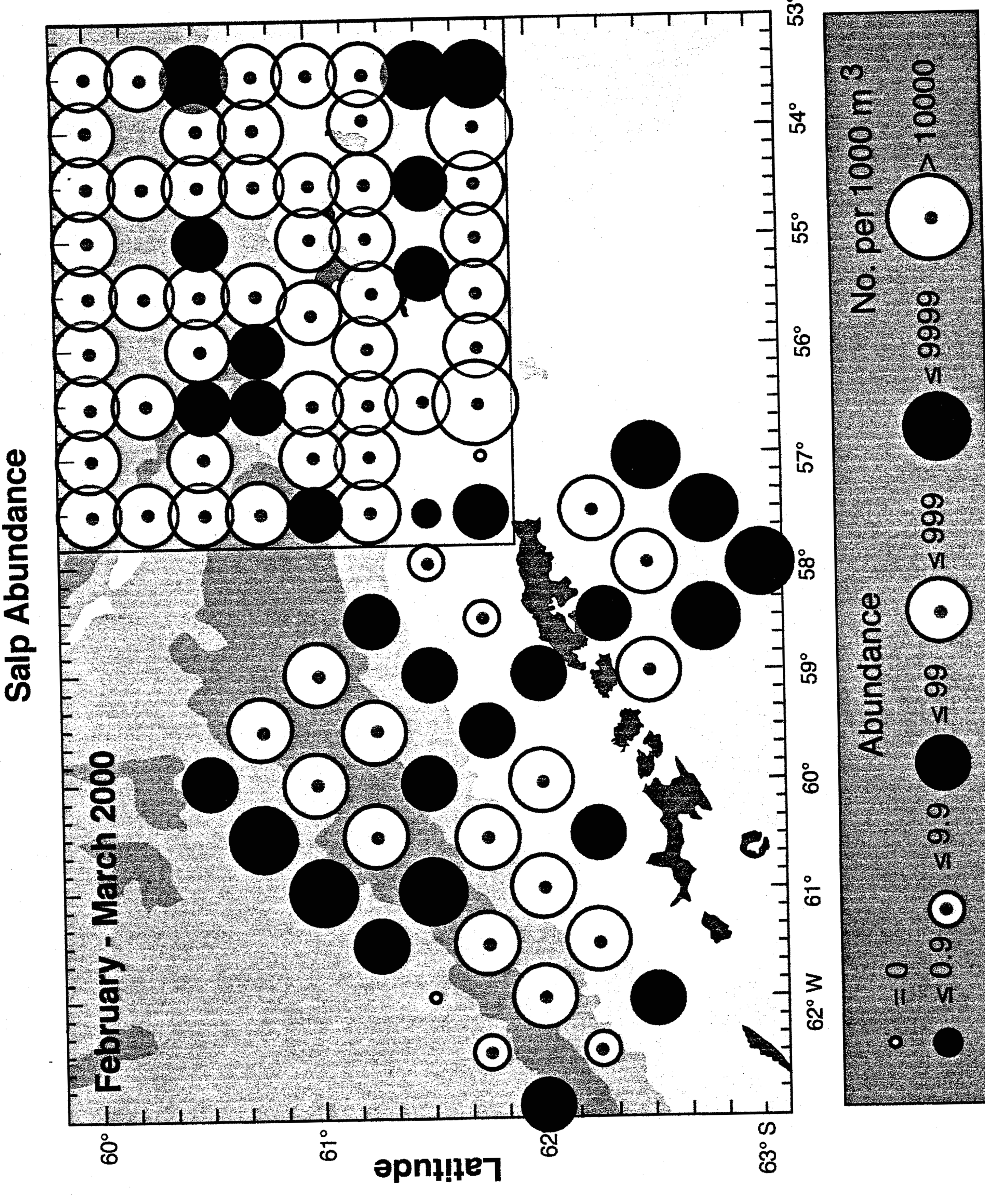


Figure 4.16 *Salpa thompsoni* abundance in the AMLR survey area, February 2000.

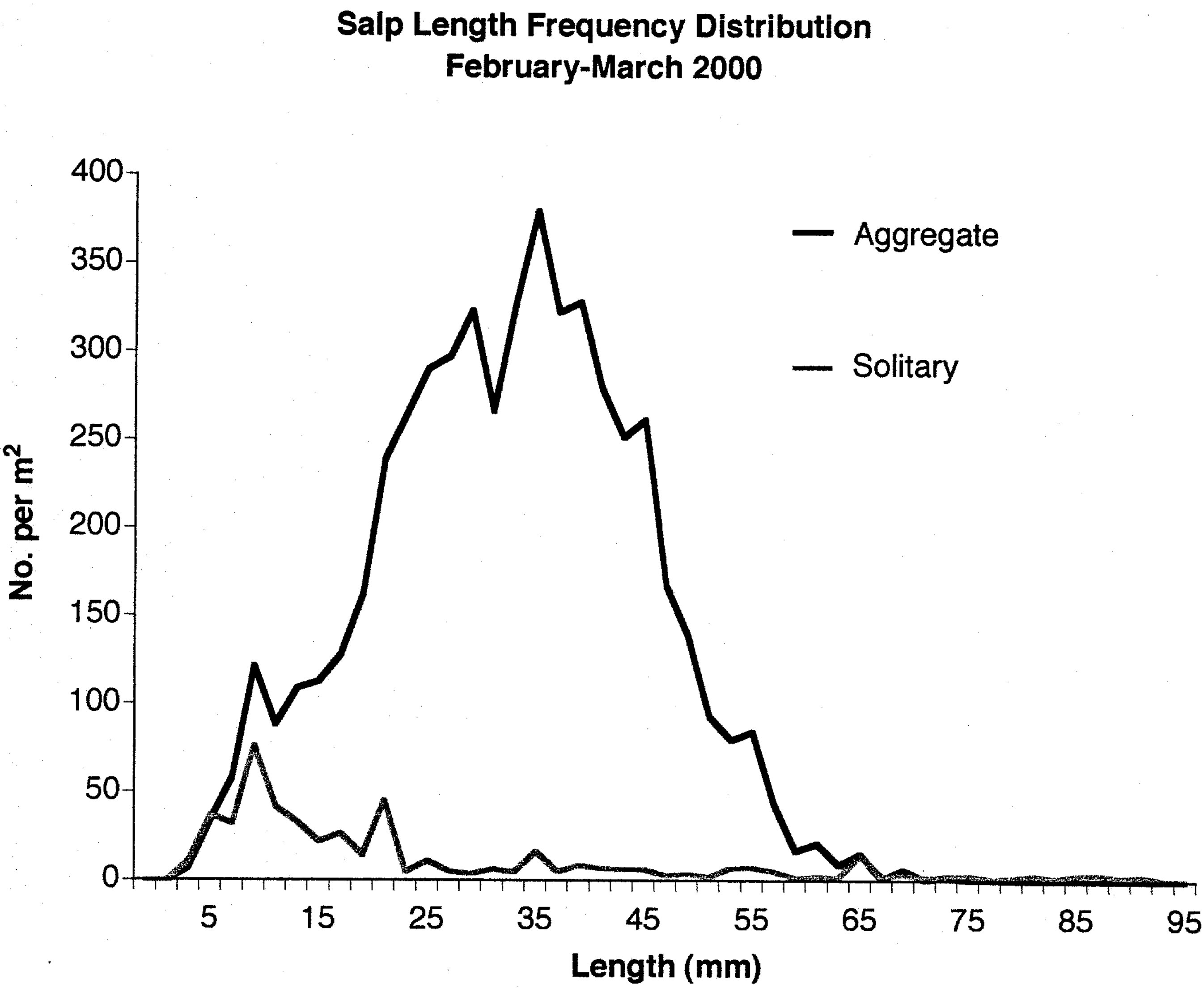


Figure 4.17 Length frequency distributions of aggregate and solitary stage salps in the AMLR survey area, February 2000,

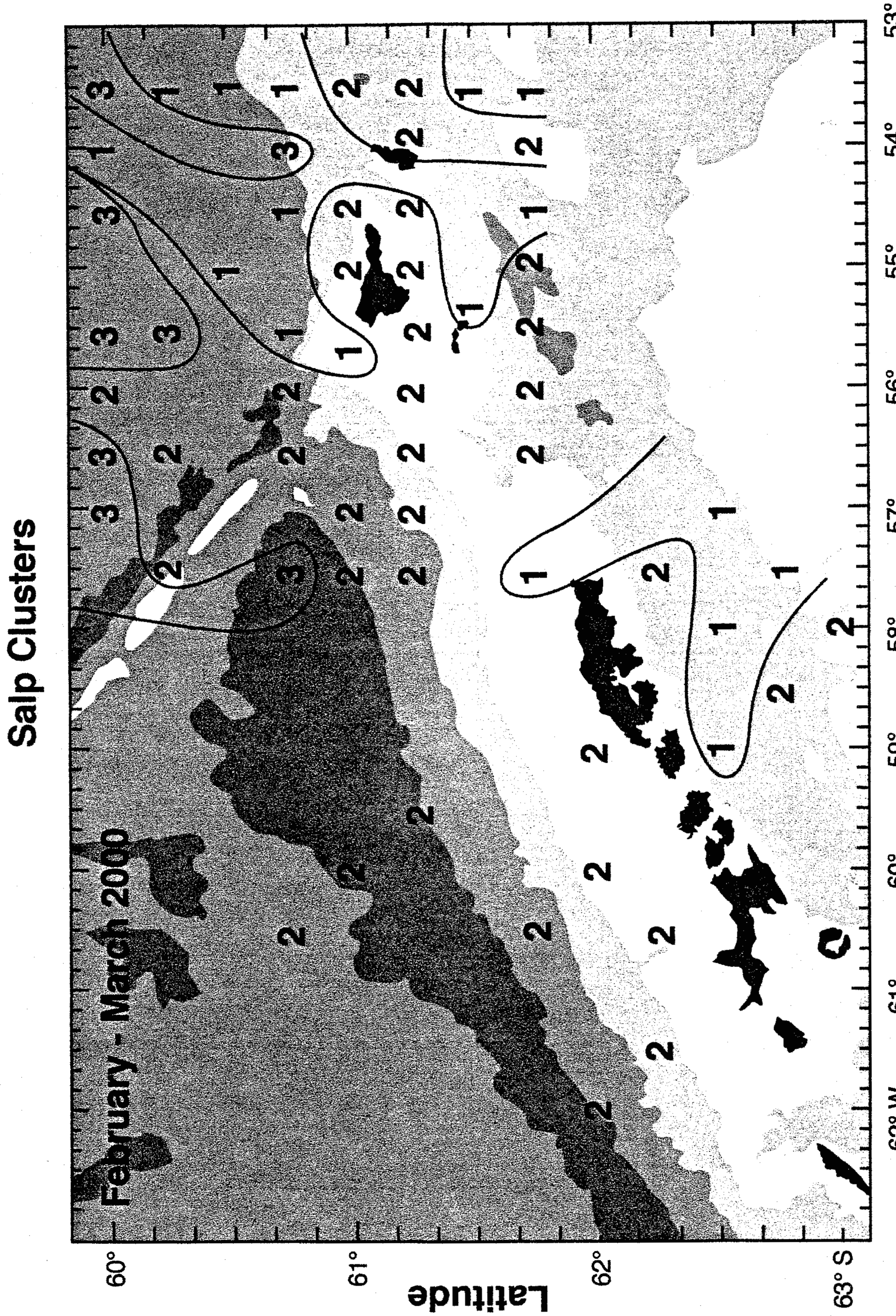


Figure 4.18 Distribution of salp length frequency clusters in the AMLR survey area, February 2000.

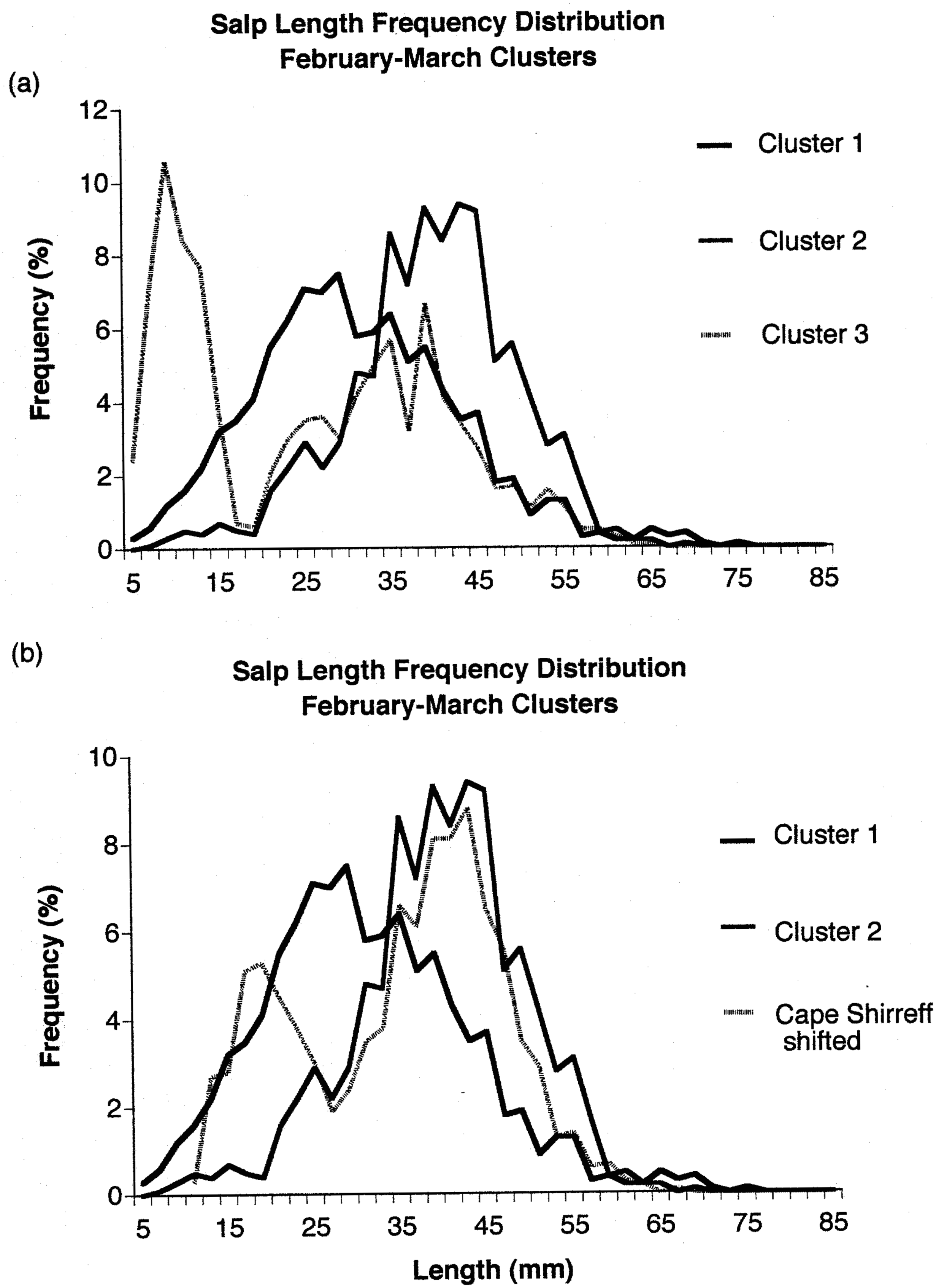


Figure 4.19 Length frequency distributions of aggregate stage salps belonging to: (a) three clusters in the AMLR survey area, February 2000; and (b) February Cluster 2 and the assemblage sampled off Cape Shirreff in January. The Cape Shirreff lengths are shifted by 10 mm to accommodate growth between the two sampling periods.

