UNITED STATES
AMLR ANTARCTIC MARINE LIVING RESOURCES PROGRAM

AMLR 2000/2001 FIELD SEASON REPORT

Objectives, Accomplishments and Tentative Conclusions

Edited by
Jessica Lipsky

September 2001

NOAA-TM-NMFS-SWFSC-314

Southwest Fisheries Science Center
Antarctic Ecosystem Research Division

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).

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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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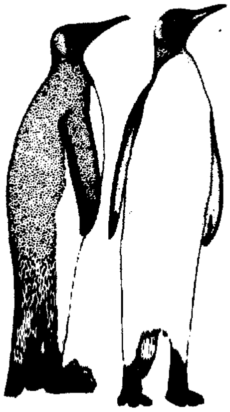

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BACKGROUND

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.

Beginning in the 1997/98 season, bottom trawl surveys were conducted to assess benthic fish and invertebrate populations. Bottom trawl surveys were conducted in 1998, 1999 and 2001.

This is the 13th issue in the series of AMLR field season reports.

SUMMARY OF 2001 RESULTS

The Russian R/V *Yuzhmorgeologiya* was chartered to support the U.S. AMLR Program during the 2000/2001 field season. Shipboard operations included: 1) two region-wide surveys of krill and oceanographic conditions in the vicinity of the South Shetland Islands (Legs I & II); 2) calibration of acoustic instrumentation at the beginning and end of survey operations; 3) a finfish bottom trawl survey (Leg III); and 4) shore camp support. Land-based operations at Cape Shirreff included: 1) observations of chinstrap, gentoo 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) continuous recording of meteorological data.

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. 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. The polar frontal zone, identified mostly by sea temperature change and minor salinity variation, was located from underway logged data during all transits to and from Punta Arenas, Chile and the study area. The position of the front during all transits this season was mainly south of the normal range (57-58°S). Chlorophyll concentrations usually increase from Leg I to Leg II; however, this year the opposite was observed. Overall chlorophyll concentrations were on average higher this year in the South Area compared to previous field seasons and lower this year in the West and Elephant Island areas compared to previous years. During both Legs I & II, zooplankton distribution exhibited patterns of mesoscale patchiness. Sampled krill were predominately large and sexually mature with large proportions in advanced female maturity stages. Data from February-March 2001 indicated a normal spawning season due to significant larval krill concentrations. Large proportions of juvenile and immature krill indicated a large recruitment of the 1998/1999 and 1999/2000 year classes. During February 2001, krill abundance in the Elephant Island area was relatively high compared to previous years. Salps showed a curtailed production season, which was indicated by the length-frequency distribution of the dominant aggregate stage. Salp abundance decreased 60% between Legs I & II in 2001 and was due to the loss of large aggregates from the upper water column. This might suggest an early downward migration prior to production of overwintering solitary stages. Copepods and larval krill dominated the zooplankton assemblage and although salps were widespread, their relative abundance decreased dramatically throughout the survey. This, and other aspects of the zooplankton assemblage, suggested that 1999, 2000 and 2001 may be classified as transition years from a salp-dominated community to a copepod-dominated community. Copepod abundances were among the highest in 2001 in the Elephant Island area. This coupled with reduced salp abundance and favorable krill spawning suggest improved larval production and survival and thus possible successful krill recruitment in 2002. Acoustically detected layers of myctophid fish and krill were mapped during Legs I & II. Myctophids tended to occupy the offshore regions of the shelf whereas krill tended to be found in the onshore regions of the shelf.

The bottom trawl survey was designed to collect data in support of an ecosystem-based assessment of finfish within the 500m isobath of the South Shetland Islands. A total of 7,238kg (17,581 individuals) of 44 fish species were processed from 71 hauls in the South Shetland Island region. Species that were caught in substantial numbers, defined as >500kg or >500 individuals, included *Notothenia coriiceps*, *Gobionotothen gibberifrons*, *Champsocephalus gunnari*, *Chaenocephalus aceratus*, *Chionodraco rastrospinosus*, *Gymnoscopelus nicholsi*, and *Lepidonotothen larseni*. The species with the greatest yield in weight was *Notothenia coriiceps* (2,296kg, 1,752 individuals) and the species with the greatest catch in numbers was *Champsocephalus gunnari* (778kg, 4,318 individuals). This information is used for management of finfish resources in the Convention for the Conservation of Antarctic Marine Living Resources (CCAMLR) in this area.

The benthic invertebrate community was highly patchy on a scale between 1.3 and 4.5nm. Individual tows were strongly dominated by a single taxon, but there was no obvious correlation in biomass, abundance, or dominance with depth or geographical location. However, sponges were mainly found around Elephant Island whereas seastars were found around the southern

South Shetland Islands. Acoustic volume backscattering strength sample data were collected for seabed classification purposes. Seabed class descriptions were based on images and sediment samples resulting from the ground truthing methods. Most samples were mixtures of sediments varying from silt, mud, dense clay, sand, gravel, pebble, cobble, to boulder. Future analyses are planned to describe the entire bottom habitat surrounding the South Shetland Islands based on data collected during this survey.

A total of 7,212 chinstrap and 1,043 gentoo penguin pairs bred at Cape Shirreff during the 2000/01 season. Penguin populations have been censused at Cape Shirreff annually since 1997/98. The 2000/01 population counts represent the lowest chinstrap penguin count on record, while the gentoo penguin census was the highest population count to date. Mean chinstrap and gentoo penguin clutch initiation dates coincided exactly with dates in 1999/00. Chinstrap penguin reproductive success in 2000/01 was within the four-year range; however, the survival of chicks from hatching to fledging was the highest ever recorded. Gentoo penguin reproductive success was also within the four-year averages. A total of 9,744 chinstrap and 1,298 gentoo penguin chicks survived to crèche age this breeding season. For both species, this season represented the largest number of chicks counted at Cape Shirreff in five years. The dominant prey species in all diet samples was krill (*Euphausia superba*), which we found in 100% of samples from both chinstrap and gentoo penguins. Chinstrap penguin diets consisted solely of krill, whereas gentoo penguins ate both krill and fish. Analysis of the length-frequency distribution of krill in the penguin's diets revealed that over 90% of all krill in the samples were from three CCAMLR size classes: 46-50, 51-55, and 56+mm. These krill are believed to be from the strong 1994/95 cohorts that have dominated the diets of the penguin species at Cape Shirreff for the last 4 years. Similar to the previous three seasons, the 2000/01 season foraging pattern displayed a bimodal distribution. This season, we observed a 2-hour decrease in the duration of short-trips, and a >1 hour decrease in the duration of long trips compared to the 1999/00 pattern. The average duration of foraging trips was the shortest in four years.

The median date of fur seal pupping at Cape Shirreff based on pup counts was two days earlier this year than in 1997/98 and 1998/99 and pup counts increased by 6.8% over last year. Although return rates for adult females were slightly lower than the previous year, a 90.2% over-winter survival in 2000/01 is still high and there was no change in arrival condition compared to last year. Return rate for yearlings was higher this year than last. Adult female trip duration for the first six trips to sea was significantly less than in previous years indicating improved foraging conditions. Fur seals this year had slightly more krill in the diet than last year and the overall percentage of fish in the diet was lower. An increasing percent occurrence of fish and squid as the season progresses was present as in previous years. Teeth were extracted from 60 lactating female fur seals for age determination and other demographic studies. Preliminary studies of the effect of tooth extraction on survival, natality, and attendance behavior indicates that there no measurable significant differences.

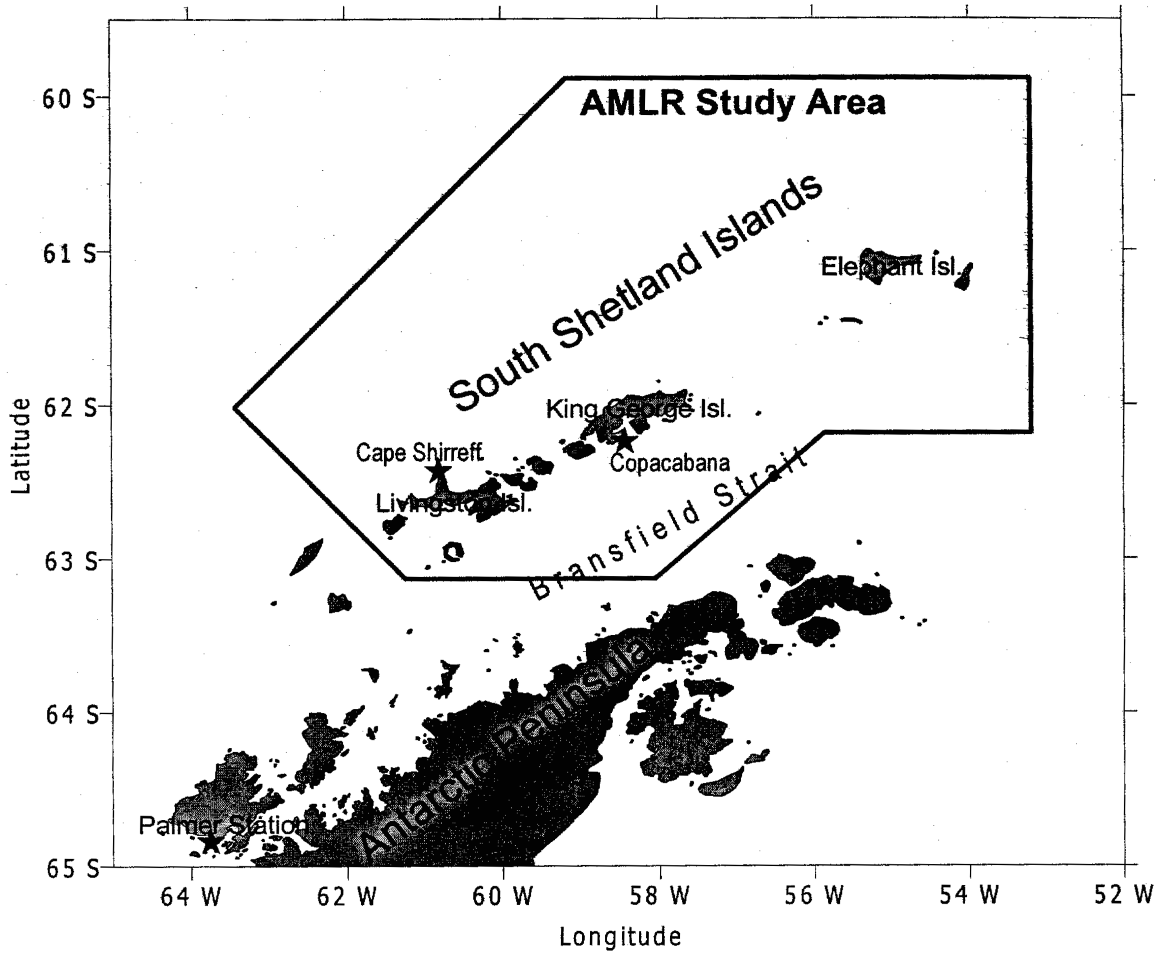


Figure 1. Locations of the U.S. AMLR field research program: AMLR study area, Cape Shirreff, Livingston Island and Copacabana, King George Island, Antarctica.

OBJECTIVES

Shipboard Research:

1. Conduct a survey in the AMLR study area during Legs I and II to map meso-scale features of the dispersion of krill, water mass structure, phytoplankton biomass and productivity, and zooplankton constituents using the R/V *Yuzhmorgeologiya*.
2. Estimate abundance and dispersion of krill and krill larvae in the AMLR study area.
3. Calibrate the shipboard acoustic system in Admiralty Bay, King George Island near the beginning of Leg I, and again at Admiralty Bay near the end of Leg II.
4. Conduct bottom trawls at selected sites in the area around the South Shetland Islands to provide baseline estimates of abundance, species size and composition and demographic structure of finfish species.
5. Collect continuous measurements of the research ship's position, water depth, 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:

Cape Shirreff

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, Platform Terminal 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.
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. Collaborate with 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 sixth consecutive year, the cruise was conducted aboard the chartered Russian research vessel R/V *Yuzhmorgeologiya*.

Itinerary

Leg I:	Depart Punta Arenas	11 January 2001
	Transfer personnel and supplies to Cape Shirreff	14 January
	Calibrate in Admiralty Bay, King George Island	15 January
	Large-area survey (Survey A)	16 January- 01 February
	Recover personnel from Cape Shirreff	02 February
	Arrive Punta Arenas	05 February
Leg II:	Depart Punta Arenas	08 February
	Transfer personnel and supplies to Cape Shirreff	11 February
	Large-area survey (Survey D)	12-28 February
	Close Cape Shirreff	01 March
	Close Copacabana and Calibrate in Admiralty Bay	02 March
	Arrive Punta Arenas	05 March
Leg III:	Depart Punta Arenas	09 March
	Bottom trawl survey, bottom typing and CTDs	12-31 March
	Arrive Punta Arenas	03 April

Leg I

1. The R/V *Yuzhmorgeologiya* departed Punta Arenas, Chile en route to Livingston Island to deliver supplies and personnel to the field camp.

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

3. Survey components included acoustic mapping of zooplankton, direct sampling of zooplankton, Antarctic krill demographics, physical oceanography and phytoplankton. A large-area survey of 101 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 A, Figure 2). Stations were located in three areas: stations to the north 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. 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.

6. The ship visited the Cape Shirreff and the Copacabana field camps to deliver provisions and supplies in the beginning of Leg I.

7. The ship recovered personnel from Cape Shirreff at the end of Leg I.

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. A large-area survey of 99 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 2). Stations were located in three areas: stations to the north 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.

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

4. As on Leg I, continuous environmental data were collected throughout Leg II.

5. At the end of Leg II, the ship then transited to Cape Shirreff to embark personnel and close the field camp.

6. Following the completion of the close of Cape Shirreff, 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.

Leg III

1. The R/V *Yuzhmorgeologiya* departed Punta Arenas, Chile via the eastern end of the Straits of Magellan. After transiting across the Drake Passage, the ship arrived at the South Shetland Islands for the first trawl station.

2. A total of 71 hauls were conducted within the 500m isobath of the South Shetland Islands (See Figure 5.1 in Section 5). The trawl gear consisted of a two-warp/four panel bottom trawl and a third-wire linked net sonde.

3. Other scientific operations included continuous acoustic data collection, bottom type habitat characterization using underwater video and camera mounted grab sampler, 26 days of continuous underway measurements of meteorological and sea surface conditions, and CTD casts.

4. At the end of Leg III, operations ceased and the R/V *Yuzhmorgeologiya* transited across the Drake Passage to the Straits of Magellan en route to Punta Arenas, Chile.

Land-based Research:

Cape Shirreff

1. A four-person field team (M. Goebel, M. Taft, I. Saxer and B. Pister) arrived at Cape Shirreff, Livingston Island, on 16 November 2000 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 (W. Trivelpiece and B. Parker), along with supplies and equipment, arrived at Cape Shirreff via the R/V *Yuzhmorgeologiya* 14 January 2001. R. Holt arrived at Cape Shirreff via the R/V *Yuzhmorgeologiya* on 11 February 2001.

3. Camp maintenance at Cape Shirreff included exterior deck construction of the emergency shelter/bird observation blind.

4. The annual census of active gentoo penguin nests was conducted on 27 November 2000, and a similar census of chinstrap penguin nests was completed on 3 and 4 December 2000. 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 19 chinstrap penguins between 4-6 January 2001; 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. Four satellite-linked transmitters were deployed on adult chinstrap penguins on 27 November 2000 to determine foraging location of adult females following clutch completion. These satellite tags were redeployed on 4 adult birds in late January and early February to coincide with the time when the AMLR 2001 marine survey was adjacent to Cape Shirreff at the end of Leg I and beginning of Leg II.

7. Diet studies of chinstrap and gentoo penguins during the chick-rearing phase were initiated on 7 January 2001 and continued through 11 February 2001. 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 25 January 2001, and for chinstrap penguin chicks on 6 February 2001. Fledging weights of chinstrap penguin chicks were collected from 20-26 February 2001. Two hundred gentoo penguin chicks were also weighed on 10 February 2001.

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 through out the season at all nesting sites around the Cape.

11. Time-depth recorders (TDRs) were deployed on 9 chinstrap penguins for 10-12 days in late January to coincide with the marine sampling offshore at Cape Shirreff at the end of Leg I and beginning of Leg II.

12. Antarctic fur seal pups and female fur seals were counted at four main breeding beaches every other day from 18 November 2000 through 10 January 2001.

13. Attendance behavior of 29 lactating female Antarctic fur seals was measured using radio transmitters. Females and their pups were captured, weighed, and measured from 5-12 December 2000.

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 began on 16 December 2000 and continued every two weeks until 14 February 2001.

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. Thirty-seven Antarctic fur seals were instrumented with time-depth recorders (TDRs) for diving behavior studies.

17. Twenty-five Antarctic fur seal females were instrumented with ARGOS satellite-linked transmitters for studies of at-sea foraging locations from 23 December 2000 to 17 February 2001.

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

19. A weather data recorder (Davis Instruments, Inc.) was set up at Cape Shirreff for wind speed, wind direction, barometric pressure, temperature, humidity, and rainfall.

20. A single post-canine tooth was extracted from 60-tagged female fur seals for aging and demography studies. Studies of the effects of tooth extraction on attendance and foraging behavior were initiated.

21. One team member (M. Goebel) left Cape Shirreff via the R/V *Yuzhmorgeologiya* on 2 February 2001.

22. The Cape Shirreff field camp was closed for the season on 28 February 2001; all U.S. personnel (R. Holt, W. Trivelpiece, B. Parker, M. Taft, I. Saxer and B. Pister) and Chilean personnel, garbage, and equipment were retrieved by the R/V *Yuzhmorgeologiya*.

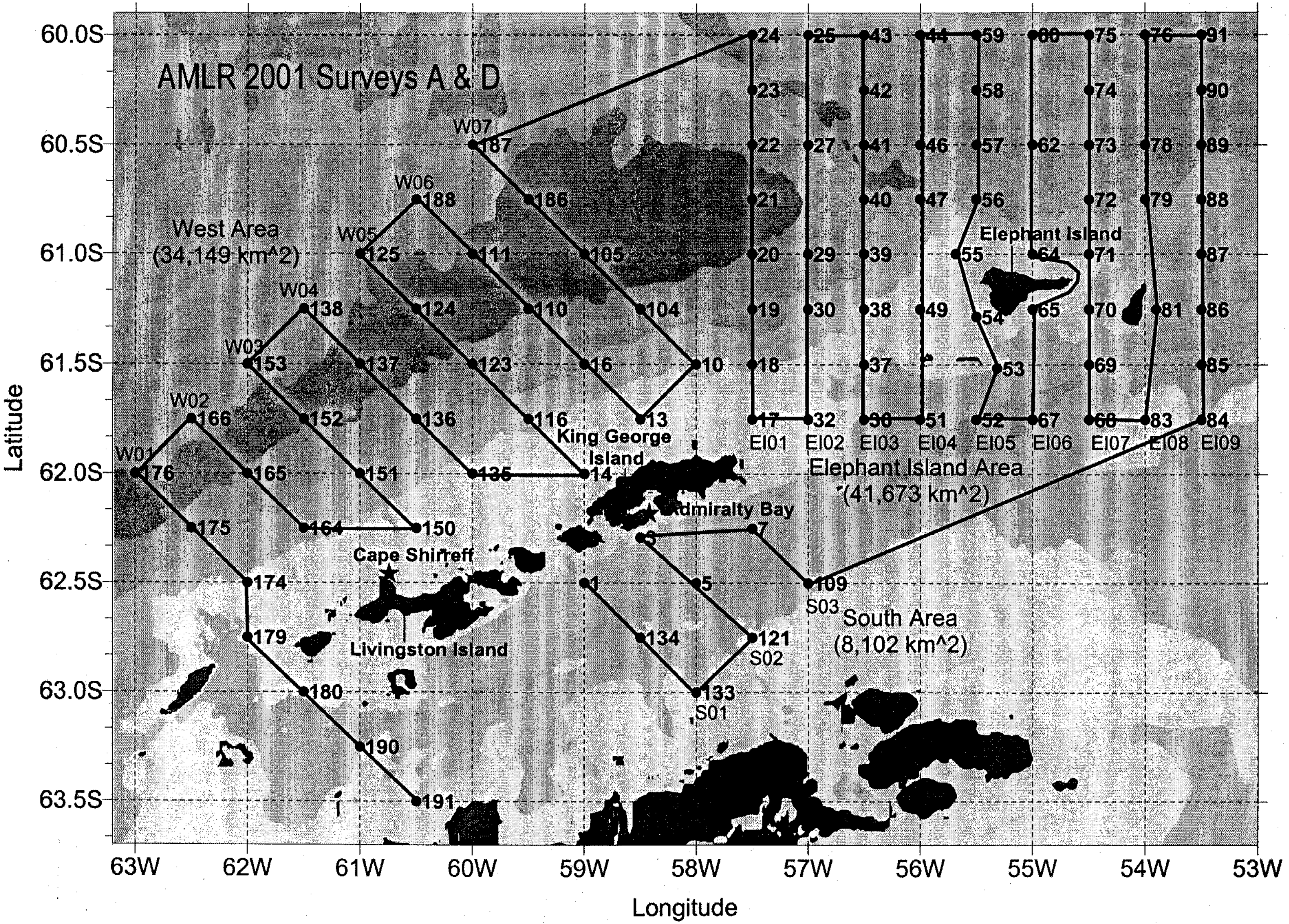


Figure 2. The large-area survey for AMLR 2001 (Survey A & D) in the vicinity of Elephant, Clarence, King George and Livingston Islands. Stations located to the north of Livingston and King George Islands are designated the "West Area", those to the south of King George Island are designated the "South 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 (Leg I)
- David A. Demer, Southwest Fisheries Science Center (Leg II)
- Christopher D. Jones, Southwest Fisheries Science Center (Leg III)

Physical Oceanography:

- Mark R. Prowse, Sea Fisheries Institute (Legs I, II & III)
- Derek J. Needham, Sea Fisheries Institute (Leg I)
- Michael A. Soule, Sea Fisheries Institute (Leg II)
- David A. Demer, Southwest Fisheries Science Center (Leg II)

Phytoplankton:

- Christopher D. Hewes, Scripps Institution of Oceanography (Legs I & II)
- John Wieland, Scripps Institution of Oceanography (Leg II)

Bioacoustic Survey:

- Jennifer H. Emery, Southwest Fisheries Science Center (Legs I, II & III)
- Roger P. Hewitt, Southwest Fisheries Science Center (Leg I)
- David A. Demer, Southwest Fisheries Science Center (Leg II)
- Andrew Dizon, Southwest Fisheries Science Center (Leg I)
- Dale Roberts, NMFS, Santa Cruz Laboratory (Leg II)
- Christopher D. Jones, Southwest Fisheries Science Center (Leg III)

Krill and Zooplankton Sampling:

- Valerie Loeb, Moss Landing Marine Laboratories (Legs I & II)
- Jenna Borberg, Southwest Fisheries Science Center (Leg I)
- Kit Clark, University of California at Santa Cruz (Legs I & II)
- Michael Force (Legs I & II)
- Nancy Gong, University of California at Santa Cruz (Leg II)
- Kate Harps, University of California at Berkeley (Leg II)
- Adam Jenkins, Southwest Fisheries Science Center (Legs I & II)
- Jessica D. Lipsky, Southwest Fisheries Science Center (Legs I & II)
- Rob Rowley, Moss Landing Marine Laboratory (Legs I & II)

Bottom Trawl Survey:

- Christopher D. Jones, Southwest Fisheries Science Center (Leg III)
- Karl-Herman Kock, Sea Fisheries Research Institute (Leg III)
- Sunhild Wilhelms, Bundesamt fuer Seeschiffahrt und Hydrographie (Leg III)
- David Ramm, CCAMLR (Leg III)
- Julian Ashford, Old Dominion University (Leg III)
- Tom Near, University of California at Davis (Leg III)
- Jennifer H. Emery, Southwest Fisheries Science Center (Leg III)
- Nancy Gong, University of California at Santa Cruz (Leg III)

Hauke Flores, Sea Fisheries Research Institute (Leg III)
Alison R. Banks, University of California at Santa Cruz (Leg III)
Mark R. Prowse, Sea Fisheries Institute (Leg III)

Invertebrate Bycatch Studies:
Stacy Kim, University of California at Santa Cruz (Leg III)
Valerie Loeb, Moss Landing Marine Laboratory (Leg III)
Rob Rowley, Moss Landing Marine Laboratory (Leg III)
Mark R. Prowse, Sea Fisheries Institute (Leg III)
Nancy Gong, University of California at Santa Cruz (Leg III)

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

Cape Shirreff Personnel:
Michael E. Goebel, Southwest Fisheries Science Center (11/16/00 to 2/2/01)
Michael R. Taft (11/16/00 to 2/28/01)
Iris M. Saxer (11/16/00 to 2/28/01)
Benjamin Pister (11/16/00 to 2/28/01)
Wayne Z. Trivelpiece, Montana State University (1/14/01 to 2/28/01)
Brian W. Parker, Southwest Fisheries Science Center (1/14/01 to 2/28/01)
Rennie S. Holt, Southwest Fisheries Science Center (2/11/01 to 2/28/01)

DETAILED REPORTS

1. Physical Oceanography and Underway Environmental Observations; submitted by Mark R. Prowse (Legs I, II & III), Derek J. Needham (Leg I), Michael A. Soule (Leg II), and David A. Demer (Leg 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 environment data underway in order to describe sea surface and meteorological conditions experienced during 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:

CTD/Carousel Stations: One hundred and one CTD/carousel casts were made on Leg I (Survey A, Stations A001-A191), 99 on Leg II (Survey D, Stations D074-D180), and 47 on Leg III. Water samples for salinity verification and phytoplankton analysis were drawn from the Niskin bottles by the Russian scientific support team at selected stations on the sampling grid (See Figure 2 in Introduction for station locations for Leg I & II and see Figure 5.1 for Leg III). Comparisons of CTD salinities against bottle samples analyzed using the Guildline AutoSal showed negligible differences with the average of 0.01% (s.d. = 0.05 over 573 comparisons). A comparison of the dissolved oxygen levels in the carousel water samples and the levels measured during the casts (via the O_2 sensor) was not attempted, primarily because the Winkler titration apparatus required was not available.

Underway Environmental Observations: Environmental and vessel position data were collected for a total of 25 days for each of Legs I, II & III respectively via the Scientific Computer System (SCS) software package (Software Version 3.0) running under Windows NT 4.0 on a Pentium III 450MHz PC. A Coastal Environmental Systems Weatherpak system was installed on the port side of the forward A-frame in front of the bridge and was used as the primary biospheric data acquisition system. The data provided covered surface environmental conditions encountered over the entire AMLR survey area for the duration of the cruise including transits to and from Punta Arenas although the thermosalinograph seawater pump was not turned on during the transit of the Magellan Straits to avoid fouling and possible damage to the pump.

1.3 Methods:

CTD/Carousel: Water profiles were collected with a SeaBird SBE-9/11+ CTD/carousel water sampler equipped with 10 Niskin sampling bottles. During Leg II, an eleventh bottle (5 meters) was added to the carousel to accommodate increased surface water volume requirements for phytoplankton analysis. This bottle was rigged to the same trigger as the 10th bottle to ensure they closed simultaneously. Profiles were limited to a depth of 750m or 5m above the sea bottom when shallower during Legs I & II and a Data Sonics altimeter was used to stop the CTD above the bottom on the shallow casts. During Leg III, the maximum depth was 500m since all work was conducted in coastal zones. A SeaBird Dissolved Oxygen (DO) sensor, fluorometer, transmissometer, and PAR (photosynthetically available radiation) sensor were used to provide additional water column data during Leg I. The configuration was changed during Leg II to include two transmissometers (C-Star), one operating in the red frequency range and the other in the blue range. For Leg III, the CTD was completely stripped down and reassembled with only the DO sensor added. It was installed on the small CTD frame that did not accommodate any sampling bottles and was deployed from the port aft deck rather than over the stern as on the previous legs. CTD scan rates were set at 24 scans/second during both down and upcasts. Sample bottles were only triggered during upcasts. Plots of the down traces were generated and stored with the CTD cast log sheets. A second plot with CTD mark files (reflecting data from the cast at bottle triggering depths) and processed traces were provided to the phytoplankton group. During Leg III, surface (5m) and bottom data were provided to the biological team for inclusion into the biological database. Raw CTD data were corrected for time constant differences. Data from casts were averaged over 1m bins and saved separately as up and down traces during post processing. Data were routinely uploaded to the Ocean Data View software (Schlitzer, 2001) for visualization and water mass identification.

Underway Data: Weather data inputs were provided by the Coastal Environmental Systems Weatherpak via a serial link and included relative wind speed and direction, barometric pressure, air temperature and irradiance (PAR). The relative wind data were converted to true speed and true direction by the internal derivation functions of the SCS logging software before logging. Measurements of sea surface temperature (SST) and salinity output in a serial format by the SeaBird SBE21 thermosalinograph were also integrated into the logged data. Ships position and heading were provided in NMEA format via a Furuno GPS Navigator and Magnavox MX 200 respectively. Due to a lack of suitable equipment, underway transmissometer and fluorometer measurements were unavailable during the 2001 survey. Serial data lines were interfaced to the logging PC via a Digi-ports 16/EM serial multiplexor.

1.4 Results and Tentative Conclusions:

Oceanography: The position of the polar frontal zone, identified mostly by sea temperature change and minor salinity variation, was located from underway logged data during all four transits to and from Punta Arenas and the South Shetland Islands study area of Legs I & II. This zone is normally found between 57-58° S. During the south transit for Leg I, the front extended gradually from 57° 56'S to 58° 57'S, shifting further south and compressing between 58° 47'S and 59° 14.5'S on the northbound transit. On the southbound transit for Leg II, it had shifted further north between 57° 57'S and 58° 34'S and was similarly compressed. On the return northbound transit at the end of Leg II, the zone relaxed southward between 57° 49'S and 59° 14'S. The position of the front during all transits this season was mainly south of the normal range of 57-58°S, particularly during Leg I (Figure 1.1).

Vertical sea temperature and salinity sections for the acoustic transects W05, EI03 and EI09 during Legs I & II were derived from CTD cast data and are shown in Figures 1.9 & 1.10. Horizontal sea temperature and salinity sections were prepared from the 100m and 500m depth CTD data for Legs I & II (Figure 1.11A). Since CTD casts were shallower during Leg III, similar sections were drawn using the 100m and 300m depth data (Figure 1.11B). The geographic extent of Leg III was much reduced from that of the two previous legs. Dynamic height contours relative to 300m and 500m were generated for Legs I & II while those for Leg III were generated from 100m and 300m because of the shallower CTD casts (Figure 1.8).

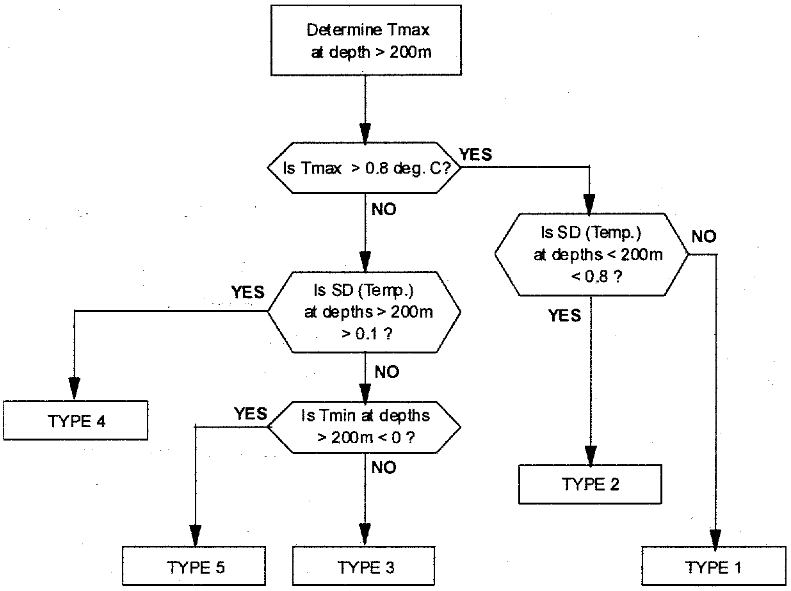
As in previous years, an attempt was made to group stations with similar temperature and salinity profiles into five water zones as defined in the table below.

	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 Zone II 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

While these classifications could generally be adhered to, instances did arise where the defined zones could not be matched because of the existence of localized conditions, which altered the expected (or prescribed) T/S characteristics. In these instances, the presence of modifying influences were taken into account during allocation. For example during Leg II, at Stations 109 and 007, the presence of numerous tabular icebergs is thought to have contributed to the low temperature (-0.91°C) and salinity (33.35ppt) surface layer extending from the surface down to approximately 25m. While the temperature and salinity profiles below this depth displayed typical Eastern Bransfield Strait characteristics, the sudden change in T/S at the surface would have precluded this classification if the above water zone definitions were strictly adhered to.

A (MATLAB) program was written to screen the data in an attempt to reduce any subjective influence on the classification of water zones. Allocation was based primarily on the temperature characteristics of the cast, which appeared to hold the most information. Shallow stations (<150m), which provided insufficient data, were not allocated, as were casts not conforming to the prescripts for a specific water zone (see flowchart below). Although the program was essentially a fairly coarse first attempt to classify water zones in the survey area, it potentially lays the basis for the implementation of a system that will ultimately eradicate any subjective influence arising during classification. Further refinements to the program and "ground-truthing" against existing datasets should be a future priority.

The classification of water zones for Legs I & II determined by this algorithm are shown in Figure 1.2. Very few classifications of Zone III (transition water) were made by either visual inspection of temperature/salinity relationships or the MATLAB routine.



Underway Data: Environmental data were recorded for the duration of Legs I, II & III including the transits between Punta Arenas and the survey area (except for thermosalinograph data which are not available for transits in the Strait of Magellan). Processed data were averaged and filtered over 5-minute intervals to reduce the effects of transients, particularly in data recorded from the thermosalinograph, which was prone to the effects of aeration. At the start of Leg I, the true wind speeds and direction were found to be in error, but this was corrected prior to arriving at Cape Shirreff, Livingston Island. Positional data was lost during Leg II on the 28th February between 0125hr and 1800hr (GMT) while in transit between Station 1 and Cape Shirreff, probably due to the Furuno GPS navigator being inadvertently turned off.

Underway data averaged over 5-minute intervals are presented for each leg in Figures 1.5, 1.6 & 1.7. Comparisons between the weather conditions experienced during Legs I, II & III show significant differences, primarily between air temperature and wind speed. The mean temperature during Leg I remained above zero (2.2°C), with the lowest recorded temperature being -0.4°C. The temperature during Leg II however, was more variable, having a mean of 1.3°C and dropping to a minimum of -4.9°C on the 24th February while surveying northeast of Elephant Island, which is one of the lowest minimums recorded during the krill surveys. During Leg III, the average temperature dropped to 0.8°C with the lowest being recorded during a cold snap on the 20th March (-7.8°C). The average wind speed during Leg I was 12.6 knots (max. 32 knots), Leg II saw an increase in the average to 16 knots (maximum 38 knots) and another small increase to 17.7 knots (maximum recorded 43.8 knots) for Leg III. During both Legs I & II, winds blew predominantly from the west and the east with the highest velocities being recorded from the east. This was particularly the case during Leg II where sustained wind speeds of greater than 20 knots were recorded over a period of three consecutive days. Winds during Leg III were variable, but the strongest winds had mostly a northerly component and in the Elephant Island area a strong southerly component. Averaged wind direction and speed vectors for each leg are presented in Figures 1.3 & 1.4. The cold snap during Leg III coincided with a period of strong southerly winds. Corresponding higher variation was noted in the barometric pressure readings for Legs II & III. Leg II was also more prone to fog and large numbers of icebergs particularly south of Elephant and King George Islands. This was confirmed by anomalous recordings at two of the CTD stations (Stations D109 and D007), which although typifying Eastern Bransfield Strait water, showed strong concentrations of low salinity water close to the surface at temperatures of -1°C. This area was not surveyed during Leg III. Light levels were lowest during Leg III due to overcast and rainy conditions often experienced. Sea surface temperature and salinity from logged thermosalinograph data are presented for each leg in Figures 1.12, 1.13 & 1.14.

1.5 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 or David.Demer@noaa.gov.

1.6 Acknowledgements: The cooperation and assistance of the Russian technical support staff was always outstanding. All requests for assistance were dealt with efficiently and in a thoroughly professional manner. Special mention should be made of Oleg Pivovarchuk and Valeriy Kazachenok whose ingenuity and technical expertise contributed significantly towards the success of the cruise.

1.7 Problems and Suggestions: Erratic behavior of the Datasonics PSA-900 Altimeter (S/N: 508) during Leg I proved to be due to flooding of the underwater housing which became evident during Station A032 when the altimeter stopped functioning. This may have resulted from damage sustained during the previous station when seven sample bottles were damaged due to impact with the hull during retrieval. The unit was opened and found to contain a small quantity of seawater (approximately 5ml), which had shorted out the electronic circuitry. Repair could not be carried out at sea. Also during Leg I, the fluorometer suddenly stopped functioning during the cast at Station A079. The unit was bench tested but still failed to function correctly with 15VDC applied to the power pins. No fluorometer data were thus available for the rest of Leg I.

A badly corroded pin on the O_2 sensor channel (AUX 1-JT2) was detected during CTD maintenance conducted at the end of Leg I. All pins on the bulkhead connector were cleaned and the interconnecting cable (CTD to O_2 sensor) was replaced with a spare. During the routine maintenance at the end of Leg II, further corrosion on the same pin made it necessary to change the O_2 sensor to a spare bulkhead connector. Near the end of Leg III some spurious readings were noted and wrongly presumed to be biological clogging of the sensor. During end of cruise servicing, more corrosion was found on the CTD bulkhead connector and it is probable that this was the cause of the spurious data. It is essential that the bulkhead connector on the CTD (JT2) be replaced before redeployment and that the others are inspected.

Corrosion also caused a pin to break on the PAR sensor when the cable was removed for inspection after excessive noise was detected during casts on Stations D027 and D025. The PAR was disassembled and the damaged connector modified to accept the (replaced) interconnecting fly-lead directly. The PAR was then reassembled and redeployed on the CTD and functioned without fault for the rest of the survey. From previous reports, it appears that this is a common problem with the PAR sensor (see AMLR 1997/98 Field Season Report) and may be related to the positioning of the sensor and the cable routing on the top of the CTD frame.

The O_2 sensor gave spurious readings during Station D068 and saturated for the full duration of the cast at Station D083. While static tests carried out with the CTD unit on deck appeared to confirm the correct operation of the sensor, it saturated immediately once deployed on the surface and remained in that state for the duration of the cast. It is suspected that the O_2 sensor element was damaged, most likely due to the excessively low temperatures (-4.9° C) experienced on deck during this segment of the survey. This would have caused any residual water in the flow path to freeze. Attempts to overcome the problem by dousing the outside of the sensor housing with seawater (thereby raising the ambient temperature of the O_2 sensor) were of limited success. The cold snap on Leg III resulted in heavy icing on the CTD and the DO sensor did ice up during this incident. The suspect sensor was replaced with a spare unit, which functioned without fault for the rest of the survey. Although excessively low air temperatures are not a normal occurrence during AMLR surveys, provision should be made to maintain the temperature of the conductivity and dissolved oxygen sensors above freezing at all times. This may be achieved either by artificially heating the area where the CTD is stored, or by continuously circulating filtered seawater through the flow path between casts.

The thermosalinograph worked well although data integrity was continuously affected during periods of bad weather when excessive aeration occurred or when the filter became blocked with biological matter (e.g. krill). The pump had to be regularly swooped and/or serviced to maintain data integrity.

The temperature difference thermosalinograph versus CTD averages out at +0.6 °C. This should either be inserted as an offset or a change to the configuration should be made to include a second temperature system on the seawater inlet side of the pump installation since it is most likely that the temperature increase is due to warming by the pump and piping to the sensor.

The Autosal Salinometer was prone to bouts of apparent instability and bursts of electrical interference manifested by sudden erratic changes in the readout on the display when the pump was running. Initial investigation showed a voltage of 46VAC between the unit and ground due to the fact that no power ground was in existence (the Autosal is supplied with 110VAC 60Hz from an inverter located in the computer room). It was noted that a new air pump had been installed but that no provision for grounding of the pump existed. The pump casing was subsequently grounded to the incoming power ground point and a separate lead was connected to ship's ground. This appeared to eradicate the bursts of interference and the instability previously noted seemed to be reduced. Periodic flushing of the conductivity cell with a 1% Triton X/distilled water solution early on during the cruise also appeared to contribute to improved stability. An additional factor to be considered is the apparent increase in pressure resulting from the installation of the new air pump and inclusion of a pressure reducing buffer-chamber by the Russians. All of the above made it difficult to ascertain whether the observed instability was due to possible contamination of water samples or to inherent system instability caused by one or more of the above factors. It is recommended that the unit be returned to the manufacturers for service and calibration prior to the next cruise.

The Coastal Environmental Systems Weatherpak worked reliably for the duration of Legs I, II and III of the cruise. Two factors should however be noted. These are; (i) the overscale humidity values (up to 110%) which occurred whenever rainy or foggy conditions arose during the survey and, (ii) evidence of sensor "shading" (wind speed, direction and possibly barometric pressure) by the bridge superstructure during Leg II. The former was previously highlighted in the AMLR 1997/98 Field Season Report and has obviously not been satisfactorily resolved as yet. The humidity sensor should either be replaced or re-calibrated by the manufacturers prior to the 2002 field season. The effects of "shading" of the Weatherpak sensors became evident during Leg II and were highlighted when the vessel altered course to run with the wind, resulting in a significant decrease in the recorded wind speed. The Weatherpak is currently mounted on the port side of the forward A-frame and serious consideration should be given to the location to a preferably permanent installation on the masthead well clear of any interfering superstructure.

1.8 References:

Schlitzer, R., 2001. Ocean Data View. http://www.awi-bremerhaven.de/GEO/ODV.

CTD/SENSOR INSTALLATION SUMMARY

DESCRIPTION	MANUF.	MODEL	SERIAL NO.	NOTE
Deck Unit	SeaBird	11 Plus	11P13966-0434	7
U/W Unit	SeaBird	9 Plus	0913966-0455	7
Temperature Sensor	SeaBird	3 Plus	3P2235	7
O_2 Sensor	SeaBird	13-02-B	130422 /130421	1, 7
Conductivity Sensor	SeaBird	4C	041816	7
Depth Sensor	SeaBird	Internal	64269	7
Carousel	SeaBird	32	3221737-027	8
Altimeter	Datasonics	PSA-900	508 / 503	2, 7
Fluorometer	Unknown	Unknown	43	3, 4
Transmissometer	Seatech	25cm	367	4
Fluorometer	Wetlabs		AFLT-014	5
Transmissometer (Blue)	Cstar		CST165B	5
Transmissometer (Red)	Cstar		No number	5
PAR	Biospherical	QCP200L	4264	6, 8

NOTES:

1. O_2 sensor changed over to S/N: 130421 on 24th February prior to Station D078.
2. Altimeter changed over to S/N: 503 on 24th January- prior to Station A018.
3. Fluorometer faulty at 19:33h (GMT) on 18th January during cast at Station A079.
4. Used on Leg I only.
5. Used on Leg II only.
6. Repaired bulkhead connector on Sunday 18th February- prior to Station D043.
7. Used on Legs I, II & III.
8. Used on Legs I & II only.

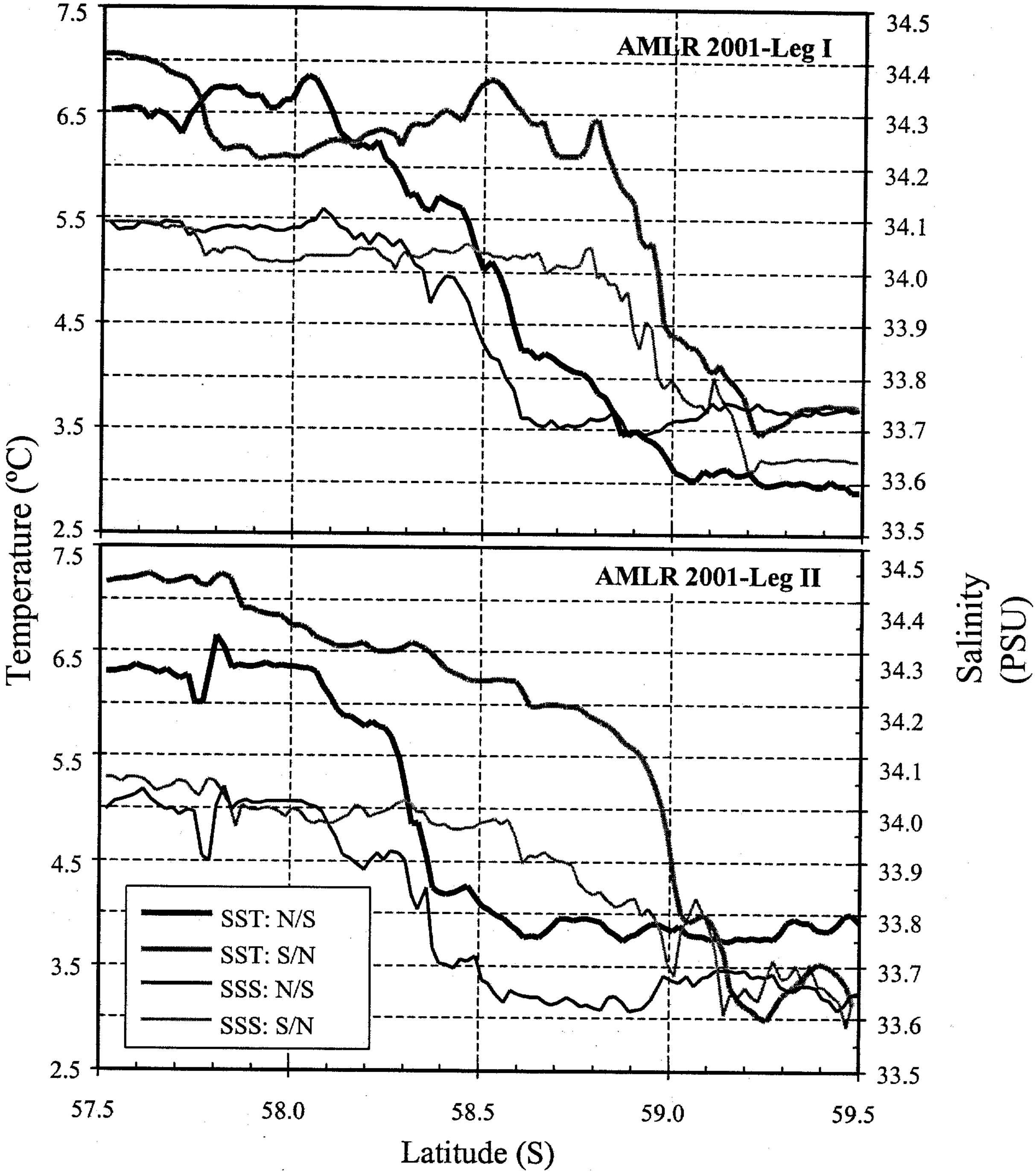


Figure 1.1. The position of the polar frontal zone as determined from the change in sea surface temperature and salinity for Legs I & II (top and bottom panels respectively) during AMLR 2001 transits. The front extended gradually from 57°56' to 58°57' south (Leg I- southbound), moving further south and compressing between 58°47' and 59°14.5' during the northbound transit. At the start of Leg II (southbound) it had shifted slightly north occuring between 57°57' and 58°34' south and was similarly compressed. On the return northbound transit, the zone had broaden southward to between 57°49' and 59°14'.

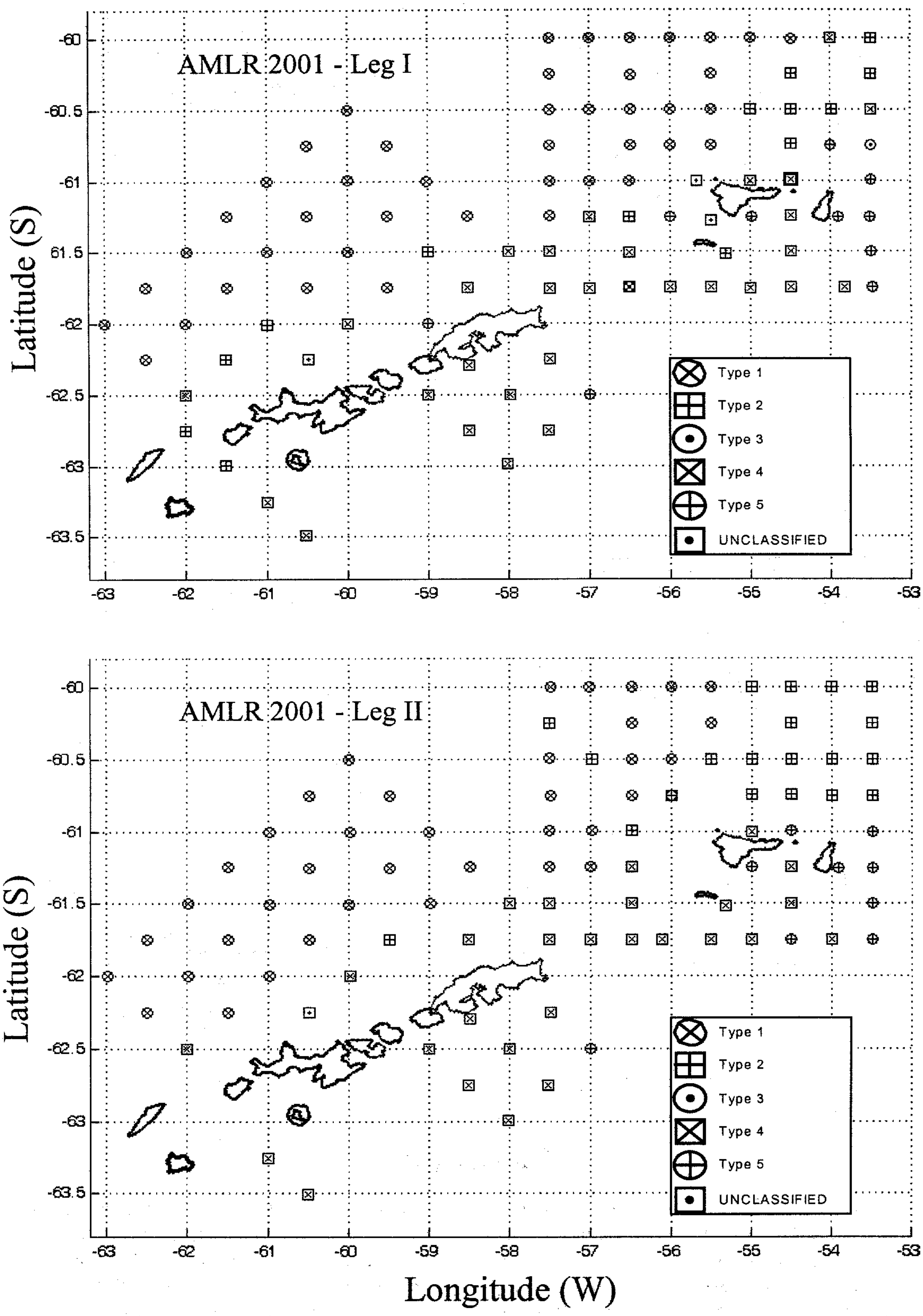


Figure 1.2. Classification of water types for Legs I & II (top and bottom panels respectively) as determined by the MATLAB classification algorithm developed during the AMLR 2001 survey.

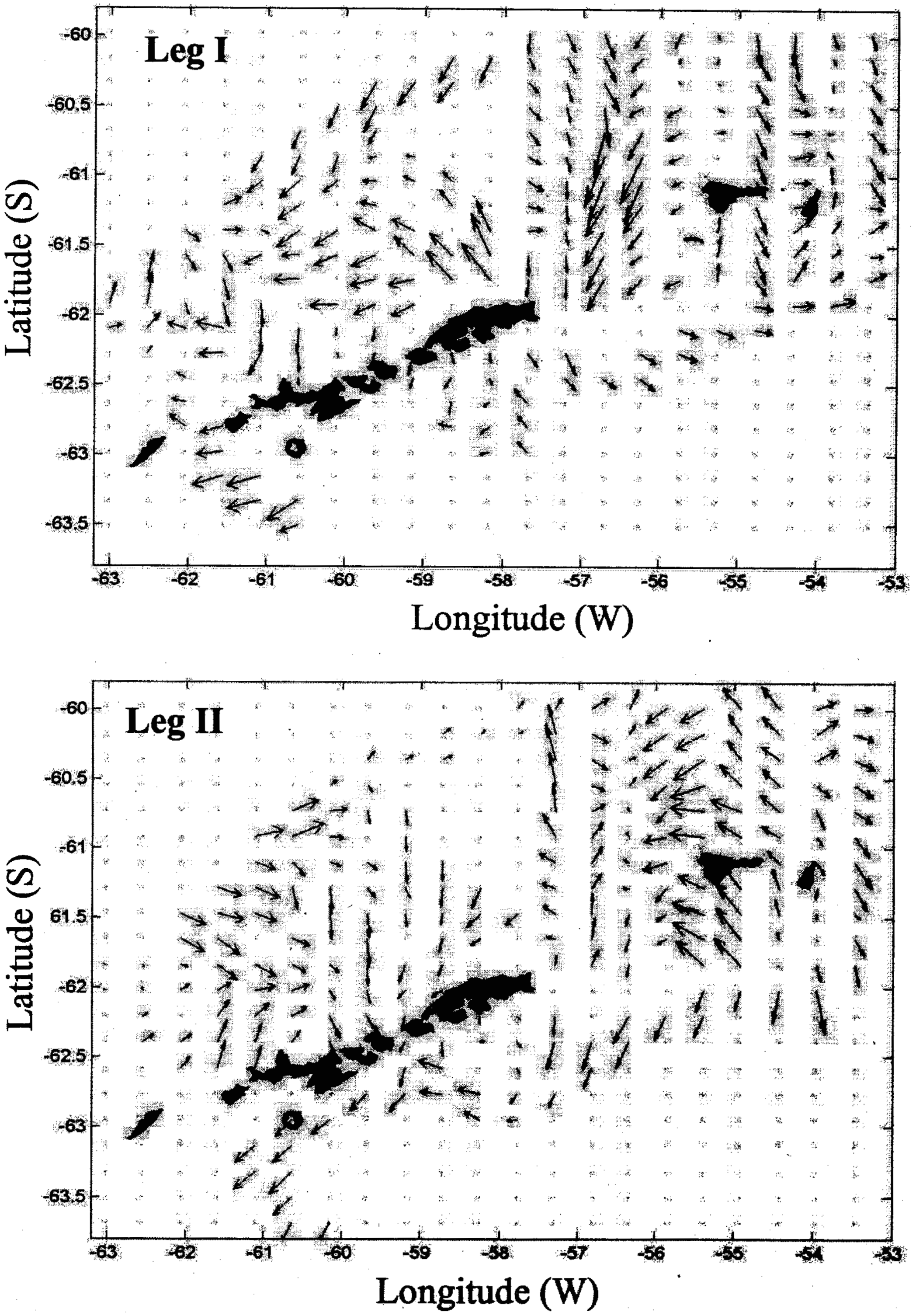


Figure 1.3. Wind speed and direction as recorded via the SCS system during Legs I & II of the AMLR 2001 cruise.

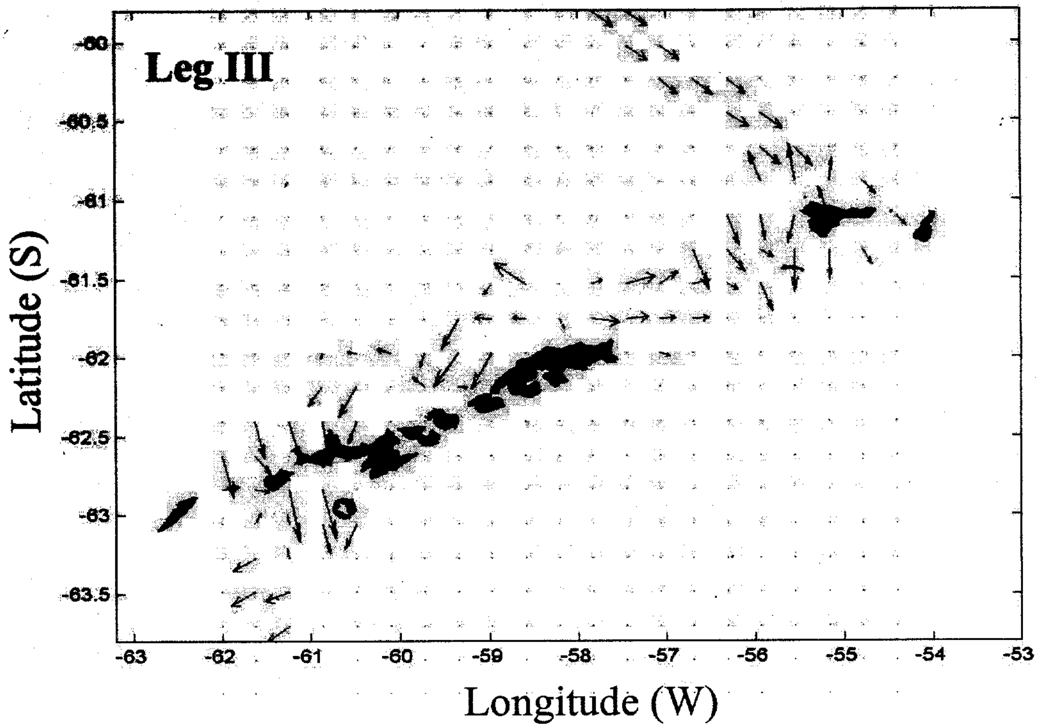


Figure 1.4. Wind speed and direction as recorded via the SCS system during Leg III of the AMLR 2001 cruise.

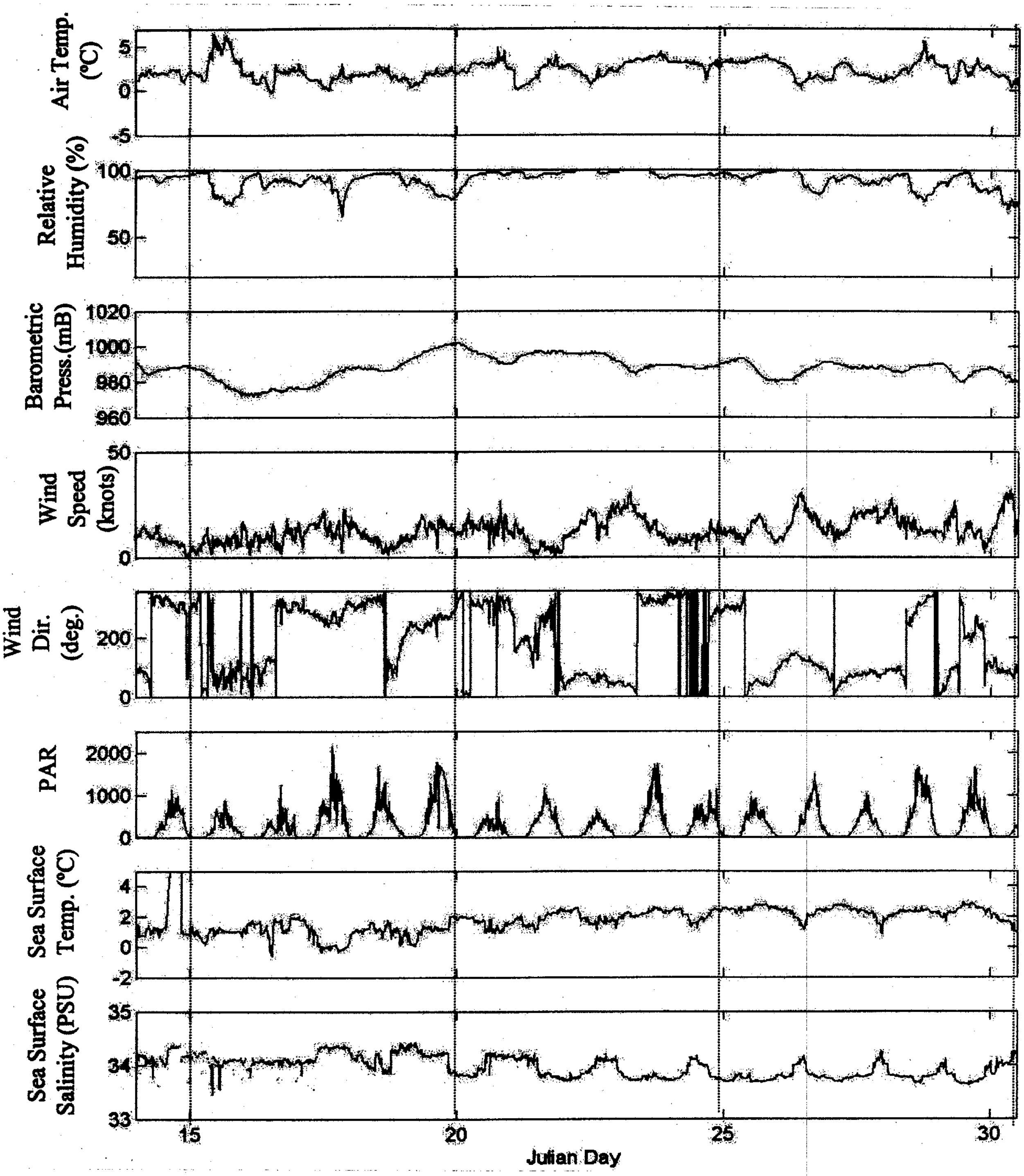
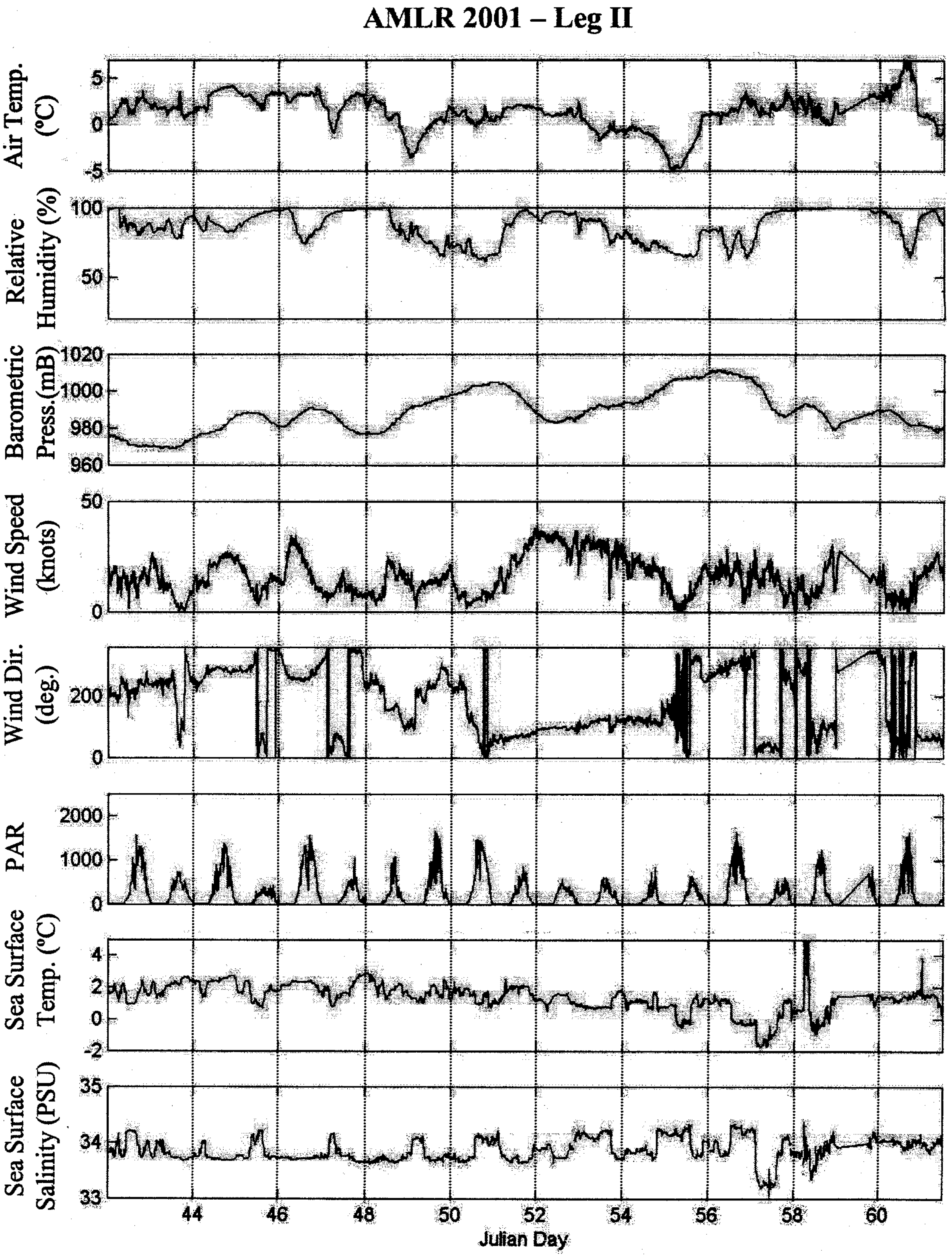


Figure 1.5. Meteorological data (5-minute averages) recorded between January 13th and January 31st during Leg I (survey only) of the AMLR 2001 cruise. PAR is photosynthetically available radiation.



AMLR 2001 – Leg II

Figure 1.6. Meteorological data (5-minute averages) recorded between February 11th and March 2nd during Leg II (survey only) of the AMLR 2001 cruise. PAR is photosynthetically available radiation.

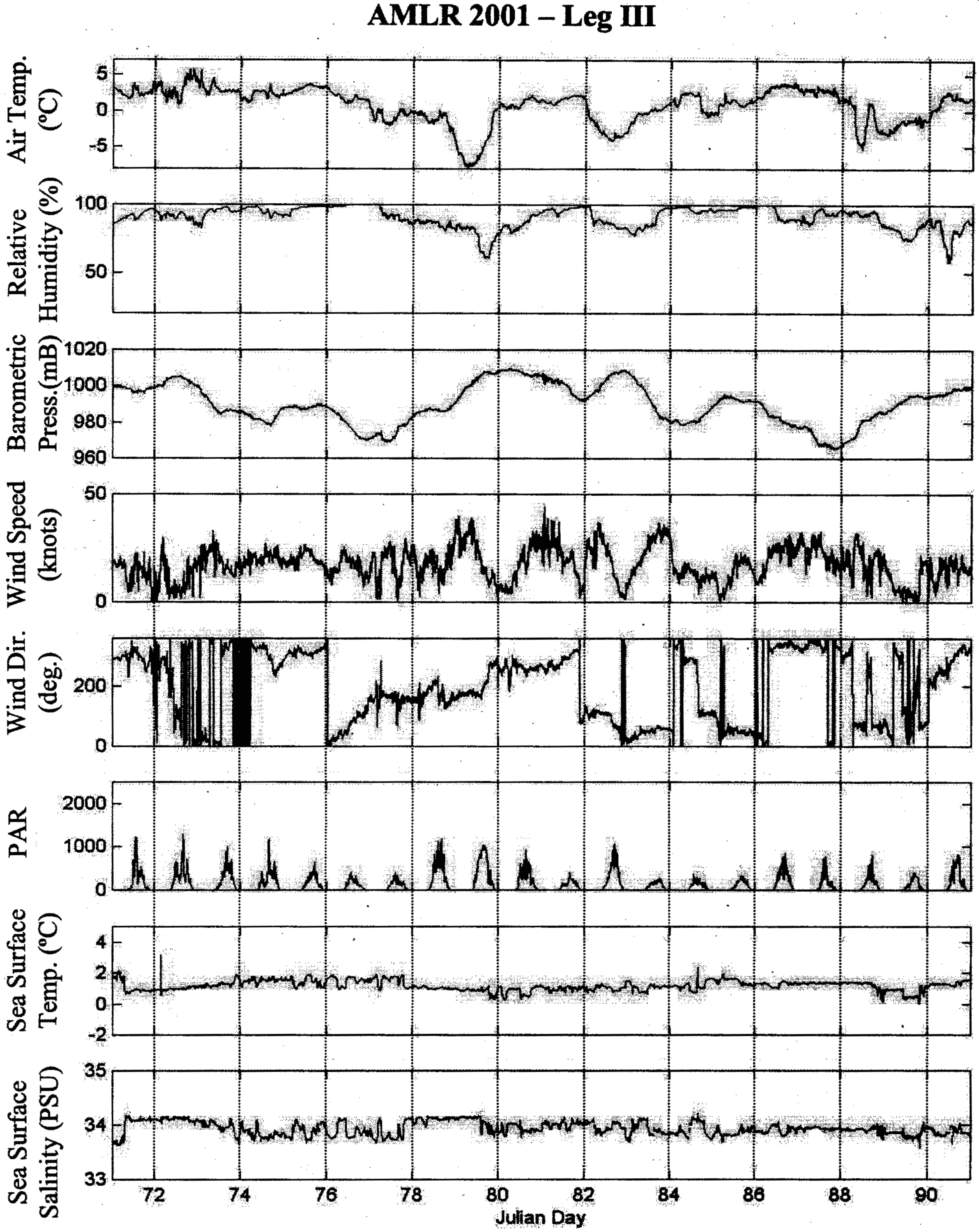

AMLR 2001 – Leg III

Figure 1.7. Meteorological data (5-minute averages) recorded between March 12th and March 31st during Leg III (survey only) of the AMLR 2001 cruise. PAR is photosynthetically available radiation.

