UNITED STATES AMLR ANTARCTIC MARINE LIVING RESOURCES PROGRAM

AMLR 2003/2004 FIELD SEASON REPORT

Objectives, Accomplishments and Tentative Conclusions

Edited by
Jessica D. Lipsky

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U.S. Department of Commerce
National Oceanic & Atmospheric Administration
National Marine Fisheries Service
Southwest Fisheries Science Center
Antarctic Ecosystem Research Division
8604 La Jolla Shores Drive
La Jolla, California, U.S.A. 92037

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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, 2001 and 2003.

This is the 16th issue in the series of AMLR field season reports.

SUMMARY OF 2004 RESULTS

The Russian R/V *Yuzhmorgeologiya* was chartered to support the U.S. AMLR Program during the 2003/04 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) (See Figure 2 for station locations); 2) calibration of acoustic instrumentation at the beginning and end of survey operations; 3) underway seabird and marine mammal observations; 4) deployment of drifter buoys and acoustically instrumented buoys with buoy-to-shore telemetry in the vicinity of Cape Shirreff; 5) a joint Zodiac/ship nearshore survey of krill and oceanographic conditions near Cape Shirreff; 6) a tagged female fur seal study at Seal Island; and 7) 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 pup 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 demographic studies; and 7) establishment of a weather station for 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 position of the polar frontal zone, identified by sea temperature and salinity change, was located from the logged SCS data during all four transits from and to Punta Arenas and the South Shetland Islands survey area. This frontal zone is normally situated between 57-58°S. During the south transit for Leg I, a well-defined front was centered around 58°S. On the northern transect the front shifted south, still clearly defined between 58° 30'S to 59°S. On the south-bound transit of Leg II the front had a similar location as the north bound transect of Leg I, but had become less defined, laying between 58°30'S and 59°30'S. On the return transit, at the end of Leg II, the zone was again well defined and was located between 58°30'S and 59°S. During Leg I, there was a less clearly defined distinction of the classical Zone I (ACC) type waters in the offshore stations of the western and northern areas, than found in previous years. Many stations in this area displayed a mixing of Zone I and II (Transition) waters. This mixing was also evident in many of the shallower inshore stations, to the north of the islands, where the distinction between Zone II (Transition), III (Transition) and IV (Bransfield Strait) waters were not as distinct as in previous years. Zone II waters were also predominant in the Elephant Island Area, extending into the eastern part of the area. Zone IV waters were predominant to the south of Elephant Island, in the northern Joinville Island and in the South Areas with the inshore stations of the South Area producing stations with mixing taking place, with surface waters (0 to 50m) having lower salinity and higher temperatures values. The Leg II Water Zone distributions conformed more closely to the classical definitions. Zone I (ACC) waters dominated the western and northern area, running parallel with the continental shelf edge. Zone IV (Bransfield Strait) waters completely filled the Straits, except for a token appearance of Zone V (Weddell Sea) water at the entrance to the Antarctic Sound. Zone IV (Bransfield Strait) waters extended to the south of Elephant Island, forming a coastwise-parallel buffer between the Weddell and the Antarctic Circumpolar Current (ACC) water in the north.

As in previous years, chlorophyll concentrations have generally increased between Legs I and II for shelf and shelf break areas, and this year there were only slight differences. Although concentrations were moderately low for all areas in the AMLR survey area relative to our 15-year time series, chlorophyll concentrations did increase slightly during Leg II. Satellite imagery shows this same trend, with moderate chlorophyll increases in the local waters near Cape Shirreff, and the dense bloom in the Bransfield Strait.

Forty drifter buoys were deployed this season: 10 during AMLR Leg I, seven along a transect between King George Island and Punta Arenas (February 4-5), and 20 during the collaborative NSF-OPP project (February-March). A primary purpose for these releases was to examine how the Shackleton Fracture Zone (SFZ) interrupted the eastward flow of the Antarctic Circumpolar Current (ACC). These indicate a deflection in the drift of the Antarctic Circumpolar Current (ACC) imposed by the Shackleton Fracture Zone (SFZ), similar to that described from drifter trajectories from the 2002/03 field season. The tracks of these drifters outline a plume of higher chlorophyll concentration east of the SFZ that began to develop in January and maximized in March. Nutrients were sampled at selected stations within the AMLR survey grid that have, from past analyses, provided extremes in physical and biological characteristics of the water column for the Drake Passage side of the South Shetland and Elephant Islands. ACC surface waters are less saline and warmer than coastal waters, and are clearly distinguished from each other in temperature verses salinity space.

During Leg I, high abundances of krill were acoustically observed along the shelf break from north of Livingston to northwest of King George Islands. Greater krill abundance was observed along the shelf from northeast of King George island into the waters northeast of Elephant Island. Small densities of krill were observed in the Joinville Island transects. The distribution of mean nautical area scattering coefficients (NASC) of myctophids was mapped and found to be highest along the 2000m isobath. Areas of greater abundance were observed northeast of Livingston Island and northwest of Elephant Island. Leg II krill densities shifted locations from Survey A. Distribution of krill density was not as uniform as Survey A in the West Area. Krill abundance was highest northwest of Elephant Island, along the Shackleton Fracture Zone. NASC distribution of myctophids differed from Survey A, being more patchy. Highest densities were observed north and south of Elephant Island.

The 1994 and 1997 austral summers were previously described as "transition" periods between years with numerical dominance by either salps or copepods ("salp years" and "copepod years"). These shifts were most extreme in 1994 when the relative abundance of salps went from 81% to 12%, and copepods from 4% to 82%, of total mean zooplankton abundance within the Elephant Island Area. The "transition" in 2004 was comparatively modest and reflects a trend for more stable copepod, salp and other zooplankton abundance relationships since 1998. The two 2004 surveys (Survey A and Survey D, Legs I and II respectively) covered a period of rapid and dramatic change in zooplankton and nekton abundance, species composition and species abundance relations. The overall krill length-frequency distribution (predominantly 35-60mm individuals) reflected strong recruitment success of 1999/00, 2000/01 and 2001/02 year classes and minimal representation from the 2002/03 spawning season. Presence of relatively advanced furcilia (F2) larval stages during Survey A and relatively large concentrations of these and older F3 stages during Survey D indicated an extremely early initiation of spawning (early to mid-November 2003). Unusually large proportions of immature reproductive stages, particularly among large krill, during January may have been "rejuvenating" post-spawning individuals. Substantial concentrations of early calyptopis (C1 and C2) larvae in conjunction with large proportions of reproductive adult stages during Survey D indicated a prolonged spawning period extending into March 2004. Based on past observations, prolonged reproductive efforts and abundant advanced larval stages presage good recruitment success the following year. Based on the 1979-2004 Elephant Island data sets seasonal abundance means of copepods and the salp, *S. thompsoni*, had a significant negative correlation prior to 1999 reflecting the marked fluctuations between salp and copepod dominance. However, after 1998 their abundance relations changed dramatically and have been positively correlated. This has been associated with a significant order of magnitude increase in mean copepod abundance between the two periods. Other zooplankton taxa such as *Euphausia frigida* and chaetognaths also demonstrated significant abundance increases after 1998. Obvious changes in krill recruitment success in recent years are consistent with these observations of large-scale ecosystem change after 1998. Associated with increased frequency of strong year classes was a change from decreasing krill population size between 1979 and 1999 to a period of population growth starting with the 1999/00 year class. Given past associations between krill recruitment success, salp abundance fluctuations and sea ice development it is not surprising to note changes in sea ice variability in recent years. Strong interannual variability in sea ice development within the Antarctic Peninsula region observed between 1979 and 2000 was associated with a significant trend for decreased spatial and temporal sea ice extent. However, seasonal sea ice development has been relatively stable since 2000.

The results of the 120kHz echosounder Nearshore survey from the R/V *Ernest* were similar to the previous two surveys during 2000 and 2002. As was seen in the 2000 and 2002 surveys, the highest concentrations of scatterers were found in the near-shore region southeast and east of Cape Shirreff. High levels of scattering were also found along the canyon walls. Scattering level magnitude was larger than in 2002, however the distribution of scattering patches was similar. From the 2004 nearshore survey net tow data from *Yuzhmorgeologiya*, the acoustical targets are believed to be euphausiids *Thysanoessa macrura* and *Euphausia superba*, although small fish contribute to the scattering as well. During the survey, many penguins and seals and one fin whale were seen in areas that had high acoustic backscatter.

For the second year consecutively, independent seabird and marine mammal observers joined the survey to collect data on the spatial distribution and abundance of seabirds and marine mammals. The importance of seabirds and mammals as indicators of the marine environment is unquestionable and the data collected at sea in collaboration with the 2003/04 AMLR survey, will provide insight on how pelagic predators respond to changes in of the distribution of Antarctic krill and the position of oceanographic features.

The seventh consecutive season of data collection at Cape Shirreff has enabled us to examine trends in penguin populations, as well as inter-annual variation in reproductive parameters, penguin diet, and foraging behavior. The chinstrap breeding population at Cape Shirreff has continued to decline over the past five years, and is at its lowest size in the past seven years of study. While the gentoo breeding population increased slightly from last year, it is at its second lowest size in the past seven years. Chinstrap fledging success was higher during the 2003/04 breeding season than in the previous season, but lower than the average for the past seven years. Gentoo fledging success in 2003/04 was greater than in 2002/03, and was either similar to or greater than the seven-year mean, depending on methodology used. Fledging weights of both species increased from last year, but were below the eight-year mean for this parameter. Chinstrap penguin diet contained more fish than in other years on average, while gentoo diets contained less fish. Total chick meal mass was larger in both species compared to the past seven years of study. Foraging trip durations were on average longer than during the 2002/03 breeding season, the interpretation of which may be aided by analysis of foraging location and diving behavior data.

The 2003/04 season was in many respects an improvement over the 2002/03 season for Antarctic fur seals at Cape Shirreff. Fur seal pup production at U.S.-AMLR study beaches increased by 5.9% over last year (though pup numbers still remain below the pre-2002/03 numbers). Neonate mortality was nearly half what it was in 2002/03. The median date of pupping based on pup counts did not change over last year and our tag returns of adult females confirm no change in the parturition date. Over-winter survival for adult females was better than last year. The natality rate also improved over last year as well. Foraging trip duration was below the long-term mean indicating better than average foraging conditions and visit duration above the long-term mean. The 1999/00 and the 2001/02 cohorts continued to dominate tag returns as in previous years.

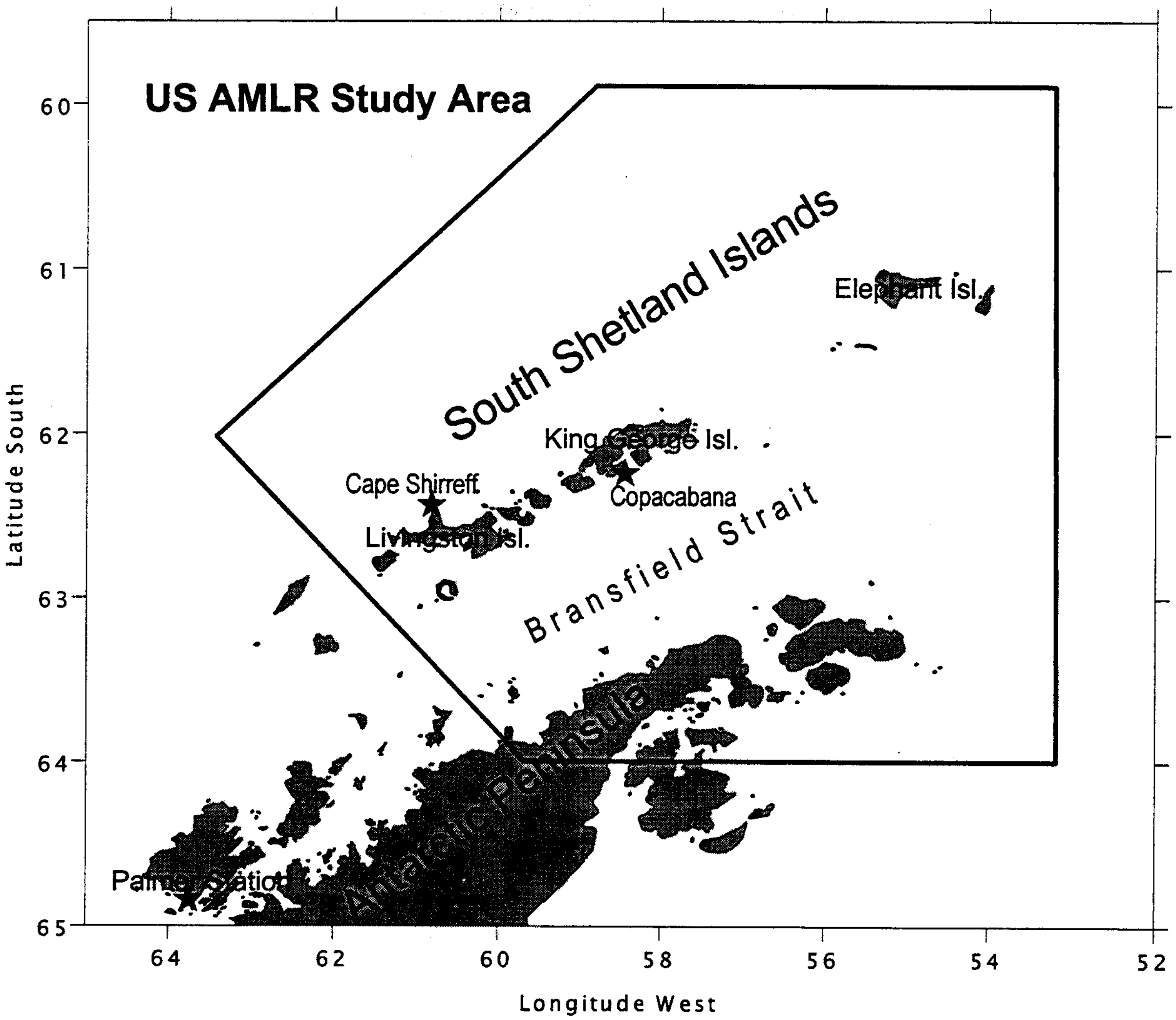


Figure 1. Locations of the U.S. AMLR field research program: AMLR study area, Cape Shirreff, Livingston Island and Copacabana, King George Island.

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 sturdy 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 underway observations of seabirds and marine mammals during Leg I.
5. Conduct a high-resolution survey of krill in the vicinity of Cape Shirreff using a specially equipped Zodiac for the inshore areas and the *Yuzhmorgeologiya* for the offshore areas.
6. Deploy three instrumented buoys with acoustical sensors and buoy-to-shore telemetry in the vicinity of Cape Shirreff at the beginning of Leg I to be recovered at the end of Leg II.
7. Conduct a survey at Seal Island of tagged Antarctic fur seal females to provide aging data for population demography.
8. 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.
9. Deploy WOCE drifter buoys during Leg I.
10. 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 500 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 (PTT's).
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 (TDR's) on chinstrap and gentoo penguins during chick rearing for diving studies.
9. Collect data on foraging locations (using PTT's) and foraging depths (using TDR's) of chinstrap penguins while concurrently collecting acoustically derived krill biomass and location data during the Nearshore survey.
10. Deploy PTT's on chinstrap penguins following adult molt to determine migration routes and winter foraging areas in the Scotia Sea region.
11. Monitor female Antarctic fur seal attendance behavior.

12. Collaborate with Chilean researchers in collecting Antarctic fur seal pup mass for 100 pups every two weeks through the season.
13. Collect 10 Antarctic fur seal scat samples every week for diet studies.
14. Collect a milk sample at each female Antarctic fur seal capture for fatty acid signature analysis and diet studies.
15. Record at-sea foraging locations for female Antarctic fur seals using Platform Terminal Transmitters (PTT).
16. Deploy time-depth recorders (TDR) on female Antarctic fur seals for diving studies.
17. Tag 500 Antarctic fur seal pups for future demographic studies.
18. Collect teeth from selected Antarctic fur seals for age determination and other demographic studies.
19. Deploy a weather station for continuous summer recording of wind speed, wind direction, ambient temperature, humidity, and barometric pressure.

DESCRIPTION OF OPERATIONS

Shipboard Research:

For the ninth consecutive year, the cruise was conducted aboard the chartered research vessel R/V *Yuzhmorgeologiya*. "CS" stands for Cape Shirreff, "Copa" stands for Copacabana and SI stands for Seal Island.

Leg I:	Depart Punta Arenas	10-12 January 2004
	Resupply & transfer personnel to CS, deploy buoys	13 January
	Calibrate in Admiralty Bay, King George Island	14 January
	Large-area survey (Survey A)	15-28 January
	Transfer personnel from Copa; continue with survey	29-31 January
	Transfer personnel from Cape Shirreff, transit to SI	01 February
	Conduct Seal Island operations	02-04 February
	Conduct nearshore survey	05-11 February
	Transfer personnel from CS to Copa	11-12 February
	Transit to Punta Arenas	12-14 February
Leg II:	Depart Punta Arenas	17-19 February
	Transfer supplies and personnel to Cape Shirreff	20 February
	Large-area survey (Survey D)	21 February - 8 March
	Close Cape Shirreff, recover buoys	9 March
	Close Copacabana and Calibrate in Admiralty Bay	10 March
	Conduct skua survey in King George Bay	11 March
	Transit to Punta Arenas	12-14 March

Leg I

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 personnel and supplies to the field camp. The ship then transited to Admiralty Bay to deliver additional personnel and supplies to the Copacabana field camp.

2. The acoustic transducers were calibrated in Admiralty Bay, King George Island. Beam patterns for the hull-mounted 38, 120 and 200kHz transducers 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 observations. Survey A consisting of 91 (out of 108 planned) Conductivity-Temperature-Depth (CTD) and net sampling stations, separated by acoustic transects, was conducted in the vicinity of the South Shetland Islands (Figure 2). Operations at each station included: (a) vertical profiles of temperature, salinity, oxygen, fluorescence, light transmission and collection of water samples at discreet depths; and (b) deployment of an IKMT (Isaacs-Kidd Midwater Trawl) to obtain samples of zooplankton and micronekton. Acoustic transects were conducted between stations at 10 knots, using hull-mounted 38kHz, 120kHz, and 200kHz down-looking transducers. An extensive field of icebergs was encountered in the southern and eastern portion of the survey area and precluded the conduct of survey operations in these areas.

4. Seabird and marine mammal observations were collected continuously throughout Leg I.

5. A high-resolution survey for krill and oceanographic conditions was conducted in the vicinity of Cape Shirreff (Figure 3). A specially-equipped Zodiac, R/V *Ernest*, conducted a series of acoustic transects, CTD deployments and small net tows (collected from 20 nearshore stations) for the nearshore areas near Cape Shirreff while concurrently the *Yuzhmorgeologiya* colleted the same data for the offshore areas.

6. Deploy three buoys, instrumented with acoustical sensors and buoy-to-shore telemetry in the vicinity of Cape Shirreff.

7. Conduct a survey at Seal Island of tagged Antarctic fur seal females to provide aging data for population demography.

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

9. A total of 10 WOCE drifter buoys were deployed at various positions north of Livingston and King George Islands (see Chapter 2 for map of release points and tracks).

10. 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.

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 to the field camp.

2. Survey D consisting of 98 (out of 108 planned) CTD and net sampling stations, separated by acoustic transects, was conducted in the vicinity of the South Shetland Islands (Figure 2). The field of icebergs was less extensive and allowed the conduct of most of the survey except for some stations in the Joinville Island Area and northwestern Weddell Sea. However, the positions of several stations at the southern ends of the transects had to be adjusted by as much as 5km because of the presence of icebergs.

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.

Land-based Research:

1. A four-person field team (M. Goebel, S. Freeman, M. Antolos, and A. Miller) arrived at Cape Shirreff, Livingston Island, on 11 November 2003 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 D. Krause), along with supplies and equipment, arrived at Cape Shirreff via the R/V *Yuzhmorgeologiya* 13 January 2004.

3. The annual censuses of active chinstrap and gentoo penguin nests were conducted on 29 and 30 November 2003. Gentoo penguin nests were censused on 4 December 2003. Reproductive success was studied by following a sample of 100 chinstrap penguin pairs and 49 gentoo penguin pairs from egg laying to crèche formation.

4. Radio transmitters were attached to 19 chinstrap penguins in the first week of January 2004 and remained on until their chicks fledged in late February 2004. These instruments were used to determine foraging trip duration during the chick-rearing phase. All data were received and stored by a remote receiver and logger set up at the bird observation blind.

5. Five satellite-linked transmitters (PTTs) were deployed on adult chinstrap penguins and four on adult gentoo penguins during the time each species was feeding chicks in early January. The PTTs were removed and placed on ten new birds in mid-January to coincide with the time when the annual AMLR 2003/04 marine survey was adjacent to Cape Shirreff during Leg I.

6. Diet studies of chinstrap and gentoo penguins during the chick-rearing phase were initiated on 9 January 2004 and continued through 8 February 2004. Chinstrap and gentoo adult penguins were captured upon returning from foraging trips, and their stomach contents were removed by lavaging.

7. Counts of all chinstrap and gentoo penguin chicks were conducted on 2-3 February and 4 February 2004, respectively. Fledging weights of 253 chinstrap penguin chicks were collected between 21 and 27 February 2004. Two hundred gentoo penguin chicks were also weighed on 18 February 2004.

8. Five hundred chinstrap penguin chicks and 200 gentoo penguin chicks were banded for future demographic studies.

9. Reproductive studies of brown skuas and kelp gulls were conducted throughout the season at all nesting sites around the Cape.

10. Time-depth recorders (TDRs) were deployed on four chinstrap and four gentoo penguins for 10-12 days in mid-January to coincide with the marine sampling offshore at Cape Shirreff at the end of Leg I. The TDRs were retrieved, downloaded and redeployed on four birds of each species in late January.

11. Antarctic fur seal pups and female fur seals were counted at four main breeding beaches every other day from early November 2003 through late January 2004.

12. Attendance behavior of 28 lactating female Antarctic fur seals was measured using radio transmitters. Females and their pups were captured, weighed, and measured from early December 2003 to mid-December 2003.

13. U.S. researchers assisted Chilean scientists in collecting data on Antarctic fur seal pup growth. Measurements of mass for a random sample of 100 pups were begun 30 days after the median date of pupping on early January 2004 and continued every two weeks until late February 2004.

14. 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.

15. Twenty-five Antarctic fur seals were instrumented with time-depth recorders (TDR's) for diving behavior studies.

16. Seventeen Antarctic fur seal females were instrumented with ARGOS satellite-linked transmitters for studies of at-sea foraging locations from late December 2003 to mid-February 2004.

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

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

19. A single post-canine tooth was extracted from 48 tagged female fur seals for aging and demography studies. Studies of the effects of tooth extraction on attendance and foraging behavior were initiated.

20. One team member (M. Goebel) left Cape Shirreff via the R/V *Yuzhmorgeologiya* on 11 February 2004.

21. The Cape Shirreff field camp was closed for the season on 9 March 2004; all U.S. personnel (R. Holt, D. Krause, M. Antolos, A. Miller and S. Freeman), garbage, and equipment were retrieved by the R/V *Yuzhmorgeologiya*.

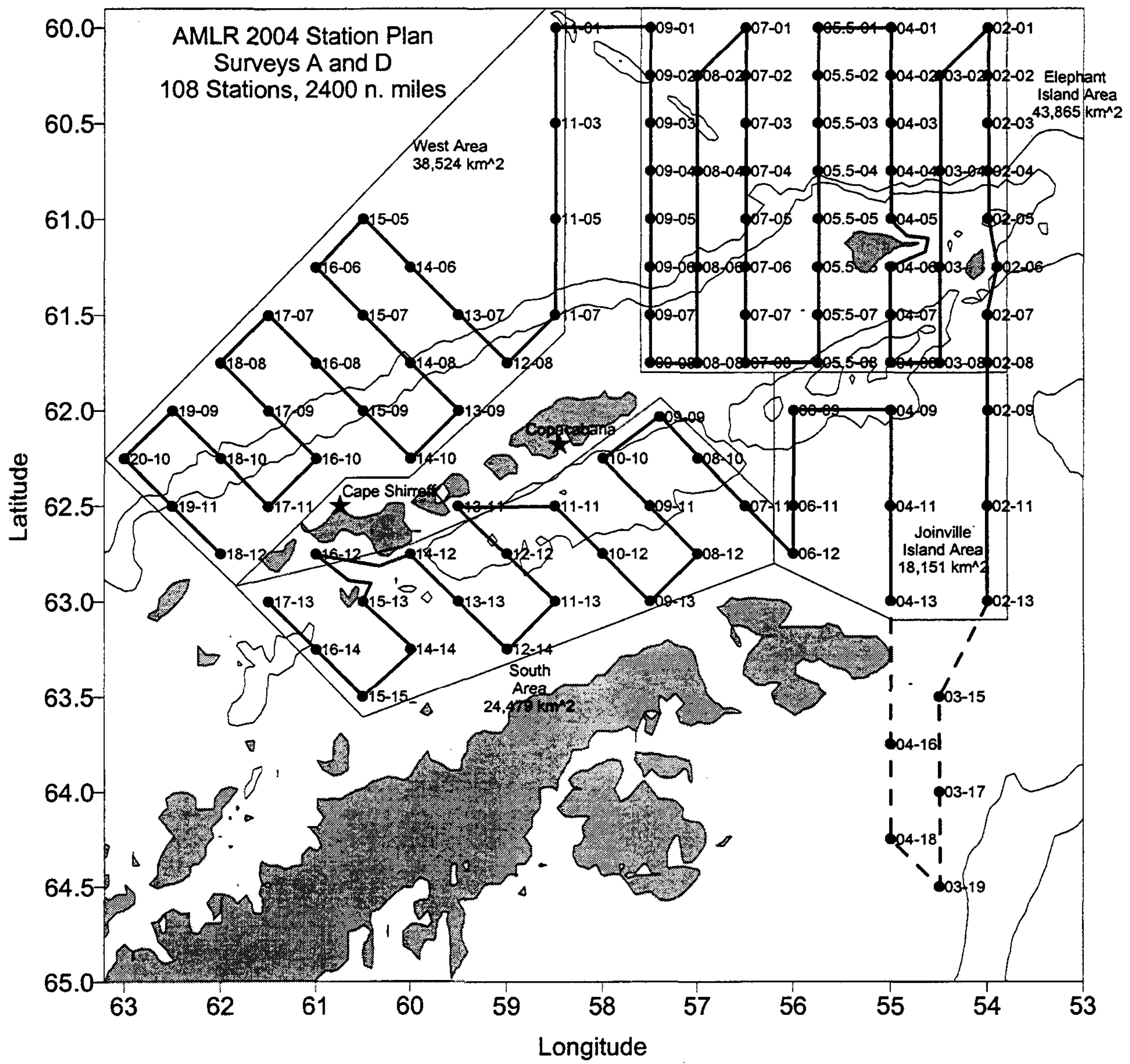


Figure 2. The planned survey for AMLR 2003/04 (Survey A & D) in the vicinity of the South Shetland Islands; field camp locations indicated by★. The survey contained four strata: the stratum containing stations in the western portion of the survey area north of Livingston and King George Islands was designated the West Area, the stratum located south of King George Island was designated the South Area, the stratum containing stations in the northern portion of the South Shetland Islands was designated the Elephant Island Area, and the stratum south of Elephant Island was designated the Joinville Island Area. Depth contours are 500m and 2000m. Black dots indicate station locations; heavy lines indicate transects between stations; and thin lines outline the stratum.

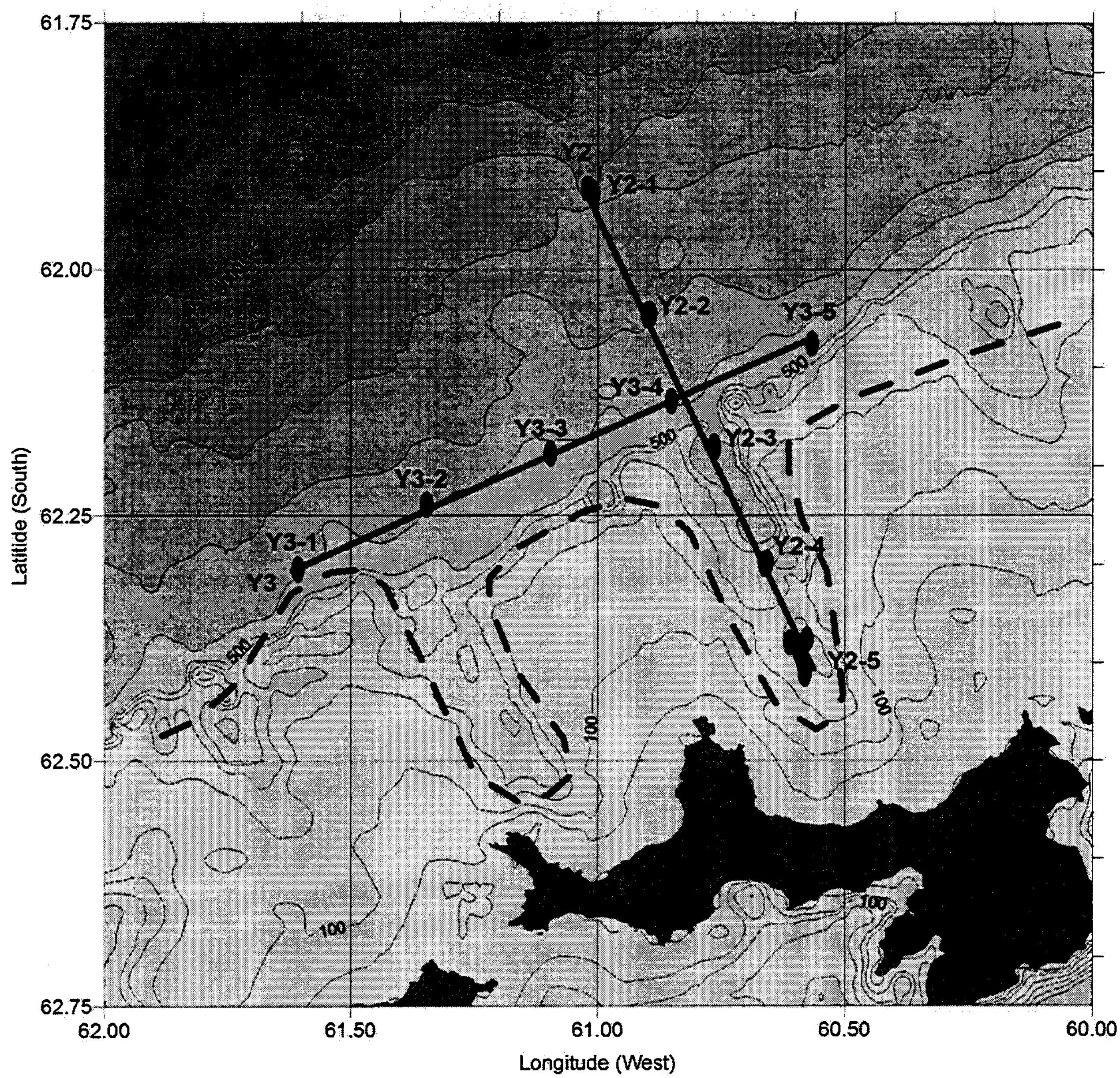


Figure 3. Cape Shirreff nearshore survey plan. Transects E1 through E8 (solid lines) to be conducted by the R/V *Ernest*. Transects Y1 through Y13 (dashed lines) to be conducted by the R/V *Yuzhmorgeologiya*. Stars indicate positions of CTD/net stations to be conducted by the R/V *Yuzhmorgeologiya*.

SCIENTIFIC PERSONNEL

Cruise Leader:
- Roger P. Hewitt, Southwest Fisheries Science Center (Leg I)
- Adam D. Jenkins, Southwest Fisheries Science Center (Leg II)

Physical Oceanography:
- Derek Needham, Sea Technology Services (Leg I)
- Marcel van den Berg, Sea Technology Services (Legs I & II)
- Mike Soule, Sea Technology Services (Leg II)

Phytoplankton:
- Christopher D. Hewes, Scripps Institution of Oceanography (Leg I)
- D. Ben Allison, Scripps Institution of Oceanography (Legs I & II)
- Jennifer Ryan, Scripps Institution of Oceanography (Legs I & II)
- Tasha Reddy, Stanford University (Leg II)

Bioacoustic Survey:
- Anthony M. Cossio, Southwest Fisheries Science Center (Legs I & II)
- Roger P. Hewitt, Southwest Fisheries Science Center (Leg I)

Krill and Zooplankton Sampling:
- Valerie Loeb, Moss Landing Marine Laboratories (Legs I & II)
- Kayt Chambers, University of Northern British Columbia (Legs I & II)
- Ethan Daniels (Legs I & II)
- Michael Force (Legs I & II)
- Nancy Gong, University of California at Santa Cruz (Leg II)
- Adam D. Jenkins, Southwest Fisheries Science Center (Leg I)
- Jonathan Reum, University of California at Santa Cruz (Legs I)
- Rob Rowley, Moss Landing Marine Laboratories (Legs I & II)
- Steve Sessions (Legs I & II)
- Joe Warren, Southampton College of Long Island University (Leg I)

Fur Seal Energetics Studies:
- Jessica D. Lipsky, Southwest Fisheries Science Center (Leg I)
- Lindsay Smith (Leg II)

Seabird and Marine Mammal Observation Studies:
- Jarrod A. Santora, College of Staten Island (Leg I)
- Andrew Bernick, College of Staten Island (Leg I)

Nearshore Survey:
- Joe Warren, Southampton College of Long Island University (Leg I)
- Adam D. Jenkins, Southwest Fisheries Science Center (Leg I)

Seal Island Survey:

Michael E. Goebel, Southwest Fisheries Science Center (Leg I)
Anthony M. Cossio, Southwest Fisheries Science Center (Leg I)
Douglas Krause, Southwest Fisheries Science Center (Leg I)
Jessica D. Lipsky, Southwest Fisheries Science Center (Leg I)

Cape Shirreff Personnel:

Michael E. Goebel, Camp Leader, Southwest Fisheries Science Center (11/11/03 to 2/11/04)
Scott Freeman (11/11/03 to 3/9/04)
Michelle Antolos (11/11/03 to 3/9/04)
Aileen Miller (11/11/03 to 3/9/04)
Douglas Krause, Southwest Fisheries Science Center (1/13/04 to 3/9/04)
Wayne Trivelpiece, Southwest Fisheries Science Center (1/13/04 to 1/28/04)
Rennie S. Holt, Southwest Fisheries Science Center (2/20/04 to 3/9/04)

DETAILED REPORTS

1. Physical Oceanography and Underway Environmental Observations; submitted by Derek Needham (Leg I), Marcel van den Berg (Leg I & II) and Mike Soule (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 the environmental conditions encountered.