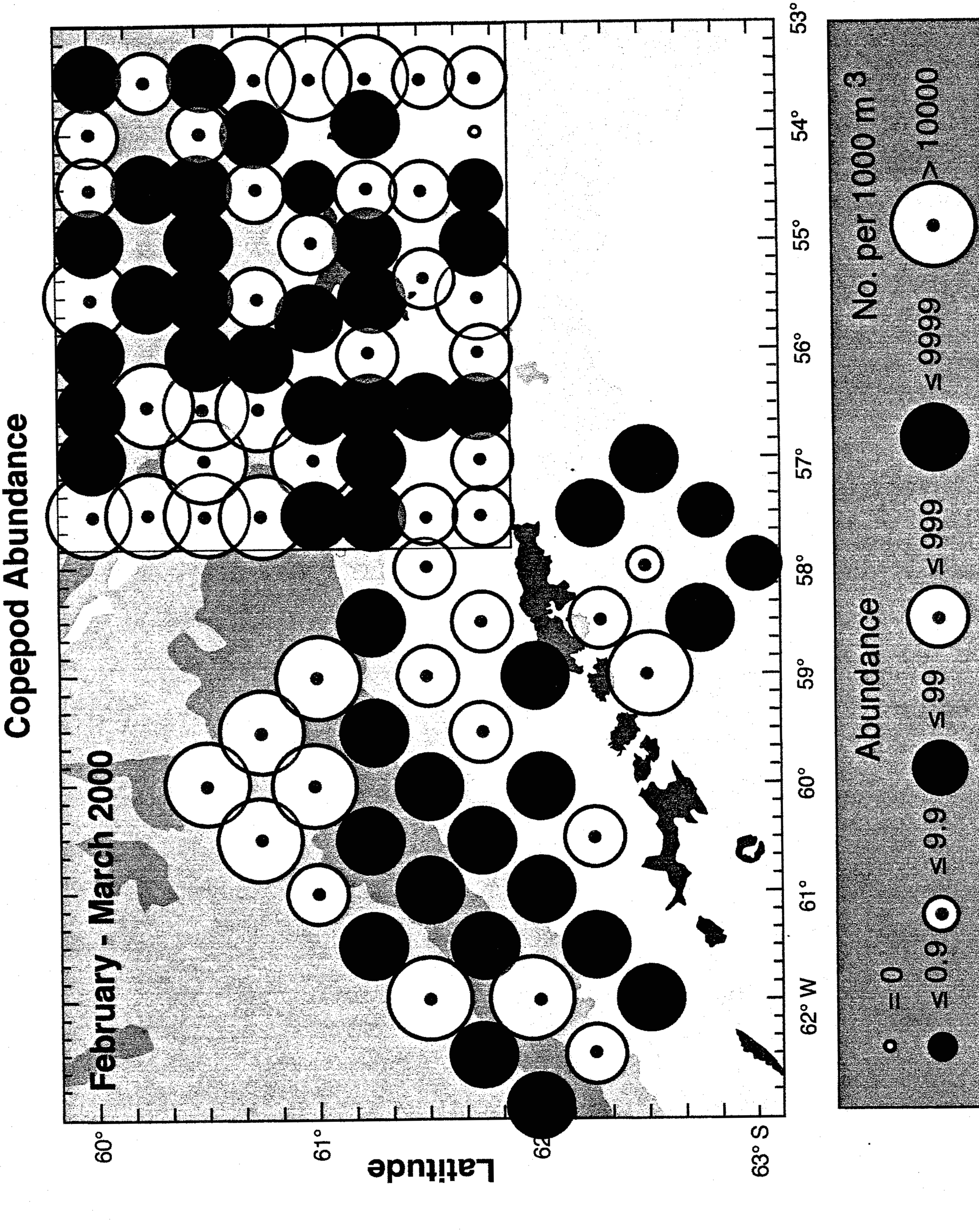


Figure 4.20a Abundance of copepods in the AMLR survey area, February 2000.

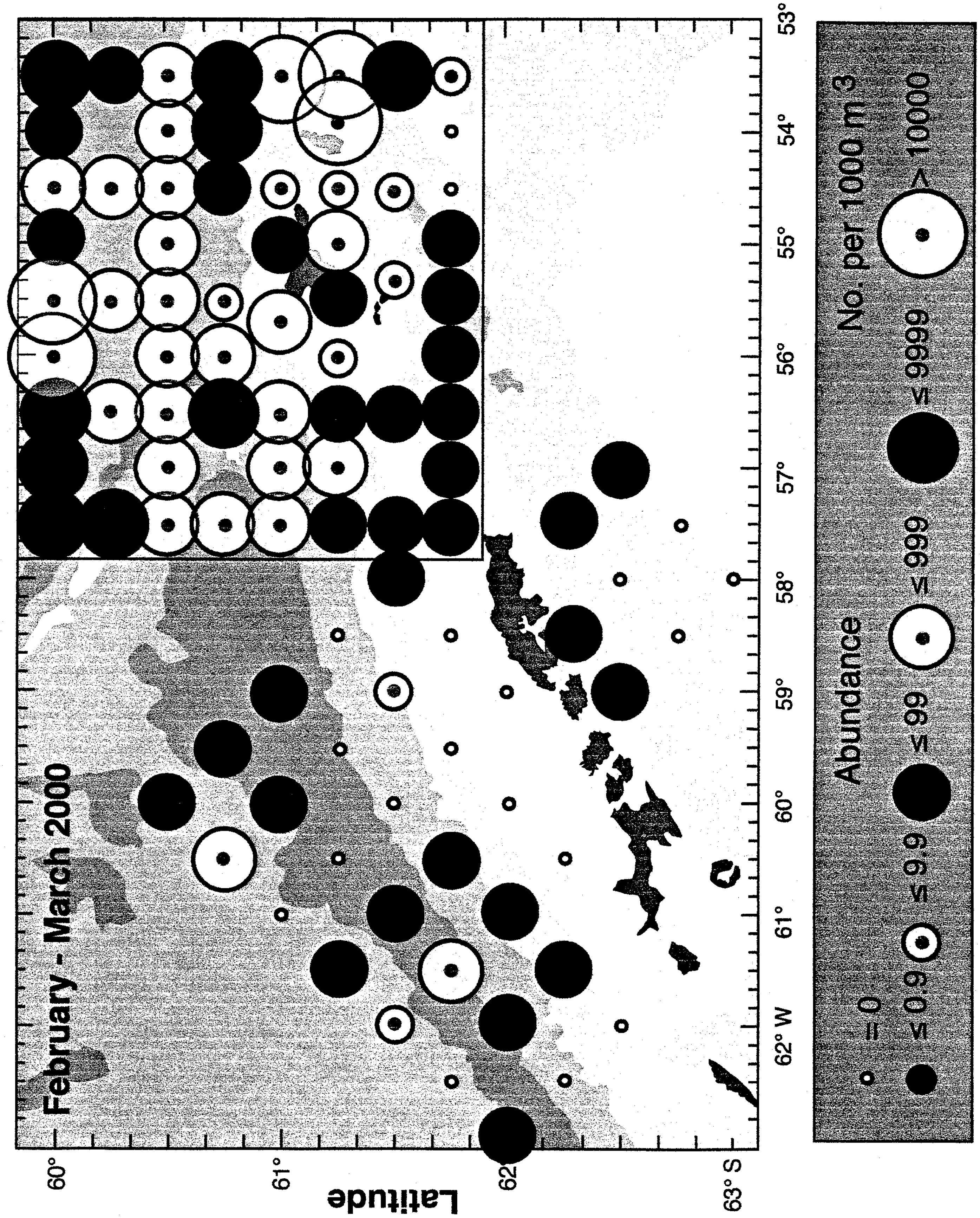


Figure 4.20b Abundance of larval krill in the AMLR survey area, February 2000.

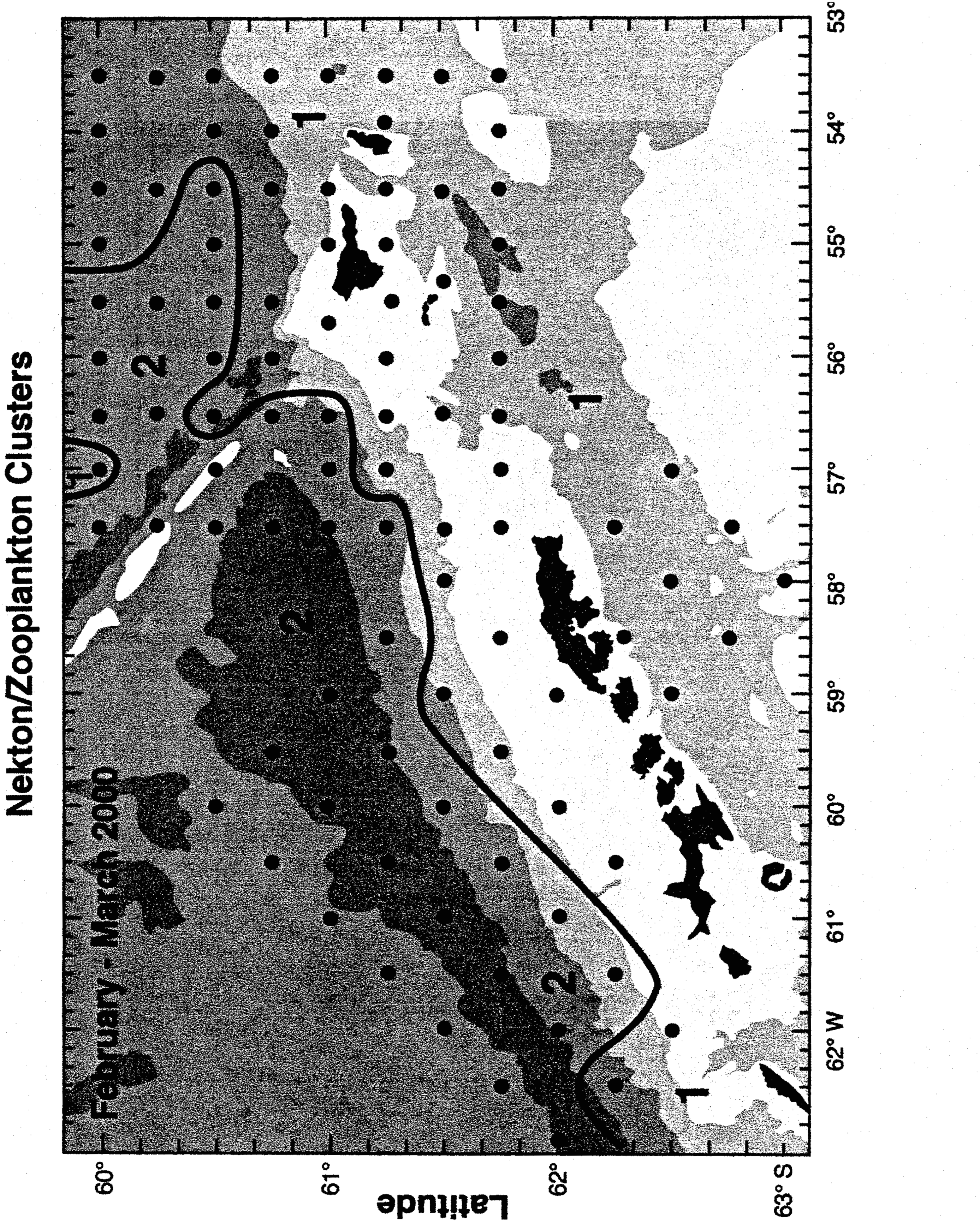


Figure 4.21 Distribution of zooplankton belonging to two different species assemblages in the AMLR survey area, February 2000.

5. Near-Shore Acoustical Survey Near Cape Shirreff, Livingston Island; submitted by David A. Demer (Leg I) and Adam Jenkins (Leg I).

5.1 Objectives: The principal aim was to survey the near-shore-prey and habitat within the foraging ranges of seals and penguins that were concurrently monitored via satellite tags at Cape Shirreff. The area covered with this multidisciplinary study is too close to shore to be safely surveyed with R/V *Yuzhmorgeologiya*. A small-craft was purpose-built for this study. The data describes the prey-field within the immediate vicinity of land-breeding predators and allows exploration of the physical oceanographic, bathymetric, and meteorological conditions that may influence the variability in the neritic dispersion and abundance of the prey.