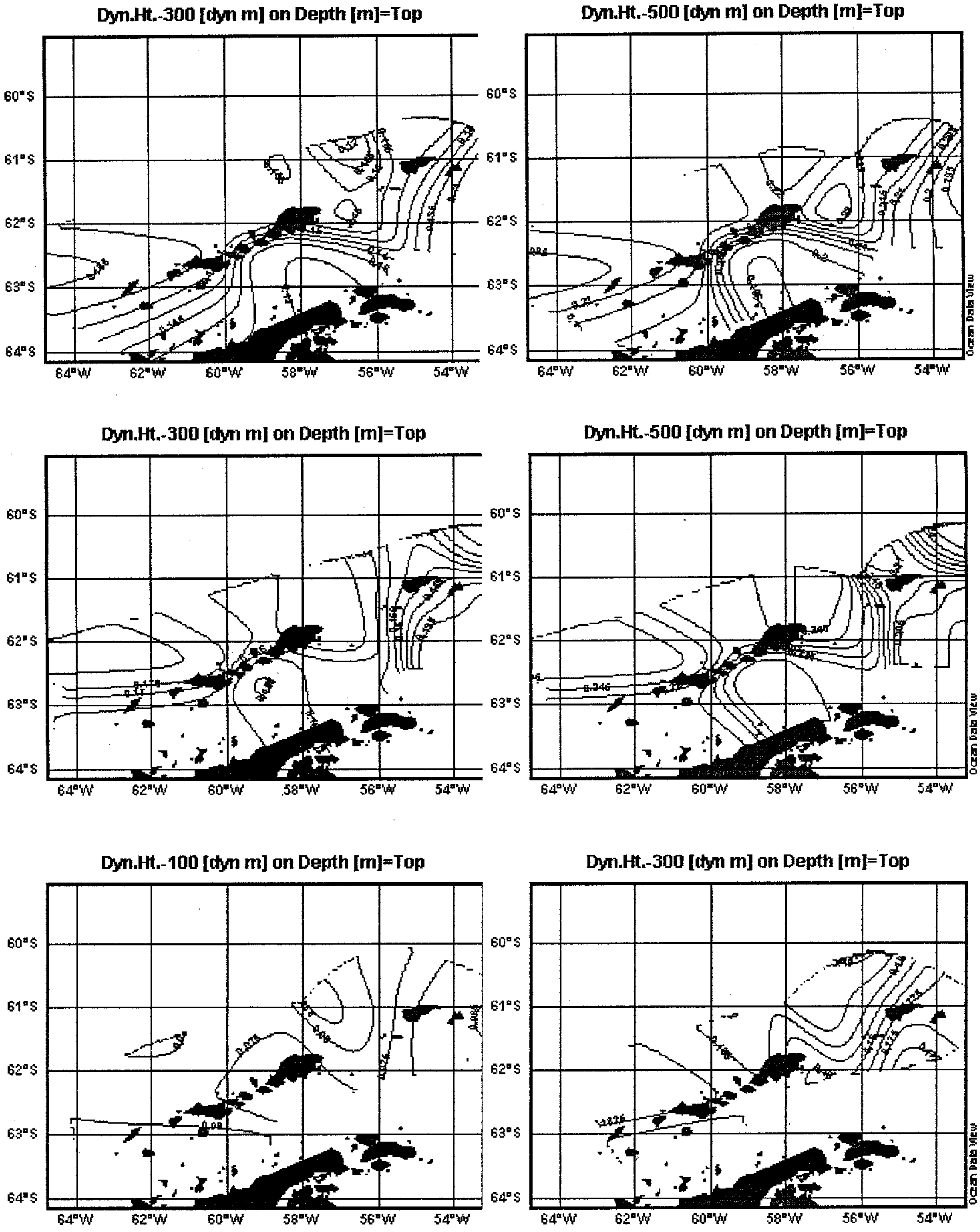
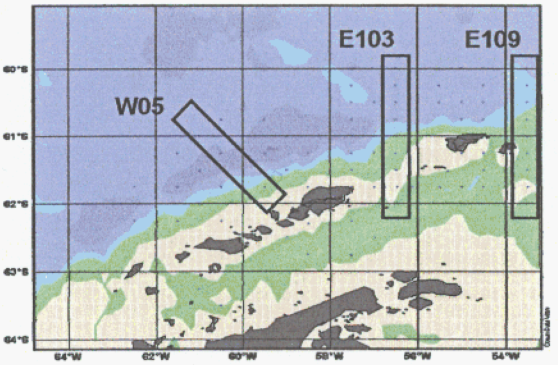
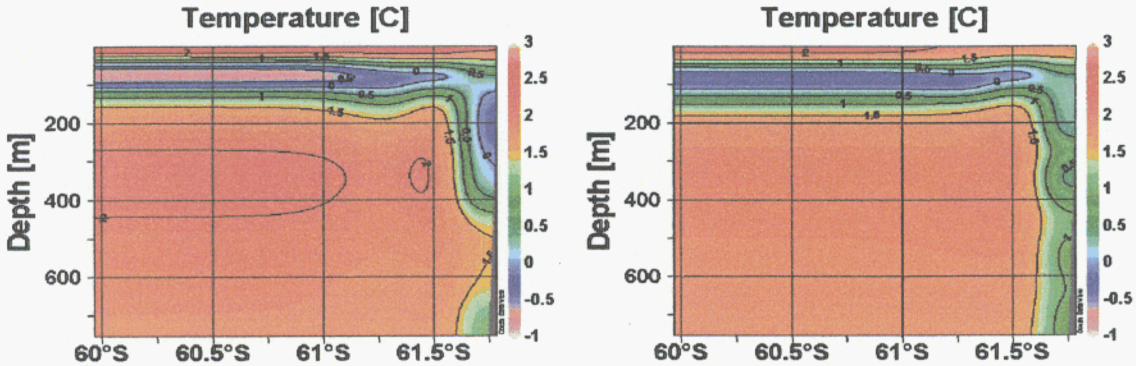


Figure 1.8. Dynamic height for survey areas of Legs I, II & III (top, middle and bottom graphs respectively) during the AMLR 2001 cruise. Reference depths for Leg III differ since the CTD casts were mostly in shallow water with a maximum depth of 300m.



Transect W05



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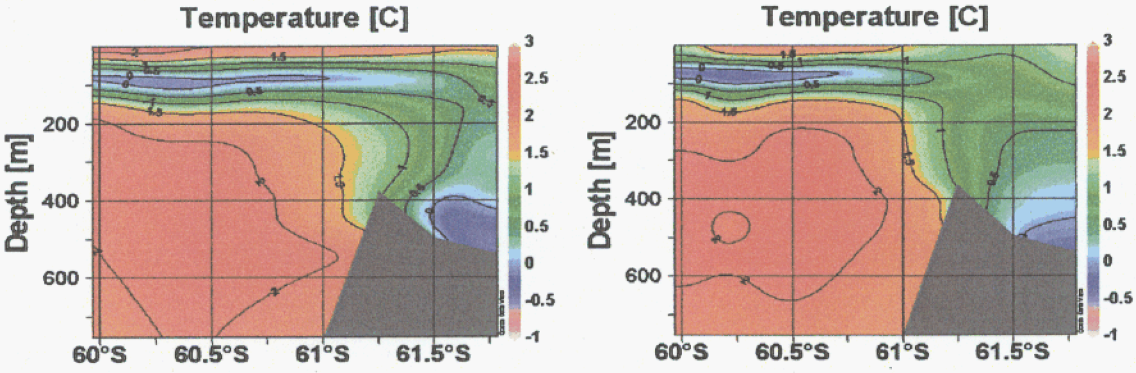

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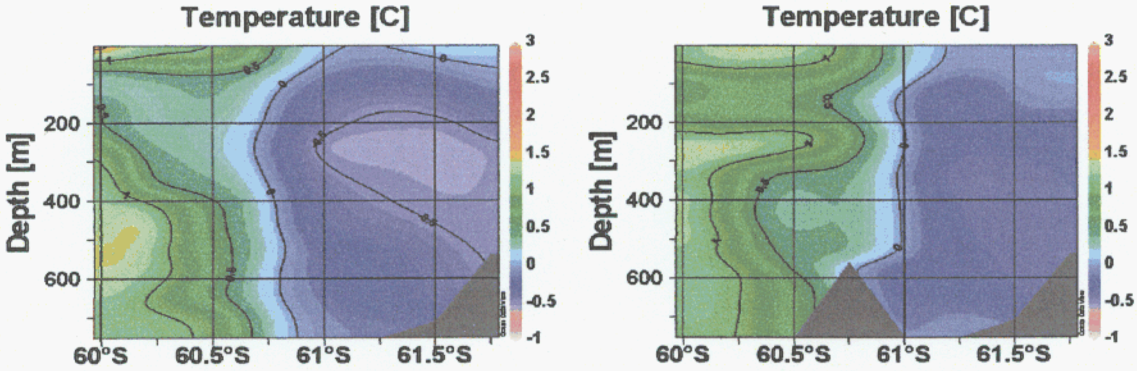

Figure 1.9. Vertical temperature (deg.C) sections on three transects during Leg I (left column) and Leg II (right column). The positions of the transects on the survey grid are shown in the diagram above.

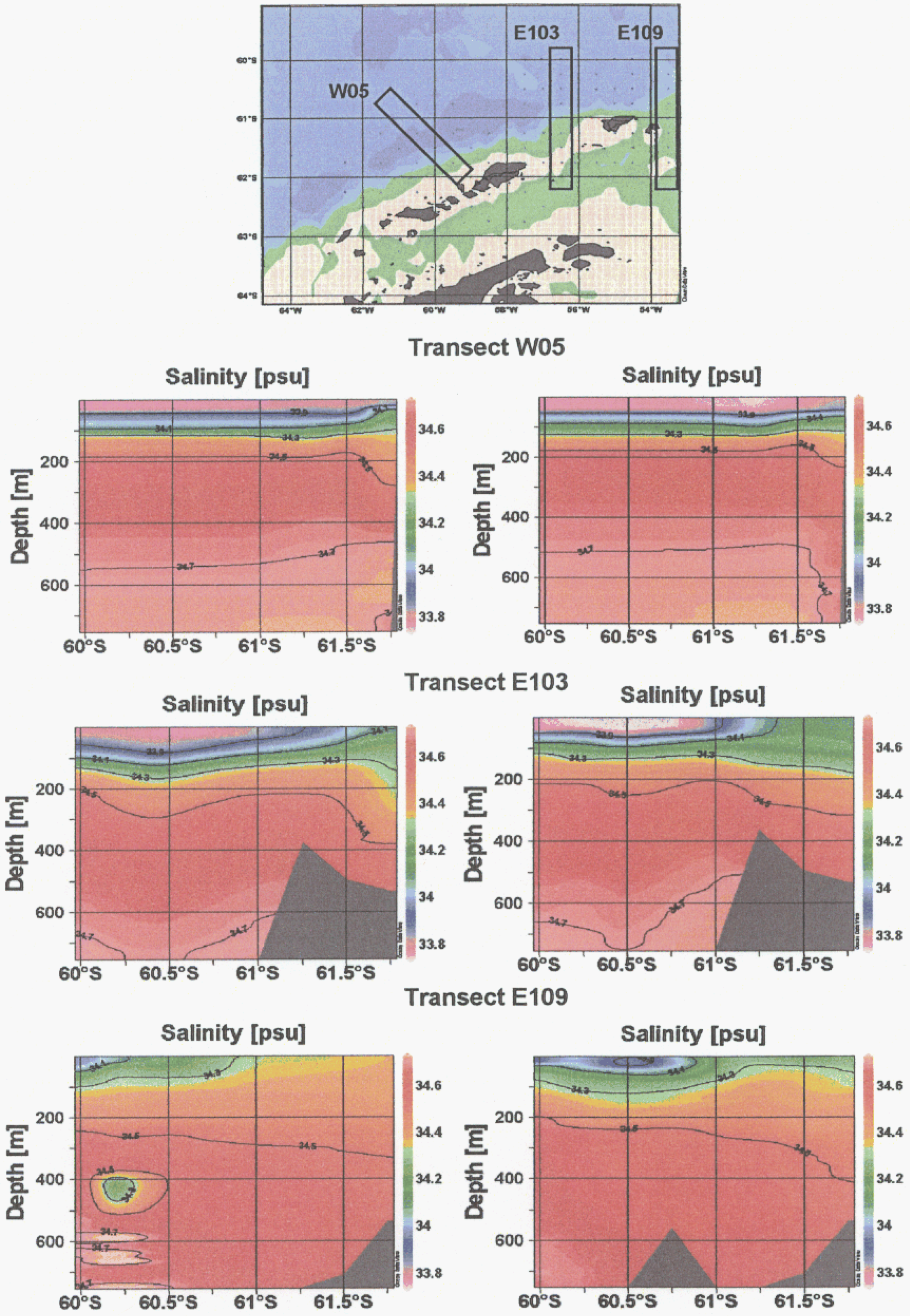

Figure 1.10. Vertical salinity (PSU) sections on three transects during Leg I (left column) and Leg II (right column). The positions of the transects on the survey grid are shown in the diagram above.

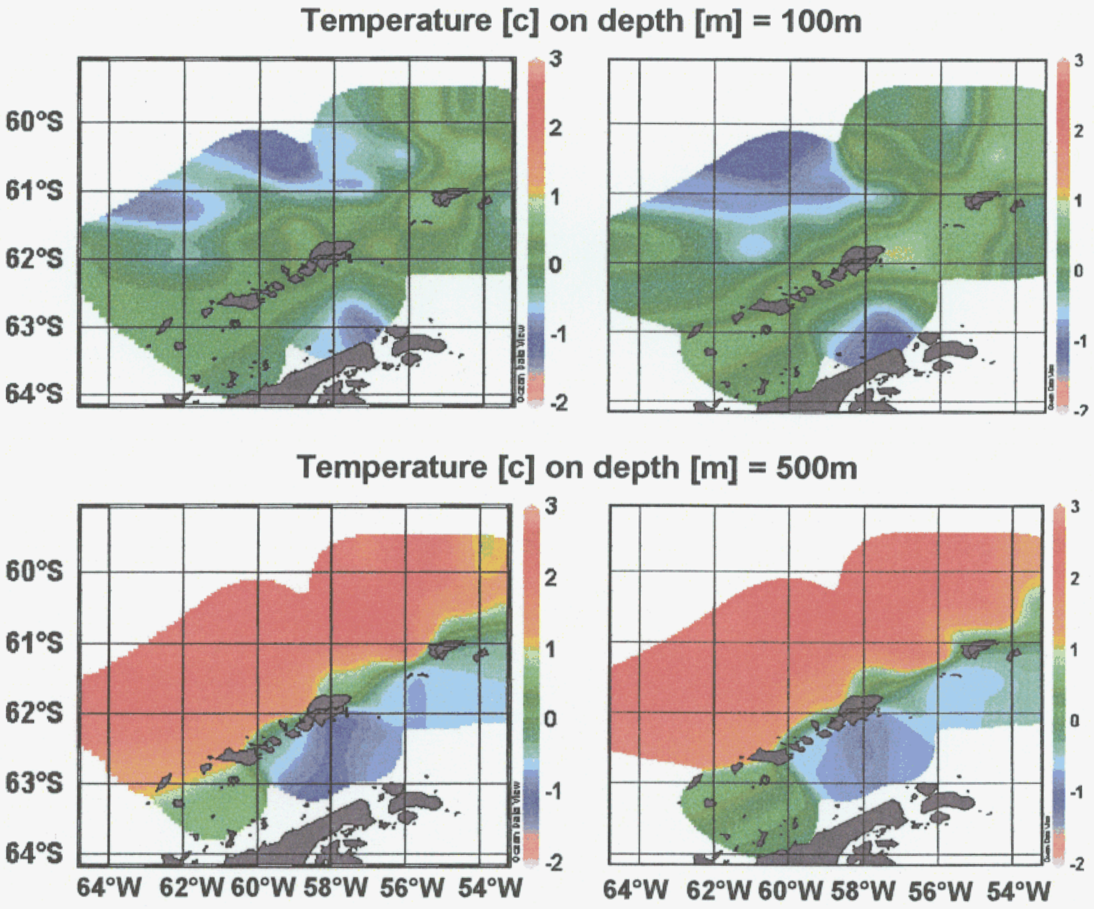

Figure 1.11A. Sea temperature (deg.C) sections at 100m and 500m during Leg I (left column) and Leg II (right column).

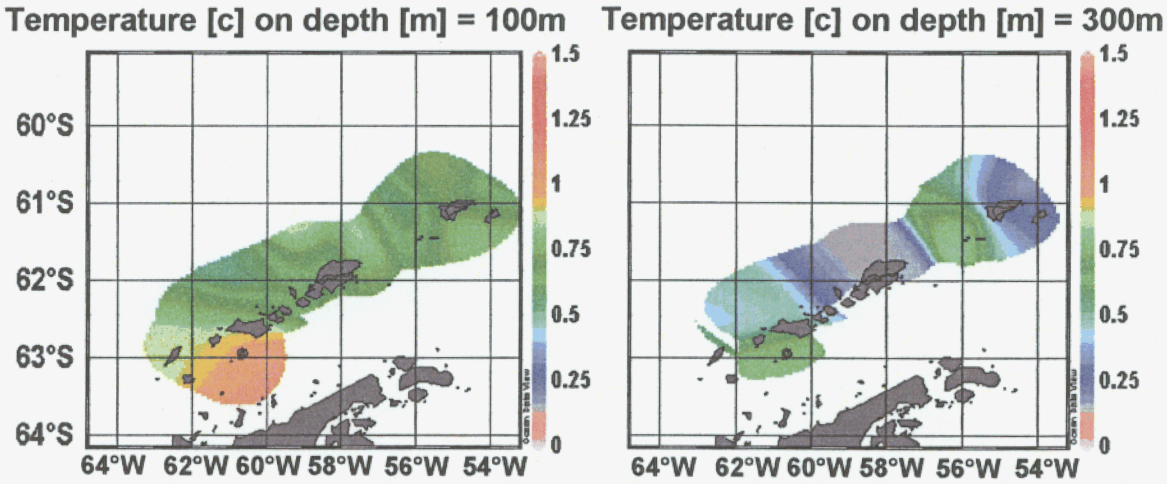

Figure 1.11B. Sea temperature (deg.C) sections at 100m and 300m during Leg III. Reference depths for Leg III differ from Legs I & II since the CTD casts were mostly in shallow water with a maximum depth of 500m.

Leg I

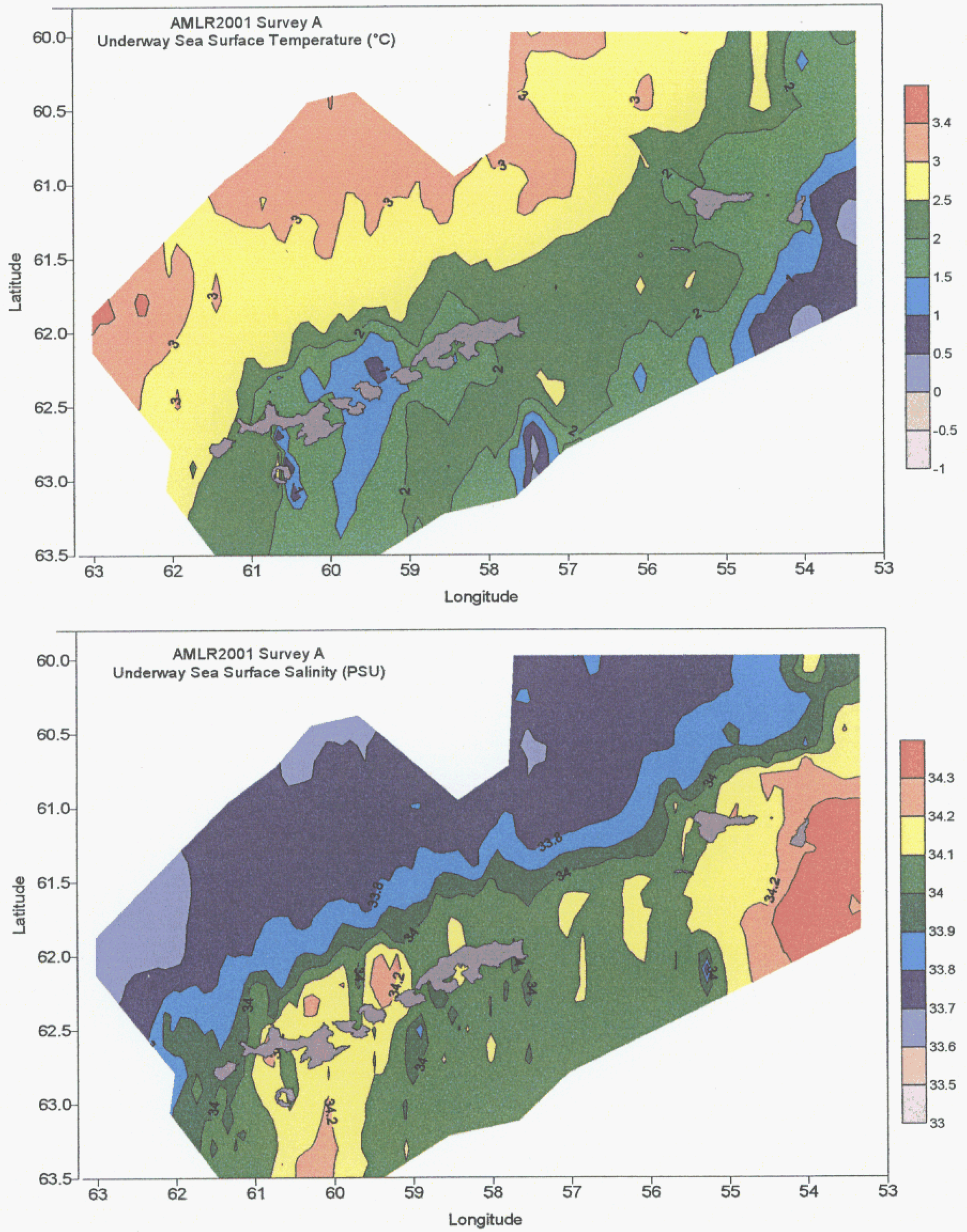

Figure 1.12. Sea Surface Temperature and Salinity from continuous thermosalinograph data (5-minute averages) for Leg I. Longitude is West and latitude is South.

Leg II

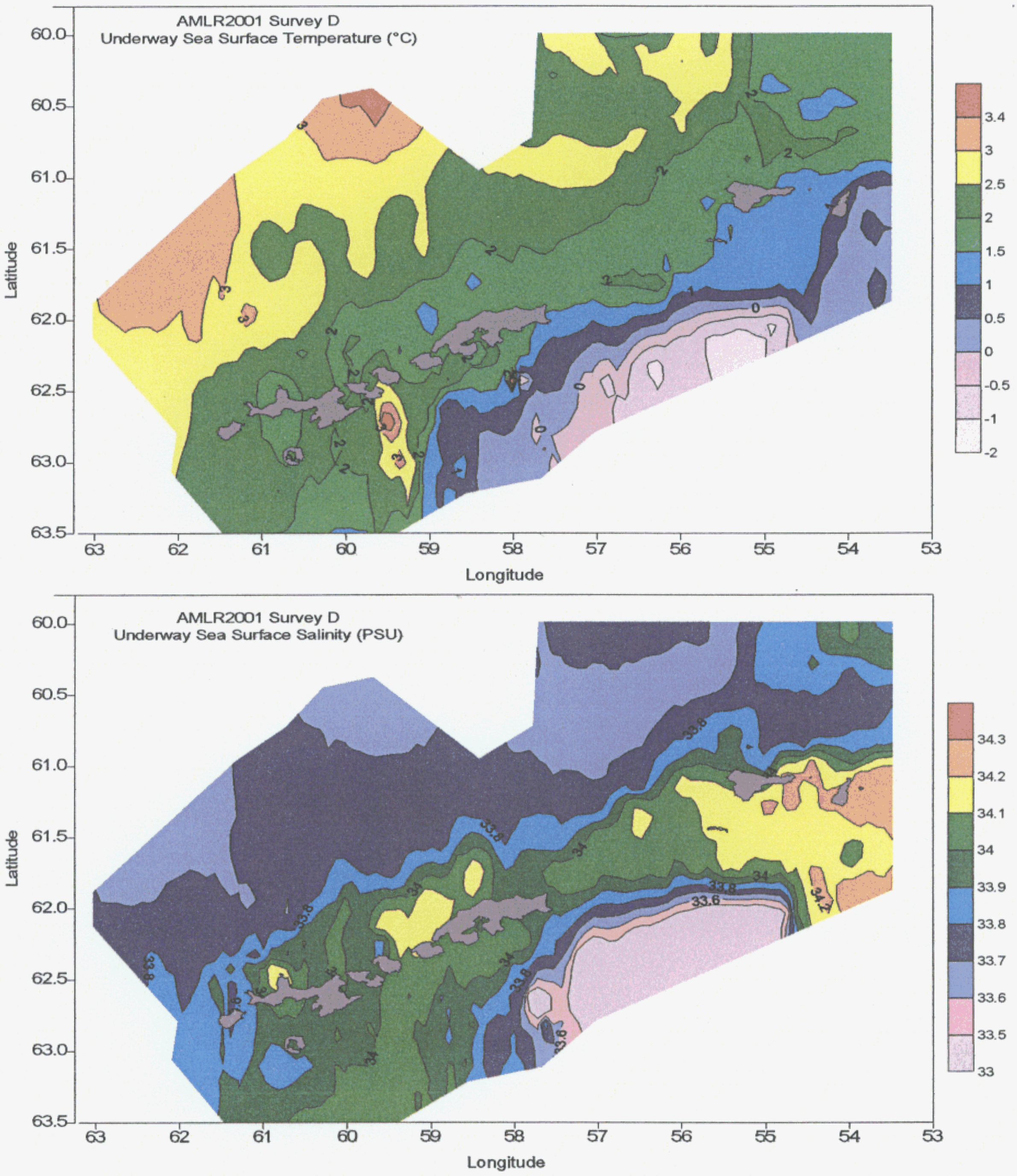

Figure 1.13. Sea Surface Temperature and Salinity from continuous thermosalinograph data (5-minute averages) Leg II. Longitude is West and latitude is South.

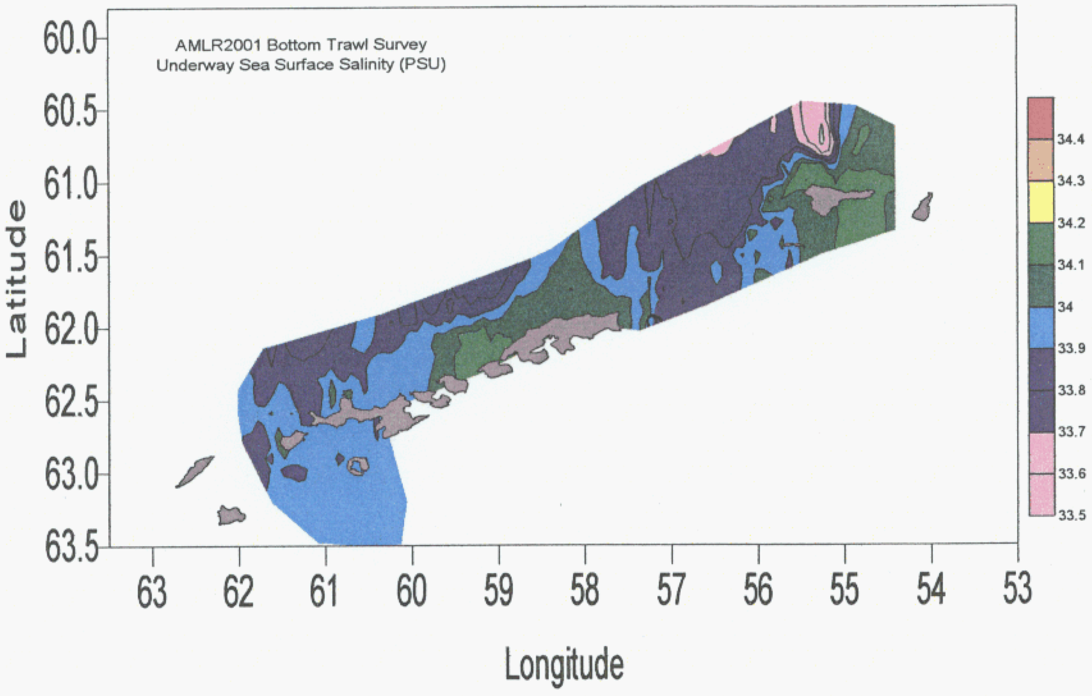

Figure 1.14. Sea Surface Temperature and Salinity from continuous thermosalinograph data (5-minute averages) for Leg III. Longitude is West and latitude is South.

2. Phytoplankton and Optical Oceanography; submitted by Christopher D. Hewes (Legs I & II), John Wieland (Leg II), B. Greg Mitchell (SIO), Mati Kahru (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 200m), 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 coverage; (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, together with an explanation of the methodology employed, are listed below.

(A) Sampling Strategy:

Protocols were to both obtain water samples for analyses and to acquire data from various sensors:

(1) During Leg I, water samples were obtained from 10-liter Niskin bottles (with Teflon covered springs) which were closed at 5 meters for every station plus eight other standard depths (10, 20, 30, 40, 50, 75, 100, and 200m) from every other station upcast of the CTD/rosette unit. During Leg II, 5m samples were obtained using 10-liter Niskin bottles at all stations plus at eight standard depths (as above) for those stations where optical profiles were also made (minimum of one per day).

(2) During Leg I, one transmissometer (660nm wavelength), and for 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.

(3) For both legs, a profiling *in situ* fluorometer was used to measure chlorophyll fluorescence.

(4) A solar irradiance sensor (BSI Inc. model QCP-200L) with a cosine response was used for recording of attenuation of photosynthetically available radiation (PAR) with depth during both legs.

(5) For both legs, SeaWiFS satellite images were processed for monthly averaged chlorophyll concentrations.

(B) Measurements and Data Acquired:

(1) Chlorophyll-*a* concentrations: Chl-*a* concentrations in the water samples were determined by measurement of chl-*a* fluorescence after extraction in an organic solvent. Sample volumes of 100ml 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 absolute methanol 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 the addition of two drops of 1.0 N HCl. Fluorescence was measured using Turner Designs Fluorometer model #700 having been calibrated using spectrophotometrically determined chl-*a* concentrations of a prepared standard (Sigma). Stability of the fluorometer was verified daily by using a fluorescence standard.

(2) Miscellaneous optical and cellular measurements: For 33 stations during Leg II, discrete water samples were obtained between 1000 and 1600 GMT (corresponding with the time that SeaWiFS satellite observations of the area became available) for pigment analyses. Water bottle samples obtained at six discrete depths were used for each of the following analyses (except where noted 1-2 liters were filtered through 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 of cellular components by UV damage to the photosystem.

- Particulate Organic Carbon and Nitrogen (POC and 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 the University of California at 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 were 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 I, a single (660nm) and 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) *In situ* optical oceanography: Corresponding approximately in time with the optimal time that the SeaWiFS satellite passed over (31 stations), a Biospherical Instruments free-fall Profiling Reflectance Radiometer (PRR-800) was deployed. The PRR-800 measured spectral downwelling (E_d) and upwelling (E_u) irradiances and upwelling radiance (l_u) at 19 wavelengths continuously from the surface to the bottom of the profile. Profile depths ranged from 50-200 meters depending on the station. Spectral values of normalized water-leaving radiance will be computed from the PRR-800 data and used to validate SeaWiFS data, as well as to develop Southern Ocean regional ocean color algorithms.

(5) Satellite Oceanography: 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:

(A) Phytoplankton Biomass

Leg I (Refer to Figure 2.1A). In the Bransfield Strait south of the South Shetland Islands (South area), mild phytoplankton blooming was found having average chlorophyll concentrations of 1.8mg m^{-3} at 5-meter depth and approximately 73mg m^{-2} as integrated through the water column to 100 meters. The pattern for surface chlorophyll concentrations in the Elephant Island sector closely followed bottom topography of the area. Although 5m chlorophyll averages 0.62 ± 0.64mg m^{-3} for the entire section, the shelf and break area around Elephant Island (29 stations) averaged 1.01 ± 0.67mg chlorophyll m^{-3} as compared to 0.26 ± 0.28mg chlorophyll m^{-3} in the oceanic region. The pattern for surface chlorophyll concentrations in the West Area closely followed bottom topography similar to the Elephant Island Area. Five-meter chlorophyll was 0.71 ± 10 mg m^{-3} for the entire section (29 stations) with stations located in waters less than 1,000-meter depth having 2.7 ± 0.49mg chlorophyll m^{-3} as compared with pelagic stations having 0.18 ± 0.21mg chlorophyll m^{-3}.

The southwestern portion of the Bransfield Strait (Stations A180, A190, and A191) had the highest 5m chlorophyll concentrations of Leg I, having 3.36 ± 0.26mg m^{-3}. However, these concentrations were greatly attenuated to less than 1.2mg m^{-3} by 20- to30-meter depth thus contributing less integrated biomass than those stations lying along the shelf region north of the South Shetland Islands. The second most phytoplankton rich area measured during Leg I was found within the continental shelf north of the South Shetland Islands with stations A150 and A174 having greater than 2.5mg chlorophyll m^{-3}.

Leg II (Refer to Figure 2.1B). The pattern for surface chlorophyll concentrations in the West Area closely followed bottom topography similar to that observed during Leg I. Five-meter chlorophyll was 0.37 ± 0.44mg m^{-3} for the entire section (29 stations) with stations located in waters less than 1,000-meter depth having 1.06 ± 0.49mg chlorophyll m^{-3} as compared with pelagic stations having 0.18 ± 0.17mg chlorophyll m^{-3}. Thus, mean near-surface chlorophyll in continental and shelf breakwaters declined by more than 50% since Leg I, while values for the Drake Passage waters remained near the same. During Leg I, stations A150 and A174 were among the richest of the survey having greater than 2.5mg chlorophyll m^{-3} each, however station D150 had decreased to 2.0mg chlorophyll m^{-3} and station D174 decreased down to 1.1mg chlorophyll m^{-3} during Leg II.

The pattern for surface chlorophyll concentrations in the Elephant Island Area closely followed bottom topography similar to that observed during Leg I. However, 5m chlorophyll was 0.40 ± 0.34mg m^{-3} for the entire section (46 stations) with stations located in waters less than 1,000-meter depth having 0.66 ± 0.34mg chlorophyll m^{-3} (15 stations) as compared with pelagic stations having 0.28 ± 0.27mg chlorophyll m^{-3}. Thus, mean near-surface chlorophyll declined about 40% since Leg I (0.62 ± 0.64mg m^{-3} for the entire section, 1.01 ± 0.67 and 0.26 ± 0.28mg chlorophyll m^{-3} in the shallow and oceanic region regions, respectively).

The general pattern of phytoplankton biomass as observed over the past 10 seasons indicate that chlorophyll concentrations generally increase during Leg II compared to Leg I for the AMLR region. This year Leg I chlorophyll concentrations (Figure 2.1A) decreased during Leg II (Figure 2.1B). However, this will be discussed further in context to satellite observations (See 2.B.1 below). Compared with previous years (1990-1999), chlorophyll concentrations for the South Area were slightly higher this year than the average of about 1.2mg m^{-3} (note however the fewer number of stations), and slightly less this year for the West and Elephant Island Areas (about 0.8 -1.0mg m^{-3}, respectively) at 5m.

(B) Satellite/Optical Oceanography

The optical oceanography component incorporated to the program (funded by NASA's SIMBIOS program to Dr. Greg Mitchell, SIO), provided satellite (SeaWiFS) images of surface chlorophyll distributions, as well as *in-situ* optical profiling and pigment spectrophotometry during Leg II.

1. Monthly composite chlorophyll distributions from SeaWiFS images for January and February for the AMLR survey region (Figure 2.2A, C) support the observation that directly measured chlorophyll concentrations declined between January and February. Some of this may be reconciled by placing this in perspective of the entire Scotia Sea (Figures 2.2B, D). 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. Also note how high chlorophyll concentrations follow the contours of the shelves for South America and the South Shetland Islands (Figures 2.2B, D), but greatest blooming occurred in the central Scotia Sea between the shallower depths of the entire Scotia Ridge. In addition, it is evident that the summer bloom that has been noted to occur in February did so, but apparently slightly northeastward of our survey area. A bloom also developed at the southwestern portion of the Bransfield Strait during February (Figure 2.2C), but we had too few stations in the region to have determined this from extracted chlorophyll measurements.

2. 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. The bio-optical properties for bio-geographic provinces of this region and their relation to photosynthesis, biomass, carbon and production are currently being studied. An example of this can be obtained from examination of two contrasting stations from Leg II, D166 (a Drake Passage water type, Figures 2.3A, B) and D014 (a coastal station, Figures 2.3C, D). Drake Passage water (Zone IA waters) is characteristic of having low chlorophyll biomass (> 0.5mg chlorophyll m^{-3}) in the upper 100 meters, but a small chlorophyll maximum found between 50 and 120 meters (Figure 2.3B; corresponding with the depth of a water temperature minimum). This is in contrast with more productive coastal waters where phytoplankton biomass is located in the upper portion of the euphotic zone. It is well known that phytoplankton account for most of the particulate absorption of light and hence attenuation of photosynthetically available irradiation (PAR) in the water column. Therefore, PAR is attenuated more rapidly with depth in the water column at a rich coastal station (Figure 2.3C) as compared to that of a blue water station (Figure 2.3A).

The spectral irradiance in the ocean is complex and varies considerably depending upon its environment (i.e., clarity, depth, particulates, and incidental sunlight). 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). Phytoplankton are the most dominant particles having color in the oceans, and contain various photosynthetic and non-photosynthetic pigments (Figure 2.4). 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. Water color (Figure 2.5) therefore greatly depends not only on both the taxonomic family of phytoplankton present (which determines the types of pigments present), but also on their concentration with depth. As a result, the quality and quantity of light upwelled from the oceans surface is dependent upon the absorption and scattering qualities of the phytoplankton present. As expected, the upwelling radiance normal to incident irradiance of a blue water station (Figure 2.5A; Station D166) is greater and of different color (note the "blue" spectral peak) than that of the richer station (Figure 2.5B; Station D014) that has a greater "green" spectral component.

It is noted that the absorption spectrum of phytoplankton (Figure 2.4) provides two major peaks (about 440 and 670nm) that are ascribed to chlorophyll, plus a variety of shoulders in the spectra that represent additional pigmentation. Furthermore, there is a general absence of absorption in the green (550-600nm) wavelengths. When the proportions of upwelled light at 443 to 555nm are examined (Figure 2.5 & 2.6), a great contrast can be measured between "blue-water" (e.g., D166) and "green-water" (e.g., D014). The ratio of 443:555nm upwelled radiance is a function of chlorophyll concentration and this relationship changes with depth (Figure 2.6). Thus, the ratio of 443:555nm upwelled radiance at the ocean surface can be obtained by SeaWiFS satellite, and was a first approximation for the estimation of chlorophyll from space (see O'Reilly *et al.*, 1998). The most recent of algorithms for estimation of chlorophyll concentration also use the 443 and 555nm channels, so that data plotted in Figure 2.7 are relevant: SeaWiFS algorithms used to estimate chlorophyll (and primary productivity) must necessarily be different for the

Southern Ocean (represented by the AMLR data) than that estimated for mid-latitudes (represented by the CalCOFI data in Figure 2.7). It is apparent from the data presented in Figure 2.7 that surface chlorophyll estimates for the AMLR study areas and associated Antarctic regions may be underestimated greatly if general SeaWiFS algorithms are used, and this supports previous predictions (Mitchell, 1992; Moore, 1999).

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 Dr. Roger Hewitt in the AERD 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: It should be noted that NOAA funding for the AMLR program does not provide funds for the calibration, repair, or replacement of field equipment (both laboratory equipment and *in situ* sensors) used in the annual surveys. Many of our instruments devoted to this program (originally obtained from other funding agencies) for the past 12 years are now beginning to fail. Unless some additional NOAA funding can be found to replace such instruments, the scope and quality of our data in future AMLR field years will be compromised.

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 paper is funded in part by a grant from the National Oceanic and Atmospheric Administration, U.S. Department of Commerce, under grant NA77RJ0453, and by NASA SIMBIOS Project awards to B. Greg Mitchell (NAS5-97130 and NAS5-01002). The views expressed herein are those of the authors and do not necessarily reflect the views of NOAA or any of its sub-agencies.

2.7 References:

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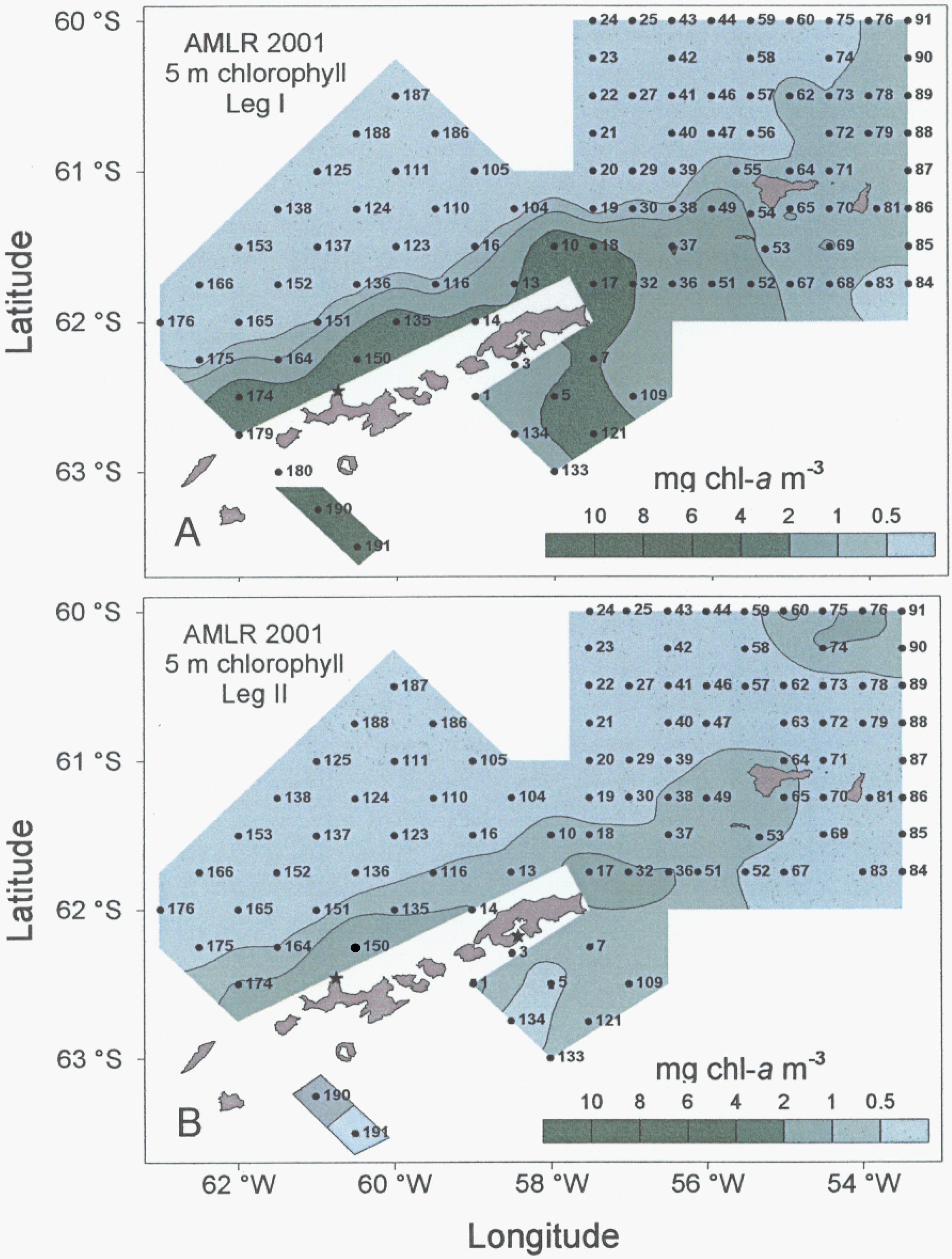

Figure 2.1. Distribution of chl-*a* concentration as obtained from Niskin bottle for stations during Leg I (A) and Leg II (B). Note 1) the elevated concentrations aligned with the island groups that corresponds with the shelf and break region of the South Shetland Islands, and 2) the general decrease of chlorophyll concentration from Leg I to Leg II.

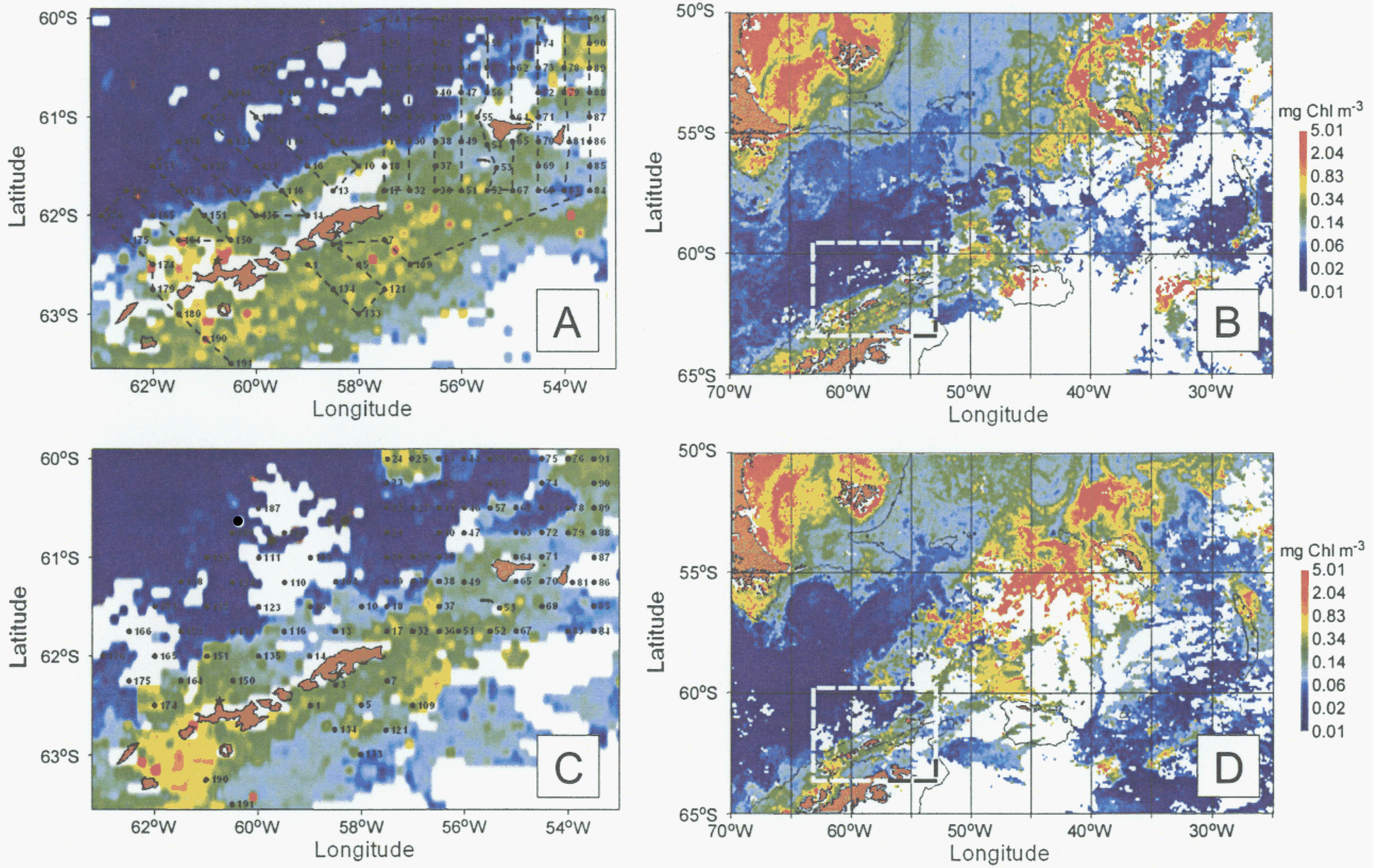

Figure 2.2. SeaWiFS satellite derived monthly composite chlorophyll concentrations for January (A, B) and February (C, D) for the AMLR survey area (A, C) and the entire Scotia Sea (B, D). Portion of the Scotia Sea area that the U.S. AMLR program surveys is indicated by a box in B and D. Although chl-*a* concentrations decreased in the AMLR survey region from January (A) through February (C), this was apparently a local phenomena, since much of the Scotia Sea developed blooms between January (B) and February (D).

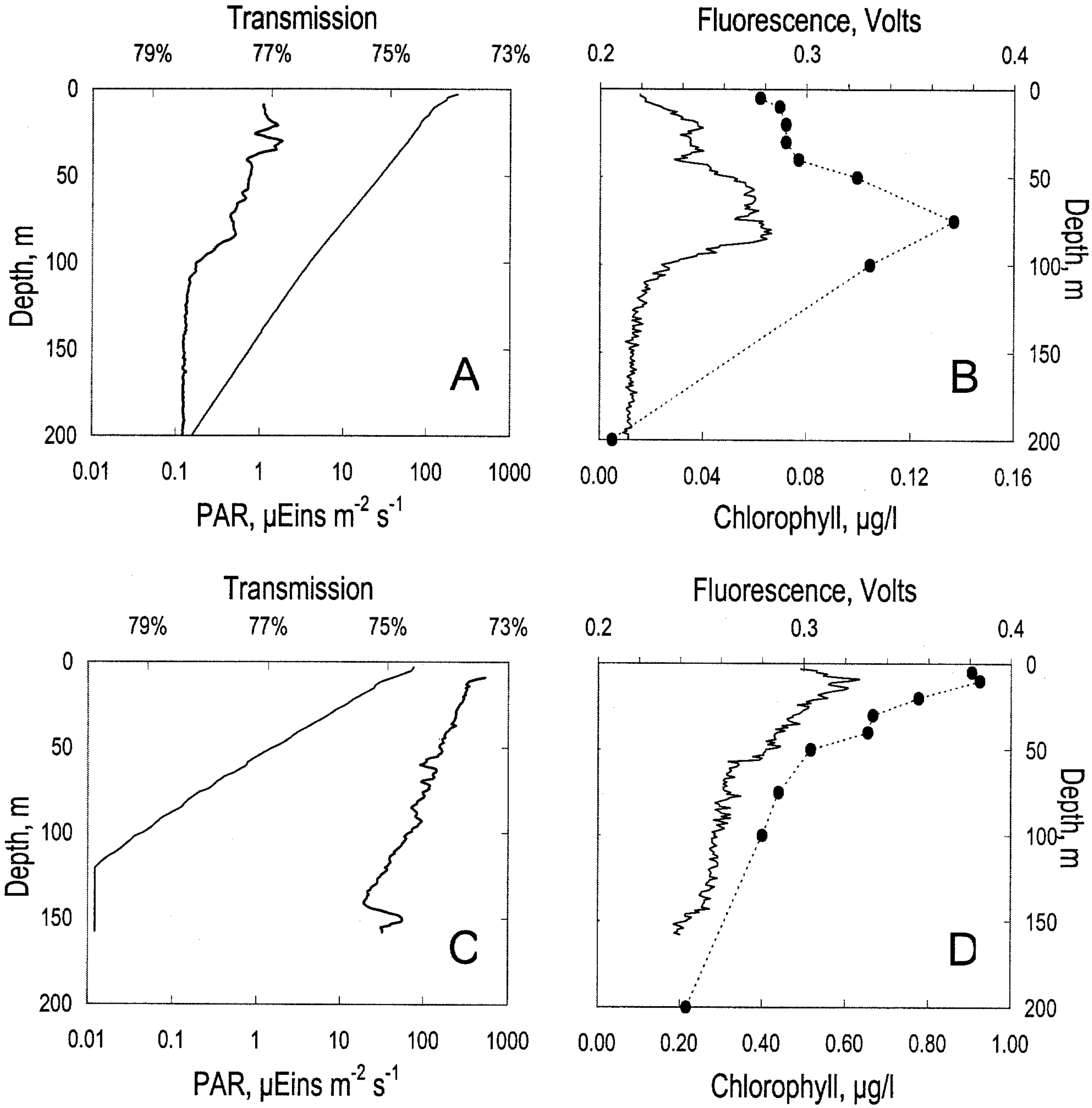

Figure 2.3. Optical and biological measures comparing a blue water Station D166 (A, B) and green water Station D014 (C, D) from Leg II (refer to Figure 2.1B & 2.2C for station references). Percent transmission (thick line) is much greater at D166 (A) than D014 (C) primarily as a function of chl-*a* concentration (symbols with dotted line) which was much less for D166 (B) than D014 (D). *In vivo* fluorescence (thin line) followed profiles of chlorophyll concentrations for both stations (B, D). Incident photosynthetically available radiation (PAR, thin line) was attenuated more rapidly with depth as a function of chlorophyll concentration in the green water station (C) than for the blue water station (A).

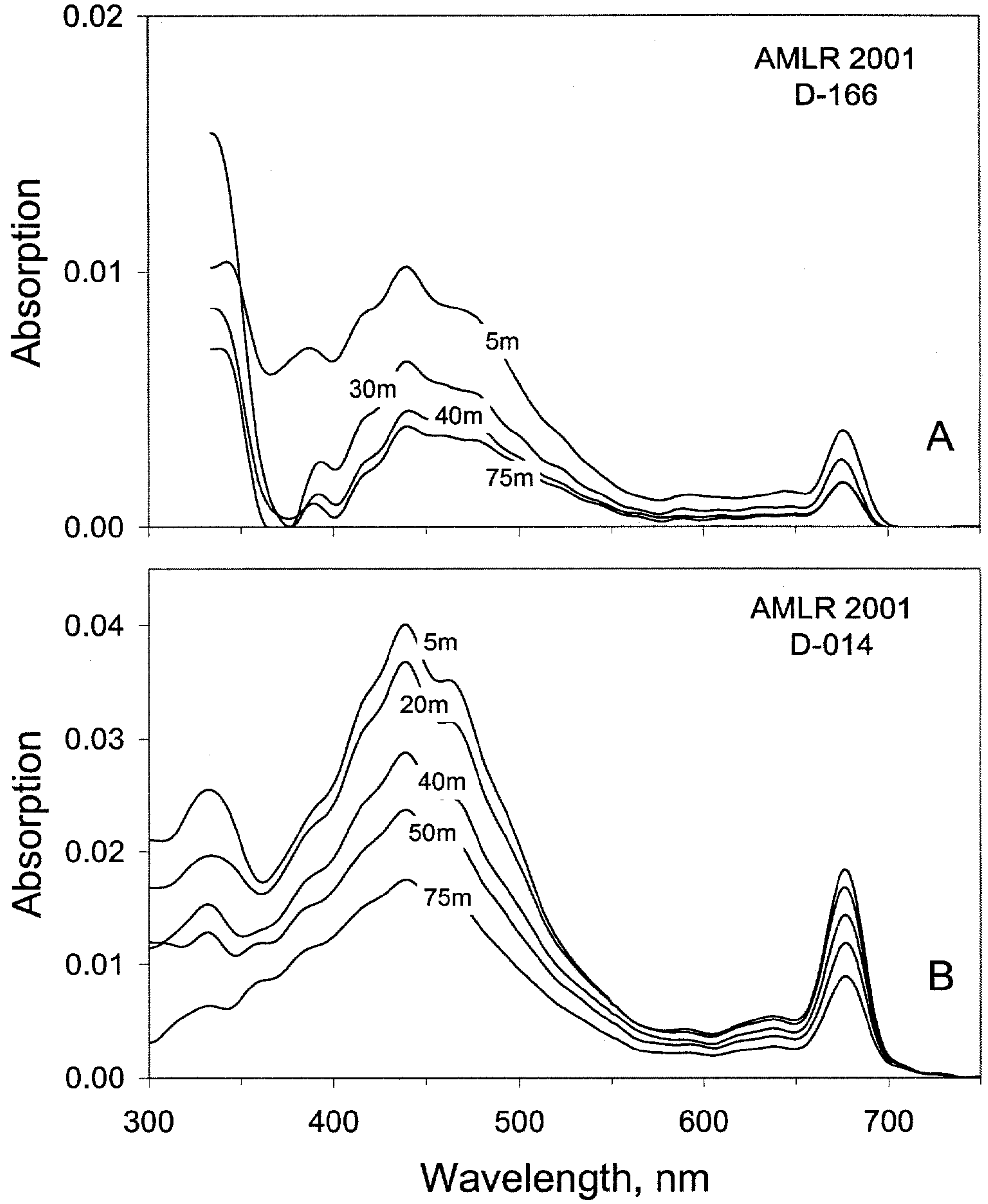

Figure 2.4. Spectral qualities of the phytoplankton populations sampled at different water depths for a blue water station, D166 (A) and a green water station, D014 (B). The scattering and attenuation of incident light in the water column (refer to Figure 2.3) is primarily a function of phytoplankton that contain various photosynthetic and non-photosynthetic pigments. Absorption by phytoplankton is dependent upon both their biomass and the taxonomy of phytoplankton, which determine the types and concentrations of other pigments in addition to chlorophyll that are present.

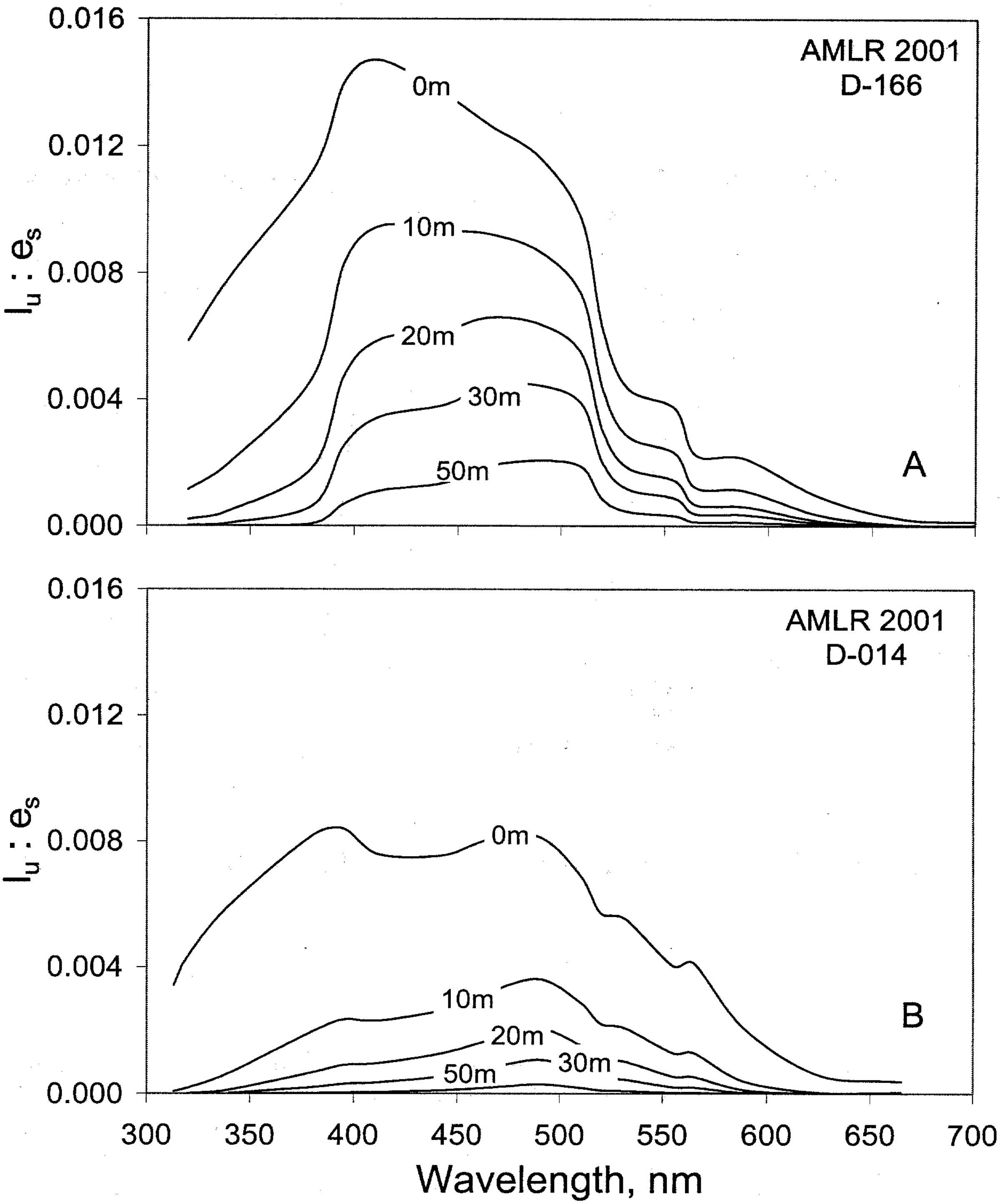

Figure 2.5. The types of pigments and their concentrations in the phytoplankton population determine the relative spectra of upwelled light (l_u) relative to incident radiation (e_s). Therefore it is seen that the blue water station D166 (A) had relatively higher amounts of upwelled blue light at the surface than did the green water station D014 (B), since it had less concentrations of chlorophyll and other "blue" absorbing pigments as shown by their spectra in Figure 2.4.

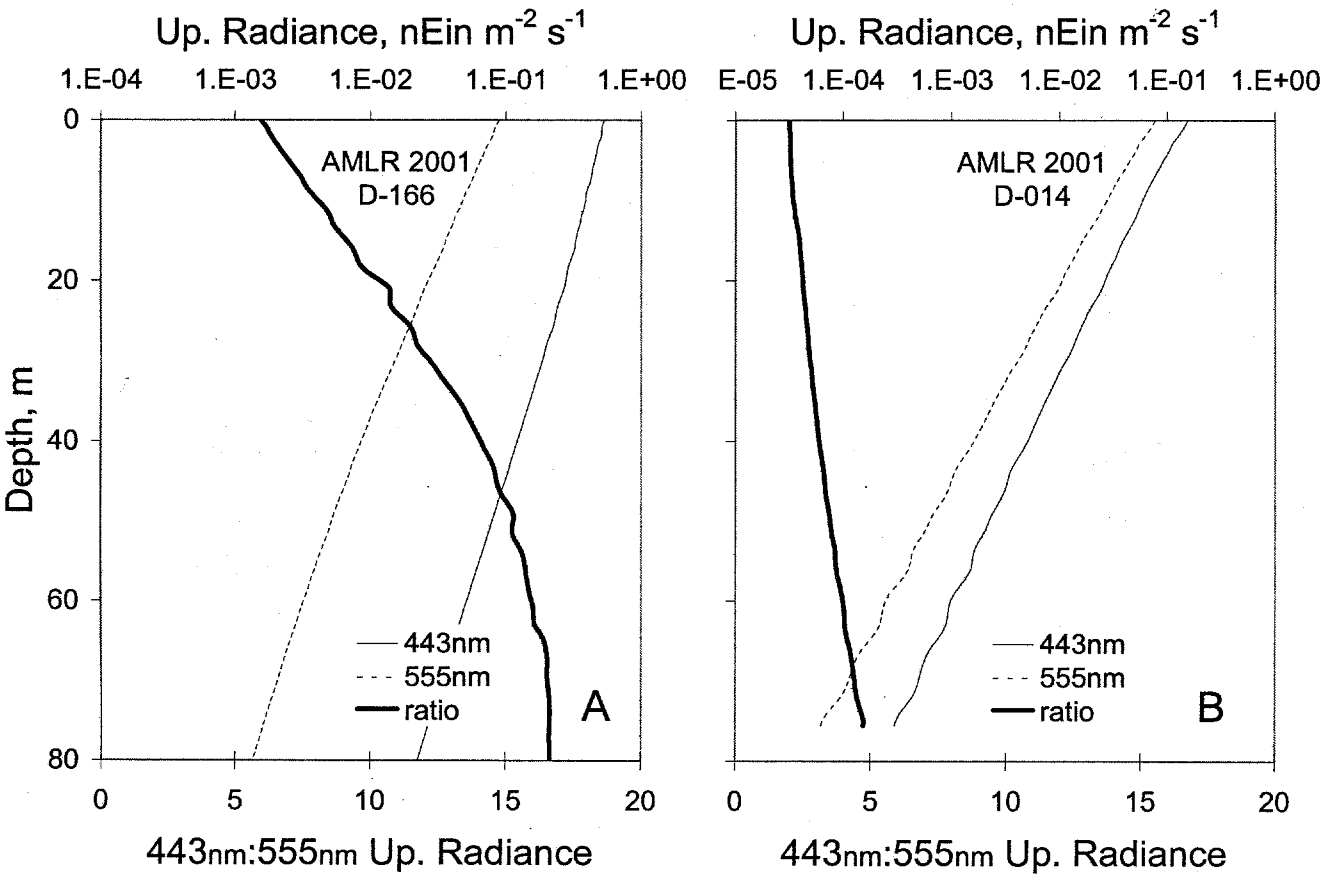

Figure 2.6. The upwelled radiance (a function of particle scattering) measured at depth (thin lines) is attenuated faster for green water than for blue water because downwelled PAR from the surface is attenuated at a greater rate (Figure 2.3A, C). Blue light penetrates further into the water column than green or red light, however *in vivo* chl-*a* absorbs light at about 443nm, while phytoplankton in general have little absorption of light at 555nm (refer to Figure 2.4). Therefore blue water (A, Station D166) will have greater upwelled light at 443nm (thin solid line) and 555nm (thick solid line) than for a rich station (B, Station D014) because there is a greater amount of PAR at depth. However, even though 443nm light penetrates a water column further, it is absorbed by chlorophyll, thus changing the ratio (thick line) of blue:green wavelengths in the richer station (B, D014) compared with a low biomass station (A, A166). The result is that a "blue" water station looks blue because it has more upwelled radiance in the blue wavelengths than a chlorophyll rich station.

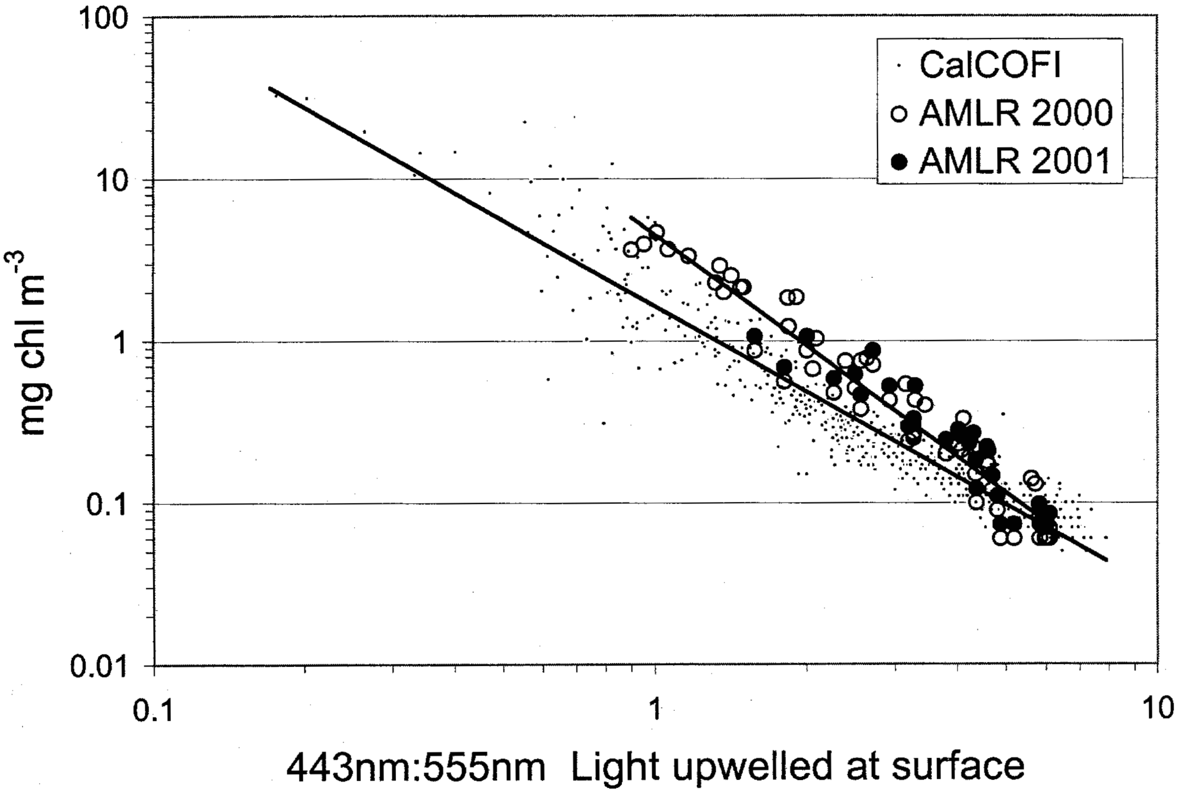

Figure 2.7. The ratio of 443nm to 555nm radiance upwelled at the surface is proportional to the concentration of chlorophyll in the first few meters of the water column. However, samples from the AMLR surveys demonstrate a higher 443:555nm value per unit chlorophyll than samples taken from Californian (CalCOFI) waters and emphasize that algorithms developed to estimate concentrations remotely either from shipboard or satellite need be made specifically for individual regions.

3. Bioacoustic survey; submitted by Jennifer H. Emery (Legs I, II & III), Roger P. Hewitt (Leg I), David A. Demer (Leg II), Andrew Dizon (Leg I), Dale Roberts (Leg II) and Christopher D. Jones (Leg III).

3.1 Objectives: The primary objectives of the bioacoustic survey during Legs I and II were to map the mesoscale 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. The focus of the acoustic program during Leg III was to describe and map the various benthic habitats surrounding the South Shetland Islands.

3.2 Methods and Accomplishments: 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 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. One unit was used for primary system control, data logging, processing with SonarData Echoview software, and archiving while the other logged data for use in seabed classification.

Acoustic surveys of the waters surrounding the South Shetland Islands were conducted on Legs I and II. These surveys were divided into three areas (See Figure 2 in Introduction): (1) a 41,673km^2 area centered on Elephant Island (Elephant Island Area) was sampled with nine north-south transects; (2) a 34,149km^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 8,102km^2 area south of King George Island in the Bransfield Strait (South Area) was sampled with three transects oriented northwest-southwest. Acoustic data were continuously collected during bottom trawling operations throughout Leg III.

Krill Delineation (Legs I & II, Surveys A & D)

Krill densities were estimated using a three-frequency delineation method as opposed to the two-frequency method used in past research (Madureira *et al.*, 1993). This method reduced the inclusion of other euphausiid species and myctophid fish in the biomass estimate. A ΔMVBS (mean volume backscattering strength) window of 2-14db was set as the acceptable difference between the 120kHz and 38kHz data for labeling acoustic targets as krill. However, this preset criteria allowed the inclusion of a small amount of myctophids in the final krill density estimate. Therefore a second ΔMVBS window of 0-5db was established as the acceptable difference between the 200kHz and the 120kHz transducer data in which backscattering values would be attributed to krill. The combined application of these two windows (three-frequency method) eliminated all acoustic targets not classified as Antarctic krill (Figure 3.1). The window ranges were selected based on the observed differences in krill backscattering values between the three frequencies.

Myctophid Delineation (Legs I & II, Surveys A & D)

A ΔMVBS 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 use of the three-frequency method to further delineate myctophids was unnecessary. The two-frequency method sufficiently reduced the acoustic data to include myctophid targets only.

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 the ΔMVBS windows were 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 (500m) and averaged over 1,852.0m (1 nautical mile) distance intervals. These data were processed using SonarData Echoview software.

Integrated krill nautical area scattering coefficient (NASC) 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):

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

Where

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

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 NASC attributed to myctophids was integrated using SonarData Echoview software and then used to map their distribution.

Seabed Classification (Leg III)

Acoustic volume backscattering strength sample data were collected for seabed classification purposes. This data was analyzed using Questar Tangent Corporation (QTC) Impact software.

A series of algorithms were applied to the data in order to generate values that are descriptive of each echo. A Principal Components Analysis (PCA) reduced this data further into three primary dimensions. Next, a series of cluster analyses were performed in order to establish a statistical classification scheme descriptive of the seabed found around the South Shetland Islands. Once these classes were formed, a statistical catalogue was created for use in describing future datasets. In order to confirm these classes, two means of ground truthing were conducted: a camera mounted bottom grab sampler and a towed body (NEPTUN) equipped with an underwater video system. Digitized images were also retained for further comparisons. Grab samples and NEPTUN transects were positioned at or near trawl stations with pre-classified bottom characteristics (Figure 3.2). A total of twelve bottom grabs and seven NEPTUN launches were successfully completed. Size class categories for sediment samples were based on those described by Greene *et al.*, (1999). Sediment types and sizes were defined as follows: mud/silt (<0.06mm), sand (0.06-2mm), gravel (2-4mm), pebble (4-64mm), cobble (64-250mm), and boulder (>250mm).

3.3 Tentative Conclusions:

Leg I (Survey A)

During Survey A, high abundances of krill were observed along the shelf break north of Livingston and King George Islands, with the first two northwestern transects exhibiting the highest krill densities (Figure 3.3). Krill was also abundant to the northwest and northeast of Elephant Island, and along the westernmost transect in the Bransfield Strait. Krill densities were calculated to be 16.98, 15.57, and 12.64g/m^2 for the West, Elephant Island, and South Areas respectively (Table 3.1). Total biomass for the entire survey area was 15.86g/m^2.

Comparisons in abundance estimates between the two-frequency and three-frequency methods were made (Table 3.2). It is possible that the two-frequency method allows the inclusion of a minor amount of myctophids, whereas the three-frequency method eliminates all fish, but might also exclude a small amount of krill. The three-frequency method was used during this survey in order to prevent overestimation. Re-analysis of historic data is proposed in order to make proper time scale comparisons.

The distribution of mean NASC of myctophids was mapped and found to be highest along the 2000m isobath (Figure 3.4). More specifically, areas of greater abundance were observed northwest of Livingston Island, north of King George Island, west and northwest of Elephant Island. There appears to be no correlation between locations of myctophids and krill, with a tendency for myctophids to be found slightly further offshore than krill.

Leg II (Survey D)

A shift in the locations of high krill density areas was observed for Survey D. The highest abundance of krill was mapped in the center transect of the West Area just north of Greenwich and Robert Islands at the shelf break (Figure 3.3). Other areas containing elevated krill abundance were northeast of Elephant Island and east of Clarence Island. Densities were calculated as 16.26, 12.77, and 9.59g/m^2 for the West, Elephant Island, and South Areas based on the three-frequency method.

Myctophid NASC distribution remained similar to that observed during Survey A, most abundant near the 2000m isobath. However, overall NASC was less than that observed during Survey A.