1.2 Accomplishments:

1.2.1 CTD/Carousel Stations: 89 of the 108 planned CTD/carousel casts were made on Leg I (Survey A, Stations A02-01 to A20-10) (See Figure 2 in the Introduction for station locations). No casts were cancelled due to bad weather, but 14 stations were cancelled due to icebergs, in the eastern and southern areas of the survey area. Extra stations (A03-09; A05-09 and A06-10) were inserted during the survey, after the southern stations of the Joinville Island Area were abandoned, bringing the total casts during the survey to 92.

After the completion of the planned survey area of Leg I, 20 stations were completed near Cape Shirreff to accompany the data collected during the Nearshore Acoustic Survey (see Nearshore Survey, Chapter 5, of this report).

A total of 99 out of the possible 108 casts were completed during Leg II, 94 being stations on the planned survey grid and five stations (D03-09; D04-10; D05-09; D05-10 and D06-10) being additional stations inserted during the survey in the northern Joinville Island Area.

Water samples were collected at 11 discrete depths on all casts and used for salinity verification and phytoplankton analysis. These were drawn from the Niskin bottles by the Russian scientific support team. Salinity calibration samples from all stations were analysed on board, using a Guildline Portasal salinometer, and close agreement between CTD-measured salinity and the Portasal values was obtained with an average error of 0.0089%. The final CTD/Portasal correlation produced an r^2=0.9965 (n=934) during the survey.

Underway comparison of the Seabird TSG salinity data with 7m CTD salinity data showed agreement (average 0.042% difference), while the sea temperature showed the TSG to be on average 0.60°C (n=180) higher than the CTD 7m data. This can be attributed to the heating effects of positioning the temperature sensor downstream of the seawater pump. Comparisons of dissolved oxygen levels in the carousel water samples and the levels measured during the casts (via the O_2 sensor) were not attempted during the survey.

The Seabird CTD underwater unit (S/N 09P13966-0454) was replaced during Leg II with the Seabird CTD underwater unit (S/N 09P13966-0455) after the initial unit malfunctioned during station D09-05. The sensors (i.e. conductivity, temperature and oxygen) used on the initial underwater unit were used with the new underwater unit. The station was not repeated as the malfunctioned occurred during the up-cast, although some water samples at the surface depths were not collected. During Leg II an additional transmissometer was installed for a comparative study with the existing transmissometer.

1.2.2 Underway Environmental Observations: Environmental and vessel positional data was collected for a total of 64 days (38 days and 26 days during Legs I and II respectively) via the Scientific Computer System (SCS) software package. The SCS software was upgraded from SCS Version 3.2 to 3.3a and was running on a new Windows XP based Pentium IV Dell PC with an Edgeport-8 USB serial port expander. A Coastal Environmental Company Weatherpak system was installed on the port side of the forward A-frame in front of the bridge and was used as the primary meteorological 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. At the start of Leg II a spare unit was installed after the pressure sensor on the initial unit malfunctioned.

1.3 Methods:

1.3.1 CTD/Carousel: Water profiles were collected with a Sea-Bird SBE-9/11+ CTD/carousel water sampler equipped with 11 Niskin sampling bottles. The 11th bottle allowed for an additional 15m sample to be collected. Profiles were limited to a depth of 750 meters or 5 meters above the sea bottom when shallower than 750m. A Data Sonics altimeter was used to stop the CTD above the bottom on the shallow casts. Standard sampling depths were 750m, 200m, 100m, 75m, 50m, 40m, 30m, 20m, 15m, 10m and 5m. A Dissolved Oxygen (DO) sensor (Seabird SBE 13Y), a Wetlabs fluorometer, a Seatech transmissometer and a Biospherical 2pi PAR sensor provided additional water column data during Legs I and II. Scan rates were set at 24 scans /second during both down and up casts. Sample bottles were only triggered during up casts. Plots of the down traces were generated and stored with the CTD cast log sheets and a copy given to the phytoplankton person, together with CTD mark files (reflecting data from the cast at bottle triggering depths) and processed up and down traces in Ocean Data View (ODV) format. Data from casts were averaged over 1m bins and saved separately as up and down traces during post processing. The data were logged and bottles triggered using Seabird Seasave Win32 Vs 5.3a and the data processed using SBE Data Processing Vs 5.3a. Downcast data was re-formatted using a SAS script and then imported into ODV for further analysis.

1.3.2 Underway Data: Weather data inputs were provided by the Coastal Environmental Systems Company 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 internally derived functions of the SCS logging software. Measurements of sea surface temperature and salinity were received by the SCS, in serial format, from the SeaBird SBE21 thermosalinograph (TSG) and integrated into the logged data. Ships position and heading were provided in NMEA format via a Furuno GPS Navigator and Guiys Gyro respectively. Serial data lines were interfaced to the new Pentium 4 (Windows XP Professional based) logging PC via an Edgeport 8 serial RS232 to USB interface.

1.4 Results and Tentative Conclusions:

1.4.1 Oceanography: The position of the polar frontal zone, identified by sea temperature and salinity change, was located from the logged SCS data during all four transits from and to Punta Arenas and the South Shetland Islands survey area. This frontal zone is normally situated between 57-58°S. During the south transit for Leg I, a well-defined front was centered around 58°S. On the northern transect the front shifted south, still clearly defined between 58° 30'S to 59°S. On the south-bound transit of Leg II the front had a similar location as the north bound transect of Leg I, but had become less defined, laying between 58°30'S and 59°30'S. On the return transit, at the end of Leg II, the zone was again well defined and was located between 58°30'S and 59°S (Figure 1.1).

As in previous years an attempt was made to group stations with similar temperature and salinity profiles into five Water Zones as defined in Table 1.1. The MATLAB program written during AMLR 2000/01 was used to confirm field classifications according to the criteria in Table 1.1, thus attempting to reduce any subjective influence on the classification of Water Zones (see AMLR 2000/01 Field Season Report for details).

The tentative Water Zone classifications according to the criteria in Table 1.1 were sometimes prone to ambiguity, particularly in the coastal regions around King George & Livingston Islands and in the south and southeast of Elephant Island. Classifications of Zone IV (Bransfield Strait) and V (Weddell Sea) waters in these areas could change if other oceanographic data such as density are considered. For the purpose of this report, in which only tentative conclusions are reported, only the criteria contained in Table 1.1 were used. This was done to ensure consistency with past cruises.

During Leg I, there was a less clearly defined distinction of the classical Zone I (ACC) type waters in the offshore stations of the western and northern areas, than found in previous years. See Figure 1.2, which was generated using the Matlab water-zoning algorithm. Many stations in this area displayed a mixing of Zone I and II (Transition) waters. This mixing was also evident in many of the shallower inshore stations, to the north of the islands, where the distinction between Zone II (Transition), III (Transition) and IV (Bransfield Strait) waters were not as distinct as in previous years. Zone II waters were also predominant in the Elephant Island Area, extending into the eastern part of the area. Zone IV waters were predominant to the south of Elephant Island, in the northern Joinville Island and in the South Areas with the inshore stations of the South Area producing stations with mixing taking place, with surface waters (0 to 50m) having lower salinity and higher temperatures values.

The Leg II Water Zone distributions conformed more closely to the classical definitions. Zone I (ACC) waters dominated the western and northern area, running parallel with the continental shelf edge. Zone IV (Bransfield Strait) waters completely filled the Straits, except for a token appearance of Zone V (Weddell Sea) water at the entrance to the Antarctic Sound. Zone IV (Bransfield Strait) waters extended to the south of Elephant Island, forming a coastwise-parallel buffer between the Weddell and the Antarctic Circumpolar Current (ACC) water in the north.

Three vertical temperature transects were chosen for plotting using ODV software – the same transects that were plotted for the 2001/02 and 2002/03 reports were chosen for comparisons (Figure 1.3). These transects were W05 in the West Area and EI03 and EI07 in the Elephant Island Area of the survey. During Leg I stations 02-06 and 02-08 were not completed due to extensive icebergs fields in the area.

A "first look" field attempt was made to determine direction and intensity of water flow inferred by water density, derived from the CTD data. This was done to compare zooplankton distributions, generated by Valerie Loeb (see Chapter 4 of this Report), with hydrographic patterns during the surveys. ODV was used to plot Dynamic Heights at the surface relative to 300m and 500m depths (Figure 1.4). With reference to the isolines on these figures, going from high to low values and the influence of Coriolis force (southern hemisphere), results in flow to the left. Arrows drawn on these isolines show a flow of water from the Weddell Sea, moving northward, then eastward in the Western Bransfield Strait and water flowing eastward in the Drake Passage offshore of the island shelf area. Especially during Leg I, the mixed Weddell Sea-influenced water extended north and then west over the northern shelves of the South Shetland Islands and was then deflected eastward under the influence of the flow within the Drake Passage. There are indications of clockwise gyres within the Southwest Bransfield Strait, between King George and Elephant Islands and southeast of Elephant Island. The close spacing of the density isolines indicate a more intense flow, over the southern shelves of the South Shetland Islands.

During Leg II flow within the Bransfield Strait was comparatively constrained. It was still most intense south of the Islands but was deflected south and westward between King George Islands. There was also an intensified flow in the offshore region, especially around the Shackleton Fracture Zone.

Comparing the Dynamic Heights plots in Figure 1.4 to the Water Zone assessments, demonstrates that there was little oceanic influence (no ACC-Southern Boundary water evident) but strong Weddell Sea water influence, westward flow, and mixing in the Leg I survey versus intrusion of ACC-Southern Boundary water and enhanced eastward flow offshore and reduced offshore influence of Weddell Sea water influence during Leg II. There are obvious gyres and frontal zones during both surveys, but the locations and intensities differ as indicated by the deflection and proximity of the isolines.

1.4.2 Underway Data: Environmental data was recorded for the duration of both Legs I and II and for the transits between Punta Arenas and the survey area (except for TSG data which is 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 sometimes prone to the effects of aeration (Figures 1.5 and 1.6 for Legs I and II respectively).

Comparisons between the weather conditions experienced during Legs I and II show significant differences, primarily between wind speed and direction (Figure 1.7). During Leg I the wind direction was predominately west to northwest, with wind speeds averaging around 20 knots. This wind regime shifted from westerly to predominantly easterly winds towards the latter part of Leg II, with wind speeds averaging around 30 knots.

Weather during Leg II, compared with Leg I, was more often partly cloudy or overcast. A number of days of poor visibility and fog were experienced and a few light snowfalls were recorded during Leg II, as can be seen when comparing the results from the PAR sensor, which indicate reduced levels of photosynthetic radiation, between Leg I and Leg II. There was a noticeable increase in the number of icebergs seen in the survey in comparison with the AMLR 2002/03 survey, as the altered survey plan will attest to.

1.5 Disposition of Data: Data are available from David A Demer, Southwest Fisheries Science Centre, 8604 La Jolla Shores Drive, La Jolla, CA, 92037; phone/fax (858) 546-5603/(858) 546-5608;email: David.Demer@noaa.gov.

1.6 Acknowledgements: The co-operation and assistance of the Russian technical support staff was once again outstanding. All requests for assistance were dealt with efficiently and in a thoroughly professional manner.

1.7 Problems and Suggestions The CTD system performed well, with the usual maintenance, attention having to be given to the underwater connectors. Very little data or time was lost during the 211 casts, except for the CTD underwater unit malfunctioning on station 02-09 (Leg II) during the up-cast, causing the surface layer (0-40m) not being sampled. The underwater unit was replaced with the spare unit, which preformed well for the rest of the survey. The faulty unit was opened to ensure that flooding had not occurred. The Beckman 13-02-B dissolved oxygen sensors were upgraded by Seabird, to a SBE 13Y dissolved oxygen sensor. This functioned well during all CTD casts and seems to not suffer from the hysterises problems experienced with the Beckman 13-02-B sensors during previous AMLR cruises. 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.

The SBE Carousel and General Oceanics Niskin bottles worked relatively trouble free, with only a few lanyard snags causing lost samples. Some of the older bottles had a tendency to leak, due to the o-rings becoming dislodged from its seat, which is caused by the metal springs "gorging" the o-ring seats. During the last two years some Niskin bottles have been broken beyond repair, and a complete new set of 10 liter bottles should be purchased for the 2004/05 AMLR season.

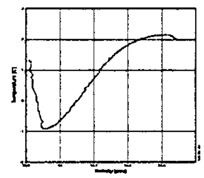
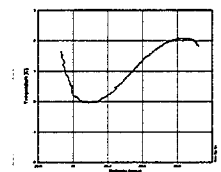
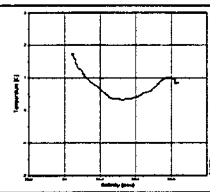
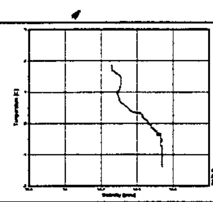
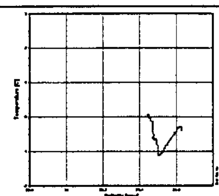
During the transit to the Shetland Islands at the beginning of Leg II, the Coastal Environmental Company Weatherpak system developed problems, with the barometric pressure sensor reading too high, when compared to readings obtained from the bridge.
The complete system was replaced with the back-up system, which functioned well for the remainder of the survey.

The TSG pump and debubbler system had to be periodically stopped and cleaned due to clogging by krill, seaweed and other biologicals.

1.8 References:

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

Table 1.1: Water Zone definitions applied for Legs I and II during AMLR 2003/04.

	T/S Relationship			
	Left	**Middle**	**Right**	**Typical TS Curve (from 2002)**
Water Zone I (ACW)	**Pronounced V shape with V at ≤0°C**			
Warm, low salinity water, with a strong subsurface temperature minimum, Winter Water, approx. -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 34.0 ppt	1 to 2°C at 34.4 to 34.7ppt (generally >34.6ppt)	
Water Zone II (Transition)	**Broader U-shape**			
Water with a temperature minimum near 0°C, isopycnal mixing below the temperature minimum and CDW evident at some locations.	1.5 to >2°C at 33.7 to 34.2ppt	-0.5 to 1°C at 34.0 to 34.5ppt (generally >0°C)	0.8 to 2°C at 34.6 to 34.7ppt	
Water Zone III (Transition)	**Backwards broad J-shape**			
Water with little evidence of a temperature minimum, mixing with Type 2 transition water, no CDW and temperature at depth generally >0°C	1 to >2°C at 33.7 to 34.0ppt	-0.5 to 0.5°C at 34.3 to 34.4ppt (note narrow salinity range)	≤1°C at 34.7ppt	
Water Zone IV (Bransfield Strait)	**Elongated S-shape**			
Water with deep temperature near -1°C, salinity 34.5ppt, cooler surface temperatures.	1.5 to >2°C at 33.7 to 34.2ppt	-0.5 to 0.5 °C at 34.3 to 34.45ppt (T/S curve may terminate here)	<0°C at 34.5ppt (salinity < 34.6ppt)	
Water Zone V (Weddell Sea)	**Small fish-hook shape**			
Water with little vertical structure and cold surface temperatures near or < 0°C.	1°C (+/- some) at 34.1 to 34.4ppt	-0.5 to 0.5°C at 34.5ppt	<0°C at 34.6ppt	

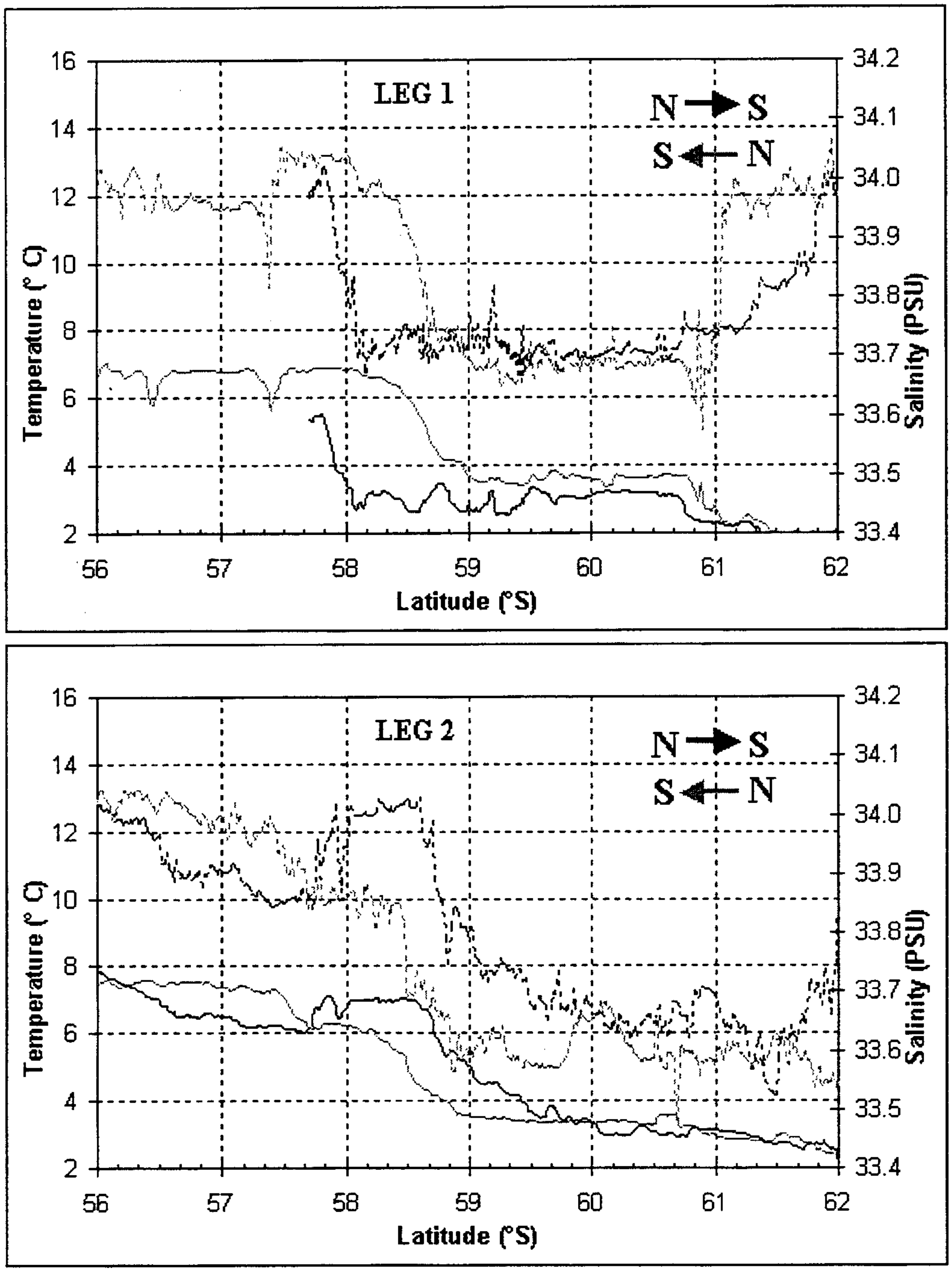


Figure 1.1. The position of the polar fronts as determined for AMLR 2003/04 Legs I (top) and II (bottom), from measurements of sea surface temperature (solid line) and salinity (broken line) for the south and north transits to and from the South Shetland Islands survey area.

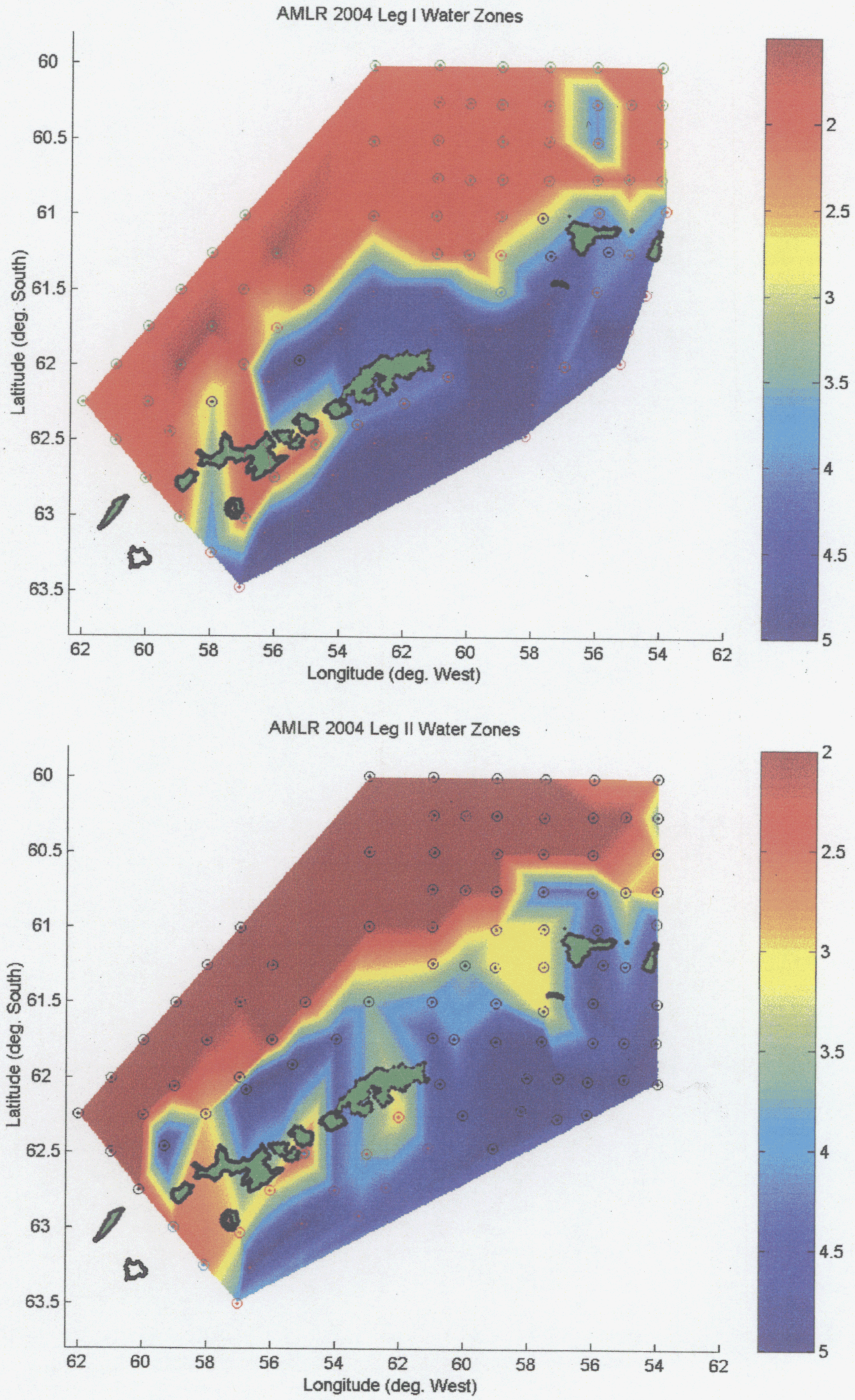


Figure 1.2. Classification of Water Zones for Leg I & II (top and bottom panels respectively) for AMLR 2003/04, as determined by the MATLAB classification routine developed during the AMLR 2000/01 survey. The colored bar on the right represents Water Zones I – V.

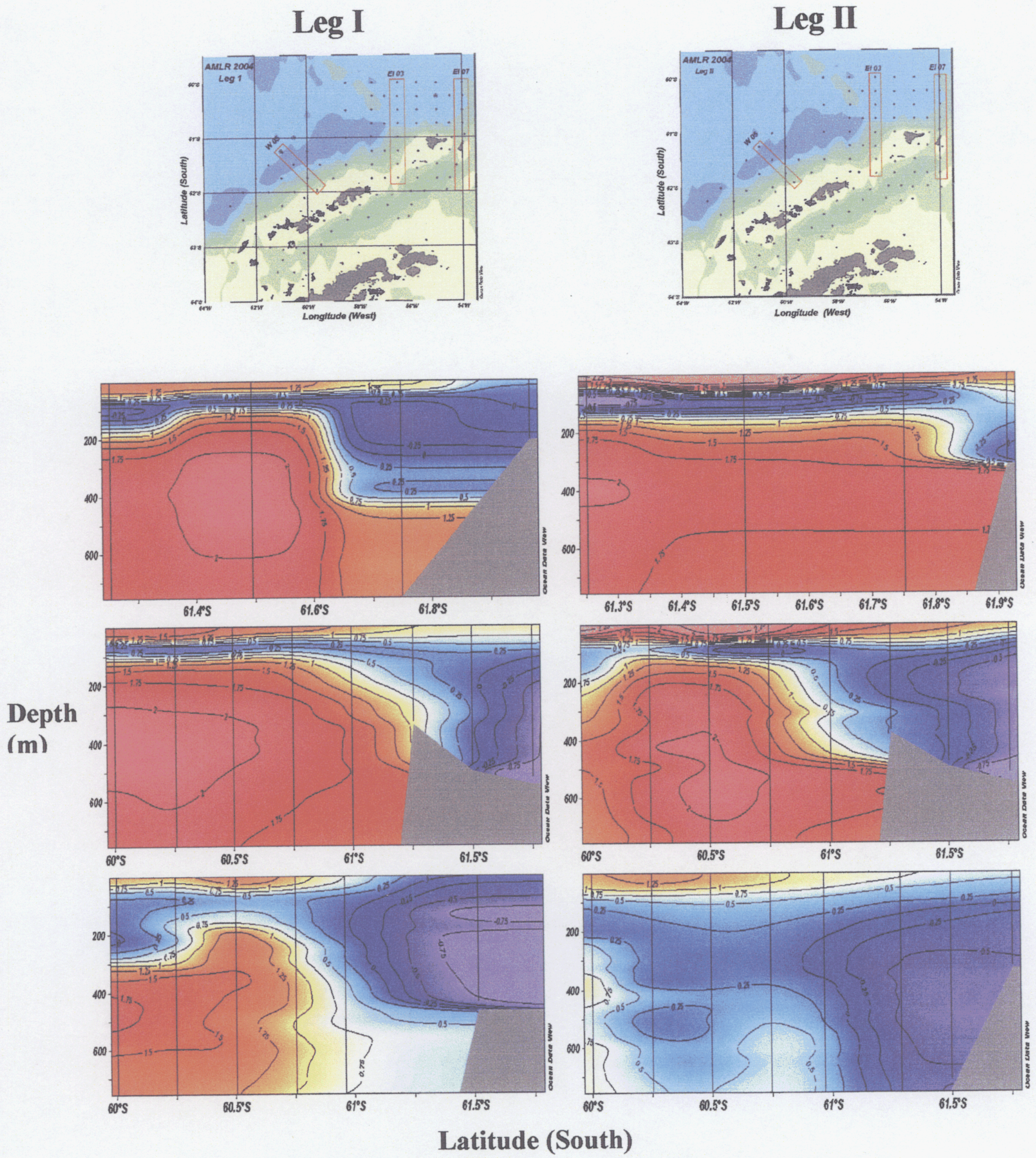
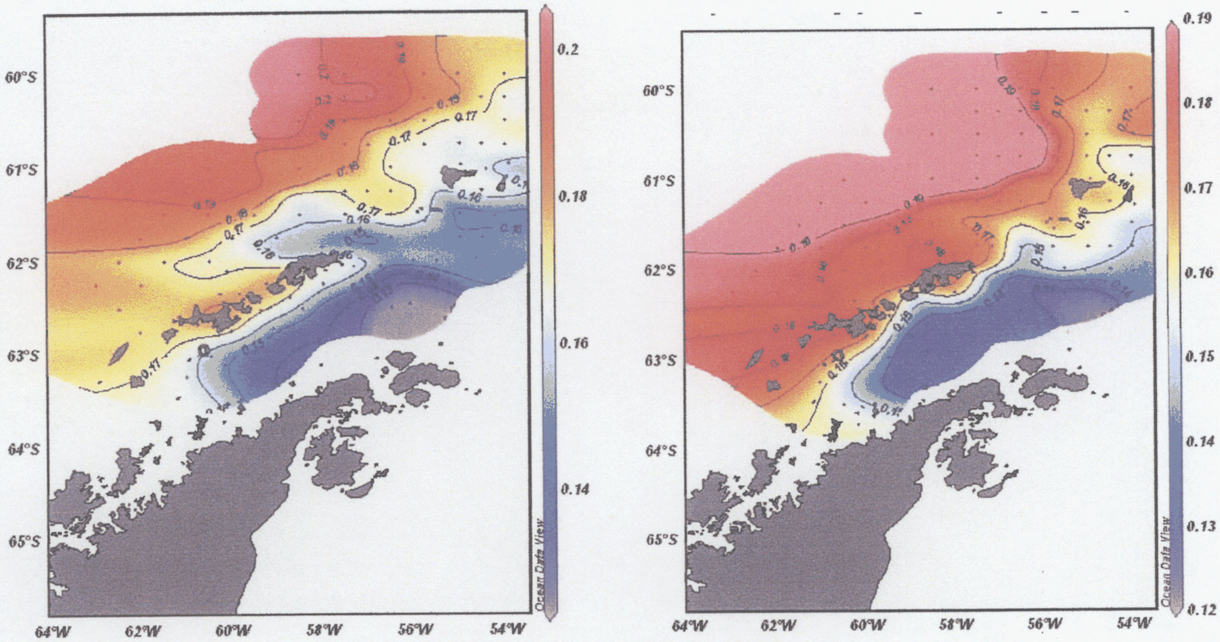
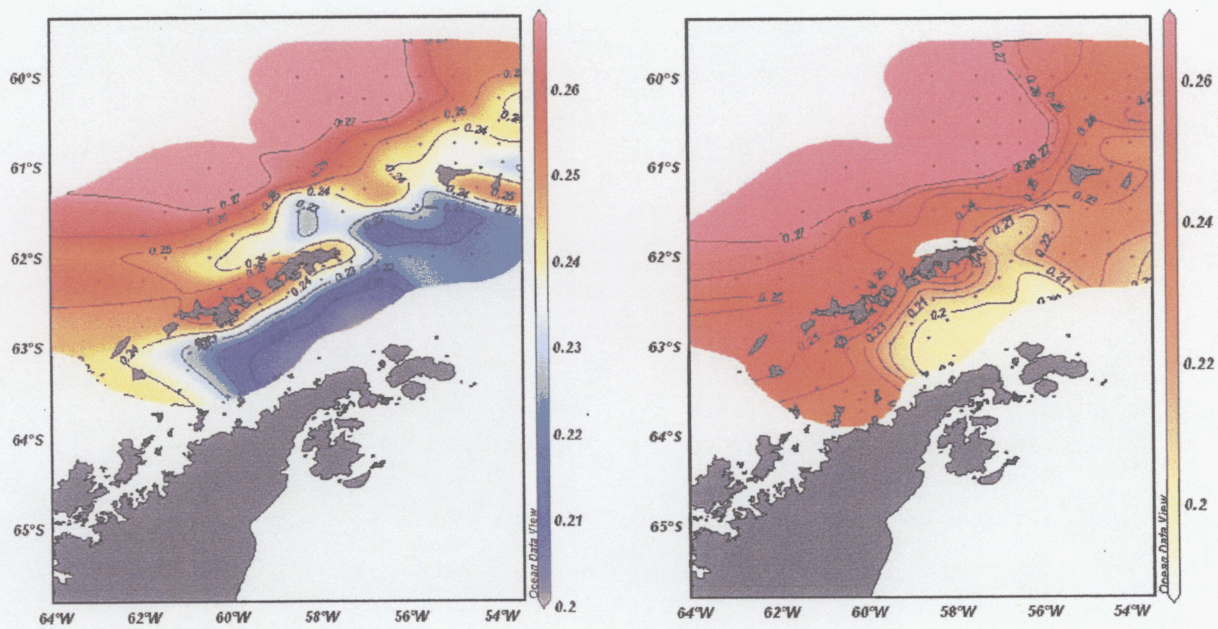


Figure 1.3. Vertical temperature profiles derived from CTD data recorded on three transects, W05 (top), EI03 (middle) and EI07 (bottom), during Legs I (left column) and II (right column) of the AMLR 2003/04 South Shetland Island survey. Stations 02-06 & 02-08 of transect EI07 was not completed during Leg I due to icebergs in the vicinity.



Dynamic Height – 300 (dyn m)



Dynamic Height – 500 (dyn m)

Figure 1.4. Dynamic heights for Legs I & II (left and right panels respectively) for AMLR 2004, as determined by ODV.