5.2 Accomplishments: A near-shore survey (out to about 10 nautical miles off Cape Shirreff) was conducted using a specially equipped 19-foot Zodiac; meanwhile, a complimentary offshore survey (out to 60 n.mi.) was conduct via *Yuzhmorgeologiya*. The Zodiac, R/V *Ernest* (Figure 5.1), was launched from the ship on 5 February. Subsequent day-to-day operations were based from the island camp. *Ernest* was used to conduct acoustical transects, deploy a CTD at selected stations, and lower an underwater video camera into acoustic targets for the purpose of species identification. The ship operated further offshore (Figure 5.3), but in such a manner so as to be ready to render assistance by picking up the survey Zodiac and/or launching a second Zodiac, which was held ready as a rescue boat. The ship concurrently conducted acoustic transects and CTD and IKMT net sampling stations following the procedures outlined for the CCAMLR 2000 Synoptic Survey. Ship operations were on a 24-hour per day basis, while Zodiac operations were conducted for approximately 6 to 9 hours each day.

To enable the multidisciplinary survey in relatively shallow waters, the 19-foot Zodiac *Mark V* was fitted with a custom aluminum house with remote steering station and wind-break; two engines (9.9 HP 4-stoke Yamaha and 45 HP Evinrude); Simrad EY500 split-beam 120kHz echosounder with control/data logging computer; motorized down-rigger for deployment of an SBE19 SeaCat CTD and a digital 3-CCD underwater video and lighting system; redundant GPS's for measuring date, time, latitude, longitude, quality, number of satellites, HDOPS, course over ground, and speed over ground, redundant VHF radios; a WeatherPak 2000 meteorological station for measuring bearing, apparent and true wind speed and direction, barometric pressure, humidity, and air temperature; a Raytheon 24 n.mi. radar; NOAA's Scientific Computer System for continuous data logging and display; four gel cell batteries for up to 20 hours of continuous survey operations; an alternator and backup generator for power restoration; compass; binoculars; survival equipment including a 406MHz EPIRB, and a camping and survival-kit.

5.3 Results and Tentative Conclusions: Volume backscattering strengths (120kHz) were integrated over 250m depths and averaged over 0.1 n.mi. trackline distances (Sa). These values are considered proportional to the densities of krill (Figure 5.2). Underwater video observations verified that the acoustic targets were large *Euphausia superba*. A 6 n.mi. long cluster of krill swarms was mapped immediately to the east of the cape; other large swarms were observed between 5 and 10 n.mi. offshore. During the survey, fur seals and penguins were frequently seen in each of the areas with high krill densities.

Due to slower than expected boat speed, every other line of the planned track was surveyed with *Ernest* out to 10 n.mi. The *Yuzhmorgeologiya* filled the gap by surveying further inshore.

In-situ target strength measurements were considered between depths of 10 and 40m and off-axis angles of less than 3 degrees (Figure 5.4). Although the single-frequency TS distribution is likely biased high, the mode between -65 and -68dB is consistent with large krill (>50mm lengths) as suggested by the underwater video observations.

5.4 Disposition of Data: Data are available from David A. Demer, Southwest Fisheries Science Center, 8604 La Jolla Shores Drive, La Jolla, CA 92037; phone/fax (858) 546-5603/5608; email: ddemer@ucsd.edu

5.5 Acknowledgements: We are indebted to Leif Knutsen of Port Townsend Shipwrights, Inc. for the design and construction of the custom aluminum house/steering station/electronics enclosure used in this survey. Leif's genius, craftsmanship, and dedication made this investigation possible. Dave Benigni and Dennis Shields of NOAA's Marine and Aviation Operations are also gratefully acknowledged for providing the SCS system.

Figure 5.1 R/V *Ernest* four-point moored off Cape Shirreff, Livingston Island, Antarctica. The red 120kHz split-beam transducer sits atop the retracted arm (port-side); the WeatherPak 2000 meteorological station, radome, and 406MHz EPIRB are mounted on the cabin top; and the motorized down-rigger used for deploying the CTD and underwater video system is positioned near the steering station (starboard side).

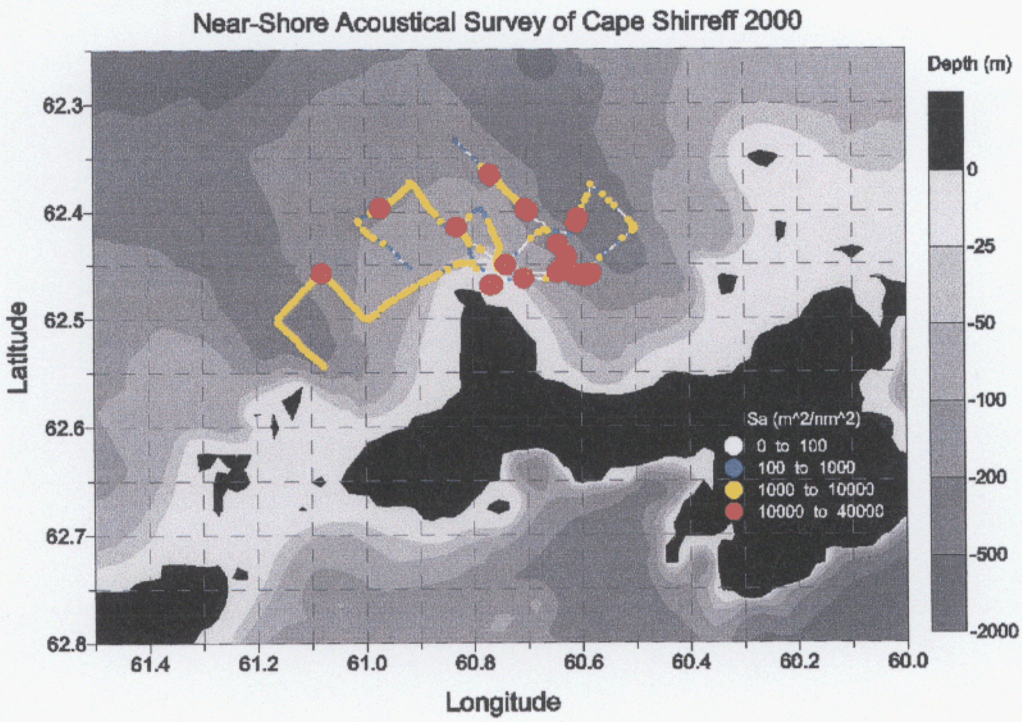


Figure 5.2 A 120kHz echosounder was used to survey Antarctic krill in the near-shore region of Cape Shirreff. Volume backscattering strengths integrated over 250m depth and averaged over 0.1 n.mi. trackline distances (Sa) are considered proportional to the densities of krill. Underwater video observations verified that the acoustic targets were large *Euphausia superba*. A 6 n.mi. long cluster of krill swarms was mapped immediately to the east of the cape; other large swarms were observed between 5 and 10 n.mi. offshore. During the survey, fur seals and penguins were frequently seen in each of the areas with high krill densities.

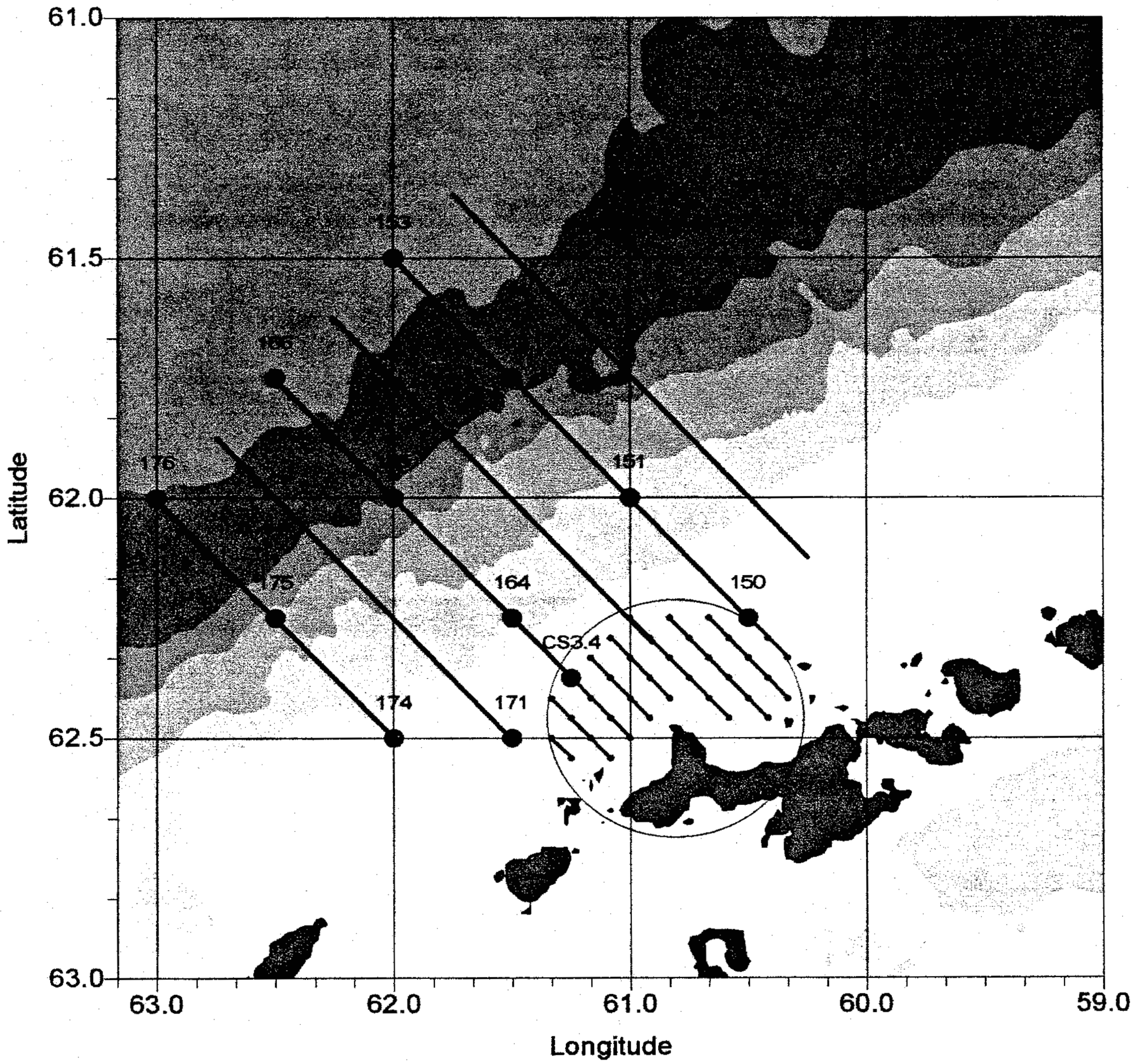


Figure 5.3 Planned Cape Shirreff survey. Thick lines and large dots indicate transects and stations for survey by the ship. Thin lines and small dots indicate transects and stations intended for survey by R/V *Ernest*. Stations D150 and CS3.4 were to be occupied by both the ship and the Zodiac. The circle indicates a 15 n.mi. radius from Cape Shirreff. Ultimately, every other line was surveyed with *Ernest* out to 10 n.mi. (see Figure 5.2) and *Yuzhmorgeologiya* filled the gap by surveying further inshore. Depth shading is 0-500m, 500-2000m, 2000-4000m and greater than 4000m.

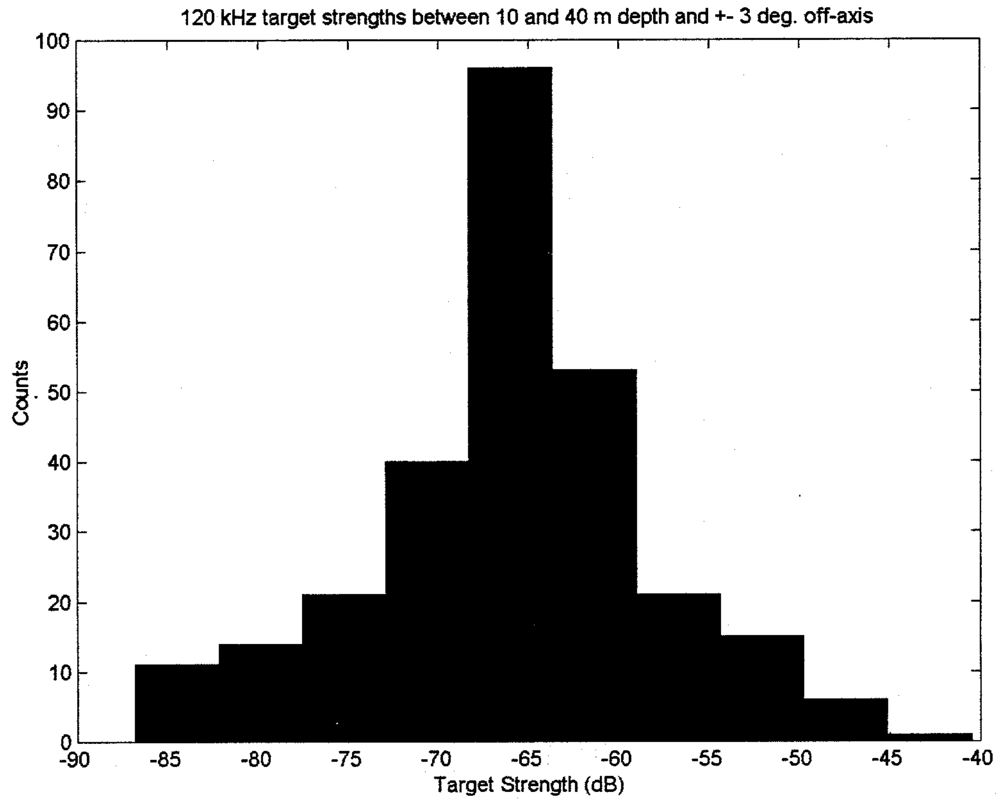


Figure 5.4 *In-situ* target strength measurements at 120kHz. Measurements were constrained to depths between 10 and 40m and off-axis angles of less than 3 degrees. The distribution is likely biased high, but the mode between -65 and -68dB is consistent with large krill (>50mm lengths) as suggested by the underwater video observations.