Leg III (Seabed Classification)

Preliminary analysis of the Sample S_v acoustic bottom data yielded seven statistically significant classes. These classes were sampled repeatedly with both bottom grabs and NEPTUN video tows in order to verify these conclusions. Seabed class descriptions were based on images and sediment samples resulting from the ground truthing methods. Most samples were mixtures of sediments varying from silt, mud, dense clay, sand, gravel, pebble, cobble, and boulder (Table 3.3). Section 5 "Bottom Trawl Survey and Finfish Research in the South Shetland Islands" presents a description of low- and high-density finfish habitats. Future analyses are planned to describe the entire bottom habitat surrounding the South Shetland Islands based on data collected during this survey.

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 10MB. Seabed classified datasets consume approximately 75MB. 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 or Jennifer.Emery@noaa.gov.

3.5 References:

Greene, G.H., Yoklavich, M.M., Starr, R.M., O'Connell, V.M., Wakefield, W.W., Sullivan, D.E., McRea Jr., J.E., and Cailliet, G.M. 1999. A classification scheme for deep seafloor habitats. *Oceanologica Acta* 22: 663-678.

Hewitt, R.P., and Demer, D.A. 1993. Dispersion and abundance of Antarctic krill in the vicinity of Elephant Island in the 1992 austral summer. *Marine Ecology Progress Series* 99: 29-39.

Jolly, G.M., and Hampton, I. 1990. A stratified random transect design for acoustic surveys of fish stocks. *Canadian Journal of Fisheries and Aquatic Science* 47: 1282-1291.

Maduriera, L.S.P., Ward, P., and Atkinson, A. 1993. Differences in backscattering strength determined at 120 and 38kHz for three species of Antarctic macroplankton. *Marine Ecology Progress Series* 99: 17-24.

Table 3.1. Mean krill biomass density for surveys conducted from 1992 to 2001. 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 2 in the Introduction Section for a description of each survey.

*Data values are based on the two-frequency krill delineation method.
†Data values are based on the three-frequency krill delineation method.
All other density measurements within this table are based on total volume backscatter.

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
2001 A (late January)	West	16.98†	34,149	580	22.5
	Elephant Island	15.57†	41,673	649	13.9
	South	12.64†	8,102	102384.57	22.2
D (late February)	West	16.26†	34,149	555	33.9
	Elephant Island	12.77†	41,673	532	11.6
	South	9.59†	8,102	77,695	40.1

Table 3.2. Two- and Three-frequency krill density estimates by area and transect for Survey A, Leg I.

Elephant Island Area			
		2-Frequency method	3-Frequency method
	n	krill density	krill density
Transect 1	111	18.96	12.03
Transect 2	116	19.51	11.51
Transect 3	103	8.96	4.36
Transect 4	114	23.33	13.14
Transect 5	123	42.44	24.90
Transect 6	134	35.42	20.26
Transect 7	118	43.94	23.04
Transect 8	112	29.52	16.88
Transect 9	116	20.57	11.18

South Area			
		2-Frequency method	3-Frequency method
	n	krill density	krill density
Transect 1	42	22.04	12.34
Transect 2	42	29.89	17.20
Transect 3	24	14.17	5.17

West Area			
		2-Frequency method	3-Frequency method
	n	krill density	krill density
Transect 1	44	45.21	36.93
Transect 2	45	42.96	32.23
Transect 3	71	30.27	24.19
Transect 4	68	7.20	5.42
Transect 5	88	19.03	14.49
Transect 6	95	18.77	15.82
Transect 7	88	7.34	6.04

	Seabed Class						
Sediment Type	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Boulder (>250mm)							X
Cobble (64-250mm)						X	X
Pebble (4-64mm)					X	X	
Gravel (2-4mm)					X	X	
Sand (0.06-2mm)				X	X	X	
Mud (<0.06mm/dense)	X	X		X	X		
Silt (<0.06mm/thin)	X		X				
Comments	soft muddy bottom mixed with silt	densely packed clay/mud with rock-like structure	hard bottom covered in very fine, runny silt	hard mud bottom topped by dense rippled sand layer	hard bottom topped by mix of above sediments	similar to class 5, but no mud (very hard substrate)	very hard, rough bottom

Table 3.3. Seabed classes in the vicinity of the South Shetland Islands based on grab samples and NEPTUN images.

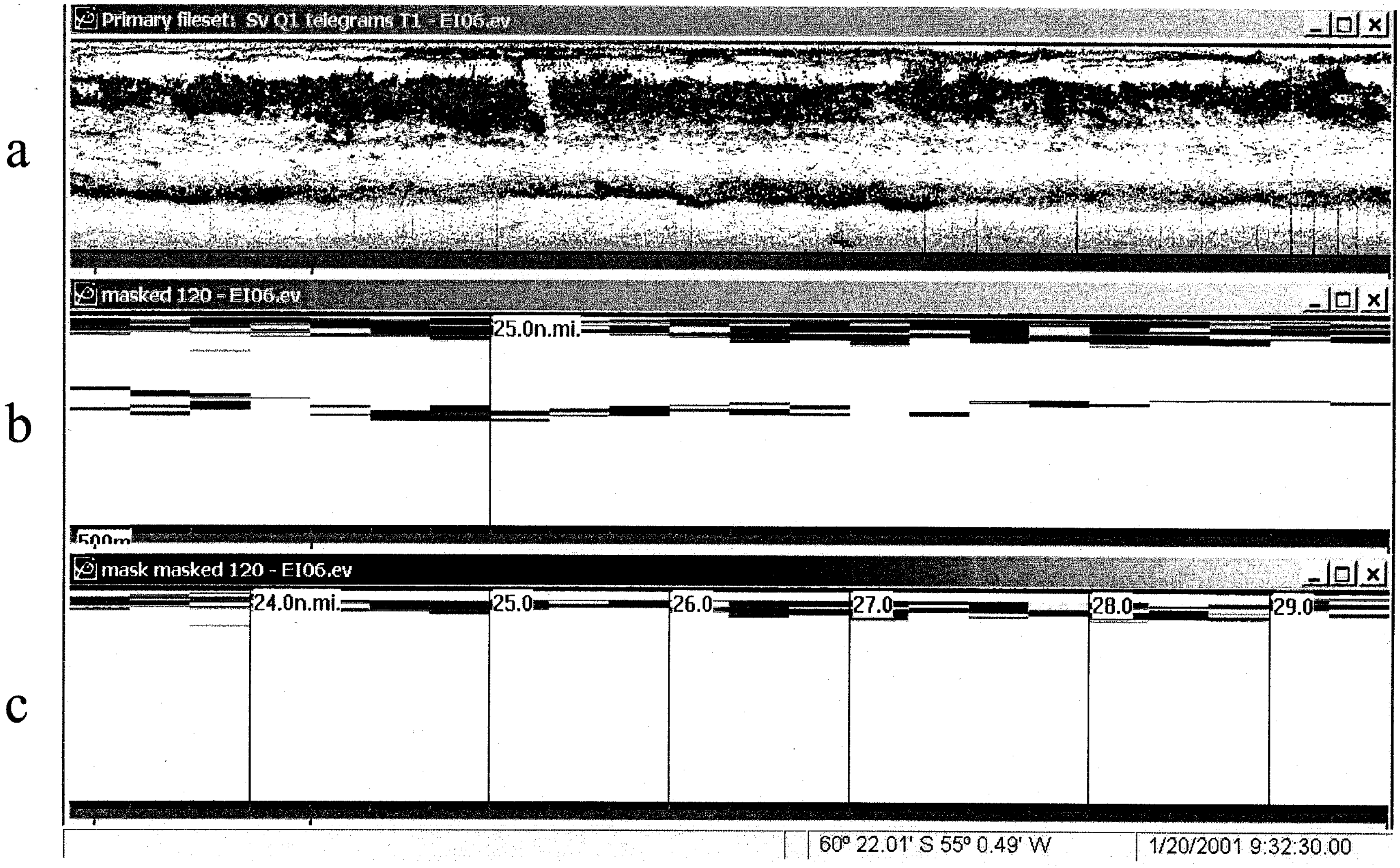

Figure 3.1. Echograms representing the three-frequency method of krill delineation. (a) Original echogram including all backscattering layers. (b) Resampled echogram with noise reduction and application of 2-16db window (120-38kHz) with remnants of fish. (c) Echogram b with the 0-5db window (200-120kHz) applied, showing krill surface layer only.

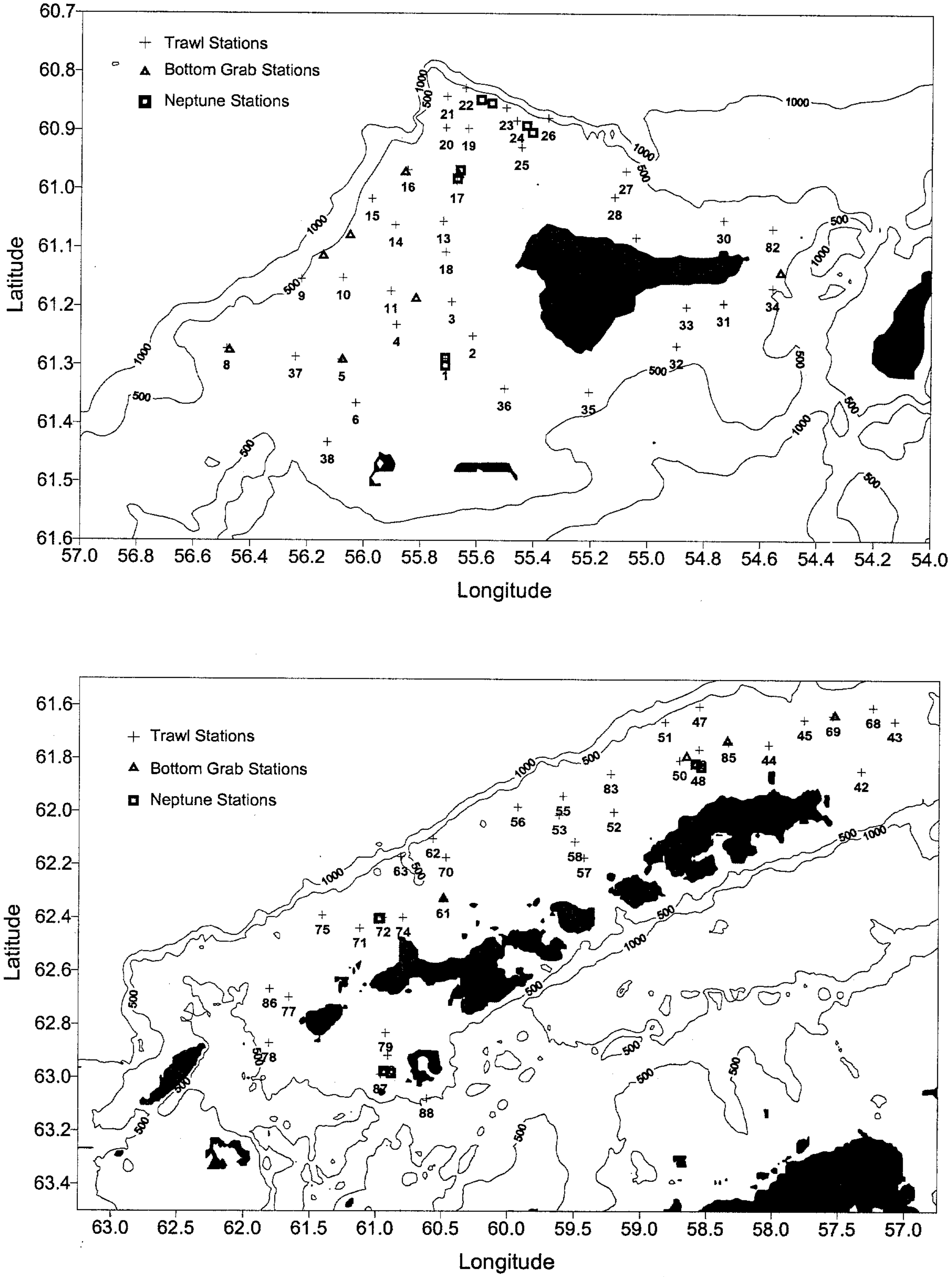

Figure 3.2. Bottom grab and NEPTUN tow positions in relation to trawl stations during Leg III. Longitude is West and latitude is South.

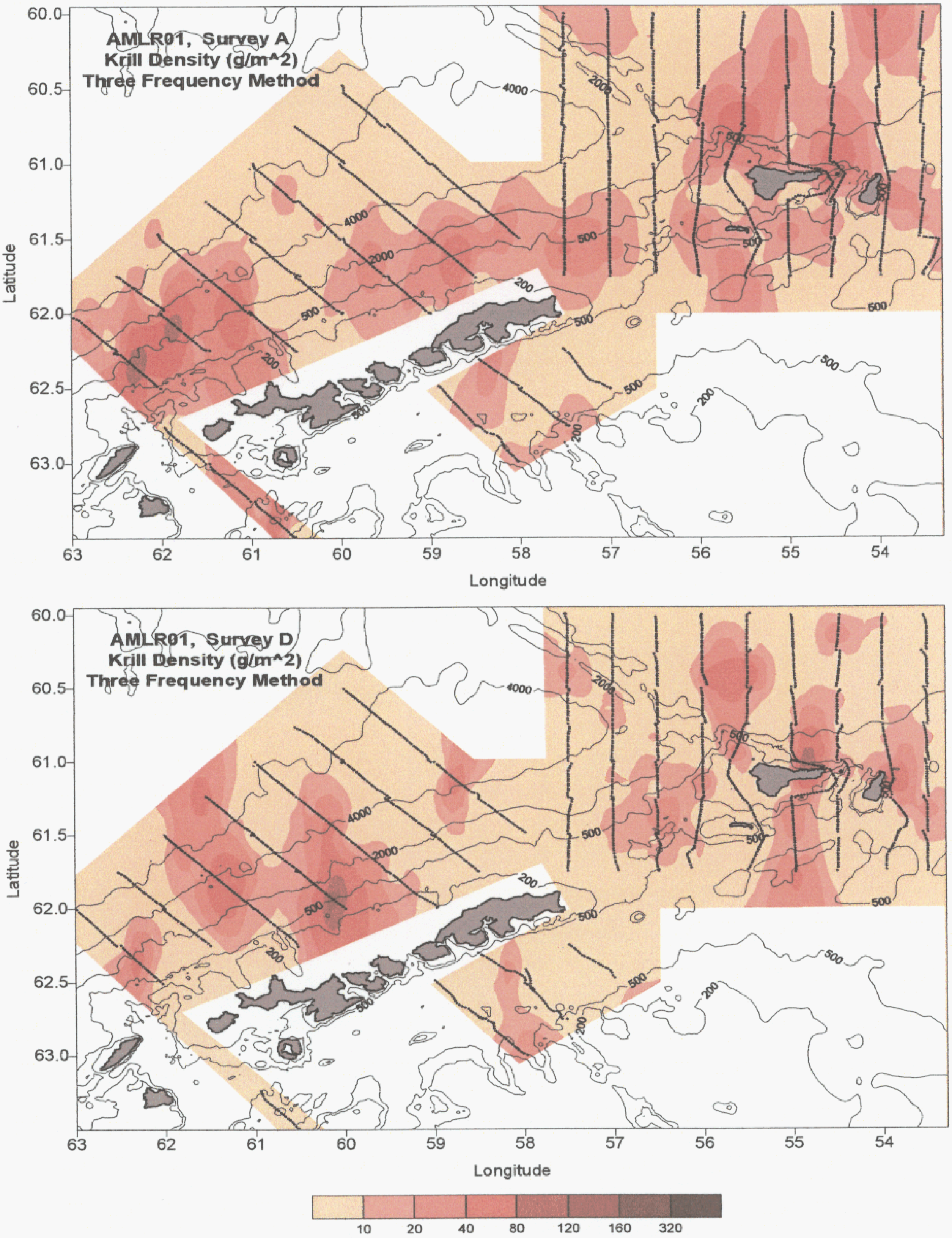

Figure 3.3. Mean krill density (g/m^2) for Surveys A and D at 120kHz as determined using the three-frequency classification method. Longitude is West and latitude is South.

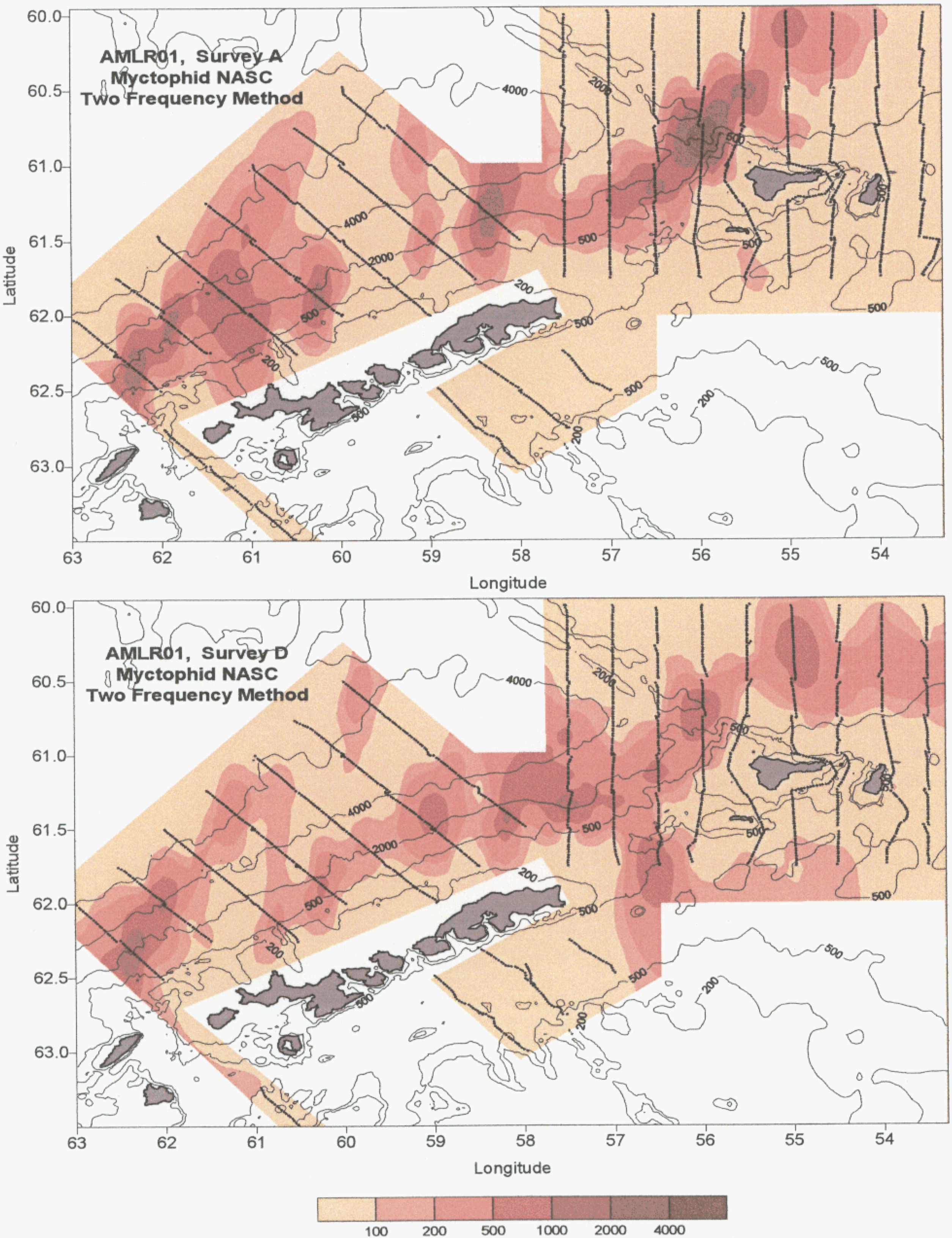

Figure 3.4. Integrated nautical are scattering coefficient (NASC, m^2/n.mile^2) for myctophids during Surveys A and D at 120kHz as determined by the two-frequency method. Longitude is West and latitude is South.

4. Net sampling: Krill and zooplankton; submitted by Valerie Loeb (Legs I & II), Jenna Borberg (Leg I), Kit Clark (Legs I & II), Michael Force (Legs I & II), Nancy Gong (Leg II), Kate Harps (Leg II), Adam Jenkins (Legs I & II), Jessica D. Lipsky (Legs I & II) and Rob Rowley (Legs I & II).

4.1 Objectives: Objectives were to provide information on the demographic structure of Antarctic krill (*Euphausia superba*) and abundance and distribution of salps and other zooplankton taxa in the vicinity of Elephant, King George and Livingston Islands. Essential krill demographic information includes length, sex ratio, maturity stage composition and reproductive condition. Information useful for determining the relationships between krill and zooplankton distribution patterns and ambient environmental conditions was derived from net samples taken at established CTD/phytoplankton stations. The salp *Salpa thompsoni* and copepod species receive special attention because their interannual abundance variations may reveal underlying hydrographic processes influencing the Antarctic Peninsula ecosystem. Results are compared to those from previous AMLR surveys to assess between-year differences in krill demography and zooplankton composition and abundance over the 1992-2001 period. Additional historical data from the Elephant Island area are used to examine copepod species abundance and abundance relations between 1981 and present.

4.2 Methods and Accomplishments:

4.2.1 Large-Area 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 General Oceanics flow meter 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. Tow depths were telemetered from a depth recorder mounted on the trawl bridle. Tow speeds were ca. 2kts. Samples were collected at Large-Area survey stations during both cruise legs (See Figure 2 in Introduction). Three regionally distinct groups of stations are considered here (Figs. 4.1A & B). 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 length composition of krill stocks to predator populations at Cape Shirreff and to the krill fishery that operates in this area during austral 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.

4.2.2 Shipboard Analyses

All samples were processed on board. Krill demographic analyses were made using fresh or freshly frozen specimens. Other zooplankton analyses were made using fresh material within 2 hours of sample collection. Abundance estimates of krill, salps, and other taxa are expressed as numbers 1,000m^{-3} water filtered. Abundance information is presented for the Elephant Island, West and South Areas, and for the total survey area.

(A) Krill. Krill were removed and counted prior to processing other samples. 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).

(B) 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 $\leq$100 individuals, the two life stages (aggregate/sexual and solitary/asexual) were enumerated and internal body length (Foxton, 1966) was measured to the nearest mm. Representative subsamples of $\geq$100 individuals were analyzed in the same manner for larger catches.

(C) Fish. All adult myctophids were removed, identified, measured to the nearest millimeter, standard length, and frozen.

(D) Zooplankton. After krill, salps, and adult fish were removed the remaining zooplankton fraction was analyzed. All of the larger organisms (e.g., other postlarval euphausiids, amphipods, pteropods, polychaetes) were sorted, identified to species if possible, and enumerated. Following this the samples were aliquoted and smaller zooplankton (e.g., copepods, chaetognaths, euphausiid larvae) in three or four subsamples were enumerated and identified to species if possible using dissecting microscopes. After analysis the zooplankton samples (without salps and adult fish) were preserved in 10% buffered formalin for long-term storage.

4.2.3 Statistical Analyses

Data from the total survey area and three subareas were analyzed for between-cruise and between-year comparisons. Analyses included a variety of parametric and nonparametric techniques. Among these were Analysis of Variance (ANOVA), Cluster Analysis, Percent Similarity Indices (PSIs) and Kolmogorov-Smirnov cumulative percent curve comparisons (D_{max}). Cluster analyses uses were Euclidean distance and Ward's linkage methods; clusters were distinguished by a distance of 0.40 to 0.60. Clusters based on size characteristics utilized proportional length-frequency distributions in each sample with at least 17 krill or 80 salps. Zooplankton clusters were based on log transformed sample abundance data for the most frequently occurring taxa; because of their uniformly high abundance across the survey area salps were omitted from the initial analysis, but were included in cluster comparisons.

4.3 Results and Preliminary Conclusions:

4.3.1 Survey A, 18-30 January 2001

4.3.1.1 Krill:

Krill Abundance (Table 4.1A, Figure 4.1A)

Postlarval krill were present at 90 of the 101 survey stations (89%). They were most frequent and abundant in the South Area where they occurred in all 11 samples and had 116 1,000m^{-3} (+/-

331) mean and 22.5 1,000m^{-3} median abundance values. Significantly lower concentrations (ANOVA, P<0.01) were represented in samples from the Elephant Island and West Areas, which had respective mean values of 20.7 and 12.8 1,000m^{-3} and medians of 6.0 and 2.3 1,000m^{-3}.

Length Composition (Figures 4.2A-D)

Krill lengths ranged from 18-61mm; the overall size-frequency distribution was bimodal with peaks around 28-30mm and 50-52mm. Approximately 30% of total krill were ≤35mm (1+ age class), 10% were 35-42mm (2+) and 60% were >42mm (3+). Length-frequency distributions in the three subareas differed greatly. The large South Area catches were comprised of individuals primarily ≤35mm (65%) and secondarily ≥45mm (25%). In contrast, 92% of krill collected in the West Area were >45mm in length. Although clearly dominated by krill >45mm long (70%) the Elephant Island samples also contained modest proportions of 35-45mm (20%) and <35mm (10%) length categories.

Maturity Stage Composition (Table 4.2; Figures 4.3A-D)

Overall and subarea maturity stage composition was in accord with length-frequency distribution. The overall composition was represented primarily by mature (64%) and juvenile (26%) stages. Juveniles (63%) plus immature stages (20%) dominated the South; here small immature stage 2a males made up 14% of the total catch. These individuals represent the 1999/00 year class. Virtually all of the West Area krill were mature. Mature forms dominated the Elephant Island Area (84%) with small contributions by juveniles (10%) and immature (6%) stages. Males outnumbered females by 80% in the South, 60% in the West and 40% in the Elephant Island Areas. Over 91% of mature females in the West area were in advanced maturity stages (i.e., with developing ovaries [3c], gravid [3d] or spent [3e]) compared to 50% in the South and 59% in the Elephant Island Areas.

Distribution Patterns (Figures 4.4A, 4.5A & B)

Cluster analysis, performed on krill lengths in samples with ≥17 individuals, yielded three groups. Although median and modal lengths were relatively large and similar to one another (42mm and 47mm, Cluster 1; both 49mm, Cluster 2; both 52mm, Cluster 3) the clusters differed in overall length and maturity characteristics. Cluster 1 contained the broadest size range (18-56mm) and relatively large proportions of individuals <40mm. Accordingly, the mixed maturity stage composition included 27% juvenile, 14% immature and 59% mature stages. This cluster was represented at 13 stations in Bransfield Strait and east of Elephant Island. Cluster 2 lengths ranged from 23-58mm, with greatest representation by 45-55mm individuals. Juvenile and immature stages contributed 2% and 6%, respectively, and mature forms (predominantly males) 92% of the total; 66% of the mature females were in advanced maturity stages. This group was represented at 22 stations offshore of Cluster 1. Cluster 3 included lengths of 26-61mm, but was predominantly composed of mature forms >50mm. These krill were collected at 14 stations primarily north of Livingston and King George Islands. Here 60% of females were gravid; these comprised 26% of total krill suggesting active spawning in this area.

4.3.1.2 *Salpa thompsoni:*

Salp Abundance (Table 4.1A; Figure 4.6A)

Salps were collected at all 101 survey stations, with between 21 and 5,780 individuals per sample (8.4 to 2,222 1,000m^{-3}). Overall mean, standard deviation and median abundance values of 506 1,000m^{-3} (+/- 441) and 383 1,000m^{-3} reflect uniformly high salp concentrations across the entire survey area. Salps were least abundant in the South Area (281 1,000m^{-3} mean, 160 1,000m^{-3} median) and most abundant in the Elephant Island Area (599 1,000m^{-3} mean, 449 1,000m^{-3} median). Salp abundance in the West Area was significantly lower than in the Elephant Island Area (ANOVA, $P<0.05$).

Maturity Stages, Size and Age (Figures 4.7A, C & D)

The aggregate (sexual) stage made up 97% and overwintering solitary stage 3% of total individuals collected. Solitary stage salps were relatively most abundant in the West (4%) followed by Elephant Island (2.5%) and South (0.4%) Areas. Over 75% of these solitaries were $\leq$20mm in length and therefore resulted from recent spawning by the aggregates. Aggregate lengths ranged from 4-66mm, but individuals >54mm were scarce; the modal length was 28mm. Given these length attributes and an estimated growth rate of 0.44mm day^{-1} (Loeb *et al.*, in press), seasonal aggregate chain production would have begun in mid-September, become continuous by early October and peaked in late November. Aggregate length-frequency distributions within the subareas differed somewhat. Smallest salps were in the South Area where the median length was 15mm and 80% of individuals were <25mm in length. Somewhat larger aggregates were in the Elephant Island Area where 50% were $\leq$25mm. Largest aggregates were in the West Area where only 35% were <25mm and the median length was 30mm. Kolmogorov-Smirnov test comparisons of salp length distributions indicate that those of the South Area were significantly smaller than those in the West Area ($D_{max}=55.0$, $P<0.05$).

Cluster analysis of salp length composition at each station resulted in three groupings, which had overlapping size distributions, but distinctly different median and modal lengths. These groupings showed no coherent or meaningful distribution pattern across the survey area and thus do not warrant further analysis.

4.3.2.3 Zooplankton and Micronekton Assemblage:

Overall Composition and Abundance (Tables 4.3 & 4.4A; Figures 4.8A & B, 4.9A & B)

A total of 71 taxonomic categories (including copepod species) were identified in the 101 survey samples; on average 21 taxa were collected at each station. Copepods and *S. thompsoni* were present in all samples. Copepods numerically dominated the catch (mean and median abundance 2,247 and 565 1,000m^{-3}, respectively) and contributed 59% of total mean zooplankton abundance. The copepod assemblage was dominated by three species: *Calanoides acutus*, an "Oceanic" species, constituted 48%; *Metridia gerlachei*, a "Coastal" form associated with Gerlache Strait water influence, 33%; *Calanus propinquus,* another Oceanic form, contributed

6% of the total. The Oceanic and Gerlache Strait sources of dominant species are seen in the overall copepod abundance pattern. Second ranked salps constituted ca. 14% of the total. Although present in only 85% of samples, *Thysanoessa macrura* larvae ranked third in abundance and contributed 12% of the mean. Other relatively abundant taxa included chaetognaths (4.6%), larval krill (4%) and postlarval *T. macrura* (2%). Frequently collected but less abundant taxa included salp-associated amphipods *Vibilia antarctica* and *Cyllopus lucasii* (98% and 87% of samples, respectively) and postlarval krill.

All krill larvae were calyptopis stages. Calyptopis stage 2 (C2) was most abundant (66%) followed by C1 (24%) and C3 (10%). Total larval abundance and abundance of more advanced stages increased over the survey period. Significantly higher concentrations ($P<0.05$) and greater proportions of C2 vs. C1 larvae occurred in the West vs. Elephant Island Area. Krill larvae were most abundant offshore of the island shelf areas; they were absent in southern Bransfield Strait and an extensive region extending northward across the Elephant Island Area. These larvae probably resulted from spawning activity 3-5 weeks earlier (i.e., early- to mid-December, 2000; Ross and Quetin, 1989) and are indicative of a normal spawning season. Larval *T. macrura* also had significantly greater concentrations in the West vs. Elephant Island Area ($P<0.05$) while the postlarvae had greatest concentrations in the South Area ($P<0.01$ for both the West and Elephant Island Areas). As during previous years larval and postlarval *T. macrura* had diametrically opposed distributions, with larvae largely concentrated offshore of the island shelves and postlarvae largely over the shelves and within Bransfield Strait.

Distribution Patterns (Table 4.5A; Figure 4.10A)

Cluster analysis, applied to the abundance [Log (N+1)] of 26 taxonomic categories, present in ≥20% of the samples, was used to identify three groups. Although these taxa were common to all three clusters, they demonstrated different absolute and relative abundance relationships across the survey area. Cluster 3, present at 29 stations, had greatest overall zooplankton abundance. Copepods (primarily *Calanoides acutus, Metridia gerlachei* and "other species"), larval *T. macrura,* chaetognaths and larval krill numerically dominated here (87% of total mean abundance). Fifth-rank *S. thompsoni* contributed only 7% of total abundance. Concentrations of *C. acutus,* chaetognaths, larval krill and *Spongiobranchaea australis* here were significantly larger than in Cluster 2 (ANOVA, $P<0.05$), while those of *C. propinquus,* "other copepods", larval *T. macrura* and *Cyllopus lucasii* were significantly larger than in Clusters 1 and 2 ($P<0.01$). This typically oceanic species assemblage occurred north of Livingston and King George Islands and in the west Elephant Island Area. Total mean abundance of Cluster 1 was 39% that of Cluster 3. Cluster 1 was located at 24 stations most of which were within or adjacent to Bransfield Strait and represented a Coastal species assemblage. *Metridia gerlachei* alone comprised 53% of total mean abundance and, along with *S. thompsoni* and postlarval *T. macrura,* accounted for 75%. Concentrations of *M. gerlachei, T. macrura, Euphausia frigida* and *Diphyes antarctica* here were significantly greater than in Clusters 2 and 3 ($P<0.05$). Cluster 2 was characterized by lowest total zooplankton abundance and dominance by *S. thompsoni.* Although their concentrations were similar in the three clusters, salps contributed 48% of total mean zooplankton abundance here due to relatively low numbers of other taxa. This cluster occurred at 48 stations most of which were south of King George and in the south, east and northwest Elephant Island Area.

Diel Abundance Differences

Various species had diel abundance differences due to vertical migrations into the upper 175m at night. Significantly greater night vs. day abundance occurred for *S. thompsoni, E. frigida,* ostracods (ANOVA, $P<0.01$) and the copepod *Pleuromama robusta* ($P<0.05$). Night abundance of *M. gerlachei* was significantly greater than during day ($P<0.01$) and twilight ($P<0.05$).

4.3.2.4 Survey A, Between-Year Comparisons:

Krill (Tables 4.6, 4.7A, 4.8A & 4.9A)

Within the 1992-2001 AMLR data set, mean and median krill abundance values in the Elephant Island Area were intermediate to a high in 1996 (82 and 11 1,000m^{-3}) and a low in 1999 (5.3 and 1.7 1,00m^{-3}) and most similar to those of January 1992. Since juveniles comprised ca. 10% of krill here, increased abundance relative to 1999 resulted in part from recruitment (i.e., the 1999/00 year class). Moderate recruitment success of the 1999/00 year class was also supported by dense concentrations and large proportions of juveniles (63%) in the South Area (Table 4.2). Relatively high krill carbon biomass values during January 2001 were most similar to the mean in 1995 (242 1,000m^{-3}) and median in 1996 (72 1,000m^{-3}).

During January 2001, 58% of mature females in the Elephant Island Area were in advanced reproductive stages; most of these were undergoing ovarian development (3c). This value is intermediate to high in 1995, 1996 and 1999 (93-98% advanced stages) and low in 1993 and 1998 (6-20%) suggesting that spawning in the Elephant Island Area may have been somewhat delayed in 2001. Krill larvae were uniformly distributed across the west Elephant Island Area, as indicated by a relatively high median abundance value (9 1,000m^{-3}), but their concentrations were low relative to those in 1995 and 1999 (mean of 33 1,000m^{-3} vs. ca. 175 1,000m^{-3}). When the entire survey area is considered, frequency of occurrence and mean abundance of krill larvae rivaled the high values of 1995 and 1999 (Table 4.9A).

Salps (Tables 4.6 & 4.8A; Figure 4.11F)

While mean salp abundance in the Elephant Island Area was modest relative to the highs of January 1993, 1994 and 1998 (932-1,213 1,000m^{-3}) the median value was second only to that during 1994 and reflected widespread distribution of large numbers of aggregates. Extremely large concentrations like those of the 1993 and 1998 salp years were not encountered. Overall aggregate size distribution, with a continuous length range of 4-54mm, was compressed relative to most other years. The length-frequency composition was most similar to those of January 1994 and 1998 (D_{max} = 14.4 and 13.1, respectively) and reflects a relatively short but productive growing season.

Zooplankton Assemblage (Tables 4.5A, 4.6, 4.9A, 4.10A & 4.11A)

Noting the absence of 2000 data, mean copepod abundance in the Survey A area was the highest observed over the 1994-2001 period. This resulted from large concentrations of *C. acutus, M. gerlachei, C. propinquus* and other copepod species offshore (Cluster 3) and of *M. gerlachei* inshore (Cluster 1). As during all January surveys except 1994 and 1998, copepods numerically dominated the Elephant Island zooplankton assemblage. Mean copepod abundance here was slightly greater than values observed in January 1995, 1996, 1997 and 1999, but the lower median value reflected a less uniform distribution in 2001. As during January 1997 and 1999 *S. thompsoni* ranked second in abundance, but salp contribution to the Elephant Island Area assemblage in 2001 was greater than in those years (29% total mean vs. 12-18%). Mean and median values of third ranked *T. macrura* larvae were comparable with the highs observed in January 1996. Chaetognaths, postlarval *T. macrura* and krill larvae followed in mean abundance. January 2001 mean and median abundance values of chaetognaths were slightly lower than in 1995 and 1999 while those of *T. macrura* were exceeded by 1995-1998 values. Although larval krill mean abundance was modest relative to values in 1995 and 1999, the median value was the highest so far recorded. Abundance of only two species was significantly different from previous January-February surveys: that of *Cyllopus lucasii* was the highest recorded while that of *Vibilia antarctica* was higher than in 1995, 1996, 1997 and 1999 (ANOVA, $P<0.01$ in all cases). The salp *Ihlea racovitzai* had the lowest frequency of occurrence and abundance since it was first noted in 1998.

Overall taxonomic composition of the Elephant Island Area zooplankton assemblage in January 2001 was similar to that in 1997 and 1999 as indicated by PSI values of ca. 75. It differed from that during salp dominated 1994 and 1998 (PSIs ca. 40)

4.3.2 Survey D, 12 February-12 March 2001

4.3.2.1 Krill:

Krill Abundance (Table 4.1B, Figure 4.1B)

Krill were present in 76 of 96 Survey D samples (79%). They were comparatively rare in the South Area, where they occurred in only 5 of 10 samples and had respective mean and median abundance values of 3.3 and 0.3 1,000m^{-3}. Median krill abundance was an order of magnitude larger and similar in the West and Elephant Island Areas (5.2 and 4.9 1,000m^{-3}), respectively. The largest catch (7,336 individuals, 2,817 1,000m^{-3}) occurred over the shelf break northwest of Elephant Island. Other relatively large catches (275-1,344 individuals, 118-431 1,000m^{-3}) occurred over the shelf north of Livingston and King George Islands and primarily offshore of Elephant Island. Predominantly small catches were made in Bransfield Strait.

Length Composition (Figures 4.12A-D)

Krill lengths ranged from 20 to 60mm. The overall length distribution was polymodal with peaks around 26-27mm, 32-35mm, 44-45mm and 47-50mm, however 80% of individuals were >40mm and 50% >46mm in length. This polymodal size distribution also characterized krill collected within the Elephant Island Area; here krill <33mm (i.e., 1 year old) comprised 11% of the total. Primarily larger krill occurred in the other areas. In the West Area, 8% of individuals were <41mm and 50% were 49-59mm while in the South Area 92% were 45-57mm in length.

Maturity Stage Composition (Table 4.2B; Figures 4.13A-D)

Overall maturity composition included predominantly mature (74%) followed by immature (14%) and juvenile (12%) stages. This composition was also characteristic of the Elephant Island Area where juveniles contributed 13%, immature forms 15% and mature stages 72% of the catch. Here females outnumbered males by 30%; 92% of the females were in advanced reproductive stages and spent individuals (3e) comprised 43% of the total. Juveniles were minor constituents in the West (4%) and South (3%) Areas. In the West Area, males outnumbered females by 50%. Relatively large proportions of stage 3c-e females in the West Area suggests ongoing spawning activity there during mid-February.

Distribution Patterns (Figures 4.4B, 4.14A & B)

Cluster analysis of krill length-frequency distributions in 36 samples with $\geq$17 specimens yielded two groups. Cluster 1 krill included various size modes (25-26mm, 32mm and 45mm) and had median and modal lengths of 45mm and 48mm, respectively. Juveniles and immature stages each comprised 15% of the total. Males and females were equally represented. Relatively large proportions of spent (3e) females and immature males (2b-c) suggest that this was largely an aggregation of post-reproductive adults (3+) and younger year classes. This cluster occurred at 17 stations over the South Shetland Island shelf and south of the frontal zone extending across the Elephant Island Area. Cluster 2 included few krill <40mm, and only 6% were <45mm; median and modal length was 50mm. Juveniles were virtually absent and immature stages made up only 4%. Males outnumbered females by 2.4:1 and reproductive males comprised 61% of the total. Most of the females were reproductively active (73% stage 3c-d) and 24% were spent. This group was primarily represented in oceanic water offshore of the South Shetlands and northwest of Elephant Island.

4.3.2.2 *Salpa thompsoni:*

Salp Abundance (Table 4.1B; Figure 4.6B)

Salps were present in all samples with numbers of 38-7,690 per tow (16-2,420 1,000m^{-3}). Overall mean and median concentrations were, respectively, 391 and 270 1,000m^{-3}. Greatest concentrations (>1,000m^{-3}) were in the eastern half of the Elephant Island Area and south of King George Island. Mean and median abundance values in the West Area (249 and 198 1,000m^{-3}) were ca. 40% lower than in the other two areas.

Maturity Stages, Size and Age (Figures 4.7B-D)

Overall, aggregate forms made up 94% of individuals. Solitary forms were relatively more abundant in the West (9%) vs. Elephant Island (6%) and South (3%) Areas. Aggregate lengths ranged from 4 to 76mm, but 95% were $\leq$40mm and median length was 30mm. Median length was also 30mm in the West and Elephant Island Areas but 27mm in the South Area. Based on a growth rate of 0.44mm day^{-1} these salps were budded ca. 2 months prior to sampling in those areas (i.e., mid- to late December). Solitary lengths ranged from 4 to 117mm. Relatively small proportions of salps <20mm reflect negligible production over the past 5 weeks. Cluster analysis provided three groups with slightly different length-frequency distributions. These were characterized by median lengths of 26, 30 and 34mm and relatively few individuals >40mm (2%, 3% and 8%, respectively). As with Survey A, these groups did not demonstrate any coherent or meaningful spatial distribution patterns.

4.3.3.3 Zooplankton:

Overall Composition and Abundance (Tables 4.3 & 4.4B; Figures 4.8C, D & 4.9C, D)

The 96 Survey D samples contained 83 taxa, including nine copepod categories; the mean was 21 per sample. Copepods were present in all but one sample and were again numerically dominant (mean and median abundance, respectively, 5,916 and 1,416 1,000m^{-3}) and comprised >66% of total mean zooplankton abundance. The abundance relations of dominant species were similar to Survey A: *C. acutus* constituted >65% of mean copepod abundance, followed by *M. gerlachei* (25%), *C. propinquus* (4%) and unidentified copepodites (2%). The Oceanic and Coastal sources of these species again are obvious in the distribution patterns.

Larval stages of *T. macrura* and krill were second and third in mean abundance, and each contributed ca. 8% of the total. Median abundance of *T. macrura* larvae was an order of magnitude larger than that of krill larvae (210 vs. 10 1,000m^{-3}) resulting from a more uniform distribution. Both had greatest abundance in offshore waters. Most krill larvae were calyptopis stages. Overall C1 were most abundant (57%) followed by C2 (30%) and C3 (11%). This stage composition also characterized the West Area. Within the Elephant Island Area C2 larvae were most abundant (36%), followed by C1 (33%), C3 (18%) and stage 1 Furcilia larvae (8%). Small catches in the South Area were dominated by C3 larvae (67%). Postlarval *T. macrura* ranked fourth in abundance and contributed 7% to the mean; it was most abundant within and adjacent to Bransfield Strait. Salps were the most frequent taxon, present in all samples, but contributed slightly more than 4% of summed mean abundance (rank 5); median salp abundance (275 1,000m^{-3}) was exceeded only by copepods (1,416 1,000m^{-3}). Salp-associates, *V. antarctica* and *C. lucasii*, were present in >97% of samples.

Distribution Patterns (Table 4.5B; Figure 4.10B)

Cluster analysis resulted in three zooplankton groups. Cluster 3 was present at 27 offshore stations and had the largest summed mean abundance. Concentrations of *C. propinquus, C. acutus, R. gigas,* copepodites and other copepods, chaetognaths, larval *T. macrura*, the pteropod *Spongiobranchaea australis* and amphipod *Primno macropa* were significantly greater (ANOVA, $P \leq 0.01$) than in Clusters 1 and 2. Cluster 3 concentrations of *S. thompsoni* were significantly smaller than in Clusters 1 and 2 ($P<0.05$). Total mean abundance of Cluster 1 was ca. 50% smaller than that of Oceanic Cluster 3. This group was dominated by *M. gerlachei* and postlarval *T. macrura*, which, respectively, contributed 49% and 25% of mean abundance. Cluster 1 concentrations of *M. gerlachei, Pareuchaeta antarctica* and *E. frigida* were significantly larger than in Clusters 2 and 3 ($P<0.01$). This Coastal species assemblage occurred at scattered locations across the survey area; it was spatially most cohesive north and northeast of Elephant Island. Cluster 2 was characterized by low overall zooplankton abundance and numerical dominance by salps (36% of total mean abidance) and larval *T. macrura* (25%). This sparse assemblage occurred at 42 stations generally over island shelf areas and in Bransfield Strait.

Diel Abundance Differences

Various species had diel abundance differences due to vertical migrations into the upper 175m at night. During February-March, significantly greater night vs. day abundance occurred for three copepod species, *M. gerlachei, Pareuchaeta antarctica* and *Pleuromama robusta,* and two euphausiids *E. frigida* and *E. triacantha* ($P<0.01$). Both *S. thompsoni* and *V. antarctica* had significantly larger twilight vs. day and night abundance ($P<0.01$).

4.3.2.4 Survey A and D 2001 Comparisons:

Krill

Krill demonstrated distributional and developmental changes as expected with the advancing season (Siegel, 1987). During Survey A, juvenile and immature stages were confined to Bransfield Strait while larger mature forms occupied shelf and offshore waters. Differences in sex ratio and maturity stage composition suggested advanced seasonal spawning activity in the West relative to Elephant Island Area at that time. Increased patchiness during Survey D was associated with (a) northward movement of juveniles and immatures, (b) southward movement of spent females and regressing male maturity stages and (c) late-season spawning activity offshore (Tables 4.2A & B; Figures 4.4A & B). Noteworthy was the abundance of immature stages in the West and Elephant Island Areas during Survey D (Table 4.2), which indicated modest recruitment success of the 1998/99 year class.

Salpa thompsoni

Mean and median salp abundance in the Elephant Island and West Areas decreased by 60-70% between the two surveys (Tables 4.4A & B; Figures 4.6A & B). In contrast, abundance in the South Area increased by ca. 50%. These changes were primarily due to the aggregate stage (Figures 4.7A-D). When January length-frequency distributions were advanced to match modes in February-March distributions, the shifts reflected temporal separation of Survey A and D sampling in each area: 10mm over 18 days for the West Area; 14mm over 31 days for the Elephant Island Area; and 18mm over 42 days for the South Area. In all cases an estimated aggregate growth rate of ca. 0.44mm day^{-1} was supported. Examination of the February-March length-frequency distributions revealed diminished numbers of aggregates >35mm in all three subareas. Abundance decreases in the West and Elephant Island Areas were largely due to this in conjunction with little new production; increased abundance in the South Area resulted from minor late-season chain production and a less dramatic loss of aggregates >35mm. The solitary stage contributed 3% of total salps in Survey A and 6% in Survey D. The increase was due to greater numbers of large individuals in the upper water column rather than small newly spawned overwintering individuals (Figure 4.7D). The Salp:Krill carbon biomass value (Table 4.8) remained low and similar to that of January due to decreased production after mid-December plus loss of large aggregates from the upper water column.

Zooplankton

Between Surveys A and D mean and median zooplankton abundance increased, respectively, 43% and 50%, and taxonomic richness increased by ca. 8%. Much of the abundance increase was due to copepods (*C. acutus, M. gerlachei, C. propinquus* and copepodites), *T. macrura* and krill larvae. The significant total copepod abundance increase (ANOVA, $P<0.01$) was due to seasonal ontogenetic migration to surface layers by *C. acutus* and *C. propinquus* and population growth of *M. gerlachei* (Atkinson, 1991; Atkinson *et al.*, 1997; Huntley and Escritor, 1992; Ward *et al.*, 1998). A moderate PSI value (72) reflects seasonal changes in abundance relations of dominant taxa across the large survey area: increased proportions of *C. acutus*, larval krill and postlarval *T. macrura;* decreased proportions of *M. gerlachei,* other copepods, salps and larval *T. macrura*. The four times abundance increase of krill larvae was mainly due to increased numbers of stage C1 (57%) and C2 (30%); these most likely were spawned over the first three weeks of January (Ross and Quetin, 1989). More developed stage C3 (11%) and F1 (2%) larvae resulted from mid- to late-December spawning.

Seasonal changes were more dramatic within the Elephant Island Area (PSI=57) due to large abundance increases of copepods (mainly *C. acutus*) and postlarval *T. macrura* (from rank 5 to 2 after total copepods) and decreases of other copepods and salps (from rank 2 to 4 after *T. macrura* larvae; Tables 4.3, 4.6 & 4.10).

Both surveys were characterized by extremely complex distribution patterns of individual species and zooplankton clusters indicating a great deal of mesoscale patchiness. Undoubtedly this complexity resulted from atmospheric and hydrographic conditions, including prevailing east winds and massive influx of icebergs from the Weddell Sea. Without information on geostrophic flow it is impossible to assess the biological patterns with respect to hydrodynamics. However, distribution differences of Oceanic and Coastal zooplankton assemblages between Surveys A and D (Figures 4.10A & B) suggest: (a) strengthening of the semipermanent Oceanic eddy northwest of Elephant Island; (b) offshore displacement of Coastal and Oceanic zooplankton in West and South Areas; and (c) both northeastward and westward transport of Coastal zooplankton across the northern Elephant Island Area.

4.3.2.5 Survey D Between-Year Comparisons:

Krill (Tables 4.6, 4.7B, 4.8B & 4.9B)

Krill abundance in the Elephant Island Area during February 2001 was high relative to other February-March surveys. The mean value was third highest after 1998 and 1996 and the median (tied with those of 1997 and 1998) followed the high observed in 1992. In terms of carbon biomass, the mean also ranked third while the median was second to that of 1997. Various factors can contribute to these results: (a) seasonal migrations of spent, juvenile and immature individuals into the area; (b) substantial proportions of large adults, remnants of the successful 1995/96 year class; and (c) modest recruitment of the 1998/99 year class.

Large proportions of advanced female maturity stages, particularly spent individuals (3e), along with substantial larval krill concentrations were also observed during February-March 1995 and 2000. These result from seasonally normal (i.e., December-March) spawning activity. This, in conjunction with presence of more developed larval stages (i.e., C3 and F1) and decreased salp abundance during mid-summer, bodes well for larval survival and 2000/01 year class success. Noteworthy is the fact that this is the third year in a row (1999, 2000 and 2001) that conditions have been favorable for krill recruitment.

Because of normal seasonal spawning activity and moderately high larval krill abundance monitored during the 1999 cruises "guarded optimism" was expressed for 1998/99 year class success. However, juveniles were virtually non-existent in February-March 2000 survey samples and so this year class warranted a 0.0 R_1 recruitment index value. The latter observation indicates the importance of the R_2 recruitment index (Siegel *et al.*, 1998, 1999) and highlights the fact that interannual variability in distribution of the various krill maturity stages can greatly bias recruitment assessments based on the large survey area as well as much more limited Elephant Island Area.

Salps (Table 4.6; Figure 4.14)

Salp mean, standard deviation and median abundance values in the Elephant Island Area during 2001 were quite similar to those in February-March 1994. Additionally, marked seasonal decreases in salp abundance during 2001 and 1994 set these two years apart from the rest in the long term Elephant Island Area data set. Typically modest to substantial abundance increases here result from augmentation of aging populations by aggregate production over summer months. The aggregate length-frequency distribution in February 2001 most resembled that of 1998 ($D_{max} = 9.6$); these both resulted from relatively late onset of spring production, which peaked in November and essentially ended in late December. Diminished numbers of aggregates >35mm in length during 2001 was unique and suggested an extremely early seasonal migration out of the upper water column prior to production of overwintering solitary stages (Foxton, 1966; Casareto and Nemoto, 1986). It is possible that such a migration could have been prompted by the large influx of melting icebergs during February. The 1994 decrease, in contrast, appeared to be due to advection of salps out of the area.

Noteworthy is that prolonged budding periods with pulses of late-season aggregate production (1996, 1997 and 1999) preceded years with enhanced salp population size (Figure 4.14). In contrast; curtailed budding periods (1994 and 1998) preceded years with diminished salp populations. These observations support the idea that overwintering solitary seed population size is in part responsible for aggregate population growth the next spring and summer. Assuming that these trends continue, greatly reduced salp populations can be expected during the 2002 field season.

Zooplankton (Tables 4.6, 4.9B, 4.10B & 4.11B)

Zooplankton abundance in the Survey D area during 2001 was second to that in 2000. These periods, along with February-March 1994 and 1995, were characterized by relatively high copepod abundance. Total copepod and chaetognath abundance this year were significantly smaller than in 2000 (ANOVA $P<0.01$). Within the Elephant Island Area, moderately high mean and median abundance values of larval krill and larval *T. macrura* were, respectively, most similar to those of 1999 and 1996. Mean and median chaetognath abundance and median postlarval *T. macrura* abundance were also most similar to the 1996 values. Overall zooplankton taxonomic composition was similar to that of February-March 1999 (PSI=85) and 1996 (PSI=81) due to similar proportions of total copepods (62-65%).

Copepods (Table 4.12)

When put in a longer-term perspective, copepod species abundances in the Elephant Island Area during February-March 2000 and 2001 rank second and third behind the extremely high concentrations encountered during March 1981 (the krill "superswarm" year). The 1981 copepod assemblage was strongly dominated by *C. propinquus* (Weddell-Scotia Confluence affiliate) and *C. acutus* (Antarctic Circumpolar Current and East Wind Drift affiliate) but also had large concentrations of *M. gerlachei* (Gerlache-Bransfield Strait affiliate). February 2000 and 2001 were also characterized by relatively large concentrations of these three species, suggesting enrichment from both offshore and coastal environments. During all but the 1981 and February 2001 surveys, *M. gerlachei* was the most abundant species due to the prevailing coastal influence in this area. Maximum *M. gerlachei* abundance occurred in February 1989 when *C. acutus* and *C. propinquus* were relatively uncommon, suggesting primarily coastal enrichment at that time. In contrast to 1981, which had an associated strong krill, recruitment index (0.76) the recruitment index from 1988/89 was quite low (0.06; Loeb *et al.*, 1997).

4.3.3 AMLR 2001 Cruise Summary

(A) Mean and median krill abundance values in the Elephant Island Area were intermediate to high in 1996 and low in 1999. Increased abundance relative to 1999 results in part from recruitment of the 1998/99 and 1999/00 year classes as indicated by modest proportions of juvenile and immature stages.

(B) Large proportions of advanced female maturity stages, substantial larval krill concentrations and late larval stages during February-March reflected normal seasonal spawning in 2000/01. This is the third year in a row that spawning conditions have been favorable for krill recruitment success.

(C) Both large area surveys were characterized by wide spread distribution of abundant salps (*Salpa thompsoni*) but extremely large concentrations like those of the 1993 and 1998 salp years were not encountered. Length-frequency distribution of the dominant aggregate stage indicated a curtailed production season. A dramatic 60% abundance decrease between the two surveys was apparently due to loss of large aggregates from the upper water column. This unique situation suggested early downward seasonal migration prior to production of overwintering solitary stages. Such a migration could have been prompted by the large influx of Weddell Sea icebergs during February.

(D) Within the 1993-2001 Elephant Island Area dataset, prolonged salp budding periods with pulses of late-season aggregate production preceded years with enhanced salp population size while curtailed budding periods preceded years with diminished salp populations. Assuming that these trends continue, reduced salp population size can be expected during the 2002 field season.

(E) Favorable krill spawning conditions in conjunction with reduced salp abundance improve the prospects of larval production and survival. Should winter sea ice development and spring bloom conditions also be favorable we may expect strong recruitment success of the 2000/01 year class.

(F) Copepod abundance values in the Elephant Island Area were among the highest observed between 1981 and 2001. This included large concentrations of *Calanoides acutus, Metridia gerlachei* and *Calanus propinquus* and indicated enrichment in oceanic and coastal waters relative to other years.

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 specimens were provided to SIO scientists Linda Holland (salps) and Erica Goetze (copepods). Frozen myctophids were provided to Mike Goebel and Dan Costa (UCSC) for chemical analyses.

4.5 Problems and Suggestions: The 2001 AMLR field season was highly successful and enjoyable. The addition this year of stations across western Bransfield Strait will enable us to link hydrographic processes in the west and north Antarctic Peninsula (i.e., the LTER and AMLR study areas). It may be advantageous to add another line of stations, or amend coverage, in the Bransfield area east of this line to strengthen this analysis. It was extremely helpful to have the expert assistance of CTD technicians at sea. However, we are still handicapped by the lack of an experienced physical oceanographer who can provide real time information on water mass distribution and dynamics. With regard to hydrodynamics, it would be extremely beneficial to have information collected with an acoustic Doppler current profiler! This is especially true for examining transport of krill larvae in relation to recruitment success in the survey area and advection to South Georgia.

The zooplankton van would benefit from modifications making it more comfortable and more easily maintained for use by both the krill and fish stock assessment surveys. Improvements would include (a) replacing storage areas with microscope benches allowing assistants to be seated while performing sample analyses and (b) installation of stainless steel counters to allow efficient and effective cleaning.

We were very pleased with the inclusion of a benthic bycatch survey during Leg III and hope that this becomes a regular part of the fish stock assessment work. In addition to assessing the impact of trawling operations on the benthic environment, it provided a great deal of useful information on the structure and composition of habitats critical to fish.

4.6 References:

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Table 4.1. AMLR 2001 Large-area survey IKMT station information.
Double lines denote subarea divisions.

A. SURVEY A

STATION #	DATE	TIME			TOW	FLOW	KRILL		SALP	
		START	END	DIEL	DEPTH	VOLUME	ABUNDANCE		ABUNDANCE	
		(LOCAL)			(m)	(m3)	TOTAL	#/1000M3	TOTAL	#/1000M3
SOUTH AREA										
A001	15/01/01	2349	0019	N	171	2845.9	6	2.1	1332	468.0
A134	16/01/01	0310	0337	T	171	2566.2	117	45.6	1175	457.9
A133	16/01/01	0615	0646	D	171	2699.0	1104	409.0	756	280.1
A121	16/01/01	0927	0955	D	171	2499.8	1350	540.0	21	8.4
A005	16/01/01	1303	1330	D	172	2686.4	35	13.0	203	75.6
A003	16/01/01	1549	1610	D	113	2040.6	46	22.5	155	76.0
A007	16/01/01	2004	2033	D	171	2661.9	12	4.5	141	53.0
A109	16/01/01	2342	0010	N	172	2454.7	3	1.2	2988	1217.3
ELEPHANT ISLAND AREA										
A084	17/01/01	1038	1105	D	171	2536.7	15	5.9	1210	477.0
A085	17/01/01	1418	1446	D	171	2647.8	133	50.2	3042	1148.9
A086	17/01/01	1719	1743	D	170	2211.6	76	34.4	718	324.6
A087	17/01/01	2013	2038	D	173	1950.1	35	17.9	711	364.6
A088	17/01/01	2250	2318	N	172	2725.2	53	19.4	5508	2021.1
A089	18/01/01	0139	0206	N	170	2821.8	9	3.2	2478	878.2
A090	18/01/01	0430	0456	T	169	2368.9	51	21.5	2515	1061.7
A091	18/01/01	0721	0748	D	177	2466.6	196	79.5	1901	770.7
A076	18/01/01	1004	1033	D	169	2675.4	148	55.3	2605	973.7
A078	18/01/01	1428	1452	D	173	2248.4	26	11.6	547	243.3
A079	18/01/01	1720	1748	D	170	2274.7	103	45.3	1228	539.9
A081	18/01/01	2146	2215	D	170	2421.6	3	1.2	2780	1148.0
A083	19/01/01	0141	0211	N	171	2954.7	6	2.0	4161	1408.3
A068	19/01/01	0437	0503	T	169	2665.2	11	4.1	326	122.3
A069	19/01/01	0736	0804	D	170	2476.6	11	4.4	318	128.4
A070	19/01/01	1021	1051	D	168	2687.4	3	1.1	401	149.2
A071	19/01/01	1325	1355	D	171	2361.9	357	151.1	1207	511.0
A072	19/01/01	1627	1653	D	174	2441.2	123	50.4	1329	544.4
A073	19/01/01	1916	1943	D	171	2522.9	16	6.3	800	317.1
A074	19/01/01	2201	2230	N	171	2483.5	4	1.6	3451	1389.6
A075	20/01/01	0053	0122	N	171	2547.8	81	31.8	1290	506.3
A060	20/01/01	0349	0418	T	170	2635.6	0	0.0	3003	1139.4
A062	20/01/01	0810	0840	D	170	2721.4	171	62.8	983	361.2
A064	20/01/01	1229	1257	D	172	2347.1	7	3.0	1062	452.5
A065	20/01/01	1720	1745	D	161	2146.4	2	0.9	1212	564.7
A067	20/01/01	2135	2202	N	170	2457.5	0	0.0	1772	721.0
A052	21/01/01	0059	0127	N	171	2471.1	27	10.9	2138	865.2
A053	21/01/01	0358	0425	T	171	2601.8	2	0.8	5780	2221.5
A054	21/01/01	0625	0636	D	50	1023.8	1	1.0	394	384.8
A055	21/01/01	0857	0908	D	59	990.8	0	0.0	539	544.0
A056	21/01/01	1141	1210	D	169	2719.1	592	217.7	3717	1367.0
A057	21/01/01	1441	1509	D	171	2674.6	23	8.6	514	192.2
A058	21/01/01	1730	1755	D	170	2402.7	29	12.1	2180	907.3
A059	21/01/01	2020	2048	D	169	2473.8	9	3.6	495	200.1
A044	21/01/01	2310	2337	N	174	2317.9	4	1.7	877	378.4
A046	22/01/01	0346	0415	T	172	2569.8	206	80.2	2184	849.9
A047	22/01/01	0651	0715	D	170	2310.8	75	32.5	2683	1161.1
A049	22/01/01	1043	1104	D	145	1774.9	3	1.7	890	501.4
A051	22/01/01	1505	1532	D	170	2617.2	109	41.6	148	56.5
A036	22/01/01	1758	1822	D	170	2367.6	44	18.6	339	143.2
A037	22/01/01	2014	2044	D	171	2890.6	22	7.6	265	91.7
A038	22/01/01	2234	2312	N	172	2343.0	14	6.0	823	351.3
A039	23/01/01	0137	0205	N	171	2491.5	0	0.0	1054	423.0
A040	23/01/01	0430	0501	T	170	2692.7	0	0.0	450	167.1
A041	23/01/01	0728	0753	D	169	2359.9	14	5.9	396	167.8
A042	23/01/01	1002	1031	D	172	2640.6	21	8.0	1041	394.2
A043	23/01/01	1252	1319	D	172	2778.8	7	0.1	1168	420.3
A025	23/01/01	1550	1619	D	171	2500.4	0	0.0	1118	447.1
A027	23/01/01	2020	2049	D	171	2842.0	28	9.9	1253	440.9
A029	24/01/01	0054	0124	N	171	2830.1	1	0.4	2228	787.3
A030	24/01/01	0407	0434	T	170	2651.0	14	5.3	1197	451.5

Table 4.1. (Contd.).

STATION #	DATE	TIME START	(LOCAL) END	DIEL	TOW DEPTH (m)	FLOW VOLUME (m3)	KRILL ABUNDANCE TOTAL	 #/1000M3	SALP ABUNDANCE TOTAL	 #/1000M3
A032	24/01/01	0816	0846	D	170	2633.1	42	16.0	202	76.7
A017	24/01/01	1056	1125	D	169	2694.8	75	27.8	278	103.2
A018	24/01/01	1339	1409	D	170	2738.3	58	21.2	622	227.1
A019	24/01/01	1630	1700	D	170	2525.6	13	5.1	618	244.7
A020	24/01/01	1925	1949	D	171	2194.2	13	5.9	580	264.3
A021	24/01/01	2205	2235	N	171	2617.2	13	5.0	4226	1614.7
A022	25/01/01	0101	0128	N	170	2461.5	41	16.7	1180	479.4
A023	25/01/01	0359	0428	T	170	2776.5	1	0.4	1200	432.2
A024	25/01/01	0653	0718	D	170	2157.7	4	1.9	627	290.6
WEST AREA										
A187	25/01/01	1607	1635	D	169	2733.3	2	0.7	2314	846.6
A186	25/01/01	1935	2001	D	170	2310.6	0	0.0	1029	445.3
A105	25/01/01	2256	2319	N	170	2444.0	1	0.4	936	383.0
A104	26/01/01	0230	0302	N	169	3004.5	1	0.3	5040	1677.5
A010	26/01/01	0557	0626	D	169	2502.2	74	29.6	155	61.9
A013	26/01/01	0900	0927	D	170	2485.1	1	0.4	128	51.5
A016	26/01/01	1235	1304	D	171	3031.0	212	69.9	1117	368.5
A110	26/01/01	1623	1648	D	171	2397.2	31	12.9	1374	573.2
A111	26/01/01	2058	2120	D	170	2593.1	0	0.0	2832	1092.1
A188	27/01/01	0133	0202	N	171	2735.8	0	0.0	1035	378.3
A125	27/01/01	0523	0553	D	170	2336.9	4	1.7	181	77.5
A124	27/01/01	0856	0922	D	170	2392.7	7	2.9	528	220.7
A123	27/01/01	1215	1244	D	171	2778.6	39	14.0	455	163.8
A116	27/01/01	1546	1615	D	170	2856.9	173	60.6	548	191.8
A014	27/01/01	1936	1959	D	145	2085.4	0	0.0	377	180.8
A135	27/01/01	2220	2248	N	169	2617.5	61	23.3	1424	544.0
A136	28/01/01	0207	0232	N	170	2727.3	0	0.0	1300	476.7
A137	28/01/01	0546	0613	D	169	2572.4	12	4.7	661	257.0
A138	28/01/01	0914	0944	D	171	2853.2	112	39.3	681	238.7
A153	28/01/01	1240	1309	D	171	2670.5	38	14.2	521	195.1
A152	28/01/01	1631	1659	D	170	2435.7	17	7.0	191	78.4
A151	28/01/01	2008	2039	D	170	2775.1	30	10.8	325	117.1
A150	28/01/01	2318	2337	N	115	1940.0	1	0.5	647	333.5
A164	29/01/01	0323	0352	T	169	2674.8	90	33.6	847	316.7
A165	29/01/01	0659	0729	D	170	2687.4	4	1.5	2088	777.0
A166	29/01/01	1020	1048	D	169	2727.5	3	1.1	617	226.2
A176	29/01/01	1344	1411	D	171	2655.7	3	1.1	852	320.8
A175	29/01/01	1705	1728	D	171	2544.3	23	9.0	530	208.3
A174	29/01/01	2000	2027	D	171	2485.5	110	44.3	2123	854.2
A179	29/01/01	2240	2308	T	170	2576.0	3	1.2	1074	416.9
SOUTH AREA										
A180	30/01/01	0139	0210	N	171	2950.1	596	202.0	572	193.9
A190	30/01/01	0456	0521	T	170	2398.7	72	30.0	385	160.5
A191	30/01/01	0804	0834	D	170	2611.6	21	8.0	255	97.6
					SURVEY AREA A		7559		127589	
					N=101	MEAN		28.7		505.7
						STD		73.3		441.0
						MEDIAN		6.0		383.0
					WEST AREA					
					N=30	MEAN	1052	12.8	31930	402.4
						STD		18.7		346.2
						MEDIAN		2.3		318.7
					ELEPHANT AREA		3145		89962	
					N=60	MEAN		20.7		598.6
						STD		36.7		473.4
						MEDIAN		6.0		449.3
					SOUTH AREA		3362		7983	
					N=11	MEAN		116.2		280.7
						STD		179.6		331.5
						MEDIAN		22.5		160.5

Table 4.1. (Contd.).

B. SURVEY D

STATION	DATE	TIME			TOW	FLOW	KRILL		SALP	
#		START	END	DIEL	DEPTH	VOLUME	ABUNDANCE		ABUNDANCE	
		(LOCAL)			(m)	(m3)	TOTAL	#/1000M3	TOTAL	#/1000M3
WEST AREA										
D174	12/02/01	0610	0636	D	170	2312.1	13	5.6	1072	463.6
D175	12/02/01	0945	1015	D	171	2764.7	38	13.7	381	137.8
D176	12/02/01	1309	1337	D	168	2836.9	8	2.8	795	280.2
D166	12/02/01	1637	1700	D	170	2307.2	3	1.3	738	319.9
D165	12/02/01	1959	2927	D	170	2482.9	13	5.2	259	104.3
D164	12/02/01	2320	2348	N	168	2485.6	101	40.6	1044	420.0
D150	13/02/01	0310	0330	N	117	1867.6	805	431.0	201	107.6
D151	13/02/01	0643	0706	D	171	2161.7	25	11.6	891	412.2
D152	13/02/01	1040	1107	D	173	2515.4	14	5.6	960	381.6
D153	13/02/01	1459	1527	D	170	2721.7	7	2.6	1008	370.4
D138	13/02/01	1922	1946	D	170	2177.9	131	60.2	432	198.4
D137	13/02/01	2328	2355	N	169	2710.1	30	11.1	1540	568.2
D136	14/02/01	0319	0349	N	169	2896.0	21	7.3	634	218.9
D135	14/02/01	0641	0704	D	170	2229.3	180	80.7	589	264.2
D014	14/02/01	1105	1129	D	142	2307.8	0	0.0	38	16.5
D116	14/02/01	1444	1513	D	170	2674.3	15	5.6	1040	388.9
D123	14/02/01	1802	1827	D	171	2277.8	4	1.8	228	100.1
D124	14/02/01	2120	2148	N	169	2592.7	5	1.9	1408	543.1
D125	15/02/01	0205	0229	N	169	2587.3	7	2.7	119	46.0
D188	15/02/01	1310	1339	D	170	2921.9	1	0.3	999	341.9
D111	15/02/01	1651	1714	D	172	2139.0	6	2.8	237	110.8
D110	15/02/01	2027	2054	D	173	2590.1	2	0.8	273	105.4
D016	15/02/01	2352	0021	N	170	3316.6	689	207.7	651	196.3
D013	16/02/01	0305	0335	N	170	2327.6	275	118.1	299	128.5
D010	16/02/01	0632	0721	D	171	2746.9	0	0.0	450	163.8
D104	16/02/01	1018	1047	D	171	2825.6	42	14.9	1558	551.4
D105	16/02/01	1334	1404	D	170	3043.3	15	4.9	223	73.3
D186	16/02/01	1653	1722	D	170	2891.0	0	0.0	425	147.0
D187	16/02/01	2015	2045	D	170	2826.5	0	0.0	183	64.7
ELEPHANT ISLAND AREA										
D024	17/02/01	0610	0635	D	170	2324.5	677	291.2	15	6.5
D023	17/02/01	0901	0930	D	170	2749.1	23	8.4	222	80.8
D022	17/02/01	1150	1218	D	169	2877.9	7	2.4	444	154.3
D021	17/02/01	1427	1545	D	171	2450.2	0	0.0	149	60.8
D020	17/02/01	1703	1729	D	172	2614.5	9	3.4	1255	480.0
D019	17/02/01	1941	2009	D	169	2753.4	5	1.8	706	256.4
D018	17/02/01	2220	2247	N	170	2668.3	357	133.8	645	241.7
D017	18/02/01	0045	0114	N	170	3025.2	156	51.6	2060	681.0
D032	18/02/01	0331	0400	N	172	2598.4	12	4.6	877	337.5
D030	18/02/01	0754	0820	D	170	2390.1	1	0.4	933	390.4
D029	18/02/01	1047	1115	D	170	2595.2	0	0.0	907	349.5
D027	18/02/01	1503	1530	D	171	2377.1	0	0.0	1228	516.6
D025	18/02/01	1829	1853	D	171	2471.8	4	1.6	82	33.2
D043	18/02/01	2158	2224	N	170	2332.1	55	23.6	267	114.5
D042	19/02/01	0041	0108	N	171	3361.2	89	26.5	401	119.3
D041	19/02/01	0317	0345	N	170	2620.5	38	14.5	858	327.4
D040	19/02/01	0556	0619	D	170	2170.9	0	0.0	280	129.0
D039	19/02/01	0843	0910	D	171	2571.1	4	1.6	610	237.3
D038	19/02/01	1110	1136	D	171	2485.5	12	4.8	688	276.8
D037	19/02/01	1339	1407	D	171	2854.4	33	11.6	1113	389.9
D036	10/02/01	1622	1648	D	170	2486.9	10	4.0	512	205.9
D051	19/02/01	1845	1910	D	171	2492.1	0	0.0	448	179.8
D049	19/02/01	2234	2259	N	150	2242.2	12	5.4	768	342.5
D047	20/02/01	0235	0305	N	170	2604.2	7336	2817.0	1029	395.1
D046	20/02/01	0515	0542	T	170	2428.4	57	23.5	1112	457.9
D044	20/02/01	0921	0948	D	169	2541.0	6	2.4	793	312.1
D059	20/02/01	1218	1245	D	170	2538.4	3	1.2	108	42.5
D058	20/02/01	1513	1541	D	171	2705.1	17	6.3	265	98.0
D057	20/02/01	1803	1828	D	170	2222.0	35	15.8	275	123.8

Table 4.1. (Contd.).