AMLR 2003/04 – Leg I

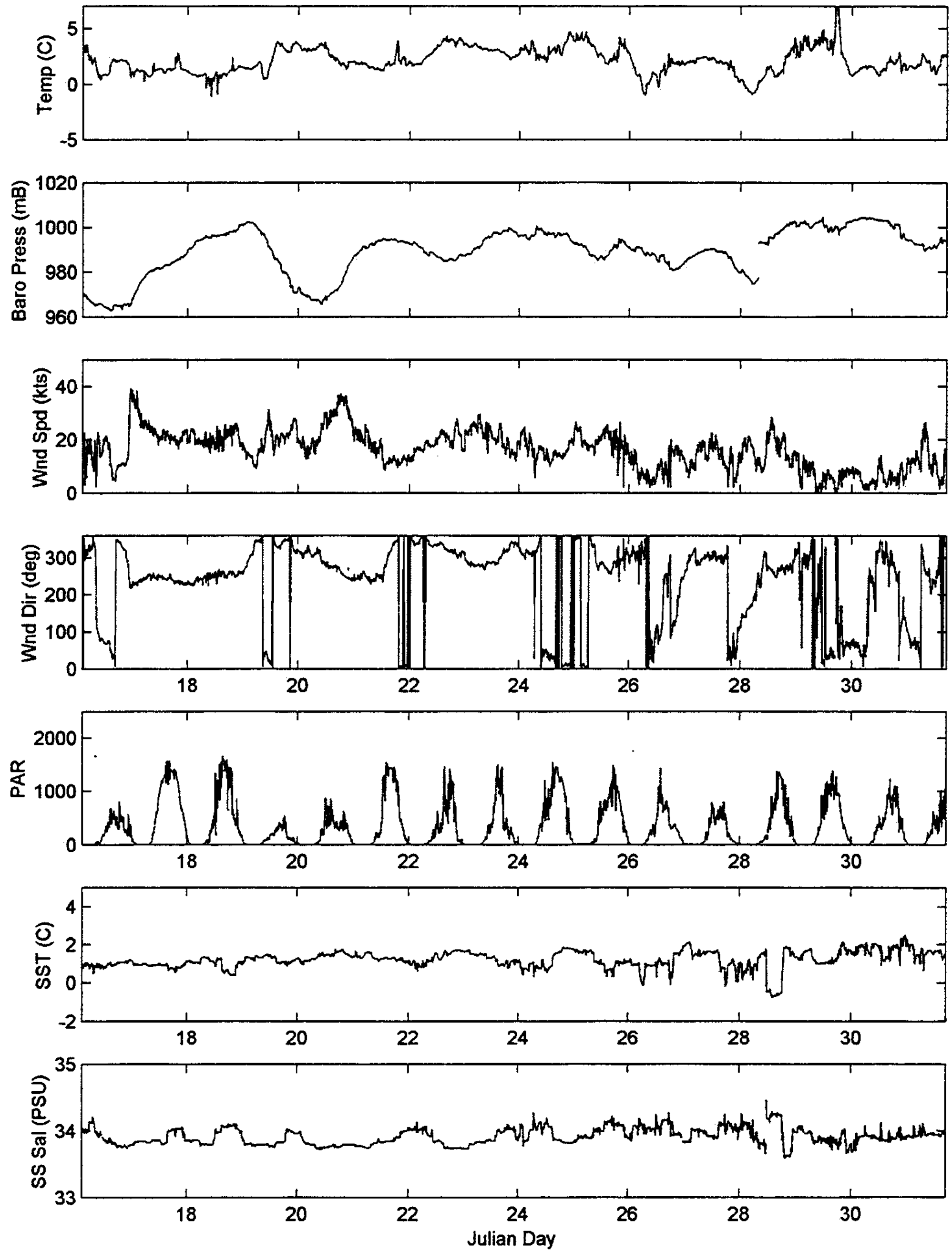


Figure 1.5. Meteorological data (5 minute averages) recorded between January 16th and January 31st during Leg I (survey only) of the AMLR 2003/04 cruise. (PAR is photo-synthetically available radiation)

AMLR 2003/04 – Leg II

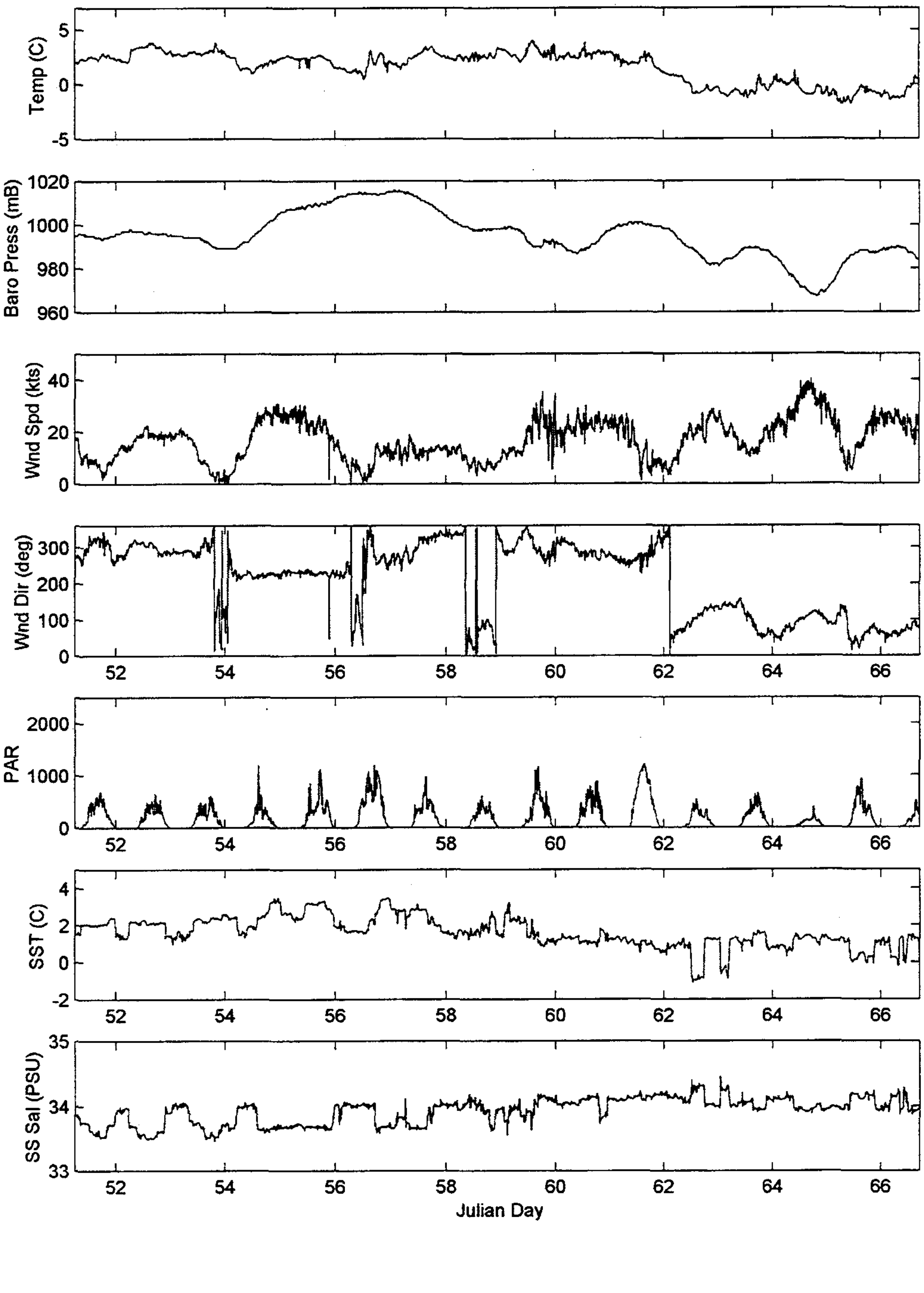


Figure 1.6. Meteorological data (5 minute averages) recorded between February 20ᵗʰ and March 6ᵗʰ during Leg II (survey only) of the AMLR 2003/04 cruise. (PAR is photo-synthetically available radiation)

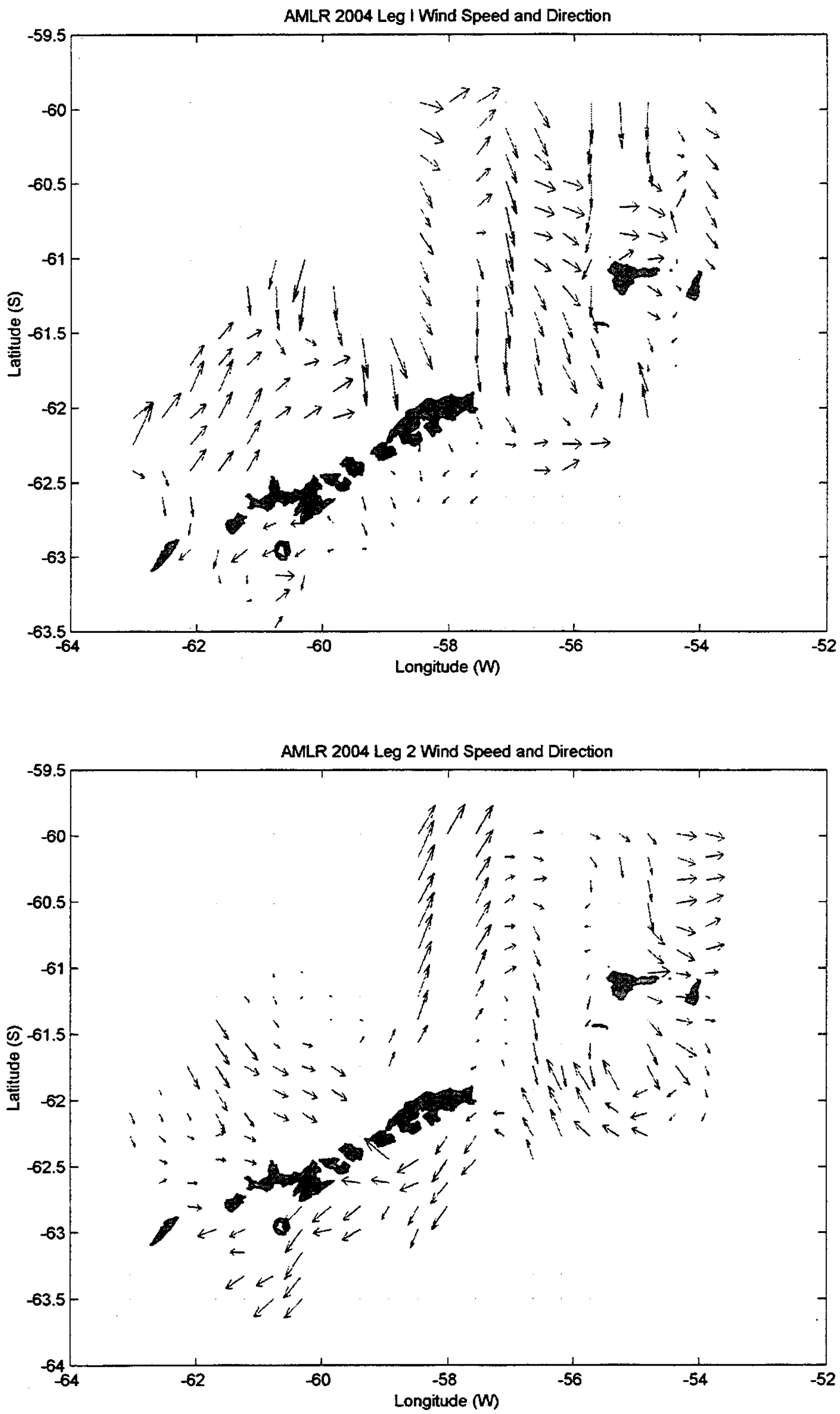


Figure 1.7. Vectors representing wind speed and direction for Legs I (top) and II (bottom) derived from data recorded by the SCS logging system during AMLR 2003/04 survey of the South Shetland Islands.

2. Phytoplankton and Related Studies; submitted by Christopher D. Hewes (Leg I, SIO), David B. Allison, Jennifer E. Ryan (Legs I & II, SIO), Tasha Reddy (Leg II, Stanford University), José Luis Iriarte (Universidad Austral de Chile), Meng Zhao (U. Mass., Boston), B. Greg Mitchell, Mati Kahru, and Osmund Holm-Hansen (SIO)

2.1 Objectives: The AMLR study area around Elephant Island is known to be very productive for krill (Macaulay *et al.*, 1984; Priddle *et al.*, 1988, Loeb *et al.*, 1997) and higher trophic levels, and has been one of the major areas for commercial harvesting of krill. The reasons why this area is so rich in krill and higher trophic levels such as birds and seals are not well understood, but it is thought to be related to the varied bottom topography (including extensive shelf regions) and to the existence of mixing zones between the various water masses encountered in this area. Much of the waters in the AMLR study area thus have high inorganic nutrients, including iron, and fairly well developed upper mixed layers. These conditions result in high phytoplankton biomass and in high, sustained rates of primary production (Everson, 1983). Support for these ideas has been provided by results from previous AMLR cruises showing the occurrence of rich phytoplankton blooms (>5.0 mg chl-*a* m^{-3}) which extend to ~50m depth in the water column (Holm-Hansen *et al.*, 1999), high rates of integrated primary production (Helbling, *et al.*, 1995; Holm-Hansen *et al.*, 1999), and that phytoplankton biomass is often enhanced in frontal zone regions (Helbling *et al.*, 1993; Hewes *et al.*, 2003b). More recently, satellite imagery has confirmed that high chlorophyll concentrations follow the shelf break regions for the northwest side of the S. Shetland and Elephant Islands (Hewes, 2001a, b; 2003a, b). The extensive continental shelf breaks and slopes in this area have also been considered to be important in regard to aggregation of krill (Macaulay *et al.*, 1984), and the larvae produced in this region are thought to be transported toward South Georgia (Hofmann, *et al.*, 1998).

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 of 2004. The specific objective of our work was to determine the distribution and biomass of phytoplankton in the upper water column (surface to 200m), with emphasis on the upper 100m. This includes knowledge of the horizontal and vertical distribution for nutrients that support phytoplankton biomass, as well as examining the optical characteristics of the water column that will expand our interpretation of remote sensing data. Also, in order to better understand mixing processes for the AMLR survey area and eastward into the Scotia Sea, last year we initiated a Lagrangian drifter buoy program to follow ocean surface current patterns. This year, we again deployed buoys to examine direction and speed of surface currents, and compare them with those released in previous years.

In addition to our traditional AMLR programs, some of our group also participated with a NSF-OPP sponsored program entitled **Collaborative Research: Plankton Community Structure and Iron Distribution in the Southern Drake Passage**. This process cruise, accomplished during February–March, 2004, on R/V *LM Gould*, allowed us to test hypotheses regarding mesoscale eddy and cross shelf transport that contribute to transport of iron to the photic zone around the Shackleton Fracture Zone. The cruise area includes the northern portion of the AMLR Elephant Island survey area and northward to about 58°S. This project focused on the biological responses to physically mediated chemical distributions. Data were collected on phytoplankton biomass, production and photosynthetic physiology (pigments, optics, variable fluorescence). Macronutrients as well as the trace metals of Fe, Mn, and Al were measured. Trace metal enrichment experiments provided an understanding of the flora within characteristic water masses in the AMLR survey area. This multidisciplinary program provided satellite data on chlorophyll distributions, primary production, winds, sea elevation and sea ice. Therefore, during Leg II of the AMLR survey, we had personnel on two ships with activities that were coordinated and optimized to provide a highly detailed description of phytoplankton distributions in the AMLR survey area. We also carried out experimental physiological studies designed to determine the controlling factors of primary production. The results of this collaborative project are yet to be finalized, and not included in this report.

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.

2.2.1 Sampling Strategy: For both Legs, a CTD carousel and independent profiling units were used to obtain samples of the water column for analyses as well as to obtain data from various profiling sensors as listed below:

(A) Water samples were obtained from 10-liter Niskin bottles (with Teflon covered springs) which were closed at 10 standard depths (5, 10, 15, 20, 30, 40, 50, 75, 100, and 200m) from every station upcast of the CTD/rosette unit.

(B) A Sea Tech transmissometer was used to determine the attenuation of collimated light (by both scattering and absorption) during CTD casts.

(C) A Sea Tech profiling fluorometer was used to measure *in situ* chlorophyll fluorescence.

(D) A Biospherical QCP200L profiling PAR (photosynthetic available radiation) sensor was used to measure the *in situ* light regime.

2.2.2 Measurements and Data Acquired:

(A) Chlorophyll-*a* concentrations: Chl-*a* concentrations in the water samples were determined by measurement of chl-*a* fluorescence after extraction in methanol. 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 (Holm-Hansen *et al.*, 1965; Holm-Hansen and Riemann, 1978). Fluorescence was measured using a Turner Designs Fluorometer model #700 that had been calibrated using chl-*a* concentrations of a prepared standard (Sigma) that had been determined by optical density measurements in a spectrophotometer. Stability of the fluorometer was verified daily by use of a solid state fluorescence standard (Turner Designs #7000-994).

(B) Measurement of beam attenuation: A Sea Tech transmissometer (660nm, 25 cm path) was fixed onto the Seabird CTD carousel for deployment at all stations. Previous studies have shown that beam attenuation (660nm) coefficients can be used to estimate total particulate organic carbon in Antarctic waters (Helbling *et al.*, 1995). This calculation assumes that there is a negligible load of inorganic sediment in the water, a condition that is apparently satisfied throughout much of the study area. During Leg II, a second transmissometer (Wetlabs, 660nm, 25cm path) was also fixed to the CTD carousel for inter-calibration purposes.

(C) Measurement of chlorophyll fluorescence: A Sea Tech profiling fluorometer was used to obtain measures of chlorophyll fluorescence intensity in the water column. These data will be used (in conjunction with the measurement of *in situ* PAR) to estimate chlorophyll concentrations in the water column, using the algorithm of Holm-Hansen *et al.* (2000) as applied specifically for the AMLR survey region.

(D) Measurement of *in situ* light: A Biospherical Instruments cosine PAR (photosynthetically available radiation, 400-700 nm) sensor (Model #QCP-200L) was used to measure light attenuation profile in the water column. This sensor is also used in conjunction with the SeaTech fluorometer to estimate chlorophyll concentrations *in situ*, and to provide a parameter to measure the variability of photophysiological responses of phytoplankton.

(E) Satellite Oceanography: MODIS (Aqua) chlorophyll images were obtained for monthly average composites from NASA archives. These data were sufficient to evaluate the time-dependence and distribution of chl-*a* within our study region.

(F) Drifter buoy deployment: In cooperation with the Global Drifter Program (P. Nieler, SIO), we deployed 10 drifter buoys during AMLR Leg I, 7 drifters during a transect from King George Island to Punta Arenas, Chile (Feburary3-4, 2004) on the *R/V LM Gould* (LMG0401), and 20 during our collaborative project (February 19-March 9, 2004) on board the *R/V LM Gould* (LMG0402). The purpose of these deployments was to determine paths and rates of ocean currents in the AMLR study area.

(G) Measurement of macronutrient concentrations in the water column: For selected stations (Figure 2.1) during Leg I, water samples were collected from water bottles fired at discrete depths into acid washed polypropylene bottles, frozen for 2-3 weeks, and measured by autoanalyzer for nitrate, nitrite, silicate, phosphate, and ammonia using an Alpkem Flow Solution IV System and following the protocol of Gordon *et al.* (2001).

(H) Phytoplankton species composition: Formalin-preserved water samples from 5m were taken at those stations where nutrient concentrations were measured (see Figure 2.1). These samples will be examined by microscope to determine the types of phytoplankton that compose the communities located in the AMLR survey area.

(I) Non-routine CTD stations: Time permitted us to obtain additional data during Leg I to describe the distribution of phytoplankton. These CTD casts included measurements of PAR, transmissometer, and fluorometer, and included chlorophyll measurements from water bottle samples.

(J) Graduate student studies: D.B. Allison and J. Ryan took samples for their graduate work (under D. Stramski and G. Mitchell, respectively, at SIO) during Legs I and II. They examined optical properties of the different Water Zones in relation to phytoplankton pigments and biomass of the AMLR survey area. Their sampling involved the following:

- An Integrated Optics Package (IOP) was deployed 1-2 times per day immediately after the CTD cast to a depth of 200m (250m on leg 2).When weather and light conditions permitted the free fall radiometer (PRR 600, 6 channels of spectra for upwelled and downwelled light and PAR) was deployed (usually during the CTD upcast) to a depth of about 100m.
- Particulate CHN and high pressure liquid chromatography (HPLC) samples were taken at 6 depths within the top 200m for every station that the IOP was deployed. CHN samples were dried and will be processed at SIO. HPLC samples were stored immediately in liquid nitrogen for processing in San Diego.

T. Reddy took samples for her graduate work (under K. Arrigo at Stanford University) during Leg II. Her study will compare nutrient and organic particulate ratios in the waters of the AMLR study area to examine for any regional differences. Ratios of nitrate:phosphate and particulate C:N, C:P, and N:P will be compared. Samples obtained were:

- POP (Particulate Organic Phosphorus) – filters dried in drying oven and transported to Stanford for analysis.
- Inorganic macronutrient concentrations – samples frozen and returned to Stanford for analysis.
- Phytoplankton size spectrum via chlorophyll size fractionation.
- Formalin-preserved water samples for microscopical examination.

2.3 Tentative Results and Conclusions:

2.3.1 Overview of phytoplankton distributions in the AMLR survey areas January-March:

West Area: Chlorophyll-*a* concentrations at 5m averaged 0.41 ± 0.41 mg Chl m^{-3} (n = 53), and values integrated to 100m were 31 ± 18 mg Chl m^{-2}. For this area, chlorophyll concentrations were not significantly different between Legs I and II. Chlorophyll concentrations were much greater along the shelf and shelf-break (<1000m) than in pelagic waters, with only a slight increase in 5m chlorophyll in the waters over the shelf and shelf-break between Legs I and II (Tables 2.1 and 2.2).

Elephant Island Area: Chlorophyll-*a* concentrations at 5m averaged 0.65 ± 0.48 mg Chl m^{-3} (n = 93), and values integrated to 100m were 45 ± 27 mg Chl m^{-2}. For this area, chlorophyll concentrations were not significantly different between Legs I and II. Chlorophyll concentrations were much greater along the shelf and shelf-break than in pelagic waters, with only a slight increase in 5m chlorophyll for shelf and shelf-break waters between Legs I and II (Tables 2.1 and 2.2).

Joinville Island and South Areas: For the Joinville Island Area, 5m chlorophylls (n = 13) averaged 0.67 ± 0.46 mg Chl m^{-3} and integrated values were 49 ± 22 mg Chl m^{-2}. For the South Area (n = 30), chlorophyll-*a* concentrations at 5 m averaged 1.03 ± 1.10 mg m^{-3}, and values integrated to 100 m were 54 ± 44 mg Chl m^{-2}. A significant bloom developed south east of King George Island in the Bransfield Strait during Leg II (see Figures 2.1 and 2.2), significantly raising the average chlorophyll concentrations from 0.75 ± 18 to 1.27 ± 1.47 mg Chl m^{-3} (integrated values from 41 ± 11 to 65 ± 58 mg Chl m^{-2} for Legs I and II, respectively).

As in previous years, chlorophyll concentrations have generally increased between Legs I and II for shelf and shelf break areas, and this year there were only slight differences (Tables 2.1 and 2.2). Although concentrations were moderately low for all areas in the AMLR survey area relative to our 15-year time series, chlorophyll concentrations did increase slightly during Leg II (Figure 2.1 and 2.2). Satellite imagery (Figure 2.2) shows this same trend, with moderate chlorophyll increases in the local waters near Cape Shirreff, and the dense bloom (5m chlorophyll was 6.4 mg m^{-3} at station D08-10) in the Bransfield Strait.

2.3.2 Ocean surface currents and circulation:

Forty drifter buoys were deployed this season: 10 during AMLR Leg I, seven along a transect between King George Island and Punta Arenas (February 4-5), and 20 during the collaborative NSF-OPP project (February-March). Release dates and locations for these drifters are listed in

Table 2.3. Figure 2.3 shows the location of deployment and available tracks of these drifters. Note the similarity of the tracks for those deployed during AMLR Leg I (blue) and the transect (red). These indicate a deflection in the drift of the Antarctic Circumpolar Current (ACC) imposed by the Shackleton Fracture Zone (SFZ), similar to that described from drifter trajectories from the 2002/03 field season (Hewes *et al.*, 2003). The tracks of these drifters outline a plume of higher chlorophyll concentration east of the SFZ that began to develop in January (Figure 2.2B) and maximized in March (Figure 2.2D).

2.3.3 Chlorophyll and nutrient concentrations with respect to water column characteristics, Leg I: Nutrients were sampled at selected stations within the AMLR survey grid that have, from past analyses, provided extremes in physical and biological characteristics of the water column for the Drake Passage side of the South Shetland and Elephant Islands (see Figure 2.1A, B for station positions). Figure 2.4 provides the standard CTD and associated sensor data for these stations. ACC surface waters (e.g., Water Zone I: Amos and Lavender, 1990) are less saline (Figure 2.4A) and warmer (Figure 2.4B) than coastal waters (Water Zone III), and are clearly distinguished from each other in temperature verses salinity space (Figure 2.4C). ACC waters have a temperature minimum of ~0.5°C at ~75m, the remnant of a previous years winter water, that defines a well mixed Upper Mixed Layer (UML) of ~50m. Intermediate to these is Water Zone II, for which of our nutrient data, there was one station. The biological components of these three Water Zones are different (Holm-Hansen *et al.*, 1997; Holm-Hansen and Hewes, 2004). Waters of the ACC can be distinguished into two groups: Water Zone IA which has very low chlorophyll in the UML but a chlorophyll maximum that lies just above the temperature minimum; Water Zone IB for which higher chlorophyll concentrations are uniformly distributed in the UML and no chlorophyll maximum is observed near the temperature minimum. For this discussion, both Water Zones of the ACC are combined, however it is shown from beam transmission (C_t) and fluorescence (Figures 2.4D, E) that this ACC water is lower in phytoplankton biomass than the other Water Zones. The C_t and fluorescence profiles (Figure 2.4D, E) are confirmed by extracted chl-*a* water column profiles for these stations (Figure 2.5A); ACC waters had much lower concentrations of chlorophyll in the UML than did the coastal stations. The macronutrient distributions in the water column however, indicate that the UML for ACC waters contained much higher ammonia (Figure 2.5E), and much lower silicate (Figure 2.5D) concentrations than coastal waters, and only slight differences in nitrate (Figure 2.5B) and phosphate (Figure 2.5C).

It has been fairly well established that macronutrients are rarely a limiting factor for phytoplankton biomass in Antarctic waters (Holm-Hansen *et al.*, 1989), and that the proportions of N:P:Si vary with respect to the different Water Zones (Holm-Hansen *et al.*, 1997). For the UML, coastal stations have more silicate (Figure 2.6A) and nitrate (Figure 2.6B) relative to their chlorophyll concentrations. Our data indicate that chlorophyll concentrations have modality about a gradient of silicate concentrations (Figure 2.6A). It could be argued that this merely represents a geographical coincidence for the AMLR survey area, where it is known that the concentration of Si in the UML increases poleward in the Southern Ocean in contrast to phytoplankton biomass that is highest around the coastal zone of the South Shetland Islands (Figures 2 and 3; Holm-Hansen *et al.*, 1997). Alternatively, it could be discussed that this reflects a difference in the utilization of nutrients by microbial assemblages being distinguished as resident of the ACC verses those of the coastal waters. For example, higher ammonia concentrations found in the UML of Water Zone IA waters (refer to Figure 2.5E) indicate extensive microbial grazing (Rönner *et al.*, 1983; Koike *et al.*, 1983; Hewes *et al.*, 1985) at rates greater than the ammonia can be assimilated through primary production. The UML of Water Zones IB, II, and III contain lower concentrations of ammonia, but also support higher phytoplankton biomass. This is but one reason to suggest that the microbial communities are different between ACC and coastal or intermediate waters (see Villafañe *et al.*, 1995).

In Figure 2.5 it is shown that macronutrient concentrations are quite similar at 200m, and we assume that deep mixing during winter would result with similar nutrient concentrations through the upper water column. Thus, differences between macronutrient values in the UML and deep water are often interpreted to represent the amount of carbon export to the deep ocean. The N_{total}:P ratio for all data are 17.7 ± 1.1, close to the Redfield ratio of 16, and was found to have no relationship with depth, Water Zone or chlorophyll concentration. Yet stoichiometry was not found for the N_{total}:Si ratio which had great differences both in relation to depth and between ACC and coastal waters (Figure 2.5F). For diatoms, the N:S ratio is ~1.0. It is generally held that nanoplankton dominate low chlorophyll containing waters and that large diatoms dominate blooms for Antarctic waters (Hewes *et al.*, 1985). As silicate is primarily utilized by diatoms, it would be expected that chlorophyll concentration and the macronutrient N:S ratio should be positively correlated in the UML. This relationship was found for the coastal waters only (Figure 2.6D). A completely different relationship was found for ACC waters. Recent findings demonstrate that under iron limitation, diatoms become more heavily silicified (Hutchins and Bruland, 1998; De La Rocha, 2000). The ACC in the AMLR survey area can be iron deficient for phytoplankton growth (Helbing *et al.*, 1991; Holm-Hansen *et al.*, 1994; unpublished results from our current NSF OPP-sponsored project). It would appear that for waters of the ACC, the low biomass and nanoplankton dominant communities have produced and exported a relatively greater proportion of diatom biomass than the more productive waters of the AMLR survey area. As these ACC waters can have high ammonia concentrations that might effectively reduce the requirement of iron for diatoms (Maldonado and Price, 1996; Cochlan *et al.*, 2002), one could speculate that Water Zone IA waters have communities with a higher ratio of diatoms to other types of phytoplankton relative to total biomass than as found in the other types of within the AMLR survey area.

2.4 Disposition of the Data: All chlorophyll and CTD-interfaced sensor data obtained during these cruises have been archived with AERD, Southwest Fisheries Science Center. HPLC and POC samples will be processed by Dr. B.G. Mitchell.

2.5 Problems and Suggestions: None

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 field season. 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. Carie Sines processed our micronutrient samples. We also thank all other AMLR personnel for help and support which was essential to the success of our program. Partial support for coordination and efforts with NSF was provided through OPP-0230443. Many thanks to the folk at Raytheon (United States Antarctic Program, USAP) who helped coordinate our efforts on the R/V *Yuzhmorgeologiya* with those of the *R/V L.M. Gould*. HPLC analysis of photosynthetic pigments will be completed by Dr. C. Trees of San Diego State University with support from the NASA Ocean Biogeochemistry Program. Dr. P. Niiler (SIO) arranged getting drifter buoys for our study through the NOAA "Global Drifter Program", NA17RJ1231, JIMO Task Number 2. Major funding for this project was to Dr. O. Holm-Hansen from the National Oceanic and Atmospheric

Administration, U.S. Department of Commerce, under JIMO NA17RJ1231, Task Number 10. 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:

Cochlan, W.P., Bronk, D.A., and Coale, K.H. 2002. Trace metals and nitrogenous nutrition of Antarctic phytoplankton: experimental observations in the Ross Sea. *Deep-Sea Research* II 49: 3365-3390.

De La Rocha, C.L., Hutchins, D.A., Brzezinski, M.A., and Zhang, Y. 2000. Effects of iron and zinc deficiency on elemental composition and silica production by diatoms. *Marine Ecology Progress Series* 195: 71-79.

Everson, I. 1983. Summary of the discussions of the sub-group on distribution, stock identity and population models, p. 269-279. In (S. B. Schnack, ed.) On the Biology of Krill *Euphausia superba*. *Berichte zur Polarforschung., Sonderheft* 4.

Gordon, L.I., Jennings, Jr., J.C., and Ross, A.A. 2001. A suggested protocol for continuous flow automated analysis of seawater nutrient using the Alpkem Flow Solution IV system (phosphate, nitrate, nitrite, silicic acid and ammonia) - chemical protocols used in the WOCE hydrographic program and the Joint Global Ocean Fluxes Study. College of Oceanic and Atmospheric Sciences Oregon State University Oceanography, Corvallis, Oregon.

Helbling, E.W., Villafane, V., and Holm-Hansen, O. 1991. Effect of Fe on Productivity and Size Distribution of Antarctic Phytoplankton. *Limnology and Oceanography* 36: 1879-1885.

Helbling, E.W., Amos, A.F., Silva, N., Villafañe, V.E., and Holm-Hansen, O. 1993. Phytoplankton distribution and abundance as related to a frontal system north of Elephant Island, Antarctica. *Antarctic Science* 5(1): 25-36.

Helbling, E.W., Villafañe, V.E., and Holm-Hansen, O. 1995. Variability of phytoplankton distribution and primary production around Elephant Island, Antarctica, during 1990-1993. *Polar Biology* 15: 233-246.

Hewes, C.D., Holm-Hansen, O., and Sakshaug, E. 1985. Alternate carbon pathways at lower trophic levels in the Antarctic food-web. In pp. 277-83 (W.R. Siegfried, P.R. Condy, and R.M. Laws, eds.) Antarctic Nutrient Cycles and Food Webs, Fourth Symposium on Antarctic Biology (SCOR/SCAR), Wilderness, South Africa, 1983. Springer Verlag, Berlin.

Hewes, C.D., Hewitt, R.P., Wieland, J., Mitchell, B.G., and Holm-Hansen, O. 2001. Phytoplankton. Pages 26-36 *in* (J.D. Lipsky, ed) AMLR 1999/2000 field season report. Objectives, accomplishments and tentative conclusions. NOAA-TM-NMFS-SWFSC-302.

Hewes, C.D., Wieland, J., Mitchell, B.G., Kahru, M., and Holm-Hansen O. 2001. Phytoplankton. Pages 37-50 *in* (J.D. Lipsky, ed) AMLR 2000/2001 field season report. Objectives, accomplishments and tentative conclusions. NOAA-TM-NMFS-SWFSC-314.

Hewes, C.D., Wieland, J., Reynolds, R., Giglio, S.B., Mitchell, B.G., Kahru, M., and Holm-Hansen, O. 2003. Phytoplankton. Pages 30-47, *in* (J.D. Lipsky, ed) AMLR 2001/2002 field season report. Objectives, accomplishments and tentative conclusions. NOAA-TM-NMFS-SWFSC-350.

Hewes, C.D., Zhao, M., Dorland, R., Mitchell, G.B., Kahru, M., and Holm-Hansen, O. 2003. Phytoplankton. Pages 28-42, *in* (J.D. Lipsky, ed) AMLR 2002/2003 field season report. Objectives, accomplishments and tentative conclusions. NOAA-TM-NMFS-SWFSC-355.

Hofmann, E.E., Klinck, J.M., Locarnini, R.A., Fach, B., and Murphy, E. 1998. Krill transport in the Scotia Sea and environs. *Antarctic Science* 10(4): 406-415.

Holm-Hansen, O., Lorenzen, C. J., Holmes, R.W., and. Strickland, J.D.H. 1965. Fluorometric determination of chlorophyll. *J. Cons. perm. int. Explor. Mer* 30: 3-15.