6. IWC Whale Survey: submitted by Steve Reilly (Leg I), Deborah Thiele (Leg I), Paula Olson (Leg I), James Cotton (Leg I), Simon Berrow (Leg I), and Amy Williams (Leg I).

6.1 Objectives: The International Whaling Commission (IWC) and its Scientific Committee have recognized for a number of years that basic understanding of the feeding ecology of Antarctic baleen whales is important. The IWC's relatively recent interest in the effects of environmental change on whale stocks has provided a new focus for research to investigate the relationships among cetaceans, their prey and their environment. Although previous surveys for cetaceans have been conducted in the Southern Ocean, a concurrent large-scale whale and krill survey had not been conducted in the Antarctic since the development of modern acoustic tools for continuously measuring krill. During Leg I, the IWC participated in its first collaborative survey effort with CCAMLR. IWC whale observation teams participated in CCAMLR's synoptic krill survey of the South Atlantic sector of the Southern Ocean. The primary objective was to collect visual line transect data on the region's cetaceans while CCAMLR scientists sampled zooplankton continuously during daylight hours.

6.2 Methods and Accomplishments: The US-chartered R/V *Yuzhmorgeologiya* was able to berth six IWC observers, the UK *RRS James Ross Clark* was able to berth four, and the Japanese R/V *Kaiyo Maru* accommodated two IWC observers. Because the krill survey vessels were able to accommodate differing numbers of observers, it was necessary to implement different observation schedules and types of secondary data collection. Data collection was based on line-transect methods and two modes of surveying for cetaceans were used: Primary (single observation team) mode and BT (two independent teams) mode. It was not possible to collect BT mode data on the R/V *Kaiyo Maru* with only two observers present, so all effort on that ship was in primary mode. Environmental data that might affect the probability of detecting whales were recorded during all searching effort. These included weather, sea state and visibility data as judged by the observers and also data from the ship's underway instrumentation. Weather conditions were considered unsuitable for surveying if the wind speed was stronger than Beaufort force 6 or visibility was less than one nautical mile. Binoculars were used to search for cetaceans.

Cetacean Passive Acoustic Survey.

On the *RRS James Clark Ross* only, passive acoustic data were collected to complement the visual data. The acoustics project leader and operator of the acoustic equipment was also a member of the visual observation team, and therefore the acoustic data collection had to be fully automated with only minimum maintenance.

Acoustic monitoring provides an opportunity to collect data in conditions such as darkness, poor visibility or high sea states- all of which are unsuitable for visual observations. Many cetacean species are highly vocal and sound propagates well in the sea, enabling passive acoustics to be used to detect many species. The main limiting factor to detecting whales acoustically from a moving vessel is the noise from the vessel. The *RRS James Clark Ross* is particularly suitable for this kind of work because the ship was designed to be as quiet as possible. Nevertheless, the vessel was still the dominant source of low frequency noise and high pass filters were employed to reduce levels below 200Hz. This precluded monitoring for baleen whales. The acoustic survey was aimed at odontocete whales whose vocal behavior included sounds in the 200Hz-20kHz range. Acoustic methods are particularly appropriate for sperm whale population assessment, a difficult species to survey visually because of their long dive cycles.

The equipment used consisted of a hydrophone array towed behind the ship and an automated recording and monitoring system. The array was towed on a 400m kelvar-reinforced cable and consisted of a 10m long, 30mm diameter, oil-filled, polyurethane tube containing two Benthos AQ-4 elements, 3m apart. Each AQ-4 element had a separate pre-amplifier with 29dB gain and a bandwidth of 200Hz to 40kHz. The complete array and cable configuration was calibrated after the cruise. Previous tests using the same pre-amplifier design, but different oil and tube wall material, gave a flat response with a sensitivity of –170dB re 1V/μPa at 20kHz. The array was streamed from the stern of the vessel at speeds of up to 12 knots and recovered using a deck winch.

The recording system used a standard Digital Audio Tape (DAT) recorder controlled by a personal computer to make 30 second recordings every two minutes. All recordings were made in stereo and the time between signals arriving at each element was used to calculate bearings relative to the axis of the array. Some of the recordings were listened to during the cruise but the majority will be analyzed following the cruise. In addition, real time monitoring software (*Rainbow Click* developed by Dr. Douglas Gillespie) designed to detect and measure bearings to sperm whale clicks was run continuously whenever the hydrophone was deployed.

Similar equipment has been used on previous studies from similar vessels in the Southern Ocean (Gillespie, 1997; Leaper and Scheidat, 1998), including from the *RRS James Clark Ross* as part of the BAS Core Programme (Leaper and Papastavrou, 1999).

6.3 IWC-CCAMLR Summaries: The associations suggested between cetacean distributions and environmental patterns are very qualitative first impressions and require a more thorough quantitative examination, as the full set of data from the cruise becomes available. The quantitative analyses that should be most interesting will be comparisons of contemporaneously collected whale sightings and krill acoustic results. The analyses will be conducted most effectively in a workshop mode with participation of both IWC and CCAMLR scientists.

The field collaboration between the IWC/SC and SC-CCAMLR was a clear success. This effort demonstrated the feasibility of expanding the scope of CCAMLR's krill surveys to include systematic surveys for cetaceans. IWC was generally successful in conducting standardized "passing mode" sighting surveys from the CCAMLR vessels. The passive acoustic survey on the James Clark Ross appears to have provided useful survey information on presence of odontocetes, particularly sperm whales.

The IWC will realize at least two categories of benefits as detailed data analyses are completed. First, it will have for the first time a depiction of contemporaneous but large-scale associations between baleen whales and krill in the Southern Ocean. This will fill an important gap in IWC's attempts to establish baseline patterns from which to judge potential effects of climate change on whale stocks. It is clear that if such effects occur it will be through the whales habitat and prey. Results of this cruise will make an important contribution to the required quantification of whale habitat and prey use patterns. Second, the addition of over 10,000 km line transect searching in Areas I and II (defined by IWC) will add substantially to our general base of knowledge of whale abundance and distribution in this region. CCAMLR will realize the benefit of quantitative measures of the distribution and abundance of baleen whales, abundant and effective krill predators, as that Commission assembles ecosystem-based krill management advice.

6.4 Disposition of Data: The sightings data are on file at the IWC Secretariat in Cambridge, UK. It is suggested that the data managers from IWC and CCAMLR establish contact to initiate transfer of respectively held data sets from this cruise so that both commissions have complete sets.

6.5 References:

Gillespie, D. 1997. An acoustic survey for sperm whales in the Southern Ocean sanctuary conducted from the RSV *Aurora Australis*. *Report of the International Whaling Commission* 47: 897-907.

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Leaper, R. and Scheidat, M. 1998. An acoustic survey for cetaceans in the Southern Ocean Sanctuary conducted from the German government research vessel *Polarstern*. *Report of the International Whaling Commission* 48: 431-437.

Siegal, V., Kawaguchi, S., Litvinov, F., Loeb, V. and Watkins, J. 2000. Krill distribution patterns in the Atlantic sector of the Antarctic during the CCAMLR Survey 2000. Working paper submitted to CCAMLR's Working Group on Ecosystem Monitoring and Management, June 2000. WG-EMM-00/6.

7. Seabird research at Cape Shirreff, Livingston Island, Antarctica, 1999/2000; submitted by Terence M. Carten, Michael Taft, Wayne Z. Trivelpiece and Rennie S. Holt.

7.1 Objectives: The austral summer of 1999-2000 marked the third season of land-based predator studies conducted by the U.S. AMLR program at the Cape Shirreff field camp, Livingston Island, Antarctica (62° 28'S, 60° 46'W). Cape Shirreff is one of two sites on the Antarctic Peninsula where long-term monitoring of predator populations is being undertaken in support of US participation in CCAMLR (Convention for the Conservation of Antarctic Marine Living Resources). The objectives of the seabird research for the 1999/2000 season were to collect the following predator monitoring data:

1. To estimate chinstrap and gentoo penguin breeding population size (CCAMLR Ecosystem Monitoring Program (CEMP) Standard Method A3);

2. To band 1000 chinstrap and 200 gentoo penguin chicks for future demography studies (CEMP Std.Method A4);

3. To determine chinstrap penguin foraging trip durations during the chick rearing stage of the reproductive cycle (CEMP Std. Method A5);

4. To determine chinstrap and gentoo penguin breeding success (CEMP Std. Methods 6a,b&c);

5. To determine chinstrap and gentoo penguin chick weights at fledging (CEMP Std. Method 7c);

6. To determine chinstrap and gentoo penguin diet composition, meal size, and krill length/frequency distributions via stomach lavage (CEMP Std. Methods 8a,b&c), and

7. To determine chinstrap and gentoo penguin breeding chronologies (CEMP Std. Method 9).

7.2 Accomplishments: Four scientists were put ashore by the expedition cruise ship R/V *Lawrence M. Gould* on the 31 October 1999, and research continued until camp closure on 9 March 2000. Additionally, two more scientists were transferred to Cape Shirreff aboard the R/V *Lawrence M. Gould* on the 22 December 1999, another scientist was brought to the field camp aboard the M/V *Prof. Molchanov* on the 29 January 2000 and the R/V *Yuzhmorgeologiya* brought one scientist to Cape Shirreff on the 21 February 2000. Logistical support and transit back to Punta Arenas, Chile at the end of the season was provided by the R/V *Yuzhmorgeologiya*.

Breeding Biology Studies.

The Cape Shirreff penguin rookery consists of 30 breeding colonies of penguins; 19 chinstrap penguin (*Pygoscelis antarctica)* colonies, six gentoo penguin (*P. papua)* colonies and five colonies with both species. Chinstrap and gentoo penguin breeding populations were censused on 28 and 30 November 1999, approximately one week following the peak of clutch initiation of both species. Only half of the rookery was censused on the 28th, due to inclement weather. The remainder of the breeding pairs was counted on the 30th. All colonies were counted in their entirety according to CEMP Standard Methods. The breeding populations in the 1999/00 season were determined to be 7,744 chinstrap penguin pairs and 922 gentoo penguin pairs. The number of chinstrap penguin breeding pairs was slightly higher than in the 1998/99 season. Gentoo penguins showed an 11% increase in breeding pairs from the 1998/99 season.

Reproductive success was determined by following a sample of 100 banded chinstrap penguin pairs and 50 gentoo penguin pairs from egg laying to crèche formation. Chinstrap penguins hatched 1.26 chicks/pair and fledged 1.02 chicks/pair, with 81% of all hatched chicks surviving to fledging. Gentoo penguins had higher reproductive success hatching 1.72 chicks/ pair and fledging 1.4 chicks/pair, also with 81% of all hatched chicks surviving to fledging. Reproductive success of chinstrap penguins declined in the 1999/00 season, compared to 1998/99, except for the percent of hatched chicks that survived to fledging, which was slightly higher. Gentoo penguin reproductive success was higher in all variables in 1999/00, compared with 1998/99.

Counts of all chicks on 8 February produced a total of 9,226 chinstrap penguin chicks and 1,159 gentoo chicks. This represented an increase of 5% for chinstrap penguins and 14% for gentoo penguins over the chick counts from the 1998/99 season.

We banded a sample of 1,000 chinstrap and 200 gentoo penguin chicks for future demographic studies. Birds that survive and return to the rookery will be followed throughout their reproductive lives during future seasons.

Chinstrap penguin chick fledging weights were collected daily between 16 February and 24 February, according to CEMP Standard Method 7c. The mean fledging weight of 223 chicks captured on the rookery beaches, as they were about to depart to sea, was 3,250g, compared with 3,200g for the 1998/99 season. "Fledging" weights were also collected for gentoo penguin chicks. Gentoo penguin chicks do not fledge in the classic sense, returning after their first trips to sea to be supplementally fed by their parents. Therefore, weights were collected at a set date during the breeding chronology, at 85 days post-mean clutch initiation, for inter-annual comparisons. Assuming a 36-day incubation period, gentoo penguin chicks were approximately 7 weeks old at the time of weighing, the age at which other *Pygoscelis* penguins fledge. Two hundred chicks were captured and weighed on 10 February, with a mean weight of 4,040g, a decrease of 410g from the 1998/99 season.

Foraging Ecology Studies.

Diet studies of chinstrap and gentoo penguins during the chick-rearing phase were initiated on 4 January and continued through 8 February 2000. Forty chinstrap and 20 gentoo penguin adults returning from foraging trips to sea were captured at their nest sites, prior to feeding their chicks, and their stomach contents were removed by lavaging. We noted the sex of the returning adult, the number of chicks present at the nest, and their approximate ages. Krill (*Euphausia superba*) was present as a prey species in 100% of the samples from both species, while evidence of fish was noted in only 3% of chinstrap, but 80% of gentoo penguin samples. The one chinstrap penguin diet sample containing fish evidence consisted of a single otolith. Gentoo penguins frequently had fresh fish in their stomachs, as well as semi-digested squid and octopi. As in the past two seasons, the length frequency distribution of krill in the penguins' diets during 1999/00 was predominated by three CCAMLR size classes, which accounted for 91% of all krill in the samples. The strong 4-5 year age class of krill represented in 1998/99 was predominant again with the majority of krill shifting up into the 41-45, 46-50 and 51-55mm CCAMLR size categories (Figure 7.1).

We attached 18 radio transmitters to adult chinstrap penguins feeding 1-1.5 week old chicks on 2-3 January and followed their foraging trips through mid-February using a remote receiver and data logger set up in the rookery. As in the past two seasons, foraging trips exhibited a bimodal distribution. The main peak for trip duration was around 8 hours, less than in the 1997/98 and 1998/99 seasons. The second peak, near 12 hours, was again shorter than the past two seasons. Trends in the diel pattern of foraging trips (Figure 7.2) were similar in all three years of data, with shorter trips beginning between dawn and noon and longer trips (> 12 hours) including the overnight period. Lack of otolith evidence in the chinstrap diets during 1999/00 may suggest that fish were not as abundant for the nocturnal foragers as in the past two seasons. It seems that in some years, fish may not be as important a component in the adult chinstrap diet as we have previously suggested. However, an inshore survey, conducted in early February, found large krill aggregations just off Cape Shirreff; the existence of abundant krill inshore may have altered the usual chinstrap penguin foraging patterns and caused adults to subsist almost entirely on krill in 1999/00.