STATION	DATE	TIME			TOW	FLOW	KRILL		SALP	
#		START	END	DIEL	DEPTH	VOLUME	ABUNDANCE		ABUNDANCE	
		(LOCAL)			(m)	(m3)	TOTAL	#/1000M3	TOTAL	#/1000M3
D053	21/02/01	2345	0011	N	168	2801.4	7	2.5	533	190.3
D052	22/02/01	0340	0408	N	171	2782.2	60	21.6	3305	1187.9
D067	22/02/01	0652	0718	D	170	2307.1	2	0.9	1276	553.1
D065	22/02/01	1139	1204	D	159	2342.6	0	0.0	487	207.9
D064	22/02/01	1612	1628	D	172	2613.5	9	3.4	1305	499.3
D063	22/02/01	1915	1942	D	172	2588.8	64	24.7	395	152.6
D060	23/02/01	0409	0438	N	169	2850.7	9	3.2	703	246.6
D075	23/02/01	0703	0728	D	170	2444.6	19	7.8	434	177.5
D074	23/02/01	0945	1013	D	170	2568.5	0	0.0	1916	746.0
D073	23/02/01	1231	1259	D	171	2688.0	104	38.7	73	27.2
D072	23/02/01	1514	1541	D	170	2665.0	13	4.9	229	85.9
D071	23/02/01	1755	1819	D	169	2075.8	48	23.1	909	437.9
D070	23/02/01	2040	2110	N	169	2919.1	0	0.0	893	305.9
D069	23/02/01	2323	2351	N	166	2999.8	15	5.0	1409	469.7
D068	24/02/01	0236	0307	N	169	3257.5	1344	412.6	1859	570.7
D083	24/02/01	0504	0535	T	170	3180.7	39	12.3	7687	2416.8
D081	24/02/01	0931	0958	D	170	2458.7	90	36.6	3385	1376.8
D079	24/02/01	1339	1408	D	170	2759.0	45	16.3	1503	544.8
D078	24/02/01	1618	1646	D	169	2863.4	13	4.5	265	92.5
D076	24/02/01	2027	2055	N	169	2621.0	2	0.8	5785	2207.1
D091	24/02/01	2324	2350	N	170	2378.1	706	296.9	1654	695.5
D090	25/02/01	0211	0240	N	169	2976.9	539	181.1	1761	591.6
D089	25/02/01	0508	0535	T	170	2664.0	70	26.3	528	198.2
D088	25/02/01	0800	0828	D	169	2973.6	12	4.0	3835	1289.7
D087	25/02/01	1105	1132	D	171	2616.3	3	1.1	1632	623.8
D086	25/02/01	1404	1432	D	168	2679.6	0	0.0	562	209.7
D085	25/02/01	1657	1723	D	169	3077.2	0	0.0	1037	337.0
D084	25/02/01	1945	2011	T	170	2558.5	0	0.0	4960	1938.6
SOUTH AREA										
D109	26/02/011	0948	1013	D	170	2390.7	0	0.0	1066	445.9
D007	26/02/01	1334	1403	D	171	2681.6	0	0.0	1719	641.0
D003	26/02/01	1729	1754	D	171	2437.9	3	1.2	557	228.5
D005	26/02/01	2058	2123	N	170	2076.6	0	0.0	3041	1464.4
D121	27/02/01	0908	0936	D	170	2971.9	2	0.7	32	10.8
D133	27/02/01	1203	1231	D	169	2622.0	0	0.0	292	111.4
D134	27/02/01	1531	1600	D	169	2815.7	0	0.0	2639	937.2
D001	28/02/01	2129	2158	N	170	2868.5	6	2.1	1229	428.5
D190	02/03/01	0353	0423	N	210	2810.8	78	27.7	429	152.6
D191	02/03/01	0710	0736	D	169	2573.6	2	0.8	523	203.2
					SURVEY AREA D		14712		99572	
					N=96	MEAN		58.9		391.3
						STD		293.4		429.9
						MEDIAN		4.0		270.5
					WEST AREA		2450		18675	
					N=29	MEAN		35.9		249.1
						STD		86.7		162.1
						MEDIAN		5.2		198.4
					ELEPHANT AREA		12171		69370	
					N=57	MEAN		86.5		426.6
						STD		387.1		475.6
						MEDIAN		4.9		305.9
					SOUTH AREA		91		11527	
					N=10	MEAN		3.3		462.3
						STD		8.2		425.2
						MEDIAN		0.3		328.5

Table 4.2. Maturity stage composition of krill collected in the large survey area and three subareas during (A) January and (B) February-March 2001. Advanced maturity stages are proportions of mature females that are 3c-3e in January and 3d-3e in February-March.

A.	*E. superba* January 2001			
Area	Survey A	Elephant I.	West	South
Stage	%	%	%	%
Juveniles	25.6	9.7	0.1	62.9
Immature	10.2	6.2	1.2	20.3
Mature	64.2	84.1	98.8	16.8
Females:				
F2	0.9	0.2	0.1	2.0
F3a	1.2	0.9	0.0	2.4
F3b	8.0	14.6	3.4	3.1
F3c	9.2	13.2	15.4	1.5
F3d	7.4	7.4	18.8	1.7
F3e	2.1	1.3	1.0	2.4
Advanced Stages	67.1	58.5	91.2	50.1
Males:				
M2a	6.5	2.1	0.1	16.2
M2b	1.6	2.1	0.5	1.3
M2c	1.1	1.7	0.6	0.9
M3a	1.3	2.1	0.4	0.5
M3b	35.1	44.6	59.9	5.3
Male:Female	1.6	1.4	1.6	1.8
No. measured	3596	2063	825	514

B.	February-March 2001			
Area	Survey D	Elephant I.	West	South
Stage	%	%	%	%
Juveniles	11.8	13.4	4.2	3.4
Immature	14.2	14.7	11.6	10.6
Mature	74.0	71.9	84.2	86.0
Females:				
F2	0.7	0.7	1.0	0.9
F3a	2.4	2.4	2.6	0.9
F3b	0.4	0.2	1.2	0.0
F3c	2.3	1.5	6.1	10.3
F3d	4.4	3.8	7.2	16.7
F3e	39.0	42.6	20.7	34.7
Advanced Stages	89.5	91.8	73.9	82.0
Males:				
M2a	3.7	4.1	2.1	1.1
M2b	2.8	2.7	3.6	0.0
M2c	6.9	7.3	4.9	8.6
M3a	2.3	2.2	2.5	12.5
M3b	23.1	19.2	43.8	11.7
Male:Female	0.8	0.7	1.5	0.5
No. measured	2592	1739	763	90

Table 4.3. Zooplankton collected during Surveys A and D, January-March, 2001. F(%) is frequency of occurrence. R is rank. N(%) is proportion of total mean abundance contributed by each taxonomic category. (L) and (J) denote larval and juvenile stages.

	JANUARY 2001 N=101						FEBRUARY-MARCH 2001 N=96					
TAXON	F(%)	R	MEAN	STD	N(%)	MED	F(%)	R	MEAN	STD	N(%)	MED
Copepods	100.0	1	2247.1	6097.4	58.9	564.9	99.0	1	5915.7	14242.1	66.4	1416.1
Calanoides acutus	97.0		1078.9	5210.7	28.3	128.6	95.8		3894.9	12957.1	43.7	93.4
Metridia gerlachei	91.1		742.4	1362.2	19.5	110.4	94.8		1483.2	2899.6	16.6	142.9
Other copepods	85.1		266.5	524.6	7.0	71.6	36.5		55.5	225.3	0.6	174.8
Calanus propinquus	86.1		132.4	406.0	3.5	32.2	97.9		234.3	398.3	2.6	0.0
Rhincalanus gigas	33.7		20.1	67.3	0.5	0.0	38.5		28.0	108.1	0.3	0.0
Pleuromama robusta	16.8		5.8	19.3	0.2	0.0	11.5		3.7	12.5	0.0	0.0
Pareucheata antarctica	7.9		0.9	6.5	0.0	0.0	61.5		71.5	127.1	0.8	11.4
Haloptilus ocellatus	0.0		0.0	0.0	0.0	0.0	3.1		2.3	17.9	0.0	0.0
Copepodites	0.0		0.0	0.0	0.0	0.0	67.7		142.2	334.0	1.6	28.6
Salpa thompsoni	100.0	2	520.7	511.1	13.7	383.0	100.0	5	392.1	429.8	4.4	274.8
Thysanoessa macrura (L)	85.1	3	458.0	1117.7	12.0	45.9	91.7	2	718.3	1496.7	8.1	209.7
Chaetognaths	84.2	4	174.2	709.2	4.6	27.1	77.1	7	164.5	385.2	1.8	22.5
Euphausia superba (L)	68.3	5	160.2	710.8	4.2	12.5	64.6	3	683.4	3607.1	7.7	10.5
Thysanoessa macrura	93.1	6	73.5	127.6	1.9	28.2	86.5	4	639.0	5617.6	7.2	21.6
Radiolarians	19.8	7	46.1	357.0	1.2	0.0	32.3	6	216.2	1227.1	2.4	0.0
Euphausia frigida	45.5	8	28.8	64.6	0.8	0.0	50.0	9	42.0	91.9	0.5	0.2
Euphausia superba	89.1	9	27.7	72.2	0.7	6.0	79.2	8	59.0	293.4	0.7	4.0
Cyllopus lucasii	87.1	10	22.4	26.5	0.6	13.8	96.9	10	26.6	29.5	0.3	16.3
Vibilia antarctica	98.0	11	16.3	16.1	0.4	12.5	99.0	11	10.9	13.8	0.1	6.3
Ostracods	37.6	12	6.7	19.0	0.2	0.0	20.8	12	10.1	70.6	0.1	0.0
Clio pyramidata	32.7	13	5.9	34.8	0.2	0.0	10.4		0.4	1.6	0.0	0.0
Limacina helicina	51.5	14	4.9	12.5	0.1	0.8	33.3		1.8	7.9	0.0	0.0
Themisto gaudichaudii	66.3	15	4.0	7.7	0.1	1.5	79.2	14	4.3	6.3	0.0	1.6
Spongiobranchaea australis	68.3		2.1	3.0	0.1	1.0	70.8	15	4.1	10.7	0.0	1.3
Tomopteris spp.	45.5		1.9	5.1	0.1	0.0	19.8		0.4	1.3	0.0	0.0
Euphausia triacantha	13.9		1.6	7.8	0.0	0.0	16.7		1.2	4.0	0.0	0.0
Ihlea racovitzai	12.9		1.1	4.4	0.0	0.0	3.1		0.3	2.9	0.0	0.0
Clione limacina	26.7		0.9	3.5	0.0	0.0	16.7		0.9	6.3	0.0	0.0
Hyperiids	12.9		0.7	3.1	0.0	0.0	5.2		0.3	1.7	0.0	0.0
Lepidonotothen larseni (L)	10.9		0.7	3.2	0.0	0.0	14.6		0.2	0.6	0.0	0.0
Polychaetes	7.9		0.7	5.5	0.0	0.0	1.0		0.1	0.8	0.0	0.0
Jellies (unid.)	16.8		0.6	1.9	0.0	0.0	4.2		0.0	0.1	0.0	0.0
Larval fish (unid.)	18.8		0.6	1.6	0.0	0.0	1.0		0.0	0.0	0.0	0.0
Cyllopus magellanicus	30.7		0.5	1.2	0.0	0.0	70.8		2.9	6.0	0.0	0.8
Diphyes antarctica	23.8		0.5	1.7	0.0	0.0	20.8		0.2	0.6	0.0	0.0
Electrona spp. (L)	10.9		0.4	1.8	0.0	0.0	12.5		0.8	3.1	0.0	0.0
Hydromedusae	14.9		0.4	1.4	0.0	0.0	4.2		0.0	0.2	0.0	0.0
Hyperiella dilatata	24.8		0.4	1.1	0.0	0.0	30.2		0.4	0.8	0.0	0.0
Lepidonotothen kempi (L)	7.9		0.4	1.9	0.0	0.0	19.8		0.2	0.7	0.0	0.0
Siphonophores	3.0		0.3	2.8	0.0	0.0	2.1		0.0	0.1	0.0	0.0
Beroe cucumis	20.8		0.3	0.7	0.0	0.0	7.3		0.1	0.3	0.0	0.0
Beroe forskalii	17.8		0.2	0.7	0.0	0.0	10.4		0.0	0.1	0.0	0.0
Dimophyes arctica	10.9		0.2	0.7	0.0	0.0	15.6		0.2	0.5	0.0	0.0
Calycopsis borchgrevinki	4.0		0.2	1.4	0.0	0.0	6.3		0.0	0.2	0.0	0.0
Hyperoche medusarum	5.0		0.1	0.9	0.0	0.0	10.4		0.1	0.3	0.0	0.0
Hyperiella spp.	5.9		0.1	0.6	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Botrynema brucei	5.0		0.1	0.6	0.0	0.0	1.0		0.0	0.0	0.0	0.0
Pleuragramma antarcticum (J)	4.0		0.1	0.5	0.0	0.0	5.2		0.1	1.1	0.0	0.0
Primno macropa	7.9		0.1	0.3	0.0	0.0	28.1		1.5	4.9	0.0	0.0
Vanadis antarctica	5.0		0.1	0.3	0.0	0.0	1.0		0.0	0.0	0.0	0.0

Table 4.3. (Contd).

	JANUARY 2001						FEBRUARY-MARCH 2001					
TAXON	F(%)	R	MEAN	STD	N(%)	MED	F(%)	R	MEAN	STD	N(%)	MED
Scina spp.	1.0		0.1	0.6	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Ctenophores	5.0		0.1	0.2	0.0	0.0	5.2		0.0	0.2	0.0	0.0
Notolepis spp. (L)	2.0		0.0	0.3	0.0	0.0	1.0		0.2	1.5	0.0	0.0
Pelagobia longicirrata	3.0		0.0	0.2	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Scyphomedusae	2.0		0.0	0.2	0.0	0.0	1.0		0.0	0.0	0.0	0.0
Electrona antarctica	5.9		0.0	0.1	0.0	0.0	5.2		0.0	0.2	0.0	0.0
Cyllopus spp.	2.0		0.0	0.2	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Electrona carlsbergi	2.0		0.0	0.2	0.0	0.0	6.3		0.0	0.1	0.0	0.0
Sipunculids	3.0		0.0	0.1	0.0	0.0	12.5		0.3	1.0	0.0	0.0
Eusirus perdentatus	1.0		0.0	0.2	0.0	0.0	1.0		0.0	0.0	0.0	0.0
Mysids	1.0		0.0	0.2	0.0	0.0	1.0		0.1	1.0	0.0	0.0
Rhynchonereella bongraini	1.0		0.0	0.1	0.0	0.0	2.1		0.0	0.1	0.0	0.0
Euphausia crystallorphorias	1.0		0.0	0.1	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Cumaceans	1.0		0.0	0.1	0.0	0.0	2.1		0.0	0.3	0.0	0.0
Adult myctophids	1.0		0.0	0.1	0.0	0.0	2.1		0.0	0.1	0.0	0.0
Cephalopods	1.0		0.0	0.0	0.0	0.0	1.0		0.0	0.0	0.0	0.0
Hyperia antarctica	1.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Epimeriella macronyx	1.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Maupasia coeca	1.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Orchomene rossi	1.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Notolepis coatsi (L)	1.0		0.0	0.0	0.0	0.0	2.1		0.0	0.4	0.0	0.0
Electrona subaspera	1.0		0.0	0.0	0.0	0.0	2.1		0.0	0.1	0.0	0.0
Gymnoscopelus braueri	1.0		0.0	0.0	0.0	0.0	7.3		0.0	0.2	0.0	0.0
Euphausiid eggs	0.0		0.0	0.0	0.0	0.0	19.8	13	9.3	51.4	0.1	0.0
Polychaetes (unid.)	0.0		0.0	0.0	0.0	0.0	6.3		0.6	2.8	0.0	0.0
Gammarids	0.0		0.0	0.0	0.0	0.0	4.2		0.4	2.6	0.0	0.0
Euphausia spp. (L)	0.0		0.0	0.0	0.0	0.0	1.0		0.4	3.5	0.0	0.0
Pegantha martgon	0.0		0.0	0.0	0.0	0.0	27.1		0.3	0.6	0.0	0.0
Eusirus antarcticus	0.0		0.0	0.0	0.0	0.0	5.2		0.1	0.3	0.0	0.0
Pleurobrachia pileus	0.0		0.0	0.0	0.0	0.0	5.2		0.0	0.2	0.0	0.0
Fish eggs	0.0		0.0	0.0	0.0	0.0	3.1		0.0	0.3	0.0	0.0
Callianira antarctica	0.0		0.0	0.0	0.0	0.0	5.2		0.0	0.2	0.0	0.0
Bylgides pelagica	0.0		0.0	0.0	0.0	0.0	2.1		0.0	0.2	0.0	0.0
Gymnoscopelus nicholsi	0.0		0.0	0.0	0.0	0.0	3.1		0.0	0.1	0.0	0.0
Krefftichthys anderssoni (J)	0.0		0.0	0.0	0.0	0.0	1.0		0.0	0.1	0.0	0.0
Chionodraco rastrospinosus (L)	0.0		0.0	0.0	0.0	0.0	1.0		0.0	0.1	0.0	0.0
Laodicea undulata	0.0		0.0	0.0	0.0	0.0	1.0		0.0	0.0	0.0	0.0
Orchomene plebs	0.0		0.0	0.0	0.0	0.0	1.0		0.0	0.0	0.0	0.0
Cyphocaris richardi	0.0		0.0	0.0	0.0	0.0	1.0		0.0	0.0	0.0	0.0
Gymnoscopelus bolini	0.0		0.0	0.0	0.0	0.0	1.0		0.0	0.0	0.0	0.0
Limacina spp.	0.0		0.0	0.0	0.0	0.0	1.0		0.0	0.0	0.0	0.0
Notothenia neglecta (L)	0.0		0.0	0.0	0.0	0.0	1.0		0.0	0.0	0.0	0.0
TOTAL			3812.7	7486.9		1414.9			8910.1	17688.7		2828.9
NO. TAXA	71		21.5	3.8		21.0	83		20.8	4.0		21.0

Table 4.4. Zooplankton composition and abundance in the Elephant Island, West and South areas sampled during (A) January and (B) February-March, 2001. F is frequency of occurrence (%) in N samples. R is rank. N(%) is proportion of total mean zooplankton abundance contributed by each taxon. (L) and (J) denote larval and juvenile stages.

A. SURVEY A	JANUARY 2001																	
	ELEPHANT ISLAND AREA (N=60)						WEST AREA (N=30)						SOUTH AREA (N=11)					
TAXON	F(%)	R	MEAN	STD	N(%)	MED	F(%)	R	MEAN	STD	N(%)	MED	F(%)	R	MEAN	STD	N(%)	MED
Copepods	100.0	1	1003.2	1582.4	46.8	252.2	100.0	1	4922.6	10394.1	64.9	1235.6	100.0	1	1734.8	2198.1	66.4	1194.5
Metridia gerlachei	88.3		488.4	1103.3	22.8	45.5	96.7		1004.6	1390.9	0.0	367.9	90.9		1412.9	2033.1	54.0	173.0
Calanoides acutus	96.7		241.0	392.0	11.2	117.7	100.0		3112.9	9230.8	0.0	223.1	90.9		102.5	104.6	3.9	96.1
Other copepods	83.3		197.5	527.3	9.2	41.8	93.3		464.7	553.1	0.0	256.0	72.7		102.2	125.7	3.9	75.5
Calanus propinquus	80.0		50.4	85.9	2.4	12.5	96.7		317.7	700.3	0.0	71.2	90.9		74.0	45.9	2.8	68.4
Rhincalanus gigas	26.7		20.2	74.8	0.9	0.0	40.0		13.7	30.0	0.0	0.0	54.5		36.9	90.6	1.4	1.5
Pleuromama robusta	15.0		5.5	21.0	0.3	0.0	20.0		6.7	18.1	0.0	0.0	18.2		4.8	10.2	0.2	0.0
Pareucheata antarctica	6.7		0.2	0.6	0.0	0.0	6.7		2.2	11.7	0.0	0.0	18.2		1.2	2.6	0.0	0.0
Salpa thompsoni	100.0	2	622.8	576.4	29.0	449.3	100.0	5	403.8	345.6	5.3	325.1	100.0	3	282.2	331.2	10.8	160.5
Thysanoessa macrura (L)	86.7	3	269.3	608.8	12.6	42.7	93.3	2	995.4	1741.8	13.1	127.1	54.5	7	21.0	36.0	0.8	6.4
Chaetognaths	78.3	4	57.4	110.9	2.7	11.3	90.0	4	461.0	1245.5	6.1	87.7	100.0	6	29.0	22.2	1.1	35.1
Thysanoessa macrura	96.7	5	46.2	49.2	2.2	32.2	86.7	7	49.3	93.2	0.7	9.1	90.9	2	288.8	246.0	11.0	281.8
Euphausia superba (L)	70.0	6	32.8	86.2	1.5	9.0	93.3	3	472.6	1243.8	6.2	66.5	27.3		2.9	6.9	0.1	0.0
Euphausia frigida	38.3	7	23.4	55.9	1.1	0.0	50.0	9	22.0	38.0	0.3	0.4	72.7	5	77.2	121.5	3.0	32.7
Vibilia antarctica	98.3	8	21.1	18.5	1.0	16.6	100.0		8.8	6.1	0.1	7.5	90.9	9	10.6	9.7	0.4	5.4
Cyllopus lucasii	85.0	9	21.0	24.5	1.0	12.3	100.0	8	32.2	30.3	0.4	21.6	63.6		3.1	5.4	0.1	1.0
Euphausia superba	90.0	10	18.9	32.7	0.9	6.0	83.3		12.8	18.7	0.2	2.3	100.0	4	116.2	179.6	4.4	22.5
Ostracods	41.7		5.3	15.4	0.2	0.0	33.3		6.8	18.0	0.1	0.0	27.3	8	13.8	32.9	0.5	0.0
Themisto gaudichaudii	65.0		3.7	5.5	0.2	1.6	86.7		5.9	11.5	0.1	2.7	18.2		0.2	0.5	0.0	0.0
Limacina helicina	46.7		3.0	6.0	0.1	0.0	46.7		7.4	19.1	0.1	0.0	90.9	10	8.7	13.3	0.3	2.9
Tomopteris spp.	41.7		2.4	6.2	0.1	0.0	50.0		1.3	2.8	0.0	0.0	54.5		1.0	2.2	0.0	0.0
Euphausia triacantha	13.3		2.1	9.8	0.1	0.0	20.0		1.1	3.7	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Spongiobranchaea australis	63.3		2.0	2.7	0.1	1.1	76.7		2.8	3.7	0.0	1.6	72.7		0.7	0.7	0.0	0.4
Clio pyramidata	33.3		1.6	3.9	0.1	0.0	33.3	10	14.8	62.5	0.2	0.0	27.3		5.5	9.8	0.2	0.0
Radiolarians	13.3		1.2	3.9	0.1	0.0	40.0	6	152.8	642.4	2.0	0.0	0.0		0.0	0.0	0.0	0.0
Hydromedusae	20.0		0.6	1.7	0.0	0.0	10.0		0.1	0.4	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Larval Fish (unid.)	20.0		0.6	1.7	0.0	0.0	13.3		0.3	1.0	0.0	0.0	27.3		1.1	1.9	0.0	0.0
Diphyes antarctica	20.0		0.6	2.0	0.0	0.0	13.3		0.1	0.4	0.0	0.0	72.7		1.1	1.6	0.0	0.7
Jellies (unid.)	13.3		0.6	1.9	0.0	0.0	26.7		0.8	2.0	0.0	0.0	9.1		0.0	0.1	0.0	0.0
Clione limacina	18.3		0.5	3.3	0.0	0.0	20.0		0.7	2.1	0.0	0.0	90.9		3.1	6.3	0.1	1.2
Hyperiella dilatata	21.7		0.5	1.3	0.0	0.0	23.3		0.3	0.6	0.0	0.0	45.5		0.2	0.3	0.0	0.0
Hyperiids (unid.)	10.0		0.5	2.1	0.0	0.0	23.3		1.6	4.8	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Cyllopus magellanicus	21.7		0.4	1.2	0.0	0.0	36.7		0.8	1.5	0.0	0.0	63.6		0.4	0.4	0.0	0.4
Electrona spp. (L)	10.0		0.4	1.9	0.0	0.0	13.3		0.6	1.5	0.0	0.0	9.1		0.6	1.9	0.0	0.0
Ihlea racovitzai	6.7		0.4	1.6	0.0	0.0	3.3		0.2	1.1	0.0	0.0	72.7		7.3	10.6	0.3	2.7
Lepidonotothen larseni (L)	6.7		0.3	1.8	0.0	0.0	10.0		1.0	4.8	0.0	0.0	27.3		1.8	3.6	0.1	0.0
Beroe cucumis	21.7		0.3	0.7	0.0	0.0	6.7		0.1	0.4	0.0	0.0	54.5		0.9	1.1	0.0	0.4
Beroe forskalii	13.3		0.2	0.9	0.0	0.0	20.0		0.2	0.5	0.0	0.0	36.4		0.2	0.4	0.0	0.0
Calycopsis borchgrevinki	3.3		0.2	1.8	0.0	0.0	3.3		0.0	0.1	0.0	0.0	9.1		0.1	0.2	0.0	0.0
Lepidonotothen kempi (L)	3.3		0.2	1.6	0.0	0.0	3.3		0.0	0.1	0.0	0.0	18.2		0.3	0.8	0.0	0.0
Dimophyes arctica	6.7		0.2	0.9	0.0	0.0	13.3		0.2	0.4	0.0	0.0	27.3		0.2	0.3	0.0	0.0
Polychaetes	6.7		0.2	0.8	0.0	0.0	13.3		2.0	9.8	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Scina spp.	1.7		0.1	0.8	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Vanadis antarctica	6.7		0.1	0.4	0.0	0.0	3.3		0.0	0.2	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Hyperiella spp.	5.0		0.1	0.5	0.0	0.0	10.0		0.2	0.8	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Pleuragramma antarcticum (J)	3.3		0.1	0.5	0.0	0.0	0.0		0.0	0.0	0.0	0.0	18.2		0.4	1.1	0.0	0.0
Lepidonotothen nudifrons (L)	1.7		0.1	0.5	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Botrynema brucei	5.0		0.1	0.4	0.0	0.0	6.7		0.2	1.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Primno macropa	6.7		0.1	0.2	0.0	0.0	13.3		0.1	0.4	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Pelagogobia longicirrata	5.0		0.1	0.2	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Scyphomedusae	3.3		0.0	0.3	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Ctenophores	3.3		0.0	0.2	0.0	0.0	3.3		0.0	0.2	0.0	0.0	18.2		0.2	0.5	0.0	0.0
Notolepis spp. (L)	1.7		0.0	0.2	0.0	0.0	3.3		0.1	0.4	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Electrona carlsbergi	1.7		0.0	0.2	0.0	0.0	3.3		0.0	0.1	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Eusirus perdentatus	1.7		0.0	0.2	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Sipunculids	3.3		0.0	0.1	0.0	0.0	0.0		0.0	0.0	0.0	0.0	9.1		0.0	0.1	0.0	0.0
Cumaceans	1.7		0.0	0.1	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Hyperia antarctica	1.7		0.0	0.1	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Cephalopods	1.7		0.0	0.1	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Electrona antarctica	1.7		0.0	0.1	0.0	0.0	6.7		0.0	0.1	0.0	0.0	27.3		0.1	0.2	0.0	0.0
Notolepis coatsi	1.7		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Pleuragramma antarcticum	1.7		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Siphonophores	0.0		0.0	0.0	0.0	0.0	3.3		0.9	5.1	0.0	0.0	18.2		0.1	0.3	0.0	0.0
Hyperoche medusarum	0.0		0.0	0.0	0.0	0.0	13.3		0.4	1.7	0.0	0.0	9.1		0.1	0.4	0.0	0.0
Mysids	0.0		0.0	0.0	0.0	0.0	3.3		0.1	0.3	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Adult Myctophids (unid.)	0.0		0.0	0.0	0.0	0.0	3.3		0.0	0.1	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Cyllopus spp.	0.0		0.0	0.0	0.0	0.0	3.3		0.0	0.1	0.0	0.0	9.1		0.1	0.4	0.0	0.0
Epimeriella macronyx	0.0		0.0	0.0	0.0	0.0	3.3		0.0	0.1	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Electrona subaspera	0.0		0.0	0.0	0.0	0.0	3.3		0.0	0.1	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Gymnoscopelus braueri	0.0		0.0	0.0	0.0	0.0	3.3		0.0	0.1	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Rhynchonereella bongraini	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	9.1		0.1	0.4	0.0	0.0
Euphausia crystallorphorias	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	9.1		0.1	0.3	0.0	0.0
Maupasia coeca	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	9.1		0.0	0.1	0.0	0.0
Orchomene rossi	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	9.1		0.0	0.1	0.0	0.0
TOTAL			2145.7	2253.2		1414.9			7586.1	12487.2		2375.9			2614.4	2507.9		1852.2
NO. TAXA	60		17.4	4.1		17.0	57		20.1	3.7		19.0		47	21.3	2.8		21.0

Table 4.4 (Contd.)

B. SURVEY D	FEBRUARY-MARCH 2001																	
	ELEPHANT ISLAND AREA (N=57)						WEST AREA (N=29)						SOUTH AREA (N=10)					
	F(%)	R	MEAN	STD	N(%)	MED	F(%)	R	MEAN	STD	N(%)	MED	F(%)	R	MEAN	STD	N(%)	MED
Copepods	98.2	1	4501.5	8072.4	63.5	1518.0	100.0	1	9636.6	22692.6	68.0	1504.9	100.0	1	3185.9	4841.0	79.0	351.2
Calanoides acutus	94.7		2540.2	6921.6	35.8	111.5	96.6		7869.4	20909.4	55.6	263.7	100.0		90.5	62.8	2.2	64.2
Metridia gerlachei	93.0		1450.0	2966.0	20.4	140.1	96.6		1064.9	1494.9	7.5	259.0	100.0		2885.5	4648.5	71.6	141.5
Calanus propinquus	96.5		247.1	402.9	3.5	122.2	100.0		272.6	438.2	1.9	101.9	100.0		50.6	43.6	1.3	49.0
Copepodites	64.9		116.1	343.8	1.6	23.2	79.3		237.0	348.0	1.7	95.3	50.0		16.4	23.7	0.4	3.0
Pareucheata antarctica	66.7		74.7	137.9	1.1	20.8	41.4		47.6	90.3	0.3	0.0	90.0		122.3	137.2	3.0	74.8
Other copepods	29.8		37.0	188.4	0.5	0.0	37.9		106.3	307.2	0.8	0.0	70.0		13.8	14.7	0.3	7.8
Rhincalanus gigas	38.6		32.4	129.1	0.5	0.0	34.5		27.5	75.6	0.2	0.0	50.0		5.0	8.2	0.1	1.2
Pleuromama robusta	10.5		3.7	13.6	0.1	0.0	13.8		4.2	12.1	0.0	0.0	10.0		1.8	5.4	0.0	0.0
Haloptilus ocellatus	1.8		0.4	2.7	0.0	0.0	6.9		7.0	31.8	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Thysanoessa macrura	89.5	2	1040.9	7262.6	14.7	44.1	75.9		17.1	43.1	0.1	3.8	100.0	3	151.4	121.9	3.8	131.6
Thysanoessa macrura (L)	89.5	3	613.3	1009.5	8.6	265.3	100.0	3	1165.1	2241.4	8.2	358.1	80.0	7	21.0	20.9	0.5	10.8
Salpa thompsoni	100.0	4	452.4	501.2	6.4	312.1	100.0	6	249.1	162.1	1.8	198.4	100.0	2	462.3	425.2	11.5	328.5
Radiolarians	31.6	5	133.6	672.2	1.9	0.0	37.9	4	452.5	2002.9	3.2	0.0	20.0		1.7	4.7	0.0	0.0
Chaetognaths	71.9	6	93.5	173.4	1.3	10.5	86.2	5	349.0	618.0	2.5	53.5	80.0	6	33.9	38.2	0.8	18.8
Euphausia superba	78.9	7	80.5	374.0	1.1	4.6	89.7	8	35.9	86.8	0.3	5.2	50.0		3.3	8.2	0.1	0.3
Euphausia superba (L)	57.9	8	71.9	176.9	1.0	5.1	89.7	2	2119.3	6328.9	15.0	42.5	30.0		4.8	9.8	0.1	0.0
Euphausia frigida	47.4	9	37.7	82.0	0.5	0.0	44.8	7	44.5	111.0	0.3	0.0	80.0	4	59.5	81.8	1.5	4.9
Cyllopus lucasii	96.5	10	30.0	33.5	0.4	16.7	96.6	10	23.3	22.4	0.2	15.4	100.0	8	16.6	16.8	0.4	10.8
Vibilia antarctica	98.2		14.4	16.6	0.2	8.2	100.0		5.9	4.2	0.0	5.0	100.0	10	5.2	4.3	0.1	3.8
Themisto gaudichaudii	82.5		4.5	6.5	0.1	2.1	89.7		5.2	6.6	0.0	1.6	30.0		0.4	0.7	0.0	0.0
Euphausiid eggs	22.8		4.1	10.1	0.1	0.0	3.4		2.8	14.6	0.0	0.0	50.0	5	58.0	146.6	1.4	3.1
Primno macropa	36.8		2.4	6.1	0.0	0.0	20.7		0.5	1.7	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Ostracods	21.1		1.9	4.9	0.0	0.0	17.2	9	25.8	126.0	0.2	0.0	30.0	9	11.4	22.7	0.3	0.0
Spongiobranchaea australis	66.7		1.9	2.4	0.0	1.2	86.2		9.7	18.0	0.1	3.0	50.0		0.7	1.2	0.0	0.2
Euphausia triacantha	19.3		1.5	4.4	0.0	0.0	17.2		1.1	3.7	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Cyllopus magellanicus	70.2		1.3	1.6	0.0	0.8	75.9		6.7	9.7	0.0	0.8	60.0		1.1	1.4	0.0	0.6
Electrona spp.	19.3		1.3	3.9	0.0	0.0	3.4		0.0	0.3	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Polychaetes (unid.)	8.8		0.7	3.2	0.0	0.0	3.4		0.5	2.6	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Euphausia spp. (L)	1.8		0.6	4.6	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Gammarids	3.5		0.4	3.2	0.0	0.0	3.4		0.3	1.5	0.0	0.0	10.0		0.2	0.7	0.0	0.0
Tomopteris spp.	17.5		0.4	1.4	0.0	0.0	24.1		0.4	1.0	0.0	0.0	20.0		0.2	0.5	0.0	0.0
Limacina helicina	21.1		0.3	1.4	0.0	0.0	48.3		4.9	13.7	0.0	0.0	60.0		1.1	1.8	0.0	0.4
Pegantha martgon	33.3		0.3	0.6	0.0	0.0	24.1		0.3	0.7	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Sipunculids	7.0		0.3	1.2	0.0	0.0	3.4		0.0	0.1	0.0	0.0	70.0		0.8	0.9	0.0	0.4
Hyperiella dilatata	26.3		0.3	0.6	0.0	0.0	31.0		0.4	0.9	0.0	0.0	50.0		1.0	1.2	0.0	0.5
Mysids	1.8		0.2	1.3	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Hyperiids	1.8		0.2	1.2	0.0	0.0	6.9		0.4	2.3	0.0	0.0	20.0		0.9	1.8	0.0	0.0
Diphyes antarctica	17.5		0.1	0.4	0.0	0.0	3.4		0.0	0.2	0.0	0.0	90.0		1.1	1.2	0.0	0.4
Dimophyes arctica	14.0		0.1	0.4	0.0	0.0	6.9		0.1	0.6	0.0	0.0	50.0		0.4	0.5	0.0	0.2
Hyperoche medusarum	12.3		0.1	0.4	0.0	0.0	10.3		0.1	0.3	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Clione limacina	5.3		0.1	0.5	0.0	0.0	34.5		2.6	11.2	0.0	0.0	30.0		0.2	0.3	0.0	0.0
Pleurobrachia pileus	8.8		0.1	0.2	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Calycopsis borchgrevinki	8.8		0.1	0.3	0.0	0.0	3.4		0.0	0.1	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Gymnoscopelus braueri	10.5		0.1	0.2	0.0	0.0	3.4		0.0	0.1	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Lepidonotothen kempi	21.5		0.1	0.2	0.0	0.0	24.1		0.3	0.6	0.0	0.0	50.0		0.8	1.9	0.0	0.2
Beroe cucumis	5.3		0.1	0.3	0.0	0.0	6.9		0.1	0.3	0.0	0.0	20.0		0.1	0.1	0.0	0.0
Electrona carlsbergi	10.5		0.0	0.1	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Beroe forskalii	10.5		0.0	0.1	0.0	0.0	10.3		0.1	0.2	0.0	0.0	10.0		0.0	0.1	0.0	0.0
Electrona antarctica	5.3		0.0	0.2	0.0	0.0	6.9		0.1	0.2	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Lepidonotothen larseni	7.0		0.0	0.1	0.0	0.0	13.8		0.2	0.5	0.0	0.0	60.0		1.1	1.3	0.0	0.5
Fish eggs	3.5		0.0	0.2	0.0	0.0	0.0		0.0	0.0	0.0	0.0	10.0		0.2	0.6	0.0	0.0
Rhynchonereella bongraini	3.5		0.0	0.2	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Ctenophores	5.3		0.0	0.1	0.0	0.0	6.9		0.1	0.2	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Pleuragramma antarcticum (J)	3.5		0.0	0.1	0.0	0.0	6.9		0.4	2.0	0.0	0.0	10.0		0.1	0.2	0.0	0.0
Jellies (unid.)	3.5		0.0	0.1	0.0	0.0	6.9		0.0	0.2	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Gymnoscopelus nicholsi	5.3		0.0	0.1	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Cumaceans	1.8		0.0	0.1	0.0	0.0	3.4		0.1	0.5	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Clio pyramidata	3.5		0.0	0.1	0.0	0.0	20.7		1.2	2.8	0.0	0.0	20.0		0.1	0.2	0.0	0.0
Krefftichthys anderssoni (J)	1.8		0.0	0.1	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Callianira antarctica	3.5		0.0	0.1	0.0	0.0	0.0		0.0	0.0	0.0	0.0	30.0		0.2	0.4	0.0	0.0
Schyphomedusae	1.8		0.0	0.1	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Cephalopods	1.8		0.0	0.1	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Vanadis antarctica	1.8		0.0	0.1	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Siphonophores	1.8		0.0	0.1	0.0	0.0	3.4		0.0	0.1	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Eusirus perdentatus	1.8		0.0	0.1	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Hydromedusae	1.8		0.0	0.1	0.0	0.0	3.4		0.0	0.1	0.0	0.0	20.0		0.2	0.4	0.0	0.0
Laodicea undulata	1.8		0.0	0.1	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Larval fish (unid.)	1.8		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Gymnoscopelus bolini	1.8		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Limacina spp.	1.8		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Notothenia neglecta	1.8		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Notolepis spp.	0.0		0.0	0.0	0.0	0.0	3.4		0.5	2.6	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Botrynema brucei	0.0		0.0	0.0	0.0	0.0	3.4		0.0	0.1	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Ihlea racovitzai	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	30.0		3.2	8.6	0.1	0.0
Eusirus antarcticus	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	50.0		0.6	0.8	0.0	0.2
Notolepis coatsi	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	20.0		0.4	1.1	0.0	0.0
Bylgides pelagica	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	20.0		0.2	0.5	0.0	0.0
Adult myctophids	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	20.0		0.1	0.3	0.0	0.0
Electrona subaspera	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	20.0		0.1	0.2	0.0	0.0
Chionodraco rastrospinosus	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	10.0		0.1	0.2	0.0	0.0
Cyphocaris richardi	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	10.0		0.0	0.1	0.0	0.0
Orchomene plebs	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	10.0		0.0	0.1	0.0	0.0
TOTAL			7093.7	11637.2		2867.6			14163.4	26804.8		2908.1			4031.7	5051.6		1148.6
NO. TAXA	70		20.2	4.0		21.0	55		20.6	3.0		20.0	52		24.7	3.9		25.0

Table 4.5. Taxonomic composition and characteristics of zooplankton clusters in the large survey areas (A) January and (B) February-March 2001. Abundance is numbers per 1000 m^3. N(%) is proportion of total mean abundance contributed by each taxonomic category. (L) denotes larval stages.

A. SURVEY A	JANUARY 2001														
	CLUSTER 1 (N=24)					CLUSTER 2 (N=48)					CLUSTER 3 (N=29)				
TAXON	RANK	MEAN	STD	N(%)	MEDIAN	RANK	MEAN	STD	N(%)	MEDIAN	RANK	MEAN	STD	N(%)	MEDIAN
(TOTAL COPEPODS)		2132.4	1934.5	(64.0)	1332.4		340.8	744.6	(29.1)	128.8		5497.2	10434.5	(63.9)	1361.7
Calanoides acutus	4	177.3	151.7	5.3	141.6	3	105.9	151.4	9.0	51.5	1	3437.9	9311.1	39.9	515.8
Thysanoessa macrura (L)	8	78.1	129.6	2.3	19.5	4	88.1	199.3	7.5	17.8	2	1385.9	1750.4	16.1	659.8
Metridia gerlachi	1	1759.9	1814.8	52.8	960.3	2	168.1	648.9	14.3	10.7	3	907.9	1321.2	10.5	359.9
Other copepods	5	155.2	133.0	4.7	126.4	7	35.7	54.7	3.1	16.1	4	744.9	781.5	8.7	416.4
Chaetognaths	6	88.1	203.7	2.6	45.1		16.8	28.9	1.4	7.1	5	505.9	1249.1	5.9	160.0
Euphausia superba (L)	10	40.4	71.8	1.2	21.6		15.6	31.1	1.3	3.1	6	500.1	1261.6	5.8	72.5
Salpa thompsoni	2	542.1	408.4	16.3	432.2	1	563.1	625.9	48.1	366.6	7	438.1	343.9	5.1	356.6
Calanus propinquus	7	88.0	94.4	2.6	61.9	8	23.3	47.2	2.0	3.6	8	352.4	702.3	4.1	100.5
Radiolarians		1.2	2.8	0.0	0.0		0.4	1.5	0.0	0.0	9	159.1	652.6	1.8	0.0
Rhincalanus gigas		25.1	64.7	0.8	0.0		4.4	17.9	0.4	0.0	10	42.7	104.8	0.5	0.0
Cyllopus lucasii		17.3	24.7	0.5	9.8		14.3	19.7	1.2	6.5		40.2	29.6	0.5	34.2
Clio pyramidata		4.7	8.9	0.1	0.0		0.9	2.3	0.1	0.0		15.5	63.4	0.2	0.0
Thysanoessa macrura	3	201.1	203.5	6.0	86.6	5	49.5	58.0	4.2	33.6		14.0	27.8	0.2	7.8
Euphausia frigida	9	73.0	82.1	2.2	42.1	10	17.7	61.8	1.5	0.0		12.8	29.4	0.1	0.0
Ostracods		11.0	23.7	0.3	3.0	9	1.9	4.1	1.6	0.0		11.4	26.6	0.1	0.0
Vibilia antarctica		18.1	16.3	0.5	14.2		18.6	17.8	0.2	14.7		10.1	9.4	0.1	7.5
Limacina helicina		3.6	9.4	0.1	1.4		3.3	6.8	0.3	0.0		8.5	19.4	0.1	0.5
Themisto gaudichaudii		4.4	7.3	0.1	1.1		2.6	3.9	0.2	0.7		6.2	11.5	0.1	2.5
Euphausia superba		37.1	89.4	1.1	4.1	6	37.8	81.5	3.2	16.9		4.4	5.0	0.1	1.7
Spongiobranchaea australis		2.5	3.2	0.1	1.1		1.0	1.3	0.1	0.4		3.7	3.9	0.0	2.1
Tomopteris spp.		1.9	4.9	0.1	0.0		1.2	2.7	0.1	0.0		3.2	7.5	0.0	0.7
Clione limacina		1.4	4.6	0.0	0.0		0.2	0.5	0.0	0.0		0.7	2.1	0.0	0.0
Hyperiella dilatata		0.4	1.1	0.0	0.0		0.3	1.1	0.0	0.0		0.5	1.1	0.0	0.0
Cyllopus magellanicus		0.7	1.3	0.0	0.0		0.5	1.3	0.0	0.0		0.5	1.1	0.0	0.0
Beroe cucumis		0.5	1.0	0.0	0.0		0.2	0.6	0.0	0.0		0.2	0.5	0.0	0.0
Diphyes antarctica		0.9	1.8	0.0	0.0		0.3	1.0	0.0	0.0		0.2	0.4	0.0	0.0
TOTAL		3334.2					1171.6					8606.8			

B. SURVEY D	FEBRUARY-MARCH 2001														
	CLUSTER 1 (N=27)					CLUSTER 2 (N=42)					CLUSTER 3 (N=27)				
TAXON	RANK	MEAN	STD	N(%)	MEDIAN	RANK	MEAN	STD	N(%)	MEDIAN	RANK	MEAN	STD	N(%)	MEDIAN
(TOTAL COPEPODS)		5206.3	4157.2	(59.7)	3150.7		322.0	460.1	(24.6)	156.9		15326.3	23787.6	(73.4)	4025.4
Calanoides acutus	3	481.3	900.3	5.5	129.5	4	103.2	154.3	7.9	41.8	1	13206.7	21802.7	63.3	2821.8
Euphausia superba (L)	10	66.6	161.3	0.8	20.8	9	19.9	85.5	1.5	0.0	2	2332.3	6514.7	11.2	145.3
Thysanoessa macrura (L)	5	391.3	501.4	4.5	270.2	2	330.3	700.2	25.2	48.3	3	1648.8	2396.8	7.9	815.9
Metridia gerlachei	1	4294.7	4074.8	49.3	2555.2	3	123.3	330.4	9.4	10.6	4	787.0	1361.8	3.8	202.3
Radiolarians		8.4	39.2	0.1	0.0		0.7	2.5	0.1	0.0	5	759.2	2223.1	3.6	42.7
Calanus propinquus	7	169.8	140.1	1.9	122.2	7	34.2	42.1	2.6	17.1	6	610.2	577.9	2.9	346.9
Chaetognaths		31.0	54.2	0.4	4.6	8	32.8	55.6	2.5	7.9	7	502.8	600.6	2.4	285.7
Copepidites		64.3	69.4	0.7	52.0	6	41.5	102.6	3.2	3.7	8	376.9	546.5	1.8	147.6
Salpa thompsoni	4	476.3	464.0	5.5	337.5	1	466.6	484.9	35.6	342.2	9	191.9	141.8	0.9	129.0
Other copepods		8.3	16.7	0.1	0.0		5.8	13.4	0.4	0.0	10	180.0	397.9	0.9	10.5
Rhincalanus gigas		3.9	13.2	0.0	0.0		2.6	5.4	0.2	0.0		91.8	188.9	0.4	8.4
Pareucheata antarctica	6	171.6	182.2	2.0	97.7		10.4	24.5	0.8	0.0		66.5	86.4	0.3	22.0
Cyllopus lucasii		29.0	36.8	0.3	15.7	10	19.0	20.2	1.4	13.3		36.0	30.2	0.2	27.7
Ostracods		6.3	15.7	0.1	0.0		0.9	2.3	0.1	0.0		28.1	130.3	0.1	0.0
Euphausia superba	8	165.6	529.5	1.9	23.5		18.3	66.1	1.4	2.7		15.6	55.2	0.1	2.4
Spongiobranchaea australis		1.5	2.4	0.0	0.4		1.8	3.3	0.1	0.5		10.4	18.2	0.0	4.3
Vibilia antarctica		12.1	13.1	0.1	8.1		11.2	13.7	0.9	7.2		9.1	14.4	0.0	5.0
Themisto gaudichaudii		4.7	7.0	0.1	1.2		2.8	4.4	0.2	1.1		6.2	7.5	0.0	4.8
Thysanoessa macrura	2	2184.7	10434.2	25.1	68.2	5	52.5	50.6	4.0	35.1		5.6	13.2	0.0	0.5
Primno macropa		0.7	2.6	0.0	0.0		0.3	0.8	0.0	0.0		4.4	8.2	0.0	0.7
Euphausiid eggs		4.6	13.1	0.1	0.0		15.7	75.4	1.2	0.0		4.0	15.9	0.0	0.0
Cyllopus magellanicus		3.5	6.6	0.0	1.4		3.4	6.6	0.3	0.7		1.6	4.0	0.0	0.4
Limacina helicina		0.2	0.4	0.0	0.0		3.3	11.6	0.3	0.0		1.0	2.5	0.0	0.0
Pegantha martgon		0.3	0.6	0.0	0.0		0.1	0.4	0.0	0.0		0.5	0.9	0.0	0.0
Hyperiella dilatata		0.5	1.0	0.0	0.0		0.3	0.8	0.0	0.0		0.4	0.7	0.0	0.4
Euphausia frigida	9	134.7	130.5	1.5	88.2		9.3	25.8	0.7	0.0		0.4	1.9	0.0	0.0
Diphyes antarctica		0.2	0.7	0.0	0.0		0.3	0.7	0.0	0.0		0.0	0.1	0.0	0.0
TOTAL		8716.0					1310.6					20877.6			

Table 4.6. Abundance of krill and other dominant zooplankton taxa collected in the Elephant Island area during January-February and February-March surveys, 1992-2001. Zooplankton data not available for February-March 1992 or January 2000.

	Euphausia superba January-February									
Year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
N	63	70	63	71	72	71	61	40		60
Mean	23.7	28.8	34.5	9.5	82.1	29.6	27.1	5.3	n.a.	18.9
SD	78.0	64.4	94.2	20.6	245.1	80.5	42.3	8.1	n.a.	32.7
Med	5.7	8.2	3.1	3.6	11.4	5.6	10.2	1.7	n.a.	6.0
Max	594.1	438.9	495.9	146.1	1500.6	483.2	175.0	35.1	n.a.	217.7
	February-March									
Year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
N	67	67	70	71	72	16	61	39	60	57
Mean	38.0	35.0	17.1	5.2	133.2	30.4	162.6	35.5	14.4	80.5
SD	77.4	89.7	63.5	12.0	867.7	56.4	768.3	155.7	35.3	374.0
Med	7.1	3.0	0.4	1.2	4.1	4.6	4.5	0.8	3.3	4.6
Max	389.9	542.0	371.1	90.0	7385.4	204.2	5667.0	978.6	253.5	2817.0

	Thysanoessa macrura January-February									
Year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
N	63	70	63	71	72	71	61	40		60
Mean	48.1	48.6	74.6	104.1	103.4	101.0	135.3	46.6	n.a.	46.2
SD	57.0	60.1	144.3	231.9	118.1	127.2	150.8	54.1	n.a.	49.2
Med	22.5	27.5	25.4	36.1	52.3	52.8	98.0	23.2	n.a.	32.2
Max	233.7	307.1	901.6	1859.0	500.1	616.2	992.3	215.8	n.a.	251.7
	February-March									
Year	1992	1993*	1994	1995	1996	1997	1998	1999	2000	2001
N		67	70	71	72	16	61	39	60	57
Mean	n.a.	128.9	77.1	79.7	116.1	181.3	140.6	95.2	35.1	1040.9
SD	n.a.	235.1	132.6	138.5	147.4	168.0	232.3	131.9	61.5	7262.6
Med	n.a.	22.1	23.8	22.2	53.6	122.6	70.0	18.0	14.0	44.1
Max	n.a.	1141.5	815.9	664.9	679.4	538.9	1638.5	589.2	291.6	55381.1

	Salpa thompsoni January-February									
Year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
N	63	70	63	71	72	71	61	40		60
Mean	94.3	1213.4	931.9	20.2	25.5	223.2	939.7	197.5	n.a.	622.8
SD	192.3	2536.7	950.2	46.5	36.3	336.4	1556.3	191.6	n.a.	576.4
Med	14.0	245.8	582.3	1.6	10.5	87.1	348.9	159.1	n.a.	449.3
Max	1231.1	16078.8	4781.7	239.9	161.6	2006.3	8030.4	873.4	n.a.	3512.4
	February-March									
Year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
N	67	67	70	71	72	16	61	39	60	57
Mean	n.a.	1585.9	495.1	20.6	33.2	1245.5	977.3	309.1	912.8	452.4
SD	n.a.	2725.5	579.4	66.5	85.7	1224.6	1496.5	376	3395.1	501.2
Med	n.a.	605.9	242.6	0.7	5.6	521.0	553.8	160.7	262.9	312.1
Max	n.a.	16662.5	2377.5	391.9	659.4	4348.3	10712.9	1550.2	24031.9	2416.8

	Copepods January-February									
Year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
N	63	70	63	71	72	71	61	40		60
Mean	n.a	73.5	32.4	741.0	897.5	656.4	41.2	928.2	n.a.	1003.2
SD	n.a	302.7	92.2	1061.3	1726.4	799.1	55.1	1590.8	n.a.	1582.4
Med	n.a	0.0	0.0	346.0	338.2	399.7	21.5	333.0	n.a.	252.2
Max	n.a	2312.6	465.3	7047.5	10598.0	4090.0	276.0	7524.8	n.a.	6909.7
	February-March									
Year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
N	67	67	70	71	72	16	61	39	60	57
Mean	n.a.	n.a.	3453.3	3707.3	1483.7	1267.8	110.4	1558.4	8019.1	4501.5
SD	n.a.	n.a.	8190.8	5750.3	2209.2	1755.6	170.3	2337.5	11824.4	8072.4
Med	n.a.	n.a.	172.4	1630.9	970.2	659.8	50.9	621.6	3478.0	1518.0
Max	n.a.	n.a.	37987.2	40998.5	16621.0	7289.2	901.1	10786.6	57498.5	39800.7

Table 4.6. (Contd.)

	Euphausia superba Larvae									
	January-February									
Year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
N	63	70	63	71	72	71	61	40		60
Mean	n.a.	n.a.	n.a.	172.1	3.4	19.3	0.4	175.1	n.a.	32.8
SD	n.a.	n.a.	n.a.	969.4	8.3	27.0	1.6	795.5	n.a.	86.2
Med	n.a.	n.a.	n.a.	0.0	0.0	6.4	0.0	4.3	n.a.	9.0
Max	n.a.	n.a.	n.a.	8076.1	42.7	96.5	11.4	5083.2	n.a.	654.0
	February-March									
Year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
N	67	67	70	71	72	16	61	39	60	57
Mean	n.a.	n.a.	n.a.	4593.4	14.1	25.0	2.5	67.2	3423.2	71.9
SD	n.a.	n.a.	n.a.	20117.0	44.0	81.4	18.3	146.0	8974.1	176.9
Med	n.a.	n.a.	n.a.	268.6	3.3	0.0	0.0	12.3	248.7	5.1
Max	n.a.	n.a.	n.a.	167575.6	368.5	339.0	144.1	692.5	44478.2	1197.7

Thysanoessa macrura larvae									
January-February									
1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
63	70	63	71	72	71	61	40		60
n.a.	n.a.	n.a.	20.2	372.0	21.5	0.0	116.5	n.a.	269.3
n.a.	n.a.	n.a.	75.2	858.1	38.4	0.0	348.8	n.a.	608.8
n.a.	n.a.	n.a.	0.0	32.1	1.5	0.0	2.8	n.a.	42.7
n.a.	n.a.	n.a.	441.5	4961.8	159.9	0.0	1519.6	n.a.	3621.0
February-March									
1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
67	67	70	71	72	16	61	39	60	57
n.a.	n.a.	31.7	344.3	511.5	10.8	0.5	185.9	1084.8	613.3
n.a.	n.a.	111.1	594.2	1432.5	24.9	2.0	535.7	4147.3	1009.5
n.a.	n.a.	0.0	79.9	36.1	1.0	0.0	10.0	26.8	265.3
n.a.	n.a.	809.1	3735.5	10875.0	104.7	12.1	2990.8	31132.5	5461.9

	Euphausia frigida									
	January-February									
Year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
N	63	70	63	71	72	71	61	40		60
Mean	5.4	4.2	4.7	12.1	2.0	9.6	0.3	15.9	n.a.	23.4
SD	14.9	18.4	14.9	32.1	4.5	21.4	1.4	29.1	n.a.	55.9
Med	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	n.a.	0
Max		143.0	76.7	175.6	22.5	91.4	10.0	116.0	n.a.	315.6
	February-March									
Year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
N	67	67	70	71	72	16	61	39	60	57
Mean	n.a.	1.0	28.9	19.7	9.5	44.8	9.0	23.0	43.1	37.7
SD	n.a.	4.7	62.0	36.7	12.7	54.2	26.0	38.7	73.0	82.0
Med	n.a,	0.0	5.5	2.9	1.2	21.0	0.0	7.6	6.8	0.0
Max	n.a.	32.6	439.7	216.1	48.8	176.2	178.4	159.1	307.2	319.2

Chaetognaths									
January-February									
1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
63	70	63	71	72	71	61	40		60
n.a.	3.1	0.2	84.7	11.9	20.1	3.3	63.9	n.a.	57.4
n.a.	7.9	0.5	159.5	25.1	26.1	5.2	159.1	n.a.	110.9
n.a.	0.0	0.0	30.0	4.2	10.3	0.9	14.7	n.a.	11.3
n.a.	41.3	2.2	781.8	184.9	120.4	24.7	960.2	n.a.	660.7
February-March									
1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
67	67	70	71	72	16	61	39	60	57
n.a.	0.7	21.8	330.2	58.4	18.4	8.9	147.4	792.3	93.5
n.a.	4.2	87.7	404.6	72.3	23.9	23.3	261.4	1543.7	173.4
n.a.	0.0	0.0	161.0	31.8	5.5	1.0	48.7	229.4	10.5
n.a.	34.9	578.9	1769.9	383.8	77.9	124.7	1146.6	8221.0	836.9

Table 4.7. Maturity stage composition of krill collected in the Elephant Island area during 2001 compared to 1992-2000. Advanced maturity stages are proportions of mature females that are (A) 3c-3e in January-February and (B) 3d-3e in February-March. Data are not available for January-February, 2000.

A. SURVEY A	ELEPHANT ISLAND AREA KRILL JANUARY-FEBRUARY									
Stage	1992 %	1993 %	1994 %	1995 %	1996 %	1997 %	1998 %	1999 %	2000 %	2001 %
Juveniles	37.1	7.2	4.0	4.6	55.0	15.2	18.4	0.4	n.a.	9.7
Immature	19.1	30.7	18.8	4.0	18.3	30.6	31.7	11.7	n.a.	6.2
Mature	43.9	62.2	77.2	91.4	26.7	54.2	49.9	87.9	n.a.	84.1
Females:										
F2	0.8	7.8	2.3	0.1	1.1	6.3	9.1	1.6	n.a.	0.2
F3a	0.6	11.7	18.0	0.2	0.0	3.5	21.4	1.7	n.a.	0.9
F3b	12.3	14.3	19.3	1.2	0.2	0.6	9.0	1.8	n.a.	14.6
F3c	9.2	5.1	20.1	15.3	1.9	6.9	1.0	14.7	n.a.	13.2
F3d	0.4	1.2	2.3	17.7	0.7	6.1	0.3	23.9	n.a.	7.4
F3e	0.0	0.0	0.0	3.7	11.6	7.4	0.7	9.2	n.a.	1.3
Advanced Stages	42.7	19.5	37.5	96.3	98.3	83.2	6.2	93.2	n.a.	58.5
Males:										
M2a	8.7	6.8	0.3	0.9	14.6	14.6	8.5	2.2	n.a.	2.1
M2b	7.3	11.9	9.4	1.5	2.1	8.2	8.4	3.9	n.a.	2.1
M2c	2.3	4.2	6.8	1.5	0.5	1.5	5.7	4.1	n.a.	1.7
M3a	2.8	3.7	4.3	4.4	1.4	1.5	3.1	1.7	n.a.	2.1
M3b	18.7	26.2	13.2	48.9	10.9	28.1	14.4	34.9	n.a.	44.6
Male:Female ratio	1.7	1.3	0.5	1.5	1.9	1.8	1.0	0.9	n.a.	1.4
No. measured	2472	4283	2078	2294	4296	3209	3600	751	n.a.	2063

B. SURVEY D	FEBRUARY-MARCH									
Stage	1992 %	1993 %	1994 %	1995 %	1996 %	1997 %	1998 %	1999 %	2000 %	2001 %
Juveniles	33.6	3.5	3.7	1.1	20.8	8.0	3.6	0.0	0.1	13.4
Immature	27.1	51.4	6.2	2.5	9.9	19.7	25.4	1.3	2.3	14.7
Mature	39.2	45.1	90.1	96.4	69.3	72.3	71.0	98.7	97.5	71.9
Females:										
F2	0.8	21.8	0.7	0.3	0.6	1.1	6.9	0.0	0.2	0.7
F3a	10.3	12.4	3.5	0.0	0.0	0.1	10.9	0.4	1.0	2.4
F3b	10.2	6.2	7.8	0.0	0.0	0.0	11.8	0.0	0.7	0.2
F3c	4.3	3.7	4.3	2.0	5.0	1.8	3.0	11.1	6.5	1.5
F3d	1.2	1.1	4.6	21.8	10.9	29.1	1.3	47.3	21.9	3.8
F3e	<0.01	1.2	0.9	20.4	4.9	7.3	0.1	4.8	22.0	42.6
Advanced Stages	4.6	9.3	26.1	95.5	76.0	95.0	5.2	81.8	84.2	91.8
Males:										
M2a	4.3	6.9	0.2	0.7	6.5	8.6	1.9	0.0	0.1	4.1
M2b	19.8	19.1	1.2	0.4	1.2	8.8	6.6	0.7	0.7	2.7
M2c	2.2	3.6	4.2	1.1	1.6	1.2	10.0	0.6	1.3	7.3
M3a	2.5	2.1	24.1	4.4	5.3	3.7	17.5	2.6	7.4	2.2
M3b	10.7	18.4	44.7	47.8	43.2	30.3	26.2	32.4	38.0	19.2
Male:Female ratio	1.5	1.1	3.4	1.2	2.7	1.3	1.9	0.6	0.9	0.7
No. measured	3646	3669	1155	1271	2984	560	3153	1176	1371	1739

Table 4.8. Salp and krill carbon biomass (mg C per m^2) in the Elephant Island area during 1994-2001 surveys. N is number of samples. Salp:Krill ratio is based on median values.

	January-February															
	1994		1995		1996		1997		1998		1999		2000		2001	
Biomass	Salps	Krill	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.	334.5	248.5
SD	563.2	856.4	16.1	201.1	30.9	756.1	1116	522.1	565.3	290.6	166.1	66.1	n.a.	n.a.	272.8	425.3
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.	251.7	81.0
Maximum	3277	4971	75.3	1545	134.2	4721.0	9435	3115.5	2699.0	1488.4	882.7	304.4	n.a.	n.a.	1395.1	2561.2
N	63	63	57	71	72	72	71	71	61	60	40	40	n.a.	n.a.	60	60
Salp:Krill Ratio	15.6		0.03		0.1		2.4		4.0		6.4		n.a.		3.1	

	February-March															
	1994		1995		1996		1997		1998		1999		2000		2001	
Biomass	Salps	Krill	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	1140	313.1	694.6	1555.8	321.9	451.0	741.2	204.4	333.9	890.3
SD	469.5	2351	47.3	149.1	146.5	12441.6	1270	655.2	1121	8218.7	335.1	2082.6	2314.9	507.6	352.4	4116.8
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	216.3	45.9
Maximum	1844	19314	325.2	1107.1	954.0	106458.5	4645	2639	8543.0	62155.8	1698.1	13133.1	16400.1	3634.6	1702.8	30967.9
N	70	70	71	71	72	72	16	16	61	60	39	39	60	60	57	57
Salp:Krill Ratio	102.0		0.1		0.1		10.1		12.0		28.0		5.6		4.7	

Table 4.9 Zooplankton and nekton taxa present in the large survey area samples during (A) January 2001 and (B) February-March 2001 compared to 1994-2000 surveys. F is the frequency of occurrence (%) in (N) tows. Mean is number per 1000 m^3. n.a. indicates taxon was not enumerated. (L) and (J) denote larval and juvenile stages.

A. SURVEY A	JANUARY -FEBRUARY															
	2001		2000		1999		1998		1997		1996		1995		1994	
	N=101		N=0		N=75		N=105		N=105		N=91		N=90		N=91	
TAXON	F(%)	Mean	F(%)	Mean	F(%)	Mean	F(%)	Mean	F(%)	Mean	F(%)	Mean	F(%)	Mean	F(%)	Mean
Copepods	100.0	2247.1	n.a.	n.a.	100.0	711.6	94.2	56.5	100.0	582.6	100.0	794.4	98.9	652.7	30.0	41.3
Salpa thompsoni	100.0	520.7	n.a.	n.a.	100.0	163.3	100.0	808.2	97.1	181.4	64.8	20.4	66.7	16.0	100.0	818.3
Vibilia antarctica	98.0	16.3	n.a.	n.a.	94.7	3.8	96.2	13.2	70.5	2.5	48.4	0.5	22.2	0.2	98.8	11.8
Thysanoessa macrura	93.1	73.5	n.a.	n.a.	93.3	135.1	100.0	180.8	97.1	104.4	98.9	106.9	91.1	96.4	90.0	79.7
Euphausia superba	89.1	27.7	n.a.	n.a.	60.0	6.1	92.3	36.8	93.3	40.4	96.7	112.5	87.8	14.5	77.5	27.1
Cyllopus lucasii	87.1	22.4	n.a.	n.a.	6.7	0.0	20.2	0.5	49.5	0.4	11.0	0.1	22.2	0.5	16.3	0.7
Thysanoessa macrura (L)	85.1	458.0	n.a.	n.a.	69.3	72.5	1.9	0.0	44.8	17.0	90.1	308.5	36.7	15.9	n.a	n.a
Chaetognaths	84.2	174.2	n.a.	n.a.	49.3	47.8	42.3	8.9	74.3	22.9	68.1	12.5	98.9	79.7	n.a	n.a
Euphausia superba (L)	68.3	160.2	n.a.	n.a.	65.3	103.1	11.5	1.0	55.2	15.2	22.0	2.7	22.2	135.8	n.a	n.a
Spongiobranchaea australis	68.3	2.1	n.a.	n.a.	69.3	1.4	45.2	0.9	67.6	2.2	47.3	1.8	64.4	0.5	11.3	0.1
Themisto gaudichaudii	66.3	4.0	n.a.	n.a.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Limacina helicina	51.5	4.9	n.a.	n.a.	61.3	2.4	73.1	8.1	47.6	2.9	74.7	33.7	43.3	1.9	6.3	0.3
Euphausia frigida	45.5	28.8	n.a.	n.a.	32.0	8.9	5.8	0.2	41.9	14.8	30.8	1.9	50.0	9.8	17.5	3.8
Tomopteris spp.	45.5	1.9	n.a.	n.a.	56.0	2.0	31.7	1.3	54.3	1.9	60.4	0.9	84.4	4.2	37.5	2.5
Ostracods	37.6	6.7	n.a.	n.a.	49.3	2.8	51.0	4.8	41.0	5.5	53.8	4.9	56.7	9.7	n.a	n.a
Clio pyramidata	32.7	5.9	n.a.	n.a.	9.3	0.1	4.8	0.3	2.9	0.0	6.6	0.1	72.2	5.3	40.0	5.4
Cyllopus magellanicus	30.7	0.5	n.a.	n.a.	78.7	2.0	64.4	1.9	76.2	3.8	41.8	1.6	24.4	0.2	82.5	6.3
Clione limacina	26.7	0.9	n.a.	n.a.	17.3	0.1	38.5	0.9	21.9	0.3	56.0	2.1	41.1	0.5	13.8	0.3
Hyperiella dilatata	24.8	0.4	n.a.	n.a.	52.0	0.5	39.4	0.4	56.2	2.2	41.8	0.6	54.4	0.3	18.7	0.3
Diphyes antarctica	23.8	0.5	n.a.	n.a.	34.7	0.5	37.5	1.1	9.5	0.2	17.6	0.1	58.9	1.0	20.0	0.3
Beroe cucumis	20.8	0.3	n.a.	n.a.	4.0	0.0	3.8	0.0	15.2	0.1	7.7	0.0	12.2	0.0	15.0	0.1
Radiolaria	19.8	46.1	n.a.	n.a.	40.0	8.9	27.9	0.7	41.0	1.8	12.1	0.1	0.0	0.0	n.a	n.a
Larval fish	18.8	0.6	n.a.	n.a.	9.3	0.1	8.7	0.1	0.0	0.0	1.1	0.0	0.0	0.0	0.0	0.0
Beroe forskalii	17.8	0.2	n.a.	n.a.	2.7	0.0	1.0	0.0	0.0	0.0	1.1	0.0	0.0	0.0	0.0	0.0
Jellies(unid.)	16.8	0.6	n.a.	n.a.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hydromedusae	14.9	0.4	n.a.	n.a.	37.3	0.2	0.0	0.0	20.0	0.1	4.4	0.0	6.7	0.1	0.0	0.0
Euphausia triacantha	13.9	1.6	n.a.	n.a.	17.3	0.4	7.7	0.3	18.1	1.4	15.4	0.5	33.3	1.5	7.5	1.2
Ihlea racovitzai	12.9	1.1	n.a.	n.a.	25.3	3.3	5.8	41.5	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Hyperiids	12.9	0.7	n.a.	n.a.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lepidonotothen larseni (L)	10.9	0.7	n.a.	n.a.	20.0	0.2	23.1	0.5	27.6	1.8	22.0	0.2	40.0	1.1	6.3	0.7
Electrona spp. (L)	10.9	0.4	n.a.	n.a.	24.0	0.2	10.6	0.2	37.1	1.4	27.5	0.7	61.1	2.5	2.5	0.0
Dimophyes arctica	10.9	0.2	n.a.	n.a.	6.7	0.1	2.9	0.1	19.0	0.3	15.4	0.1	25.6	0.8	7.5	0.0
Polychaetes	7.9	0.7	n.a.	n.a.	20.0	0.6	28.8	1.5	1.0	0.0	1.1	0.0	0.0	0.0	0.0	0.0
Lepidonotothen kempi	7.9	0.4	n.a.	n.a.	6.7	0.0	13.5	0.3	32.4	0.6	30.8	0.3	20.0	0.1	6.3	0.3
Primno macropa	7.9	0.1	n.a.	n.a.	69.3	2.5	26.0	0.7	63.8	4.3	20.9	0.1	20.0	0.1	6.3	0.5
Hyperiella spp.	5.9	0.1	n.a.	n.a.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Electrona antarctica	5.9	0.0	n.a.	n.a.	1.3	0.0	3.8	0.1	9.5	0.0	13.2	0.0	13.3	0.1	2.5	0.0
Hyperoche medusarum	5.0	0.1	n.a.	n.a.	5.3	0.0	1.0	0.0	1.0	0.0	3.3	0.0	18.9	0.0	0.0	0.0
Botrynema brucei	5.0	0.1	n.a.	n.a.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.0	0.0	0.0
Vanadis antarctica	5.0	0.1	n.a.	n.a.	5.3	0.1	4.8	0.1	1.0	0.0	4.4	0.0	15.6	0.1	2.5	0.0
Ctenophores	5.0	0.1	n.a.	n.a.	6.7	0.0	3.8	0.1	16.2	0.1	0.0	0.0	6.7	0.0	0.0	0.0
Calycopsis borchgrevinki	4.0	0.2	n.a.	n.a.	2.7	0.0	1.0	0.0	2.9	0.0	2.2	0.0	1.1	0.0	1.3	0.0
Pleuragramma antarcticum (J)	4.0	0.1	n.a.	n.a.	1.3	0.1	4.8	0.0	2.9	0.0	1.1	0.0	2.2	0.0	0.0	0.0
Siphonophores	3.0	0.3	n.a.	n.a.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pelagobia longicirrata	3.0	0.0	n.a.	n.a.	0.0	0.0	0.0	0.0	1.0	0.0	1.1	0.0	0.0	0.0	0.0	0.0
Sipunculids	3.0	0.0	n.a.	n.a.	10.7	0.0	11.5	0.1	10.5	0.1	7.7	0.0	24.4	0.1	0.0	0.0
Notolepis spp. (L)	2.0	0.0	n.a.	n.a.	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Scyphomedusae	2.0	0.0	n.a.	n.a.	1.3	0.0	1.9	0.0	1.0	0.0	13.2	0.1	0.0	0.0	1.3	0.0
Cyllopus sp.	2.0	0.0	n.a.	n.a.	28.0	0.4	1.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Electrona carlsbergi	2.0	0.0	n.a.	n.a.	2.7	0.0	1.0	0.0	10.5	0.1	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Scina spp.	1.0	0.1	n.a.	n.a.	0.0	0.0	0.0	0.0	4.8	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Eusirus perdentatus	1.0	0.0	n.a.	n.a.	1.3	0.0	0.0	0.0	0.0	0.0	1.1	0.0	22.2	0.1	0.0	0.0
Mysids	1.0	0.0	n.a.	n.a.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rhynchonereella bongraini	1.0	0.0	n.a.	n.a.	33.3	0.8	9.6	0.2	4.8	0.1	2.2	0.0	3.3	0.1	0.0	0.0
Euphausia crystallorphorias	1.0	0.0	n.a.	n.a.	9.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	4.4	0.0	0.0	0.0
Cumaceans	1.0	0.0	n.a.	n.a.	0.0	0.0	0.0	0.0	3.8	0.4	1.1	0.0	0.0	0.0	0.0	0.0
Cephalopods	1.0	0.0	n.a.	n.a.	1.3	0.0	1.0	0.0	0.0	0.0	0.0	0.0	2.2	0.0	0.0	0.0
Hyperia antarctica	1.0	0.0	n.a.	n.a.	0.0	0.0	0.0	0.0	1.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Epimeriella macronyx	1.0	0.0	n.a.	n.a.	0.0	0.0	5.8	0.2	1.9	1.4	1.1	0.0	8.9	0.0	0.0	0.0
Maupasia coeca	1.0	0.0	n.a.	n.a.	1.3	0.0	0.0	0.0	1.9	0.0	1.1	0.0	0.0	0.0	0.0	0.0
Orchomene rossi	1.0	0.0	n.a.	n.a.	4.0	0.0	0.0	0.0	8.6	0.0	0.0	0.0	5.6	0.0	0.0	0.0
Notolepis coatsi (L)	1.0	0.0	n.a.	n.a.	5.3	0.0	3.8	0.0	6.7	0.0	8.8	0.0	27.8	0.1	0.0	0.0
Electrona subaspera	1.0	0.0	n.a.	n.a.	0.0	0.0	0.0	0.0	0.0	0.0	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Gymnoscopelus braueri	1.0	0.0	n.a.	n.a.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 4.9. (Contd.)