Holm-Hansen, O., and Riemann, B. 1978. Chlorophyll a determination: Improvements in methodology. *OIKOS* 30: 438-447.

Holm-Hansen, O., Amos, A.F., Silva S. N., Villafañe, V., and Helbling, E.W. 1994. *In situ* evidence for a nutrient limitation of phytoplankton growth in pelagic Antarctic waters. *Antarctic Science* 6: 315-324.

Holm-Hansen, O., C.D. Hewes, E.W. Helbling, V. Villafañe, and A.F. Amos. 1997. Phytoplankton biomass and distribution in relation to water masses around Elephant Island, Antarctica. Polar Biology 18: 145-153.

Holm-Hansen, O., Hewes, C. D., Guzman, E., Cuevas, G.A., Chade, V.E.C., Munoz, S.B.G., and Ruiz, H.R.W. 1999. Phytoplankton. Pages 38-53, *in* (J. Martin, ed.) AMLR 1998/99 field season report. Objectives, accomplishments and tentative conclusions. NOAA-TM-NMFS-SWFSC Administrative Report LJ-99-10. September 1999.

Holm-Hansen, O., Amos, A.F., and Hewes, C.D. 2000. Reliability of estimating chlorophyll-*a* concentrations in Antarctic waters by measurement of *in situ* chlorophyll-*a* fluorescence. *Marine Ecology Progress Series* 196: 103-110.

Holm-Hansen, O., and Hewes, C.D. 2004. Deep chlorophyll-*a* maxima (DCMs) in Antarctic waters: I - Relationships between DCMs and the physical, chemical, and optical conditions in the upper water column. *Polar Biology* In press.

Hutchins, D.A., and Bruland, K.W. 1998. Iron-limited diatom growth and Si:N uptake ratios in a coastal upwelling regime. *Nature* 393(6685):561-564.

Koike, I., Redalje, D.G., Ammerman, J.W., and Holm- Hansen, O. 1983. High-affinity uptake of an ammonium analogue by two marine microflagellates from the oligotrophic Pacific. *Marine Biology* 74: 161-168.

Loeb, V., Siegel, V., Holm-Hansen, O., Hewitt, R., Fraser, W., Trivelpiece, W., and Trivelpiece, S. 1997. Effects of sea-ice extent and krill or salp dominance on the Antarctic food web. *Nature* 387: 897-900.

Macaulay, M.C., English, T.S., and Mathisen, O.A. 1984. Acoustic characterization of swarms of Antarctic krill (*Euphausia superba*) from Elephant Island and Bransfield Strait. *Journal of Crustacean Biology* 4: 16-44.

Maldonado, M.T., and Price, N.M. 1996. Influence of N substrate on Fe requirements of marine centric diatoms. *Marine Ecology Progress Series* 141: 161-172.

Priddle, J.,. Croxall, J.P., Everson, I., Heywood, R.B., Murphy, E.J., Prince, P.A., and Sear, C.B. 1988. Large-scale fluctuations in distribution and abundance of krill. A Discussion of possible causes, p. 169-182. *In* (D. Sahrhage, ed.), Antarctic Ocean and Resources Variability. Springer-Verlag, Berlin.

Rönner, U., Srensson, F., and Holm-Hansen, O. 1983. Nitrogen assimilation by phytoplankton in the Scotia Sea. *Polar Biology* 2: 137-147.

Villafañe, V.E., Walter E.H., and Holm-Hansen, O. 1995. Spatial and temporal variability of phytoplankton biomass and taxonomic composition around Elephant Island, Antarctica, during summers of 1990-1993. *Marine Biology* 123: 677-686.

Table 2.1. Statistical details for 5m chlorophyll concentrations measured during Leg I ("A" stations) and Leg II ("D" stations) for the different areas of the AMLR survey area and in relation to being located in pelagic (bottom depth >1000 m) or shelf and shelf-break related waters. The different areas are Elephant Island Area (EI), Joinville Island Area (JI), South Area (SA) and West Area (WA). These areas are delineated on the map from Figure 2 of the Introduction Summary of 2004 results at the beginning of this Field Season Report.

Leg	Area	Number of Stations	Avg Chl-a, mg m^{-3}	St Dev Chl-a, mg m^{-3}	Maximum Chl-a, mg m^{-3}	Minimum Chl-a, mg m^{-3}	Average Bottom Depth, m
		Shelf and Shelf Break Areas					
A	EI	14	0.69	0.19	1.19	0.48	492
A	JI	3	0.59	0.13	0.74	0.44	545
A	SA	9	0.77	0.24	1.05	0.30	636
A	WA	9	0.63	0.46	1.54	0.11	497
D	EI	16	0.86	0.51	2.36	0.23	458
D	JI	5	0.39	0.12	0.60	0.24	576
D	SA	11	0.88	0.56	1.97	0.29	614
D	WA	8	0.70	0.22	1.04	0.44	421
		Pelagic Areas					
A	EI	32	0.58	0.49	2.51	0.01	3063
A	JI	2	1.00	0.55	1.55	0.19	1642
A	SA	5	1.43	1.71	6.40	0.40	1610
A	WA	18	0.29	0.37	1.30	0.05	3189
D	EI	31	0.58	0.49	2.51	0.01	3063
D	JI	3	1.00	0.54	1.55	0.19	1642
D	SA	5	1.43	1.70	6.40	0.40	1610
D	WA	18	0.29	0.37	1.30	0.05	3189

Table 2.2. Statistical details for integrated (to 100m) chlorophyll concentrations measured during Leg I ("A" stations) and Leg II ("D" stations) for the different areas of the AMLR survey area and in relation to being located in pelagic (bottom depth >1000 m) or shelf and shelf-break related waters. Abbreviations as in Table 2.1.

Leg	Area	Number of Stations	Avg Chl-a, mg m^{-2}	St Dev Chl-a, mg m^{-2}	Maximum Chl-a, mg m^{-2}	Minimum Chl-a, mg m^{-2}	Average Bottom Depth, m
		Shelf and Shelf Break Areas					
A	EI	14	44	10	64	21	492
A	JI	3	45	1	46	44	545
A	SA	9	42	11	65	28	636
A	WA	9	44	22	100	23	497
D	EI	16	61	33	146	24	458
D	JI	5	33	7	42	26	576
D	SA	11	46	17	77	26	614
D	WA	8	38	12	56	24	421
		Pelagic Areas					
A	EI	32	41	26	141	9	3063
A	JI	2	67	24	98	36	1642
A	SA	5	73	68	266	28	1610
A	WA	18	26	15	63	10	3189
D	EI	31	41	26	141	9	3063
D	JI	3	67	24	98	36	1642
D	SA	5	73	68	266	28	1610
D	WA	18	26	15	63	10	3189

Table 2.3. Drifter deployments during the 2003/04 season, listing cruise, date, drifter ID, and position. LMG0401 was aboard the *R/V LM Gould* during its transect from King George Island to Punta Arenas, Chile. LMG0402 was our collaborative project, February 12 – March 25, 2004, onboard the *R/V LM Gould*. Drifter tracks are shown in Figure 3.

Cruise	Date	ID	Latitude	Longitude
AMLR 2004	01/13/04	39284	-60.50	-60.00
AMLR 2004	01/13/04	39285	-61.00	-60.00
AMLR 2004	01/13/04	39296	-59.50	-60.00
AMLR 2004	01/13/04	39297	-60.00	-60.00
AMLR 2004	01/20/04	39282	-60.48	-58.53
AMLR 2004	01/20/04	39283	-59.99	-58.56
AMLR 2004	01/21/04	39278	-60.51	-57.54
AMLR 2004	01/21/04	39280	-60.26	-57.53
AMLR 2004	01/21/04	39281	-60.02	-57.54
AMLR 2004	01/22/04	39279	-59.99	-56.54
LMG0401	02/03/04	39286	-59.71	-59.87
LMG0401	02/03/04	39288	-60.21	-59.31
LMG0401	02/03/04	39289	-60.45	-59.02
LMG0401	02/03/04	39294	-61.06	-58.34
LMG0401	02/03/04	39295	-60.76	-58.67
LMG0401	02/04/04	39291	-59.08	-60.64
LMG0401	02/04/04	39293	-58.79	-61.01
LMG0402	02/19/04	44294	-61.25	-57.99
LMG0402	02/19/04	44295	-61.25	-57.99
LMG0402	02/20/04	44293	-61.01	-58.16
LMG0402	02/26/04	41298	-60.42	-56.70
LMG0402	02/26/04	43573	-60.08	-55.05
LMG0402	02/26/04	43574	-59.97	-54.40
LMG0402	02/27/04	43575	-60.26	-52.95
LMG0402	02/27/04	43576	-59.99	-53.67
LMG0402	02/28/04	43570	-59.51	-53.56
LMG0402	02/29/04	43568	-60.18	-54.31
LMG0402	02/29/04	43569	-60.33	-54.85
LMG0402	02/29/04	43571	-60.01	-54.12
LMG0402	03/01/04	41295	-60.35	-54.00
LMG0402	03/01/04	41296	-60.37	-54.46
LMG0402	03/03/04	41294	-60.10	-54.76
LMG0402	03/09/04	39292	-61.01	-56.20
LMG0402	03/09/04	41274	-60.87	-56.40
LMG0402	03/09/04	41292	-60.86	-56.33
LMG0402	03/09/04	41293	-61.00	-56.25
LMG0402	03/09/04	43572	-60.95	-56.28

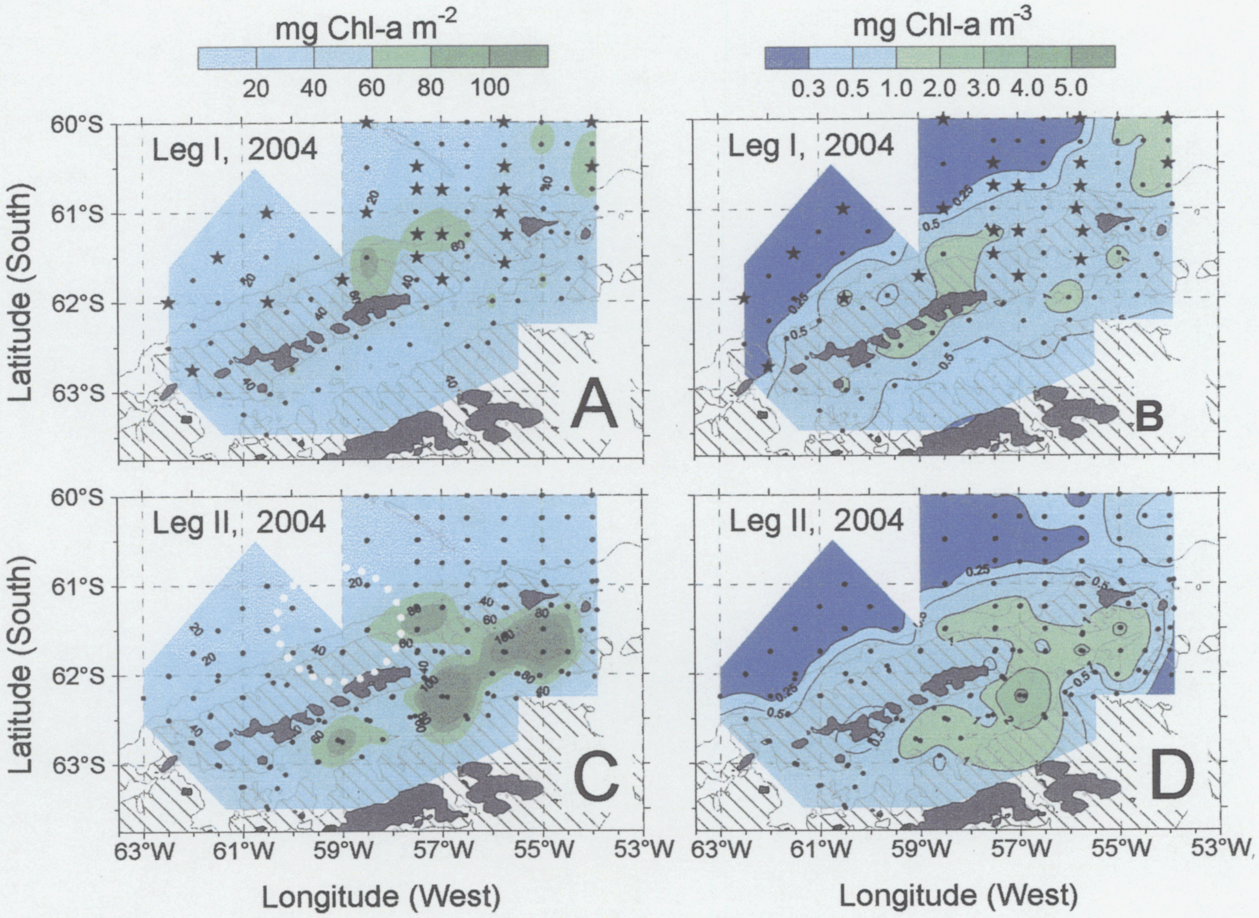


Figure 2.1. Distributions of integrated (**A** and **C**; to 100m) and 5 m (**B** and **D**) chlorophyll concentrations during Leg I (top) and Leg II (bottom) of the 2003/2004 AMLR field season. Station positions indicated by the filled circles. The shelf (<500m, diagonal lines) and 2000 meter (black lines) contours are shown. Macro-nutrient and formalin-preserved water samples were taken during Leg I, with stations indicated by stars.

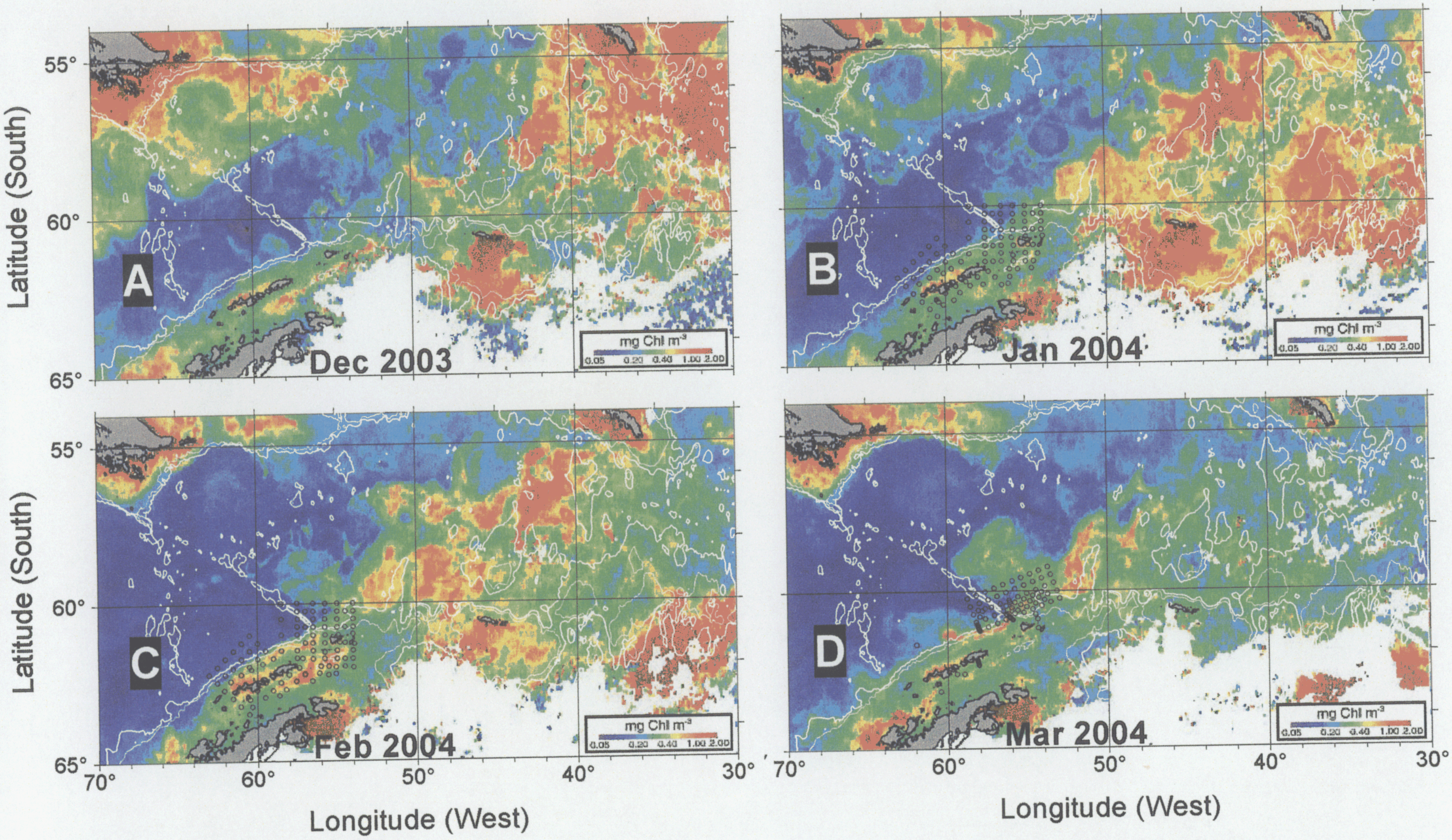


Figure 2.2. MODIS satellite monthly composite images of surface chlorophyll distribution from December 2003 through March 2004 (**A-D**). AMLR stations for Leg I are shown in (**B**), for Leg II in (**C**), and the complementary "BWZ" cruise on the R/V *LM Gould* (NSF-LMG0402) are in (**D**). White lines are 2000 and 3000m contours. Dotted white circle in (**C**) outlines the plume of chlorophyll of which drifter buoys (Figure 2.3) went around.

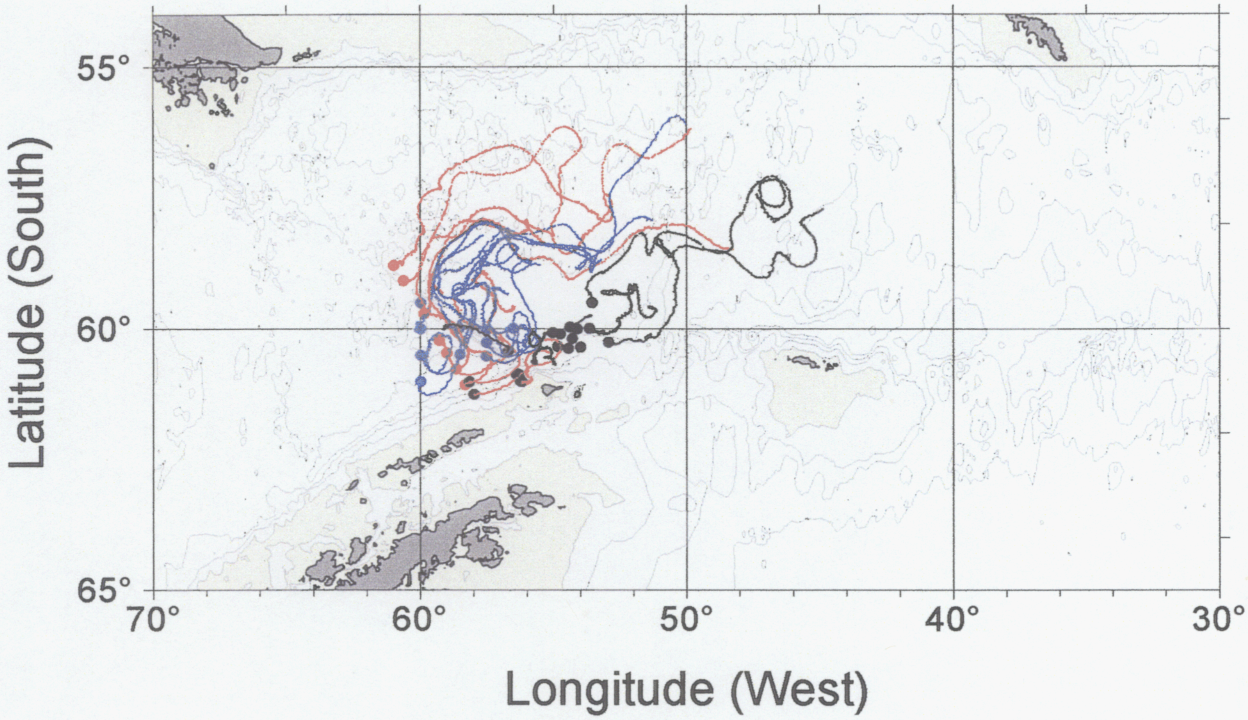


Figure 2.3. Bathymetric map of the area in which Lagrangian drifter buoys were released during AMLR Leg I (blue tracks), during a transect between the South Shetland Island to Punta Arenas, Chile, February 6 – 8, 2004 (red), and those released during LMG0402 (late-February through mid-March, 2004; black). Filled circles represent release positions for the drifters. Contours are at 1000 meter intervals.

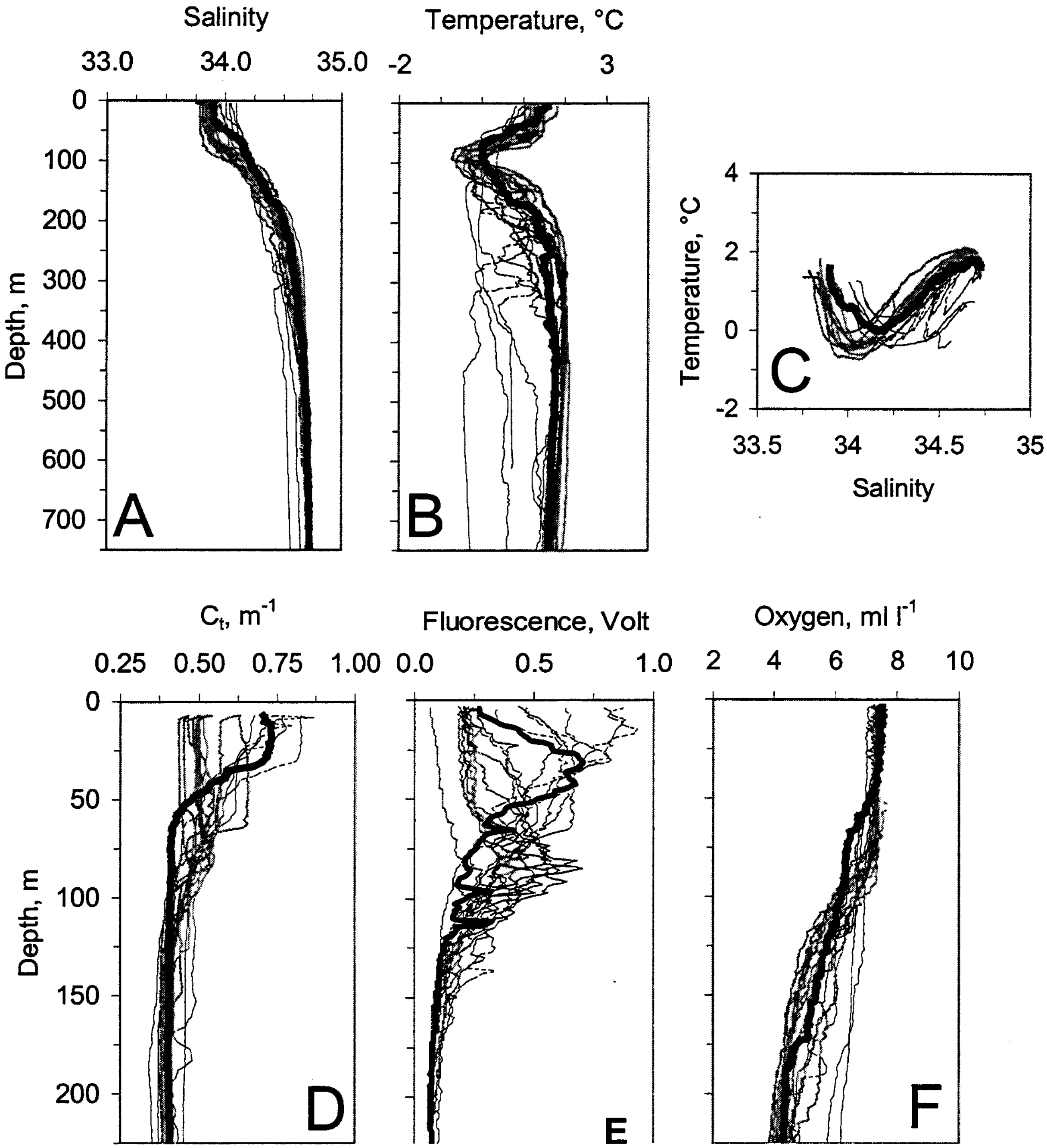


Figure 2.4. Physical characteristics (**A-C**), phytoplankton distribution (**D-E**), and oxygen concentration (**F**) of the water column for stations in which nutrient samples were obtained. Water Zones shown as follows: 1A, Antarctic Circumpolar Current water (gray lines); 2 intermediate water (heavy black line); 3, coastal water (stippled black lines).

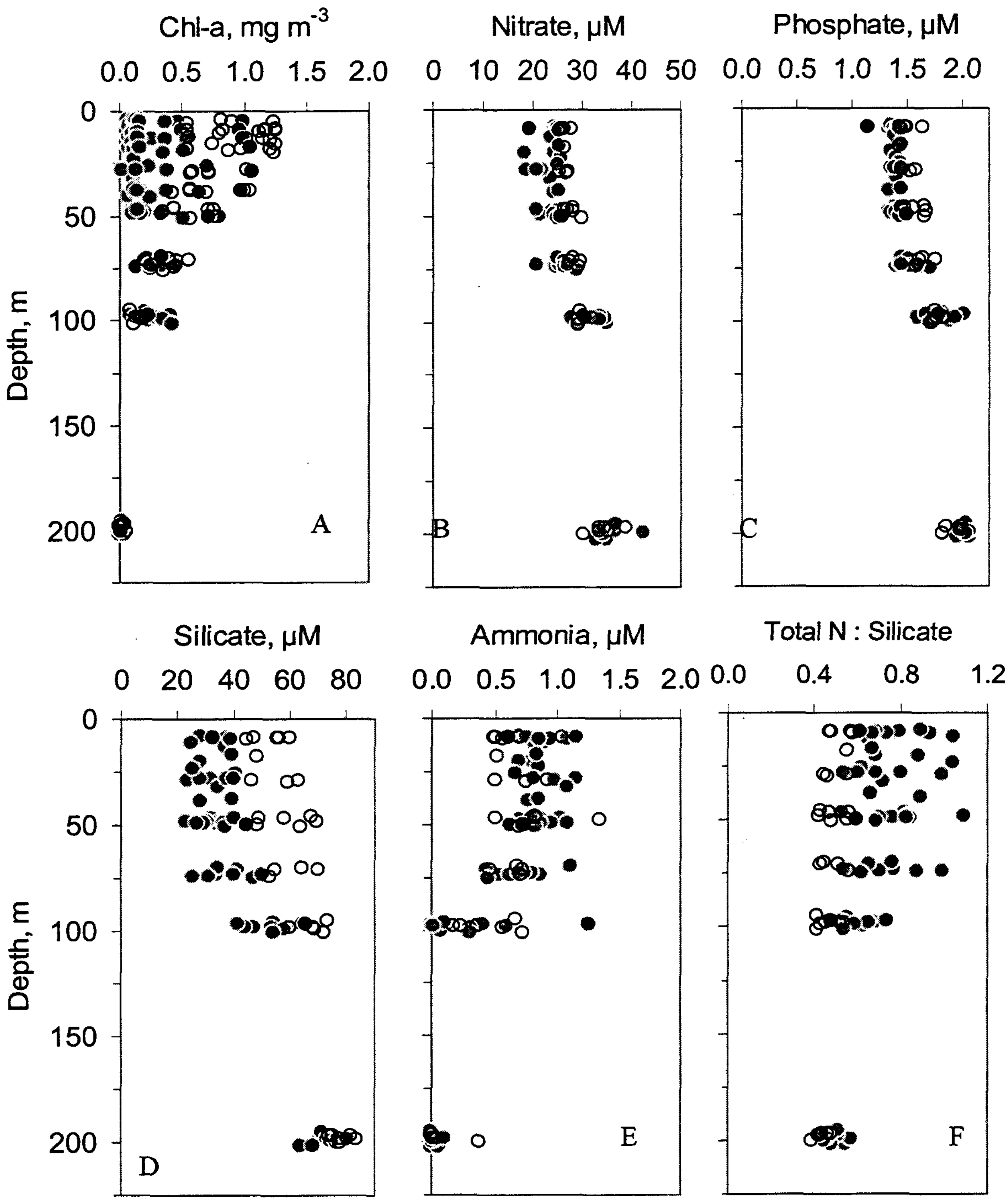


Figure 2.5. Chlorophyll (**A**) and macro-nutrient distributions (**B-D**) in the water column for same stations whose physical profiles were described in Figure 4. Water Zones shown as follows: 1A, Antarctic Circumpolar Current water (filled gray circles); 2 intermediate water (solid black circles); 3, coastal water (open circles). In the upper mixed layer (about 50m), ACC waters had low chlorophyll (**A**) and high NH_4^- (**E**) relative to the higher chlorophyll and lower NH_4^+ found in coastal waters. Coastal waters had higher silicate (**D**) and slightly higher nitrate (**B**) and phosphate (**C**) than found for the ACC. The total N (e.g., NO_3+NH_4^+):SiOH ratio was found much higher in the ACC than in coastal waters (**F**).

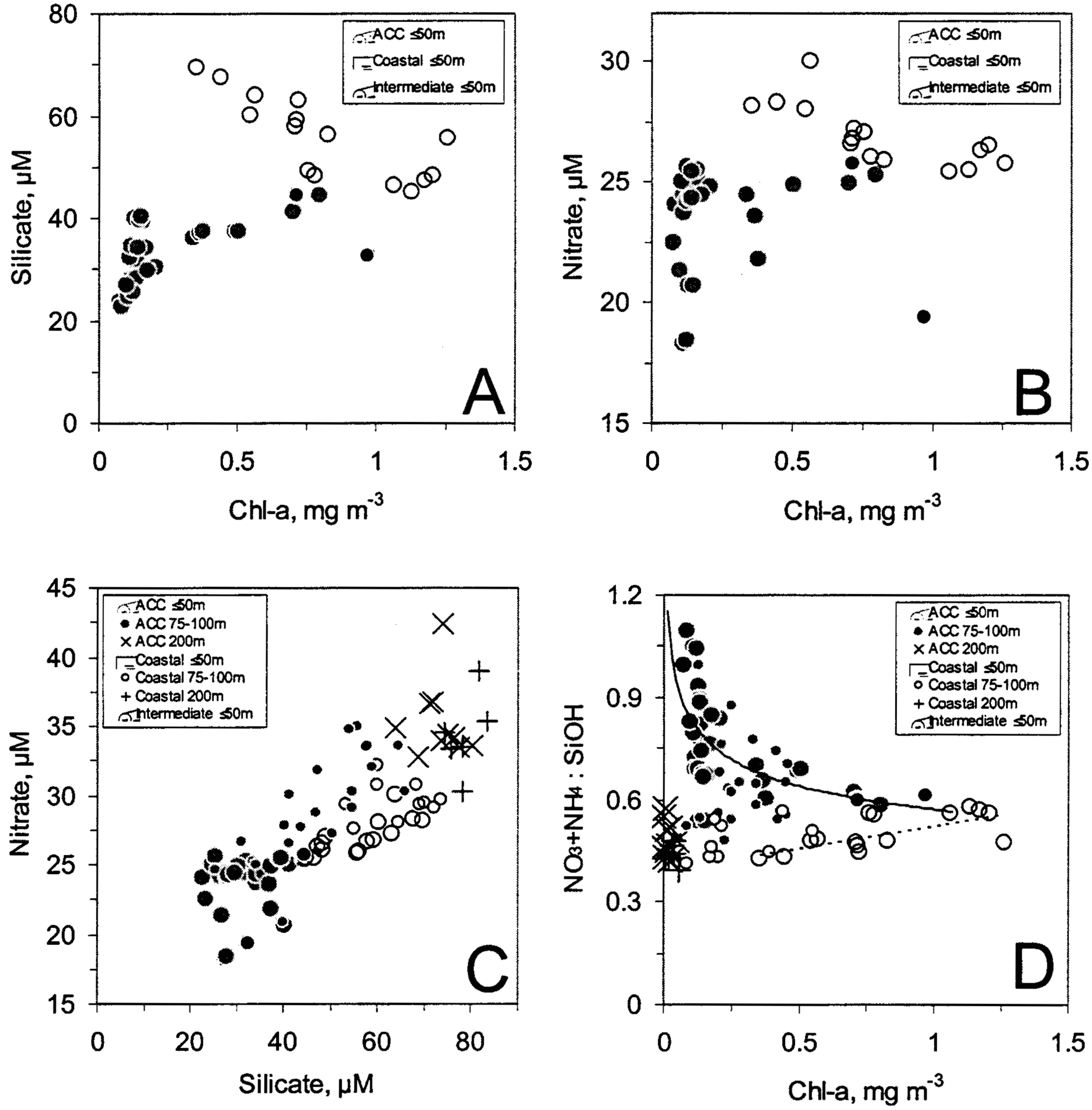


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Figure 2.6. Relationships between chlorophyll-*a*, nitrate and silicate in the upper mixed layer (≤50m, large circles) of the water column for ACC waters (gray filled circles, X for 200m samples), intermediate waters (black filled circles) and coastal waters (open black circles, + for 200m samples). Per unit chlorophyll, coastal waters have more silicate (A) and nitrate (B) than ACC waters. Concentrations of silicate and nitrate distinguish coastal and ACC waters (C). The ratio of $(NO_3^- + NH_4^+):Si(OH)_4$ relative to chlorophyll concentration (D) indicates that more silicate per unit nitrogen has been consumed in the upper mixed layer for ACC than for coastal waters. In (C) and (D), small circles are for 75-100 m samples which, for ACC waters, is where the chlorophyll maximum occurs in ACC waters (Figures 4D, 4E, and 5A).