Time-depth recorders (TDRs) were deployed three times during the season to study diving behavior. Five TDRs were placed on chinstrap penguins and five on gentoo penguins in early January. A second deployment (5 chinstrap, 5 gentoo) occurred in mid-January. All TDRs remained on for 7-10 days of foraging before being removed and downloaded. A third deployment of five TDRs was put on chinstrap penguins in early February to coincide with a nearshore hydroacoustic survey off Cape Shirreff. All instruments remained on the penguins throughout the five-day survey.

In addition to the radio transmitters and time-depth recorders, PTTs (satellite-linked transmitters) were deployed on chinstrap penguins during the chick-rearing phase to determine foraging locations. Five PTTs were deployed in early January. The instruments remained on for 7-10 days before being retrieved for another deployment in mid/late January. One penguin failed to return from the second deployment leaving us with four instruments. A third and final round was put out to coincide with the nearshore hydroacoustic survey. These remaining PTTs stayed on for the entire five-day survey as well. Analyses of penguin foraging locations and dive records are currently being processed.

Reproductive studies of brown skuas (*Catharacta lonnbergi*) were conducted throughout the field season. All skua chicks and any new breeding adults were banded. Measurements of culmen length and depth, tarsus length, and weight were collected for all newly banded skuas. Reproductive performance of kelp gulls (*Larus dominicanus*) was followed opportunistically throughout the season.

7.3 Preliminary Conclusions: The third (and for some parameters, fourth) season of data collection at Cape Shirreff has allowed us to compare annual indices of population size, foraging behavior, and reproductive performance among years. Overall reproductive success of chinstrap penguins was lower in the 1999/00 season than in 1998/99 and slightly lower than the three year mean. Gentoo penguin reproductive success was higher in 1999/00 compared with 1998/99, and was also above the three-year mean. The mean fledging weight of chinstrap penguin chicks for the 1999/00 season was slightly higher than in 1998/99, and comparable to the four-year mean (fledging weights were also collected during the 1996/97 season). Mean fledging weights for gentoo penguin chicks were lower in 1999/00 than in 1998/99, and below the three-year mean. The number of chinstrap and gentoo penguin breeding pairs was higher in 1999/00 than in the previous season, as were the numbers compared to the three-year mean. Future research plans include continuing the annual CCAMLR predator monitoring protocols and at-sea foraging behavior studies with time-depth recorders (TDRs) and satellite-linked transmitters (PTTs). These methods, in addition to the annual marine survey, will enable us to investigate the seasonal and inter-annual variability of the land-based predator indices at Cape Shirreff and to compare this variability to data from the adjacent marine ecosystem, collected by the AMLR marine surveys.

7.4 Acknowledgments: We would like to thank the Chilean research team, who graciously assisted us with some of our fieldwork, were our neighbors and friends, and became something of a second family during the season when we were so far away from our own. A special thanks goes to INACH (Instituto Antarctico Chileno) and the Chilean Navy for taking one of the authors back to South America with their field team. We are grateful to Mike Goebel and Matt Rutishauser for help with the seabird research and for being there through the thick and thin of a long field season. Dan Costa assisted us with some of the dirtier aspects of penguin field research, and we thank him. The crew of the NSF R/V *Laurence M. Gould* are to be commended for our smooth and timely transit to Cape Shirreff to open the season, as are the crew of the AMLR chartered R/V *Yuzhmorgeologiya* for their assistance in resupplying the camp and for transit back to Chile at the end of the season. Special thanks to Stephanie Sexton and Jane Martin for keeping communication open with the outside world, supplying us with satellite foraging locations, and keeping everything together on the home front.

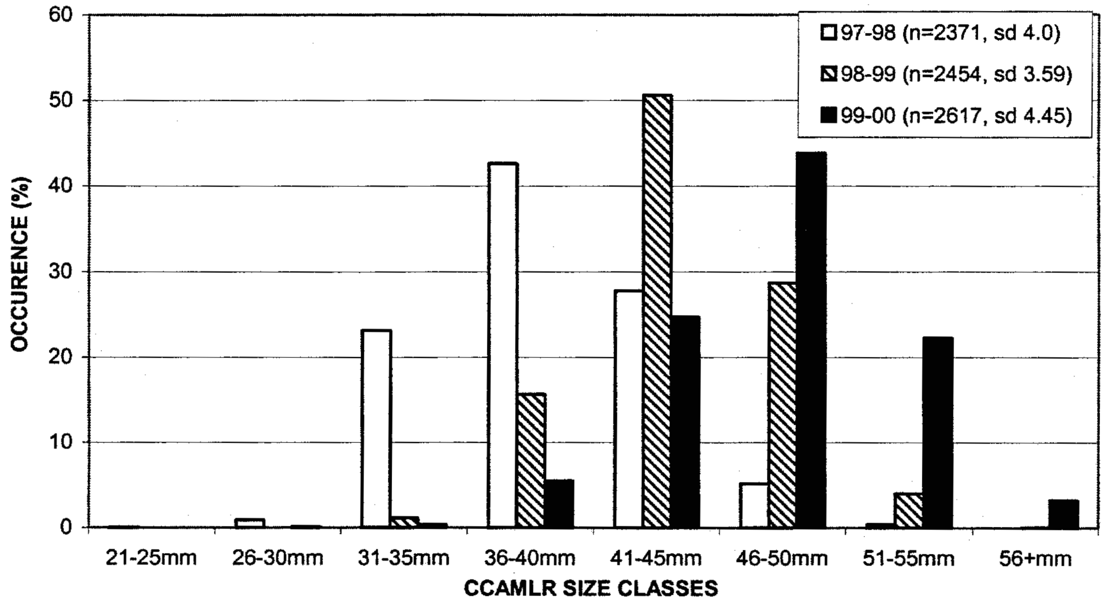

Figure 7.1 Krill length frequency distribution from penguin diet samples at Cape Shirreff, Livingston Island, Antarctica.

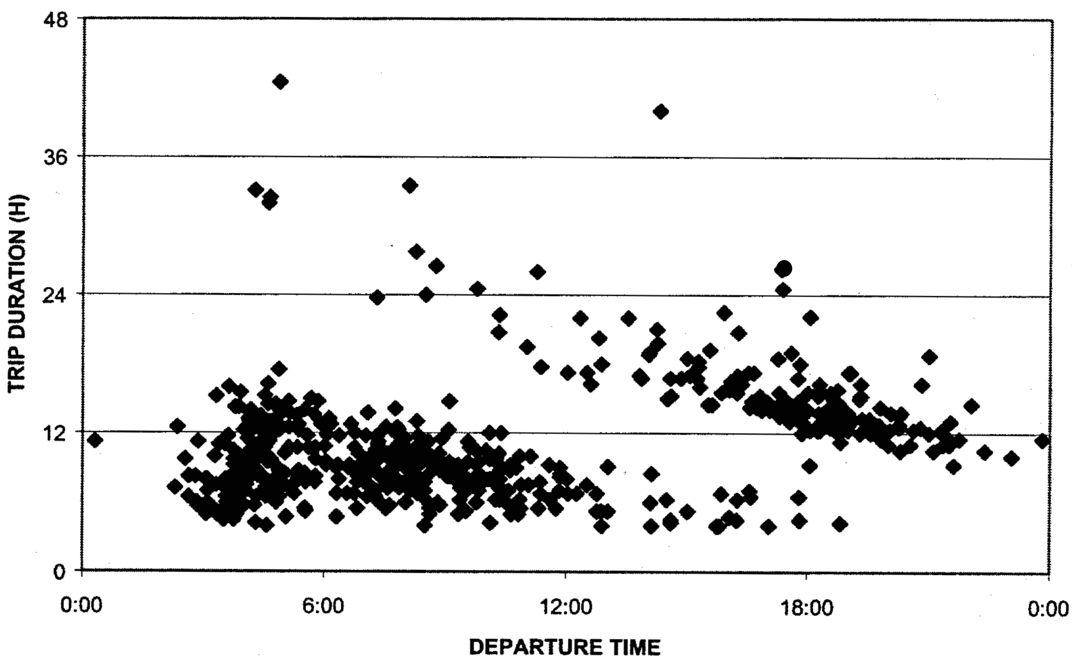

Figure 7.2 Diel pattern of chinstrap penguin foraging trip durations at Cape Shirreff, Livingston Island, Antarctica, 1999/2000.

8. Pinniped research at Cape Shirreff, Livingston Island, Antarctica, 1999/2000; submitted by Michael E. Goebel, Matthew Rutishauser, Brian Parker, Alison Banks, Daniel P. Costa, Nick Gales, and Rennie S. Holt.

8.1 Objectives: Pinniped research was conducted by the U.S. AMLR Program at Cape Shirreff, Livingston Island, Antarctica (62°28'S, 60°46'W) during the 1999/2000 season. Studies on the foraging ecology and energetics of adult female fur seals were conducted by the University of California-Santa Cruz in collaboration with the US-AMLR Program. A four-person field team arrived at Cape Shirreff via the R/V *Lawrence M. Gould* on 31 October 1999. Research activities were initiated soon after and continued until closure of the camp on 9 March 2000. Our research objectives for the 1999/2000 field season were to:

A. Monitor Antarctic fur seal female attendance behavior (time at sea foraging and time ashore attending a pup);

B. Assist Chilean researchers in collecting length, girth, and mass for fur seal pups every two weeks throughout the season;

C. Document fur seal pup production at designated rookeries on Cape Shirreff and assist Chilean colleagues in censuses of fur seal pups for the entire Cape and the San Telmo Islands;

D. Collect fur seal scats weekly for diet studies;

E. Collect a milk sample at each adult female fur seal capture for fatty acid signature analysis and diet studies;

F. Deploy time-depth recorders on adult female fur seals for diving studies;

G. Record at-sea foraging locations for adult female fur seals using ARGOS satellite-linked transmitters;

H. Measure at-sea metabolic rates and foraging energetics of lactating female fur seals using doubly-labeled water (deployments to coincide with the US-AMLR Oceanographic Survey cruises);

I. Tag fur seal pups for future demographic studies;

J. Extract a lower post-canine tooth from adult female fur seals for aging studies;

K. Measure metabolic rates (O_2 consumption) and thermo-neutral zones of pups and juvenile (yearling) Antarctic fur seals using a metabolic chamber; and

L. Deploy a weather station for continuous recording of wind speed, wind direction, ambient temperature, humidity and barometric pressure during the study period;

8.2 Accomplishments:

A. Female Fur Seal Attendance Behavior: Sometime after parturition, Otariid females begin a cyclical series of trips to sea and visits to shore to suckle their offspring. These cycles are called attendance behavior. Measuring changes in attendance patterns (especially the duration of trips to sea) of lactating Otariids is one of the standard indicators of a change in the foraging environment. We instrumented 24 lactating females from 5-11 December 1999. The study was conducted according to CCAMLR protocol (CCAMLR Standard Method C1.2 Procedure A) using VHF radio transmitters (Advanced Telemetry Systems, Inc., Model 7PN with a pulse rate of 40ppm). Presence or absence on shore was monitored for each female every 30 minutes for 30 seconds. All females were instrumented 1-2 days post-partum (determined by the presence of a newborn or a pup with an umbilicus) and were left undisturbed for at least their first six trips to sea. Pups were captured at the same time as their mothers, and weighed, measured, and marked with an identifying bleach mark. The health and condition of the pups were monitored throughout the study by making daily visual observations. One of the 24 females lost her pup during her perinatal period and we report results for the remaining 23. Our record of presence and absence was nearly continuous throughout the season (5 December-9 March) except for two breaks. The first break began midnight 31 December (a Y2K software problem); the break was corrected by 11a.m. 1 January. The second break was longer. It began at midnight 31 January on both recording systems (the main recorder located on the ridge above Maderas beach and the backup recorder located on El Condor). The problem was not discovered until 6 February at 10:51 and was corrected then.

The first female in our study of attendance patterns to begin her foraging cycles did so on 10 December 1999. The last female to complete six trips to sea did so on 26 January 2000. The mean trip duration for the combined first six trips to sea this year was less than the previous two seasons (Table 8.1; Figure 8.1; ANOVA, $df_{2,501}$, $p<0.005$). Visit durations were also longer in 1999/00 than in 1997/98 and 1998/99 (Table 8.1; Figure 8.1; ANOVA, $df_{2,501}$, $p<0.005$). In two out of the three years (1998/99 and 1999/00), the distribution of trip durations was skewed to longer trips (Table 8.1; Figure 8.2). Visit durations for all three years were likewise skewed (Table 8.1). There was also less variance in the duration of trips to sea in 1999/2000 than in the previous two seasons (Figure 8.1).

There was no difference in the postpartum mass of our attendance females for 1998/99 and 1999/2000. Females in 1998/99 and 1999/2000 were, however, larger than females in 1997/98 (Figure 8.3a; ANOVA, $df_{2,83}$, $p<0.0001$; **97/98:** Mean=39.2kg ±5.76, N=31; **98/99:** Mean=45.6kg ±6.67, N=32; **99/00:** Mean=46.5kg ±5.90, N=23). This is because females in that year were sampled later (21-31 December) and late arriving females tend to be younger and smaller. The mass-to-length ratio for all three years was not different (Figure 8.3b; ANOVA,

$df_{2,83}$, $p<0.58$; **97/98:** Mean=0.338 ±0.033, N=31; **98/99:** Mean=0.347 ±0.041, N=32; **99/00:** Mean=0.346 ±0.034, N=23).

B. Fur Seal Pup Growth: Measures of fur seal pup growth was a collaborative effort between the US research team and Chilean researchers. Data on pup weights and measures were collected every two weeks beginning on 16 December and ending 1 March (six bi-weekly samples). Data were collected as directed in CCAMLR Standard Method C2.2 Procedure B. Growth rates for male pups were higher this year than last (Torres, unpublished data); results will be submitted to CCAMLR by Chilean colleagues.