A. SURVEY A	JANUARY -FEBRUARY															
	2001		2000		1999		1998		1997		1996		1995		1994	
TAXON	F(%)	Mean	F(%)	Mean	F(%)	Mean	F(%)	Mean	F(%)	Mean	F(%)	Mean	F(%)	Mean	F(%)	Mean
Acanthepyra pelagica	0.0	0.0	n.a.	n.a.	17.3	0.2	3.8	0.0	9.5	0.1	0.0	0.0	22.2	0.1	0.0	0.0
Euphausia spp. (L)	0.0	0.0	n.a.	n.a.	10.7	11.1	0.0	0.0	0.0	0.0	1.1	0.0	0.0	0.0	0.0	0.0
Bolinopsis infundibulum	0.0	0.0	n.a.	n.a.	5.3	0.0	1.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hyperiella macronyx	0.0	0.0	n.a.	n.a.	2.7	0.0	2.9	0.1	8.6	0.1	5.5	0.0	23.3	0.1	0.0	0.0
Gammarids	0.0	0.0	n.a.	n.a.	2.7	0.0	1.0	0.0	0.0	0.0	1.1	0.0	0.0	0.0	0.0	0.0
Notolepis annulata (L)	0.0	0.0	n.a.	n.a.	2.7	0.0	0.0	0.0	1.0	0.0	0.0	0.0	13.3	0.0	0.0	0.0
Decapod larvae	0.0	0.0	n.a.	n.a.	1.3	0.0	2.9	0.0	0.0	0.0	2.2	0.2	0.0	0.0	0.0	0.0
Chionodraco rastrospinosus (L)	0.0	0.0	n.a.	n.a.	1.3	0.0	1.9	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Fish Eggs	0.0	0.0	n.a.	n.a.	1.3	0.0	1.0	0.0	2.9	0.1	1.1	0.0	4.4	0.0	0.0	0.0
Gobionotothen gibberifrons (L)	0.0	0.0	n.a.	n.a.	1.3	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.1	0.0	0.0	0.0
Vogtia serrata	0.0	0.0	n.a.	n.a.	1.3	0.0	0.0	0.0	3.8	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Bylgides pelagica	0.0	0.0	n.a.	n.a.	1.3	0.0	0.0	0.0	2.9	0.1	0.0	0.0	5.6	0.0	0.0	0.0
Periphylla periphylla	0.0	0.0	n.a.	n.a.	1.3	0.0	0.0	0.0	0.0	0.0	1.1	0.0	1.1	0.0	0.0	0.0
Notothenia coriiceps	0.0	0.0	n.a.	n.a.	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.0	1.3	0.0
Patagonitothen b. guntheri (J)	0.0	0.0	n.a.	n.a.	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Chaenocephalus aceratus (L)	0.0	0.0	n.a.	n.a.	0.0	0.0	3.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Orchomene plebs	0.0	0.0	n.a.	n.a.	0.0	0.0	1.0	0.0	2.9	0.0	1.1	0.0	4.4	0.0	1.3	0.0
Bathylagus sp. (L)	0.0	0.0	n.a.	n.a.	0.0	0.0	1.0	0.0	1.0	0.0	2.2	0.0	8.9	0.0	0.0	0.0
Artededraco skottsbergi (L)	0.0	0.0	n.a.	n.a.	0.0	0.0	1.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hyperia macrocephala	0.0	0.0	n.a.	n.a.	0.0	0.0	1.0	0.1	1.0	0.0	0.0	0.0	3.3	0.0	1.3	0.0
Eusirus sp.	0.0	0.0	n.a.	n.a.	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bolinopsis sp.	0.0	0.0	n.a.	n.a.	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Eusirus antarcticus	0.0	0.0	n.a.	n.a.	0.0	0.0	1.0	0.0	0.0	0.0	1.1	0.0	0.0	0.0	0.0	0.0
Gymnoscopelus opisthopteris	0.0	0.0	n.a.	n.a.	0.0	0.0	0.0	0.0	3.8	0.0	2.2	0.0	7.8	0.0	0.0	0.0
Atolla wyvillei	0.0	0.0	n.a.	n.a.	0.0	0.0	0.0	0.0	2.9	0.0	1.1	0.0	7.8	0.0	0.0	0.0
Krefftichthys anderssoni (L)	0.0	0.0	n.a.	n.a.	0.0	0.0	0.0	0.0	1.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gymnoscopelus nicholsi	0.0	0.0	n.a.	n.a.	0.0	0.0	0.0	0.0	1.9	0.0	1.1	0.0	1.1	0.0	0.0	0.0
Cyphocaris richardi	0.0	0.0	n.a.	n.a.	0.0	0.0	0.0	0.0	1.9	0.0	0.0	0.0	4.4	0.0	0.0	0.0
Krefftichthys anderssoni	0.0	0.0	n.a.	n.a.	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Travisiopsis coniceps	0.0	0.0	n.a.	n.a.	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Artededraco sp. B (L)	0.0	0.0	n.a.	n.a.	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Oediceroides calmani	0.0	0.0	n.a.	n.a.	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Thyphloscolex muelleri	0.0	0.0	n.a.	n.a.	0.0	0.0	0.0	0.0	1.0	0.0	4.4	0.0	0.0	0.0	0.0	0.0
Chorismus antarcticus	0.0	0.0	n.a.	n.a.	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.0	0.0	0.0	0.0	0.0
Cryodraco antarctica (L)	0.0	0.0	n.a.	n.a.	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.0	0.0	0.0	0.0	0.0
Artededraco mirus (L)	0.0	0.0	n.a.	n.a.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.0	0.0	0.0
Arctapodema ampla	0.0	0.0	n.a.	n.a.	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.0	0.0	0.0	0.0	0.0
Chaenodraco wilsoni (L)	0.0	0.0	n.a.	n.a.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Travisiopsis levinseni	0.0	0.0	n.a.	n.a.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.0	0.0	0.0
Lepidonotothen nudifrons (L)	0.0	0.0	n.a.	n.a.	0.0	0.0	0.0	0.0	0.0	0.0	2.2	0.0	8.9	0.1	1.3	0.2
Hyperiella antarctica	0.0	0.0	n.a.	n.a.	0.0	0.0	0.0	0.0	0.0	0.0	2.2	0.0	2.2	0.0	0.0	0.0
Pegantha martagon	0.0	0.0	n.a.	n.a.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.0	0.0	0.0
Phalacrophorus pictus	0.0	0.0	n.a.	n.a.	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.0	0.0	0.0	0.0	0.0
Harpagifer antarcticus (L)	0.0	0.0	n.a.	n.a.	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.0	0.0	0.0	0.0	0.0
Eusirus microps	0.0	0.0	n.a.	n.a.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.4	0.0	0.0	0.0
Euphysora gigantea	0.0	0.0	n.a.	n.a.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.2	0.0	0.0	0.0
Gymnodraco acuticeps (L)	0.0	0.0	n.a.	n.a.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.0	0.0	0.0
Gosea brachyura	0.0	0.0	n.a.	n.a.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.3	0.0	0.0	0.0
TOTAL		3812.2		n.a.		1293.7		1172.7		1015.2		1408.9		1052.2		1001.2
NO. TAXA	63		n.a.		65		63		70		66		68		32	

Table 4.9. (Contd.)

B. SURVEY D	FEBRUARY-MARCH															
	2001 N=97		2000 N=97		1999 N=67		1998 N=104		1997 N=16		1996 N=91		1995 N=89		1994 N=89	
TAXON	F(%)	Mean	F(%)	Mean	F(%)	Mean	F(%)	Mean	F(%)	Mean	F(%)	Mean	F(%)	Mean	F(%)	Mean
Salpa thompsoni	100.0	392.1	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
Copepods (Total)	99.0	5915.7	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
Vibilia antarctica	99.0	10.9	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
Cyllopus lucasii	96.9	26.6	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
Thysanoessa macrura (L)	91.7	718.3	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.
Thysanoessa macrura	86.5	639.0	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
Euphausia superba	79.2	59.0	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
Themisto gaudichaudii	79.2	4.3	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
Chaetognaths	77.1	164.5	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.
Spongiobranchaea australis	70.8	4.1	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
Cyllopus magellanicus	70.8	2.9	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
Euphausia superba (L)	64.6	683.4	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 frigida	50.0	42.0	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
Limacina helicina	33.3	1.8	45.4	205.4	26.9	1.9	37.5	0.8	0.0	0.0	24.2	1.9	4.5	0.0	0.0	0.0
Radiolaria	32.3	216.2	40.2	531.4	40.3	6.3	28.8	1.0	12.5	0.7	34.1	0.9	27.0	0.4	n.a.	n.a.
Hyperiella dilatata	30.2	0.4	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
Primno macropa	28.1	1.5	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
Pegantha martgon	27.1	0.3	13.4	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ostracods	20.8	10.1	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.
Diphyes antarctica	20.8	0.2	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
Euphausiid eggs	19.8	9.3	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Tomopteris spp.	19.8	0.4	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
Lepidonotothen kempi (L)	19.8	0.2	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	16.7	1.2	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
Clione limacina	16.7	0.9	5.2	0.0	3.0	0.0	10.6	0.1	12.5	0.0	15.4	0.2	0.0	0.0	0.0	0.0
Dimophyes arctica	15.6	0.2	15.5	0.6	0.0	0.0	16.3	0.4	12.5	0.1	13.2	0.1	13.5	0.3	10.1	0.0
Lepidonotothen larseni (L)	14.6	0.2	3.1	0.0	11.9	0.0	13.5	0.1	0.0	0.0	13.2	0.3	10.1	0.0	0.0	0.0
Electrona spp. (L)	12.5	0.8	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
Sipunculids	12.5	0.3	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
Clio pyramidata	10.4	0.4	5.2	0.0	13.4	0.1	0.0	0.0	0.0	0.0	3.3	0.0	12.4	0.0	9.0	0.2
Hyperoche medusarum	10.4	0.1	3.1	0.0	4.5	0.0	0.0	0.0	12.5	0.3	2.2	0.0	12.4	0.0	0.0	0.0
Beroe forskalii	10.4	0.0	13.4	0.1	9.0	0.0	2.9	0.0	0.0	0.0	0.0	0.0	1.1	0.0	3.4	0.1
Beroe cucumis	7.3	0.1	2.1	0.0	9.0	0.0	4.8	0.0	0.0	0.0	11.0	0.1	4.5	0.0	2.2	0.0
Gymnoscopelus braueri	7.3	0.0	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.
Polychaetes	6.3	0.6	18.6	2.6	7.5	0.3	13.5	0.3	0.0	0.0	3.3	0.1	2.2	0.0	0.0	0.0
Calycopsis borchgrevinki	6.3	0.0	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
Electrona carlsbergi	6.3	0.0	1.0	0.0	4.5	0.0	1.9	0.0	0.0	0.0	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Hyperiids (unid)	5.2	0.3	8.2	2.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pleuragramma antarcticum (J)	5.2	0.1	0.0	0.0	0.0	0.0	2.9	0.0	0.0	0.0	1.1	0.0	2.2	0.0	0.0	0.0
Eusirus antarcticus	5.2	0.1	1.0	0.0	1.5	0.0	1.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pleurobrachia pileus	5.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Electrona antarctica	5.2	0.0	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
Ctenophores	5.2	0.0	6.2	0.1	4.5	0.0	0.0	0.0	6.3	0.0	1.1	0.0	3.4	0.0	0.0	0.0
Callianira antarctica	5.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gammarids	4.2	0.4	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hydromedusae	4.2	0.0	23.7	0.5	40.3	0.3	12.5	0.2	12.5	0.2	3.3	0.1	5.6	0.0	0.0	0.0
Ihlea racovitzai	3.1	0.3	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.
Fish eggs	3.1	0.0	0.0	0.0	1.5	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.1	0.0	7.9	0.1
Gymnoscopelus nicholsi	3.1	0.0	1.0	0.0	1.5	0.0	1.0	0.0	12.5	0.1	3.3	0.0	1.1	0.0	0.0	0.0
Notolepis coatsi (L)	2.1	0.0	6.2	0.0	0.0	0.0	4.8	0.0	0.0	0.0	18.7	0.1	36.0	0.2	0.0	0.0
Cumaceans	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.0	0.0	0.0	0.0	0.0
Bylgides pelagica	2.1	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	2.2	0.0	0.0	0.0
Rhynchonereella bongraini	2.1	0.0	5.2	0.6	31.3	2.3	1.0	0.0	0.0	0.0	5.5	0.1	20.2	0.1	0.0	0.0
Electrona subaspera	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Siphonophores	2.1	0.0	10.3	2.3	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Euphausia spp. (L)	1.0	0.4	11.3	4.3	13.4	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Notolepis spp. (L)	1.0	0.2	0.0	0.0	7.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.2	0.0	5.6	0.0
Mysids	1.0	0.1	1.0	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Krefftichthys anderssoni (L)	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Chionodraco rastrospinosus (L)	1.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Schyphomedusae	1.0	0.0	0.0	0.0	0.0	0.0	1.9	0.0	12.5	0.0	19.8	0.1	13.5	0.1	0.0	0.0
Botrynema brucei	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cephalopods	1.0	0.0	2.1	0.0	4.5	0.0	1.9	0.0	0.0	0.0	9.9	0.0	0.0	0.0	0.0	0.0
Vanadis antarctica	1.0	0.0	4.1	0.1	1.5	0.0	3.8	0.1	0.0	0.0	1.1	0.0	6.7	0.0	7.9	0.1
Eusirus perdentatus	1.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	2.2	0.0	6.7	0.1	0.0	0.0
Laodicea undulata	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Larval fish (unid.)	1.0	0.0	6.2	0.6	14.9	0.7	1.9	0.1	0.0	0.0	1.1	0.0	0.0	0.0	0.0	0.0
Cyphocaris richardi	1.0	0.0	3.1	0.0	1.5	0.0	0.0	0.0	0.0	0.0	1.1	0.0	3.4	0.1	0.0	0.0
Orchomene plebs	1.0	0.0	2.1	0.8	0.0	0.0	1.9	0.0	0.0	0.0	2.2	0.0	3.4	0.0	2.2	0.1
Gymnoscopelus bolini	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Limacina spp.	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Notothenia neglecta	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 4.9. (Contd.)

B. SURVEY D	FEBRUARY-MARCH															
	2001		2000		1999		1998		1997		1996		1995		1994	
TAXON	F(%)	Mean	F(%)	Mean	F(%)	Mean	F(%)	Mean	F(%)	Mean	F(%)	Mean	F(%)	Mean	F(%)	Mean
Cyllopus spp.	0.0	0.0	25.8	2.9	0.0	0.0	24.0	0.7	24.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0
Hyperiella spp.	0.0	0.0	9.3	0.3	9.0	0.1	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pelagobia longicirrata	0.0	0.0	5.2	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gastropods	0.0	0.0	4.1	17.6	6.0	0.5	1.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Euphausia spp.	0.0	0.0	4.1	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bolinopsis infundiluus	0.0	0.0	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gobionotothen gibberifrons (L)	0.0	0.0	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Leusia sp.	0.0	0.0	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Epimeriella macronyx	0.0	0.0	2.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.0	5.6	0.6	0.0	0.0
Scina spp.	0.0	0.0	1.0	0.0	1.5	0.0	0.0	0.0	6.3	0.5	2.2	0.0	1.1	0.0	0.0	0.0
Promyctophum bolini	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Solomondella sp.	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pasiphea sp.	0.0	0.0	1.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Harpagifer antarcticus	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.0	0.0	0.0	0.0	0.0
Orchomene spp.	0.0	0.0	1.0	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Champsocephalus gunnari (L)	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.0	0.0	0.0
Acanthephyra pelagica (L)	0.0	0.0	0.0	0.0	3.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	5.6	0.0	0.0	0.0
Bathylagus antarcticus	0.0	0.0	0.0	0.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Orchomene rossi	0.0	0.0	0.0	0.0	1.5	0.0	1.0	0.0	0.0	0.0	5.5	0.5	6.7	0.0	0.0	0.0
Periphylla periphylla	0.0	0.0	0.0	0.0	1.5	0.0	0.0	0.0	0.0	0.0	1.1	0.0	1.1	0.0	3.4	0.0
Hyperiella macronyx	0.0	0.0	0.0	0.0	1.5	0.0	0.0	0.0	6.3	0.0	6.6	0.1	13.5	0.0	0.0	0.0
Chorismus antarcticus	0.0	0.0	0.0	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gymnoscopelus sp.	0.0	0.0	0.0	0.0	0.0	0.0	1.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hyperia macrocephala	0.0	0.0	0.0	0.0	0.0	0.0	1.9	0.0	0.0	0.0	1.1	0.0	5.6	0.0	0.0	0.0
Pagothenia brachysoma	0.0	0.0	0.0	0.0	0.0	0.0	1.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Chaenodraco wilsoni	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Artedidraco skottsbergi (L)	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rhynchonereella sp.	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lepidonothen larseni (J)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.0	0.0	0.0
Notolepis annulata (L)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.3	0.0	5.5	0.0	3.4	0.0	0.0	0.0
Eusirus microps	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.3	0.0	0.0	0.0	0.0	0.0
Pagetopsis macropterus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.0	0.0	0.0
Decapod larvae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.0	0.0	0.0	0.0	0.0
Lepidonotothen nudifrons (L)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.0	3.4	0.0	0.0	0.0
Atolla wyvillei	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.0	0.0	0.0	0.0	0.0
Bathylagus sp. (L)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.3	0.0	1.1	0.0	14.6	0.0	0.0	0.0
Travisiopsis coniceps	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.0	1.1	0.0	0.0	0.0
Hyperia spp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.1	0.0	0.0	0.0	0.0
Gymnoscopelus opisthopteris	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.3	0.0	10.1	0.0	2.2	0.0
TOTAL		8910.2		12378.9		2207.6		1224.4		2854.0		2196.4		7713.3		3809.5
NO. TAXA	61		72		57		59		36		62		61		30	

Table 4.10. Percent contribution and abundance rank (R) of numerically dominant zooplankton and nekton taxa in the Elephant Island area during (A) January-February and (B) February-March surveys, 1994-2001. Includes the 10 most abundant taxa each year. No samples were collected during January-February 2000. n.a. indicates that taxon was not enumerated during other surveys. Shaded column is a "salp year".

A. SURVEY A	JANUARY-FEBRUARY ELEPHANT ISLAND AREA															
	1994		1995		1996		1997		1998		1999		2000		2001	
TAXON	%	R	%	R	%	R	%	R	%	R	%	R	%	R	%	R
Copepods	4.08	3	61.54	1	56.18	1	57.16	1	4.80	3	58.05	1	n.a.		46.76	1
Salpa thompsoni	80.83	1	1.51	5	1.45	6	17.79	2	68.76	1	12.35	2	n.a.		29.03	2
Thysanoessa macrura (L)	n.a.		1.50	6	21.82	2	1.67	6	0.00		7.29	4	n.a.		12.55	3
Chaetognaths	0.04		7.84	4	0.90	7	2.28	5	0.92	7	4.00	5	n.a.		2.68	4
Thysanoessa macrura	7.87	2	9.09	3	7.56	4	10.24	3	15.38	2	2.92	6	n.a.		2.15	5
Euphausia superba (L)	n.a.		12.80	2	0.19	10	1.49	7	0.09		10.95	3	n.a.		1.53	6
Euphausia frigida	0.38	9	0.92	8	0.14		1.45	8	0.02		1.00	7	n.a.		1.09	7
Vibilia antarctica	1.17	5	0.02		0.04		0.24		1.12	6	0.32	9	n.a.		0.98	8
Cyllopus lucasii	0.62	7	0.02		0.11		0.37		0.16	10	0.15		n.a.		0.98	9
Euphausia superba	2.68	4	1.37	7	7.95	3	3.96	4	3.13	5	0.33	8	n.a.		0.88	10
Ostracods	n.a.		0.91	9	0.35	8	0.54	9	0.41	9	0.13		n.a.		0.25	
Themisto gaudichaudii	1.05	6	0.46		0.34	9	0.35		0.03		0.02		n.a.		0.17	
Limacina helicina	0.03		0.18		2.38	5	0.28		0.69	8	0.07		n.a.		0.14	
Tomopteris spp.	0.25	10	0.40		0.06		0.19		0.11		0.15	10	n.a.		0.11	
Euphausia triacantha	0.12		0.14		0.04		0.14		0.02		0.03		n.a.		0.10	
Primno macropa	0.05		0.01		0.01		0.42	10	0.06		0.13		n.a.		0.10	
Spongiobranchaea australis	0.01		0.05		0.13		0.22		0.07		0.09		n.a.		0.09	
Clio pyramidata	0.53	8	0.50	10	0.01		0.00		0.02		0.01		n.a.		0.08	
Ihlea racovitzai	n.a.		n.a.		n.a.		n.a.		3.53	4	0.15		n.a.		0.02	
TOTAL	99.69		99.26		99.64		98.79		99.32		98.15		n.a.		99.68	

B. SURVEY D	FEBRUARY-MARCH ELEPHANT ISLAND AREA															
	1994		1995		1996		1997		1998		1999		2000		2001	
TAXON	%	R	%	R	%	R	%	R	%	R	%	R	%	R	%	R
Copepods	82.15	1	40.49	2	62.07	1	44.46	1	7.38	4	62.77	1	54.20	1	64.68	1
Thysanoessa macrura	1.83	3	0.87	5	4.86	4	6.36	3	9.40	3	3.84	5	0.24	8	14.96	2
Thysanoessa macrura (L)	n.a.		3.76	3	21.40	2	0.38	8	0.03		7.49	3	7.33	3	8.81	3
Salpa thompsoni	11.78	2	0.22	7	1.39	6	43.62	2	65.31	1	12.46	2	6.17	4	6.50	4
Chaetognaths	0.47	6	3.61	4	2.43	5	0.65	7	0.60	8	5.94	4	5.35	5	1.34	5
Euphausia superba	0.41	7	0.06	10	5.57	3	1.07	5	10.87	2	1.43	7	0.10		1.15	6
Euphausia superba (L)	n.a.		50.16	1	0.59	7	0.88	6	0.16		2.71	6	23.14	2	1.03	7
Euphausia frigida	0.69	5	0.21	8	0.40	8	1.57	4	0.60	7	1.00	8	0.29	7	0.54	8
Cyllopus lucasii	0.14	10	0.01		0.01		0.08		0.14		0.01		0.00		0.43	9
Vibilia antarctica	0.16	9	0.00		0.05		0.28	9	0.71	6	0.15		0.18	10	0.21	10
Themisto gaudichaudii	0.27	8	0.01		0.09		0.10		0.01		0.01		0.02		0.07	
Primno macropa	0.00		0.00		0.15	10	0.02		0.11		0.08		0.02		0.03	
Ostracods	n.a.		0.43	6	0.38	9	0.17	10	0.35	10	0.65	9	0.20	9	0.03	
Euphausia triacantha	0.03		0.02		0.03		0.03		0.04		0.06		0.01		0.02	
Cyllopus magellanicus	0.12		0.01		0.10		0.12		0.55	9	0.17		0.07		0.02	
Electrona spp. (L)	0.75	4	0.07	9	0.04		0.01		0.01		0.01		0.03		0.02	
Limacina helicina	0.00		0.00		0.01		0.00		0.03		0.00		2.21	6	0.00	
Ihlea racovitzai	n.a.		n.a.		n.a.		n.a.		2.77	5	0.34	10	0.00		0.00	
TOTAL	97.93		99.86		99.42		99.66		95.72		98.58		99.57		99.85	

Table 4.11. Percent Similarity Index (PSI) values from comparisons of overall zooplankton composition in the Elephant Island area during Surveys (A) A and (B) D, 1994-2001. Shading denotes the 1998 "salp year".

A	JANUARY-FEBRUARY PSI VALUES						
Year	1995	1996	1997	1998	1999	2000	2001
1994	16.7	16.6	34.2	85.0	20.9	n.a	38.7
1995	xxxxx	70.3	76.8	18.7	80.7	n.a.	58.9
1996		xxxxx	73.4	19.3	70.0	n.a.	65.9
1997			xxxxx	38.4	80.2	n.a.	75.7
1998				xxxxx	22.6	n.a.	39.8
1999					xxxxx	n.a.	75.1
2000						xxxxx	n.a.

B	FEBRUARY-MARCH PSI VALUES						
Year	1995	1996	1997	1998	1999	2000	2001
1994	42.4	66.9	60.1	22.9	78.4	61.8	74.9
1995	xxxxx	49.1	44.0	10.0	52.4	72.0	48.1
1996		xxxxx	54.3	21.1	80.3	67.0	80.9
1997			xxxxx	60.5	65.2	53.6	61.3
1998				xxxxx	27.7	15.5	26.2
1999					xxxxx	76.9	85.0
2000						xxxxx	71.0

Table 4.12. Abundance of biomass dominant copepod species in the Elephant Island area during various cruises 1981-2001. 1981-1990 data provided by John Wormuth (Texas A&M). (N) is number of samples. Abundance is numbers per 1000 m^3.

SURVEY PERIOD		*Calanoides acutus*	*Calanus propinquus*	*Metridia gerlachei*	Total Copepods
Mar 81	Mean	4786.9	5925.8	2402.5	13115.2
(10)	STD	5482.2	6451.6	3321.4	12799.9
	Median	2197.7	2048.7	609.5	8466.8
Feb-Mar 84	Mean	25.5	121.7	1154.4	1301.6
(13)	STD	29.6	134.4	2999.9	3043.9
	Median	16.2	51.4	23.1	96.6
Jan-Feb 88	Mean	429.7	93.6	1639.0	2162.3
(48)	STD	676.8	104.3	3488.0	3928.6
	Median	80.5	45.5	57.0	618.5
Feb 89	Mean	161.4	194.9	3189.3	3545.6
(25)	STD	240.9	151.5	4017.2	4071.5
	Median	88.0	162.0	1051.0	1776.0
Jan 90	Mean	302.5	354.4	981.3	1700.2
(23)	STD	405.8	365.8	1620.7	2003.7
	Median	170.1	243.6	192.3	656.7
Jan 99	Mean	335.4	109.1	340.5	927.0
(40)	STD	1009.5	161.9	512.7	1590.8
	Median	28.9	52.0	66.0	332.9
Feb 99	Mean	511.8	300.9	521.1	1557.9
(39)	STD	1395.6	630.6	699.0	2337.8
	Median	70.7	70.8	216.9	621.6
Feb 00	Mean	1846.3	741.8	3051.7	8019.1
(60)	STD	3177.2	1546.5	4783.5	11824.4
	Median	225.2	193.3	1249.7	3478.0
Jan 01	Mean	241.0	50.4	1003.2	1003.2
(60)	STD	392.0	85.9	1582.4	1582.4
	Median	117.7	12.5	252.2	252.2
Feb-Mar 01	Mean	2540.2	247.1	1450.0	4501.5
(57)	STD	6921.6	402.9	2966.0	8072.4
	Median	111.5	122.2	140.1	1518.0

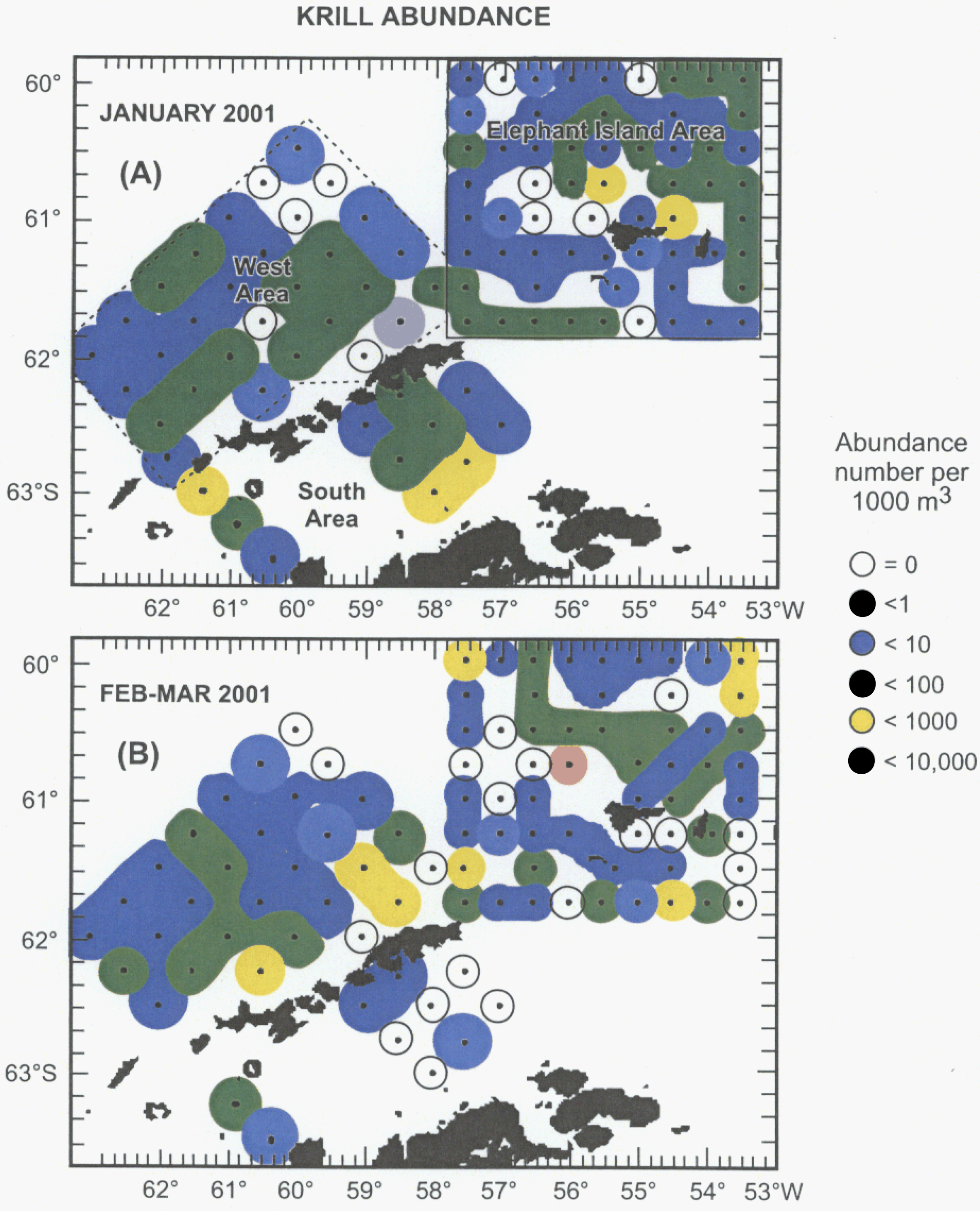

Figure 4.1. Krill abundance in IKMT tows collected during (A) Survey A, January 2001 and (B) Survey D, February-March 2001. The outlined stations are included in the Elephant Island Area and used for between-year comparisons. West and South Area stations are indicated.

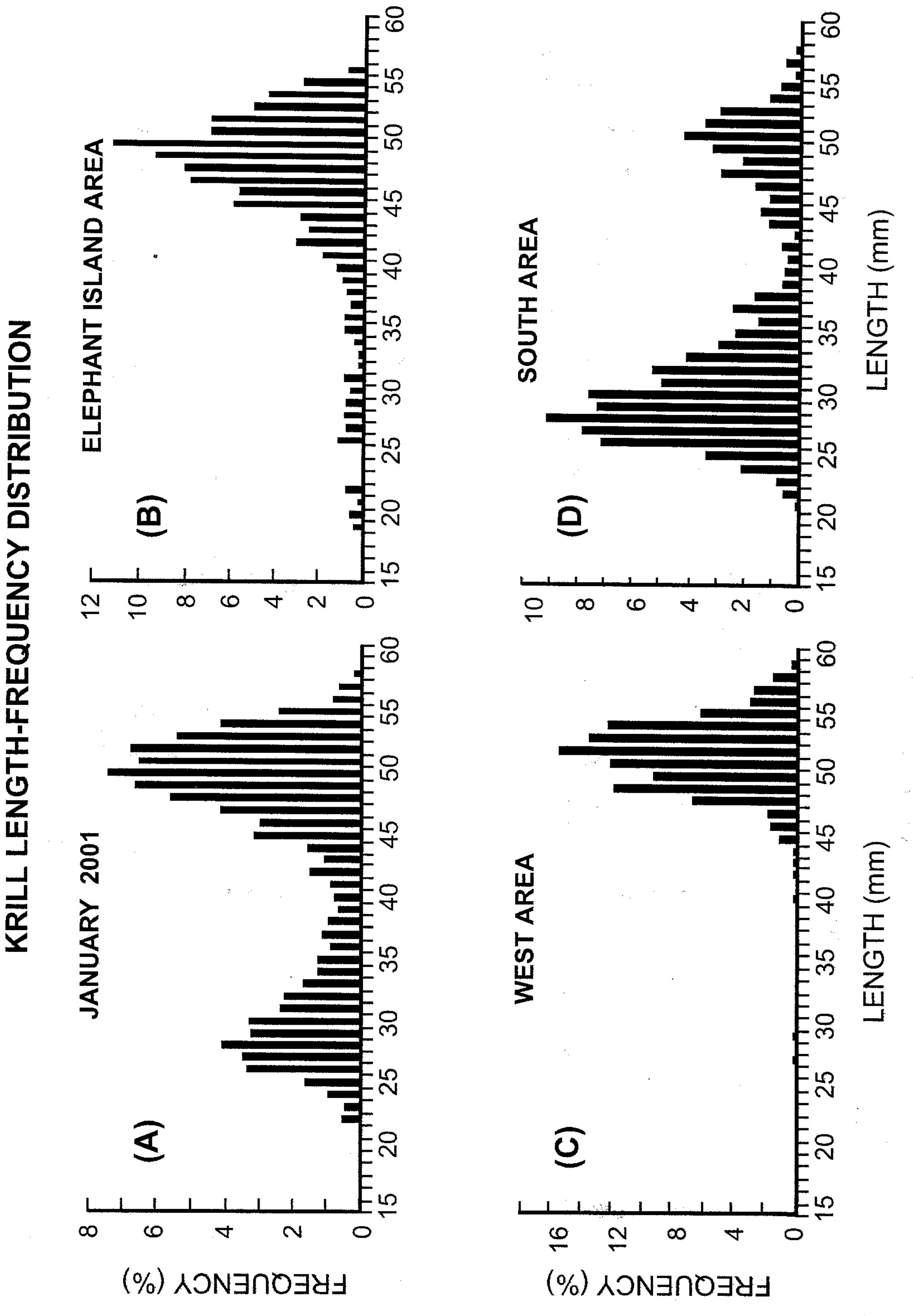

Figure 4.2. Overall length-frequency distribution of krill collected (A) during Survey A and in the (B) Elephant Island Area, (C) West Area and (D) South Area, January 2001.

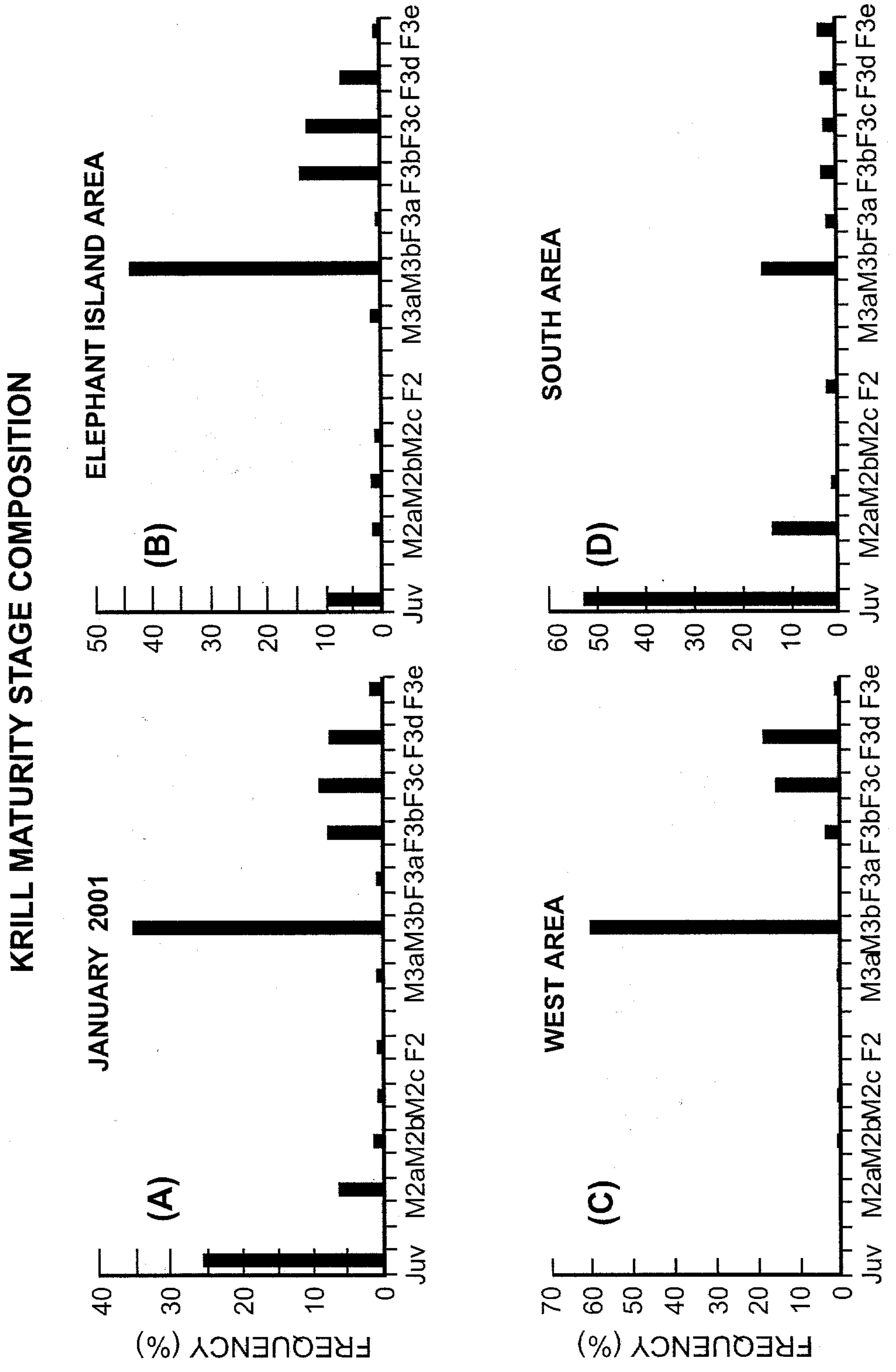

Figure 4.3. Maturity stage composition of krill collected (A) during Survey A and in the (B) Elephant Island Area, (C) West Area and (D) South Area, January 2001.

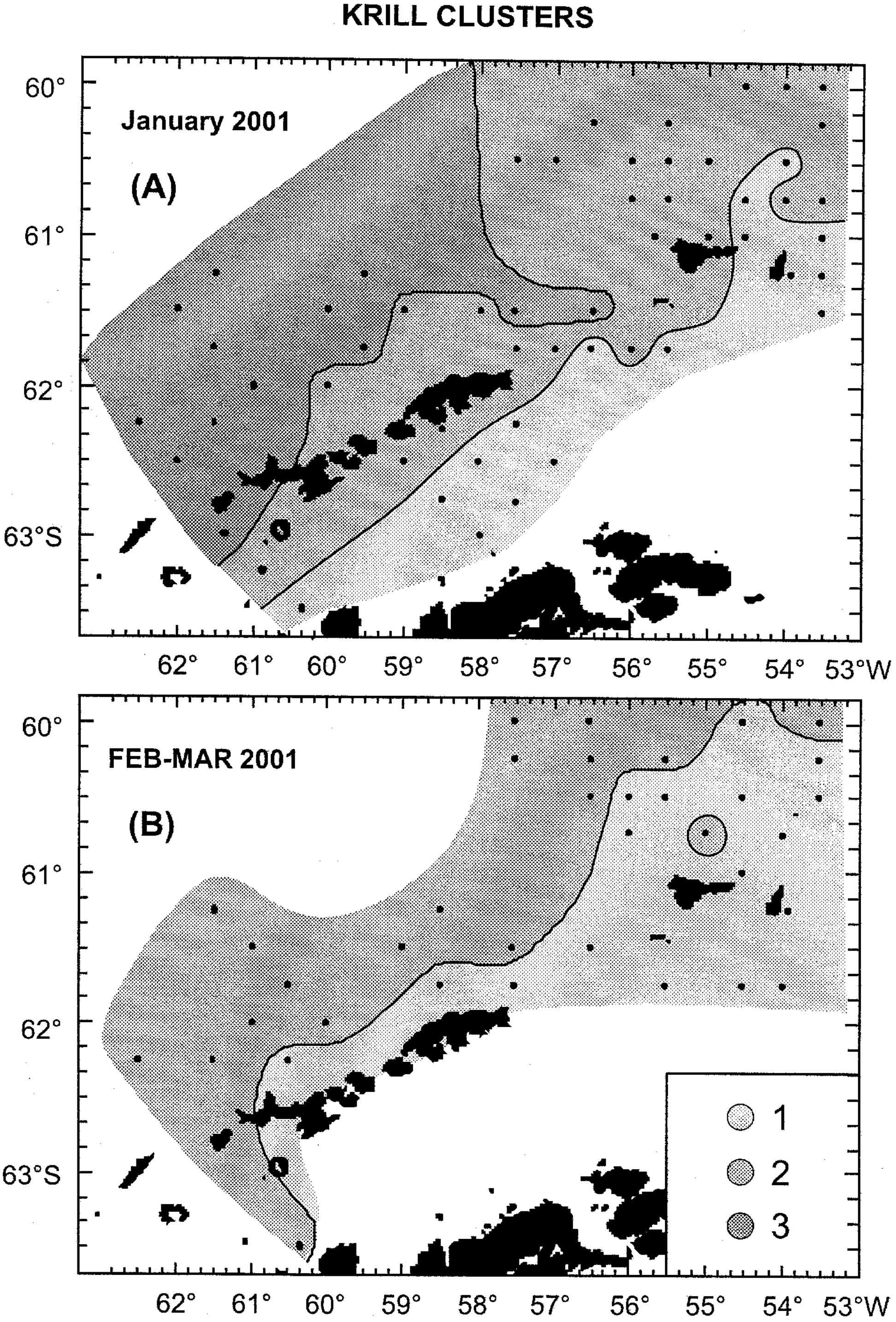

Figure 4.4. Distribution patterns of krill belonging to different length categories within (A) the Survey A Area, January 2001, and (B) the Survey D Area, February-March 2001.

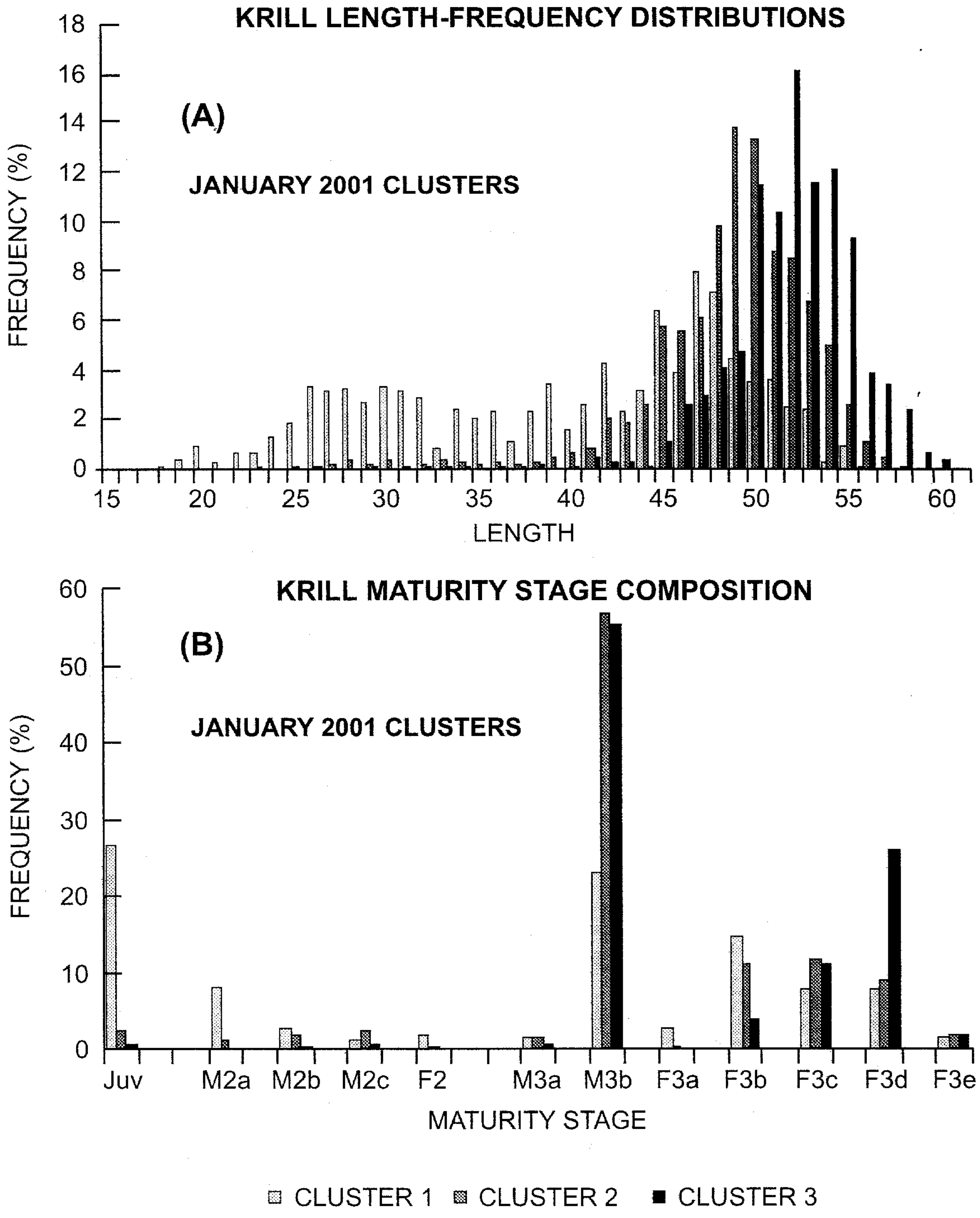

Figure 4.5. (A) Length-frequency distribution and (B) maturity stage composition of krill belonging to three length categories (Clusters 1-3) in the Survey A Area, January 2001.

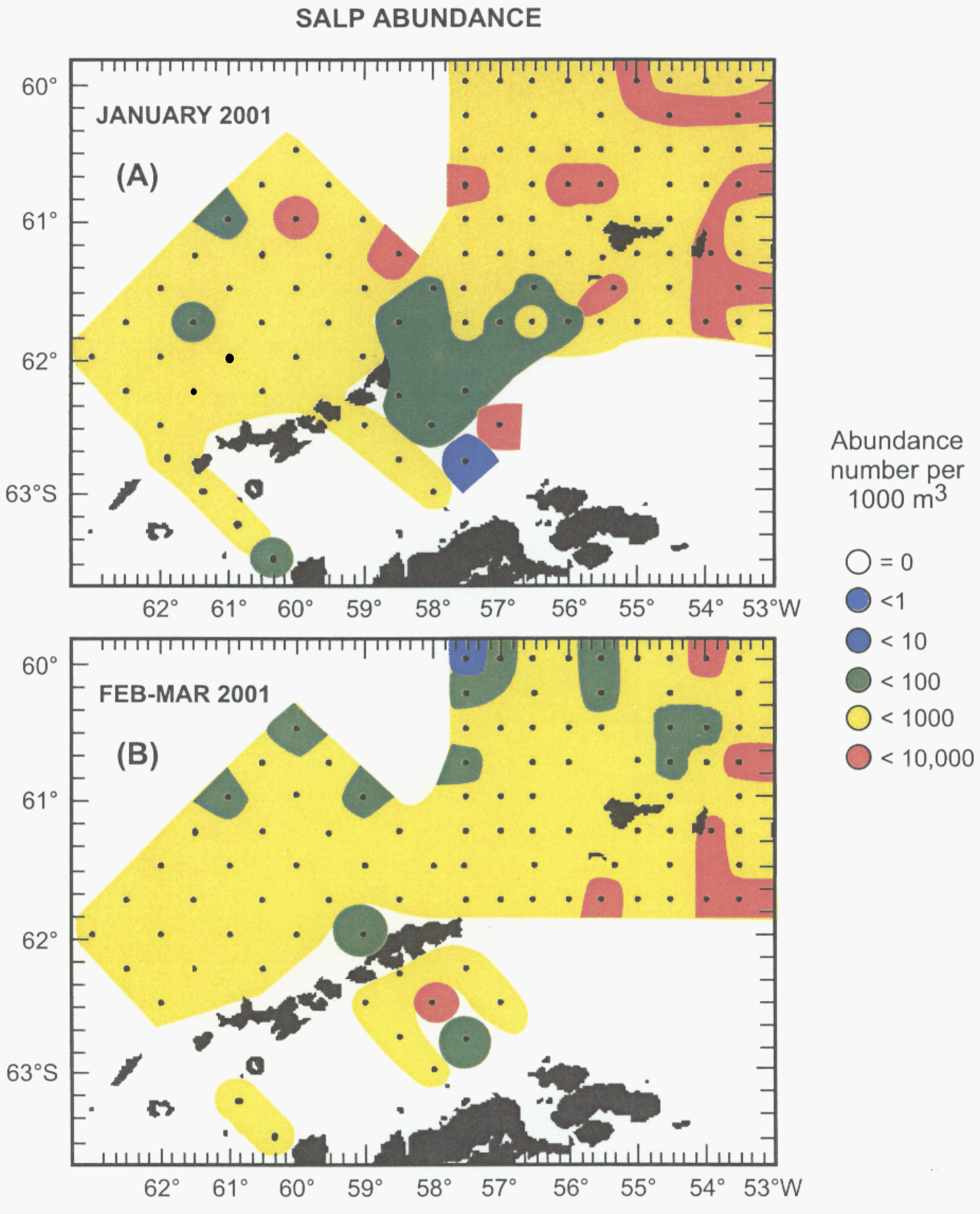

Figure 4.6. Distribution and abundance of *Salpa thompsoni* in the (A) Survey A Area, January 2001 and (B) Survey D Area, February-March 2001.

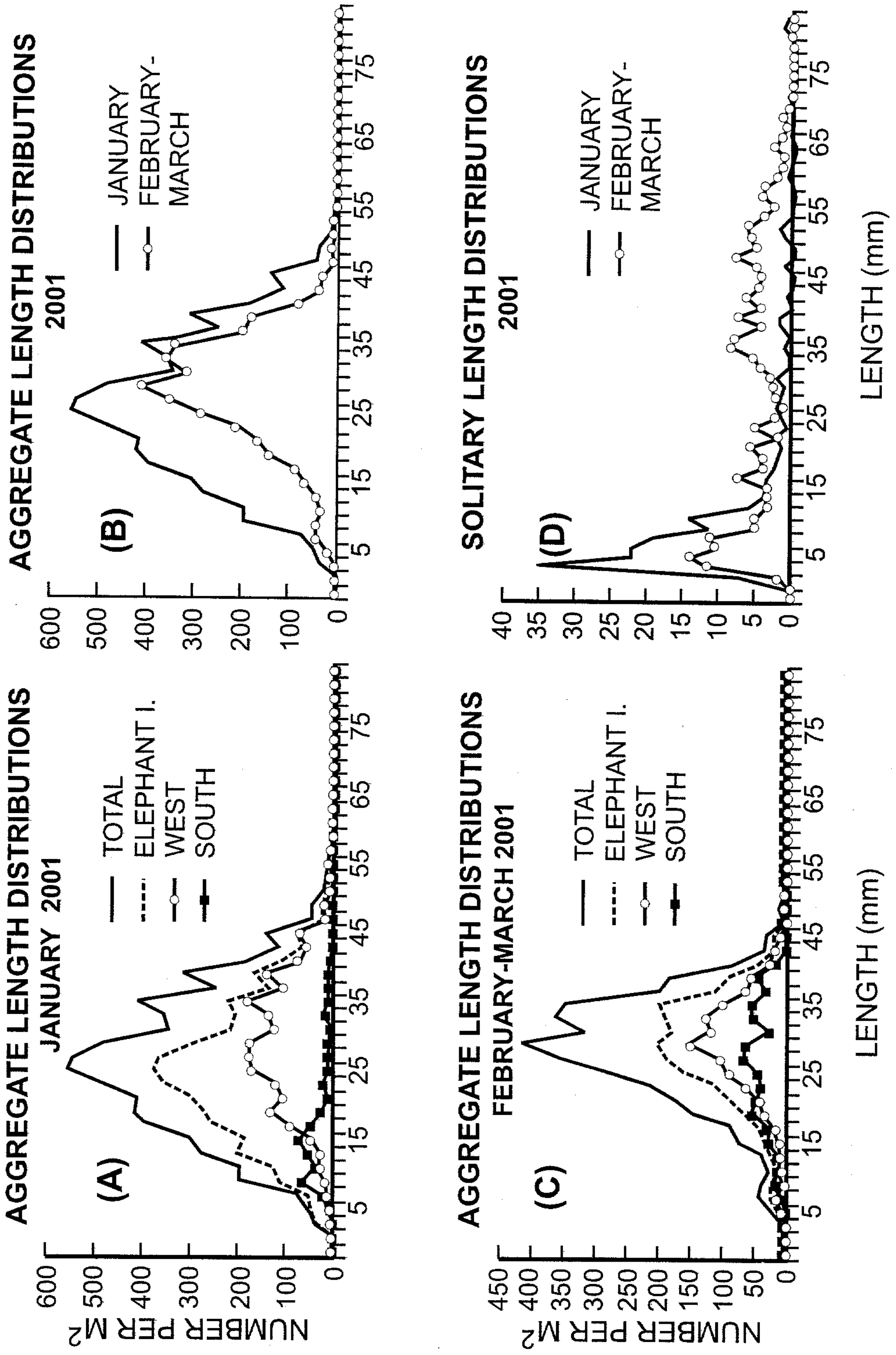

Figure 4.7. Length-frequency distributions of aggregate stage *Salpa thompsoni* in the Survey Area and three subareas (A) January 2001 and (B) February-March 2001 and seasonal differences in (C) aggregate stage and (D) solitary stage length-frequency distributions, January-March, 2001.

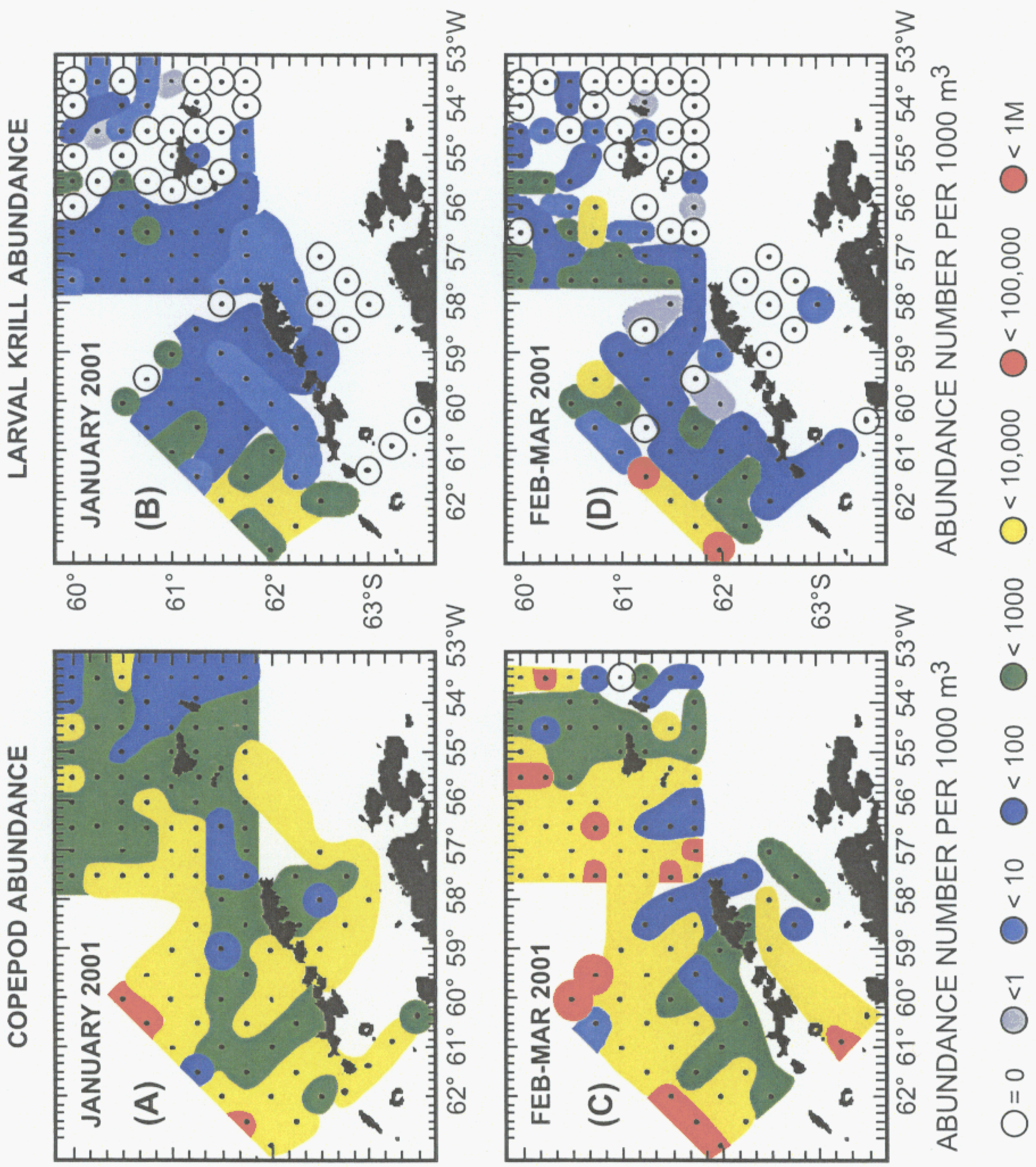

Figure 4.8. Distribution and abundance of copepods and larval krill in the (A,B) Survey A Area, January 2001 and (C,D) Survey D Area February 2001.

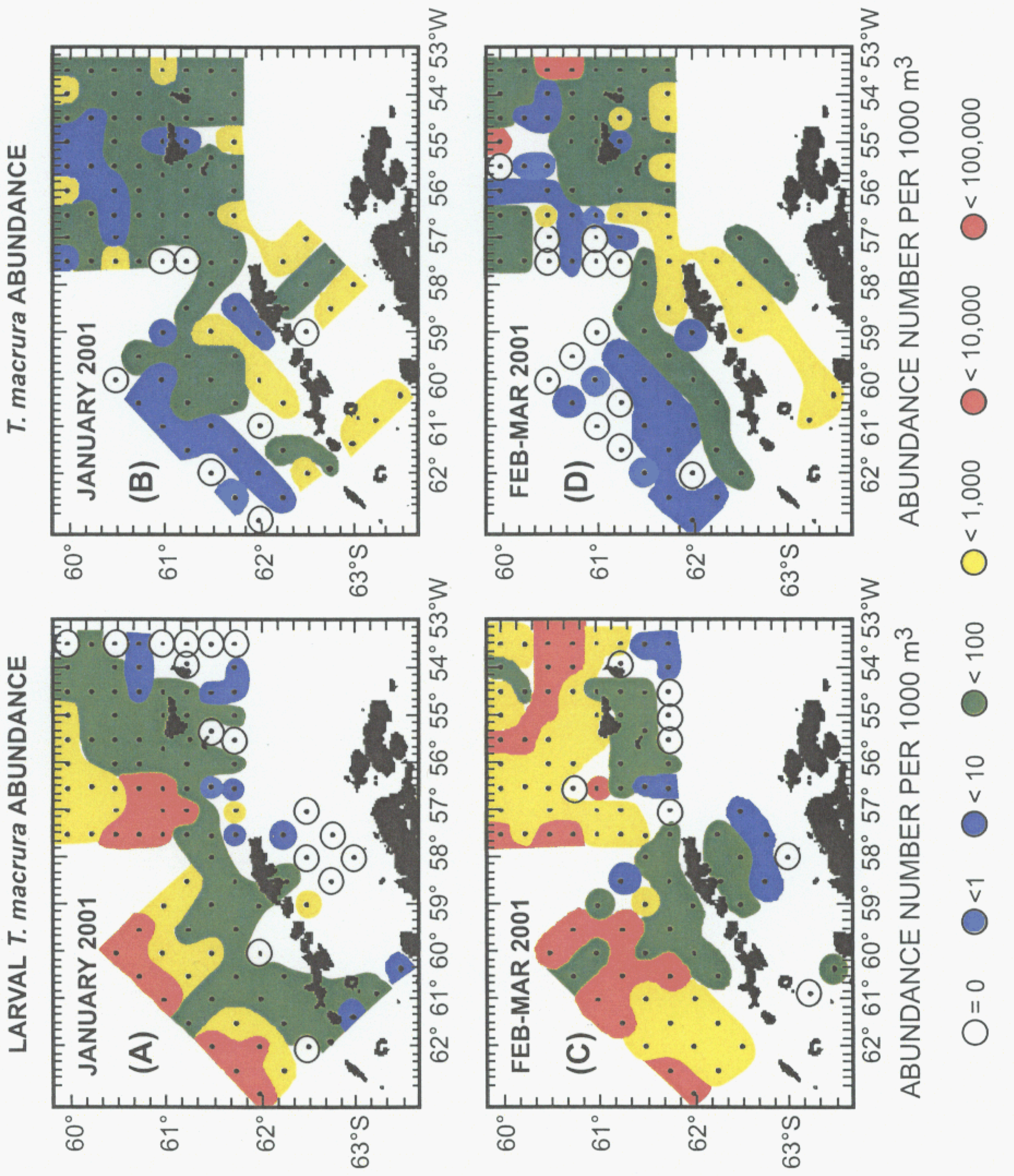

Figure 4.9. Distribution and abundance of larval and postlarval *Thysanoessa macrura* in (A,B) Survey A Area, January 2001 and (C,D) Survey D Area February-March, 2001.

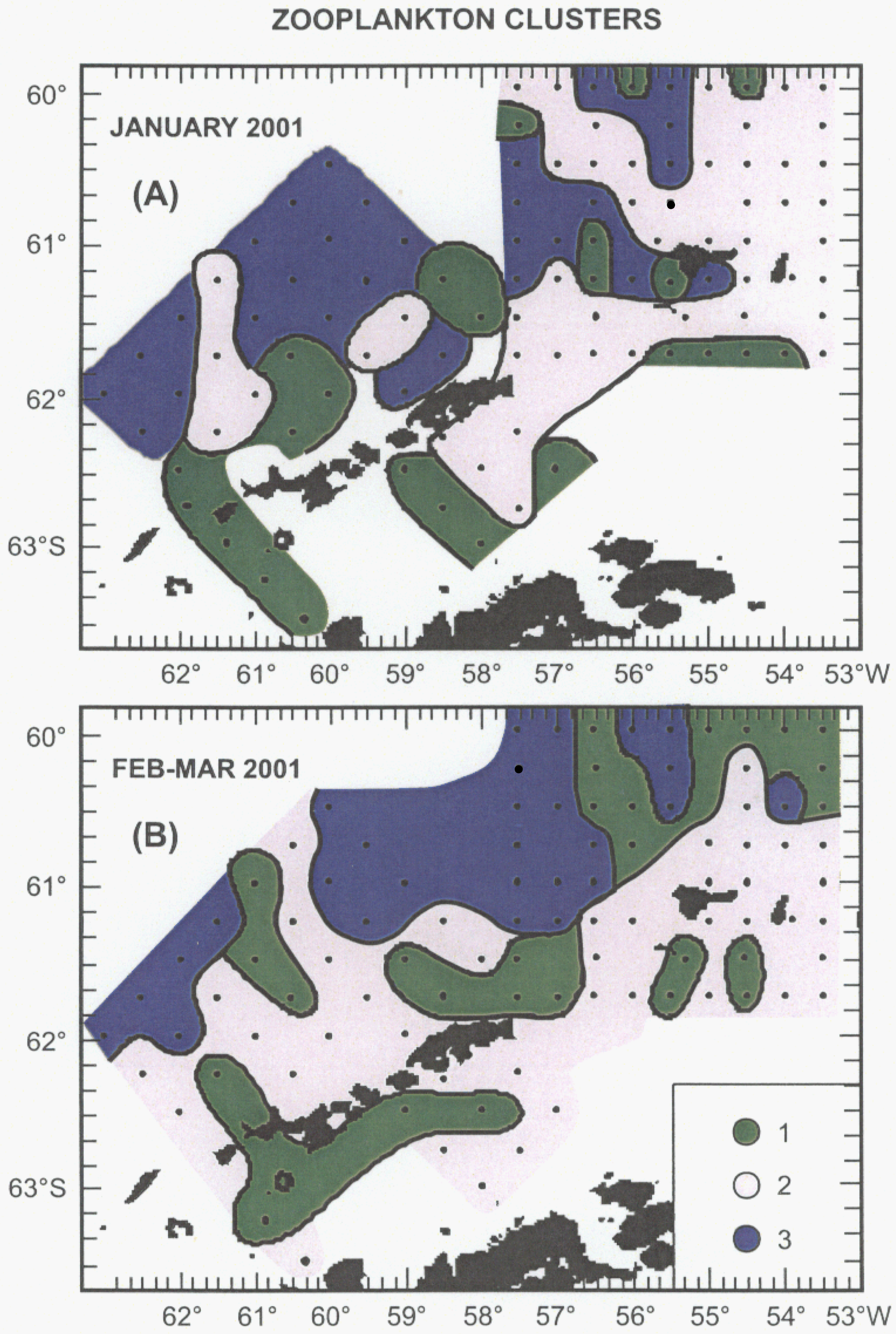

Figure 4.10. Distribution patterns of zooplankton taxa belonging to different station groupings in the (A) Survey A Area, January 2001 and (B) Survey D Area, February-March 2001.

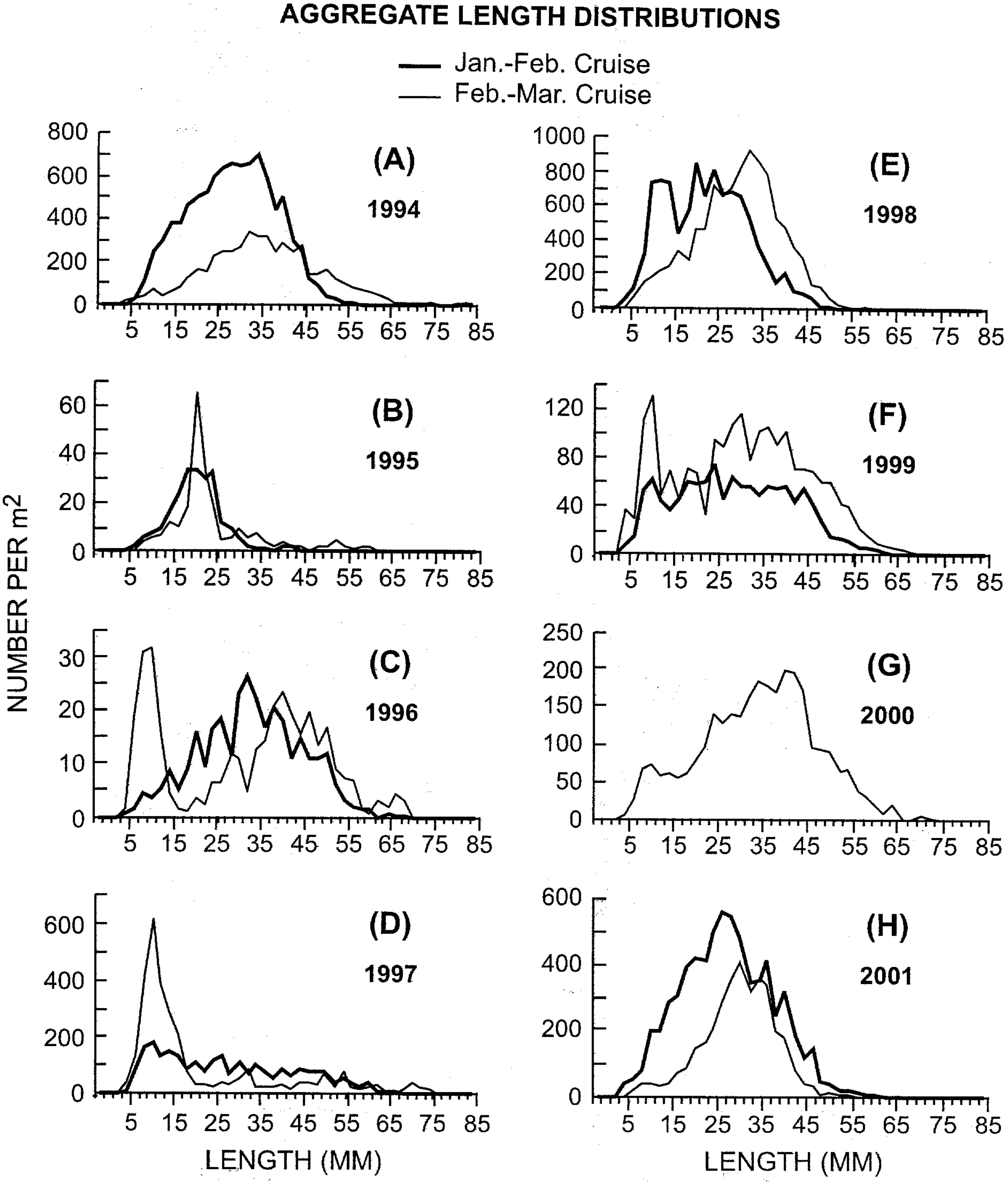

Figure 4.11. Length-frequency distributions of aggregate stage salps during AMLR cruises, 1994-2001.