3. Bioacoustic survey; submitted by Anthony M. Cossio (Legs I & II) and Roger P. Hewitt (Leg I).

3.1 Objectives: The primary objectives of the bioacoustic survey during Legs I and II were to map the meso-scale dispersion of Antarctic krill (*Euphausia superba*) in the vicinity of the South Shetland Islands; 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 to determine their relationship with water mass boundaries and zooplankton distribution.

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 survey 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 one Windows XP workstation and one Windows 2000 workstation. Both stations were running SonarData EchoLog. One unit was used for primary system control, data logging, processing with SonarData Echoview software, an archiving while the other ran in parallel for back-up logging and archiving.

Acoustic surveys of the water surrounding the South Shetland Islands were conducted on Legs I and II. These surveys were divided into four areas (See Figure 2 in Introduction): (1) a 43,865km^2 area centered on Elephant Island (Elephant Island Area) was sampled with seven north-south transects; (2) a 38,524km^2 area along the north side of the southwestern portion of the South Shetland archipelago (West Area) was sampled with six transects oriented northwest-southwest and one oriented north-south; (3) a 24,479km^2 area in the western Bransfield Strait (South Area) was sampled with seven transects oriented northwest-southwest; (4) and an 18,151km^2 area north of Joinville Island (Joinville Island Area). Due to extensive sea ice accumulation, only two transects were completed in the Joinville Island Area during Leg I (Survey A) and three were completed during Leg II (Survey D).

3.2.1 Krill Delineation (Legs I & II, Surveys A & D): Krill densities were estimated using a three-frequency delineation method (Hewitt *et al.*, 2003) 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 4 to 16 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 -4 to 2 was established as the acceptable difference between the 120kHz and 200kHz 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. The window ranges were selected based on models of krill backscattering strength at each frequency (Demer, in press).

3.2.2 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.

3.2.3 Abundance Estimation and Map Generation: Backscattering values were averaged over 5m by 20s bins. Time varied gain (TVG) noise was subtracted from the echogram and the ΔMVBS window was applied. TVG values were based on levels required to erase the rainbow effect plus 2dB. The remaining volume backscatter classified as krill was integrated over depth (500m) and averaged over 1,852m (1 nautical mile) distance intervals. These data were processed using SonarData Echoview software.

Integrated krill nautical area scattering coefficient (NASC) (Maclennan and Fernandes, 2000) 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):

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

Where

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

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

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

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

3.3 Tentative Conclusions:

3.3.1 Leg I (Survey A): High abundances of krill were observed along the shelf break from north of Livingston to northwest of King George Islands (Figure 3.1). Greater krill abundance was observed along the shelf from northeast of King George island into the waters northeast of Elephant Island. Small densities of krill were observed in the Joinville Island transects. Krill densities were calculated to be 13.75, 11.45, 3.81, and 1.48 g/m² for the West, Elephant Island, South and Joinville Island Areas respectively (Table 3.1). Density estimates by transect are listed in Table 3.2.

The distribution of mean nautical area scattering coefficients (NASC) of myctophids was mapped and found to be highest along the 2000m isobath (Figure 3.2). Areas of greater abundance were observed northeast of Livingston Island and northwest of Elephant Island.

3.3.2 Leg II (Survey D): Krill densities shifted locations from Survey A. Distribution of krill density was not as uniform as Survey A in the West Area. Krill abundance was highest northwest of Elephant Island, along the Shackleton Fracture Zone. Densities were calculated to be 8.41, 14.71, 4.49, and 7.32 g/m^2 for the West, Elephant Island, South and Joinville Island Areas respectively.

NASC distribution of myctophids differed from Survey A, being more patchy. Highest densities were observed north and south of Elephant Island.

3.4 Disposition of Data: All integrated acoustic data will be made available to other U.S. AMLR investigators in ASCII format files. The analyzed echo-integration data consume approximately 10 MB. The data are available from Anthony Cossio, Southwest Science Center, 8604 La Jolla Shores Dr, La Jolla, CA 92037; phone/fax – (858) 546-5609/546-5608; e-mail: Anthony.Cossio@noaa.gov.

3.5 References:

Demer, D.A. In press. An estimate of error for the CCAMLR 2000 estimate of krill biomass. *Deep Sea Research II, Special issue.*

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.

Hewitt, R.P., Demer, D.A., and Emery, J.H. 2003. An eight year cycle in krill biomass density inferred from acoustic surveys conducted in the vicinity of the South Shetland Islands during the austral summers of 1991/92 through 2001/02. *Aquatic Living Resources* 16(3): 205-213.

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.

Maclennan, H. and Fernandes, P. Definitions, units and symbols in fisheries acoustics. Draft 03/04/00. Contr FAST Working Group Meeting, Haarlem, April 2000. 6p.

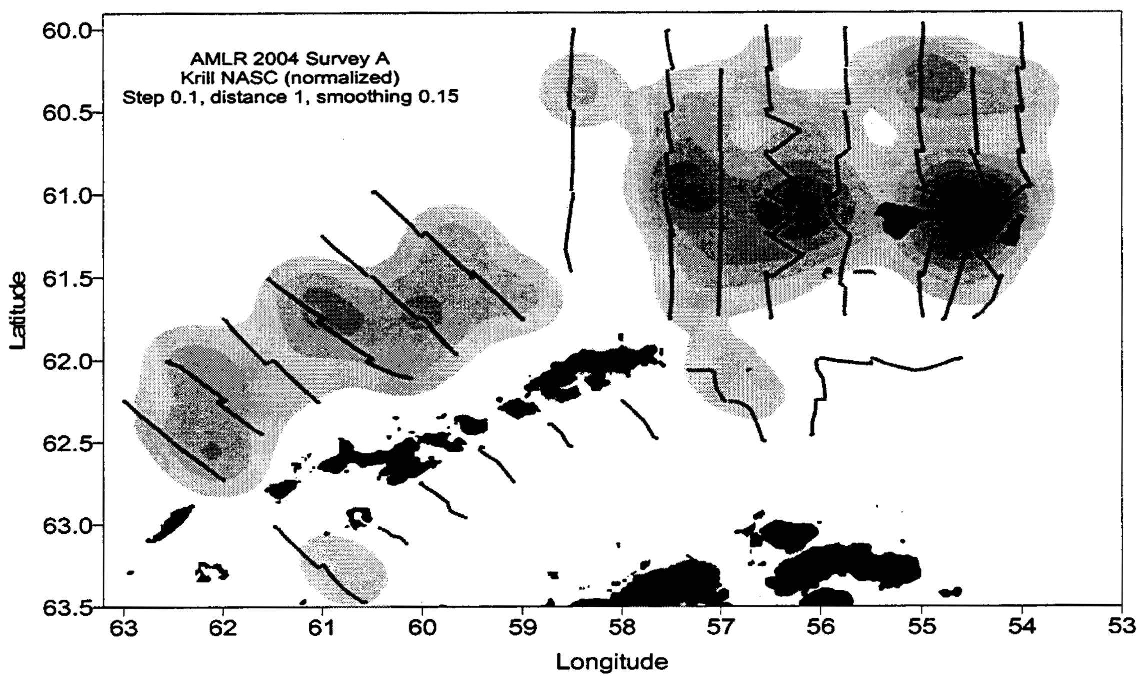
Maduriera, L.S.P., Ward, P., and Atkinson, A. 1993. Differences in backscattering strength determined at 120 and 38 kHz for three species of Antarctic macroplankton. *Marine Ecology Progress Series* 99: 17-24.

Table 3.1. Mean krill biomass density for surveys conducted from 1992 to 2004. 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 are 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. Data values are based on the three-frequency krill delineation method (2-16dB difference between 120 and 38kHz and –4-2dB difference between 200 and 120kHz). See Figure 2 in the Introduction Section for description of each survey. (*Density measurements are based on data collected during both day and night hours. All other density measurements are based on data collected during daylight hours).

Survey	Area	Mean Density (g/m²)	Area (km²)	Biomass (10³ tons)	CV %
1992 A (late January)	Elephant Island	38.03	36,271	194	20.1
D (early March)	Elephant Island	7.91	36,271	287	14.3
1994 A (late January)	Elephant Island	3.07	41,673	128	34.7
D (early March)	Elephant Island	2.14	41,673	13	33.7
1995 A (late January	Elephant Island	7.47	41,673	311	23.5
D (early March)	Elephant Island	13.22	41,673	551	28.8
1996 A (late January)	Elephant Island	26.85	41,673	1119	29.0
D (early March)	Elephant Island	17.00	41,673	708	36.0
1997 A (late January)	Elephant Island	50.04	41,673	2085	21.4
1998 A (late January)	Elephant Island	60.22	41,673	2509	19.4
	West	75.39	34,149	2575	30.5
	South	29.35	8,102	238	27.1
D (late February)	Elephant Island	20.84	41,673	868	16.3
	West	75.03	34,149	2563	28.7
	South	37.87	8,102	307	12.4
1999 A (late January)	Elephant Island	14.84	41,673	619	38.1
	West	16.92	34,149	578	31.6
	South	15.52	8,102	126	14.8
D (late February)	Elephant Island	13.37	41,673	557	39.8
	West	16.18	34,149	552	35.7
2000 D (late February)	West	32.51	34,149	1110	37.4
	Elephant Island	34.57	41,673	1441	28.6
	South	19.83	8,102	161	4.0
2001 A (late January)	West	4.70	34,149	161	16.4
	Elephant Island	6.65	41,673	277	19.1
	South	6.50	8,102	53	20.9
D (late February)	West	7.83	34,149	268	42.8
	Elephant Island	5.99	41,673	250	10.4
	South	2.77	8,102	22	40.1
2002 A (late January)	West	2.29	38,524	88	117.6
	Elephant Island	3.34	43,865	147	78.7
	South	2.11	24,479	351	53.3
	Joinville Island	1.05*	18,151	19	9.2
D (late February)	West	1.69	38,524	65	19.3
	Elephant Island	1.17	43,865	51	23.5
	South	1.05	24,479	26	32.9
	Joinville Island	0.51*	18,151	9	73.3
2003 A (late January)	West	28.58	38,524	1101	13.9
	Elephant Island	24.48	43,865	1044	0.2
	South	13.10	24,479	331	0.3
D (late February)	West	36.71	38,524	1414	19.3
	Elephant Island	16.86	43,865	739	23.5
	South	20.34	24,479	498	13.1
2004 A (late January)	West	13.75	38,524	530	16.1
	Elephant Island	11.45	43,865	502	12.0
	South	3.81	24,479	93	24.1
	Joinville Island	1.48	18,151	27	35.3
D (late February)	West	8.41	38,524	324	33.6
	Elephant Island	14.71	43,865	645	16.4
	South	4.49	24,479	110	75.9
	Joinville Island	7.32	18,151	133	25.6

Table 3.2. Krill density estimates by area and transect for Surveys A and D, (Legs I and II). n = 1 interval = 1 nautical mile.

West Area				
		Survey A		Survey D
	n	krill density	n	krill density
Transect 1	40	21.12	42	19.91
Transect 2	44	17.43	44	18.58
Transect 3	43	9.17	40	23.49
Transect 4	60	21.27	58	10.42
Transect 5	58	12.73	54	1.49
Transect 6	72	13.76	71	0.12
Transect 7	88	6.35	100	1.52
Elephant Island Area				
		Survey A		Survey D
	n	krill density	n	krill density
Transect 1	118	14.62	107	34.75
Transect 2	88	13.59	97	19.36
Transect 3	157	11.78	128	18.95
Transect 4	107	7.53	114	7.16
Transect 5	149	15.99	176	11.06
Transect 6	97	9.35	96	11.93
Transect 7	132	6.42	140	4.92
Joinville Island Area				
		Survey A		Survey D
	n	krill density	n	krill density
Transect 1	44	0.00	72	10.04
Transect 2	32	3.52	19	1.97
Transect 3	0	0.00	13	0.07
South Area				
		Survey A		Survey D
	n	krill density	n	krill density
Transect 1	40	14.36	44	0.12
Transect 2	18	1.56	19	0.64
Transect 3	12	2.24	17	0.23
Transect 4	18	6.16	38	21.11
Transect 5	20	3.52	23	0.16
Transect 6	10	0.02	17	0.16
Transect 7	40	12.49	46	1.89



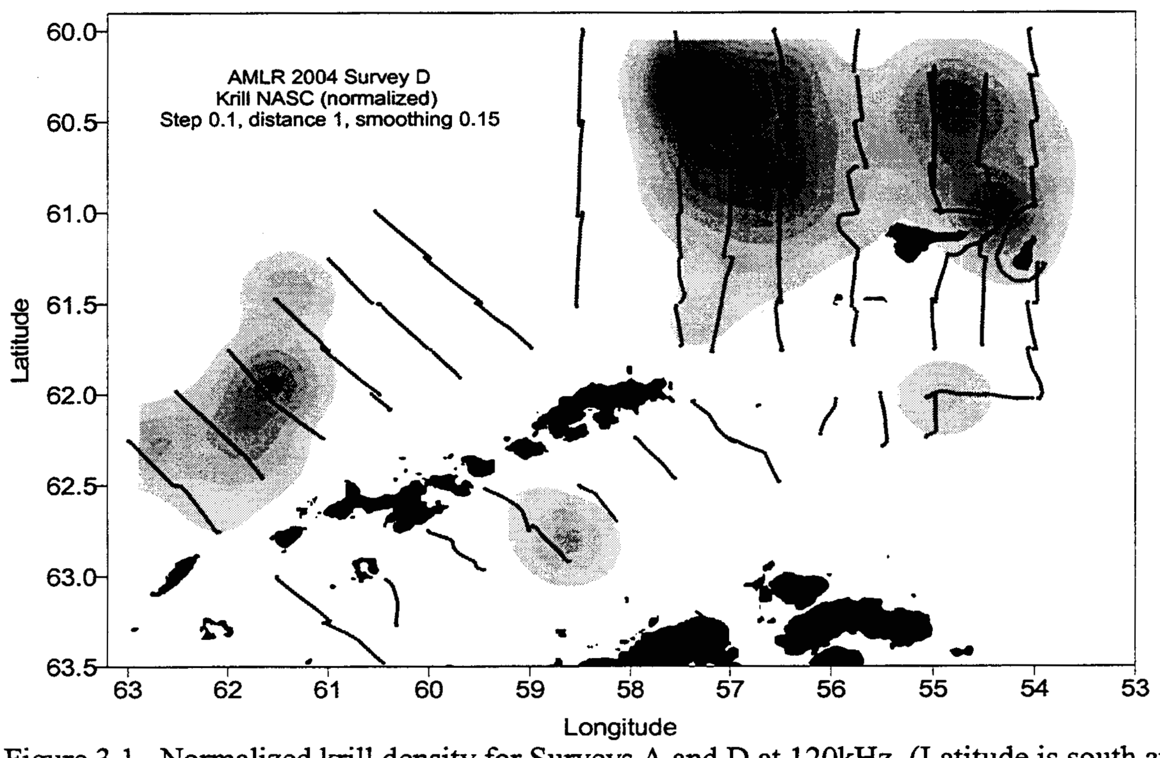
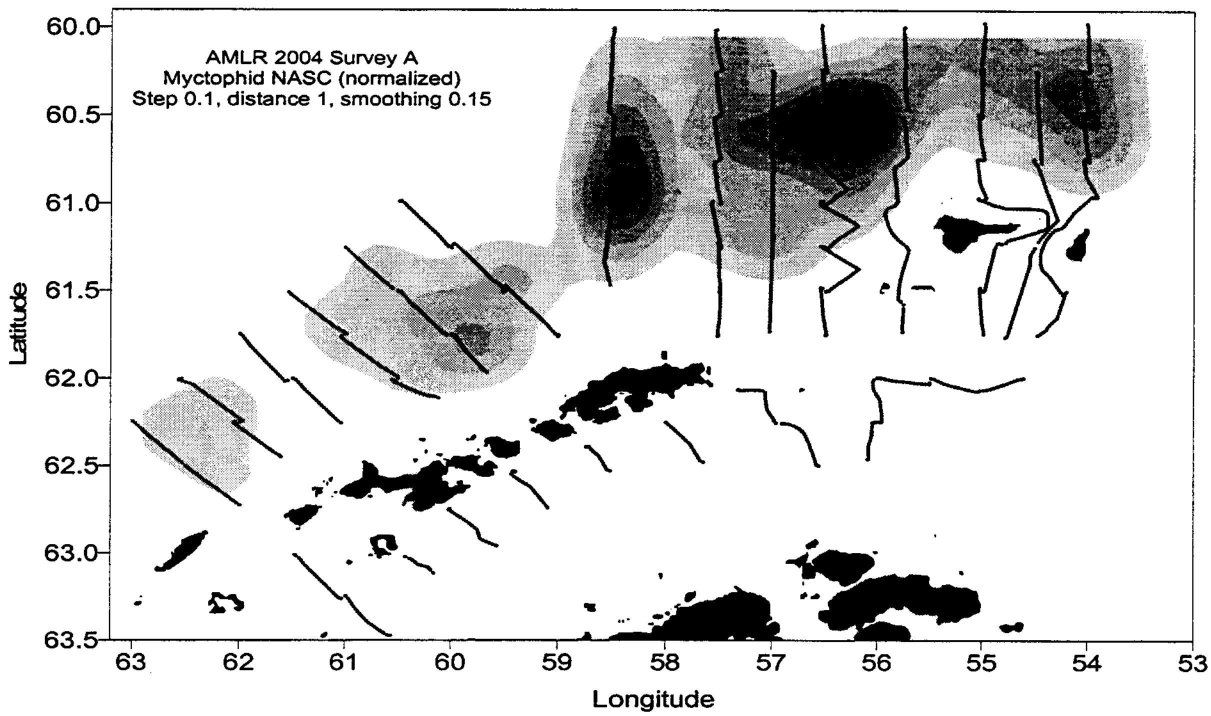


Figure 3.1. Normalized krill density for Surveys A and D at 120kHz. (Latitude is south and longitude is west).



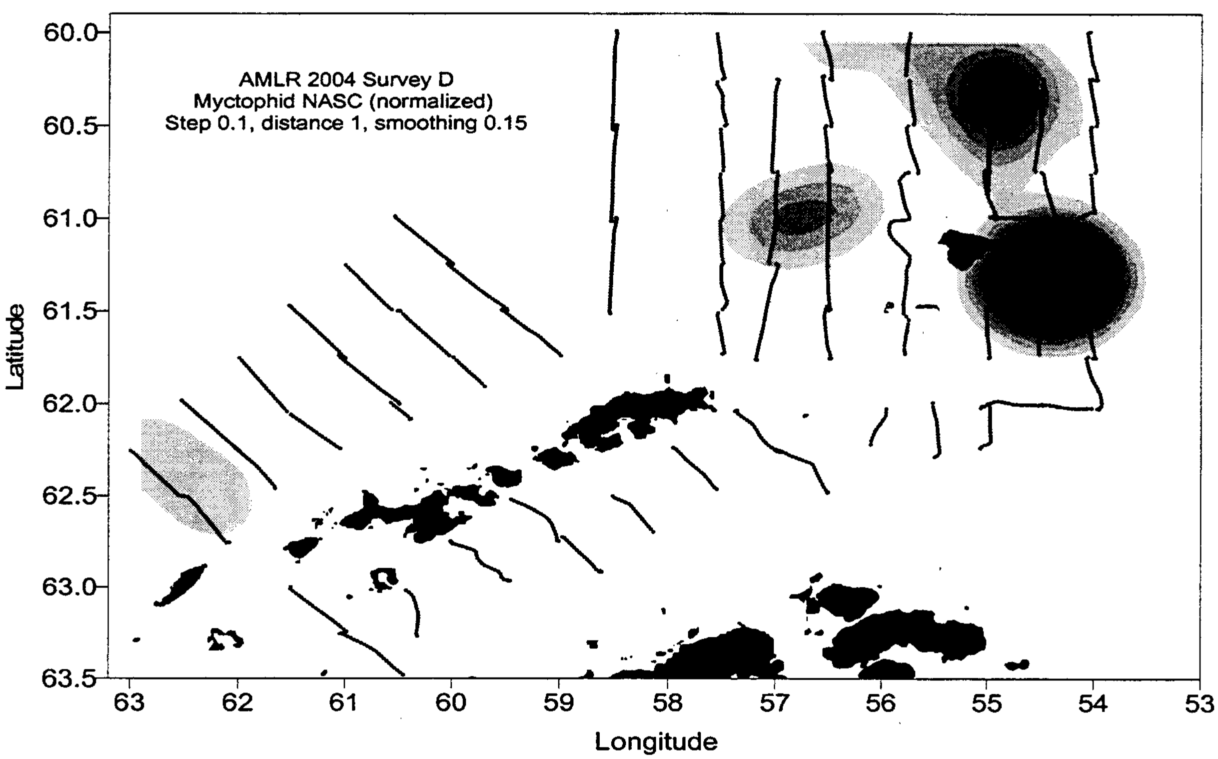


Figure 3.2. Normalized myctophid density for Surveys A and D at 120kHz. (Latitude is south and longitude is west).

4. Net sampling: Krill and zooplankton; submitted by Valerie Loeb (Legs I & II), Kayt Chambers (Legs I & II) , Ethan Daniels (Legs I & II), Michael Force (Legs I & II) , Nancy Gong (Leg II), Adam Jenkins (Leg I), Jonathan Reum (Leg I), Rob Rowley (Legs I & II), Steve Sessions (Legs I & II) and Joe Warren (Leg I).

4.1 Objectives: Here we 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 biomass dominant 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 1992-2004 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 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 to approximately 10m above bottom in shallower waters. Real-time tow depths were derived from a depth recorder mounted on the trawl bridle. Tow speeds were approximately two knots. Samples were collected at Large-Area survey stations during both cruise legs. Four regionally distinct groups of stations are considered (Figure 2 Introduction section; Figures 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 summer months. Within Bransfield Strait the "South Area" stations are used to monitor krill supplies available to predator populations in Admiralty Bay, King George Island, while "Joinville Island Area" stations, to the east, are sampled to determine whether significant aggregations of juvenile krill occur there in association with Weddell Sea influence.

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 two hours of sample collection. Abundance estimates of krill, salps, and other taxa are expressed as numbers per 1000 m3 water filtered. Twilight samples were collected between one hour before and one hour after local sunrise and sunset. Abundance information is presented for the Elephant Island, West, South and Joinville Island Areas, and for the total survey area.

(A) Krill: Krill were removed and counted prior to other sample processing. All krill from samples containing <100 individuals were analyzed. For larger samples, generally 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). Length-at-age estimates are based on Siegel (1987) and Siegel and Loeb (1994).

(B) Salps: All salps were removed from samples of two liters or less and enumerated. For larger catches the numbers of salps in one to two liter subsamples were used to estimate abundance. For samples with <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 >100 individuals were analyzed in the same manner for larger catches.

(C) Fish: All adult myctophids were removed, identified, measured to the nearest mm 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.

The long-term AMLR zooplankton data set reflects the evolution of shipboard sample processing and identification techniques. Taxonomic diversity increases evident over the past decade result in part from inclusion of smaller taxa (e.g., copepod species and euphausiid larvae). Additionally, recent survey grid expansions into higher latitudes incorporate zooplankton taxa not encountered by earlier surveys. Most notable are areas influenced by Weddell Sea shelf water (Weddell Sea and Joinville Island Areas) and by outflow from Gerlache Strait. Use of a more protective codend starting in 2002 also increases the numbers of previously unidentifiable delicate taxa such as jellies and pteropods.

4.2.3 Statistical Analyses: Data from the total survey area and four subareas are analyzed here for between-cruise and between-year comparisons. Analyses include a variety of parametric and nonparametric techniques. Among these are Analysis of Variance (ANOVA), Cluster Analysis, Percent Similarity Indices (PSIs), Kendall's Tau (T) correlation tests and Kolmogorov-Smirnov cumulative percent curve comparisons (D_{max}). Cluster analyses use Euclidean distance and Ward's linkage method; clusters are distinguished by a distance of 0.40 to 0.60. Clusters based on size characteristics utilize proportional length-frequency distributions in each sample with at least 17 krill or 50 salps. Zooplankton clusters are based on log-transformed sample abundance data (N+1) for the most frequently occurring taxa. Statistical analyses were performed using Statistica software (StatSoft).

4.3 Results and Preliminary Conclusions:

4.3.1 Survey A, 2004

4.3.1.1 Krill:

Frequency and Abundance (Table 4.1A, Figure 4.1A)

Postlarval krill were present in 76 of the total 91 Survey A (Leg I) samples (84%). Frequency of occurrence was similar in the West, Elephant Island and South Areas (83-88% of samples in each area). The two largest catches (1,500 and 2,400 krill, estimated 782 and 852 per 1000 m3) were well offshore north and south of Elephant Island; other relatively large catches (500-900 individuals, estimated 212-375 per 1000 m3) were southwest of Elephant Island and in the southwestern portion of Bransfield Strait. Highest mean abundance occurred in the South and Elephant Island Areas (65 and 60 per 1000 m3, respectively). Greatest median abundance, representing more even (less patchy) distributions, occurred in the Elephant Island and West Areas (3 and 2 per 1000 m3, respectively). A total of four krill were collected in five Joinville Island Area samples (0.3 per 1000 m3 mean abundance).

Length and Maturity Stage Composition (Table 4.2; Figures 4.2A & B; 4.3A-F)

Krill lengths ranged from 20-57mm but 80% of individuals were between 35 and 50mm and exhibited a normal distribution around 42mm modal and 40mm median values. Only 17% were <35mm and 3% >50mm. Similar length-frequency distributions, centered at 42-43mm (age-class 3) were represented in the West and Elephant Island Areas (D_{max}=8). Relatively small krill dominated in the South Area; 86% of these were 29-39mm and the length-frequency distribution, centered around 34-35mm (age-class 2), was significantly smaller than in the West and Elephant Island Areas (D_{max}=58, $P<0.01$).

Similar proportions of immature and mature stages (48% each) dominated the overall catch while juveniles (1 year old) comprised only 4%. Males slightly outnumbered females. About 28% of mature females were in advanced reproductive stages (F3c-e); together these made up approximately 9% of total krill. A similar proportion was comprised of reproductively advanced (M3b) males. In accordance with length-frequency distributions, juvenile and immature stages were primarily represented in the South Area where they comprised, respectively, 9 and 77% of the catch. Mature males dominated in the West (30% M3a-b) while together mature males and females (primarily F3c) dominated in the Elephant Island Area.

Overall scarcity of small juveniles, particularly in the South Area, suggests minimal recruitment success from the 2002/03 spawning season. That had been predicted based on apparently delayed or deferred spawning observed then. The majority of krill sampled represented the highly successful 1999/00, 2000/01 and 2001/02 year classes now, respectively, the 40-50mm mature forms (3 and 4 year old krill, primarily in the West and Elephant Island Areas) and 30-39mm immature forms (age-class 2, primarily in the South Area).

Distribution Patterns (Figures 4.4A; 4.6A)

Cluster analysis applied to krill length data from 31 samples yielded three groups; these demonstrated with length and maturity stage compositions and associated distribution patterns representative of 2, 3 and 4-5 year old krill (Siegel 1987, 1988; Siegel and Loeb 1994). Per

Siegel (1988) an offshore progression was demonstrated by the age-related length and maturity stages. Cluster 1, present at 11 stations within Bransfield Strait, along the inner shelf areas of the South Shetland and Elephant Islands and in the northeast corner of the Elephant Island Area, was characterized by small juvenile and immature stages. Cluster 1 median length was 37mm and 90% of individuals were <44mm. Juveniles made up 7% and immature forms 64%; over 25% of the mature individuals were female but only 3% were represented by advanced stages F3c-e (i.e., developing ovaries, gravid or spent). Cluster 2 krill were present at 11 stations generally located over the outer island shelves and/or vicinity of the Shackleton Fracture Zone. Cluster 2 sizes were centered around 40mm modal and 42mm median lengths with 45% between 40-45mm. Immature and mature stages comprised 33% and 66%, respectively. Reproductively advanced males (M3b) represented 11% and females (F3c-e) 20% of the total. Cluster 3 krill were present at nine stations adjacent to, and offshore of, Cluster 2. These were predominantly mature individuals (83%); modal and median lengths were 44mm and 46mm and 27% were >48mm. With 64% of individuals in advanced maturity stages this cluster represented an actively spawning component of the population. Of note is the concentration and close proximity of the three clusters extending southwest to northeast across the Elephant Island Area.

Larval Krill Distribution, Abundance and Stage Composition (Tables 4.3-4.5A; Figure 4.6A)

Larval krill were collected at 50% of survey stations. They were least frequent and abundant in the West Area (33% of samples, 2 per 1000 m3 mean abundance). Their frequency of occurrence in the Elephant Island and South Areas was similar (54-56% of samples) but the larvae were more evenly distributed in the South vs. Elephant Island Area (mean and median 7 and 2.4 per 1000 m3 vs. 9.8 and 0.4 per 1000 m3). Larvae were present in four of five (80%) Joinville Island samples with mean and median abundance values similar to those in the South (4.6 and 2 per 1000 m3).

Larval stages ranged from early calyptopis (C1) to early furcilia (F2), the latter relatively advanced forms suggesting an extremely early initiation of seasonal spawning effort (e.g., early-November; Spiridonov, 1995). However 95% were calyptopis stages, primarily C1 (64.5%) and C2 (18.5%) resulting from early- to mid-December spawning. The least and most developed larvae, respectively, were found in the West (80% C1) and South (19% F1, 3% F2). The F1 stage comprised 7% of Joinville Island larvae. Only calyptopis stages were sampled in the Elephant Island Area (63% C1, 22% C2 and 12% C3). With respect to implied flow from dynamic topography the distribution of calyptopis and furcilia larvae appeared associated with input from the Weddell Sea and retention within the northeast portion of the Elephant Island Area (see Physical Oceanography report this volume).

4.3.1.2 Salps:

Frequency and Abundance (Tables 4.4, 4.5; Figure 4.7A)

Salpa thompsoni occurred in 85 (93%) of the survey samples with overall mean and median abundance of 179 and 90 per 1000 m3. This salp was most evenly distributed within the Elephant Island Area where it was present in all 46 samples with mean and median values of 176 and 134 per 1000 m3. It was also quite frequent and abundant, but with a patchier distribution, in the West (96% of samples, mean and median abundance, respectively, 280 and 63 per 1000 m3). Elevated mean abundance here was due to large catches of ca. 1000-2000 per 1000 m3 at three offshore stations north of Livingston Island. *Salpa thompsoni* was less common and abundant in Bransfield Strait. In the Joinville Island Area, it occurred in three of five samples with mean and median abundance values (14 and 11 per 1000 m3) nearly an order of magnitude smaller than in the West and Elephant Island Areas. Intermediate values (81% of samples, 89 and 29 per 1000 m3) were represented in the South Area. The overall distribution pattern indicates elevated concentrations in association with Zone II water offshore and complex hydrography over the island shelves (see Physical Oceanography Chapter in this report).

Ihlea racovitzai, a high latitude salp species, was present in 39 (43%) Survey A samples. In contrast to *S. thompsoni* it was primarily collected within Bransfield Strait where it occurred at all five Joinville Island Area stations (131 and 97 per 1000 m3 mean and median) and 11 of 16 (69%) South Area stations (119 and 9 per 1000 m3) with densest concentrations (ca. 100-800 per 1000 m3) typically located over deep basins. Generally modest numbers were collected at 39% of the Elephant Island stations; the three largest concentrations there (100-200 per 1000 m3) were located over deep basins south of Elephant and Clarence Islands and in the far northeast corner. Scattered modest catches were also made over the inner Shetland Island shelf area. Mean concentrations in the West and Elephant Island Areas (2.7 and 16 per 1000 m3) were substantially lower than in the Joinville Island and South Areas. The overall distribution of *I. racovitzai* was associated with Zone IV and V water and reflected mixing and implied transport of Weddell Sea and Bransfield Strait waters. Overall distributions of *I. racovitzai* and *S. thompsoni* had a strong negative correlation ($T = -0.3$, $P < 0.001$) suggesting different source waters. Casareto and Nemoto (1986) also noted spatial separation of these species.

<u>Composition, Size and Distribution (Table 4.9; Figures 4.8A & B, 4.9, 4.10A & B)</u>

The aggregate form made up 95% of *S. thompsoni* individuals. These ranged in size from 5-64mm, with a continuous range of 5-56mm and lengths distributed around a 30mm median and mode. These lengths suggest an early September onset and mid-November peak of chain production with little recent budding activity. Length-frequency distributions were fairly uniform across the West, South and Elephant Island Areas however cluster analysis of samples with at least 50 aggregates indicated two spatially coherent groups with significantly different attributes ($D_{max} = 45.3$, $P < 0.01$). These clusters, represented at similar numbers of stations, were aligned more or less parallel to bottom topography. Cluster 2, comprised of older larger individuals (median 33mm, mid-November peak release), was distributed in bands over the outer offshore shelf region and south of the South Shetland Islands and was largely associated with intensified northeast flow. Younger Cluster 1 individuals (23mm median, early-December peak release) primarily occurred offshore centered around the Shackleton Fracture Zone and between the South Shetland Island northern shelf and south shelf of Elephant Island, areas characterized by gyres and eddies. Aggregates are considered to be reproductively mature at about 25mm so the two clusters represent, predominantly mature (Cluster 2) and maturing populations (Cluster 1) in relatively advective vs. retentive zones.

Solitaries were represented by individuals ranging from 4-151mm but overall modal and median lengths of 6-8mm and 30mm, respectively, indicate a predominantly newly released and immature composition. Over twice as many solitaries and greater proportions of reproductively mature sizes (>60mm) were associated with Cluster 1 aggregates supporting its comparatively young composition (i.e., the location of late season aggregate chain production) in areas characterized by hydrographic retention.

Salp and krill carbon biomass estimates are based on abundance of each size category collected at each station and therefore reflect changes in distributions, concentrations and length over space and time. During Survey A mean and median salp carbon biomass values within the Elephant Island Area were respectively about 120 and 85 mg per m2. Due to more even (less patchy) salp distributions this median value was three times greater than that of krill.