C. Fur Seal Pup Production: Fur seal pups (live and dead) and females were counted by US researchers at four main breeding beaches (Copihue, Maderas, Cachorros, and Chungungo) on the east side of the Cape. Censuses were conducted every other day from 2 November 1999 through 9 January 2000. The maximum number counted at the combined four beaches in 1999/2000 was 2,104 on 3 January 2000 (Figure 8.4), a 5.8% increase over the maximum count for the same sites in 1998/99 (1,983 on 27 December 1998). The median date of pup births was 8 December, two days earlier than in the previous two seasons.

With increasing numbers of pups at Cape Shirreff, there is some concern that a mark-recapture study should be initiated to get a more accurate estimate of the total number of pups born. Such a study is particularly important at sites where there is tussock grass or terrain that obscures animals from being seen. Cape Shirreff (and the San Telmo Islands) and its beaches, however, are all very open with very few areas, such as boulders or caves, which could obscure pups. Nonetheless, we conducted a study to test the accuracy of our counts. We used the four study beaches that we count every other day. We selected a day (9 January) soon after the last pups were born (estimated from previous years' counts) and before pups begin to disperse from breeding beaches. Three observers counted all pups on the four beaches independently from 16:20-19:00. Each observer counted three times by walking from one end of the study area to the other each time. Weather conditions were dry, partly sunny, 3.9°C, with moderate west wind (15 knots). Results are presented below (Table 8.2).

The overall mean of the nine counts was 1,871 pups (s.e.=44.29). All counts were within 6.6% of the overall mean and the maximum within observer percent difference was only 2.9%. We conclude that even though pup numbers have increased substantially over the last decade at Cape Shirreff, an accurate estimate of the total pup production can still be obtained from simple counts. This is primarily because of the open terrain, low density of animals and the lack of obscuring features.

D. Diet Studies: Information on fur seal diet was collected using three different sampling methods: collection of scats, enemas, and fatty acid signature analysis of milk. In addition to scats and enemas, an occasional regurgitation is found in female suckling areas. Regurgitations often provide whole prey that is only minimally digested. Scats are collected from around suckling sites of females or from captured animals that defecate while captive. Enemas are given to all females that are captured to remove a time-depth recorder or satellite-linked transmitter (PTT). Ten scats were collected every week beginning 29 December. In total, we collected and processed 84 scats, 27 enemas, and 3 regurgitations from 29 December 1999-5 March 2000. Diet samples that were not processed within 24 hours of collection were frozen. All samples were processed by 12 March. Up to 30 krill carapaces were measured from each sample that contained krill. Otoliths were sorted, dried, identified to species and measured for length and width. The number of squid beaks were counted and preserved in 70% alcohol for later identification. Results indicated an increasing proportion of fish and squid in the diet from December through February and a reduction in the percent of krill from December to January (Figure 8.5). The percentage of krill in the diet remained the same from January through February. Compared to our results from last year, there was more fish and less krill in the diet this year (Table 8.3, X^2=7.00, d.f.=2, p=0.03).

E. Fatty Acid Signature Analysis of Milk: In addition to scats, enemas, and regurgitations, we collected 201 milk samples from 121 female fur seals. Each time a female was captured (either to instrument or to remove instruments) a 30ml (or less) sample of milk was collected by manual expression. Prior to collection of the milk sample, an intra-muscular injection of oxytocin was administered (0.25ml, 10 UI/ml). The milk sample was returned (within several hours) to the lab where two 0.25ml aliquots were collected and each stored in a solvent-rinsed glass tube with 2ml of Chloroform with 0.01% butylated hydroxytoluene (BHT, an antioxidant). Samples were flushed with nitrogen, sealed, and stored frozen until later extraction of lipid and trans-esterification of fatty acids. Of the 201 samples, 37 were collected from perinatal females and 46 were collected from 34 females that had dive data for the foraging trip prior to milk collection.

F. Diving Studies: Six of our 23 females which were fitted with transmitters for attendance studies, also received a time-depth recorder (TDR, Wildlife Computers Inc., Mark 7, 8.6 x 1.9 x 1.1cm, 27g) on their first visit to shore. All females carried their TDR for at least the first six trips to sea. In addition, all other females captured for studies of foraging locations and energetics also received a TDR. The total number of females with diving data for 1999/2000 was 37. The total number of trips recorded on TDRs from 10 December 1999- 5 March 2000 was 109.

G. Adult Female Foraging Locations and Energetics: We instrumented 34 females with satellite-linked transmitters (ARGOS-linked PTT's) from 29 December- 5 March. Twenty-one carried a PTT for a single trip to sea, five others for two trips to sea and eight females carried their PTT for three trips to sea. Results of fur seal foraging location data analysis and comparisons to the two previous seasons are pending.

H. Foraging Energetics: Twenty (10 in January, 10 in February) of the 34 females we instrumented with PTT's also received an intra-peritoneal (IP) injection of doubly-labeled water (DLW). Each female was captured on her second day on shore, administered DLW, and recaptured as soon as possible on the next visit to shore. The resulting measures of water flux and at-sea metabolic rate are pending and will be presented elsewhere.

I. Demography and Tagging: Together Chilean and US researchers tagged 500 fur seal pups from 20 January- 8 March 2000. All tags placed at Cape Shirreff were Dalton Jumbo Roto tags with white tops and orange bottoms. Each pup was tagged on both fore-flippers with identical numbers (1500-1999). Most pups were tagged on the east side of the Cape from Playa Daniel to Chungungo beach on 31 January and 14 February. Thirty-four tags (1566-1599) were placed on pups at Loberia Beach on the northwest side of the Cape.

In addition to the 500 pups tagged, we also tagged 100 adult lactating females (088-187). All but three tags were placed on females with parturition sites on Copihue, Maderas, Cachorros, and Chungungo beaches. The three remaining tags were placed on females at Loberia.

Last year we added 52 adult females to our tagged population at Cape Shirreff bringing the total tagged population present in 1998/99 to 83 females (Table 8.4). Of these, 78 (94.0%) returned in 1999/2000 to Cape Shirreff and (72) 92.3% returned pregnant. Both return rate and natality were higher in 1999/2000 than in the previous year (Figure 8.7).

Our tagged population of females returned (on average) two days earlier than last year. In 1998/99, the mean date of pupping for tagged females (which had a pup in both years) was 11 December (±8.0, N=67) and in 1999/2000, for the same females, it was 9 December (±6.6, N=67). This result agrees with our estimates of the median date of pupping based upon pup counts for the season.

We also observed six yearlings (one female, five males tagged as pups in 1998/99) and 37 2-year-olds (21 females, 14 males, 2 unknowns) that returned to Cape Shirreff in 1999/2000. The first observation of a tagged yearling in 1998/99 was 8 December. This year the first yearling was not observed until 25 January. The return rate for the first year for the two cohorts (97/98 and 98/99) was substantially different (Table 8.5); most of the difference was in the return of females.

The number returning at age 1 is not necessarily an adequate estimate of survival. This is borne out by the return of 2-yr-olds. Of the 22 yearlings observed in 1998/99, only five were observed as 2-yr-olds and 86.5% (n=32) of all the 2-yr-olds sighted had not been observed as yearlings. Thus the percent survival for year 1 of the 1997/98 cohort reported in Table 8.6 is a **minimum** estimate. Tag returns of the 1997/98 cohort in future years will determine how close this value is to the actual survival.

Tag loss in our study is high. We calculated the probability of losing a tag by dividing the number missing one tag by the total number of tags (with known tag status). By age two the probability of losing both tags was 0.19 and, for the 1998/99 cohort, it was 0.11. Most tag loss was by the tag hole stretching and the tag falling out rather than by tearing. Tag loss (for the 1997/98 cohort) was higher in females than in males (Table 8.6).

J. Tooth Extraction and Age Determination: We began an effort of tooth extraction from adult female fur seals for age determination in 1999/2000. Tooth extraction was a 3-day effort that began on 21 February. The procedures for extraction of the post-canine were as follows:

- Female fur seals were captured using a hand net containing a strengthened opening in the cod end through which the seal's muzzle fit snugly.

- The seal, restrained by the net, was carried to the anesthesia machine or the machine was brought to the seal, depending on which was more convenient.

- O_2 flow was set at 10 L/min and the vaporizer (containing isoflurane) was set to the maximum of 5%. Before the gas mask (a standard veterinarian mask for a large dog) was placed over the muzzle of the restrained seal, the breathing circuit's exhaust port was closed and the gas mask was blocked with the palm of a hand until the gasbag partially inflated.

- The seal was manually restrained in the net as the gas mask was placed over the protruding muzzle. The exhaust port was then opened about 80%. Once the seal was breathing calmly, the O_2 flow was reduced to 4-5 L/min.

- The anesthetist then monitored the seal's breathing rate and level of consciousness. At all times, the anesthetist kept one hand on the seal's head so as to provide limited control of her head should she arouse. Best results were obtained by keeping the seal on the full 5% isoflurane and 4-5 L/min O_2 until the tooth extraction was completed.

- During the initial placing of the seal on the oral anesthetic, the seal also received an intravenous injection of 1cc of midazolam hydrochloride to further anaesthetize her.

- After the intravenous injection, when the anesthetist deemed the seal sufficiently anaesthetized, the net was removed from the seal and measurements (mass, length, & girth), milking, tagging (if untagged), and finally tooth extraction were conducted. The anesthetist continuously monitored the seal□s breathing rate and level of consciousness and suspended tooth extraction operations whenever a seal began to show signs of arousal. (The gas mask must be removed for tooth extraction and the seal usually became aroused within 45 seconds). Tooth extraction rarely took more than 60 seconds.

- Tooth extraction was conducted using a dental elevator to sever the anterior and posterior ligaments of the tooth. Once the tooth ligaments were cut dental extractor pliers were used to pull the tooth using a slight twisting motion.

- After tooth extraction, if release time was going to be a matter of some minutes, the seal was placed on a mixture of 2.5%-3.5% isoflurane & 4 L/min O_2. If release time was expected to occur within 1 minute (for example only weighing of the seal remained), she was placed on the full mixture of 5% isoflurane & 4 L/min O_2. Before final removal of the gas mask, the level of consciousness of the seal was noted and the seal was carried in a weighing stretcher to a distance away (approximately the location of capture). The seal was lifted off the stretcher and placed with the head up-hill and fore-flippers outstretched. Researchers then retreated from the area to allow the seal to arouse slowly without being startled by the presence of the researchers. Released seals were monitored throughout recovery from anesthesia; in all cases, recovery took only several minutes.

The post-canine was successfully extracted from 80 fur seals (41 tagged females, 38 untagged females, one sub-adult tagged male). All females were either tagged and known to have a pup, or untagged and suckling a pup. Females ranged in size from a mass of 31.0-58.2kg and length of 114-144cm. The mean total time captive was 12.6 minutes (±3.9) and the mean total time under anesthesia was 9.6 minutes (±2.7, n=80).

Five females in our sample carried VHF radio transmitters (for the attendance behavior study) before and after tooth extraction. Table 8.7 summarizes data on trip and visit durations for these females. There was no difference in visit durations when comparing the visits preceding tooth extraction, the visit of tooth extraction, and the following visits (ANOVA, $p=0.39$). Similarly, trip durations before and after tooth extraction were not different (paired Student's t-test, $p=0.31$).

The entire sampling for teeth went remarkably well and no adverse post-extraction effects were noted for any individuals. Many of the females were sited suckling their pups on subsequent visits. A subjective assessment of wariness of females on subsequent visits indicated that females that had been captured multiple times for foraging location and energetics studies appeared to be more wary than females that had been captured for tooth extraction. This may be because midazolam, at least in humans, causes temporary amnesia whereas Diazepam (the drug used in routine captures for foraging location and diving studies) does not. Thus females administered Diazepam may have better recollection of capture experiences than those administered Midazolam.

Age determination of extracted teeth is currently underway.

K. Metabolic Rates of Pups and Juveniles: Survival in the first year of life is a critical part of the life history in long-lived vertebrates. In most Otariid species, it is difficult or impossible to study age one animals because they do not return to the natal rookery and are often not seen again until they are several years old. This makes it difficult to assess the important factors that allow survival through their first year of life. In contrast to many Otariid species, yearlings of Antarctic fur seals have a relatively high rate of return to their natal rookery, making them ideal candidates to examine two important factors of their life history: energy stores and thermal homeostasis. Soon after weaning, fur seal pups must learn to find adequate food and maintain their body temperature in water close to freezing. Because blubber is both an energy store and an insulator, body composition is likely to play an important role in survivorship to age one.

We used a metabolic chamber to measure metabolic rates and thermo-neutral zones, and tritiated water to measure body composition for six yearlings and five molted pups. The energetic data collected with these measures also provides the means to produce a simple model to examine how long a weaned animal can survive before it must forage successfully.

L. Weather at Cape Shirreff: A weather data recorder (Davis Weather Monitor II) was set up at Cape Shirreff from 16 November 1999 to 6 March 2000. The data logger was set up at the US-AMLR field camp. The recorder archived wind speed and direction, barometric pressure, temperature, humidity, and rainfall at 15-minute intervals. The sampling rate for wind speed, temperature, and humidity was every eight seconds; the averaged value for each 15-minute interval was stored in memory. Barometric pressure was measured once at each 15-minute interval and stored. When wind speed was greater than 0, the wind direction for each 8-second interval was stored in one of 16 bins corresponding to the 16 compass points. At the end of the 15-minute archive interval, the most frequent wind direction was stored in memory.