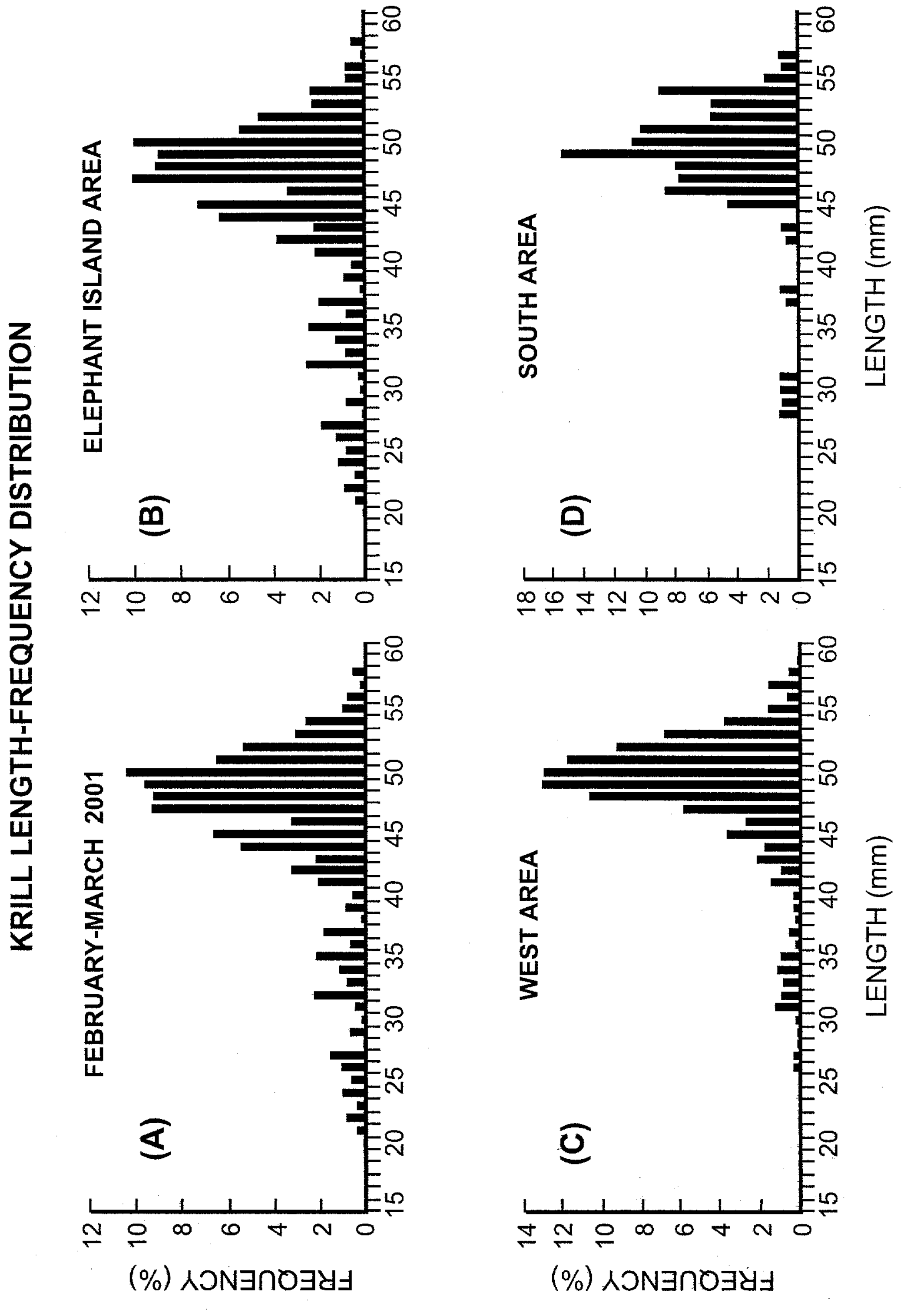

Figure 4.12. Overall length-frequency distribution of krill collected (A) during Survey D and in the (B) Elephant Island Area, (C) West Area and (D) South Areas, February-March 2001.

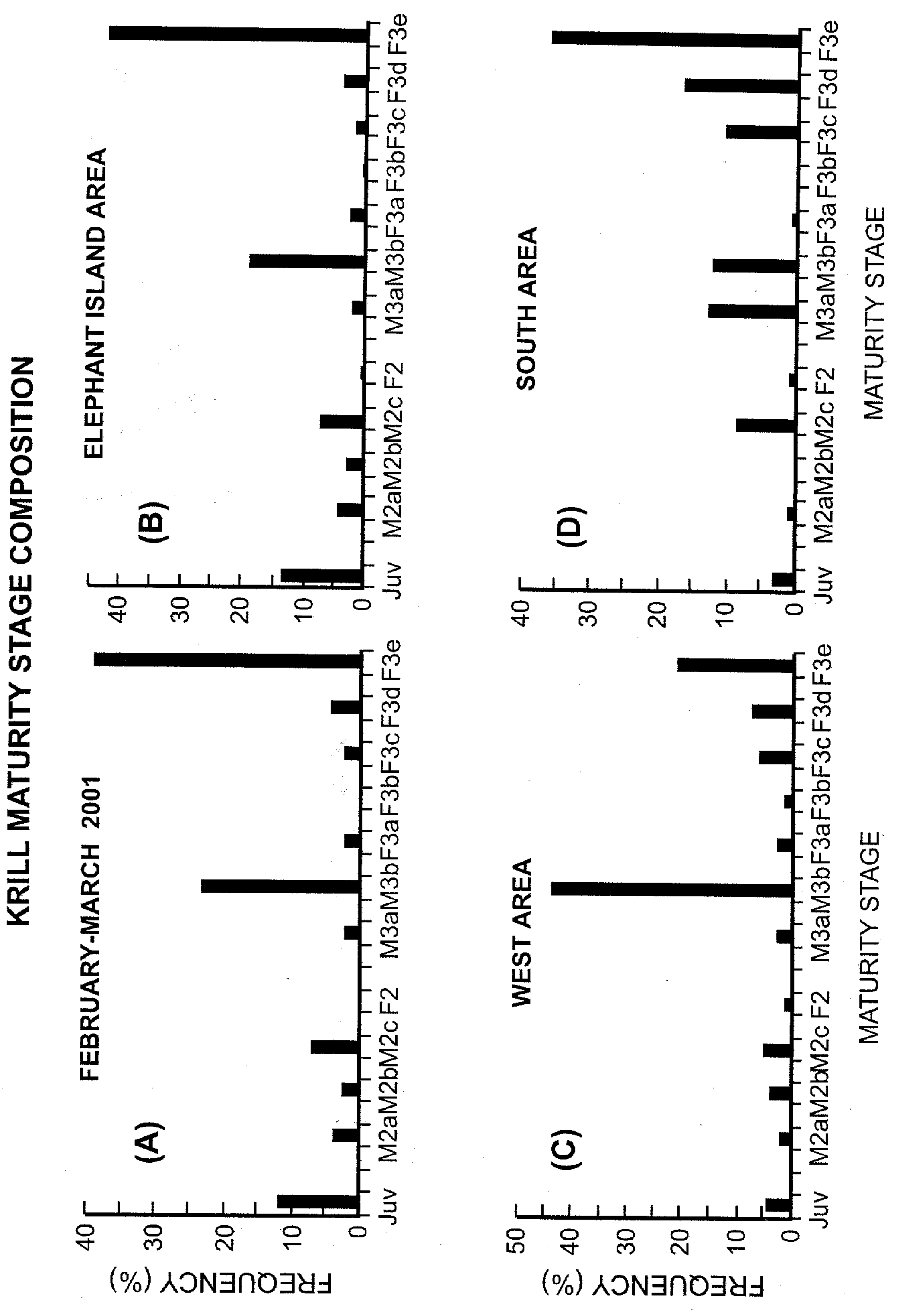

Figure 4.13. Maturity stage composition of krill collected (A) during Survey D and in the (B) Elephant Island Area, (C) West Area and (D) South Areas, February-March 2001.

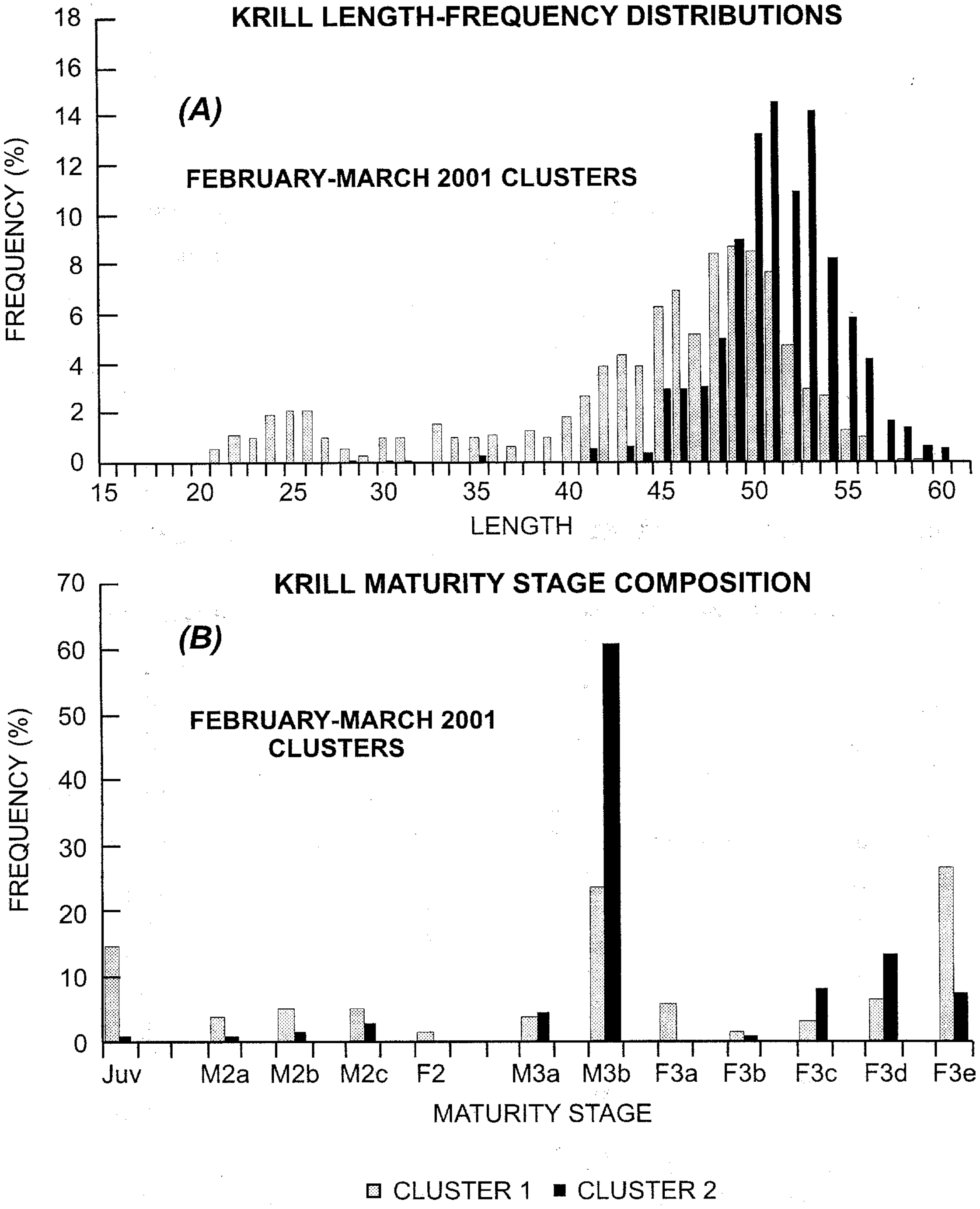

Figure 4.14. (A) Length-frequency distributions and (B) maturity stage composition of krill belonging to different length categories (Clusters 1 and 2) in the Survey D Area, February-March 2001.

Section 5. Bottom Trawl Survey and Finfish Research in the South Shetland Islands; submitted by Christopher D. Jones (Leg III), Karl-Hermann Kock (Leg III), Sunhild Wilhelms (Leg III), David Ramm (Leg III), Julian Ashford (Leg III), Tom Near (Leg III), Jennifer H. Emery (Legs I, II & III), Nancy Gong (Legs II & III), Hauke Flores (Leg III), Alison R. Banks (Legs I, II & III) and Mark Prowse (Legs I, II & III).

5.1 Objectives: Commercial fishing for finfish in the South Shetland Island chain was conducted from 1978/79 through 1988/89. The main species fished or taken in this region were *Champsocephalus gunnari* and *Notothenia rossii* (Agnew and Nichol, 1996), as well as several bycatch species, including *Gobionotothen gibberifrons*, *Chaenocephalus aceratus*, and *Chionodraco rastrospinosus* (CCAMLR, 1990). Within two years after the fishery was developed, catches declined substantially. This lead CCAMLR eventually to impose a moratorium on taking finfish from the South Shetland Islands from 1989/90 to the present. Before the shelf areas can be re-opened to possible exploitation, it is essential to monitor the biomass of potentially fishable stocks, and to better understand the biology, ecology, and life history characteristics of the finfish species, as well as the impact of exploitation on the Antarctic ecosystem.

Before the closure of the fishery, there were several bottom trawl surveys of the Elephant Island region conducted by the Federal Republic of Germany (Kock, 1998) and one semipelagic trawl survey in 1987 conducted by Spain (Balguerias, 1987). The Spanish survey was also extended to the lower South Shetland Islands. Since the moratorium, there has been one German survey of the Elephant Island Region in the 1996/97 split year (Kock, 1998), and two AMLR bottom trawl surveys (including this one) of the entire South Shetland Islands (Jones *et al.*, 1998). The AMLR program has expanded coverage of the southern Scotia Arc to include the South Orkney Islands (Jones *et al.*, 2000; Kock *et al.*, 2000), effectively examining the fishable shelf regions of the entire southern Scotia Arc region.

This bottom trawl survey was designed to provide baseline estimates of abundance, species composition, size composition, and demographic structure, and to collect information on the biology of finfish species within the 500m isobath of the South Shetlands Islands. In addition to trawling to determine levels of biomass of demersal finfish, we also conducted finfish diet studies, underway acoustic sampling of krill swarms and myctophid layers, and CTD's, and collected and characterized all benthic invertebrate by-catch, performed classification of the seabed types, and collected video and grab samples of seabed for substrate ground truthing. The overall objective was collection of data to conduct an ecosystem-based assessment of the biomass and distribution of Antarctic demersal fish within the 500m isobath of the South Shetland Islands.

5.2 Methods and Accomplishments:

Bottom Trawling

The fishing gear used was the "Hard Bottom Snapper Trawl" with vented V-Doors both manufactured by Net Systems, Inc. (Bainbridge Island, WA). A "Netsweep 325" net sonar system (Ocean Systems Inc.) was used to record the net mensuration (height and width of the trawl mouth), as well as optimize the trawl interaction with the bottom. Diagrams of the net, doors, and rigging can be obtained from the AMLR program upon request.

Trawling operations were conducted aboard the R/V *Yuzhmorgeologiya* March 12, 2001 through March 31, 2001. The sampling strategy was based on a random depth stratified survey design, and stations were positioned to account for a wide geographic range. There were five designated depth strata: 50-100m, 100-200m, 200-300m, 300-400m and 400-500m. There were a total of 71 hauls completed (Figure 5.1) around the South Shetland Islands: 37 around Elephant Island (Table 5.1) and 34 around the lower South Shetlands Islands (Table 5.2). The numbers of hauls within the five depth strata were 11 (50-100m), 23 (100-200m), 16 (200-300m), 12 (300-400m), and 9 (400-500m). Allocation of hauls within depth strata were proportional to the known areas of seabed (Jones *et al.*, 1999) and weighted by previous estimates of abundance in each stratum from the 1998 AMLR Survey of the South Shetland Islands (Jones *et al.*, 1998). In all cases, a haul was taken only after initial acoustic reconnaissance verified that bottom conditions were suitable for trawling. The initial survey design called for one additional haul within the 400-500m depth range northwest of Snow Island in the far western lower South Shetlands. However, due to rough ocean conditions, this station was abandoned for safety reasons. At least two other stations were repositioned from this area to a more sheltered region west of Deception Island after suitable seabed within targeted depth strata was located. The realized locations of almost all hauls varied considerably from the initial planned coordinates due to sea, wind, bottom, and ice conditions. However, with the exception of one station, the planned survey design was completed successfully.

All hauls were conducted during daylight hours. The target time for a trawl was 30 minutes. Any haul less than 20 minutes was considered invalid, and discarded. Trawling started as soon as the footrope made contact with the bottom. Once contact with the bottom was made, position, time, ship speed, bearing, headrope depth, bottom depth, and net mensuration were recorded. Recordings were made every five minutes thereafter, for a total of seven observations for each haul. Supplementary data collected for each haul included ship course, air temperature, wind speed and direction, weather, cloud conditions, sea state, light and ice conditions. All haul and cruise specific information is stored in hardcopy format and in a computer database maintained by the U.S. AMLR Program.

Haul Processing

After a successful haul, the contents of the trawl were emptied onto the deck and transferred to a sorting table, where fish were identified, separated into species, and placed into individual species baskets. Organisms other than fish were processed separately (See Section 6 of this report "Invertebrate Bycatch From Benthic Trawling Around Elephant and South Shetland Islands, Antarctica"). Baskets were weighed to obtain total catch weights by species. Where catches of a single species were very large, a subsample of the catch was taken (see Sub-sampling Protocol below). In several cases, large yields of finfish were released live after the sub-sampling protocol.

There were two categories of catch processing. Category 1 included length (nearest cm below), sex, and gonad maturity stage. Lengths were measured as total length (length from tip of snout to end of caudal fin) for all species except myctophids, for which length was measured as standard length (length from tip of snout to end of caudal peduncle). Maturity was classified on a scale of 1 to 5 (immature, maturing virgin or resting, developing, gravid, spent) according to the method of Kock and Kellermann (1991). Category 2 processing included full biometric data including length, weight, sex, maturity, gonad (ovary or testis) weight, diet composition, eviscerated weight, and otoliths. All weights were measured as total fresh weight to the nearest gram.

An intensive diet study of 20 finfish species was conducted. Stomach contents information included whole stomach weight and stomach contents weight. A measure of the filling degree was taken according to a scale of 0-5 (empty, 25% full, 50% full, 75% full, 100% full, regurgitated). A measure of fullness was recorded according to a scale of 1-3 (fresh, moderately digested, fully digested). The relative volume of each species present within a stomach was recorded by assigning each dietary component a proportion from 0-10, with the total score for each stomach totaling 10. A total of 4,023 stomachs of 20 species was examined. The variability in diet was substantial for most species, and may be related to the depth strata, benthic and seafloor composition and geographic location of station. An additional 1,200 stomachs were preserved for transport to home laboratories for detailed analysis.

Otoliths were taken from 3,073 fish of 10 species for age and growth work to be undertaken at the Center for Quantitative Fisheries Ecology (CQFE) based at Old Dominion University (ODU) in Virginia. Collections were made for the following species: *Chaenocephalus aceratus* (462), *Champsocephalus gunnari* (696), *Chionodraco rastrospinosus* (418), *Dissostichus mawsoni* (60+), *Electrona antarctica* (128), *Gobionotothen gibberifrons* (405), *Gymnoscopelus nicholsi* (277), *Lepidonotothen squamifrons* (182), *Notothenia coriiceps* (277), and *N. rossii* (91). Otoliths will be used to estimate age and construct age-length keys, which will allow age-based models to be used in assessing the population biology and stock status of each species. Further collections have been made of hard parts from *C. aceratus* and *C. gunnari* to examine alternative calcified structures for their potential in estimating age. Hard parts collected were the three pairs of otoliths: the asterisci, lapilli, and sagittae; the pectoral and pelvic fin rays; the dorsal and anal fin spines; vertebrae; and opercula. Hard parts were also collected from 30 *D. mawsoni*. The best calcified structure for each species will be used to analyze the precision of repeated age estimates using an experimental design developed at the CQFE. This information will be used to assess the reliability of age estimates and capacity of the resulting age-length key to discriminate between age cohorts in age-based modeling.

Rare or unusual specimens/biological materials were preserved in buffered formalin or ethanol and packaged for transport to home laboratories. In addition to collection of *D. mawsoni* tissue samples for DNA analysis, we processed 348 fish of 28 species for systematic and phylogenetic studies at the University of California, Davis. A number of oocytes were also collected from running ripe individuals and their diameter was measured. Oocytes were counted and collected from the zoarcid *Pachycara brachycephalum*. Gonads of the channichthyid *Cryodraco antarcticus* were collected for a more detailed study at the Institute for Sea Fisheries laboratory in Hamburg, Germany. The measurements of gonado-somatic index (GSI) (Kock, 1989) were collected from several species to describe the individual gonad stage.

Sub-sampling Protocol

Where yields of a species were too large to process in their entirety, sub-sampling was performed using randomized techniques for either Category 1 or Category 2 processing. When using a straightforward simple random sampling with each fish as an independent sampling unit was logistically impractical, we used full baskets of fish as primary sampling units (PSUs). Two forms of sampling strategies were then used: *cluster sampling*, where all fish within a basket were sampled, and *multi-stage sampling*, were only some of the fish within a basket were sampled at random. These strategies generate parameter estimates with reliable estimates of variance, which allow for statistical inferences to be made. Sampling effort was adjusted for each haul to allow sampling to be completed before the next haul was on deck.

The basic methodology was as follows: 1) Sorting by species was completed and all baskets (*i*) weighed. 2) The weighed baskets were treated as *i*PSUs. A minimum of two PSUs (baskets)/species were selected for sub-sampling using a random number table (Rohlf and Sokal, 1995). All fish within the selected PSU were processed, either for Category 1 data or Category 2 data. 3) Category 2 fish were selected from all fish in a PSU by drawing from a pack of shuffled cards. In most cases, we sampled a 25% proportion by selecting fish corresponding to drawn cards marked by hearts. Cards were used to sample smaller numbers of Category 2 fish using fish corresponding to royalty (23%), kings and queens (15%), or aces (7.6%). 4) Both baskets were weighed and recorded, and processing was completed.

5.3 Results and Tentative Conclusions:

Catches

A total of 7,238kg (17,581 individuals) of 44 fish species was processed from all hauls from Elephant Island (Table 5.3) and the lower South Shetlands Islands (Table 5.4). Species that were caught in substantial numbers, defined as >500kg or >500 individuals, included *Notothenia coriiceps*, *Gobionotothen gibberifrons*, *Champsocephalus gunnari*, *Chaenocephalus aceratus*, *Chionodraco rastrospinosus*, *Gymnoscopelus nicholsi*, and *Lepidonotothen larseni*. The greatest combined yields occurred at stations on the western and northwestern shelf of Elephant Island and north of King George Island within the 100-200m depth strata (Figure 5.2A). The highest diversity of finfish species occurred north and east of King George Island within the 300-400m depth strata (Figure 5.2B). The species with the greatest yield in weight was *Notothenia coriiceps* (2,296kg, 1,752 individuals), followed by *Gobionotothen gibberifrons* (2,128kg, 3,041 individuals) and *Champsocephalus gunnari* (778kg, 4,318 individuals). The greatest catch in numbers was *C. gunnari* followed by the myctophid *Gymnoscopelus nicholsi* (3,662 individuals) and *G. gibberifrons* (2,128kg, 3,041 individuals).

There was substantial variation in catches between stations. The average yield for a single haul was 102kg (σ=217), and 248 individual fish (σ=324). The greatest yield in weight for a single haul was 1,568kg (1,371 individuals) at Station 48 north of King George Island (Figure 5.2A).

This haul was dominated in weight by *Notothenia coriiceps* (98%). Other substantial yields were encountered northwest of Elephant Island at Station 20 (635kg, 655 individuals), in which 56% were *Gobionotothen gibberifrons* and 33% were *Chaenocephalus aceratus*, and west of Elephant Island at Station 4 (610kg, 1,126 individuals), 69% of which was comprised of *G. gibberifrons* and 17% were comprised of *C. aceratus*. Another notable catch occurred west of Elephant Island at Station 1, were 1,320 (143kg) juvenile *C. gunnari* were captured.

Although there were a total of 44 different species encountered, the number of species present in each haul (Figure 5.2B) ranged from 2 to 16, with an average of 9 species per haul. Figure 5.2B demonstrates substantial variability in species richness per haul around the South Shetland Islands, with a somewhat lower species diversity at the most nearshore stations. The most frequently encountered species was *C. aceratus*, which was found within catches at 61 of the 71 stations (86%). Other species encountered frequently were *G. gibberifrons* (83%), *C. gunnari* (76%), *C. rastrospinosus* (68%), *L. larseni* (64%), and *N. coriiceps* (58%). All other species occurred in less than 50% of hauls.

General Features of Finfish in the Southern Scotia Arc

Two ichthyofaunal elements overlap in the southern Scotia Arc region: the low-Antarctic (or peri- or lesser Antarctic) and the high-Antarctic fauna. Most finfish species within the 500m isobath of island groups in the southern Scotia Arc are nototheniids and channichthyids of low-Antarctic origin. This group makes up about 85% of the overall finfish biomass. The most dominant low-Antarctic species before commercial fishing commenced were *N. rossii*, *G. gibberifrons*, *L. squamifrons*, *C. gunnari*, *C. aceratus* and *Pseudochaenichthys georgianus*.

High-Antarctic species reach their northernmost limit of distribution in the southern Scotia Arc. High-Antarctic species are represented primarily by nototheniids, such as *Trematomus eulepidotus*, and channichthyids, such as *Cryodraco antarcticus*. They are more likely encountered in waters deeper than 250m. Members of the other two notothenioid families, Bathydraconidae (except *Parachaenichthys charcoti*) and Artedidraconidae are extremely rare, and are usually caught as single individuals. Other rare high-Antarctic species include the nototheniids *T. bernacchii*, *T. newnesi*, *T. pennellii* and *T. loennbergi*. The only high Antarctic species of the family Channichthyidae that is caught in substantial numbers is *C. rastrospinosus*. During this survey, we also encountered the rare channichthyid *Pagetopsis macropterus*.

Mesopelagic species, primarily *Gymnoscopelus nicholsi* and *Electrona antarctica* are more abundant in waters deeper than 350m. Other mesopelagic fish regularly encountered are *Paradiplospinus gracilis* and in deeper hauls below 400m *Gymnoscopelus braueri*. Other myctophids, such as *G. opisthopterus* and *Krefftichthys anderssoni* were only caught as single individuals.

Non-notothenioid species which are observed in some numbers are the three rajiid species: *Bathyraja eatonii*, *B. maccaini*, which grow to more than 100cm; and the small-sized *Bathyraja* sp. 2, which rarely exceeds 60cm in size. Zoarcids are mostly deep-water species. Only three species occur regularly in water shallower than 500m, and all were found to be much more abundant than in 1998. *Lycodichthys antarcticus* was only caught as individuals. However, the other two species, *Pachycara brachycephalum* and *Ophthalmolycus amberensis*, occurred regularly.

Results - Finfish Species of Importance:

Champsocephalus gunnari

One of the most important finfish in the South Shetland Islands, and throughout the Scotia Sea, is the channichthyid *C. gunnari*, an active bentho-pelagic species. A total of 789kg (4,318 individuals) was captured from 54 stations (Tables 5.3 & 5.4), and the overall average standardized density was 252.3kg/nm^2 ($\sigma = 451.8$). The majority of the *C. gunnari* catch (about 68%) occurred around Elephant Island, particularly in areas to the west and northwest (Figure 5.3A). In both Elephant Island and the lower South Shetlands Islands, there appears to be a general spatial increase in abundance in westerly stations, particularly along the South Shetlands. The highest average densities occur within the 100-200m depth strata of both areas (Tables 5.3 & 5.4). The large catches west of Elephant Island were mainly due to concentrations of juvenile fish. The size distribution ranged from 12 to 54cm, with strong overall modes at 25cm, 37cm, and 44cm (Figure 5.4A). There appears to be an additional mode in the lower South Shetlands Islands at about 28cm, and a substantially greater proportion of adult fish. This pattern was also observed during the 1998 AMLR survey of the South Shetland Islands, suggesting that a higher proportion of juvenile *C. gunnari* relative to mature individuals are more likely to be found west of Elephant Island during the austral summer.

Most fish (50%) were juveniles (maturity stage 1) with 21%, 29%, and .5% observed at maturity stages 2, 3, and 5, respectively. About 54% of the catch was female. *C. gunnari* appears to spawn over a more extended period of time than other channichthyids. The different stages of gonadal development expressed by a large range of GSIs observed in different parts of the shelf point at an extended period of spawning of about 3 months. The first spent fish were observed in the catch in the beginning of the survey. However, no fish in spawning condition were observed during this survey (Table 5.5). Spawning appears to be less synchronized than in other channichthyids and occurs over a longer period of time in *C. gunnari*.

An intensified diet composition sampling effort was conducted for *C. gunnari* to investigate potential differences in food composition and the amount in various parts of the shelf. A total of 1,072 stomachs from *C. gunnari* was analyzed. Of these stomachs, 17.5% were empty. Whenever sample sizes of the species were large enough, 40 stomachs were frozen and the necessary ancillary information from the individual fish (length to the cm below, total and eviscerated weight, sex, maturity stage, gonad weight, stomach fullness and stomach fresh weight) was collected. All stomachs containing food were frozen from catches containing less than 40 individuals. A total of 834 stomachs contained food and were frozen for further studies.

The stomach contents of 238 fish, randomly sampled of the catch (See "Sub-sampling Protocol" above) were examined at sea. Of the fish with full or partially full stomachs, the composition of 99% of stomach contents consisted solely of krill (*Euphausia superba*), and 1% consisted of myctophid fish and unidentified species (Figure 5.5). However, the amount of food taken and the degree of digestion varied considerably between stations and even within a station. Stomach content weight varied from < 1 to 10 % of the body weight.

Chaenocephalus aceratus

The channichthyid *C. aceratus*, a sluggish sedentary species, was the most frequently encountered finfish species. A total of 738kg (1,091 individuals) was captured from 61 stations (Tables 5.3 & 5.4), and the overall average standardized density was 785.4kg/nm^2 ($\sigma = 2,115.6$). The overall distribution of biomass was similar to that of *C. gunnari*, where the majority of the *C. aceratus* catch (about 72%) occurred around Elephant Island, particularly in areas to the west and northwest (Figure 5.3B). Catches were made from all strata, with the greatest average densities occurring within the 100-200m depth strata of both areas (Tables 5.3 & 5.4). The size distribution of *C. aceratus* was among the greatest of any species captured, ranging from 10 to 71cm. Well-defined modes appear at 25cm, 33cm, 48cm, and 60cm (Figure 5.4B), with substantially more fish in the 2nd modes in the South Shetland Islands and greater numbers of larger size classes around Elephant Island.

Fish were found at all stages of maturity. Most fish (58%) were juveniles (maturity stage 1) with 23%, 15%, 0.6%, and 3% observed at maturity stages 2, 3, 4 and 5, respectively. Sexes were equally represented in the catch. Spawning starts in March (Table 5.5). We found a small number of spent females from mid-March onwards. The similar developmental stage of the ovaries suggested that maturation for *C. aceratus* is more synchronized than *C. gunnari*. Consequently the spawning time is shorter than in *C. gunnari* and is unlikely to extend past 6-8 weeks. GSIs were mostly >14 with some females close to spawning with a GSI of > 23. Oocyte diameter was 4.4-4.7mm for *C aceratus*.

An intensified stomach composition sampling effort of *C. aceratus* was conducted. A total of 692 stomachs from *C. aceratus* was analyzed (Figure 5.5). Because regurgitation of the stomach contents often occurred, a total of 150 stomachs of *C. aceratus* containing food were examined. *C. aceratus* change their diet when they reach sizes of 25-30cm. Small fish fed on krill, and to a lesser extent on fish (Figure 5.5). Larger *C. aceratus* lived entirely on other fish.

Chionodraco rastrospinosus

The channichthyid *C. rastrospinosus* is the only true high Antarctic species that appears regularly in catches. A total of 503kg (1,133 individuals) was captured from 48 stations (Tables 5.3 & 5.4), and the overall average standardized density was 540.2kg/nm^2 ($\sigma = 1,238.7$). The majority of catches occurred north of King George Island and the most offshore stations west of Elephant Island (Figure 5.3C). Although we have observed in the past that *C. rastrospinosus* tend to favor depths greater than 300 meters, the highest average densities were encountered within the 200-300m depth strata of both areas (Tables 5.3 & 5.4). The size distribution of *C. rastrospinosus* ranged from 21 to 48cm. Well-defined modes appeared at 31cm and 40cm (Figure 5.4C), with greater numbers of large fish encountered in the lower South Shetland Islands.

Fish were found at all stages of maturity. Most fish (52%) were juveniles, with 20%, 26%, 0.8%, and 1% observed at maturity stages 2, 3, 4 and 5, respectively. Most fish (57%) were males. The development of the ovaries was slightly more advanced in the South Shetland Islands than around Elephant Island. This suggests a slightly earlier start of the spawning season (about 14 days) in the South Shetland Islands. The synchronized development of most ovaries suggests a comparatively short spawning period of 4-6 weeks. GSIs in most females were 16-21 around Elephant Island and 18-24 in the South Shetland Islands. GSIs in some spawning fish were 24-28 (Table 5.5). Egg diameter at spawning was 4.5-5.0mm.

A total of 436 stomachs from *C. rastrospinosus* was analyzed. All stomachs were filled to at least 25% capacity. The average diet composition consisted mainly of krill (84%; Figure 5.5). In addition, their diet consisted of fish (12%), amphipods, octopus, salps, and unidentified organisms (Σ=6%).

Dissostichus mawsoni

The nototheniid *D. mawsoni* is the most likely fish species to be targeted in any future fishing operations, and thus warranted special attention during our surveys. A total of 40kg (66 individuals) was captured from 32 stations (Table 5.3 & 5.4), and the overall average standardized density was 41.8kg/nm^2 (σ = 67.5). Although this is a small number relative to the other species captured, this represents about twice as much as was captured during the 1998 survey. Fish were relatively evenly distributed across the entire island chain (Figure 5.3D). Although the sample sizes were small, catches were observed at all strata, with the greatest average densities occurring within the 200-300m depth strata of both areas (Table 5.3 & 5.4). The size distribution ranged from 13 to 60cm. Although there are fairly well-defined modes (Figure 5.4D), the sample sizes were small.

Most fish (97%) were juveniles, with the other 3% at the maturing virgin stage, with no other information available regarding the spawning. Sexes were equally represented in the catch. Stomach contents were examined from all fish. About 18% of these fish had empty stomachs. The composition of the diet for those fish with stomach contents consisted mostly of fish (68%), and krill (32%) and an occasional amphipod (Figure 5.5). There was no apparent shift in diet composition with size.

Gobionotothen gibberifrons

The nototheniid *G. gibberifrons* is the most abundant finfish in the South Shetlands Islands, as well as the second most frequently encountered. A total of 2,128kg (3,041 individuals) was captured from 59 stations (Tables 5.3 & 5.4), and the overall average standardized density was 2,222.2kg/nm^2 (σ = 5,696.5). The majority of catches occurred west and northwest of Elephant Island and north of King George Island (Figure 5.3E). Catches were observed at all strata, with the greatest average densities occurring between 100-300 meters (Tables 5.3 & 5.4). The size distribution ranged from 22 to 50cm, with a single mode appearing at around 38cm for combined area length distributions (Figure 5.4E). However, when broken down by area, there were two clearly defined modes, one at 36cm at the lower South Shetlands Islands and the other at 39cm around Elephant Island. An almost identical pattern was observed during the 1998 AMLR survey, and this suggested that a higher proportion of juvenile *G. gibberifrons* are likely to be found in the lower South Shetlands Islands, which is the opposite of what we observed in the case of *C. gunnari*.

Fish were either maturing virgin or had developing gonads. Most fish (61%) were stage 2, and stage 1 (31%), with 7% immature, with slightly more females (55%) than males. Most fish appear to mature at 33-36cm lengths. Testes have a similar size as ovaries. Low GSIs of less than 8 in most individuals confirmed earlier observations around Elephant Island (Kock, 1989) and in the South Orkney Islands in 1999 that the species is a winter spawner (July-August; Table 5.5).

This species demonstrated the highest degree of variability in diet composition of all finfish encountered. A total of 411 stomachs from *G. gibberifrons* was analyzed. Most stomachs (96%) were at least 25% full. *G. gibberifrons* is primarily a benthic browser, and thus has a varied diet (Figure 5.5). Due to a large content of partially digested benthic invertebrate species, about 30% of the average diet was unidentifiable to species group. The greatest species groups that were identified were amphipods (17%), followed by ophiroids (12%), polychaetes (9.6%), salps (8.5%), krill (7.3%), isopods (7.2%), echinoderms (3.2%), and combined fish, pycnogonids, octopus, mysids, siphonophores, and fish eggs (Σ=5%).

Lepidonotothen larseni

The nototheniid *L. larseni* is small and not commercially important, but is relatively abundant and encountered quite often in the southern Scotia Sea. A total of 29kg (585 individuals) was captured from 46 stations (Tables 5.3 & 5.4), and the overall average standardized density was 31.9kg/nm^2 ($\sigma = 44.4$). The majority of catches occurred northwest of Elephant Island in deep stations and north of King George Island (Figure 5.F). This species was encountered in greatest numbers between 200 and 400 meters (Tables 5.3 & 5.4). The size distribution of *L. larseni* ranged from 7 to 22cm, with a well-defined mode at 18 cm, and a smaller mode at 14cm (Figure 5.4F). There was an almost identical size distribution in both areas.

Most fish (72%) were females that had started the process of gonad maturation. The majority of fish (48%) were mature stage 3, with 21% immature and 25% developing virgin. However, the still low GSIs (<8) confirmed earlier observations (Kock, 1989) that the species is a winter spawner (July-August; Table 5.5).

A total of 102 stomachs from *L. larseni* was analyzed. Most stomachs were (78%) at least 25% full. The average diet was composed of krill (66%), salps (9%), amphipods (7%), and unidentified benthic invertebrate organisms (Σ=18%) (Figure 5.5).

Lepidonotothen nudifrons

The nototheniid *L. nudifrons* is a small species which rarely exceeds 21cm in size, not commercially important, but potentially important in the Antarctic finfish community. A total of 13.8kg (325 individuals) was captured from 32 stations (Tables 5.3 & 5.4), and the overall average standardized density was 15.6kg/nm^2 ($\sigma = 47.7$). Two hot spots of *L. nudifrons* were encountered: one south of the eastern tip of Elephant Islands and one north of Snow Island in the western South Shetland Islands (Figure 5.G). This species has a shallow water distribution, with the greatest densities between 50 and 100 meters (Tables 5.3 & 5.4). The size distribution of *L. nudifrons* ranged from 7 to 20cm, with a well-defined mode at 15cm, and similar size composition in both areas.

Mostly female (67%) sexually mature individuals were captured. Gonads were well advanced in development with GSIs of 18-22 in most females. The smallest females observed with developing gonads were 11cm long. Spawning is likely to start in mid-April. The synchronized development of the gonads suggests a comparatively short spawning season of 4-6 weeks (Table 5.5).

A total of 43 stomachs from *L. nudifrons* was analyzed. Most stomachs (about 80%) were at least 25% full. This species has a varied diet (Figure 5.5). Due to a large proportion of partially digested benthic invertebrate species, about 40% of the average diet was unidentifiable to species. The largest groups identified were krill (33%), followed by amphipods (19%), isopods (5.3%), and polychaetes (2.6%).

Lepidonotothen squamifrons

The deep-water nototheniid *L. squamifrons* has been commercially exploited in other Antarctic island groups, and is abundant in other parts of the southern Scotia Arc, such as the South Orkney Islands. A total of 132kg (410 individuals) was captured from 23 stations (Tables 5.3 & 5.4), and the overall average standardized density was 132.4kg/nm^2 ($\sigma = 407.2$). The majority of catches occurred in the most offshore stations to the north and west of Elephant Island and north of King George Island (Figure 5.3H). The highest average densities were encountered between 400-500 meters, although there were some catches as well in the 300-400 meter strata (Tables 5.3 & 5.4). The size distribution of *L. squamifrons* ranged from 14 to 47cm. Most of the size class modes were mixed (Figure 5.4H), with a similar size composition between areas.

Fish were found at four stages of maturity, with 61% juveniles, and 22%, 8%, and 7% observed at maturity stages 2, 3, and 5, respectively. Most fish (60%) were females. The species was in the middle of the spawning season (Table 5.5). Spawning may occur in waters deeper than 500m, which were not covered by our survey.

A total of 185 stomachs from *L. squamifrons* was analyzed for diet composition. About 78% of these fish had stomachs that were at least 25% full. Like other species in the genus *Lepidonotothen*, the diet was complex, but was comprised mainly of krill (66%), unidentified benthic invertebrates (18%), salps (9%), amphipods (7%), polychaetes, and echinoderms ($\Sigma<2\%$) (Figure 5.5).

Notothenia coriiceps

The nototheniid *N. coriiceps* is the second most abundant finfish species in the South Shetlands Islands, after *G. gibberifrons*, and was the species that yielded the greatest catch in weight in this survey. A total of 2,296kg (1,752 individuals) was captured from 41 stations (Tables 5.3 & 5.4), and the overall average standardized density was 2,739kg/nm^2 ($\sigma = 16,458$). Similar to the 1998 AMLR survey, we encountered a very large pre-spawning aggregation north of King George Island (Figure 5.3I). This species has a shallow water distribution, with greatest average densities between 100 and 200 meters (Tables 5.3 & 5.4). The size distribution ranged from 25 to 58cm, with a single mode appearing at around 42cm for combined area length distributions (Figure 5.4I). The size compositions were similar between areas.

Almost all individuals (95%) caught were stage 3 sexually mature; the remaining at stage 2 (though close to 3). There were slightly more males (58%) than females. Maturation of most gonads appears to be synchronized, suggesting that the species reproduces over a comparatively short spawning season. This confirms earlier observations by Kock (1989) in the Elephant Island region in May-June 1986 who found that more than 80% of the females spawned within a 4-week period between mid-May and mid-June. GSIs of mostly 10-14 indicate that *N. coriiceps* spawn in 6-8 weeks time (Table 5.5).

This species demonstrated a surprising degree of variability in diet composition. A total of 296 stomachs from *C. coriiceps* was analyzed. Most stomachs (81%) were at least 25% full. The average diet was comprised of krill (44%), fish (28%), unidentified benthic invertebrates (9%), amphipods (8%), salps (5%), isopods, octopus, mysids, ophiroids, pycnogonids, polychaetes, and eggs (Σ=5.3%) (Figure 5.5).

Notothenia rossii

The nototheniid *N. rossii* was the primary target species in this area in the late 1970's fishery, and the recovery of this species is being closely monitored. A total of 129kg (118 individuals) was captured from 32 stations (Tables 5.3 & 5.4), and the overall average standardized density was 139.8kg/nm^2 ($\sigma = 345.2$). Although these are still relatively small numbers, these yields were about three times as much as that captured during the 1998 AMLR survey. The majority of catches occurred north of King George Island and at stations northwest of Elephant Island (Figure 5.3J). This species was captured in all depth strata, with the highest average densities encountered within 200-400 meters of both areas (Tables 5.3 & 5.4). The size distribution ranged from 20 to 65cm, with no well defined length modes (Figure 5.4J). Several very large specimens of *N. rossii* were encountered in the lower South Shetlands Islands.

Fish were found at all stages of maturity, with the majority of fish (48%) at maturing virgin or resting stage (stage 2), and 30%, 19%, 1%, and 1% observed at maturity stages 1, 3, 4 and 5, respectively. Sexes were equally represented in the catch. Most individuals in the 30-50cm length range were apparently recruiting to the adult stock. Ovaries were still largely in the juvenile stage while most testes were in an early stage of development, indicating that males mature at a smaller size than females. The early stage of development of the testes suggests that these individuals would not spawn this year. The comparatively few developing ovaries were well advanced (GSI: 14-17 in females, 10-15 in males). Spawning was likely to start in about 4 weeks after these samples were taken (Table 5.5).

A total of 101 stomachs from *N. rossii* was analyzed for diet composition. About 80% of these stomachs were at least 25% full. The average diet composition was similar to that of *N.*

coriiceps, though slightly less diverse. Their diet consisted mainly of krill (60%), fish (20%), unidentified benthic invertebrates (6%), salps (3%), isopods, and, mysids (Σ=2%) (Figure 5.5).

Parachaenichthys charcoti

P. charcoti was the only species of the family Bathydraconidae caught in relatively substantial numbers. There has been very little information published on this species, particularly in terms of their diet. Thus, we took the opportunity to conduct intensified sampling to better understand this important bathydraconid species. A total of 7.4kg (112 individuals) was captured from 30 stations (Tables 5.3 & 5.4), and the overall average standardized density was 8.3kg/nm^2 (σ = 15.7). The majority of catches occurred at shallow water stations to the west of Elephant Island, north of King George Island and Nelson Island (Figure 5.3K). This species was encountered in greatest numbers between 50 and 100 meters, with fewer numbers in deeper strata (Tables 5.3 & 5.4). The size distribution of *P. charcoti* ranged from 13 to 40cm, with a well-defined mode at 23-25cm and similar size composition in both areas (Figure 5.4K). Sexes were equally represented in the catches. Most fish (90%) were immature (stage 1), and with the exception of the other 10% at stage 2, gonads showed little indication of development, suggesting that the species spawns in the austral winter.

An intensive investigation of stomach contents and diet composition was performed for *P. charcoti*. A total of 85 out of 112 stomachs were processed. The majority of the diet composition of all stomachs consisted of mysids (55.8%), *Euphausia superba* (15.8%), unknown digested material (9.4%), amphipods (9.1%), fish (6.4%), and other crustaceans, isopods, tubeworms, and sponges (3.5%). The index of relative importance (Karpov and Caillet, 1979) indicated that mysids were the major prey item found in the stomachs of *P. charcoti*. Unknown digested material was found more often than *E. superba*, even though *E. superba* had comprised a greater percent composition than unknown digested material. The relative importance from greater to least prey items found in *P. charcoti* stomachs are unknown digested material, *E. superba*, fish, amphipods, tubeworms, other crustaceans, *Serolis* spp., and sponges. These preliminary findings disputed those of Targett (1981) and Gon and Heemstra (1990), who characterize fish the primary prey item of *P. charcoti*, based on a single specimen.

Pseudochaenichthys georgianus

A total of 141kg (169 individuals) of the channichthyid *P. georgianus* was captured from 24 stations (Tables 5.3 & 5.4). The majority of catches occurred at stations off Nelson, Greenwich, and Livingston Islands and northwest of Elephant Island (Figure 5.3L). Fish were encountered in all strata, with the highest average densities between 50-300 meters (Tables 5.3 & 5.4), and the overall average standardized density was 148kg/nm^2 (σ = 312.1). The size distribution of *P. georgianus* ranged from 19 to 59cm. There were clear modes at 36 and 45cm, and a higher proportion of larger animals were captured off Elephant Island (Figure 5.4L).

Fish were found at three stages of maturity. Most fish (39%) were juveniles, with 24%, and 29% observed at maturity stages 2 and 3, respectively. Sexes were equally represented in the catch. *P. georgianus* spawns in April-May at South Georgia (Kock and Kellermann, 1991). However, the low GSIs of <8 found in most individuals suggested that spawning occurs later further to the south and is unlikely to commence before June.

A total of 71 stomachs from *P. georgianus* was analyzed for diet composition. However, only about half had any stomach contents. The average diet was comprised mainly of fish (71%), krill (28%) and a small fraction of unidentified material (1.48%) (Figure 5.5).

Electrona antarctica and *Gymnoscopelus nicholsi*

These two species of mesopelagic myctophids are captured opportunistically during our surveys. Because they are likely the most important prey item after krill for several species of finfish, as well as many higher order birds and mammals, they are one of the most important finfish species in terms of the Antarctic ecosystem. A total of 4kg (265 individuals) of *E. antarctica* were captured from 15 stations and a total of 124kg (3,662 individuals) of *G. nicholsi* were captured from 23 stations. The majority of catches occurred at offshore stations north of Elephant Island for *E. antarctica* (Figure 5.3M) and north of Livingston Island for *G. nicholsi* (Figure 5.3N). While *G. nicholsi* was captured at all depth strata, the majority of both species was encountered in waters deeper than 300 meters (Tables 5.3 & 5.4). The size distribution of *E. antarctica* ranged from 69 and 114mm, with no well-defined length modes (Figure 5.4M). The length range for the larger, more abundant *G. nicholsi* was 118 to 175mm (Figure 5.4N), with large specimens encountered in the lower South Shetlands Islands.

Maturity stages were different for the two species. *E. antarctica* were in three stages of maturity, with most at maturing virgin or resting stage (stage 2), a limited number observed at maturity stages 1 and 3. *G. nicholsi* were almost all immature stage 1, with a small fraction observed at stage 2.

A total of 139 stomachs from *E. antarctica* and 340 stomachs from *G. nicholsi* were analyzed for diet composition. About 45% of *E. antarctica* and 80% of *G. nicholsi* stomachs were at least 25% full. The diet of both species consists primarily of krill (Figure 5.5), along with a small number of unidentified species, as well as amphipods.

Notes on Other Species

Several other species were captured in smaller numbers and were processed using the same sampling protocols, including analysis of diet composition (Figure 5.5), as the above species. At least eight species in the genus *Trematomus* were captured, all in small numbers. The most abundant was *Trematomus eulepidotus*. We captured about 7.6kg (26 individuals) from 10 stations, mostly around Elephant Islands between 300 and 400 meters. We examined the diet of 17 of these individuals, 11 of which had some contents in the stomach. Their diet consisted mainly of isopods (55%), and to a lesser extent fish (20%), and krill (18%) (Figure 5.5). This contradicts the findings of Tarverdiyeva and Pinskaya (1980) who found that *T. eulepidotus* fed mainly on krill, with no isopods as part of their diet in the South Shetland Islands. Most individuals were sexually mature and close to spawning. Spawning probably occurs in April-May. The species exhibits a sexual dimorphism in size in that females grow about 7cm larger than males. All individuals larger than 27cm were females. GSIs were 16-20.

We also captured several interesting specimens of the high Antarctic channichthyid *Cryodraco antarcticus* (48kg, 77 individuals from 20 stations). *C. antarcticus* is similar in size and morphology to *C. aceratus* and appears to replace *C. aceratus* in deeper water. Our survey only covered the upper part of the depth range of the species, which extends to 800m or beyond. A total of 62 stomachs from was analyzed, although only 21 fish had some stomach contents. The average composition consisted mainly of fish (80%), as well as krill (10%), and mysids (10%) (Figure 5.5). The species exhibits the same sexual dimorphism in size as *C. aceratus* in that females grow 15-18cm larger than males. Spawning appears to start in March as the first spent individuals were found. GSIs were 10-18. No females in spawning condition were caught. The very few mature males observed had GSIs of 6-7. Ovaries were preserved to estimate absolute and relative fecundity.

In addition, we captured several interesting specimens of the zoarcid *Pachycara brachycephalum* (5.8kg; 69 individuals from 17 stations). A total of 6 stomachs was analyzed for diet composition, half of which had some stomach contents. The diet composition for these specimens consisted of krill (50%), and amphipods (50%). Only one of the two ovaries is functional in zoarcids. We were able to collect four females of 26 to 32cm length with running ripe oocytes. Absolute fecundity was low and varied between 52 and 63 eggs with oocyte diameter greater than 6mm. The low number of eggs and the comparatively long incubation period suggested that eggs are either deposited in well-protected locations under stones or are guarded by either the male or female.

Antarctic Finfish Habitat Characterization

The seafloor of the shelf areas around the South Shetland Islands can include such features as banks, seamounts, plateaus, and submarine canyons. These are *megahabitat* features (Greene *et al.*, 1999) and can be identified in bathymetric maps such as those presented by Jones *et al.* (1999). These features may provide very broad indicators of finfish distribution, such as the probability of presence of high-Antarctic vs. low-Antarctic fauna as a function of depth. To examine the role of habitat on similar fish assemblages it is necessary to examine smaller scale *mesohabitat* features (Auster, 1998). Mesohabitats are features that have a size from tens of meters to a kilometer (Greene *et al.*, 1999), and the complexity of these habitats on Antarctic shelf areas can be influenced by a number of factors, including current regimes, proximity to landmass and glacial outflow, physical disturbance resulting from iceberg scouring, and impacts from fishing gear.

To determine the composition of the seafloor and available habitat for finfish, an acoustic digital discrimination and classification system was used. The seabed classes from the acoustic analysis were ground-truthed by means of a video system on a towed body (NEPTUN), and camera mounted grab sampler. A total of twelve successful bottom grab samples and seven Neptune tows were completed. The details of seabed classification and habitat characterization are presented in Section 3, "Bioacoustic Survey" in this report.

Mesohabitat features identified around the South Shetland Islands included areas of mud (silt and ooze), sand, gravel, pebble, cobble, boulder, bedrock and lava. We also found areas rich in

Antarctic invertebrate epifauna, which among other things, may provide Antarctic fish with structures for egg laying, settling and predator avoidance (Gutt and Ekau, 1996). In numerous instances, we observed fish in close proximity to sponges and other benthic invertebrate epifauna. Figure 5.6A shows a large colony of sponges with a fish (likely *C. gunnari*) very near the base of the structure. This behavior was observed with fish near very small benthic epifauna as well (Figure 5.6B). Given the proclivity of finfish to associate with structures on the seabed, our large scale habitat information will give valuable insight into the distribution and demographics of demersal finfish species, as well as potentially introducing alternative approaches to stratify surveys or post-stratify random survey designs prior to quantitative biomass modeling using habitat types as stratification criteria. At present, the relationship between Antarctic mesohabitats and finfish distribution and abundance requires considerable analysis, and any conclusions at this point would be premature. However, habitat information was collected from two areas that were distinctly different in finfish inventory and composition in the South Shetland Islands.

Low Diversity Habitat

The area west of Elephant Island around station 17 (Figure 5.1; Table 5.1) has among the lowest finfish density and diversity in the island chain (Figures 5.2A & 5.2B). This area yielded a total of only 12kg of three species of fish, *C. gunnari* (15), *C. aceratus* (3), and *C. coriiceps* (4). The acoustic seabed characterization of this transect indicated a statistically significant seabed class, and we conducted both video and grab sampling of this area for ground truthing (Figure 5.7). We confirmed that this area showed little structural diversity, and was composed primarily of bedrock (96%) with a thin layer of sand (.06-2mm grain size), gravel (2-4mm), and pebbles (4-64mm) and few other seabed features (Figure 5.7A-C). The development of benthic invertebrate fauna was among the lowest of any stations around Elephant Island. The invertebrate fauna was dominated by Asteroidea, which provides no usable structure for demersal fish. Interestingly, we found that krill were abundant in this region, particularly close to the bottom. Large numbers of krill were observed in the video right at the substrate (Figure 5.7A) and covering sporadic boulders (Figure 5.7D), suggesting that the substantial presence of prey does not necessarily indicate the potential for finfish presence. The krill that were observed were involuntarily carried by a strong current, which likely was responsible for the lack of fine silt settling in this region. Whether this current is a permanent hydrographic feature of this region requires further study.

High Diversity Habitat

The fishable grounds north of King George Island are interesting for several reasons. In addition to grounds that contain the highest densities of several species, this region also has areas of substantial finfish diversity. The seabed around Station 48 is an example of a high biomass, high diversity region (Figure 5.1; Table 5.1). This was the station where a large pre-spawning aggregation of *N. coriiceps*, as well as nine other species were encountered. The acoustic seabed characterization of the station 48 transect indicated several mixed significant seabed classes, with mostly (71%) dense structured mud/clay (grain size <0.06mm) and bedrock layered with sand and sediments (.06-2mm grain size) with wave-like structures. We conducted a video tow of this area for ground truthing these mixed areas (Figure 5.8). Figure 5.8A shows the very rich benthic epifauna community that characterized the seafloor. The benthic invertebrate fauna encountered in this area was dominated by species in the phylum Porifera, which suggests that this substrate is more conducive to richer benthic development than the low diversity area dominated by sea stars described in the previous paragraph. The area also was characterized by "structured" mud and outcroppings and increased diversity of the seabed (Figure 5.8B). These mixed seabed classes, along with the rich epifauna, may provide a more optimal location for the *N. coriiceps* prespawning aggregations (visible in Figures 5.8C & 5.8D), which was also observed in this area during the 1998 AMLR fish survey.

5.4 Disposition of Data: All data collected were documented on hardcopy datasheets and entered into an MS-ACCESS computer database. The U.S. AMLR program maintains these hardcopies and computer databases.

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Table 5.1. Station and catch information for the 2001 AMLR finfish survey of the South Shetland Islands: Elephant Island stations.

Station	Region	Latitude	Longitude	Strata	Mean Depth	Number of Species	Total Catch (Kg)	Total Number
1	Elephant Island	61° 17.330’	55° 42.735’	2	143	11	182.393	1371
2	Elephant Island	61° 15.030’	55° 36.940’	1	80	8	11.795	33
3	Elephant Island	61° 11.505’	55° 41.410’	1	84	7	5.915	23
4	Elephant Island	61° 13.850’	55° 53.150’	2	137	8	609.901	1126
5	Elephant Island	61° 17.455’	56° 04.735’	3	285	9	50.491	164
6	Elephant Island	61° 21.885’	56° 01.735’	4	337	7	24.902	86
8	Elephant Island	61° 16.340’	56° 29.000’	5	416	10	59.607	267
9	Elephant Island	61° 09.200’	56° 13.355’	5	467	8	11.416	44
10	Elephant Island	61° 09.080’	56° 04.530’	2	156	4	46.854	174
11	Elephant Island	61° 10.435’	55° 54.355’	2	112	5	36.45	41
12	Elephant Island	61° 04.920’	56° 02.615’	3	232	5	17.312	27
13	Elephant Island	61° 03.260’	55° 43.280’	1	93	7	23.227	120
14	Elephant Island	61° 03.645’	55° 53.485’	2	143	4	110.929	327
15	Elephant Island	61° 00.975’	55° 58.470’	4	314	10	34.569	89
16	Elephant Island	60° 58.030’	55° 50.970’	2	157	9	416.865	1189
17	Elephant Island	60° 59.145’	55° 40.475’	1	58	3	12.584	22
18	Elephant Island	61° 06.430’	55° 42.705’	1	59	4	1.88	7
19	Elephant Island	60° 53.780’	55° 38.040’	2	141.6	10	101.407	129
20	Elephant Island	60° 53.690’	55° 42.790’	2	173	7	635.119	655

21	Elephant Island	60° 50.525'	55° 42.590'	3	267	5	19.337	26
22	Elephant Island	60° 49.625'	55° 38.665'	5	409	12	36.139	234
23	Elephant Island	60° 51.660'	55° 30.050'	3	261.9	14	80.747	147
24	Elephant Island	60° 52.975'	55° 27.825'	3	226	10	341.563	438
25	Elephant Island	60° 55.715'	55° 26.730'	2	105	9	47.496	69
26	Elephant Island	60° 52.695'	55° 21.170'	4	327	9	8.9371	132
27	Elephant Island	60° 58.125'	55° 04.815'	3	291	12	29.549	62
28	Elephant Island	61° 00.770'	55° 07.145'	2	132	8	86.098	133
30	Elephant Island	61° 03.135'	54° 44.035'	5	402	11	14.673	64
31	Elephant Island	61° 11.645'	54° 43.960'	3	240	10	24.196	72
32	Elephant Island	61° 16.015'	54° 53.935'	2	139	7	38.378	268
33	Elephant Island	61° 12.010'	54° 51.845'	1	70.4	6	12.158	122
34	Elephant Island	61° 10.095'	54° 33.535'	4	331	13	12.106	119
35	Elephant Island	61° 20.735'	55° 12.450'	3	244	12	56.535	113
36	Elephant Island	61° 20.405'	55° 30.170'	2	142	6	8.301	17
37	Elephant Island	61° 17.155'	56° 14.570'	4	302	8	16.627	33
38	Elephant Island	61° 25.940'	56° 07.715'	4	306	11	33.423	98
82	Elephant Island	61° 04.000'	54° 33.580'	2	198	6	35.966	46

Table 5.1. continued.

Table 5.2. Station and catch information for the 2001 AMLR finfish survey of the South Shetland Islands: lower South Shetland Islands stations.

Station	Region	Latitude	Longitude	Strata	Mean Depth	Number of Species	Total Catch (Kg)	Total Number
42	South Shetland Islands	61° 50.705	57° 20.025	3	252	9	56.83	177
43	South Shetland Islands	61° 39.395	57° 05.060	5	438	6	7.734	96
44	South Shetland Islands	61° 44.780	58° 02.180	3	242	10	147.165	168
45	South Shetland Islands	61° 39.100	57° 46.045	4	317	16	90.765	160
47	South Shetland Islands	61° 36.115	58° 33.830	4	332	11	66.55	221
48	South Shetland Islands	61° 49.525	58° 34.310	2	165	10	1567.753	1310
49	South Shetland Islands	61° 45.845	58° 33.875	3	261	11	483.837	456
50	South Shetland Islands	61° 48.355	58° 42.785	3	244	10	119.874	189
51	South Shetland Islands	61° 39.665	58° 49.415	4	357	13	76.73	1113
52	South Shetland Islands	62° 00.010	59° 12.600	2	126	11	69.178	126
53	South Shetland Islands	62° 00.715	59° 37.210	2	163	13	184.742	315
55	South Shetland Islands	61° 56.460	59° 35.535	3	235	13	63.193	140
56	South Shetland Islands	61° 58.975	59° 55.785	3	264	9	79.318	172
57	South Shetland Islands	62° 10.385	59° 25.875	1	62	2	4.345	6
58	South Shetland Islands	62° 06.745	59° 30.145	1	80.6	6	8.539	26
61	South Shetland Islands	62° 19.705	60° 29.460	2	113	12	50.326	167
62	South Shetland Islands	62° 06.105	60° 34.300	4	363	8	23.468	285
63	South Shetland Islands	62° 10.190	60° 49.015	5	403	8	35.544	1090
68	South Shetland Islands	61° 36.290	57° 14.910	5	426	10	10.36	63

69	South Shetland Islands	61° 38.175	57° 33.025	5	400	12	27.48	119
70	South Shetland Islands	62° 10.385	60° 28.365	2	174	14	63.967	244
71	South Shetland Islands	62° 26.340	61° 07.495	2	138	8	14.741	43
72	South Shetland Islands	62° 23.900	60° 56.855	1	92	7	35.714	80
74	South Shetland Islands	62° 23.910	60° 47.885	1	80	8	18.384	74
75	South Shetland Islands	62° 23.415	61° 24.580	4	344	14	47.66	763
77	South Shetland Islands	62° 41.895	61° 39.650	1	87	10	82.853	254
78	South Shetland Islands	62° 52.255	61° 48.600	2	141	13	60.182	187
79	South Shetland Islands	62° 49.870	60° 55.615	2	186	11	36.391	167
80	South Shetland Islands	62° 55.075	60° 54.545	2	175	7	6.088	39
83	South Shetland Islands	61° 51.395	59° 13.990	3	244	12	162.433	316
85	South Shetland Islands	61° 44.195	58° 20.525	3	272	13	147.879	188
86	South Shetland Islands	62° 40.025	61° 48.370	2	143	10	56.324	211
87	South Shetland Islands	62° 59.285	60° 57.800	4	359	16	30.88	452
88	South Shetland Islands	63° 04.705	60° 36.700	5	429	9	5.667	78

Table 5.2. continued.

Table 5.3. Total weight and numbers of species caught within the 500m isobath of Elephant Island.

	Depth											
	50-100m		100-200m		200-300m		300-400m		400-500m		Sum	
Species	Kg.	Num.	Kg.	Num.	Kg.	Num.	Kg.	Num.	Kg.	Num.	Kg.	Num.
Bathylagus antarcticus									0.4	15	0.4	15
Bathyraja eatonii					4.5	2					4.5	2
Bathyraja maccaini	5.4	3	29.5	5	15.	2					49.9	10
Bathyraja sp2					0.3	2	1.1	2	0.3	3	1.6	7
Chaenocephalus aceratus	9.5	9	463.5	388	34.6	80	16.5	42	10.7	11	534.9	530
Champsocephalus gunnari	21.4	152	470.9	3219	55.1	82	3.9	8	1.7	2	552.9	3463
Chionodraco rastrospinosus			3.7	9	53.8	119	31.5	95	12.9	30	101.8	253
Cryodraco antarcticus					1.5	5	2.6	12	4.0	7	8.0	24
Dissostichus mawsoni	0.01	1	2.9	6	8.4	10	4.3	7	3.5	3	19.1	27
Electrona antarctica					0.04	3	0.5	36	0.4	47	0.9	86
Gobionotothen gibberifrons	3.6	5	1223.2	1670	396.2	445	41.1	69	8.0	11	1672.1	2200
Gymnoscopelus nicholsi					0.6	18	5.5	169	6.4	188	12.4	375
Gymnoscopelus opisthopterus									5.1	133	5.1	133
Icichthys australis									0.9	1	0.9	1
Lepidonotothen larseni			3.4	65	7.7	158	2.5	52	2.1	30	15.7	305
Lepidonotothen nudifrons	3.9	117	2.2	48	0.1	2					6.2	167
Lepidonotothen squamifrons					20.7	85	7.8	38	62.0	115	90.6	238
Magnisudis prionosa							0.1	1			0.07	1
Muraenolepis microps					0.3	2	0.6	1	1.2	5	2.1	8
Notothenia coriiceps	18.6	16	105.4	75	2.7	2	1.6	1			128.3	94
Notothenia rossii	1.8	2	16.4	17	11.7	9	2.7	2			32.6	30
Pachycara brachycephalum			0.04	1	0.4	6			0.05	1	0.4	8
Parachaenichthys charcoti	0.7	15	1.1	13	0.2	3					2.0	31
Paradiplospinus gracilis							1.0	1	0.09	1	1.1	2
Pogonophryne dolichobranchiata					0.2	1					0.2	1
Pogonophryne species							0.2	1	0.05	1	0.3	2

Table 5.3. continued.

Depth

	50-100m		100-200m		200-300m		300-400m		400-500m		Sum	
Species	Kg.	Num.	Kg.	Num.	Kg.	Num.	Kg.	Num.	Kg.	Num.	Kg.	Num.
Pseudochaenichthys georgianus	2.0	1	32.9	24	4.4	7	3.3	6	0.5	1	43.2	39
Trematomus bernacchii	0.7	1	0.8	3							0.9	4
Trematomus eulepidotus					1.4	4	3.8	14	1.7	4	6.9	22
Trematomus hansoni			0.2	1							0.2	1
Trematomus newnesi	0.6	5	0.1	1							0.7	6
Trematomus spp.					0.01	2					0.01	2

Table 5.4. Total weight and numbers of species caught within the 500m isobath of the lower South Shetland Islands.

Depth

	50-100m		100-200m		200-300m		300-400m		400-500m		Sum	
Species	Kg.	Num.	Kg.	Num.	Kg.	Num.	Kg.	Num.	Kg.	Num.	Kg.	Num.
Bathyraja eatonii					11.4	2			1.6	1	12.9	3
Bathyraja maccaini	3.4	11	0.2	2			0.8	1			4.4	14
Bathyraja sp2			1.1	1			3.7	35	1.2	5	5.9	41
Chaenocephalus aceratus	19.7	71	150.7	420	27.5	52	5.3	18			203.1	561
Chaenodraco wilsoni			0.4	4	0.5	1	0.1	1			0.6	6
Champsocephalus gunnari	44.0	159	148.2	555	29.9	50	13.6	91			235.6	855
Chionodraco rastrospinosus	0.6	1	10.9	21	281.4	581	90.5	242	17.4	35	400.9	880
Cryodraco antarcticus					1.9	2	32.1	42	6.4	9	40.4	53
Dissostichus mawsoni			5.2	21	12.8	14	3.2	4			21.2	39
Electrona antarctica					0.1	4	0.1	10	2.9	165	3.1	179
Gerlachea australis							0.1	1			0.6	1
Gobionotothen gibberifrons	1.1	3	101.9	210	330.5	582	19.1	39	3.7	7	456.3	841
Gymnodraco acuticeps					0.2	1	0.1	1	0.03	1	0.3	3
Gymnoscopelus braueri									0.5	9	0.5	9
Gymnoscopelus nicholsi	1.0	2	0.2	4	0.03	1	73.3	2143	38.2	1137	111.9	3287
Gymnoscopelus opisthopterus					0.04	1					0.04	1
Krefftichthys anderssoni			0.01	1							0.01	1

Table 5.4. continued.

Depth

	50-100m		100-200m		200-300m		300-400m		400-500m		Sum	
Species	Kg.	Num.	Kg.	Num.	Kg.	Num.	Kg.	Num.	Kg.	Num.	Kg.	Num.
Lepidonotothen larseni	0.02	3	3.2	82	4.5	90	5.2	94	0.6	11	13.5	280
Lepidonotothen nudifrons	3.9	74	3.0	67	0.7	16	0.1	1			7.6	158
Lepidonotothen squamifrons							34.0	137	7.3	35	41.3	172
Muraenolepis microps									1.2	2	1.2	2
Notothenia coriiceps	60.0	61	1602.2	1285	485.3	295	20.5	17			2168.0	1658
Notothenia rossii	3.8	6	14.4	18	48.7	47	25.8	14	3.9	3	96.4	88
Ophthalmolycus amberensis					0.3	2	1.5	24	0.2	3	2.1	29
Pachycara brachycephalum			0.4	4	1.1	12	3.8	45			5.3	61
Pagetopsis macropterus			0.05	1							0.05	1
Parachaenichthys charcoti	2.4	36	1.2	18	1.4	21	0.3	6			5.3	81
Paradiplospinus gracilis							1.0	14	0.8	10	1.8	24
Pleuragramma antarcticum							0.2	5	0.9	12	1.1	17
Pogonophryne marmorata							0.1	1			0.1	1
Pseudochaenichthys georgianus	10.9	13	64.7	85	23.0	32					98.6	130
Trematomus bernacchii			0.3	1							0.3	1
Trematomus eulepidotus							0.7	3	0.1	1	0.7	4
Trematomus hansoni			1.0	4			0.7	4			1.7	8
Trematomus loennbergii			0.1	1							0.1	1
Trematomus newnesi			0.3	2							0.3	2
Trematomus pennellii			0.1	1							0.1	1
Trematomus scotti			0.1	1			0.1	1			0.2	2

Table 5.5. Estimated spawning time, gonado-somatic indices (GSI) at spawning, GSI in March 2001, and egg size at spawning for abundant nototheniids, bathydraconids and channichthyids in the Elephant Island-South Shetland Island region.