Ihlea racovitzai individuals were predominantly aggregates (>99%). These ranged in length from 4-36mm with a 20mm median and 22mm mode. The solitaries were 17-54mm with a 28mm mode. Cluster analysis performed on length distributions in samples with at least 16 individuals did not provide any meaningful patterns.

4.3.1.3 Zooplankton and Micronekton Assemblage:

Overall Composition and Abundance (Tables 4.4A, 4.5A)

A total of 90 taxonomic categories were identified. These include larval and postlarval stages of krill and other euphausiid species and seven copepod species. The median number of taxa identified per sample was 22. Copepods comprised the most frequent and numerous taxonomic category. These were present at all but one station and contributed 46% of total mean zooplankton abundance. Coastal copepod species, *Metridia gerlachei*, although present in only 78% of samples, contributed over 23% of total mean abundance and was by far the most abundant species. *Salpa thompsoni* contributed 17% of the total and ranked 2 in abundance. Postlarval *Thysanoessa macrura* were present in all but three samples and had mean and median abundance values only slightly smaller than those of *S. thompsoni*. Two additional copepod species, *Calanoides acutus* and *Calanus propinquus* were both present in 89 of 91 samples, together contributed about 18% to the total and ranked fourth and fifth most abundant species. Next in contributions to overall mean abundance were postlarval krill (4.3%), *Ihlea racovitzai* (3.6%) and chaetognaths (3.5%)

Distribution Patterns (Figures 4.11A & B)

Greatest copepod concentrations were primarily in Bransfield Strait and portions of the Elephant Island A influenced by Weddell Sea water. These included shelf areas of Livingston, King George and Elephant Islands and other locations that, based on implied flow, were likely to be influenced by frontal zones and eddies. Lowest concentrations prevailed in offshore Drake Passage regions with minimal mixing with coastal water. Elevated abundance of postlarval *T. macrura* occurred in Bransfield Strait and over South Shetland and Elephant Island shelf areas characterized by mixed Zone II and IV water while greatest concentrations of *T. macrura* larvae generally occurred in Drake Passage; unlike previous surveys the negative correlation between their distributions was not significant (T=-0.14, P>0.5).

Areal Differences (Table 4.5A)

Mean and median zooplankton abundance values for the South and Joinville Areas were slightly, but not significantly, greater than those of the West and Elephant Island Areas (1,026-1,364 per 1000 m3 vs. 718-982 per 1000 m3). Species richness was greatest in the Joinville Island Area where the five samples yielded 52 taxa with a mean of 26 taxa per tow. South and Elephant Island Area samples on average collected 22-24 taxa. The West Area was comparatively species-poor with on average only 18 taxa per sample, significantly less than in the other areas (ANOVA P<0.05).

Overall species abundance relationships were most similar for the South vs. Elephant and Joinville Island Areas (PSIs = 76 and 71, respectively); those of the West Area differed substantially from the rest (PSIs 39-60) due to relatively large proportion of offshore stations in the Area. Only two of the more common species had significantly greater abundance in the West vs. other Areas, the pteropod *Limacina helicina* (West >Elephant Island, P<0.01) and amphipod *Themisto gaudichaudii* (West >all others, P<0.001). West Area abundance of the copepod *Paraeuchaeta antarctica* was significantly less than in all other areas (P<0.001). In contrast, Joinville Island and South Area abundance of *Ihlea racovitzai* and pteropod *Clione limacina* were significantly greater than in the West and Elephant Island Areas (P<0.01) and Joinville Island Area abundance of the polychaete *Tomopteris* spp. exceeded than of all other areas (P<0.001).

Zooplankton Assemblages (Table 4.6A; Figure 4.12A)

Cluster analysis applied to abundance of taxa present in >20% of samples yielded two groupings with distinctly different species abundance relations as indicated by a low PSI value of 53. These formed an "onshore" group, at 44 stations largely associated with Bransfield Strait Zone IV water, and "offshore" group located at 47 stations associated with Zone II water. The onshore zooplankton assemblage was significantly more abundant and taxonomically-rich than that offshore (ANOVA, P<0.001 in both cases) largely due to greater concentrations of the copepods *Metridia gerlachei*, *Calanus propinquus*, *Paraeuchaeta antarctica*, *Pleuromamma robusta* and *Rhincalanus gigas*, and to a lesser extent chaetognaths, *Ihlea racovitzai*, ostracods, *Tomopteris* spp. and amphipod *Cyllopus lucasii*. Common taxonomic categories represented by similar abundance in both assemblages include broadly distributed postlarval krill, *T. macrura* and *E. frigida*, *S. thompsoni*, *L. helicina* and radiolaria.

Within the onshore assemblage a strong positive correlation existed between the distributions of *I. racovitzai* and siphonophore *Diphyes antarctica* (P<0.01) both of which were most abundant over deep basins in central Bransfield Strait and outer northern shelf of South Shetland and Elephant Islands. Distributions of copepods, chaetognaths and ostracods were also strongly correlated (P<0.01) with greatest concentrations located along the southern Shetland Island shelf, the Loper Channel between King George and Elephant Islands and the northeast corner of the Elephant Island Area. Overall, the distributions of amphipods *Vibilia antarctica*, *C. lucasii* and *C. magellanicus* were all significantly correlated with *S. thompsoni* reflecting their association (parasitic or commensal) with this salp.

Diel Abundance Variations

Analysis of variance indicated significant diel abundance differences for a number of categories including total zooplankton and total copepods and result from diel vertical migrations. *Salpa thompsoni*, the copepod *P. robusta* and *E. frigida* were significantly more abundant during night and twilight than day. Krill and *M. gerlachei* had significantly greater night versus day and twilight abundance. *Ihlea racovitzai* and *Rhincalanus gigas* were more abundant during night than day. Interestingly, salp-affiliated amphipods *C. lucasii* and *C. magellanicus* were significantly more abundant during twilight than either day or night and *V. antarctica* during twilight vs. day.

4.3.2 Survey A Between-Year Comparisons:

4.3.2.1 Krill:

Post larvae (Tables 4.7, 4.8A)

January 2004 mean krill abundance in the Elephant Island Area was about average and the median about half the mean value for the 1992-2004 period. An order of magnitude decrease from 2003 resulted from poor recruitment of the 2002/03 year class compared to that of 2001/02. Low recruitment success relative to the previous two years is indicated by the small proportion of juveniles compared to January 2002 and 2003 surveys (<2% vs. 42-46%). Interannual recruitment variations over the past four years are also indicated by the length-frequency distribution with the 1999/00, 2000/01 and 2001/02 year classes now representing the dominant 35-50mm length range. Recruitment indices based on January survey data indicate high values for the 1999-2002 period (R1 values 0.573, 0.403 and 0.478) contrasting with an extremely low value for 2003 (0.001) signifying recruitment failure from the previous year class (V. Siegel, pers. comm.).

Few of the mature females were in advanced reproductive stages compared to most January surveys. This is in part due to the large contribution by maturing 2-year old individuals; unusually large numbers of stage F2, and even stage F3a females of 30-35mm lengths were noted this year. Similar low proportions of advanced F3d (gravid) and F3e (spent) stages were observed in January 1992, 1998 and 2003. Even more unusual this year were relatively large numbers of males >40mm (3+) that were not fully mature; such a large proportion of M2c and M3a stages during January is unprecedented in the long term data set. This could reflect delayed maturation or, in light of the extremely early onset of spawning activity, "rejuvenation" of a post-spawning component of the population.

Larvae (Tables 4.3; 4.7)

Despite low proportions of advanced female and male maturity stages mean and median larval krill abundance in the Elephant Island Area (10 and 0.4 per 1000 m3) were greater than the lows observed during the 1996, 1998 and 2003 January surveys. These were most similar to values observed during 2003. Moderate proportions of Furcilia 1 and 2 stage larvae, particularly in the South and Joinville Island Areas, were also observed during January 2002 and suggested an early initiation of seasonal spawning activity.

4.3.2.2 Salps:

Salpa thompsoni (Tables 4.7, 4.9)

Mean and median salp abundance were a bit below average for the long term Elephant Island data set; proportions of aggregates and solitaries were typical. Given slightly lower abundance of both salps and krill, their carbon biomass 3:1 ratio remained about average for the 1995-2004 period. The salp length-frequency distribution, indicating an aggregate production period initiated in spring (i.e. early September) with a mid-November peak and little subsequent budding activity, was also typical. Thus the 2003/04 spring-summer period, like that of most other years, contrasts strongly with 1996/97 and 1997/98, characterized by prolonged periods of elevated chain production, and 1994/95, marked by temporally limited pulses of chain production.

Ihlea racovitzai (Tables 4.10A, 4.12)

The frequency of occurrence and abundance of this salp species sets the 2004 and 1998 apart from all other years. Large numbers of this high latitude salp in the Antarctic Peninsula region were first noted during summer 1986 when catches were reported from the vicinity of Seymour Island (northwest Weddell Sea), Bridgeman, Brabant and Trinity Islands (Bransfield Strait) and Biscoe and Adelaide Islands (West Antarctic Peninsula; Esnal and Daponte, 1990). It was also reported to be abundant in the South Shetland Island Area during December 1990-January 1991 (Nishikawa *et al.*, 1995). *Ihlea racovitzai* was first noted in AMLR samples during January 1998 when it comprised the fourth most abundant taxon overall and ranked 8 in abundance within the Elephant Island Area. Greatest concentrations then, extending between the northern shelves of Elephant and South Shetland Islands into Bransfield Strait south of King George Island, suggested the Polar Slope Current (a deep westward flowing current from the Weddell Sea) as the source (E. Hofmann, pers. comm.). Greatest concentrations over deep basins within Bransfield Strait during January 2004 support this association. However, the reported presence over the West Antarctic Peninsula during 1986 (Esnal and Daponte, 1990) indicates that this species could also have been advected into the area from the west.

Zooplankton and Micronekton (Tables 4.7, 4.10A, 4.11, 4.12)

During January 2004 copepods comprised 50% of total mean zooplankton abundance in the Elephant Island Area which is "normal" compared to extreme lows in 1994 and 1998 (4-5%) and the high in 2002 (76%). Mean and median abundance of three dominant species *M. gerlachei*, *C. acutus* and *C. propinquus* as well as total copepods were quite similar to the 2003 values; total copepod abundance during January 2003 and 2004 were about 40% below the long-term averages of 838 and 338 per 1000 m3. Of note during January 2004 were relatively large numbers of *P. robusta* and absence of "other" copepods, primarily small species.

Overall abundance relationships and proportional contributions of the five most abundant taxonomic categories (copepods, *S. thompsoni*, *T. macrura*, krill and chaetognaths) were quite similar to those of January 1997 (PSI=90). The presence of *I. racovitzai* and relatively large proportions of ostracods and pteropod *Limacina helicina* in 2004 versus relatively large proportions of larval krill and *T. macrura* in 1997 distinguish the two seasons.

4.3.3 Survey D, 2004

4.3.3.1 Krill:

Frequency and Abundance (Table 4.1B, Figure 4.1B)

Postlarval krill were present in 74 of 97 (76%) Survey D samples with an overall mean abundance of 73 per 1000 m3. Greatest mean abundance was within the South (168 per 1000 m3) and Joinville Island (72 per 1000 m3) Areas. Similar means were represented in the West and Elephant Island Areas (approximately 51 per 1000 m3). Individuals were most evenly distributed across the Elephant and Joinville Island Areas as indicated by high frequency of occurrence (92% and 88%) and median abundance values (approximately 10 per 1000 m3) relative to the South and West Areas (approximately 60% of samples, median abundance <1 per 1000 m3). Greatest concentrations (approximately 6,400 and 2,950 individuals, 2,300 and 1,220 per 1000 m3) occurred south of Deception Island and north of King George Island resulting in large standard deviations associated with abundance means (i.e. enhanced patchiness) within the South and West Areas.

Length and Maturity Stage Composition (Table 4.2; Figures 4.2C & D; 4.3G-N)

Krill lengths ranged from 18-60mm with a 40mm median; the majority of individuals (72%) were 35-50mm while 23% were <35mm and 5% >50mm. The overall length-frequency distribution was polymodal around 33-35 (age-class 2), 43-45 (age-class 3) and 50 mm (age-class 4) lengths and, in contrast to Survey A, reflected substantially different size compositions within the four subareas (D_{max}=35-80). Most extreme differences occurred between the Elephant Island Area dominated by large krill (77% 42-52mm, 47mm median) and South Area dominated by smaller individuals (78% 32-38mm, 35mm median). More uniform length distributions occurred within the West Area (82% 37-47mm, 43mm median) and Joinville Island Area (81% 32-42mm, 38mm median).

Juveniles only constituted 4% of the total krill catch supporting Survey A observations that the 2002/03 year class had relatively poor recruitment success. The older individuals included 51% immature and 45% mature stages with equal representation of males and females. More than half of the mature females were in advanced stages (52% F3d-e) and 80% of mature males were producing spermatophores (M3b); these results indicate a late-season pulse of spawning activity that continued into March. Juveniles and immature stages were most abundant in the South Area where they constituted, respectively, 9% and 78% of the total. Juveniles were also relatively abundant in the Joinville Island Area (6%) but here mature forms comprised 34% compared to 13% in the South. Mature stages strongly dominated the Elephant Island (84%) and West (78%) Area catches; juveniles were essentially absent from the Elephant Island Area and contributed only 2% in the West Area. Males outnumbered females by ca. 50% in both areas. Although stage M3b males were similarly represented substantially greater proportions of advanced female stages occurred in the Elephant Island vs. West Area (83% vs. 26%).

Distribution Patterns (Figures 4.4B; 4.5C & D)

Cluster analysis applied to length-frequency distributions in 40 samples yielded three groups. The length/age/maturity stage composition and spatial distribution of these groups were similar to those of Survey A. Cluster 1 krill were smallest: 93% were <40mm and the median length was 37mm. Juveniles were largely restricted to this group and comprised 6% while immature stages were 73%, of the total. This group of largely 1 and 2 age-class krill was located at nine stations primarily within Bransfield Strait. Cluster 2 krill were predominantly age-class 3 with 71% of individuals 40-49mm and a 43mm median length; immature and mature stages made up 36% and 64%, respectively. Males outnumbered females by 80%; 45% of mature females were in advanced maturity stages (gravid or spent). This group occurred at 14 stations located over the north shelf of the South Shetland Islands and primarily deeper areas northwest and east of Elephant Island. Cluster 3 was comprised of larger, predominantly mature 3 year and older individuals: 73% were 45-54mm; median length was 48mm; 10% were immature and 90% mature. Males and females were more equally represented (1.3:1 ratio) and 77% of mature females were in advanced stages. This actively spawning group was represented at 17 primarily offshore stations, 15 of which were within the Elephant Island Area.

4.3.3.2 Larval Krill:

<u>Distribution, Abundance and Stage Composition (Tables 4.3, 4.4, 4.5B; Figure 4.6B)</u>

Larval krill were present at 85 of the 97 (88%) Survey D stations with relatively large mean and median abundance values of 108 and 20 per 1000 m3, respectively. Generally high concentrations (including the two largest 5,160 and 590 per 1000 m3) were located around the Shackleton Fracture Zone and in Bransfield Strait south of Elephant Island. Accordingly, they were most frequent and abundant in the Elephant (92% of samples, 177 and 39 per 1000 m3 mean and median) and Joinville Island (100% of samples, 87 and 41 per 1000 m3 mean and median) Areas where they were, respectively, the fifth and fourth most abundant taxonomic category. Although relatively frequent (88% of samples) lowest mean and median larval krill abundance was in the South Area (23 and 5 per 1000 m3).

Overall, furcilia outnumbered calyptopis larvae due to the abundance and proportions (61%) of these more advanced stages (primarily F2 and F3) in the Elephant Island Area. Calyptopis stages comprised 73-99% of larvae in the other areas. Samples with >50% furcilia larvae were located in a band offshore of the Elephant Island shelf, over deep basins of the Joinville Island Area and over southern shelves of the South Shetland Islands. Stations with >50% early calyptopis (C1) larvae were mostly offshore of the South Shetland Island shelves, in a band extending between King George and Elephant Islands and in central Bransfield Strait south of the South Shetland Islands. Along with abundance these distributions suggest both Weddell Sea and Antarctic Circumpolar Current Southern Boundary (ACC-SB) sources and accumulation in areas characterized by frontal zones and eddies (See Physical Oceanography Report, this volume). Based on the long-term AMLR data set, large concentrations of advanced larvae in conjunction with active spawning in the Elephant Island Area during February-March reflect a prolonged and successful reproductive effort that bodes well for recruitment success of the 2003/04 year class.

4.3.3.3 Salps:

<u>Frequency and Abundance (Tables 4.4; 4.5B; Figure 4.7B)</u>

Salpa thompsoni occurred in 88 (91%) of the Survey D samples with overall mean and median abundance of 123 and 32 per 1000 m3. The three greatest concentrations (1,030 to 1,448 per 1000 m3) were located offshore adjacent to the Shackleton Fracture Zone; other moderately high concentrations (>100 per 1000 m3) were also primarily located offshore, in Bransfield Strait southwest of King George Island and between King George and Elephant Islands. This salp was absent from most of the southern Bransfield Strait stations. Greatest concentrations tended to occur near the boundaries between Water Zones I and II offshore and water Zones II and IV over the island shelves suggesting accumulation via frontal zones and increased eastward advection associated with onshore intrusion of the ACC (See Physical Oceanography Report, this volume). Consequently, abundance in the West and Elephant Island Areas (means 140 and 159 per 1000 m3, medians 15 and 39 per 1000 m3) were about an order of magnitude greater than in the South and Joinville Island Areas but these differences were not significant.

Ihlea racovitzai occurred in approximately 53% of the samples. It was primarily collected within Bransfield Strait, around Elephant Island and over the northern island shelf area and was largely associated with Zone IV (Bransfield Strait) water. Overall mean and median abundance were 22 and 0.6 per 1000 m3. Frequency of occurrence was highest in the South and Joinville Island Areas (about 75% of samples) followed by the Elephant Island Area (51%). Greatest concentrations (100-259 per 1000 m3) occurred between Elephant and Joinville Island Areas; greatest mean and median abundance values (47 and 33 per 1000 m3) were within the Joinville Island Area. Abundance within Joinville and Elephant Island Areas was significantly greater than in the West Area ($P<0.05$). Unlike Survey A, the negative correlation between distributions of *S. thompsoni* and *I. racovitzai* were not significant possibly due to enhanced eastward transport and mixing processes.

Composition, Size and Distribution (Table 4.9; Figures 4.8C & D)

Solitary stages of *S. thompsoni* were unusually abundant and contributed 46% of total individuals. Solitaries ranged in size from 5-145mm; 76% were <11mm and resulted from recent production; 11% were >60mm sexually mature lengths. Aggregate lengths ranged from 6-67mm; the continuous range was 6-55mm. Overall aggregate length distribution was polymodal around 11, 26, 31 and 41mm modes and had a 22mm median; 26% were recently budded forms <11mm in length. Greatest proportions of recently budded (<11mm) aggregates were in the Joinville and Elephant Island (51% and 31% of aggregates) vs. West and South Areas (19% and 10%). Recently spawned small solitaries comprised 87% and 74% of the solitary catch in the West and Elephant Island Areas but only 3% in the Joinville Island Area; they were absent from the South. These results indicate both a seasonally prolonged, pulsed aggregate production period and active production of the overwintering solitary stage in the Elephant Island and West Areas. Unlike Survey A, cluster analysis applied to aggregate length-frequency distributions did not yield meaningful and/or spatially coherent results.

Mean and median salp carbon biomass values within the Elephant Island Area were about 123 and 42 mg per m2, respectively; both were lower than those of krill. The salp:krill biomass ratio derived from their median values was 0.5:1

Aggregates constituted 98% of total *I. racovitzai* individuals. These were 5-35mm in length with 18 and 20mm median and modal values. Solitaries ranged from 8-67mm with 20 and 18mm median and modal values.

4.3.3.4 Zooplankton and Micronekton Assemblage:

Overall Composition and Abundance (Tables 4.4, 4.5B)

The 97 Survey D samples yielded 105 taxonomic categories; median richness was 24 taxa per sample. Copepods strongly dominated; they were present in all samples with high respective mean and median abundance values of approximately 4,410 and 1,790 per 1000 m3 and contributed 72% of total mean zooplankton abundance. Nine copepod species were identified including *Heterorhabdus* species which previously had been lumped in the "other copepod" category. Four species, *M. gerlachei*, *C. acutus*, *C. propinquus* and *R. gigas*, each outnumbered all other zooplankton taxa. Of these *M. gerlachei* followed by *C. acutus* were most abundant and together contributed 43% of total mean zooplankton abundance. Chaetognaths, present at 94 stations with mean and median values of about 333 and 127 per 1000 m3, ranked second to total copepods. Although not particularly frequent, radiolaria and larval *T. macrura* (present in 46% and 68% of samples, respectively) ranked 3 and 4 in mean abundance due to occasionally dense concentrations. These were followed by more widely spread postlarval *T. macrura*, *S. thompsoni* and larval krill.

Distribution Patterns (Figures 4.11C & D)

Six of the eight greatest copepod concentrations (14,200-12,041 per 1000 m3) were in Zone I water adjacent to the Shackleton Fracture Zone; the remaining two (15,690 and 23,930 per 1000 m3) were located southwest of Elephant Island and south of Clarence Island. Relatively large concentrations (i.e., >1,000 per 1000 m3) also occurred over the South Shetland Island shelves and deeper waters surrounding Elephant Island. Three of the four largest chaetognath concentrations (1,120-7,570 per 1000 m3) were also adjacent to the Shackleton Fracture Zone. Most of the larger radiolaria catches, and all of the largest concentrations, occurred offshore of the island shelf area particularly near the Shackleton Fracture Zone. Postlarval *T. macrura* tended to be most abundant inshore of the northern island shelves while their larvae were generally more abundant offshore; as in previous surveys their distribution patterns had a significant negative correlation ($T=-0.31$, $P<0.001$).

Areal Differences (Table 4.5B)

Taxonomic richness (medians 22-24 taxa per sample), total zooplankton abundance, absolute and relative abundance of most taxa were fairly similar within the four areas. PSI values from comparison of overall taxonomic composition were moderate (60-84) with greatest similarity between the West and Elephant Island (84) and South and Joinville Island (71) Areas. Among the few taxa with significant areal abundance differences the copepod *Pleuromamma robusta* and amphipod *Themisto gaudichaudii* were more abundant in the West vs. other areas (ANOVA, $P<0.01$), postlarval *T. macrura* and *Primno macropa* were more abundant in the South vs. Elephant and Joinville Island Areas, *I. racovitzai* and *Diphyes antarctica* had greater abundance in the Elephant and Joinville Island vs. West Areas ($P<0.05$ in all cases). These differences are reflected in mean abundance rankings within the various areas.

Zooplankton Assemblages (Table 4.6B; Figure 4.12B)

Cluster analysis again yielded two groups with onshore and offshore distributions however, these were quite different from the clusters identified during Survey A. Onshore Cluster 1 was present at 82 Survey D stations and therefore distributed across most of the area. Offshore Cluster 2 was located at 15 stations around and to the west of the Shackleton Fracture Zone, primarily associated with Zone I water (i.e., ACC-SB). While the clusters had similar taxonomic richness their species abundance relationships differed markedly as indicated by a low PSI value of 42. This dissimilarity was due primarily to large proportions of *M. gerlachei* and postlarval *T. macrura* in broadly spread onshore Cluster 1 and of *C. acutus*, *R. gigas*, radiolaria and larval *T. macrura* in the spatially limited offshore Cluster 2. Abundance of total zooplankton and of most taxa were significantly greater offshore. Only three taxa, postlarval *T. macrura*, *I. racovitzai* and *D. antarctica*, had significantly greater concentrations onshore. Twelve taxa were equally abundant in both assemblages: postlarval krill; *E. frigida*; *E. triacantha*; *M. gerlachei*; *P. robusta*; ostracods; salp associates *V. antarctica* and *C. lucasii*; *T. gaudichaudii*; larval *Electrona* spp., *L. kempi* and *L. larseni*.

Total copepods (primarily *C. acutus*, *C. propinquus*, *R. gigas*) and krill larvae were significantly more abundant offshore; there a strong positive correlation existed between their distributions ($T=+0.68$, $P<0.001$). Abundance of both calyptopis and furcilia stage krill larvae were significantly greater in the offshore assemblage although calyptopis stages were proportionately more abundant onshore (84% vs. 24% of larvae). Significant positive correlations existed between distributions of *M. gerlachei* and calyptopis stages ($T=+40$, $P<0.001$) at onshore stations and of *P. robusta* and furcilia stages ($T=+0.50$, $P<0.01$) at offshore stations. Overall, strong positive correlations existed between distributions of *S. thompsoni* and *C. lucasii*, *C. magellanicus* and *V. antarctica* across the Survey D Area.

Diel Abundance Variations

A relatively large number of taxa demonstrated significant diel abundance differences. Those with greater concentrations in the upper water column during night vs. day and twilight include postlarval *T. macrura*, *E. frigida*, *S. thompsoni*, *C. lucasii* (ANOVA, $P<0.01$), postlarval krill and ostracods ($P<0.05$). *Metridia gerlachei* and *C. magellanicus* had greater night and twilight vs. day abundance ($P<0.05$) and *I. racovitzai* were more abundant during night than day ($P<0.05$).

4.3.5 Survey A and D (Seasonal) Comparisons:

4.3.5.1 Postlarval Krill:

Distribution, Abundance, Length and Maturity Stage Composition (Tables 4.2, 4.4, 4.5; Figures 4.1, 4.2, 4.3, 4.4, 4.5)

Overall abundance and maturity stage composition of postlarval krill were fairly constant between the two surveys. However, seasonal distribution changes resulted in increased patchiness and lower median values in the West and South Areas and more uniform concentrations and increased median abundance in the Elephant and Joinville Island Areas. These changes were associated with increased proportions of mature stages in the West and Elephant Island Areas and of predominantly immature stages in the Joinville Island Area. Reproductively advanced males and females contributed substantially greater proportions to the total catch during Survey D (30 vs. 18%) indicating late-season spawning activity. The concentration of these stages in the Elephant Island and West Areas suggests onshore migration of reproductively active forms.

Overall, greater proportions of larger, older krill occurred during Survey D; this was most evident in the Elephant Island Area where significantly greater proportions were >44mm in length compared to the previous month (D_{max}=39; $P<0.01$). This is in accordance with seasonal onshore migration of large, and in this case actively spawning krill, particularly into the Elephant Island Area.

As noted above, the three krill clusters had similar distributions both surveys with Cluster 1 krill mostly south of the islands and Cluster 3 krill offshore of the island shelf area. Of interest is the offshore location of Cluster 2 krill east of the Shackleton Fracture Zone; this appears to be associated with northward flow here during both surveys (see Physical Oceanography Section). Length-frequency distributions of Clusters 1 and 2 were quite similar both surveys (D_{max}=about 5) while Cluster 3 had 20% more individuals >46mm in length (i.e., increased proportions of age-class 4 and older krill) during Survey D. Cluster 1 had greater proportions of immature females (F2) vs. mature stages while Clusters 2 and 3 had larger proportions of male and female spawning stages during Survey D. Overall, greatest changes between the two surveys were in Cluster 3 and reflect migration associated with a prolonged spawning season rather than post-reproductive and ontogenetic onshore migration (Siegel, 1988).

Larvae (Tables 4.3, 4.4, 4.5; Figure 4.6)

Overall abundance of calyptopis stage larvae was significantly greater during Survey D and resulted from significant abundance increases within all four areas (ANOVA, $P<0.01$ in all cases). Although furcilia stages were also much more abundant during Survey D, the seasonal difference was not significant due to their extremely patchy distributions. Inclusion of more advanced F3 stage (about 85 days old) larvae during Survey D supports the early November initiation of spawning activity. Distributions of calyptopis and furcilia larvae suggested primarily a Weddell Sea source during Survey A but both Weddell Sea and offshore sources during Survey D with resulting concentrations located primarily over deep basins in eastern Bransfield Strait and near the Shackleton Fracture Zone.

Salps (Tables 4.4, 4.5, 4.9; Figures 4.7, 4.8)

Median *S. thompsoni* abundance during Survey D was approximately 30% that of Survey A due to decreased catch sizes in all, but particularly, the West and Elephant Island Areas. This was associated with substantially increased abundance and proportions of small overwintering solitaries which contributed 60 and 42% of individuals in the West and Elephant Island Areas. The strong late-season pulse of aggregate production was limited to the Elephant Island Area but even there small recently released solitaries outnumbered small aggregates by nearly 2:1. The continuous aggregate size range was similar both surveys suggesting substantial loss of larger individuals (e.g., >45mm) from the upper water column through ontogenetic migration and/or mortality (Foxton, 1966; Caserto and Nemoto, 1986). The lack of apparent pattern in aggregate length-frequency distributions during Survey D may be a consequence of late-season behavior and/or altered hydrographic conditions (e.g., augmented eastward flow and/or mixing).

As a consequence of elevated and more uniform krill concentrations and decreased salp abundance and length composition in the Elephant Island Area the salp:krill carbon biomass ratio decreased from 3:1 to 0.5:1 between the two surveys.

Ihlea racovitzai was more frequent during Survey D (53% vs. 43% of samples) due to broader distributions across the South, West and Elephant Island Areas. Although still most abundant in the Joinville Island Area, mean Survey D abundance was doubled in the Elephant Island Area compared to 30 and 90% reductions of mean and median abundance in the Joinville Island and South Areas, respectively; West Area abundance was similar both surveys. These distribution changes suggest decreased Polar Slope Water influence in Bransfield Strait, particularly the western portion, and increased northward transport and mixing across the Elephant Island Area during Survey D. This would also account for the greater overlap in *S. thompsoni* and *I. racovitzai* distributions compared to Survey A. Maturity stage and length composition of *I. racovitzai* were similar both surveys.

Zooplankton (Tables 4.4, 4.5, 4.6; Figures 4.11, 4.12)

Total zooplankton abundance during Survey D was significantly greater than Survey A (ANOVA, P<0.01). This was due to order of magnitude increases in copepods (specifically *C. propinquus*, *M. gerlachei*, *P. antarctica* and "others"), chaetognaths and larval *T. macrura* (ANOVA, P<0.01) augmented by significantly greater numbers of krill calyptopis larvae, postlarval *E. frigida*, *T. gaudichaudii*, *P. macropa*, *S. australis*, *C. magellanicus* and larval *Electrona* spp. Among the common taxa only *S. thompsoni* had decreased mean and median abundance values during Survey D. Altered species abundance relations between the two surveys are reflected in a relatively low PSI value of 59. Although abundance ranks of individual copepod species remained the same, copepods comprised 72% of total mean zooplankton abundance during Survey D vs. 46% during Survey A due to substantial increases in proportions of oceanic species *C. acutus*, *C. propinquus* and *R. gigas*. Numerically dominant *M. gerlachei* contributed similar proportions (22-23%) both surveys. In contrast, postlarval *T. macrura* and *S. thompsoni* contributed, respectively, 12% and 15% less to total mean zooplankton abundance during Survey D. In terms of ranked abundance the top three taxa after copepods were *S. thompsoni*, postlarval *T. macrura* and krill during Survey A and chaetognaths, radiolaria and larval *T. macrura* during Survey D.

Cluster analyses resulted in distinct onshore and offshore zooplankton assemblages during both surveys. The most dramatic seasonal changes occurred in the distribution, abundance and abundance relations of the offshore assemblage. This assemblage present at 47 stations during Survey A was limited to 15 stations during Survey D. These were in the vicinity of the Shackleton Fracture Zone, an area characterized by an influx of Zone I water and hydrographic features associated with the ACC-SB. Here mean and median abundance of total zooplankton and dominant taxa were increased by one to two orders of magnitude over the previous survey.

Among copepods the offshore Cluster 2 abundance increases of *C. acutus*, *R. gigas*, *C. propinquus*, *M. gerlachei* and *P. antarctica* were all significant (P<0.01). Cluster 2 abundance increases of chaetognaths, larval *T. macrura* and *L. helicina* were also significant at P<0.01. As a consequence of these increases species abundance relations were radically different from those of the Survey A offshore assemblage (PSI=32). Numerical dominance of the offshore assemblage by *S. thompsoni* and postlarval *T. macrura*, and to a lesser extent krill and *L. helicina* during Survey A was replaced by an assemblage dominated by *C. acutus, R. gigas, C. propinquus*, radiolaria, larval *T. macrura* and *M. gerlachei.*

In contrast the onshore Cluster 1 assemblage demonstrated modest seasonal changes. Although this assemblage was more broadly distributed during Survey D, (82 vs. 44 stations) the composition and abundance relations were fairly similar both surveys (PSI=80) and mean and median abundance of total zooplankton and individual taxa generally demonstrated modest two to three fold seasonal increases. Among the copepods abundance increases were significant for *C. acutus*, *R. gigas*, *C. propinquus* and *P. antarctica* (P<0.01). Chaetognaths, larval krill, *P. macropa* and *E. frigida* also had abundance increases significant at P<0.01. Overall, the onshore assemblage was characterized by dominance and relatively stable abundance relations of *M. gerlachei, C. acutus, C. propinquus* and postlarval *T. macrura*; seasonal changes primarily reflected increased proportions of oceanic taxa *R. gigas, P. antarctica* and chaetognaths and decreased proportions of *S. thompsoni* and *I. racovitzai.*

The rapidity of zooplankton distribution, abundance and composition changes as well suggest underlying hydrographic rather than biological processes. This is likely due to the influx of ACC-SB at the Shackleton Fracture Zone and associated changes faunal source waters and hydrographic regimes between the two surveys.

4.3.6 Survey D Between-Year Comparisons:

4.3.6.1 Krill (Tables 4.3, 4.7, 4.8, 4.9):

Postlarvae

Mean krill abundance in the Elephant Island Area during Survey D, like Survey A, was about average for the 1992-2004 period (54 per 1000 m3). However, the median value (10 per 1000 m3) was the highest for the 13 year period; relatively large median values also occurred during the 2003 and 1992 D surveys (8.1 and 7.1 per 1000 m3, respectively). Virtual absence of juveniles from the Elephant Island Area was common to the February-March surveys in 1999, 2000 and 2004 and reflected poor recruitment success the previous spawning season compounded by seasonal onshore migrations out of the area. The overall maturity stage composition, with relatively large proportions of advanced female and male stages, indicative of late-season spawning activity, was most similar to that during February-March 1995 (PSI=82) and 2000 (PSI=79) and likewise might presage good recruitment success the following year.