Mean daily temperature at Cape Shirreff was (on average) warmer this year than in 1998/99 for the time period 4 December-24 February ($t_{0.05(2), 82}$= -1.98, p=0.05, **1998/99:** 2.23 °C, s.e.=0.11, **1999/00:** 2.51 °C, s.e.=0.11). There was also slightly less precipitation and fewer days of measurable precipitation for the time period 21 December-24 February (**1998/99:** 59.6mm for 43 days, **1999/00:** 57.1mm for 35 days). Cape Shirreff had less over-winter snow cover at the start of this season, although we do not have a precise measure of this. By the time fur seal pupping began in late November, most snow had melted from the breeding areas. The lighter snow cover and decreased precipitation resulted in a relatively dry season for the Cape. Warmer, dryer conditions at the Cape may (in part) explain improved growth rates of pups. When weather conditions are favorable, pups may put more into energetic reserves and growth, and less into thermoregulation.

8.3 Preliminary Conclusions: Fur seal pup production at US-AMLR study beaches on Cape Shirreff increased by 5.8% in 1999/2000 over last year. The median date of pupping based on pup counts was two days earlier. The mean arrival and parturition dates for our tagged female population was also two days earlier. Indicating that females did indeed arrive earlier and not simply that there were fewer late-arriving females. Return rates for adult females indicate good over-winter survival and no change in arrival condition compared to last year. Return rate of yearlings, however, was lower this year than last. Adult female trip duration for the first six trips to sea was significantly less than in the last two years indicating improved foraging conditions. Fur seals had slightly more fish in the diet than last year and the trend for an increasing percent occurrence of fish and squid as the season progresses was evident this year as last year. In general, the 1999/2000 season was better for fur seals by several measures than the previous two seasons at Cape Shirreff.

8.4 Acknowledgements: We are most grateful to our Chilean colleagues: Veronica Vallejos, Olivia Blank, Layla Osmund, Jorge Acevedo, and Mario Brione for their assistance in the field, good humor and for sharing their considerable knowledge and experience of Cape Shirreff. We are also grateful to Terrance Carten and Michael Taft for their considerable help with Pinniped studies. We are particularly grateful to the captain and crew of the R/V *Lawrence M. Gould* who provided transport and assistance to the Cape Shirreff opening team. Without their help we would not have been able to start our studies on time. We are, likewise, grateful to the AMLR personnel and the Russian crew of the R/V *Yuzhmorgeologiya* for their invaluable support and assistance to the land-based AMLR personnel. Studies on the foraging ecology and energetics of fur seals and the metabolic rates of juvenile fur seals were supported by National Science Foundation Grant #OPP 9726567.

	Year	Mean (days)	St.Dev.	N	Range	Skewness[1]	SE	Significance	(-/+)
Trip Durations:									
	1997/98	4.19	1.35	180	8.58	0.0835	0.1811	0.46	-
	1998/99	4.65	1.82	186	11.11	0.8498	0.1782	4.77	+
	1999/00	3.47	1.00	138	7.65	1.2450	0.2063	6.03	+
Visit Durations:									
	1997/98	1.35	0.46	180	2.22	0.6093	0.1816	3.36	+
	1998/99	1.32	0.54	186	3.28	0.9469	0.1782	5.31	+
	1999/00	1.71	0.63	138	4.15	1.0880	0.2063	5.27	+

[1]Skewness: A measure of asymmetry of the distribution of the data. A significant positive value indicates a long right tail. Significance is indicated when the absolute value of Skewness/SE is greater than two.

Table 8.1 Summary statistics for the first six trips and visits (non-perinatal) for female Antarctic fur seals rearing pups at Cape Shirreff, Livingston Island, 1997/98-1999/00.

Observer #	Count #	Total Pups	Observer Mean	S.E.	Within Observer % Difference	% Difference From Overall Mean
1	1	1871			0.4	0.0
1	2	1900			1.2	1.5
1	3	1863	1878	11.24	0.8	0.5
2	1	1889			2.9	0.9
2	2	1952			0.4	4.3
2	3	1993	1945	30.25	2.5	6.5
3	1	1747			2.5	6.6
3	2	1787			0.3	4.5
3	3	1841	1792	27.24	2.8	1.6

Table 8.2 Results of multiple counts of total pup production by three observers on the east-side beaches (Copihue to Chungungo) of Cape Shirreff, Livingston Island. Counts include newly dead pups present on 9 January but not those counted in censuses prior to that date.

	1998/99		1999/2000	
Prey	Observed	Expected	Observed	Expected
Krill	84	73.5	94	105.0
Fish	32	42.5	71	60.5
Squid	12	12.0	17	17.0

Table 8.3 Results of a contingency table on the proportions of major prey types (krill, fish, and cephalopods) in Antarctic fur seal scats and enemas collected at Cape Shirreff, Livingston Island in two years, 1998/99 and 1999/2000. Chi-square=7.00, degrees of freedom=2, p=0.03.

Year	Known Tagged Population[1]	Returned	Pregnant	% Returned	% Pregnant	Tags Placed
1997/98						37[2]
1998/99	37	31	28	83.8	90.3	52
1999/00	83	78	72	94.0	92.3	100

[1]Females tagged and present on Cape Shirreff beaches the previous year.
[2]Includes one female present prior to the initiation of current tag studies.

Table 8.4 Tag returns and pregnancy rates for adult female fur seal at Cape Shirreff, Livingston Island, 1998/99-1999/00.

Tag Returns in Year 1 (%):	Total	Males	Females
1997/98 Cohort:	22 (4.4)	10 (2.0)	12 (2.4)
1998/99 Cohort:	6 (1.2)	5 (2.0)	1 (0.4)

Table 8.5 A comparison of first year tag returns for two cohorts: 1997/98 and 1998/99. Values in parentheses are percents.

1997/98 Cohort Sightings	Total	Males	Females
Sighted in Year 1:	22	10	12
Additional Tags Sighted in Year 2	32	10	20
Minimum survival in Year 1:	54[1]	20	32
Tag Loss:			
Unknown tag status:	3	1	2
Both tags present:	29	13	14
Missing 1 tag:	22	6	16
Probability of missing one tag:	0.43	0.32	0.53
Probability of missing both tags[2]:	0.19	0.10	0.28
1997/98 Cohort Survival:			
Minimum % Survival 1st year:	10.8	8.00	12.80
Adjusted % Survival[3]:	12.8	8.80	16.44

[1]Includes two sightings of seals of unknown sex.
[2]Assumes tag loss is independent for right and left tags.
[3]Adjusted for double tag loss.

Table 8.6 Tag re-sights and minimum percent survival for the 1997/98 cohort.

	Preceding Visit (d)	Tooth Extraction Visit (d)	Next Visit (d)	Preceding Trip (d)	Following Trip (d)
Mean:	1.45	1.83	2.06	2.69	3.12
S.E.:	0.02	0.34	0.39	0.48	0.40
N:	5	5	5	5	5
Max:	1.51	2.87	3.46	3.81	4.69
Min:	1.39	1.21	1.21	1.65	2.55

Table 8.7 Summary of attendance data for 5 females that had a VHF radio transmitter at the time of capture for tooth extraction.

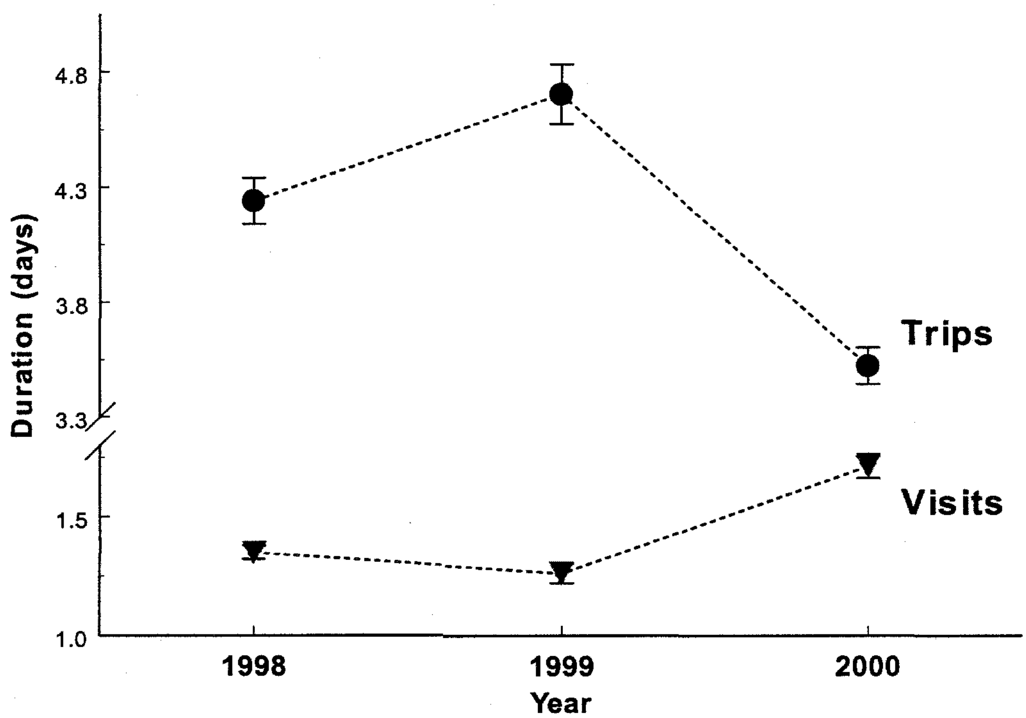

Figure 8.1 Antarctic fur seal trip and visit durations for females rearing pups at Cape Shirreff, Livingston Island. Data plotted are for the first six trips to sea and the first six non-perinatal visits following parturition for the last three years (**1997/98:** $N_{Females} = 30$, $N_{Trips} = 180$; **1998/99:** $N_{Females} = 31$, $N_{Trips} = 186$; and **1999/2000:** $N_{Females} = 23$, $N_{Trips} = 138$). Sample sizes for visits are the same as trips.

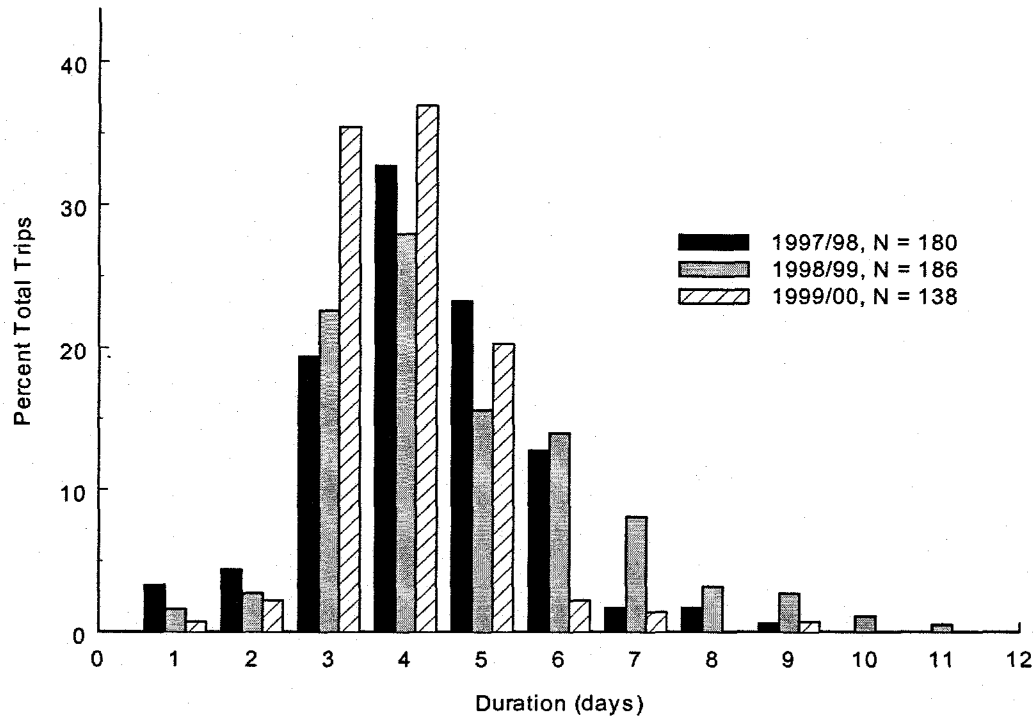

Figure 8.2 Distribution of Antarctic fur seal trip durations for three seasons of study at Cape Shirreff, Livingston Island.

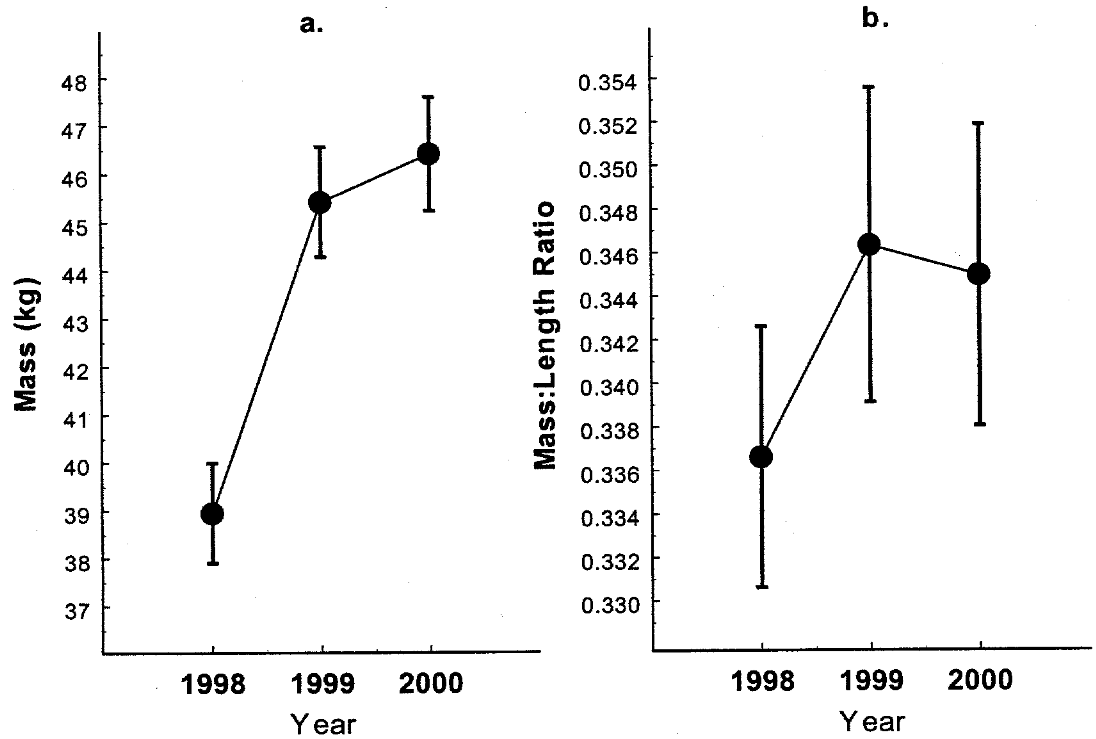

Figure 8.3 a) Mean mass for CCAMLR Attendance Study females for 1997/98-1999/2000 (**1997/98:** N=31, **1998/99:** N=32, **1999/00:** N=23). b) Mean mass to length ratio for CCAMLR Attendance Study females for 1997/98-1999/2000 (**1997/98:** N=31, **1998/99:** N=32, **1999/00:** N=23).