Species	Estimated spawning time	GSI at spawning	GSI in March 2001 *	Egg size (mm)
Notothenia rossii	May - June	20 - 30	10 - 12	4.7 - 5.0
N. coriiceps	May - June	23 - 28	8 - 12	4.4 - 4.7
Lepidonotothen squamifrons	February - April	unknown	unknown	Probably 1.4
L. larseni	July - August	unknown	8	1.8 - 2.0
L. nudifrons	April - May	23 - 28	18 - 22	2.5
Gobionotothen gibberifrons	July - August	unknown	8	1.7 - 2.0
Parachaenichthys charcoti	August	unknown	5	unknown
Champsocephalus gunnari	March - May (June)	23 - 28	5 - 18	3.5 - 3.7
Chaenocephalus aceratus	March - April	23 - 28	12 - 18	4.4 - 4.7
Pseuchaenichthys georgianus	June - July	10	23 - 28	4.5 - 4.8
Chionodraco rastrospinosus	March - April	18 - 24	23 - 28	4.5 - 5.0
Cryodraco antarcticus	March - April	10 - 18	unknown	4
Pachycara brachycephalum	Probably extended	unknown	unknown	6

* Figures may change slightly when all material is analysed.

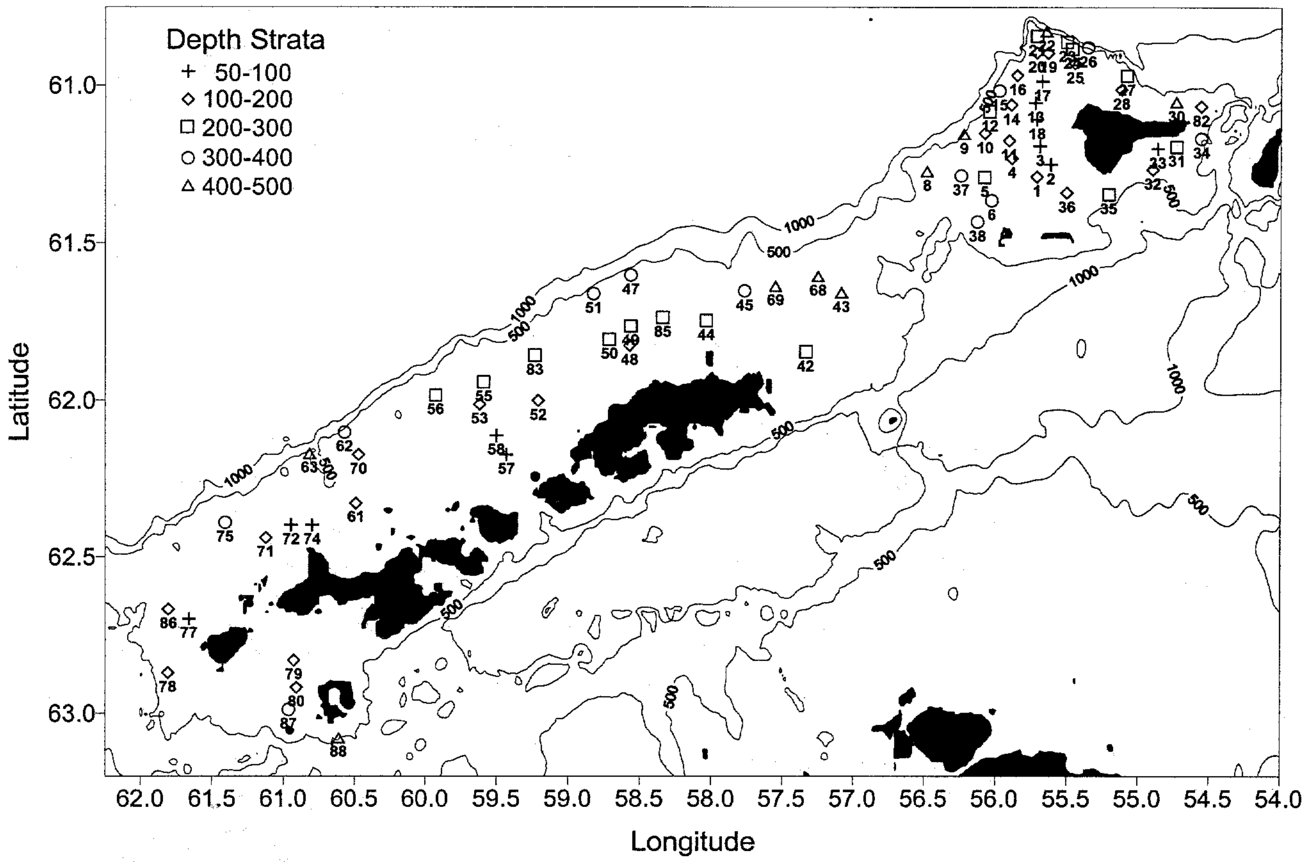

Figure 5.1. Station locations for the 2001 AMLR finfish bottom trawl survey. Longitude is West and latitude is South.

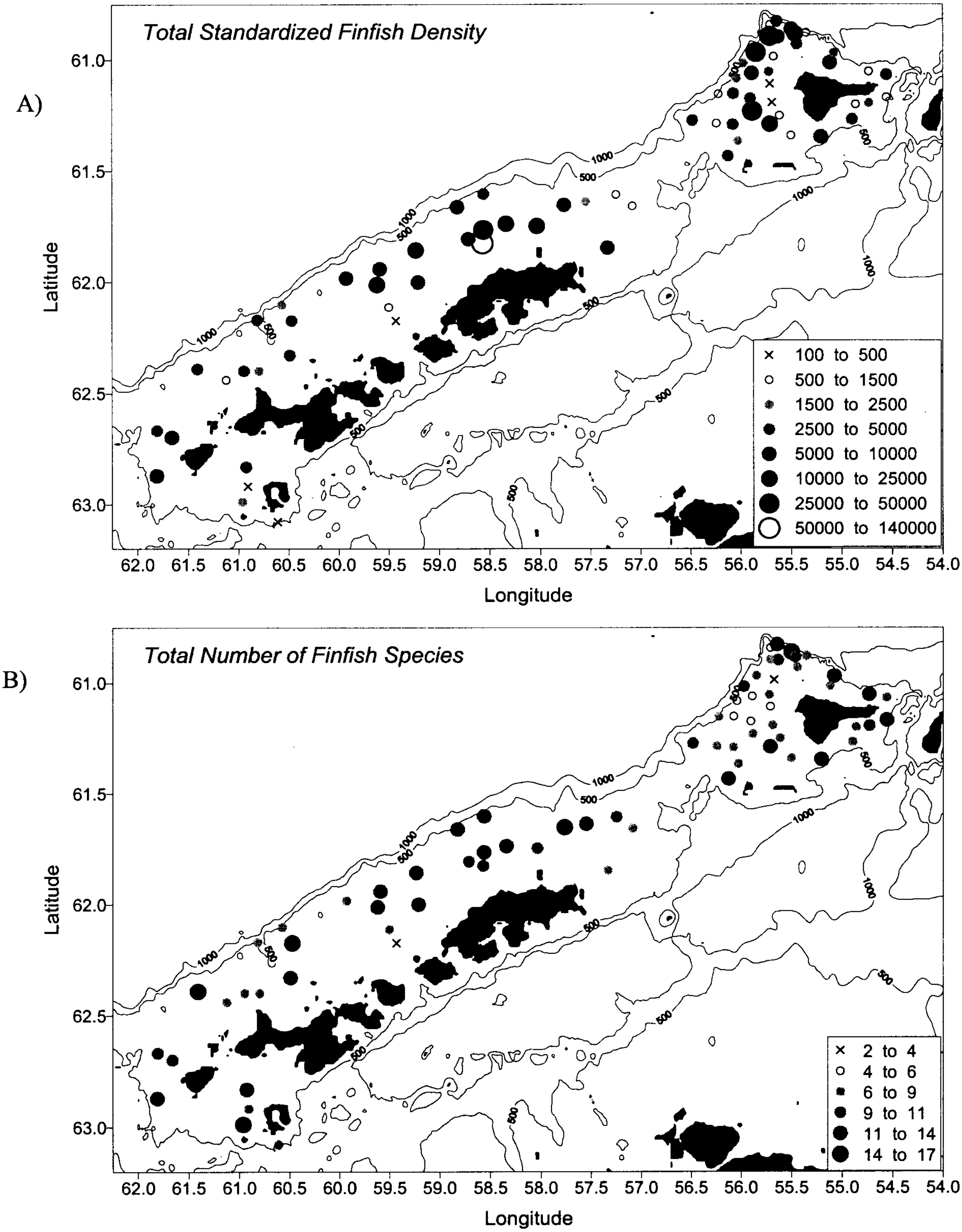

Figure 5.2. A) Total standardized finfish density in kg/nm^2, and B) total number of species taken from the 2001 AMLR finfish survey of the South Shetland Islands. Longitude is West and latitude is South.

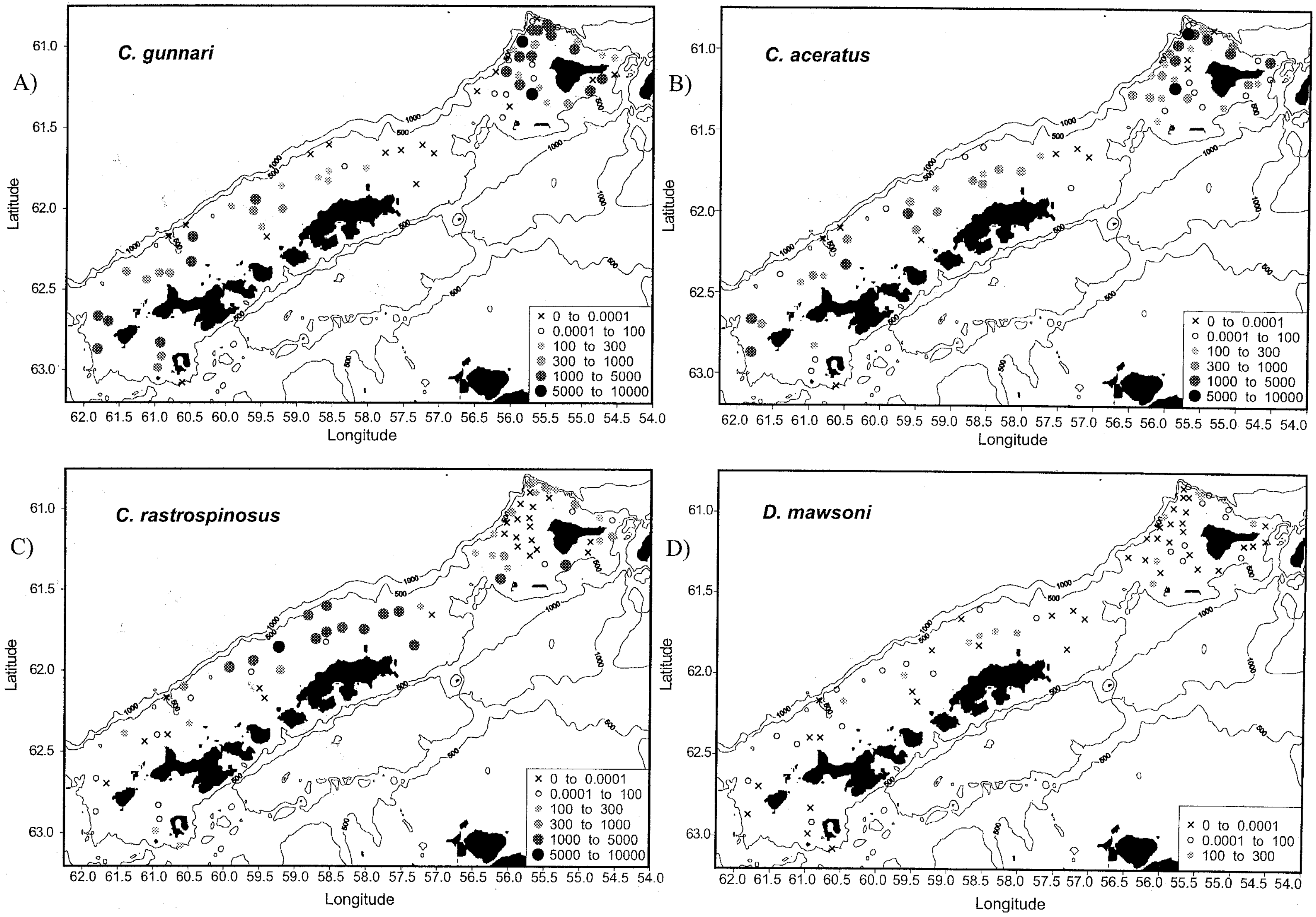

Figure 5.3. Standardized density (kg/nm^2) for A) *C. Gunnari*; B) *C. Aceratus*; C) *rastrospinosus*; D) *D. Mawsoni* from the 2001 AMLR finfish survey of the South Shetland Islands. Longitude is West and latitude is South.

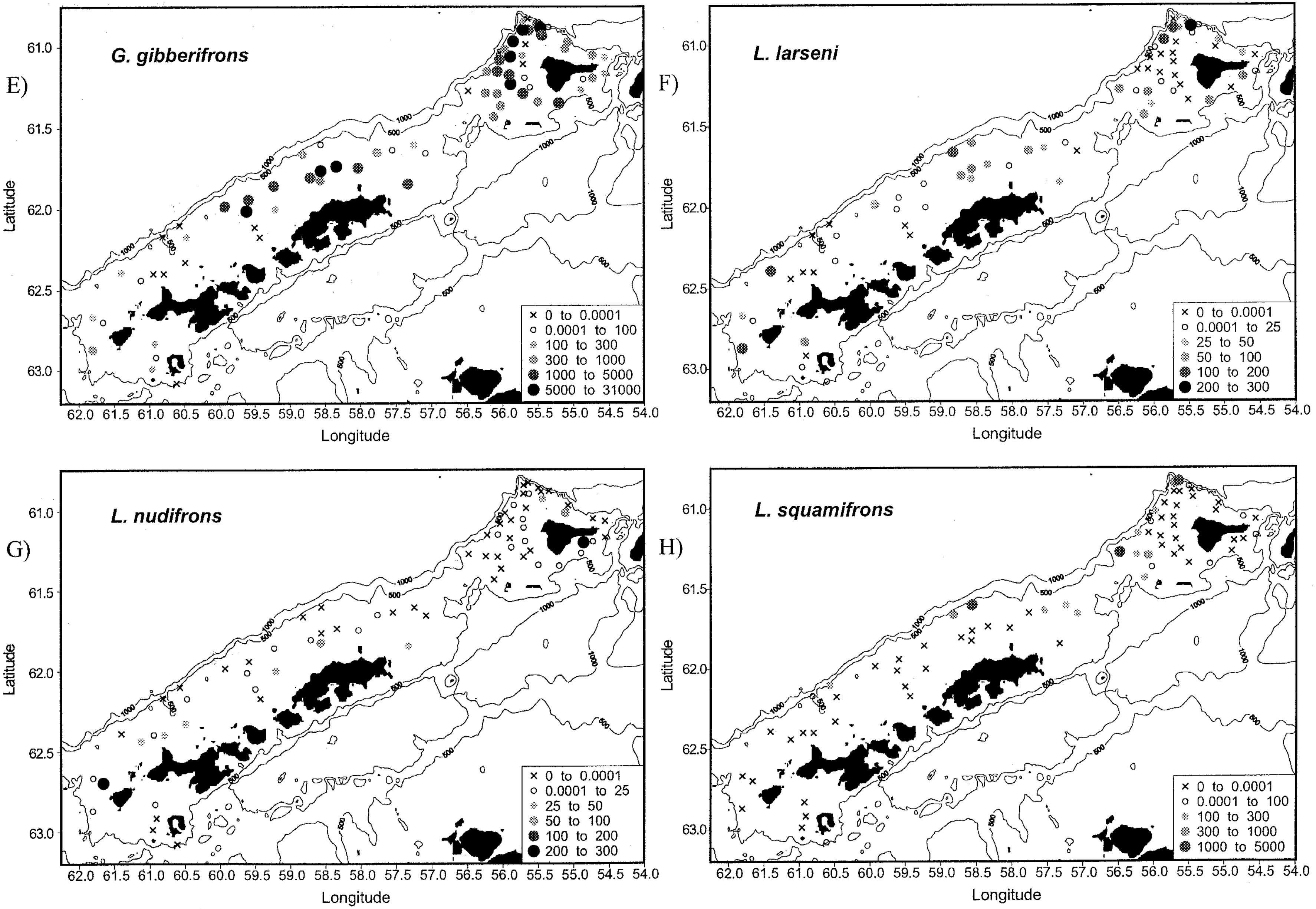

Figure 5.3. Continued. Standardized density (kg/nm2) for E) *G. gibberifrons*; F) *L. larseni*; G) *L. nudifrons*; H) *L. squamifrons* from the 2001 AMLR finfish survey of the South Shetland Islands. Longitude is West and latitude is South.

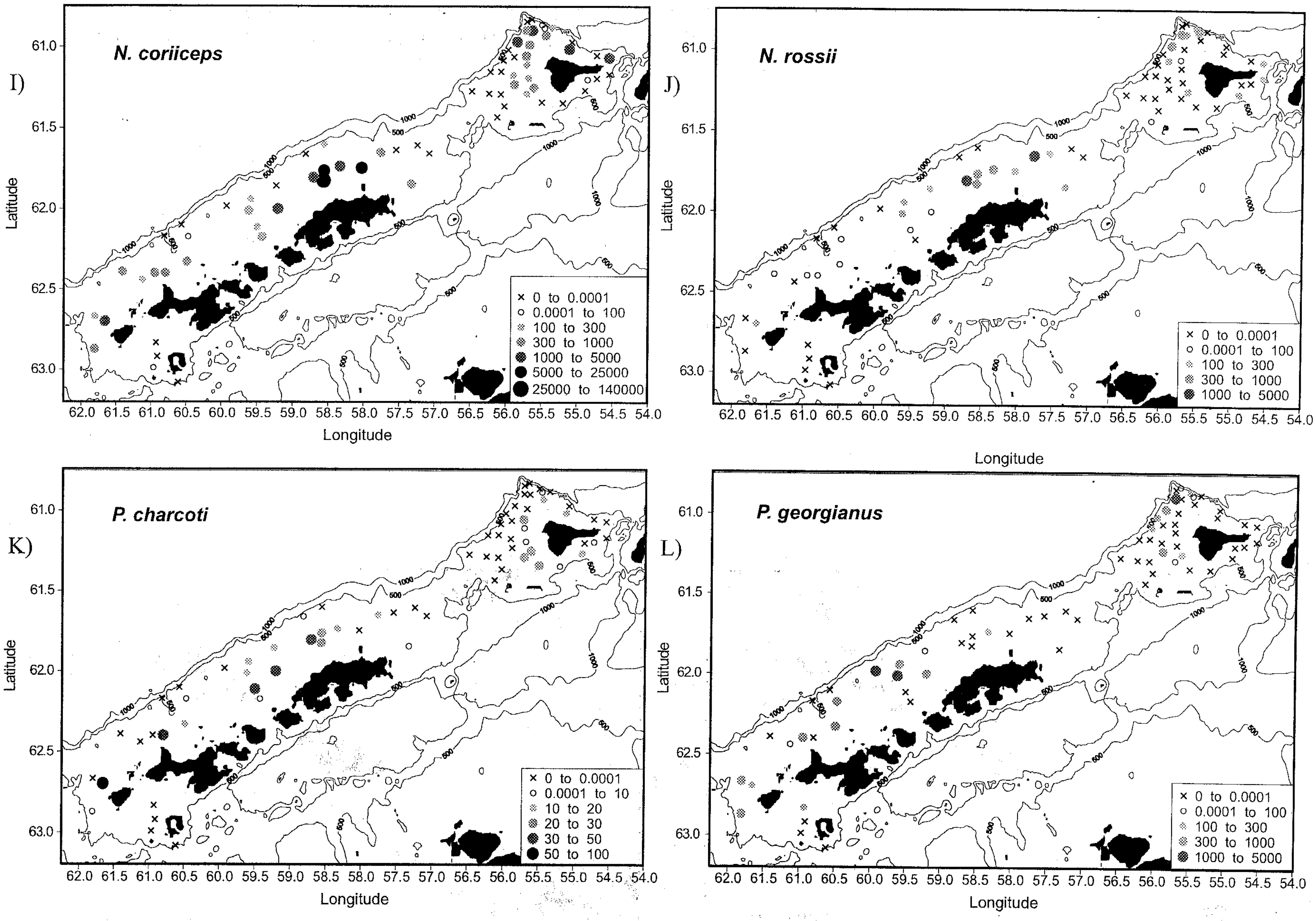

Figure 5.3. Continued. Standardized density (kg/nm2) for I) *N. coriiceps*; J) *N. rossii*; K) *P. charcoti*; L) *P. georgianus* from the 2001 AMLR finfish survey of the South Shetland Islands. Longitude is West and latitude is South.

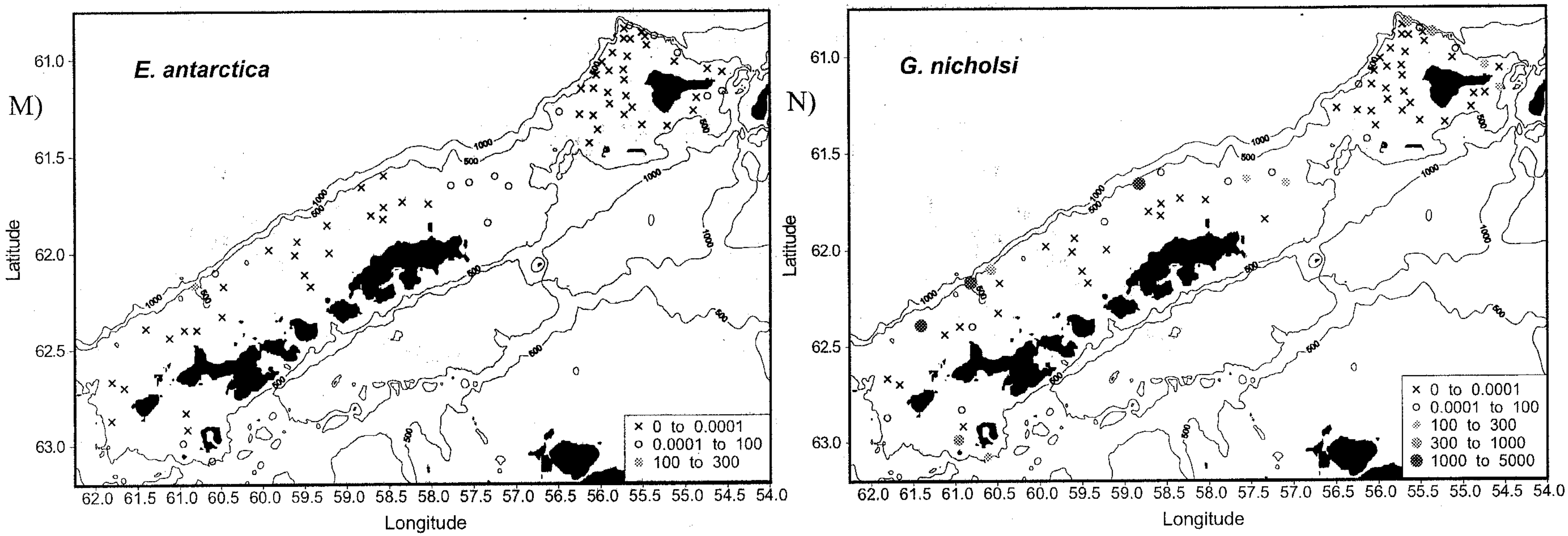

Figure 5.3. Continued. Standardized density (kg/nm2) for M) *E. antarctica*; N) *G. Nicholsi* from the 2001 AMLR finfish survey of the South Shetland Islands. Longitude is West and latitude is South.

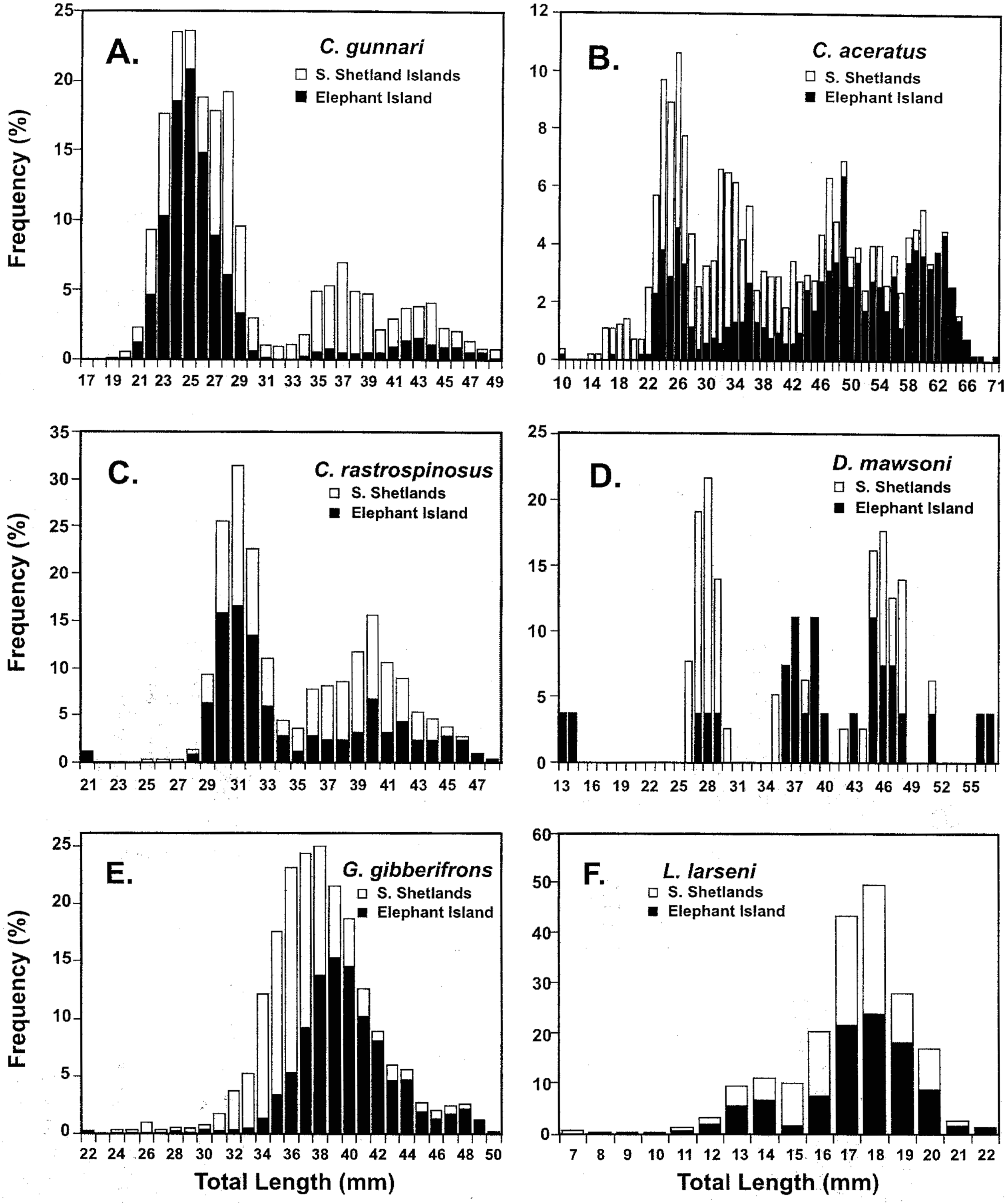

Figure 5.4. Length-frequency distributions for species with significant catches: A) *C. Gunnari*; B) *C. Aceratus*; C) *rastrospinosus*; D) *D. Mawsoni*; E) *G. Gibberifrons*; F) *L. Larseni*.

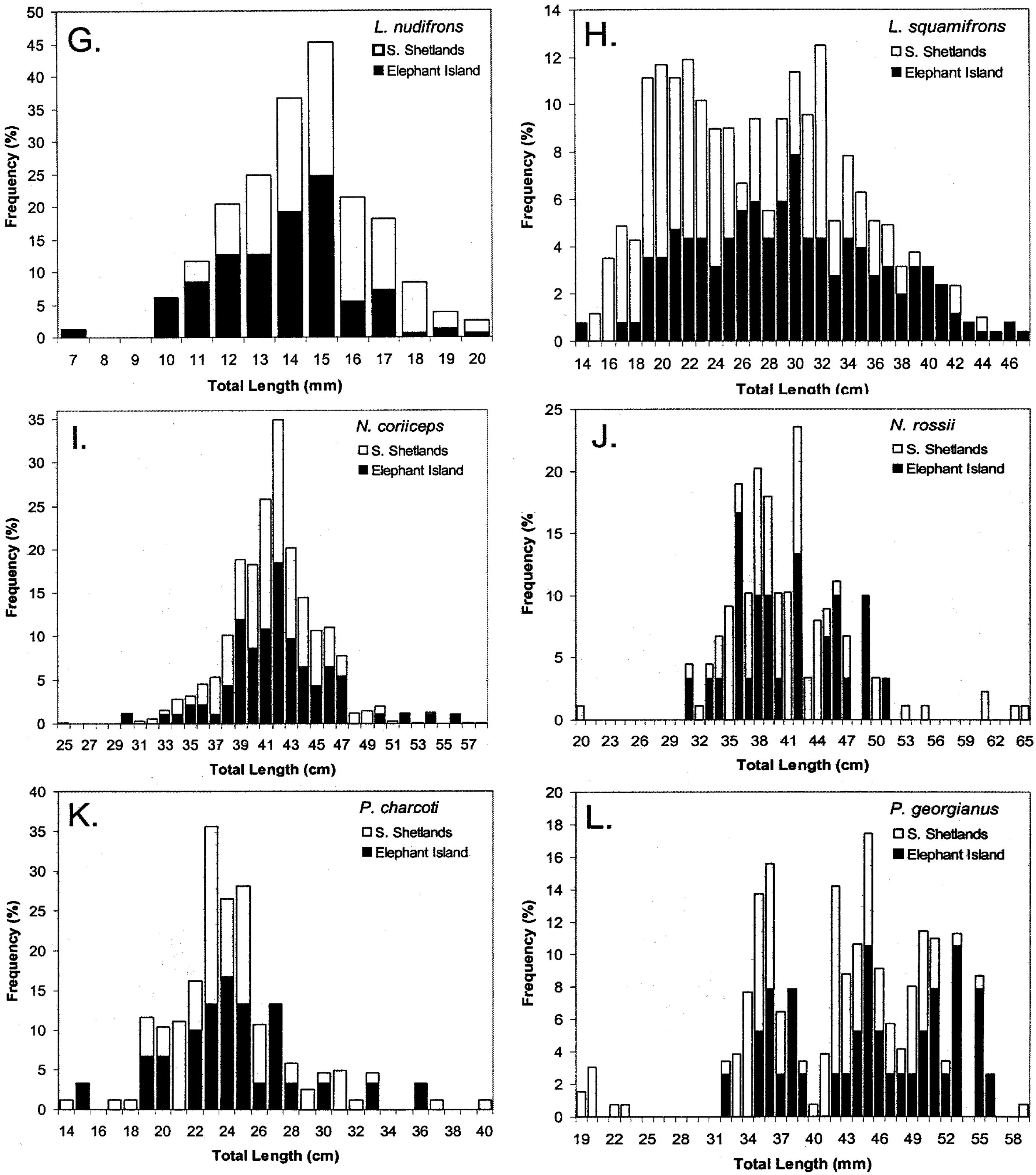

Figure 5.4. continued. Length-frequency distributions for species with significant catches: G) *L. nudifrons*; H) *L. squamifrons*; I) *N. coriiceps*; J) *N. rossii*; K) *P. charcoti*; L) *P. georgianus*.

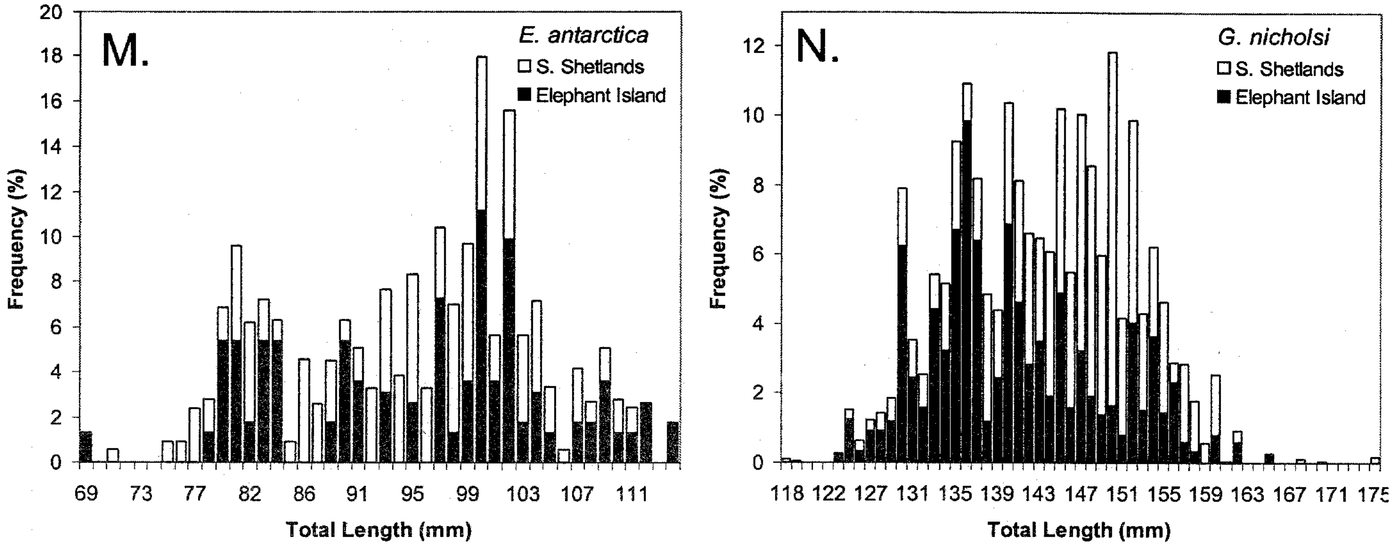

Figure 5.4. continued. Length-frequency distributions for species with significant catches: M) *E. Antarctica*; N) *G. nicholsi*.

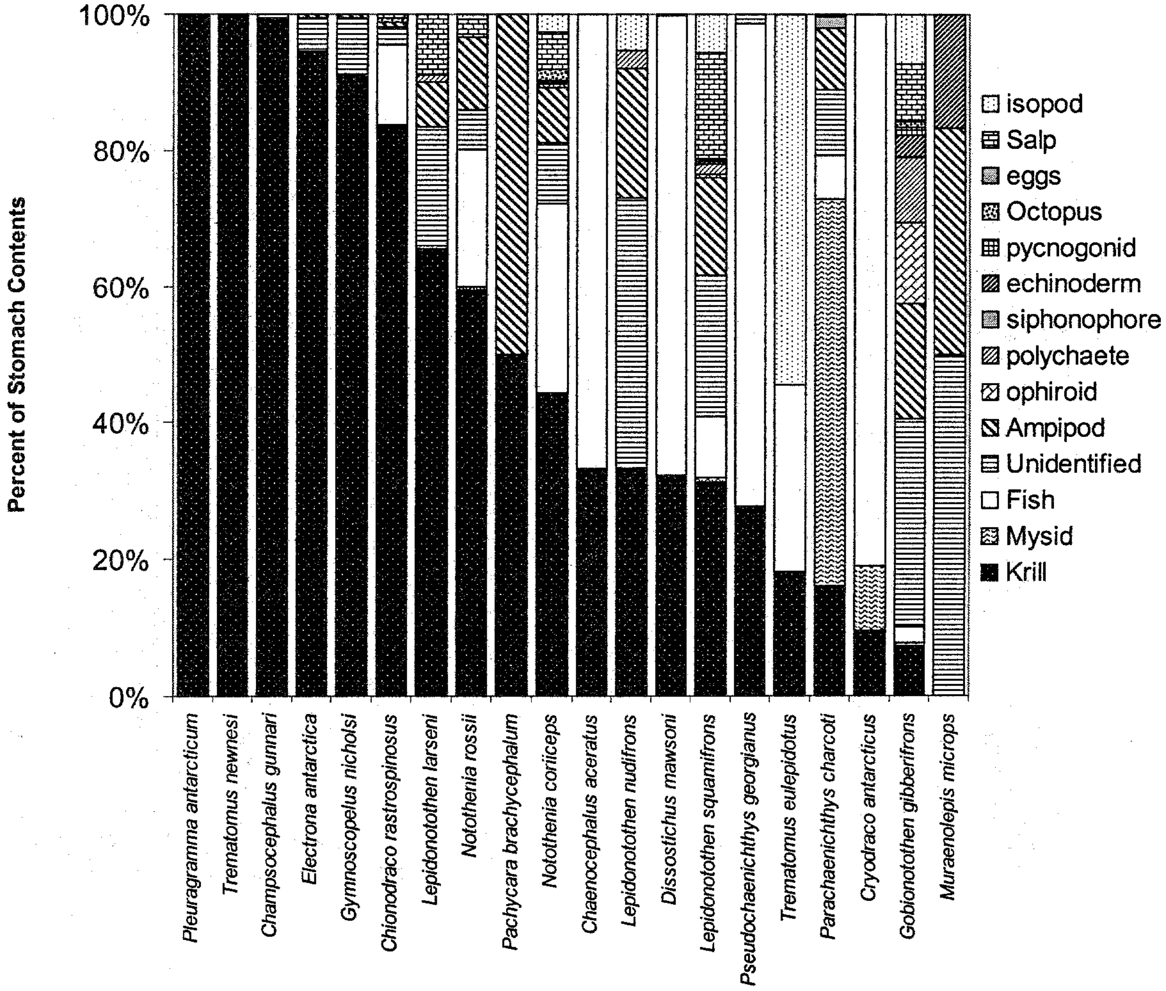

Figure 5.5. Summary of diet composition of 20 species of finfish, based on mean stomach content scores, from the 2001 AMLR finfish bottom trawl survey of the South Shetland Islands.

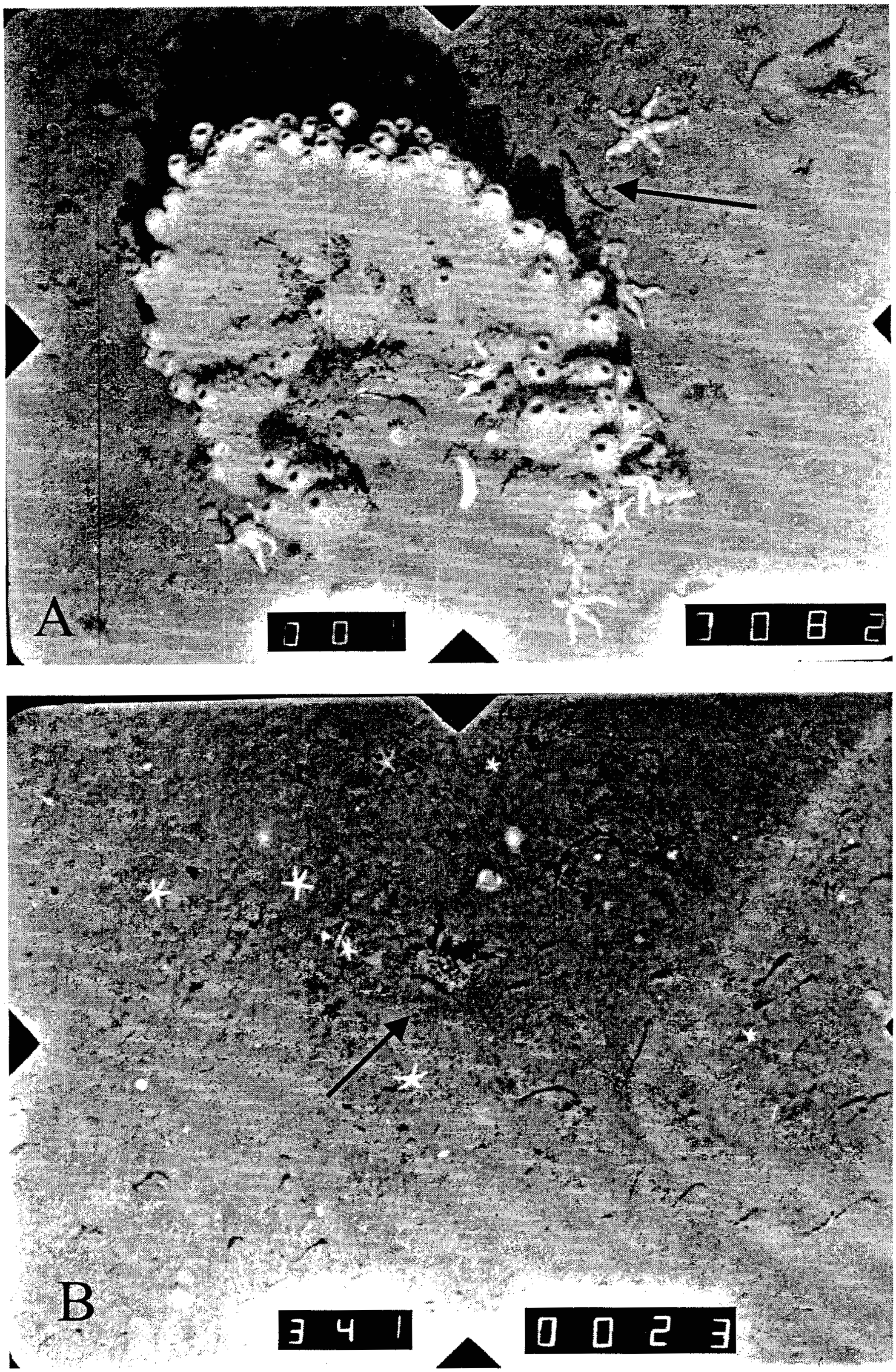

Figure 5.6. Video images of demersal finfish associated with benthic epifauna. Figure 5.6A was taken near Station 22 and 5.6B was taken near Station 26.

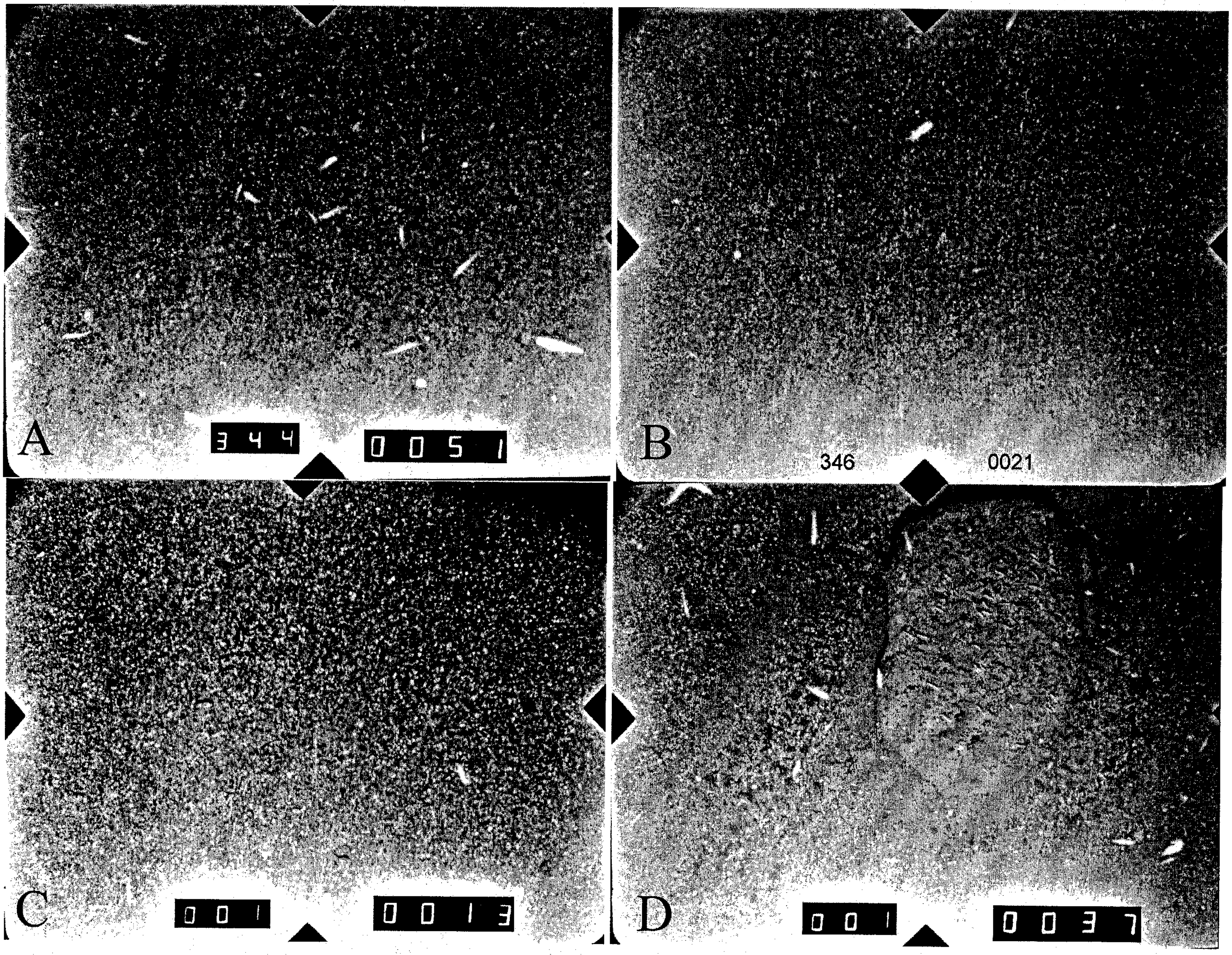

Figure 5.7. Video images of seabed features near Station 17 from the 2001 AMLR survey.

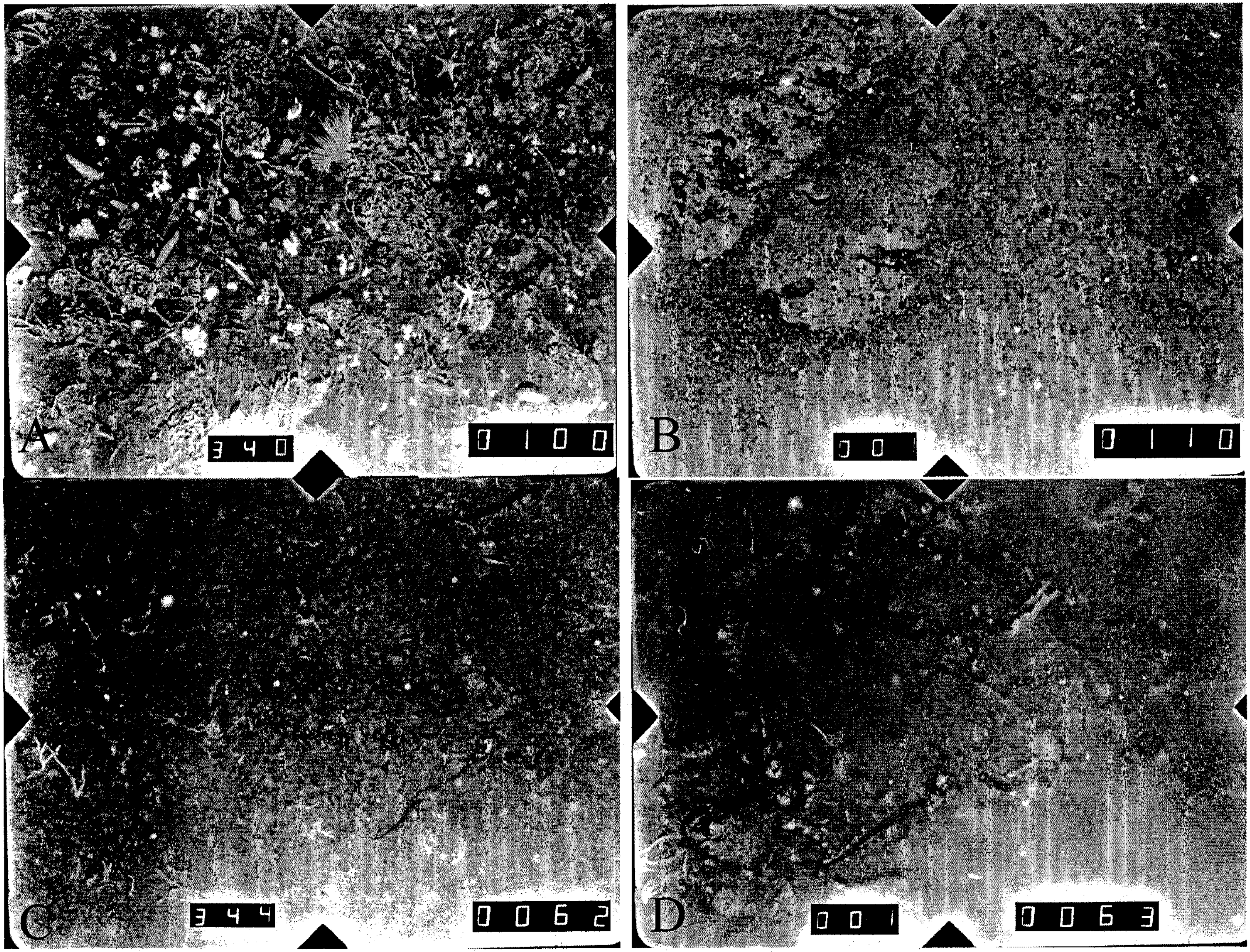

Figure 5.8. Video images of seabed features near Station 48 from the 2001 AMLR survey. *N. coriiceps* can be seen in 5.7C and 5.6D.

6. Benthic invertebrate bycatch from bottom trawling around Elephant Island and South Shetland Islands, Antarctica; submitted by Stacy Kim, Valerie Loeb, Rob Rowley, Mark Prowse and Nancy Gong.

6.1 Objectives: The main objective of this work was to characterize the benthic invertebrate component from the bottom trawl sampling (See Section 5 of this report). The invertebrate "bycatch" from trawl fishing is a habitat characterization parameter that can influence fish species abundances in several ways (Watling and Norse, 1998). Large invertebrates (e.g. sponges) create structure that fishes may use as shelter or camouflage from predatory species, particularly when the fish are small (McAllister and Spiller, 1994; Auster *et al.*, 1995, 1996; Lindholm *et al.*, 1997). Alternatively, some predators such as octopus may find concealment among sessile invertebrates and negatively impact fish populations. Other invertebrates are substrates where fish eggs are laid; the invertebrates often have defense mechanisms that may protect the fish eggs as well (e.g. sponge spicules).

The variety of interactions between fish species and the surrounding invertebrate species requires, initially, a description of the invertebrate community and assessment of the positive or negative correlations in abundances (Wanteiz and Kulbicki, 1995). Ultimately, the abundance of invertebrate species or complexes, if matched with fish abundances (e.g. Thrush *et al.*, 1998; Gaertner *et al.*, 1999), can be introduced as a parameter in a predictive model of fishery health.

6.2 Methods and Accomplishments: Trawl samples were stratified around two island groups, Elephant Island and the South Shetland Islands. Samples were also stratified into depth bins between 50 and 500m. Specifics on trawling activities and techniques are described by C. Jones *et al.* in Section 5 of this report. The invertebrates were completely characterized for all hauls except one (haul 5) when the extremely large biomass made sampling the entire catch unfeasible; this haul was subsampled.

Immediately after the trawl was secured on deck the organisms were put into fish baskets to move the samples off the back deck. If the catch was very small the invertebrates were separated from the vertebrates on the back deck. Usually, all organisms were simply shoveled together and sorted on tables away from the trawl gear. Initially, the invertebrates were grouped into visually distinctive taxa (e.g. "bath" sponge, "vase" sponge). As the cruise progressed and we had some time to work on species identifications, the taxonomic place-holders were amended. In some cases (e.g. hard corals) several species were initially lumped under a single taxonomic place-holder.

Once the invertebrates had been sorted, each taxon was weighed and, if the organisms were individuals (not colonial), they were counted. In cases where the number of organisms was too great to count each individual, a subset was weighed and counted, and then the total number of individuals was estimated from the proportion of the total weight. For each new taxon encountered, a representative sample was fixed in 10% buffered formaldehyde in seawater. Whenever possible, the remaining organisms were returned to the sea, although the survival of the sessile organisms was likely low (e.g. Evans *et al.*, 1994). At the end of the cruise the fixed samples were transferred to 70% ethanol for transport to the US.

Digital video and photographs of all taxa encountered were made to assist in shipboard and postcruise identification and analysis.

Data were entered into an Access benthic database linked with the fish and trawl databases, and double-checked for accuracy. As the taxonomy was refined, taxonomic place-holders were changed to species names when possible. Initial statistical analysis included multivariate analysis on all taxonomic place-holders and on larger taxonomic groupings, for both biomass and abundance measures.

6.3 Results and Preliminary Conclusions: Biomass and diversity were the two main descriptive parameters for the invertebrate communities. Biomass was adjusted to the trawled area that ranged from $0.009039nm^2$ to $0.017157nm^2$.

The maximum biomass of invertebrates recorded was $97{,}533kg/nm^2$. This value is nearly three orders of magnitude larger than the minimum biomass of $140kg/nm^2$. The distribution of biomass values is shown in Figure 6.1; there was no obvious correlation between biomass and bottom depth, however the biomass was generally higher at the South Shetland Island stations than at the Elephant Island stations.

Diversity ranged from 14 to 65 taxa per haul. Figure 6.2 shows how species counts were distributed. Again, there was no clear pattern with depth or location. It is important to note that the preliminary division of taxa into visually distinctive groups undoubtedly underestimated the species diversity; the diversities reported here are comparable between our sites but cannot be compared with other values from the literature. Further taxonomic work on the preserved specimens will be needed to relate this project to other studies.

No distinctive groupings were found in a preliminary multivariate analysis (Figures 6.3 and 6.4). Hierarchical clustering of Bray-Curtis dissimilarity indices on the total data set of all taxa, for both biomass and abundance, revealed no clear pattern. Only some of the taxa were individuals that could be counted; these were often smaller animals that did not contribute greatly to biomass. Because not all taxa were individuals, the abundance comparison was less robust than the biomass analysis. The same statistical tests on reduced data sets of only the major taxonomic groupings likewise resulted in poorly correlated groupings (Figures 6.5 and 6.6). More detailed analysis by canonical correlation with physical factors (depth, substrate type, proximity, exposure, etc.) may clarify patterns, though none of these factors alone had any obvious effect. Given the relatively large area of seafloor sampled in each haul, and the lack of similarity between adjacent hauls, the invertebrate community appears to be patchy on a scale greater than 1.3nm (the average linear distance of a tow) but smaller than 4.5nm (a typical distance between tows).

A consistent pattern of a single taxonomic grouping dominating the biomass of each sample was observed. The biomass dominants are listed in Table 6.1. Because trawl sampling for benthic invertebrates was semiquantitative, no statistical comparison was justified. Nevertheless, a pattern emerged of Asteroidea (seastar) dominants at the southwest stations with Porifera (sponge) becoming dominant towards the northeastern stations. The distributional groupings suggested that Elephant Island provides a more stable habitat supporting long-lived sponges than the South Shetland Islands that support motile seastars.

6.4 Tentative Conclusions: The benthic community sampled by trawling at depths between 50 and 500m around Elephant and the South Shetland Islands was highly patchy on a scale between 1.3 and 4.5nm. Individual tows were strongly dominated by single taxon, but there was no obvious correlation in biomass, abundance, or dominance with depth or geographical location.

6.5 Disposition of data and samples: Electronic data files have been sent to Christopher D. Jones of AERD. Preserved samples were shipped to MLML where they will be used for refined taxonomic analysis. Digital images of freshly collected specimens will provide a photographic guide to benthic invertebrates that will be utilized in future bycatch studies.

6.6 Problems and Suggestions: For an initial effort the invertebrate survey went extremely well. The effort would be improved primarily by expanding the number of dedicated personnel. We were able to complete a good general survey, but more detailed taxonomic information would be very desirable. A team of four could complete rough sorting and database management, and focus on specific identifications for the major taxa of sponges, seastars, and tunicates. With an additional two personnel, the less dominant but potentially important habitat structuring taxa (bryozoans, anemones, corals, gorgonians) and potential competitors (octopus, polychaetes) could also be investigated. Alternatively, support could be provided to perform in-depth analysis on preserved specimens after return to the US.

The equipment was adequate but data collection could be streamlined by a few improvements. Electronic balances (500g capacity) and improved sorting tables including a weatherproof organizer would enable more efficient and accurate sample processing. We had loan of an excellent video camera and would find a dedicated one invaluable for maintaining continuity of naming conventions. A Plexiglas aquarium for specimen maintenance would have been very useful. In the lab, a dedicated computer would have permitted more timely data analysis.

If this portion of the study is continued, several other improvements could be considered to enhance data quality and utility. These include improved weather protection, quality microscope/light sources, and laser scaling for the towed camera system. The invertebrate portion of the study has the potential to provide information on general biotic habitat parameters and species-specific associations relevant to the structured fisheries model, more tightly incorporating the invertebrate research into the overall goal of the project.

6.7 References:

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Table 6.1. Individual taxa that were biomass dominants at each station. When the greatest biomass was represented by a single large mobile organism (e.g. octopus), the taxa with the second highest biomass was listed.

Station	Trawl	Taxonomic Group	"Place-holder"
82	1	Porifera	Common
30	2	Porifera	Common
34	3	Porifera	Moon
31	4	Porifera	Small vase
33	5	Porifera	Jicama
32	6	Holothuroidea	Spine
35	7	Urochordata	Potato
36	8	Porifera	Elephant ear
1	9	Porifera	Spongin skeleton
2	10	Urochordata	Bulb
3	11	Asteroidea	Skeleton
11	12	Porifera	Polymastia?
10	13	Asteroidea	Skeleton
38	14	Holothuroidea	Spine
8	15	Asteroidea	Sun
37	16	Asteroidea	Sun
5	17	Asteroidea	Sun
4	18	Porifera	Spongin skeleton
9	19	Holothuroidea	Spine
12	20	Asteroidea	Sun
14	21	Asteroidea	Skeleton
13	22	Urochordata	Bulb
18	23	Urochordata	Peach
15	24	Holothuroidea	Spine
16	25	Asteroidea	Skeleton
17	26	Asteroidea	Sun
19	27	Urochordata	Bulb
20	28	Porifera	Spongin skeleton
21	29	Porifera	Common
22	30	Anthozoa	Floppy
23	31	Asteroidea	Sun
24	32	Asteroidea	Sun
25	33	Porifera	Spongin skeleton
26	34	Asteroidea	Skeleton
27	35	Asteroidea	Sun
28	36	Porifera	Spongin skeleton
6	37	Holothuroidea	Spine
42	38	Porifera	Yellow brick

Table 6.1. continued.

43	39	Porifera	Yellow brick
68	40	Porifera	Yellow brick
69	41	Porifera	Scolymastra?
44	42	Porifera	Yellow brick
45	43	Porifera	White bread
85	44	Holothuroidea	Spine
48	45	Porifera	Yellow brick
51	46	Anthozoa	Pink
47	47	Porifera	Half and half
50	48	Porifera	Spongin skeleton
49	49	Asteroidea	Sun
52	50	Urochordata	Cnemidocarpa
83	51	Urochordata	Cnemidocarpa
55	52	Asteroidea	Leather
57	53	Urochordata	Cnemidocarpa
58	54	Octopus	Rough
53	55	Asteroidea	Sun
56	56	Asteroidea	Sun
63	57	Asteroidea	Leather
62	58	Urochordata	Bulb
70	59	Asteroidea	Sun
61	60	Porifera	Polymastia?
74	61	Asteroidea/Urochordata	Skeleton/bulb
72	62	Ateroidea	Skeleton
71	63	Porifera	Polymastia?
79	64	Asteroidea	Sun
80	65	Asteroidea	Sun
87	66	Asteroidea	Sun
88	67	Asteroidea	Sun
78	68	Asteroidea	Sun
86	69	Asteroidea	Sun
77	70	Asteroidea	Sun
75	71	Sipuncula	Purple

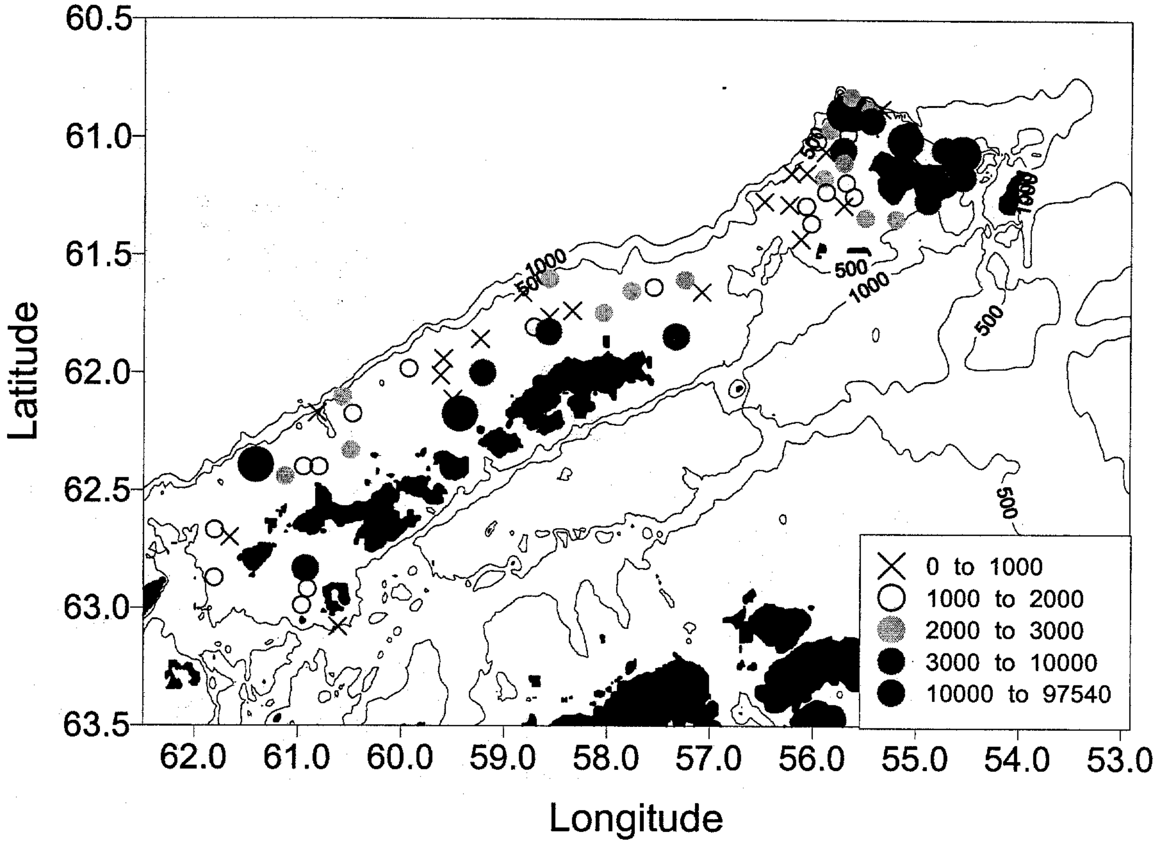

Figure 6.1. Biomass of invertebrates collected at each haul station. Scaled circles are in kg/nm^2. Longitude is West and latitude is South.

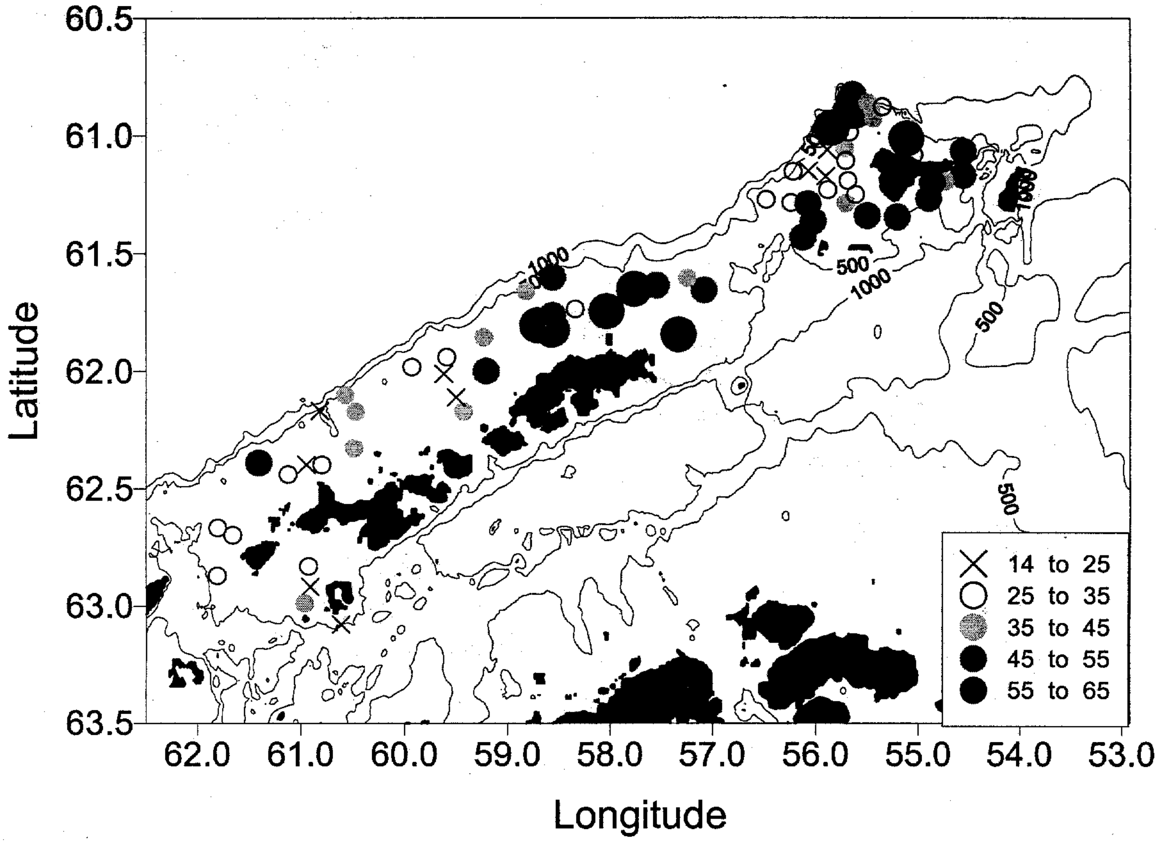

Figure 6.2. Diversity of invertebrates collected at each haul station. Scaled circles are for number of taxonomic "place-holders" per haul, and are not corrected for tow area, which varied little between hauls. Longitude is West and latitude is South.

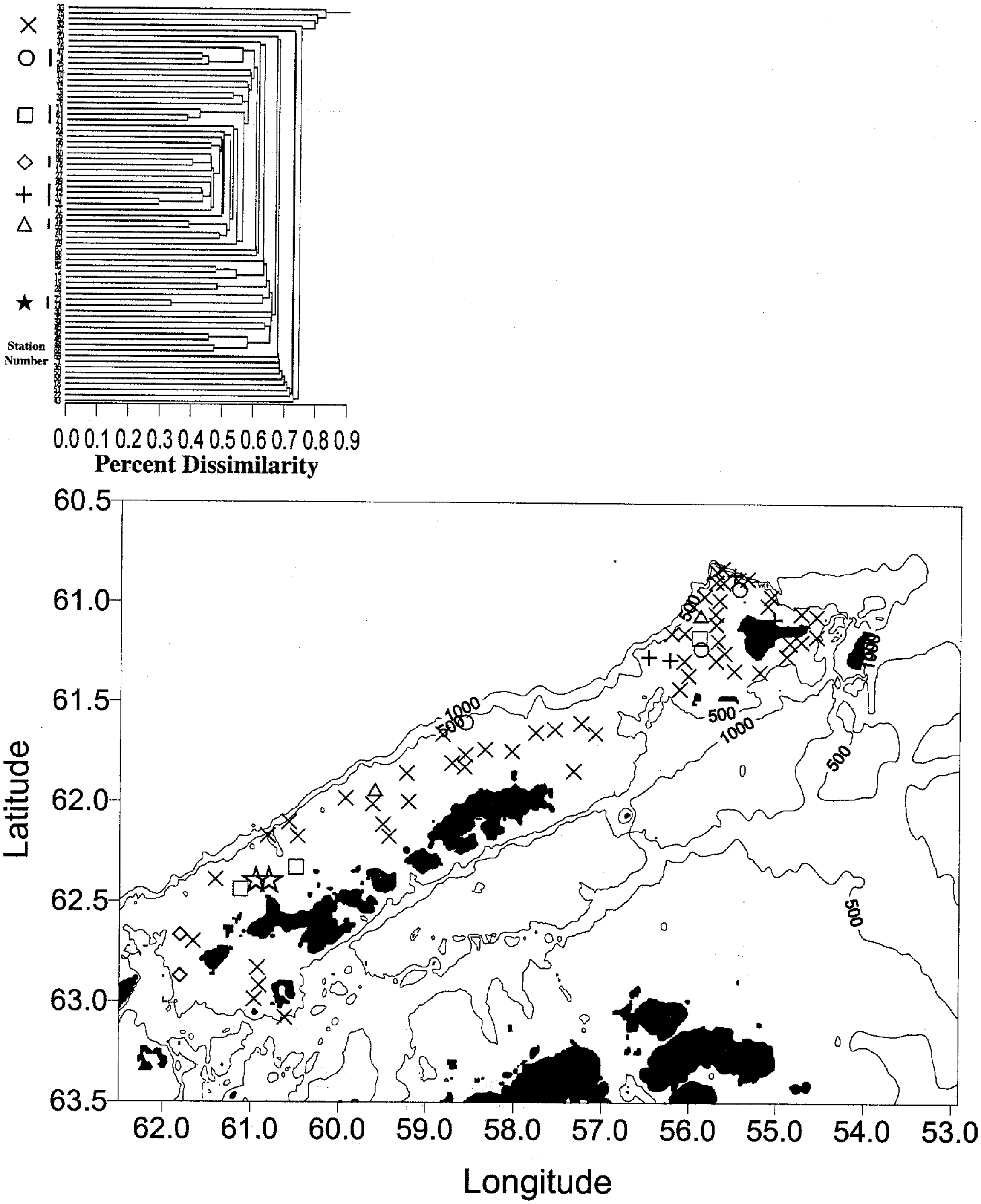

Figure 6.3. Hierarchical clustering of Bray-Curtis dissimilarity indices on the biomass of all taxa. The stations that cluster together are shown geographically on the maps. Longitude is West and latitude is South.