Larvae

Widespread distribution of krill larvae across the Survey D Area (88% of samples) exceeds all other years except 1995 (93%) but then sampling was limited to the Elephant Island Area and around King George Island. Mean and median larval krill abundance values in the Elephant Island Area during February-March 2004 were an order of magnitude less than during 1995 and 2000 (both followed by strong recruitment, R1=0.622 and 0.573, respectively), but at least two and eight times greater than during 2001 and 2002 (also with strong recruitment, R1=0.403 and 0.478). More striking than the widespread distribution, was the large contribution of furcilia stage larvae (56% of total), particularly in the Elephant and Joinville Island Areas. Furcilia contributed between 11-15% of total larvae sampled during Survey D in 1996, 2002 and 2003. Within the five year period for which comparable data are available, furcilia were also relatively abundant (30% and 60%) in the Elephant and Joinville Island Areas during 2002. The relatively large proportions of F2 and F3 stage larvae in the Elephant Island Area during the 2004 Survey D far exceed the high contributions observed in the Joinville Island Area during 2001. Based on the present data set the combination of widespread geographic distribution, elevated abundance and relatively large proportions of advanced larval krill stages during Survey D all bode well for strong recruitment of the 2003/2004 year class. To have four out of the past five years marked by strong krill recruitment success would be unprecedented in the historic Elephant Island Area record that, before 2002, was characterized by strong recruitment every one our of four or five years (Loeb *et al.*, 1997).

<u>Salps (Tables 4.7, 4.9)</u>

<u>*Salpa thompsoni*</u>

Mean and median abundance values of *S. thompsoni* in the Elephant Island Area during Survey D were, like Survey A, increased somewhat (three and six times, respectively) over those the previous year. However, the February-March 2003 and 2004 values, along with those from 1995 and 1996, lie well below average for the 1993-2004 period. Although the 2003 and 2004 values are an order of magnitude greater than the extreme lows of 1995 and 1996 these two two-year sequences of relatively low salp abundance remain distinct from the other years. Salp:krill carbon biomass relationships from these four periods (0.1-0.5 reflecting krill dominance) also sets them apart from other years.

<u>*Ihlea racovitzai*</u>

This salp species was less frequent (53 vs. 65% of samples) and abundant (22 vs. 52 per 1000 m3 mean) than during the 1998 D Survey but values from these two years were at least one order of magnitude greater than those observed in 2000-2003. Elevated abundance during both years was associated with enhanced westward flow of Weddell Sea water and deep Polar Slope water into Bransfield Strait and relatively extensive coverage of cold surface water across the survey area (Loeb *et al.*, in prep.). The northward distribution shift observed during 2004 suggests a large-scale advective change associated with influx of the ACC-SB that did not occur during 1998 when the distribution was more like that during Survey A 2004.

<u>Zooplankton (Tables 4.7, 4.10, 4.11, 4.12)</u>

In contrast to the previous month, mean and median copepod abundance values in the Elephant Island Area were well above average and ranked third after the extreme highs in February-March 2002 and 2000. This primarily reflected large concentrations of *C. acutus*, *C. propinquus*, and *R.*

gigas, however, *P. antarctica* and *H. ocellatus* were also relatively abundant compared to February-March 2001 and 2003. Below average values of *M. gerlachei* were similar to those observed during 2001 and 2003. Among the other zooplankton taxa, mean and median abundance of larval and postlarval *T. macrura* were about average and most similar to those in 1995 and 1996, respectively; above average chaetognath abundance values were also most like those of 1996. Overall abundance relationships in the Elephant Island Area during February-March 2004 were most like those in 1994 (PSI>85) and 2002 (PSI=80). Interestingly 1994 and 2004 were both characterized by substantial rapid seasonal zooplankton abundance increases attributed to increased influence of the ACC-SB in vicinity of the Shackleton Fracture Zone (Loeb *et al.*, in prep.). Zooplankton assemblage differences were greatest between 2004 and 1998 (PSI=14) due to extreme contrasts in copepod and *Salpa thompsoni* dominance and overall taxonomic richness.

4.4 AMLR 2004 Cruise Summary and Long-Term Perspective:

(1) The overall krill length-frequency distribution (predominantly 35-60mm individuals) reflected strong recruitment success of 1999/00, 2000/01 and 2001/02 year classes (respective R1 values, provided by V. Siegal, 0.573, 0.403, 0.478) and minimal representation from the 2002/03 spawning season (R1=0.001).

(2) Presence of relatively advanced furcilia (F2) larval stages during Survey A and relatively large concentrations of these and older F3 stages during Survey D indicated an extremely early initiation of spawning (early to mid-November 2003). Unusually large proportions of immature reproductive stages, particularly among large krill, during January may have been "rejuvenating" post-spawning individuals.

(3) Substantial concentrations of early calyptopis (C1 and C2) larvae in conjunction with large proportions of reproductive adult stages during Survey D indicated a prolonged spawning period extending into March 2004. Based on past observations, prolonged reproductive efforts and abundant advanced larval stages presage good recruitment success the following year; given optimal overwintering conditions a reasonable expectation would be an R1 value of about 0.5 for the 2003/04 year class.

(4) The two 2004 surveys covered a period of rapid and dramatic change in zooplankton and nekton abundance, species composition and species abundance relations. Similar abrupt changes were also observed over the 1994 and 1997 field seasons and were believed to result from hydrographic processes. Those process, involving large-scale atmospheric coupling, sea-ice and atmospheric pressure anomalies as described by Venegas and Drinkwater (2001), exhibit a periodicity of about 3-4 years and are attributed to propagation by the Antarctic Circumpolar Wave; they are thus linked to the El Niño-Southern Oscillation (ENSO; Peterson and White, 1998).

(5) The 1994 and 1997 austral summers were previously described as "transition" periods between years with numerical dominance by either salps or copepods ("salp years" and "copepod years"). These shifts were most extreme in 1994 when the relative abundance of salps went from 81% to 12%, and copepods from 4% to 82%, of total mean zooplankton abundance within the Elephant Island Area. The "transition" in 2004 was comparatively modest and reflects a trend

for more stable copepod, salp and other zooplankton abundance relationships since 1998 (Table 4.12).

(6) Based on the 1979-2004 Elephant Island data sets seasonal abundance means of copepods and S. thompsoni had a significant negative correlation prior to 1999 (N= 10, T=-0.56, P<0.05) reflecting the marked fluctuations between salp and copepod dominance. However, after 1998 their abundance relations changed dramatically (Figure 4.13A) and have been positively correlated (N=6, T=+0.47). This has been associated with a significant order of magnitude increase in mean copepod abundance between the two periods (ANOVA, P<0.05). Other zooplankton taxa such as Euphausia frigida and chaetognaths also demonstrated significant abundance increases (P<0.01) after 1998 (Figure 4.13B).

(7) Obvious changes in krill recruitment success in recent years (Figure 4.14A) are consistent with these observations of large-scale ecosystem change after 1998. Associated with increased frequency of strong year classes (Figure 4.14B) was a change from decreasing krill population size between 1979 and 1999 (r2=0.24; B= -0.49; P<0.05) to a period of population growth (r2=0.23, B=+0.48) starting with the 1999/00 year class.

(8) Given past associations between krill recruitment success, salp abundance fluctuations and sea ice development (Loeb *et al.*, 1997) it is not surprising to note changes in sea ice variability in recent years (Figure 15A). Strong interannual variability in sea ice development within the Antarctic Peninsula region (Hewitt, 1996) observed between 1979 and 2000 was associated with a significant trend for decreased spatial and temporal sea ice extent (r2=0.20, B=-0.46; P<0.05). However, seasonal sea ice development has been relatively stable since 2000 (r2=0.02, B=+0.14).

(9) The 1976-1998 period was distinguished by a "warm phase" in the North Pacific Ocean , however this changed after the 1998 el Niño in what is acknowledged as a regime shift affecting the entire Pacific Ocean basin (Chavez *et al.*, 2003). This is seen in plots of the Pacific Decadal Oscillation which demonstrates alterations between positive and negative sea surface temperature anomalies which persist on the order of 20-30 years (Figure 4.15B). The dramatic ecological changes observed in the AMLR survey area were coincidental with this regime shift and, per Nicol *et al.* (2000), reflect changes in oceanic circulation and primary productivity (Loeb *et al.*, in prep.).

4.5 Disposition of Data and Samples: All of the krill, salp and other zooplankton data have been digitized and are available upon request from Valerie Loeb. These data have been submitted to Roger Hewitt (Southwest Fisheries Science Center). Frozen krill and myctophids were provided to Mike Goebel (Southwest Fisheries Science Center) for chemical analyses. Preserved krill samples were saved for chemical analyses by Adina Paytan (Stanford University) and Julian Ashford (Old Dominion University) and for demographic work by Steve Nicol and co-workers (Australian Antarctic Division).

4.6 Problems and Suggestions:

(1) Ship Operations: A major problem encountered during the past two field seasons has been a ship policy decision to maintain an extraordinarily large distance away from physical features

such as ice bergs and coastlines. This policy has caused us loss of ship time and stations during some of the most benign conditions encountered in the Southern Ocean. Some reasonable compromise must be established whereby the ships Captain should be allowed to command the ship as he feels safe and to work with the scientific party to achieve their field season goals.

(2) Field Season Report.

Event Log. The usefulness of the AMLR field season report would increase through the regular inclusion of an "Event Log" listing times, locations and specifics of events occurring over each survey (e.g., CTD cast, time start and end, location start and end, water depth, primary productivity data collected; IKMT tow, time, location, water depth, flow volume; ancillary activities). Such information, regularly logged by the various program components, would help ground-truth data sets used for scientific collaborations. Its placement ideally would be included in the overview section which precedes individual component reports.

Consistency. Trying to mine past field season reports for coherent and meaningful insights into trends over the past 13 years has been extraordinarily frustrating due to lack of consistency in what and how information is presented. Obviously the P.I.'s want to protect their data sets and don't want to just add new numbers to last field season's boiler plate verbage. However, there are ways of synthesizing data to present meaningful results (e.g., mean values and associated standard deviations for different survey areas) without allowing one's data to be scooped. Essential and important sorts of information should be identified for each program component and these should be included in standard and consistent formats in all future field season reports. One example is the regular inclusion of dynamic height information for each survey as part of the Hydrography section; this information is very important for understanding zooplankton distribution patterns. Another example would be regular inclusion of integrated 0-100m Chl-*a* data for each of the survey areas allowing some appreciation for long-term variations.

(3) Zooplankton Van. The zooplankton van would benefit from modifications making it more comfortable and more easily maintained. 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. Should funds become available a new van designed specifically to accommodate needs of the zooplankton and fish stock assessment programs would be in order.

(4) Zooplankton Team. The zooplankton team relies on experienced personnel, preferably ones with a history with the AMLR Program. Unfortunately, we find ourselves with a chronic problem of having to locate acceptable participants and then go through the training process. This problem would be in part addressed through the support of graduate students who would participate in annual field season activities and help mine the wealth of AMLR data as part of their thesis/dissertation work.

(5) Collaboration. Collaboration among the AMLR scientists should be encouraged and supported. In the distant past the program held work sessions in order to coordinate and encourage collaborative efforts but those failed dismally, probably due to combination of personalities and the program's newness. Now with a wealth of data and insight resulting from

14 years of experience it is time to focus on data synthesis and production of publishable multidisciplinary manuscripts.

(6) Additional Recommendations. Over the past several years one of the stated objectives in AMLR cruise plans is to "collect tissue samples from killer whales, time and circumstances permitting". These samples will be used to determine whether there are three separate species of killer whales in the Antarctic, two of which occur within the AMLR study area. Unfortunately, due to time constraints and the relatively inflexible sampling schedule, we have not had opportunity to achieve this objective during occasions when we have sighted killer whales. Therefore, I recommend scheduling several extra days during one of the cruise legs to pursuing this objective. One of the two whale types is associated with icy coastal regions where they prey upon abundant krill-feeding seals. An ideal area to locate and sample these whales is Gerlache Strait. Ship time spent there could also be invested in assessing krill stock size and the abundance and composition of other macrozooplankton than support resident seal populations.

4.7 References:

Casareto, B.E., and Nemoto, T. 1986. Salps of the Southern Ocean (Australian Sector) during the 1983-84 summer, with special reference to the species *Salpa thompsoni*, Foxton 1961. Memoirs of the National Institute of Polar Research, Special Issue, 40: 221-239.

Chavez, F.P., Ryan, J., Luch-Cota, S.E., and Ñiguen, C.M. 2003. From anchovies to sardines and back: multidecadal change in the Pacific Ocean. *Science* 299(5604): 217-221.

Esnal, G.B., and Daponte, M.C. 1980. Stolon development and some aspects of musculature in the characterization of *Ihlea racovitzai* (van Beneden, 1913) and *Ihlea magalhanica* (Apstein, 1894) (Tunicata, Thaliacea). *Polar Biology* 10: 265-268.

Foxton, P. 1966. The distribution and life history of *Salpa thompsoni* Foxton, with observations on a related species, *Salpa gerlachei,* Foxton. *Discovery Report* 34: 1-116.

Loeb, V., Siegel, V., Holm-Hansen, O., Hewitt, R., Fraser, W., Trivelpiece, W., and Trivelpiece, S. 1997. Effects of sea-ice extent and krill or salp dominance on the Antarctic food web. *Nature* 387: 897-900.

Loeb, V., Hofmann, E.E., Klinck, J.M., Hewitt, R., and Holm-Hansen, O. In Preparation. Hydrographic control of copepod and salp distributions in the South Shetland-Elephant Island and Bransfield Strait region. To be submitted to *Deep-Sea Rearch.*

Makarov, R.R., and Denys, C.J.I. 1981. Stages of sexual maturity of *Euphausia superba.* BIOMASS Handbook 11.

Nicol, S., Pauly, T., Bindoff, N.L., Wright, S., Thiele, D., Hosie, G.W., Strutton, P.G. and Woehler, E. 2000. Ocean circulation off east Antarctica affects ecosystem structure and sea-ice extent. *Nature* 406: 504-507.

Nishikawa, J., Naganobu, M., Ichii, T., Ishii, H., Terazaki, M., and Kawaguchi, K. 1995. Distribution of salps near the South Shetland Islands during austral summer, 1990-1991 with special reference to krill distribution. *Polar Biology* 15: 31-39.

Peterson, R.G., and White, W.W. 1998. Slow oceanic teleconnections linking the Antarctic Circumpolar Wave with the tropical El Niño-Southern Oscillation. *Journal of Geophysical Research* 103(C11): 24573-24583.

Siegel, V. 1987. Age and growth of Antarctic Euphausiacea (Crustacea) under natural conditions. *Marine Biology* 96: 483-495.

Siegel, V. 1988. A concept of seasonal variation of krill (*Euphausia superba*) distribution and abundance west of the Antarctic Peninsula. Pp. 219-230 *In* D. Sahrhage (ed.) Antarctic Ocean and Resources Variability. Springer-Verlag, Berlin.

Siegel, V. and Loeb, V. 1994. Length and age at maturity of Antarctic krill. *Antarctic Science* 6: 479-482.

Spiridonov, V.A. 1995. Spatial and temporal variability in reproductive timing of Antarctic krill (*Euphausia superba* Dana). *Polar Biology* 15: 161-174.

Venegas, S.A. and M.R. Drinkwater. 2001. Sea ice, atmosphere and upper ocean variability in the Weddell Sea, Antarctica. *Journal of Geophysical Research* 106(C8): 16747-16765.

Table 4.1. AMLR 2004 Large-area survey IKMT station information. Double lines denote subarea divisions.

A. SURVEY A

STATION NO	DATE	TIME START (LOCAL)	TIME END (LOCAL)	DIEL	TOW DEPTH (m)	FLOW VOL. (m3)	KRILL ABUNDANCE TOTAL	KRILL ABUNDANCE NO/m2	KRILL ABUNDANCE NO/1000m3
WEST AREA:									
A18-12	16/01/04	1308	1336	D	170	3012.1	258	14.6	85.7
A19-11	16/01/04	1640	1708	D	170	2697.9	45	2.8	16.7
A19-09	17/01/04	0701	0727	D	170	2615.5	5	0.3	1.9
A18-10	17/01/04	1057	1123	D	170	2406.9	0	0.0	0.0
A17-11	17/01/04	1441	1503	D	170	2728.9	14	0.9	5.1
A16-10	17/01/04	1803	1829	D	170	2455.9	2	0.1	0.8
A17-09	17/01/04	2125	2153	D	170	2559.3	23	1.5	9.0
A18-08	18/01/04	0056	0122	N	170	2335.9	27	2.0	11.6
A17-07	18/01/04	0433	0458	T	170	2279.5	1	0.1	0.4
A16-08	18/01/04	0756	0825	D	170	2773.8	95	5.8	34.2
A15-09	18/01/04	1120	1147	D	168	2420.4	2	0.1	0.8
A14-10	18/01/04	1346	1413	D	170	2528.7	1	0.1	0.4
A13-09	18/01/04	1650	1716	D	170	2535.5	6	0.4	2.4
A14-08	18/01/04	1955	2019	D	170	2247.3	44	3.3	19.6
A15-07	19/01/04	0046	0110	T	178	2342.1	3	0.2	1.3
A16-06	19/01/04	0413	0441	T	170	2654.7	0	0.0	0.0
A15-05	19/01/04	0729	0754	D	172	2312.2	0	0.0	0.0
A14-06	19/01/04	1046	1111	D	170	2261.2	2	0.2	0.9
A13-07	19/01/04	1446	1512	D	170	2330.1	4	0.3	1.7
A12-08	19/01/04	1755	1821	D	170	2236.2	12	0.9	5.4
A11-07	19/01/04	2116	2142	D	170	2635.3	175	11.3	66.4
A11-05	20/01/04	0137	0202	N	170	2550.0	10	0.7	3.9
A11-03	20/01/04	0545	0609	D	170	2443.6	9	0.6	3.7
A11-01	20/01/04	1010	1038	D	170	2719.5	0	0.0	0.0
ELEPHANT ISLAND AREA:									
A09-01	21/01/04	0111	0136	N	170	2342.3	489	35.5	208.8
A09-02	21/01/04	0405	0430	T	170	2314.3	4	0.3	1.7
A09-03	21/01/04	0704	0732	D	170	2631.9	3	0.2	1.1
A09-04	21/01/04	0955	1022	D	170	2551.1	8	0.5	3.1
A09-05	21/01/04	1340	1408	D	170	2772.7	186	11.4	67.1
A09-06	21/01/04	1640	1705	D	170	2406.5	34	2.4	14.1
A09-07	21/01/04	1930	1955	D	170	2472.4	36	2.5	14.6
A09-08	21/01/04	2223	2253	T	168	2630.9	1	0.1	0.4
A08-08	22/01/04	0201	0229	N	170	2898.8	2	0.1	0.7
A08-06	22/01/04	0626	0656	D	170	2588.2	99	6.5	38.3
A08-04	22/01/04	1044	1110	D	170	2377.8	58	4.1	24.4
A08-02	22/01/04	1536	1604	D	170	2946.0	9	0.5	3.1
A07-01	22/01/04	1901	1926	D	170	2412.7	7	0.5	2.9
A07-02	22/01/04	2155	2222	T	170	2326.2	0	0.0	0.0
A07-03	23/01/04	0055	0120	N	170	2186.3	349	27.1	159.6
A07-04	23/01/04	0550	0619	D	170	2769.3	24	1.5	8.7
A07-05	23/01/04	0952	1022	D	170	2712.1	15	0.9	5.5
A07-06	23/01/04	1345	1413	D	170	2816.8	88	5.3	31.2
A07-07	23/01/04	1809	1836	D	170	2852.2	3	0.2	1.1
A07-08	23/01/04	2101	2124	D	170	2249.4	600	45.3	266.7
A05.5-08	24/01/04	0024	0048	N	170	2142.2	3	0.2	1.4
A05.5-07	24/01/04	0241	0307	N	170	2516.9	2	0.1	0.8
A05.5-06	24/01/04	0555	0614	D	110	1797.9	133	8.1	74.0
A05.5-05	24/01/04	0829	0851	D	140	1971.8	16	1.1	8.1
A05.5-04	24/01/04	1123	1148	D	170	2299.7	201	14.9	87.4
A05.5-03	24/01/04	1440	1516	D	170	2501.2	91	6.2	36.4
A05.5-02	24/01/04	1746	1813	D	170	2518.6	22	1.5	8.7
A05.5-01	24/01/04	2021	2049	D	170	2407.7	1	0.1	0.4
A04-01	25/01/04	0035	0100	N	170	1958.4	1532	133.0	782.3
A04-02	25/01/04	0410	0435	T	170	2139.1	16	1.3	7.5
A04-03	25/01/04	0704	0732	D	170	2732.6	2	0.1	0.7
A04-04	25/01/04	0959	1025	D	170	2455.5	6	0.4	2.4
A04-05	25/01/04	1244	1310	D	170	2591.2	20	1.3	7.7
A04-06	25/01/04	1730	1745	D	85	1345.4	2	0.1	1.5
A04-07	25/01/04	2108	2135	D	170	2462.6	1	0.1	0.4
A04-08	26/01/04	0013	0041	N	170	2826.9	2409	144.9	852.2
A03-08	26/01/04	0314	0340	T	170	2122.5	0	0.0	0.0
A03-06	26/01/04	1333	1400	D	170	2728.6	1	0.1	0.4

Table 4.1 (Contd.)

STATION NO	DATE	TIME START (LOCAL)	TIME END (LOCAL)	DIEL	TOW DEPTH (m)	FLOW VOL. (m3)	KRILL ABUNDANCE TOTAL	NO/m2	NO/1000m3
A03-04	26/01/04	1822	1849	D	170	2349.6	0	0.0	0.0
A03-02	26/01/04	2240	2305	T	170	2288.1	7	0.5	3.1
A02-01	27/01/04	0208	0234	N	170	2142.6	35	2.8	16.3
A02-02	27/01/04	0514	0544	D	170	2675.7	19	1.2	7.1
A02-03	27/01/04	0814	0842	D	171	2614.4	0	0.0	0.0
A02-04	27/01/04	1118	1143	D	170	2214.9	1	0.1	0.5
A02-05	27/01/04	1356	1423	D	170	2385.5	0	0.0	0.0
A02-07	27/01/04	1905	1931	D	170	2572.1	0	0.0	0.0
JOINVILLE ISLAND AREA:									
A03-09	27/01/04	2320	2350	T	170	2579.5	2	0.1	0.8
A05-09	28/01/04	0358	0425	T	170	2151.6	2	0.2	0.9
A06-09	28/01/04	0655	0720	D	170	2158.6	0	0.0	0.0
A06-10	28/01/04	0932	0959	D	171	2506.8	0	0.0	0.0
A06-11	28/01/04	1156	1217	D	170	2441.5	0	0.0	0.0
SOUTH AREA:									
A07-11	28/01/04	1422	1449	D	170	2411.6	1	0.1	0.4
A08-10	28/01/04	1810	1835	D	170	2395.8	508	36.0	212.0
A09-09	28/01/04	2114	2139	D	172	2241.9	6	0.5	2.7
A10-10	29/01/04	0109	0135	N	170	2675.7	182	11.6	68.0
A09-11	29/01/04	2019	2046	D	170	2626.0	3	0.2	1.1
A11-11	30/01/04	0217	0244	N	170	2545.9	1	0.1	0.4
A12-10	30/01/04	0459	0524	T	170	2269.8	1	0.1	0.4
A13-11	30/01/04	0834	0902	D	172	2975.2	0	0.0	0.0
A12-12	30/01/04	1217	1245	D	170	2769.2	6	0.4	2.2
A13-13	30/01/04	1615	1640	D	171	2323.4	293	21.6	126.1
A14-12	30/01/04	2005	2032	D	170	2710.2	1	0.1	0.4
A15-13	30/01/04	2318	2344	T	170	2242.4	3	0.2	1.3
A14-14	31/01/04	0155	0221	N	170	2332.4	0	0.0	0.0
A15-15	31/01/04	0724	0750	D	170	2388.1	896	63.8	375.2
A16-14	31/01/04	1022	1050	D	170	2752.4	688	42.5	250.0
A17-13	31/01/04	1334	1403	D	170	2765.1	3	0.2	1.1

			TOTAL	NO/m2	NO/1000m3
SURVEY A TOTAL:	N = 91		9869		
		MEAN		7.5	44.7
		STD		22.6	132.7
		MEDIAN		0.4	2.2
WEST AREA:	N = 24		738		
		MEAN		1.9	11.3
		STD		3.6	21.2
		MEDIAN		0.4	2.1
ELEPHANT ISLAND AREA:	N = 46		6535		
		MEAN		10.1	59.8
		STD		29.0	170.5
		MEDIAN		0.5	3.1
JOINVILLE ISLAND AREA:	N = 5		4		
		MEAN		0.1	0.3
		STD		0.1	0.4
		MEDIAN		0.0	0.0
SOUTH AREA:	N = 16		2592		
		MEAN		11.1	65.1
		STD		19.1	112.1
		MEDIAN		0.2	1.2

Table 4.1 (Contd.)

B. SURVEY D

STATION NO	DATE	TIME START (LOCAL)	TIME END (LOCAL)	DIEL	TOW DEPTH (m)	FLOW VOL. (m3)	KRILL ABUNDANCE TOTAL	KRILL ABUNDANCE NO/m2	KRILL ABUNDANCE NO/1000m3
WEST AREA:									
D18-12	20/02/04	0337	0403	N	172	2537.0	54	3.7	21.3
D19-11	20/02/04	0704	0731	D	170	2470.5	0	0.0	0.0
D20-10	20/02/04	1052	1120	D	170	2620.0	0	0.0	0.0
D19-09	20/02/04	1523	1553	D	170	2645.1	1	0.1	0.4
D18-10	20/02/04	1903	1931	D	171	2461.2	5	0.3	2.0
D17-11	20/02/04	2148	2215	T	166	2318.6	0	0.0	0.0
D16-10	21/02/04	0122	0150	N	170	2362.1	35	2.5	14.8
D17-09	21/02/04	0512	0538	T	170	2234.4	35	2.7	15.7
D18-08	21/02/04	0847	0912	D	170	2238.4	0	0.0	0.0
D17-07	21/02/04	1253	1320	D	170	2516.3	58	3.9	23.1
D16-08	21/02/04	1700	1725	D	171	2399.1	1	0.1	0.4
D15-09	21/02/04	2054	2120	T	169	2350.5	0	0.0	0.0
D14-10	21/02/04	2248	2314	N	168	2440.9	6	0.4	2.5
D13-09	22/02/04	0308	0334	N	170	2176.7	19	1.5	8.7
D14-08	22/02/04	0612	0640	T	170	2457.1	2	0.1	0.8
D15-07	22/02/04	0958	1024	D	170	2613.2	0	0.0	0.0
D16-06	22/02/04	1342	1410	D	170	2597.0	0	0.0	0.0
D15-05	22/02/04	1655	1721	D	170	2510.4	0	0.0	0.0
D14-06	22/02/04	2025	2054	T	170	2487.3	1	0.1	0.4
D13-07	23/02/04	0008	0035	N	170	2405.4	2	2.6	0.8
D12-08	23/02/04	0344	0414	N	170	2422.5	2950	207.0	1217.7
D11-07	23/02/04	0754	0821	D	170	2280.8	4	0.3	1.8
D11-05	23/02/04	1246	1314	D	173	2565.7	0	0.0	0.0
D11-03	23/02/04	1728	1755	D	168	2507.9	0	0.0	0.0
D11-01	24/02/04	0048	0112	N	169	2060.1	6	0.5	2.9
NT ISLAND AREA:									
D09-01	24/02/04	0610	0640	T	171	2357.4	0	0.0	0.0
D09-02	24/02/04	0920	0950	D	170	2424.4	228	16.0	94.0
D09-03	24/02/04	1217	1245	D	170	2515.4	48	3.2	19.1
D09-04	24/02/04	1511	1539	D	169	2499.1	3	0.2	1.2
D09-05	24/02/04	1810	1836	D	168	2805.3	0	0.0	0.0
D09-06	24/02/04	2102	2128	T	170	2354.3	75	5.4	31.9
D09-07	25/02/04	0242	0314	N	170	2821.1	450	27.1	159.5
D09-08	25/02/04	0507	0534	T	171	2484.8	26	1.8	10.5
D08-08	25/02/04	0757	0825	D	170	2543.2	0	0.0	0.0
D08-04	25/02/04	1746	1813	D	168	2473.0	30	2.0	12.1
D08-02	25/02/04	2155	2222	N	168	2770.8	269	16.3	97.1
D07-01	26/02/04	0127	0156	N	170	2866.5	9	0.5	3.1
D07-02	26/02/04	0421	0448	N	169	2459.7	10	0.7	4.1
D07-03	26/02/04	0720	0746	D	170	2505.9	26	1.8	10.4
D07-04	26/02/04	1043	1113	D	170	2906.7	6	0.4	2.1
D07-05	26/02/04	1406	1432	D	168	2800.1	322	19.3	115.0
D07-06	26/02/04	1727	1750	D	170	2034.8	0	0.0	0.0
D07-07	26/02/04	2014	2040	T	170	2585.5	9	0.6	3.5
D07-08	26/02/04	2301	2327	N	170	2441.7	374	26.0	153.2
D05.5-08	27/02/04	0247	0311	N	170	2263.8	342	25.7	151.1
D05.5-07	27/02/04	0537	0604	T	170	2451.3	2	0.1	0.8
D05.5-06	27/02/04	0827	0848	D	110	2116.7	2	0.1	0.9
D05.5-05	27/02/04	1112	1135	D	120	2136.0	0	0.0	0.0
D05.5-04	27/04/02	1427	1454	D	170	2668.2	6	0.4	2.2
D05.5-03	27/02/04	1727	1757	D	169	2972.5	3	0.2	1.0
D05.5-02	27/02/04	2042	2108	T	168	2687.1	50	3.1	18.6
D05.5-01	27/02/04	2323	2350	N	169	2440.4	213	14.8	87.3
D04-01	28/02/04	0314	0342	N	170	2775.5	214	13.1	77.1
D04-02	28/02/04	0615	0646	T	171	2396.7	20	1.4	8.3
D04-03	28/02/04	0908	0937	D	171	2574.4	3	0.2	1.2
D04-04	28/02/04	1211	1241	D	170	2782.2	85	5.2	30.6
D04-05	28/02/04	1508	1538	D	171	3254.3	104	5.5	32.0
D04-06	28/02/04	1949	2006	T	82	1720.4	1	0.0	0.6
D04-07	28/02/04	2235	2304	N	171	2443.8	213	14.9	87.2
D04-08	29/02/04	0150	0216	N	170	2438.0	3	0.2	1.2
D03-08	29/02/04	0514	0539	T	172	2272.6	465	35.2	204.6

Table 4.1 (Contd.)

STATION NO	DATE	TIME START (LOCAL)	TIME END (LOCAL)	DIEL	TOW DEPTH (m)	FLOW VOL. (m3)	KRILL ABUNDANCE TOTAL	NO/m2	NO/1000m3
D03-06	29/02/04	0905	0934	D	170	2575.0	2	0.1	0.8
D03-04	29/02/04	1401	1429	D	168	2772.9	11	0.7	4.0
D03-02	29/02/04	1813	1842	D	170	2615.4	39	2.5	14.9
D02-01	29/02/04	2135	2203	N	170	2707.6	1050	65.9	387.8
D02-02	01/03/04	0044	0110	N	169	2585.2	157	10.3	60.7
D02-03	01/03/04	0337	0405	N	170	2599.0	1105	72.3	425.2
D02-04	01/03/04	0630	0655	T	171	2506.0	36	2.5	14.4
D02-05	01/03/04	0904	0931	D	170	2332.0	69	5.0	29.6
D02-06	01/03/04	1503	1531	D	170	2373.0	39	2.8	16.4
D02-07	01/03/04	1817	1846	D	169	2779.5	12	0.7	4.3
D02-08	01/03/04	2050	2115	T	170	2214.2	2	0.2	0.9
LE ISLAND AREA:									
D02-09	02/03/04	0036	0059	N	170	2780.0	470	28.7	169.1
D03-09	02/03/04	0345	0414	N	170	2903.8	52	3.0	17.9
D04-09	02/03/04	0730	0803	D	170	2143.3	57	4.5	26.6
D04-10	02/03/04	1038	1107	D	170	2645.7	3	0.2	1.1
D05-10	02/03/04	1323	1352	D	170	2722.2	974	60.8	357.8
D05-09	02/03/04	1713	1740	D	169	2692.9	1	0.1	0.4
D06-09	02/03/04	2040	2108	T	170	2533.4	2	0.1	0.8
D06-10	02/03/04	2332	2358	N	170	2371.4	0	0.0	0.0
)UTH AREA:									
D07-11	03/03/04	0701	0728	D	170	2621.5	0	0.0	0.0
D08-10	03/03/04	1027	1054	D	170	2547.4	3	0.2	1.2
D09-09	03/03/04	1305	1327	D	145	2218.6	0	0.0	0.0
D10-10	03/03/04	1644	1717	D	170	2857.9	0	0.0	0.0
D09-11	03/03/04	2019	2045	T	168	2402.4	0	0.0	0.0
D10-12	04/03/04	0137	0205	N	170	2662.5	15	1.0	5.6
D11-11	04/03/04	0511	0539	N	171	2779.0	1224	75.3	440.5
D13-11	04/03/04	0539	0604	T	170	2426.7	38	2.7	15.7
D12-12	05/03/04	0923	0950	D	171	2544.1	0	0.0	0.0
D11-13	05/03/04	1239	1307	D	170	2570.1	1	0.1	0.4
D13-13	05/03/04	1638	1704	D	168	2466.5	0	0.0	0.0
D14-12	05/03/04	2002	2027	T	168	2324.7	6	0.4	2.6
D15-13	05/03/04	2335	0001	N	172	2477.3	2	0.1	0.8
D14-14	06/03/04	0255	0324	N	170	2778.5	6370	389.7	2292.6
D15-15	06/03/04	0632	0657	T	170	2606.7	4	0.3	1.5
D16-14	06/03/04	1002	1032	D	170	2439.8	0	0.0	0.0
D17-13	06/03/04	1323	1352	D	170	2485.4	225	15.4	90.5

			TOTAL	NO/m2	NO/1000m3
SURVEY D TOTAL:	N=97		18759		
		MEAN		12.5	73.4
		STD		45.9	270.3
		MEDIAN		0.4	2.5
WEST AREA:	N=25		3179		
		MEAN		9.0	52.5
		STD		40.4	237.9
		MEDIAN		0.1	0.4
ELEPHANT ISLAND AREA:	N=47		6133		
		MEAN		8.6	50.6
		STD		15.4	90.7
		MEDIAN		1.8	10.5
JOINVILLE ISLAND AREA:	N=8		1559		
		MEAN		12.2	71.7
		STD		20.5	120.7
		MEDIAN		1.6	9.5
SOUTH AREA:	N=17		7888		
		MEAN		28.5	167.7
		STD		92.0	541.2
		MEDIAN		0.1	0.8

Table 4.2 Maturity stage composition of krill collected in the large survey area and subareas during January-March 2004. Advanced maturity stages are proportions of mature females that are 3c-3e in January and 3d-3e in February.