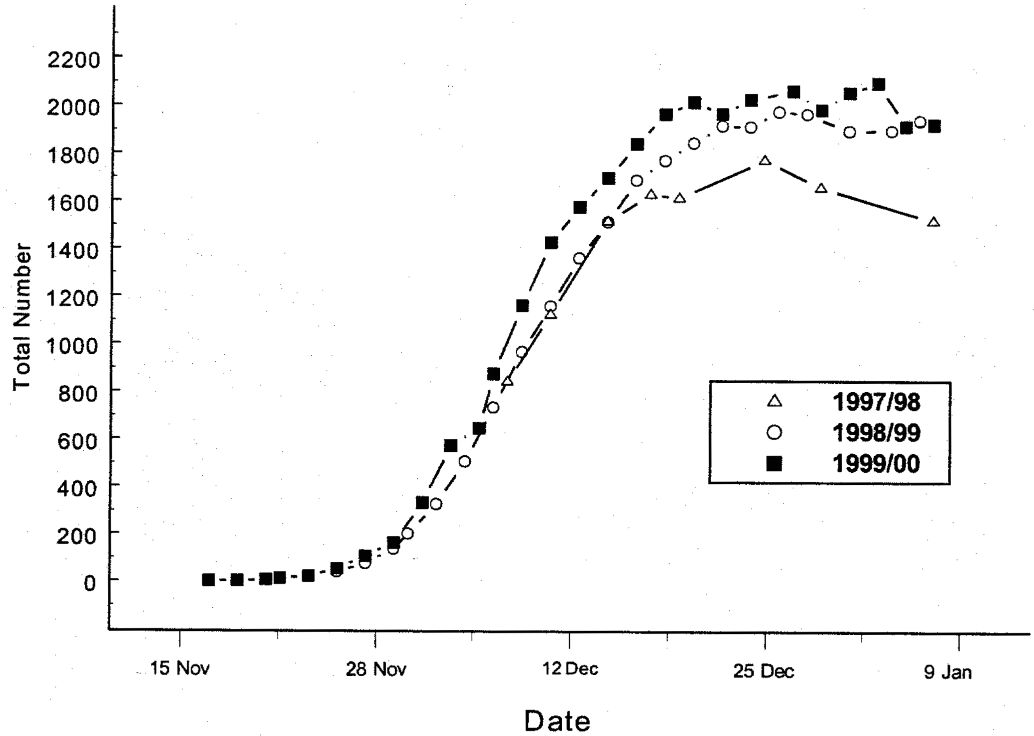

Figure 8.4 Antarctic fur seal pup production at US-AMLR study beaches, Cape Shirreff, Livingston Island, 1997/98-1999/2000.

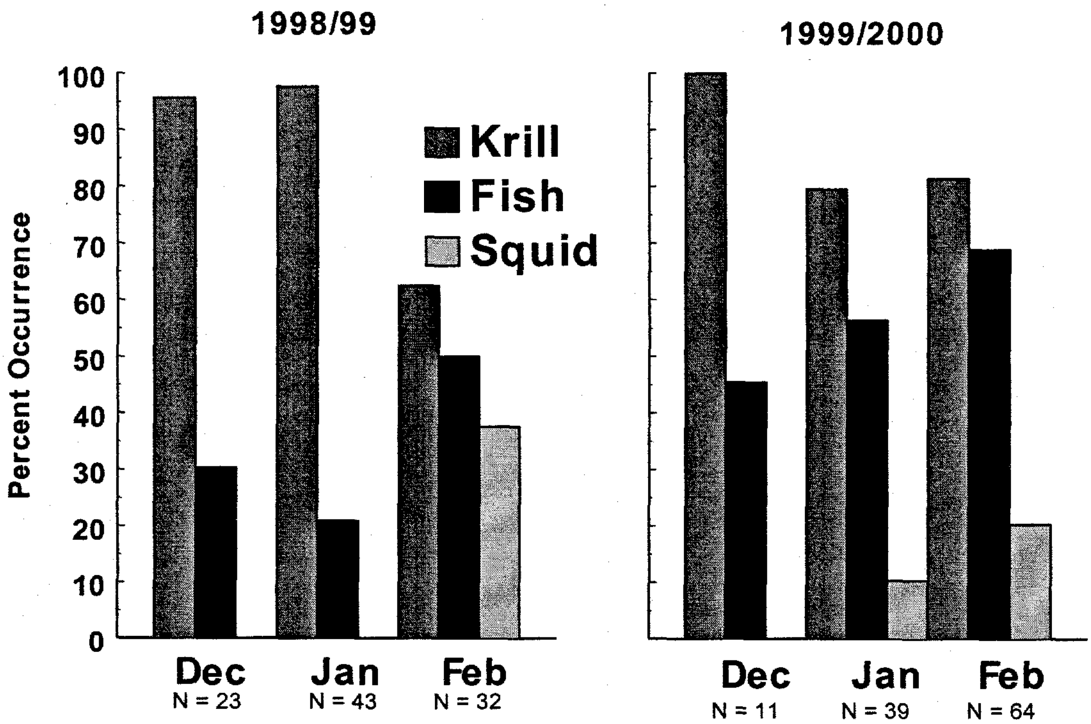

Figure 8.5 Antarctic fur seal diet results from scats, enemas, and regurgitations collected from female suckling areas at Cape Shirreff, Livingston Island for 1998/99 and 1999/00. The percent occurrence of primary prey types (krill, fish, and squid) from December through February are shown.

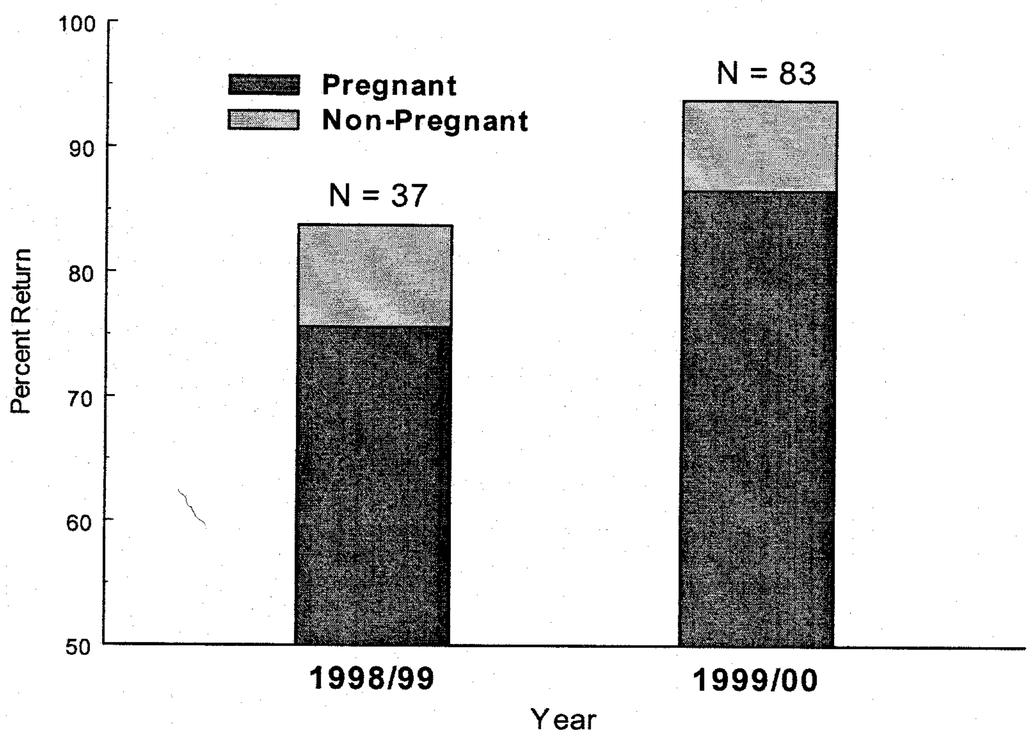

Figure 8.6 Female Antarctic fur seal tag returns for Cape Shirreff, Livingston Island, 1998/99 and 1999/2000.

9. Operations and logistics at Cape Shirreff, Livingston Island; and Copacabana, King George Island, Antarctica, 1999/2000; submitted by Jane Martin and Rennie S. Holt.

9.1 Objectives: During the 1999/2000 field season, the AMLR program occupied a field camp at Cape Shirreff, Livingston Island, Antarctica (62°28'07"S, 60°46'10"W) to support land-based research on seabirds and pinnipeds. The camp was occupied continuously from 31 October 1999 through 9 March 2000. The AMLR program provided logistical support to the Copacabana field camp on King George Island (62°10'S, 58°30'W), which is the site of seabird research funded by the National Science Foundation. The main logistical objectives of the 1999/2000 season were:

1. To deploy three personnel and provisions in mid-October 1999 from the R/V *Lawrence M. Gould* to the Copacabana field camp at Admiralty Bay, King George Island;

2. To deploy a four-person field team and provisions in late October 1999 from the R/V *Lawrence M. Gould* to Cape Shirreff, Livingston Island to initiate research activities pertaining to seabirds and pinnipeds;

3. To deploy two personnel to Cape Shirreff, along with supplies and equipment, in late December 1999 from the R/V *Lawrence M. Gould*;

4. To deploy two personnel to the Copacabana field camp from the M/V *Explorer* in mid-January 2000;

5. To deploy one person to Cape Shirreff in late January from the M/V *Prof. Molchanov;*

6. To deploy four personnel to the Copacabana field camp from the R/V *Lawrence M. Gould* in early February 2000;

7. To deploy one person to Cape Shirreff in late February 2000 from the R/V *Yuzhmorgeologiya*;

8. To retrieve four personnel from the Copacabana field camp in mid-February 2000 aboard the R/V *Yuzhmorgeologiya*;

9. To retrieve two personnel from Cape Shirreff in late February 2000 aboard the M/V *Prof. Molchanov*, and one person aboard a Chilean Navy vessel;

10. To recover five personnel from the Copacabana field camp in early March 2000 aboard the R/V *Yuzhmorgeologiya* and to retrograde equipment and trash at the end of the season;

11. To recover five personnel from Cape Shirreff in early March 2000 aboard the R/V *Yuzhmorgeologiya* and to retrograde equipment and trash at the end of the field season;

12. To maintain effective communication systems on Cape Shirreff and maintain daily radio contact with either Palmer station or Copacabana camp, or R/V *Yuzhmorgeologiya*.

9.2 Accomplishments: Three personnel (L. Shill, S. Wang, and K. Wallace) and provisions were deployed from the R/V *Lawrence M. Gould* to the Copacabana field camp at Admiralty Bay, King George Island on 13 October 1999.

A four-person field team (M. Goebel, T. Carten, M. Rutishauser, and M. Taft), along with supplies and equipment, arrived at Cape Shirreff aboard the R/V *Lawrence M. Gould* on 31 October 1999. Scientific activities were quickly initiated. Maintenance of the campsite also began. Two additional personnel (R. Holt and B. Parker) and supplies arrived at the Cape Shirreff campsite aboard the R/V *Lawrence M. Gould* on 22 December 1999.

Two field team members (W. Trivelpiece and S. Trivelpiece) and provisions were deployed from the M/V *Explorer* to the Copacabana field camp on 16 January 2000.

One person (D. Costa) was deployed to Cape Shirreff on 29 January 2000 from the M/V *Prof. Molchanov*, and another person (N. Gales) arrived via the R/V *Yuzhmorgeologiya* on 21 February 2000.

Four personnel (K. Salwicka, T. Stiehr, M. Stiehr, and J. Yarkin) arrived at the Copacabana camp from the R/V *Lawrence M. Gould* on 9 February 2000.

On 12 February 2000, the R/V *Yuzhmorgeologiya* retrieved four personnel (L. Shill, S. Wang, K. Wallace, and S. Trivelpiece) from the Copacabana camp for return to the United States.

One person (T. Carten) departed Cape Shirreff via a Chilean Navy vessel on 23 February 2000, while two other personnel (N. Gales and D. Costa) were retrieved by the M/V *Prof. Molchanov* on 24 February 2000.

Five field team members (W. Trivelpiece, K. Salwicka, T. Stiehr, M. Stiehr, and J. Yarkin) were retrieved from the Copacabana field station by the R/V *Yuzhmorgeologiya* on 8 March 2000; the station was closed for the season and retrograded equipment and trash were removed.

On 9 March 2000, the field camp at Cape Shirreff was closed for the season. All personnel (R. Holt, M. Goebel, M. Rutishauser, M. Taft, and B. Parker), along with garbage and equipment requiring maintenance or protection from the winter cold, were removed to the R/V *Yuzhmorgeologiya*.

Daily radio communications were maintained by Cape Shirreff with either the R/V *Yuzhmorgeologiya*, or Palmer station and Copacabana camp by SSB radio.

9.3 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 Cape Shirreff. Use of the Chilean ATV and trailer were vital for transporting materials and supplies from the boat landing to the Cape Shirreff campsite. As in past seasons, the practice of using four swimmers in dry-suits to assist with Zodiac beach operations was invaluable.

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