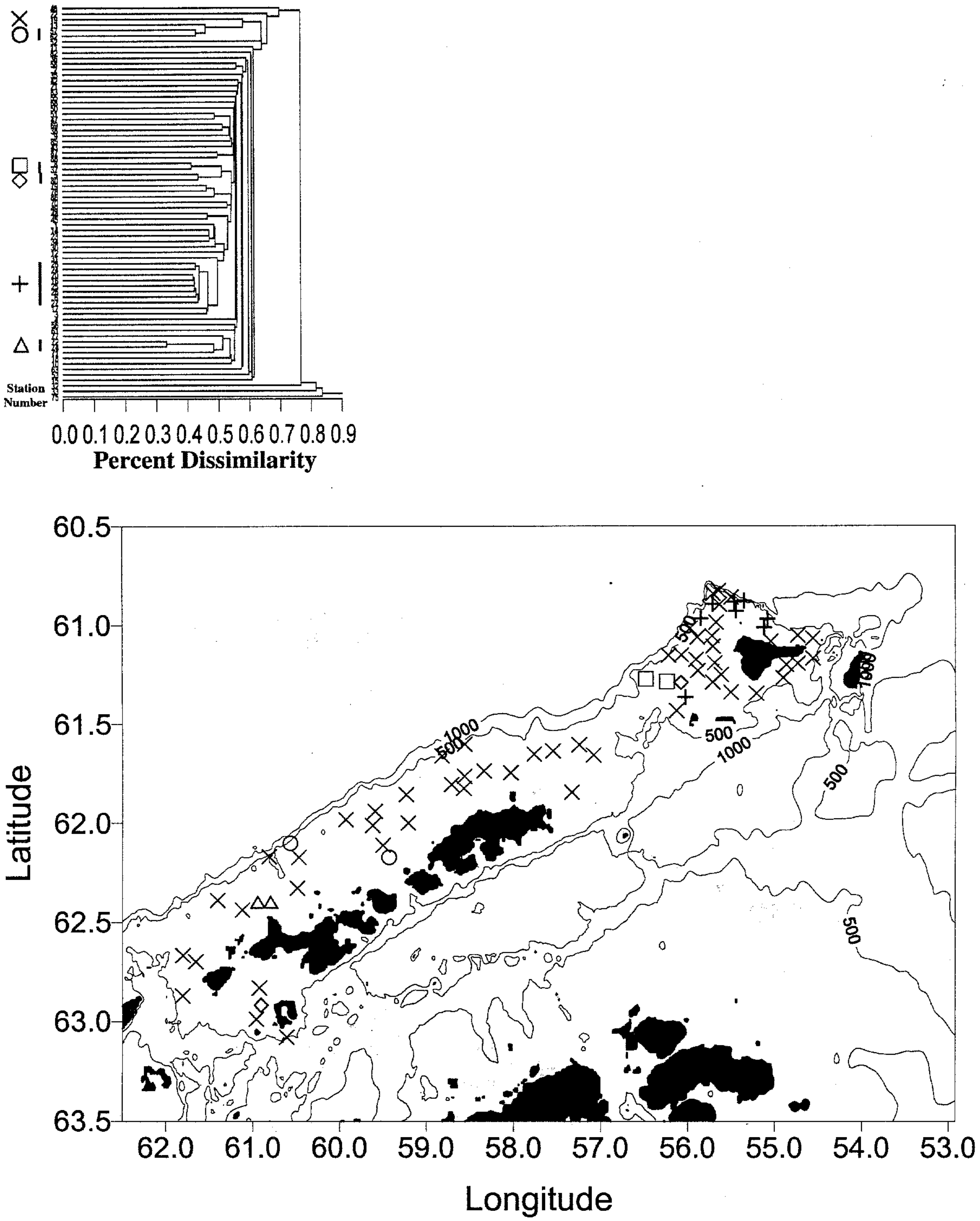

Figure 6.4. Hierarchical clustering of Bray-Curtis dissimilarity indices on the abundances of individual taxa. The stations that cluster together are shown geographically on the maps. Longitude is West and latitude is South.

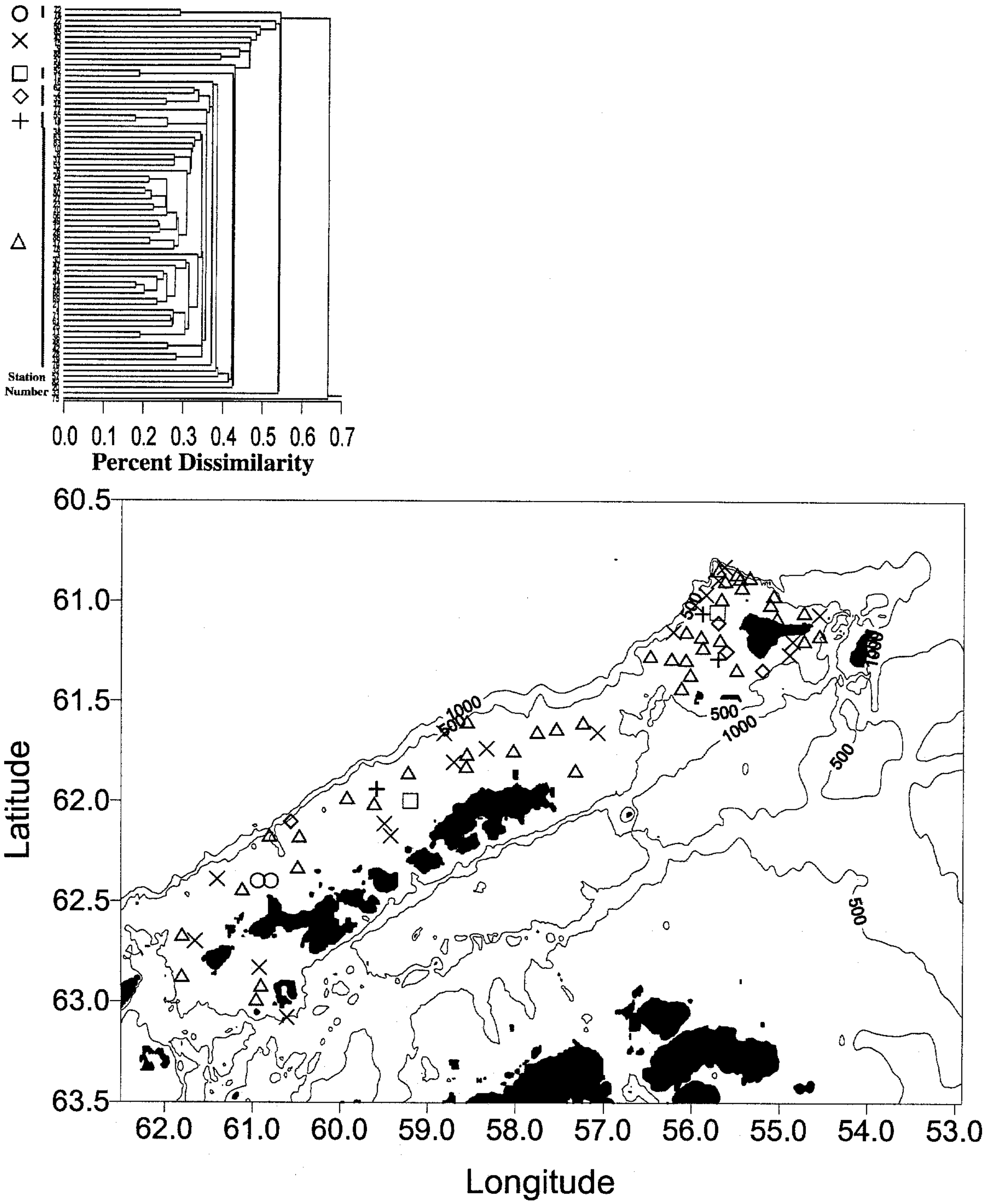

Figure 6.5. Hierarchical clustering of Bray-Curtis dissimilarity indices on the biomass of higher taxonomic groups. The stations that cluster together are shown geographically on the maps. Longitude is West and latitude is South.

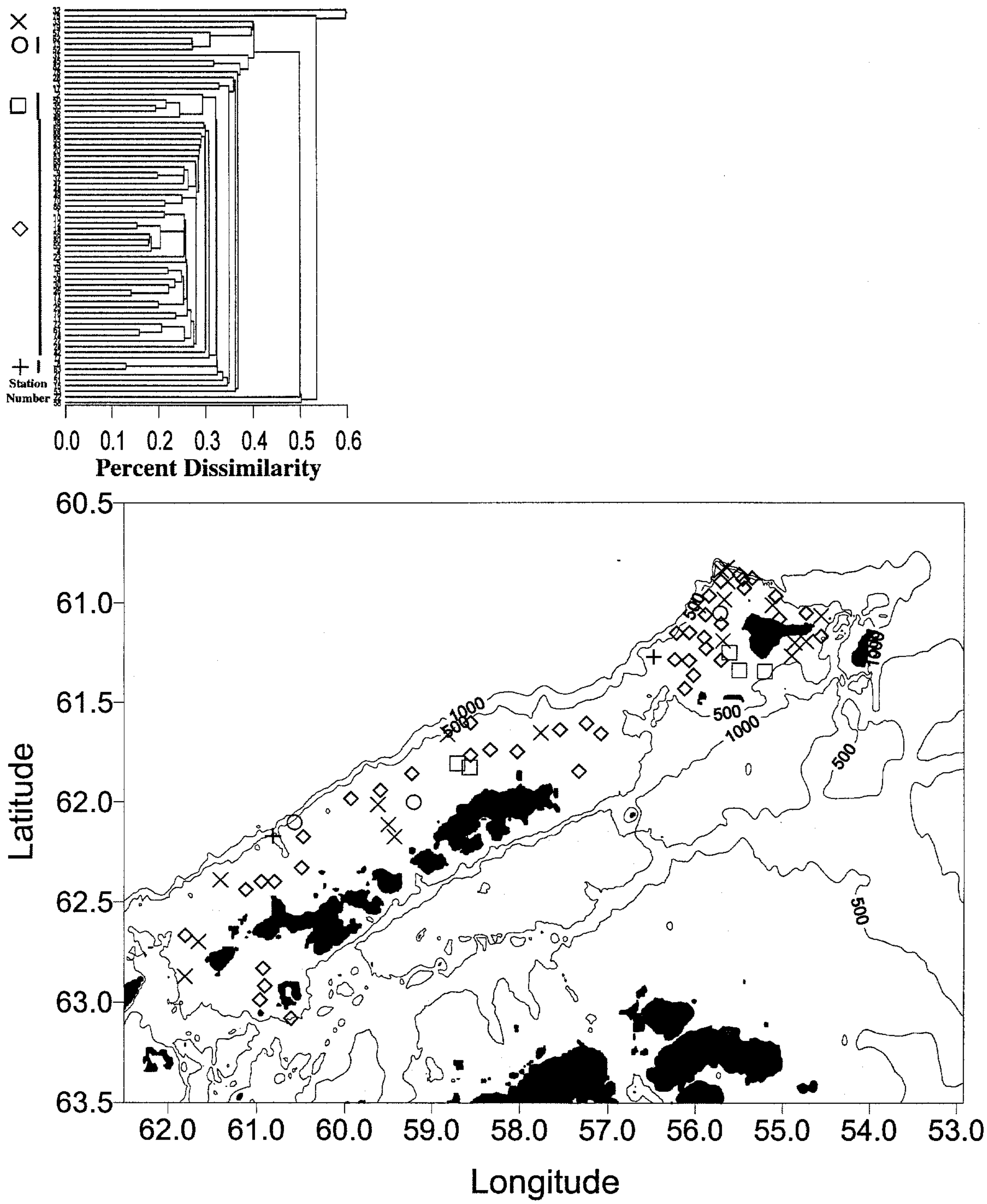

Figure 6.6. Hierarchical clustering of Bray-Curtis dissimilarity indices on the abundances of higher taxonomic groups. The stations that cluster together are shown geographically on the maps. Longitude is West and latitude is South.

7. Seabird research on Cape Shirreff, Livingston Island, Antarctica, 2000-2001; submitted by Michael R. Taft, Iris M. Saxer, and Wayne Z. Trivelpiece.

7.1 Objectives: The austral summer of 2000-2001 marked the fourth season of land-based predator research conducted by the United States Antarctic Marine Living Resources (AMLR) program at Cape Shirreff, Livingston Island, Antarctica (62° 28'S, 60° 46'W). Through long-term monitoring of krill predator populations, our research on Cape Shirreff contributes to U.S. participation in the international CCAMLR (Convention for the Antarctic Marine Living Resources). Our objectives for the 2000-2001 seabird season were to:

1. To estimate chinstrap and gentoo penguin breeding population size (CCAMLR Ecosystem Monitoring Program (CEMP) Standard Method 3a);

2. To band 1,000 chinstrap and 200 gentoo penguin chicks for demography studies (CEMP Standard Method 4a);

3. To determine chinstrap penguin foraging trip durations during the chick rearing stage of the reproductive cycle (CEMP Standard Method 5a);

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

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

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

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

7.2 Accomplishments: Four scientists opened the Cape Shirreff field camp on 16 November 2000 with the assistance of the National Science Foundation (NSF) vessel R/V *Laurence M. Gould*, which provided logistical support and transportation from Punta Arenas, Chile to Cape Shirreff. Additionally, the R/V *Yuzhmorgeologiya* brought two scientists ashore on 14 January 2001 with an additional scientist arriving at the Cape on 11 February 2001. Research continued until camp closure on 28 February 2001 when the U.S. AMLR-chartered vessel R/V *Yuzhmorgeologiya* furnished logistical support and passage from Cape Shirreff to Punta Arenas, Chile.

7.3 Results and Conclusions:

Breeding Biology Studies

The penguin rookery at Cape Shirreff is comprised of 29 active breeding colonies of penguins: 16 chinstrap penguin (*Pygoscelis antarctica*) colonies, seven gentoo penguin (*P. papua*) colonies, and six colonies with both penguin species. To determine penguin breeding population size, we counted all breeding pairs in all colonies approximately one week after the peak clutch initiation date for both species. Gentoo penguins were censused on 27 November and chinstrap penguins on 3 and 4 December. A total of 7,212 chinstrap and 1,043 gentoo penguin pairs bred at Cape Shirreff during the 2000/01 season. Penguin populations have been censused at Cape Shirreff annually since 1997/98. The 2000/01 population counts represent the lowest chinstrap penguin count on record, while the gentoo penguin census was the highest population count to date.

We determined reproductive success by banding and following a sample of 100 chinstrap and 50 gentoo penguin pairs, from egg-laying until the time chicks entered crèches. The mean nest initiation date for chinstrap penguins was 20 November and ranged from 14-29 November. Gentoo penguins nested earlier, with a mean clutch initiation date of 17 November and a range from 7-25 November. The incubation for both chinstrap and gentoo penguins is very fixed, ranging from 36-37 days from the laying of the first egg to the hatching of the first chick. When the nests of both species hatched chicks, the team was able to back calculate the lay dates using the 36-37 day known incubation period; hence the data showing that the earliest breeders initiated clutches prior to the arrival of the scientific team at the Cape. Mean chinstrap and gentoo penguin clutch initiation dates coincided exactly with dates in 1999/00. Chinstrap penguins hatched 1.40 chicks per pair, fledged 1.26 chicks per pair, and 88% of all chicks that hatched survived to fledging. Gentoo penguins hatched 1.62 chicks per pair, fledged 1.36 chicks per pair, and 84% of all chicks that hatched survived to fledging. Chinstrap penguin reproductive success in 2000/01 was within the four-year range, however, the survival of chicks from hatching to fledging was the highest ever recorded. Gentoo penguin reproductive success was also within the four-year averages.

We conducted the annual chinstrap and gentoo penguin chick censuses on 5-6 February and 25 January 2001, respectively. A total of 9,744 chinstrap and 1,298 gentoo penguin chicks survived to crèche age this breeding season. For both species, this season represented the largest number of chicks counted at Cape Shirreff in five years.

As part of our ongoing demographic study, we banded a sample of 1,000 chinstrap penguin chicks on 12 February, and 200 gentoo penguin chicks on 10 February. This season we had a large number of known-age chinstrap and gentoo penguins breeding in the colonies. Future demographic data will continue to be collected on these and other known-age birds as they return to the rookery to establish territories, select mates and breed.

From 16-25 February, we captured and weighed a sample of 198 chinstrap penguin chicks as they congregated on rookery beaches in preparation for fledging to sea. The mean chinstrap penguin chick fledging weight for the season was 3,166g, the lowest in five years. However, the peak of fledging occurred during a severe three-day windstorm that suspended all scientific activity until the storm passed, and this may have biased these results. In addition, we weighed gentoo penguin chicks for comparisons of chick masses among years. Gentoo penguins do not have a fledging exodus, but rather receive supplemental feedings by their parents after their first at-sea foraging trips. We therefore obtain an annual index of gentoo penguin chick mass by weighing chicks at a standard 85 days following the mean clutch initiation date each year. Chicks are approximately seven weeks old at this time, the age at which the other two species of

Pygoscelis penguins fledge. We weighed 200 gentoo penguin chicks on 10 February 2001. The average weight for this sample was 4,509g, the heaviest mean weight over the last four seasons.

Foraging Ecology Studies

We collected 40 chinstrap and 20 gentoo penguin diet samples between 7 January and 11 February 2001 to determine the meal size and prey composition of food delivered to chicks by foraging adults. All sampled adults were verified breeders, as individuals were captured at their nest sites just prior to feeding their chicks. Stomach contents were removed by lavaging, sorted into prey types and weighed separately to the nearest 0.1 grams. The dominant prey species in all diet samples was krill (*Euphasia suberba*), which we found in 100% of samples from both chinstrap and gentoo penguins. Chinstrap penguin diets consisted solely of krill, whereas gentoo penguins ate both krill and fish. We used otoliths collected from gentoo penguin samples to identify fish species in their diets. Analysis of the length-frequency distribution of krill in the penguin's diets revealed that over 90% of all krill in the samples were from three CCAMLR size classes: 46-50, 51-55, and 56+mm. These krill are believed to be from the strong 1994/95 cohort that has dominated the diets of the penguin species at Cape Shirreff for the last 4 years (Figure 7.1).

To determine foraging trip durations during the chick-rearing phase, we attached 19 radio transmitters to adult chinstrap penguins with one week-old chicks during the first week in January and tracked their foraging trips until chicks fledged in late February. All data were received by a remote antenna and stored by a field computer located at our bird blind in the penguin rookery. Similar to the previous three seasons, the 2000/01 season foraging pattern displayed a bimodal distribution. This bimodal pattern is attributed to chinstrap penguins undertaking two types of foraging trips related to breeding energetics: one of shorter duration, one longer. This season, we observed a 2-hour decrease in the duration of short-trips, and a >1 hour decrease in the duration of long trips compared to the 1999/00 pattern. The average duration of foraging trips was the shortest in four years. The short foraging trip patterns this season may be attributed to the abundance of larger krill inshore. As mentioned above, penguin diet samples contained krill of a larger body size than in previous years (Table 7.1). We hypothesize that penguins spent less time foraging because the larger krill available meant fewer dives were needed to gather a full stomach load of food for chicks.

To gather additional at-sea foraging data, we outfitted chinstrap penguins with satellite-linked transmitters (PTTs) during two periods in their reproductive cycle: 1) after clutch completion, and 2) during chick-rearing. In November, we attached four PTTs to breeding female chinstrap penguins after the first egg was laid but prior to clutch completion. We were interested in the location and duration of the female's first foraging trip to sea after clutch completion. Upon returning to their nest after their first foraging trip, we removed their PTTs. Our preliminary data suggested the females had short trips to sea and remained near the rookery, which may indicate nearshore food resources were abundant. On 24 January, we redeployed the four PTTs on chinstrap penguin adults to determine adult foraging locations during the chick-rearing phase. The timing of this deployment coincided with the annual AMLR marine prey survey conducted in adjacent ocean waters. The PTTs remained on the birds for approximately 10 days before removal. Plots of the PTT location data indicated that all birds foraged within 10km of the colony. The AMLR marine, acoustical survey conducted during this period found large krill swarms within 5-10km of the colony in the areas frequented by the foraging penguins.

To study penguin diving behavior during the chick-rearing phase, we placed nine time-depth recorders (TDRs) on adult chinstrap penguins with chicks. The timing of the deployment (24 January) coincided with the AMLR marine prey survey. The TDRs gathered data on variables such as the dive depth, dive duration, time, and sea temperature. We are currently analyzing data on penguin foraging locations and diving profiles collected by satellite-linked transmitters and time-depth recorders, respectively.

In addition to our penguin research, we studied the breeding biology of the brown skua (*Catharacta antarctica lonnbergi*). Brown skuas are key predators on the Cape Shirreff penguin populations. Penguin eggs and chicks provide a major food source for brown skuas during the breeding season. Throughout the season, we followed the reproductive success of all brown skua breeding pairs (n=21) on Cape Shirreff and one territory off the cape. We have banded all breeding brown skuas in previous seasons and we banded all brown skua chicks produced in the 2000-01 year. Brown skua chicks begin returning to their natal grounds as three-year-olds. We began banding chicks in the 1996/97 season and in 1999/00, we observed six known-age chicks that returned to Cape Shirreff as adults. In the 2000/01 season we had a total of 12 known-age skuas return. It was the first time seven of these skuas had returned since being banded as chicks at Cape Shirreff. We also followed reproductive performance of kelp gulls (*Larus dominicanus*) opportunistically throughout the season.

7.3 Future Research: Our future research plans include the continuation of the annual CCAMLR predator monitoring protocols and at sea foraging behavior studies with TDRs and PTTs. These methods, in association with the Antarctic fur seal research at Cape Shirreff, and the annual AMLR marine prey survey, will allow us to further investigate and gain insight on the seasonal and inter-annual variability of the krill and predator populations in this region.

7.4 Acknowledgments: We would like to thank Michael Goebel, Brian Parker, Benjamin Pister, Rennie Holt and our Chilean research team colleagues for providing assistance, friendship and laughter throughout the field season. We thank the crew of the NSF R/V *Laurence M. Gould* for providing a safe voyage to our site in November and for valuable assistance in offloading our 5-month supply of food and scientific gear. We appreciate the hard work of the crew and AMLR scientists aboard the R/V *Yuzhmorgeologiya* in re-supplying the Cape Shirreff field camp and for a smooth migration from Antarctica to Chile at the season's close. Thanks to Stephanie Sexton and Sue Trivelpiece for plotting our penguin satellite foraging data and for keeping us in touch with the world beyond the Cape. Finally our special thanks and gratitude to our partners, families and friends for their emails, letters, and support.

Table 7.1. Mean length of krill 2mm and greater from chinstrap and gentoo penguin diet samples at Cape Shirreff, Livingston Island, Antarctica, 1997-2001.

Year	Number of krill measured	Mean length ± SD
1997/98	2,371	39.00 ± 4.00
1998/98	2,454	44.07 ± 3.59
1999/00	2,617	47.71 ± 4.45
2000/01	2,539	50.92 ± 4.72
Overall[a]	9,981	45.54 ± 6.14

a All four years (1997-2001) of data combined.

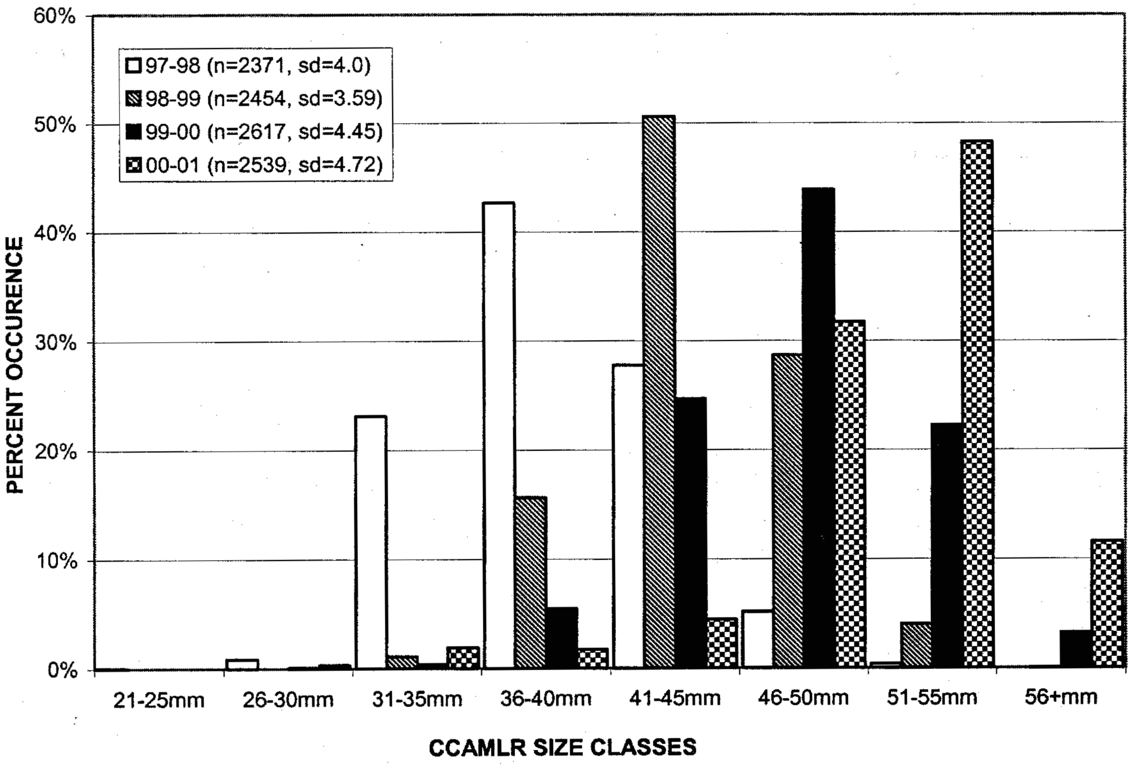

Figure 7.1. Krill length-frequency distribution from chinstrap and gentoo penguin diet samples at Cape Shirreff, Livingston Island, Antarctica 1997-2001.

8. Pinniped research at Cape Shirreff, Livingston Island, Antarctica, 2000-2001; submitted by Michael E. Goebel, Brian W. Parker, Alison R. Banks, Daniel P. Costa, Benjamin Pister 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 2000/2001 season. Studies on the diving and foraging ecology of adult female fur seals were also conducted in collaboration with the University of California-Santa Cruz. A four-person field team arrived at Cape Shirreff via the R/V *Lawrence M. Gould* on 16 November 2000. Research activities were initiated soon after and continued until closure of the camp on 28 February 2001. Our research objectives for the 2000/01field 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 from each adult female fur seal captured 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 (deployments to coincide with the US-AMLR Oceanographic Survey cruises);

H. Tag fur seal pups for future demographic studies;

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

J. 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 29 lactating females from 5-12 December 2000. 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 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 general health and condition of the pups were monitored throughout the study by making daily visual observations. Of the 29 mother-pup pairs, one pup died shortly after birth and we report results for the remaining 28. The presence/absence onshore was recorded for each female for the first six trips to sea.

The first female in our study to begin her foraging cycles did so on 10 December and last female to complete six trips to sea did so on 26 January. The mean trip duration for the combined first six trips to sea this year was lowest since data collection began at Cape Shirreff in 1997/98 (Table 8.1, Figure 8.1; ANOVA, $df_{3,667}$, $p<0.005$). Visit durations were also longer in 1999/00 and 2000/01 than in the first two years but were no different from each other (Table 8.1, Figure 8.1; ANOVA, $df_{3,667}$, $p<0.005$). In three out of the four years (1998/99-2000/01), the distribution of trip durations was skewed to longer trips (Table 8.1, Figure 8.2). Visit durations for all four years were likewise skewed (Table 8.1).

There was no difference in the postpartum mass of our attendance females from 1998/99 to 2000/01. Females in those three years were, however, larger than females in 1997/98 (Figure 8.3a; ANOVA, $df_{3,115}$, $p<0.0001$; **97/98:** Mean=39.2 kg ±5.76, N=31; **98/99:** Mean=45.6 kg ±6.67, N=32; **99/00:** Mean=46.5 kg ±5.90, N=23; **00/01:** Mean=46.3 kg ±4.52, N=28). 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, $df_{3,115}$, $p=0.62$; **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; **00/01:** Mean=0.35 kg ±0.026, N=28).

B. Fur Seal Pup Growth: Measures of fur seal pup growth were 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 14 February (five bi-weekly samples). Data were collected as directed in CCAMLR Standard Method C2.2 Procedure B. The results will be submitted to CCAMLR by Chilean researchers.

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 18 November 2000 through 10 January 2001. The maximum number counted at the combined four beaches in 2000/01 was 2,248 on 29 December 2000 (Figure 8.4), a 6.8% increase over the maximum count for the same sites in 1999/00 (2,104 on 3 January 2000). The median date of pup births was 8 December, the same day as last year but two days earlier than in 1997/98 and 1998/99.

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. All females that are captured to remove a time-depth recorder or satellite-linked transmitter (PTT) are given an enema to collect fecal material. Ten scats were collected from female suckling sites every week beginning 20 December. In total, we collected and processed 104 scats and enemas from 20 December 2000-23 February 2001. Diet samples that cannot be processed within 24 hours of collection were frozen. All samples were processed by 26 February. 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 was counted and preserved in 70% alcohol for later identification. Results indicated an increasing proportion of fish in the diet from December through February; however, all scats collected through the season had at least some krill (Figure 8.5). Squid occurred only in a few scats (2) in February (Figure 8.5, Table 8.2). Compared to our results from last year, there was more krill and less fish in the diet this year (Table 8.2, X^2=20.8, d.f.=4, $p<0.0005$).

The length and width of krill carapaces found in fur seal scats were measured to determine length distribution of krill consumed. Up to thirty carapaces from each scat were randomly selected and measured according to Hill (1990). The following linear discriminant function (Reid and Measures, 1998) was applied to the carapace length (CL) and width (CW) to determine sex of individual krill:

$$D = -1.04 - 0.146(CL) + 0.265(CW)$$

Positive discriminant function values were identified as female and negative values male. Once the sex for each krill was determined the following regression equations from Reid and Measures (1998) were applied to calculate total length (TL) from the carapace length:

$$\text{Females: } TL = 15.3 + 2.09(CL)$$
$$\text{Males: } TL = 13.9 + 2.29(CL)$$

A total of 2,941 carapaces was measured from 104 scats in 2000/01. Summary statistics are presented in Table 8.3. Data from 1999/00 are also presented for comparison. Krill consumed by fur seals in 2000/01 were on average larger than in 1999/00 (Table 8.3; ANOVA, $\text{d.f.}_{1,5465}$, F-ratio = 833.3, $p<0.0005$). The length distributions for both years in 2mm increments are presented in Figure 8.6.

E. Fatty Acid Signature Analysis of Milk: In addition to scats, enemas, and regurgitations, we collected 116 milk samples from 69 female fur seals. Each time a female was captured (either to instrument or to remove instruments), 30ml of milk was collected by manual expression. Prior to collection of the milk sample, an intra-muscular injection of oxytocin (0.25ml, 10 UI/ml) was administered. Milk was taken (within several hours) to the lab where two 0.25ml aliquots were collected and 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 for later extraction of lipid and trans-esterification of fatty acids. Of the 116 samples, 27 were collected from perinatal females and 34 were collected from 26 females for which we had dive data for the foraging trip prior to milk collection.

F. Diving Studies: Twelve of our 28 females transmittered 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 of them carried their TDR for at least the first six trips to sea. In addition, all other females captured for studies of at-sea foraging locations also received a TDR. The total number of females with diving data for 2000/01 was 28. The total number of trips recorded on TDRs from 10 December 2000- 17 February 2001 was 125.

G. Adult Female Foraging Locations: We instrumented 25 females with satellite-linked transmitters (ARGOS-linked PTT's) from 23 December- 17 February. Twenty of these were deployed to coincide with the US-AMLR large-scale oceanographic survey. Of the 25, nine carried a PTT for a single trip to sea, two for two trips to sea, thirteen others for three trips and one female carried her PTT for four trips. Results of fur seal foraging location data analysis and comparisons to the two previous seasons are pending.

H. Demography and Tagging: Together Chilean and U.S. researchers tagged 499 fur seal pups (266 females, 232 males, 1 unknown sex) from 20 January- 27 February 2001. 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 (2001-2294, 2296-2500). Most pups were tagged on 31 January and 14 February and most (449) on the east side of the Cape from Playa Marko to Chungungo beach. Fifty tags were put on pups at Loberia on the northwest side of the Cape.

In addition to the 499 pups tagged, we also tagged 35 adult lactating, previously untagged, females (188-221,230). All tags were placed on females with parturition sites on east-side beaches (Copihue, Maderas, Cachorros, and Chungungo beaches).

Last year we added 100 adult females to our tagged population. Of the 100 tags added, four were placed at Loberia (outside our study area) and one was a re-tagged female (011), leaving 95 new tags to add to those already tagged. These 95, when added to the females that returned in the previous season (n=78), gave an expected known tagged population of 173 for 2000/01 (Table 8.4). Of these, 156 (90.4%) returned in 2000/01 to Cape Shirreff and 136 (87.2%) returned pregnant (Figure 8.7). The return rate was higher in 2000/01 than in 1998/99 but lower than last year; natality was lower than in the two previous years (87.2% vs. 90.3% in 1998/99 and 92.3% in 1999/00; Figure 8.7).

Our tagged population of females returned (on average) one day earlier than last year. In 1999/00, the mean date of pupping for tagged females (which had a pup in both years) was 9 December (±7.5, N=94) and in 2000/01, for the same females, it was 8 December (±7.7, N=94). The median date of pupping for our tagged females for both years was one day earlier (1999/00: 8 December, 2000/01: 7 December). This result is one day earlier for both years than our estimates of the median date of pupping based upon pup counts for the season (see section C above).

We observed 26 yearlings (11 females, 15 males that were tagged as pups in 1999/00; Table 8.5) in 2000/01. This is more tagged yearlings than we sighted last season. Table 8.5 presents observed tag returns for three cohorts in their first year. Tag deployment and re-sighting effort for all three cohorts were similar and differences are likely due to changes in the post-weaning physical and/or biological environment. The differences in return rates are not necessarily due to survival but may be due to other factors (e.g. physical oceanography of the region, over-winter prey availability or other factors) that influence whether animals return to natal rookeries in their first year.

We calculated the minimum percent survival based upon tag re-sights for the first two years following tagging (Table 8.6). The survival values are adjusted based upon the probability that an individual would lose both tags. Tag loss (right or left) was assumed to be independent. The results presented are for the minimum percent survival because animals return for the first time to natal rookeries at different ages and the probability of returning at age 1, age 2, *et cetera* may vary for different cohorts. Most notable, given similar re-sighting effort the two cohorts presented have return rates in the first two years that are very different. This difference is important whether due to survival or differences in dispersal that result in different rate of return.

I. Tooth Extraction and Age Determination: We began an effort of tooth extraction from adult female fur seals for age determination in 1999/00. Tooth extractions are made using gas anesthesia (isoflurane, 2.5-5.0%), oxygen (4-10 liters/min), and midazolam hydrochloride (1cc). A detailed description of the procedure was presented in the 1999/00 annual report.

This year, from 17 January through 1 February, we took a single post-canine tooth from 60 previously tagged females. Two of these were from 3-year old nulliparous females tagged as pups and one was from a female that was tagged as a pup at Seal Island. The teeth collected from these three females will be used for validation of the aging technique. Females ranged in size from a mass of 25.0-56.5kg and length of 117-150cm. The mean total time captive was 18.0 min (±6.0) and the mean total time under anesthesia was 14.0 min (± 3.0, n=60). The time captive and the time under anesthesia both increased over last year (12.6 and 9.6 min, respectively) due to fewer personnel assisting (five in 1999/00 vs. three in 2000/01).

Tooth extraction is the most invasive of our research techniques and could potentially affect reproductive success. We therefore have focused some effort to measure the effects of extracting a tooth on attendance behavior (i.e. trip and visit durations), diving behavior, and return and natality rate in the year following tooth extraction.

Last year we extracted a tooth from 79 of our 173 tagged females expected to arrive this year. We compared return and natality of those 79 females to the remaining 94 females, treated as a control group because they were not captured for a tooth extraction last year (Figure 8.8). Females that had a tooth extracted in 1999/00 had a slightly lower rate of return (0.5% lower) and natality (2.3% lower) in 2000/01 than did females that did not have a tooth extracted (Percent return: 90.4 vs. 89.9; Natality: 88.2 vs. 85.9%). The differences were not significant however (Return: X2=0.015, d.f.=1, P=0.90; Natality: X2=0.186, d.f.=1, P=0.67).

Eleven females in our sample carried VHF radio transmitters before and after tooth extraction. Arrival and departures were recorded with a remote VHF receiver and a data-logging device that recorded and stored presence or absence ashore every 15 minutes. The durations of the visit preceding, the visit following and the visit of tooth extraction were compared using analysis of variance (ANOVA). Likewise, the trip duration for the trip before the tooth extraction visit and for the two subsequent trips were compared. There was a difference in visit durations but no difference was found in trip durations (Figure 8.9). The difference in visits was due to the tooth extraction visit being on average about 0.5 day (d) longer (**Preceding visit:** 1.6d ±0.5, **Tooth extraction visit:** 2.0d ±0.6, **Following visit:** 1.5d ±0.5; $F_{2,30}$=3.79, P=0.034). Trip durations were on average 3.1d ±0.8 (**Preceding trip:** 3.0d ±0.6, **Following trip:** 3.0d ±0.9, **Following 2nd trip:** 3.2d ±1.0; $F_{2,30}$=0.27, P=0.767). Age determination of the teeth collected this year is currently underway.

J. Weather at Cape Shirreff: A weather data recorder (Davis Weather Monitor II) was set up at the US-AMLR field camp at Cape Shirreff from 16 November 2000 to 26 February 2001. 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) 0.5°C cooler this year than in 1999/00 for the same time period (4 December-24 February). Total measurable precipitation in 2000/01 was similar to 1999/00 with similar total number of 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, 2000/01: 56.0mm for 36 days). Over-winter snow cover at the start of this season was similar to last year though we do not have a precise measure of this. By the time fur seal pupping began in late November most snow had melted from breeding areas. The lighter snow cover and decreased precipitation over 1998/99 resulted in a relatively dry season similar to last year.

8.3 Preliminary Conclusions: The 2000/01 season was better for Antarctic fur seals by several measures than the previous three seasons. Fur seal pup production at US-AMLR study beaches on Cape Shirreff increased by 6.8% over last year. The median date of pupping based on pup counts was two days earlier than in 1997/98 and 1998/99. The mean arrival and parturition dates for our tagged female population was also two days earlier than those years but the same as last year. Though return rates for adult females were slightly lower than the previous year, at 90.2% over-winter survival is still high and there was no change in arrival condition compared to last year. Return rate for yearlings was higher this year than last. Adult female trip duration for the first six trips to sea was significantly less than in previous years indicating improved foraging conditions. Fur seals this year had slightly more krill in the diet than last year and though the overall percent of fish in the diet was lower, the trend for an increasing percent occurrence of fish and squid as the season progresses was present as in previous years. The mean length of krill in fur seal diet increased this year over last year, reflecting the same results as found in at-sea surveys from our oceanographic survey vessel. Our preliminary studies of the effect of tooth extraction on survival, natality, and attendance behavior indicate that if there are any measurable significant differences, they are minimal.

8.4 Acknowledgements: We are grateful to our Chilean colleagues: Layla Osman, Jorge Acevedo, Romeo Vargas, Olivia Blank, and Rodrigo Hueke-Gaete for their assistance in the field, good humor and for sharing their considerable knowledge and experience of Cape Shirreff. Some of the tag re-sight data used in this report were provided by our Chilean colleagues. Thanks to Benjamin Pister, Michael Taft, Iris Saxer, and Wayne Trivelpiece for their help with pinniped studies and to the captain and crew of the L.M. Gould who provided transport and assistance to the Cape Shirreff opening team. 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 were supported by National Science Foundation Grant #OPP 9726567 to Daniel P. Costa and Michael E. Goebel.

8.5 References:

Hill, H.J. 1990. A new method for the measurement of Antarctic krill *Euphausia superba* Dana from predator food samples. *Polar Biology* 10(4): 317-320.

Reid, K., and Measures, J. 1998. Determining the sex of Antarctic krill *Euphausia superba* using carapace measurements. *Polar Biology* 19(2): 145-147.

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 – 2000/01.

	Year	N	Range	Median	Mean	St.Dev.	Skew[1]	SE Skew	Significance	(+/-)
Trip Durations:										
	1997/98	180	0.50-9.08	4.07	4.19	1.352	0.083	0.181	0.459	-
	1998/99	186	0.48-11.59	4.23	4.65	1.823	0.850	0.178	4.775	+
	1999/00	138	0.60-8.25	3.25	3.47	0.997	1.245	0.206	6.044	+
	2000/01	168	0.75-5.66	2.69	2.71	0.828	0.874	0.187	4.674	+
Visit Durations:										
	1997/98	179	0.46-2.68	1.25	1.35	0.462	0.609	0.182	3.346	+
	1998/99	186	0.21-3.49	1.27	1.33	0.535	0.947	0.178	5.320	+
	1999/00	138	0.10-4.25	1.51	1.72	0.635	1.088	0.206	5.282	+
	2000/01	168	0.44-3.15	1.52	1.68	0.525	0.485	0.187	2.594	+

[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/Standard Error of Skewness (SE) is greater than two.

Table 8.2. 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 three years, 1998/99 through 2000/01. X^2=20.8, d.f.=4, P<0.0005.

	1998/99		**1999/00**		**2000/01**	
Prey	**Observed**	**Expected**	**Observed**	**Expected**	**Observed**	**Expected**
Krill	84	79.3	94	113.0	104	89.9
Fish	32	39.9	71	56.8	39	45.3
Squid	12	8.7	17	12.4	2	9.9

Table 8.3. Krill length (mm) in fur seal diet for 1999/00 and 2000/01.

	1999/00: All Krill	**Female**	**Male**	**2000/01: All Krill**	**Females**	**Males**
N:	2528	1623	905	2941	1578	1363
Median (mm):	50.8	52.9	48.3	52.9	52.9	52.8
Mean (mm):	50.6	52.0	47.9	53.1	53.6	52.5
St.Dev.:	4.462	3.314	5.005	3.824	3.567	4.017
Maximum:	59.7	59.2	59.7	39.1	40.4	39.1
Minimum:	13.9	40.4	13.9	64.3	63.4	64.3
Sex Ratio:	1:1.8			1:1.2		

Table 8.4. Tag returns and pregnancy rates for adult female fur seals at Cape Shirreff, Livingston Island, 1998/99 – 2000/01.

Year	**Known Tagged Population**[1]	**Returned**	**Pregnant**	**% Return**	**% 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
2000/01	173	156	136	90.4	87.2	35

[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 8.5. A comparison of first year tag returns for three cohorts: 1997/98 – 1999/00. Values in parentheses are percents.

Cohort	**Total Tags Placed**	**Tag Returns in Year 1 (%)** **Total**	**Males**	**Females**
1997/98	500	22 (4.4)	10 (2.0)	12 (2.4)
1998/99	500	6 (1.2)	5 (2.0)	1 (0.4)
1999/00	500	26 (5.2)	15 (3.0)	11 (2.2)

Table 8.6. Tag re-sights and minimum percent survival for two cohorts, 1997/98 and 1998/99 using the first two years of sighting data for each cohort.

	1997/98:			**1998/99:**		
	TOTAL	**Males**	**Females**	**TOTAL**	**Males**	**Females**
Sightings:						
Sighted in Year 1:	22	10	12	6	5	1
Additional Tags Sighted in Year 2:	32	10	20	13	7	6
Minimum survival in year 1:	54[1]	20	32	19	12	7
Tag loss:						
Unknown tag status:	3	1	2	2	2	0
Both tags present:	29	13	14	12	6	6
Missing 1 tag:	22	6	16	5	2	3
Probability of missing one tag:	0.43	0.32	0.53	0.29	0.25	0.33
Probability of missing both tags[2]:	0.19	0.10	0.28	0.09	0.06	0.11
Survival estimates:						
Minimum % Survival 1st year:	10.8	8.00	12.80	3.8	4.8	2.8
Adjusted minimum % Survival for year 1[3]:	**12.8**	8.80	16.44	**4.1**	5.1	3.1

[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.

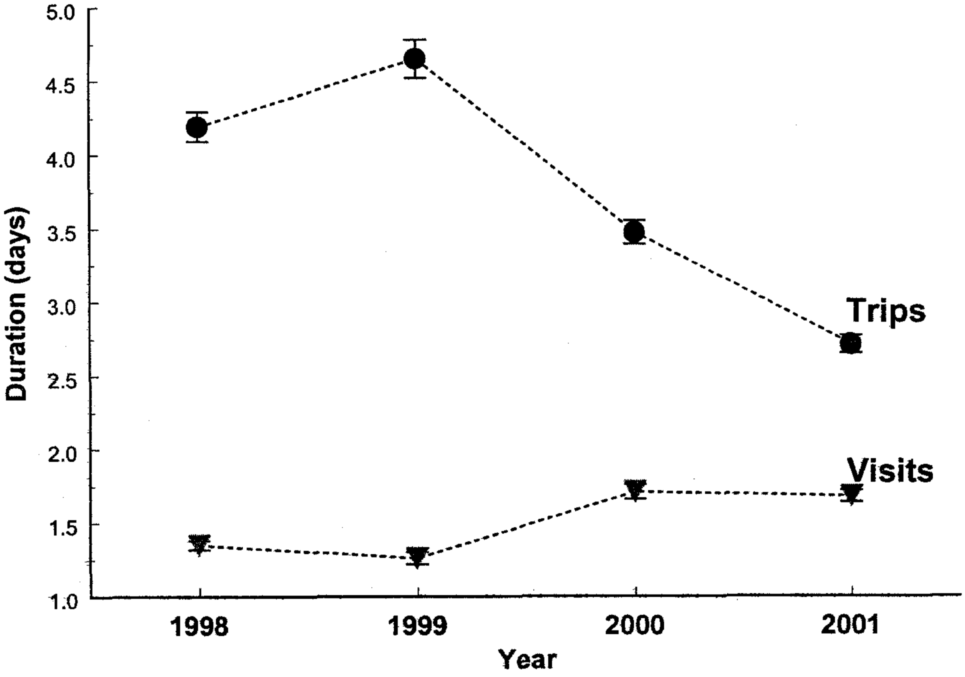

Figure 8.1. Antarctic fur seal trip and visit durations for females rearing pups at Cape Shirreff, Livingston Island. Data plotted are for the first six trips to sea and the first six non-perinatal visits following parturition for the last three years (**1997/98:** $N_{Females} = 30$, $N_{Trips} = 180$; **1998/99:** $N_{Females} = 31$, $N_{Trips} = 186$; **1999/00:** $N_{Females} = 23$, $N_{Trips} = 138$; **2000/01:** $N_{Females} = 28$, $N_{Trips} = 168$). Sample sizes for visits are the same as trips.

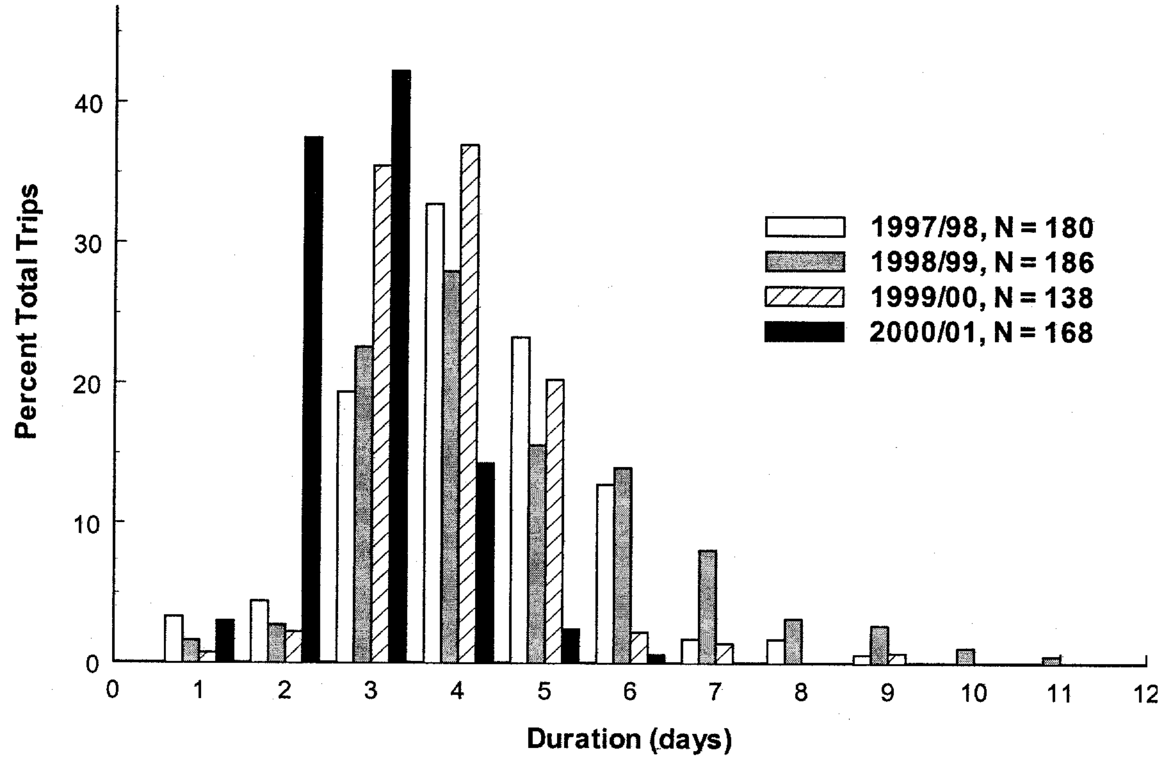

Figure 8.2. The distribution of Antarctic fur seal trip durations at Cape Shirreff, Livingston Island for four years (1997/98-2000/01).

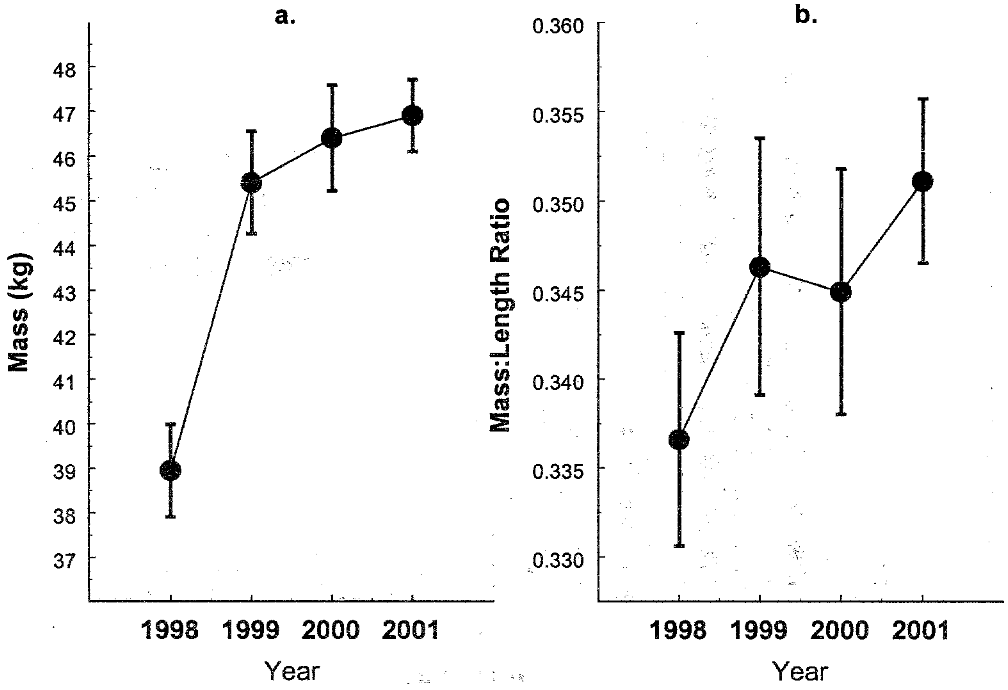

Figure 8.3. The mean mass (**a.**) and mass:length ratio (**b.**) for CCAMLR Attendance Study females for 1997/98 – 2000/01 (**1997/98:** N=31, **1998/99:** N=32, **1999/00:** N=23, **2000/01:** N=28).

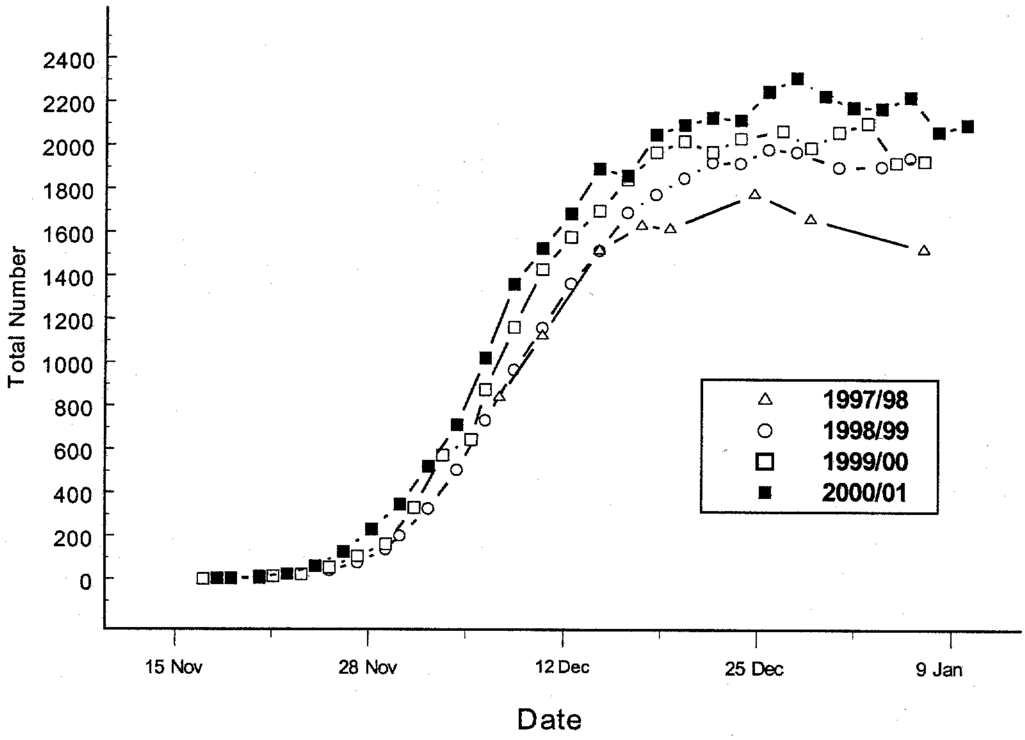

Figure 8.4. Antarctic fur seal pup production at US-AMLR study beaches, Cape Shirreff, Livingston Island, 1997/98-2000/01.

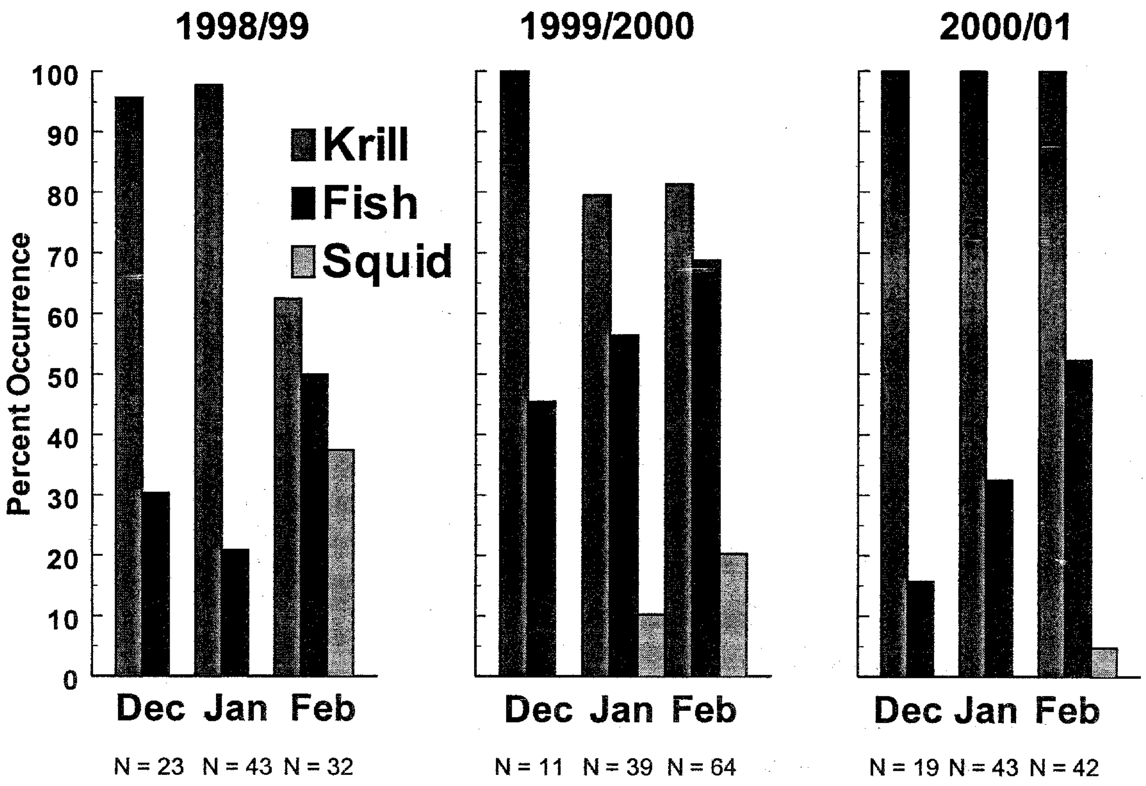

Figure 8.5. The percent occurrence of primary prey types (krill, fish, and squid) from December through February for Antarctic fur seal scats and enemas collected from female suckling areas at Cape Shirreff, Livingston Island for 1998/99 through 2000/01.

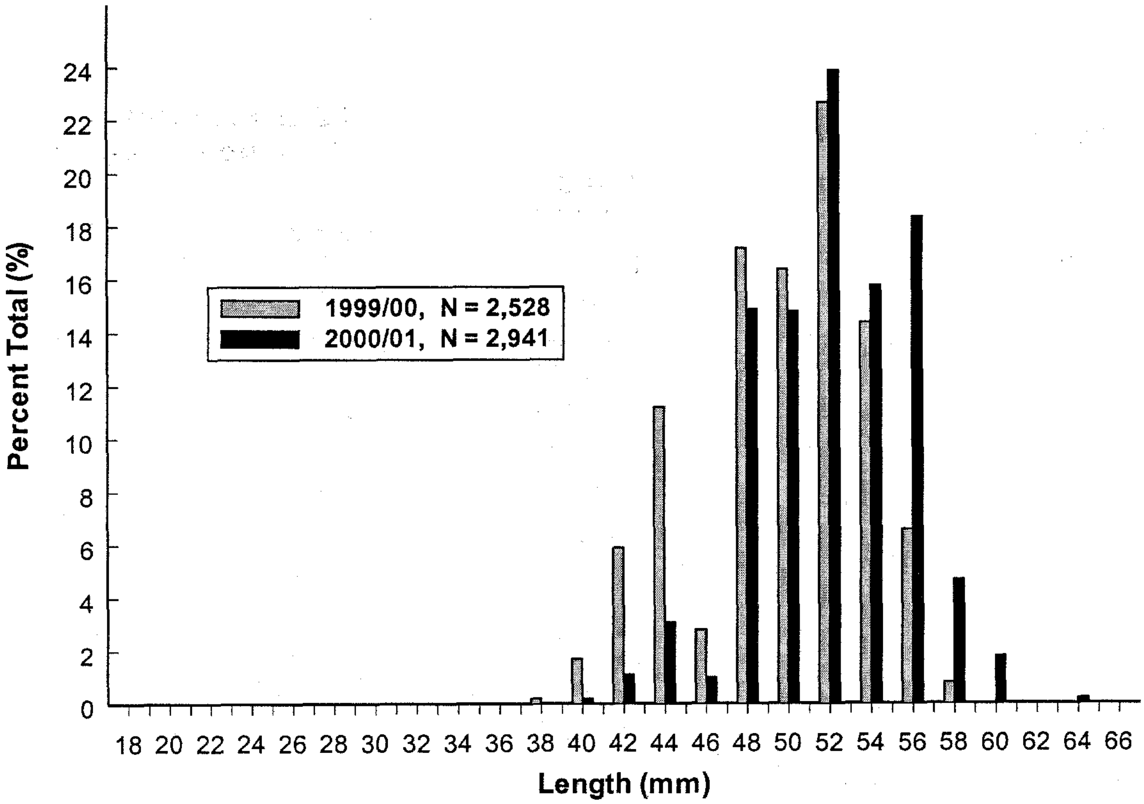

Figure 8.6. The size distribution of krill in Antarctic fur seal diet at Cape Shirreff, Livingston Island in 1999/2000 and 2000/01.

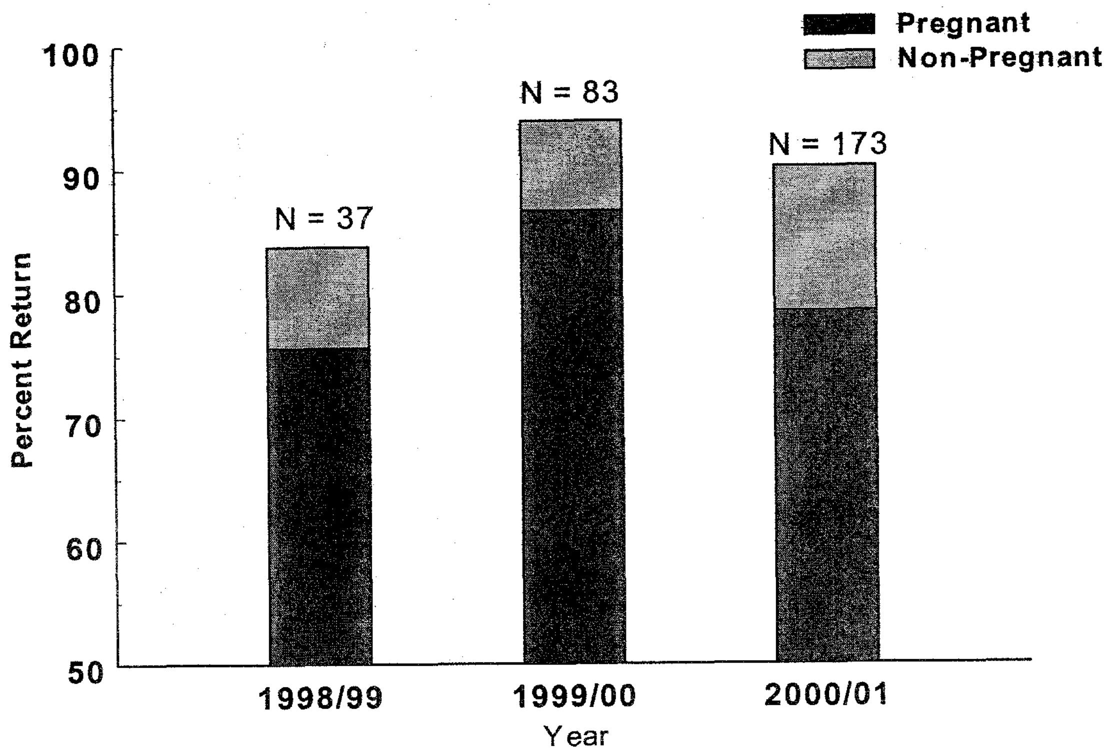

Figure 8.7. Adult female Antarctic fur seal tag returns for three years (1998/99-2000/01) at Cape Shirreff, Livingston Island.

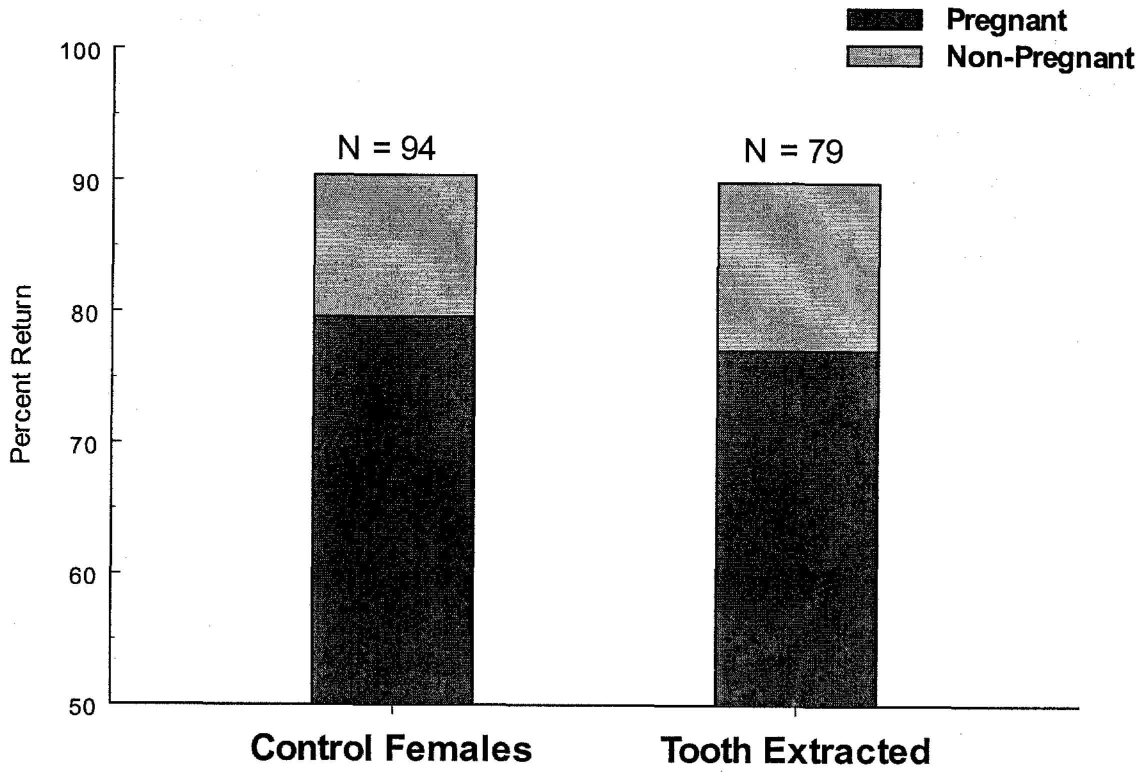

Figure 8.8. The effect of extracting a single post-canine tooth on the following year's tag returns and natality for adult female fur seals at Cape Shirreff, Livingston Island.

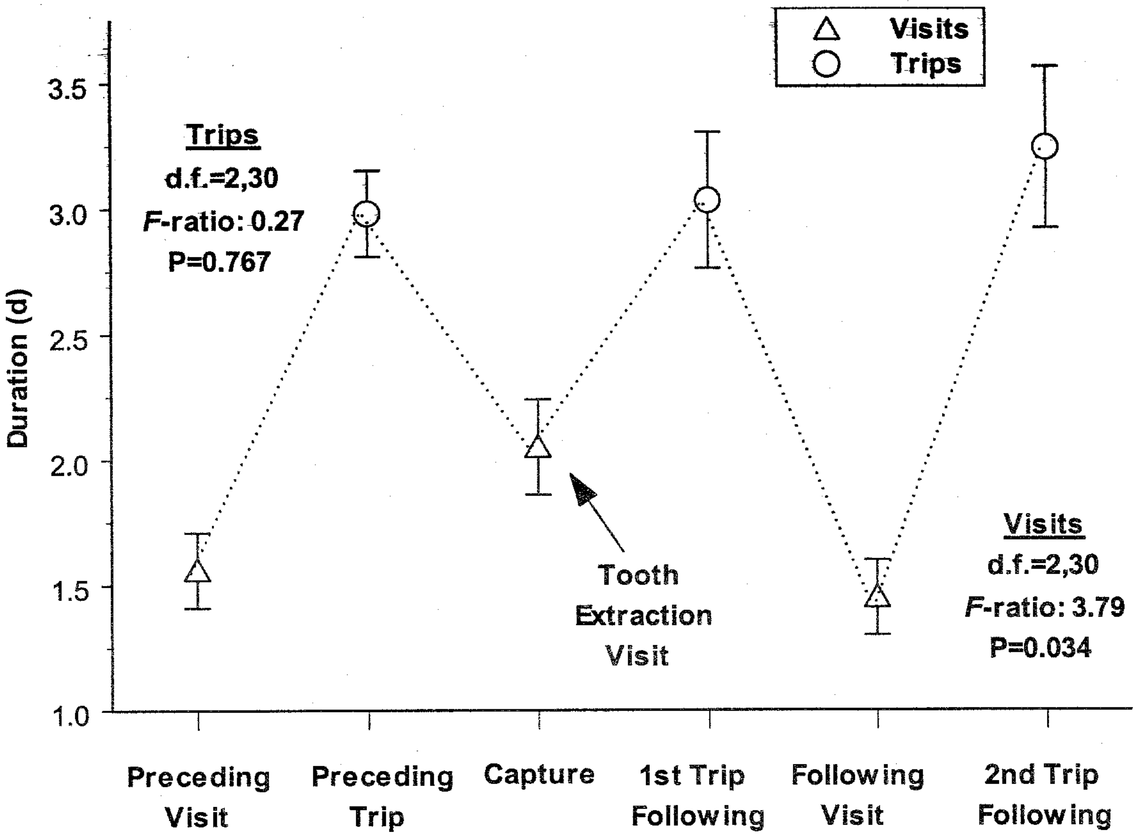

Figure 8.9. The effect of capture and extraction of a single post-canine tooth on female visit and trip duration. Data are for 11 females that were captured from 17-29 January 2001.

9. Operations and logistics at Cape Shirreff, Livingston Island; and Copacabana, King George Island, Antarctica, 2000/01; submitted by Jessica D. Lipsky and Rennie S. Holt.

9.1 Objectives: During the 2000/01 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 16 November 2000 through 28 February 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 2000/01 season were:

1. To deploy four personnel and provisions in mid-October 2000 from the R/V *Lawrence M. Gould* to the Copacabana field camp at Admiralty Bay, King George Island;

2. To deploy a four-person team and provisions in mid-November 2000 from the R/V *Lawrence M. Gould* to Cape Shirreff, Livingston Island to initiate research activities pertaining to seabirds and pinnipeds;

3. To deploy one person and provisions in late December 2000 to the Copacabana field camp from the Marine Expeditions tour ship *Maria Yurmulova*;

4. To deploy two personnel to Cape Shirreff, along with supplies and equipment, in early January 2001 from the R/V *Yuzhmorgeologiya*;

5. To deploy one person to Cape Shirreff in early February 2001 from the R/V *Yuzhmorgeologiya*;

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

7. To recover one person from Copacabana field camp in early December 2000 aboard the R/V *Lawrence M. Gould*;

8. To recover one person from Cape Shirreff in early February 2001 and to retrieve trash and pinniped scat samples;

9. To recover one person form the Copacabana field camp in early mid-February 2001 aboard the R/V *Lawrence M. Gould*;

10. To recover six personnel from Cape Shirreff in late February 2001 aboard the R/V *Yuzhmorgeologiya* and to retrograde equipment and trash at the end of the field season;

11. To recover four personnel from the Copacabana field camp in early March 2001 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 to maintain daily radio contact with either Cape Shirreff and Copacabana camps with the R/V *Yuzhmorgeologiya.*

9.2 Accomplishments: Four personnel (S. Trivelpiece, C. Thiessen, M. Owczarek and L. Rektoris) and provisions were deployed from the R/V *Lawrence M. Gould* to the Copacabana field camp at Admiralty Bay, King George Island on 12 October 2000.

A four-person field team (M. Goebel, M. Taft, I. Saxer and B. Pister), along with provisions, equipment and supplies, arrived at Cape Shirreff, Livingston Island aboard the R/V *Lawrence M. Gould* on 16 November 2000. Scientific activities were quickly initiated. Maintenance of the campsite and bird blind observation deck also began.

One person (L. Shill) and field supplies were deployed to the Copacabana field camp on 21 December 2000 from the Marine Expeditions tour ship *Maria Yurmulova.*

Two additional personnel (W. Trivelpiece and B. Parker) and supplies arrived at the Cape Shirreff campsite from the R/V *Yuzhmorgeologiya* on 14 January 2001.

One person (J. Yarkin) arrived at the Copacabana camp from the R/V *Lawrence M. Gould* on 5 February 2001.

One person (R. Holt) and supplies were deployed on 11 February 2001 to the Cape Shirreff field camp from the R/V *Yuzhmorgeologiya.*

One person (S. Trivelpiece) departed Copacabana on 1 December 2000 aboard the R/V *Lawrence M. Gould.*

One person (M. Goebel) was retrieved from the Cape Shirreff field camp on 2 February 2001 aboard the R/V *Yuzhmorgeologiya.*

One person (J. Yarkin) departed the Copacabana camp on 12 February 2001 aboard the R/V *Lawrence M. Gould.*

On 28 February 2001, a six-person team closed the Cape Shirreff field camp for the season. All personnel (R. Holt, W. Trivelpiece, B. Parker, M. Taft, I. Saxer and B. Pister), along with garbage and equipment requiring maintenance for protection from the winter weather, were removed and loaded aboard the R/V *Yuzhmorgeologiya* for return to the United States.

On 1 March 2001, a four-person team (L. Shill, C. Thiessen, M. Owczarek and L. Rektoris) closed and departed for the season the Copacabana campsite by the R/V *Yuzhmorgeologiya,* along with trash and retrograded equipment.

Daily radio communications were maintained by Cape Shirreff with the R/V *Yuzhmorgeologiya* and Copacabana field 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 camp 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. Thanks to the R/V *Lawrence M. Gould* crew and scientific parties during the opening of Copacabana field camp.

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