	Euphausia superba January 2004				
AREA	Survey A	West	Elephant I.	Joinville I.	South
STAGE	%	%	%	%	%
Juveniles	3.8	3.0	1.8	-----	9.0
Immature	48.0	31.0	38.5	-----	77.4
Mature	48.2	66.0	59.7	-----	13.6
Females:					
F2	9.5	1.9	4.3	-----	25.1
F3a	16.0	20.0	18.1	-----	9.7
F3b	6.0	10.4	7.5	-----	1.0
F3c	8.1	4.4	11.2	-----	1.1
F3d	0.3	0.3	0.1	-----	0.9
F3e	0.4	0.3	0.6	-----	0.0
Advanced Stages	28.6	14.1	31.7	-----	15.7
Males:					
M2a	13.1	8.0	7.4	-----	29.2
M2b	15.6	12.8	14.7	-----	18.6
M2c	9.9	8.3	12.2	-----	4.4
M3a	8.7	12.8	11.5	-----	0.2
M3b	8.7	17.7	10.8	-----	0.6
Male:Female	1.4	1.6	1.4	-----	1.4
No. measured	2454	511	1410	-----	533

	February 2004				
AREA	Survey D	West	Elephant I.	Joinville I.	South
STAGE	%	%	%	%	%
Juveniles	4.2	1.8	0.1	5.9	9.2
Immature	50.7	20.4	16.3	60.6	78.2
Mature	45.1	77.8	83.6	33.5	12.6
Females:					
F2	22.6	3.7	2.9	41.2	42.0
F3a	9.6	18.5	3.7	19.0	10.6
F3b	0.9	0.0	0.3	1.1	0.0
F3c	1.1	7.4	2.2	0.3	0.0
F3d	7.2	9.3	17.0	3.0	0.8
F3e	5.4	0.0	13.0	4.4	0.5
Advanced Stages	56.7	47.4	88.8	27.6	10.6
Males:					
M2a	10.8	5.6	2.4	9.3	19.9
M2b	12.1	5.6	7.3	6.4	14.3
M2c	5.2	5.6	3.7	3.8	2.0
M3a	3.4	0.0	4.8	2.2	0.1
M3b	17.4	42.6	42.7	3.5	0.7
Male:Female	1:1	1.5:1	1.6:1	0.4:1	0.7:1
No. measured	3047	329	2081	271	366

Table 4.3. Larval krill stage composition in (A) Large Survey areas, 1996-2004, and (B) total and individual areas, 2000-2004. Only pooled calyptopis and furcilia stages provided for 1996-1999. Individual stages provided for 2000-2004 surveys.

(A) Large Survey Area

STAGE %	A96	A97	A98	A99	A00	A01	A02	A03	A04
Calyptopis Total	100	93	68	100	n.a.	100	70	100	95
Furcilia Total	---	7	32	---	n.a.	---	30	---	5

STAGE %	D96	D97	D98	D99	D00	D01	D02	D03	D04
Calyptopis Total	86	100	99	97	97	98	85	89	44
Furcilia Total	14	---	1	3	3	2	15	11	56

(B) Total, Elephant Island, West, South and Joinville Island Areas

SURVEY	A00				A01				A02					A03					A04				
STAGE %					Total	West	Eleph	South	Total	West	Eleph	South	Joinvl	Total	West	Eleph	South	Joinvl	Total	West	Eleph	South	Joinvl
C1	---	---	---	---	24.0	17.6	68.4	95.3	37.3	50.0	40.3	13.9	5.0	87.5	77.7	89.7	100	100	64.5	80.0	63.4	60.7	68.2
C2	---	---	---	---	66.3	72.7	22.1	---	15.8	50.0	16.3	7.0	2.9	9.6	1.9	8.8	---	---	18.5	8.3	22.1	7.6	24.9
C3	---	---	---	---	9.7	9.7	9.3	---	17.4	---	20.3	---	52.5	3.6	20.4	1.5	---	---	10.3	---	12.4	8.6	---
Unid.	---	---	---	---	---	---	0.2	4.7	---	---	---	---	---	---	---	---	---	---	1.8	4.3	2.0	---	---
Calyptopis Total	---	---	---	---	100	100	100	100	70.5	100	76.9	20.9	60.4	100	100	100	100	100	95.1	92.6	100	76.9	93.1
F1	---	---	---	---	---	---	---	---	9.6	---	6.2	35	38.2	---	---	---	---	---	3.7	---	---	19.3	6.9
F2	---	---	---	---	---	---	---	---	19.9	---	17.0	44.1	1.4	---	---	---	---	---	0.7	---	---	3.9	---
F3	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Unid.	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	0.6	7.4	---	---	---
Furcilia Total	---	---	---	---	---	---	---	---	29.5	---	23.1	79.1	39.6	---	---	---	---	---	4.9	7.4	---	23.1	6.9

SURVEY	D00				D01				D02					D03					D04				
STAGE %	Total	West	Eleph	South	Total	West	Eleph	South	Total	West	Eleph	South	Joinvl	Total	West	Eleph	South	Joinvl	Total	West	Eleph	South	Joinvl
C1	46.3	48.8	46.3	32.6	57.1	37.6	58.4	17.8	18.5	3.2	42.2	50.3	---	67.7	100	63.4	78.8	100	17.0	31.6	14.2	37.5	17.8
C2	40.5	29.3	40.5	55.2	29.8	36.1	29.4	15.2	12.1	16.7	4.1	49.7	15.6	21.2	---	22.8	21.2	---	15.1	27.1	10.7	29.6	41.3
C3	9.9	21.1	9.8	12.2	11.2	18.0	10.7	67.0	49.5	70.0	23.5	---	29.5	---	---	---	---	---	11.8	40.2	8.0	14.9	13.5
Unid.	0.6	---	0.6	---	---	0.8	---	---	5.3	9.5	---	---	---	---	---	---	---	---	---	---	---	---	---
Calyptopis Total	96.9	99.2	96.9	100	98.2	92.5	98.6	100	85.5	99.3	69.8	100	45.1	---	---	---	---	---	43.9	98.9	32.9	82.0	72.6
F1	1.4	0.8	1.4	---	1.8	7.4	1.4	---	10.4	0.7	22.8	---	26.8	1.1	---	1.3	---	---	5.8	1.1	5.8	9.0	11.4
F2	1.2	---	1.2	---	---	0.1	---	---	3.4	---	7.4	---	12.1	10.0	---	12.5	---	---	24.5	---	29.3	4.7	13.4
F3	0.1	---	0.1	---	---	---	---	---	0.7	---	---	---	16.1	---	---	---	---	---	25.6	---	31.6	4.3	2.6
Unid.	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	0.3	---	0.4	---	---
Furcilia Total	2.7	0.8	2.7	---	1.8	7.5	1.4	---	14.5	0.7	30.2	---	54.9	---	---	---	---	---	56.1	1.1	67.1	18.0	27.4

Table 4.4. Composition and abundance of zooplankton assemblages sampled in large Survey A and D areas, January-March, 2004. F(%) is frequency of occurrence in samples. R is rank and % is percent of total mean abundance represented by each taxon. L and J denote larval and juvenile stages.

	AMLR 2004 SURVEY A (N=91)							AMLR 2004 SURVEY D (N=97)						
TAXON	F(%)	R	%	MEAN	STD	MED	MAX	F(%)	R	%	MEAN	STD	MED	MAX
Copepods	98.9	1	46.5	479.9	770.4	200.7	4566.7	100.0	1	72.0	4412.5	12983.0	1789.2	120411.5
Metridia gerlachei	78.0		23.3	240.8	670.8	13.0	4160.4	100.0		22.4	1371.5	2943.3	368.9	22730.1
Calanoides acutus	97.8		11.2	115.3	180.2	58.1	1009.6	100.0		20.3	1242.6	5523.9	255.8	51260.9
Calanus propinquus	97.8		6.6	68.6	66.8	45.8	364.6	99.0		12.7	775.1	2606.6	253.9	24082.3
Paraeuchaeta antarctica	64.8		2.7	28.0	66.5	5.9	450.5	95.9		2.4	148.7	225.7	73.9	1720.2
Rhincalanus gigas	47.3		0.9	8.9	19.0	0.0	111.5	93.8		11.7	717.0	3755.0	96.4	36467.5
Other copepods	6.6		0.1	0.7	3.6	0.0	31.2	56.7		1.2	73.6	172.8	5.0	1032.1
Pleuromamma robusta	52.7		1.7	17.7	47.5	0.4	354.0	28.9		0.5	28.2	91.1	0.0	597.2
Heterorhabdus sp.	—		—	—	—	—	—	19.6		0.7	44.1	387.0	0.0	3832.6
Haloptilus ocellatus	1.1		0.0	0.0	0.1	0.0	0.8	16.5		0.2	10.0	41.0	0.0	344.0
Pareuchaeta simillus	0.0		0.0	0.0	0.0	0.0	0.0	2.1		0.0	1.6	14.6	0.0	144.1
Copepodites	0.0		0.0	0.0	0.0	0.0	0.0	1.0		0.0	0.2	1.5	0.0	15.0
Chaetognaths	84.6	6	3.5	36.1	63.9	13.4	385.3	96.9	2	5.4	332.7	802.2	127.3	7568.7
Thysanoessa macrura	95.6	3	15.1	156.4	228.5	74.2	1425.5	95.9	5	3.4	209.4	327.5	79.2	1515.6
Salpa thompsoni	93.4	2	17.3	179.1	281.8	90.3	1880.2	90.7	6	2.0	123.4	237.1	32.1	1448.1
Euphausia superba (L)	50.5		0.7	7.0	14.6	0.4	95.7	87.6	7	1.8	107.7	523.1	20.2	5160.5
Themisto gaudichaudii	72.5		0.3	2.9	4.6	1.4	27.4	87.6		0.1	4.5	6.5	2.4	34.8
Primno macropa	67.0		0.5	5.4	10.4	2.0	74.0	76.3		0.3	16.1	28.2	6.9	220.3
Euphausia superba	83.5	4	4.3	44.7	132.7	2.2	852.2	76.3	8	1.2	73.5	270.3	2.4	2292.6
Cyllopus lucasii	78.0		0.3	3.0	5.1	1.7	42.0	76.3		0.1	3.4	4.8	1.4	26.4
Limacina helicina	83.5	7	2.1	22.1	37.2	6.5	224.0	73.2	9	0.7	42.6	130.9	1.5	853.9
Spongiobranchaea australis	79.1		0.2	2.5	3.3	1.2	17.6	71.1		0.1	5.9	16.1	0.6	132.3
Thysanoessa macrura (L)	57.1	10	1.3	13.3	63.8	1.4	603.2	68.0	4	5.1	315.1	1002.8	13.6	5918.2
Cyllopus magellanicus	35.2		0.0	0.4	1.4	0.0	11.2	59.8		0.0	0.9	1.4	0.4	8.3
Euphausia frigida	36.3	8	1.6	16.1	50.9	0.0	374.9	59.8	10	0.6	35.3	64.2	2.1	449.0
Ostracods	63.7	9	1.4	14.6	45.5	1.2	353.7	52.6		0.4	26.9	82.5	0.4	666.9
Ihlea racovitzai	42.9	5	3.6	37.0	109.7	0.0	824.5	52.6		0.4	22.3	47.4	0.6	258.7
Hyperiella dilatata	47.3		0.0	0.4	0.9	0.0	6.2	47.4		0.1	3.5	17.4	0.0	156.3
Radiolaria	65.9		0.3	3.6	7.9	0.8	47.8	46.4	3	5.9	362.1	2838.4	0.0	27871.1
Vibilia antarctica	54.9		0.1	0.7	1.1	0.4	6.2	42.3		0.0	1.0	2.5	0.0	17.2
Electrona spp. (L)	16.5		0.0	0.3	1.2	0.0	10.2	36.1		0.0	1.2	3.4	0.0	21.8
Tomopteris spp.	53.8		0.1	1.4	2.5	0.4	13.8	36.1		0.0	1.6	3.9	0.0	24.3
Diphyes antarctica	23.1		0.0	0.3	0.8	0.0	4.8	29.9		0.0	0.2	0.5	0.0	2.2
Clione limacina	33.0		0.1	0.6	1.9	0.0	15.0	28.9		0.0	0.5	1.2	0.0	7.6
Lepidonotothen kempi (L)	11.0		0.0	0.3	1.5	0.0	14.5	28.9		0.0	0.8	2.7	0.0	23.4
Sipunculids	19.8		0.0	0.3	1.1	0.0	8.3	28.9		0.0	1.3	5.4	0.0	40.5
Euphausia frigida (L)	2.2		0.0	0.2	1.4	0.0	12.5	24.7		0.1	5.7	20.7	0.0	187.5
Lepidonotothen larseni (L)	36.3		0.1	0.9	2.2	0.0	13.8	24.7		0.0	0.5	2.1	0.0	19.8
Euphausia triacantha	15.4		0.1	0.7	2.9	0.0	17.3	20.6		0.0	1.3	4.4	0.0	32.4
Orchomene plebs	2.2		0.0	0.0	0.2	0.0	1.6	15.5		0.0	0.1	0.3	0.0	1.8
Electrona antarctica	8.8		0.0	0.1	0.3	0.0	2.0	12.4		0.0	0.1	0.2	0.0	1.2
Dimophyes arctica	9.9		0.0	0.2	1.0	0.0	8.0	12.4		0.0	0.5	3.4	0.0	33.9
Notolepis coatsi (L)	18.7		0.0	0.2	0.7	0.0	4.7	12.4		0.0	0.1	0.4	0.0	1.9
Hydromedusae (unid)	6.6		0.0	0.0	0.2	0.0	1.7	11.3		0.0	0.1	0.4	0.0	3.1
Rhynchonereella bongraini	9.9		0.0	0.2	0.7	0.0	5.8	10.3		0.0	1.0	3.4	0.0	18.6
Beroe forskalii	18.7		0.0	0.2	0.5	0.0	3.2	10.3		0.0	0.1	0.7	0.0	7.0
Calycopsis borchgrevinki	3.3		0.0	0.0	0.1	0.0	0.5	8.2		0.0	0.0	0.2	0.0	1.3
Cyllopus spp.	0.0		0.0	0.0	0.0	0.0	0.0	7.2		0.0	0.0	0.2	0.0	1.3
Euphausia crystallorophias	11.0		0.0	0.3	1.1	0.0	6.3	6.2		0.0	2.4	16.0	0.0	122.4
Siphonophora (unid.)	4.4		0.0	0.1	0.3	0.0	2.4	6.2		0.0	0.6	3.5	0.0	32.1
Gymnoscopelus braueri	0.0		0.0	0.0	0.0	0.0	0.0	6.2		0.0	0.0	0.2	0.0	1.2
Limacina spp.	2.2		0.0	0.2	2.2	0.0	20.8	5.2		0.0	1.0	6.6	0.0	60.4
Scina spp.	0.0		0.0	0.0	0.0	0.0	0.0	5.2		0.0	0.3	1.4	0.0	10.9
Euphausia triacantha (L)	0.0		0.0	0.0	0.0	0.0	0.0	5.2		0.0	0.3	1.5	0.0	11.9
Eusirus antarcticus	0.0		0.0	0.0	0.0	0.0	0.0	5.2		0.0	0.1	0.6	0.0	5.4
Hyperiella spp.	0.0		0.0	0.0	0.0	0.0	0.0	5.2		0.0	0.0	0.2	0.0	1.0
Polychaetes (unid.)	8.8		0.0	0.1	0.6	0.0	4.3	4.1		0.0	0.4	2.3	0.0	18.6
Gammarids (unid.)	7.7		0.0	0.1	0.3	0.0	2.6	4.1		0.0	0.2	1.4	0.0	13.0
Ctenophora (unid.)	0.0		0.0	0.0	0.0	0.0	0.0	4.1		0.0	0.1	0.4	0.0	3.3
Vanadis antarctica	0.0		0.0	0.0	0.0	0.0	0.0	4.1		0.0	0.0	0.1	0.0	1.2
Beroe cucumis	5.5		0.0	0.0	0.1	0.0	0.5	4.1		0.0	0.0	0.1	0.0	0.4
Bathylagus antarcticus	0.0		0.0	0.0	0.0	0.0	0.0	4.1		0.0	0.0	0.1	0.0	0.4
Gymnoscopelus nicholsi	0.0		0.0	0.0	0.0	0.0	0.0	4.1		0.0	0.0	0.1	0.0	0.4

Table 4.4 (Contd.)

	AMLR 2004 SURVEY A							AMLR 2004 SURVEY D						
TAXON	F(%)	R	%	MEAN	STD	MED	MAX	F(%)	R	%	MEAN	STD	MED	MAX
Cumaceans	3.3		0.0	0.1	0.6	0.0	5.6	3.1		0.0	0.0	0.2	0.0	1.6
Spongiobranchaea sp.	2.2		0.0	0.0	0.2	0.0	2.0	3.1		0.0	0.0	0.2	0.0	1.5
Clio pyramidata antarctica	11.0		0.0	0.1	0.4	0.0	3.9	3.1		0.0	0.0	0.2	0.0	1.5
Pegantha martgon	8.8		0.0	0.2	0.6	0.0	4.8	3.1		0.0	0.0	0.2	0.0	1.5
Leusia spp.	0.0		0.0	0.0	0.0	0.0	0.0	3.1		0.0	0.0	0.1	0.0	0.8
Clio pyramidata sulcata	2.2		0.0	0.1	0.7	0.0	6.6	3.1		0.0	0.0	0.1	0.0	0.9
Acanthophyra pelagica	5.5		0.0	0.0	0.2	0.0	1.6	3.1		0.0	0.0	0.1	0.0	0.5
Cephalopods	1.1		0.0	0.0	0.0	0.0	0.4	3.1		0.0	0.0	0.1	0.0	0.4
Euphausia crystallorophias (L)	3.3		0.0	0.0	0.2	0.0	1.3	2.1		0.0	0.7	6.3	0.0	62.4
Electrona carlsbergi	0.0		0.0	0.0	0.0	0.0	0.0	2.1		0.0	0.0	0.2	0.0	1.4
Hyperiids (unid.)	1.1		0.0	0.0	0.3	0.0	3.2	2.1		0.0	0.0	0.2	0.0	2.2
Clione antarctica	13.2		0.0	0.1	0.4	0.0	2.5	2.1		0.0	0.0	0.1	0.0	1.3
Hyperiella macronyx	1.1		0.0	0.0	0.1	0.0	0.9	2.1		0.0	0.0	0.1	0.0	1.2
Harpagifer antarcticus (L)	0.0		0.0	0.0	0.0	0.0	0.0	2.1		0.0	0.0	0.1	0.0	0.4
Orchomene rossi	1.1		0.0	0.0	0.0	0.0	0.4	2.1		0.0	0.0	0.1	0.0	0.4
Staurophora mertensi ?	0.0		0.0	0.0	0.0	0.0	0.0	2.1		0.0	0.0	0.1	0.0	0.4
Krefftichthys anderssoni (L)	0.0		0.0	0.0	0.0	0.0	0.0	2.1		0.0	0.0	0.1	0.0	0.4
Clio pyramidata martensi?	1.1		0.0	0.0	0.0	0.0	0.4	1.0		0.1	3.5	34.8	0.0	344.0
Travisiopsis coniceps	2.2		0.0	0.0	0.1	0.0	0.4	1.0		0.0	0.1	1.0	0.0	10.2
Thyphloscolex muelleri	0.0		0.0	0.0	0.0	0.0	0.0	1.0		0.0	0.1	1.0	0.0	10.1
Amphipods (unid)	0.0		0.0	0.0	0.0	0.0	0.0	1.0		0.0	0.1	1.0	0.0	10.1
Larval Fish (unid.)	0.0		0.0	0.0	0.0	0.0	0.0	1.0		0.0	0.0	0.3	0.0	3.2
Gastropods (unid.)	0.0		0.0	0.0	0.0	0.0	0.0	1.0		0.0	0.0	0.3	0.0	3.1
Gobionotothen gibberifrons (L)	0.0		0.0	0.0	0.0	0.0	0.0	1.0		0.0	0.0	0.3	0.0	2.8
Eusirus perdentatus	1.1		0.0	0.0	0.0	0.0	0.5	1.0		0.0	0.0	0.1	0.0	0.9
Notolepis annulata (L)	1.1		0.0	0.0	0.1	0.0	0.8	1.0		0.0	0.0	0.0	0.0	0.5
Hyperia macrocephala	0.0		0.0	0.0	0.0	0.0	0.0	1.0		0.0	0.0	0.0	0.0	0.5
Chromatonema rubra?	0.0		0.0	0.0	0.0	0.0	0.0	1.0		0.0	0.0	0.0	0.0	0.5
Lepidonotothen larseni (J)	3.3		0.0	0.0	0.1	0.0	1.0	1.0		0.0	0.0	0.0	0.0	0.4
Hyperoche medusarum	2.2		0.0	0.0	0.1	0.0	0.4	1.0		0.0	0.0	0.0	0.0	0.4
Periphylla periphylla	1.1		0.0	0.0	0.0	0.0	0.5	1.0		0.0	0.0	0.0	0.0	0.4
Epimeriella macronyx	4.4		0.0	0.0	0.2	0.0	1.5	1.0		0.0	0.0	0.0	0.0	0.4
Harpagrifer spp. (L)	0.0		0.0	0.0	0.0	0.0	0.0	1.0		0.0	0.0	0.0	0.0	0.4
Cyphocaris richardi	0.0		0.0	0.0	0.0	0.0	0.0	1.0		0.0	0.0	0.0	0.0	0.4
Hyperia antarctica	0.0		0.0	0.0	0.0	0.0	0.0	1.0		0.0	0.0	0.0	0.0	0.4
Pelagobia longicirrata	2.2		0.0	0.0	0.1	0.0	0.6	1.0		0.0	0.0	0.0	0.0	0.4
Macrourid (L)	0.0		0.0	0.0	0.0	0.0	0.0	1.0		0.0	0.0	0.0	0.0	0.4
Pleuragramma antarcticum (L)	0.0		0.0	0.0	0.0	0.0	0.0	1.0		0.0	0.0	0.0	0.0	0.4
Larvaceans	3.3		0.0	0.0	0.1	0.0	0.4	1.0		0.0	0.0	0.0	0.0	0.4
Schyphomedusae (unid.)	0.0		0.0	0.0	0.0	0.0	0.0	1.0		0.0	0.0	0.0	0.0	0.3
Atolla wyvillei	0.0		0.0	0.0	0.0	0.0	0.0	1.0		0.0	0.0	0.0	0.0	0.3
Trematomus scotti (L)	1.1		0.0	0.0	0.0	0.0	0.5	1.0		0.0	0.0	0.0	0.0	0.0
Eusirus antarcticus	13.2		0.0	0.1	0.4	0.0	3.3	0.0		0.0	0.0	0.0	0.0	0.0
Amphipods (unid.)	7.7		0.0	0.1	0.8	0.0	6.5	0.0		0.0	0.0	0.0	0.0	0.0
Chionodraco rastrospinosus (L)	5.5		0.0	0.0	0.1	0.0	0.4	0.0		0.0	0.0	0.0	0.0	0.0
Nototheniops nudifrons (L)	4.4		0.0	0.1	0.4	0.0	2.8	0.0		0.0	0.0	0.0	0.0	0.0
Artedidraco mirus (L)	2.2		0.0	0.0	0.1	0.0	1.4	0.0		0.0	0.0	0.0	0.0	0.0
Decapods (unid.)	2.2		0.0	0.0	0.1	0.0	0.8	0.0		0.0	0.0	0.0	0.0	0.0
Bolinopsis infundibulus	2.2		0.0	0.0	0.1	0.0	0.5	0.0		0.0	0.0	0.0	0.0	0.0
Ctenophora (unid.)	2.2		0.0	0.0	0.1	0.0	0.6	0.0		0.0	0.0	0.0	0.0	0.0
Gymnoscopelus braueri	1.1		0.0	0.0	0.3	0.0	3.1	0.0		0.0	0.0	0.0	0.0	0.0
Isopods (unid.)	1.1		0.0	0.0	0.2	0.0	1.7	0.0		0.0	0.0	0.0	0.0	0.0
Notolepis spp. (L)	1.1		0.0	0.0	0.1	0.0	1.3	0.0		0.0	0.0	0.0	0.0	0.0
Hyperiella antarctica	1.1		0.0	0.0	0.1	0.0	1.3	0.0		0.0	0.0	0.0	0.0	0.0
Trematomus lepidorhinus (L)	1.1		0.0	0.0	0.1	0.0	0.8	0.0		0.0	0.0	0.0	0.0	0.0
Travisiopsis levinseni	1.1		0.0	0.0	0.0	0.0	0.4	0.0		0.0	0.0	0.0	0.0	0.0
Pasiaphaea spp. (L)	1.1		0.0	0.0	0.0	0.0	0.4	0.0		0.0	0.0	0.0	0.0	0.0
Cryodraco antarctica (L)	1.1		0.0	0.0	0.0	0.0	0.4	0.0		0.0	0.0	0.0	0.0	0.0
Hyperiella spp.	1.1		0.0	0.0	0.0	0.0	0.4	0.0		0.0	0.0	0.0	0.0	0.0
Pleurobrachia pileus	1.1		0.0	0.0	0.0	0.0	0.4	0.0		0.0	0.0	0.0	0.0	0.0
TOTAL				1033.1	903.2	773.9	5293.1				6124.5	17500.5	2772.6	166759.9
TAXA	89			21.6	4.4	22	34	104			23.7	4.0	24	35

Table 4.5. Composition and abundance of zooplankton assemblages sampled in four subareas, during (A) January and (B) February 2004. F(%) is frequency of occurrence in samples. R is rank and % is proportion of total mean abundance represented by each taxon. L and J denote larval and juvenile stages.

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	WEST AREA (N = 24)						ELEPHANT ISLAND AREA (N = 46)						JOINVILLE ISLAND AREA (N = 5)						SOUTH AREA (N = 16)					
TAXON	F(%)	R	%	MEAN	STD	MED	F(%)	R	%	MEAN	STD	MED	F(%)	R	%	MEAN	STD	MED	F(%)	R	%	MEAN	STD	MED
Copepods	95.8	2	25.8	235.6	377.0	106.4	100.0	1	50.4	494.5	796.1	208.7	100.0	1	67.9	698.7	280.2	656.3	100.0	1	54.0	736.2	1070.1	350.7
Calanoides acutus	91.7		14.8	135.1	228.4	50.7	100.0		7.9	77.4	97.2	42.7	100.0		16.6	170.8	190.3	85.7	100.0		13.0	177.5	241.6	97.0
Calanus propinquus	91.7		6.0	55.1	78.4	32.4	100.0		7.5	73.2	63.8	57.1	100.0		12.1	124.0	65.0	142.2	100.0		4.3	58.1	41.6	43.4
Metridia gerlachei	37.5		1.8	16.3	50.5	0.0	91.3		29.9	293.6	706.6	25.4	100.0		26.2	269.1	265.6	129.7	93.8		30.5	416.6	991.4	76.0
Pleuromamma robusta	25.0		2.0	17.9	70.7	0.0	76.1		2.5	24.1	41.0	7.8	20.0		0.3	3.0	6.0	0.0	37.5		0.3	3.7	8.6	0.0
Rhincalanus gigas	20.8		0.1	0.9	2.4	0.0	50.0		1.0	9.7	19.0	0.2	40.0		1.0	10.8	19.5	0.0	81.3		1.3	17.8	26.7	10.1
Other copepods	16.7		0.2	1.9	6.3	0.0			0.0	0.0	0.0	0.0	20.0		0.3	2.7	5.4	0.0	6.3		0.0	0.1	0.3	0.0
Paraeuchaeta antarctica	12.5		0.9	8.4	39.0	0.0	76.1		1.7	16.4	25.0	7.6	100.0		11.5	118.2	167.2	43.2	100.0		4.6	62.5	87.5	18.4
Haloptilus ocellatus			0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0	6.3		0.0	0.0	0.2	0.0
Salpa thompsoni	95.8	1	30.6	279.3	461.2	63.1	100.0	2	17.9	176.1	166.7	134.1	60.0		1.3	13.9	17.0	10.7	81.3	4	6.5	88.8	144.2	29.1
Spongiobranchaea australis	91.7		0.3	2.9	2.0	2.5	80.4		0.3	2.8	3.9	1.5	60.0		0.3	3.2	5.4	0.8	62.5		0.0	0.5	0.6	0.4
Themisto gaudichaudii	91.7		0.6	5.8	6.9	2.9	80.4		0.2	2.4	3.0	1.5			0.0	0.0	0.0	0.0	43.8		0.1	0.7	1.1	0.0
Limacina helicina	91.7	4	4.8	43.4	43.7	27.5	76.1	9	1.3	12.8	35.4	2.7	80.0	5	2.6	27.2	25.6	31.5	93.8	7	1.1	15.4	14.4	11.4
Thysanoessa macrura	87.5	3	23.1	211.1	333.6	49.4	97.8	3	11.0	108.2	161.5	55.4	100.0	3	6.5	66.6	52.5	75.0	100.0	2	17.7	241.1	182.6	219.0
Euphausia superba	83.3	8	1.2	11.3	21.2	2.1	87.0	4	6.1	59.8	170.5	3.1	40.0		0.0	0.3	0.4	0.0	87.5	5	4.8	65.1	112.1	1.2
Chaetognaths	66.7	6	3.3	29.8	42.9	9.6	87.0	5	3.6	35.3	78.5	9.3	100.0		1.8	18.0	10.1	18.0	100.0	6	3.9	53.4	47.5	37.4
Tomopteris spp.	66.7		0.1	1.2	1.6	0.6	47.8		0.1	1.1	2.4	0.0	80.0		0.6	6.1	4.7	6.5	43.8		0.1	0.8	1.2	0.0
Cyllopus lucasii	58.3		0.1	1.2	1.6	0.6	84.8		0.4	3.7	6.4	2.2	80.0		0.5	5.1	5.0	3.2	87.5		0.2	3.2	3.1	1.8
Radiolaria	58.3		0.5	4.5	10.1	0.6	82.6		0.5	4.4	8.1	1.6	80.0		0.1	0.7	0.7	0.5	25.0		0.0	0.5	1.2	0.0
Ostracods	54.2	10	0.9	7.8	26.6	0.6	69.6	7	1.7	17.0	55.8	1.3	80.0	4	3.7	37.8	58.4	9.3	56.3	8	0.8	10.6	20.8	1.1
Primno macropa	50.0	9	0.9	8.1	17.1	0.4	80.4		0.4	3.9	4.4	2.7	40.0		0.1	0.8	1.0	0.0	62.5	9	0.5	7.1	9.7	2.8
Thysanoessa macrura (L)	45.8	5	3.9	35.6	120.3	0.0	69.6		0.7	6.7	11.0	2.1	20.0		0.0	0.5	0.9	0.0	50.0		0.2	2.5	3.6	0.2
Vibilia antarctica	45.8		0.1	0.5	0.7	0.0	58.7		0.1	0.6	0.9	0.4	60.0		0.1	1.2	1.1	0.9	56.3		0.1	1.1	1.7	0.3
Hyperiella dilatata	45.8		0.1	0.5	0.7	0.0	45.7		0.0	0.4	1.1	0.0	60.0		0.0	0.4	0.3	0.4	50.0		0.0	0.3	0.3	0.2
Euphausia superba (L)	33.3		0.2	2.2	6.5	0.0	54.3	10	1.0	9.8	18.5	0.4	80.0		0.5	4.6	6.3	2.0	56.3	10	0.5	7.0	9.4	2.4
Euphausia frigida	29.2	7	2.5	22.5	75.9	0.0	39.1	6	2.0	19.2	44.5	0.0	40.0		0.4	4.5	5.7	0.0	37.5		0.1	1.1	2.9	0.0
Lepidonotothen larseni (L)	29.2		0.2	1.4	3.7	0.0	28.3		0.0	0.3	0.8	0.0	80.0		0.2	1.8	1.2	2.3	56.3		0.1	1.1	1.8	0.4
Electrona spp. (L)	29.2		0.1	0.8	2.1	0.0	15.2		0.0	0.1	0.5	0.0			0.0	0.0	0.0	0.0	6.3		0.0	0.0	0.1	0.0
Ihlea racovitzai	20.8		0.3	2.7	11.6	0.0	39.1	8	1.6	16.0	35.1	0.0	100.0	2	12.8	131.3	132.5	96.9	68.8	3	8.7	119.0	216.2	8.7
Diphyes antarctica	20.8		0.0	0.2	0.4	0.0	19.6		0.0	0.2	0.8	0.0	60.0		0.1	0.6	0.7	0.4	25.0		0.0	0.6	1.2	0.0
Cyllopus magellanicus	16.7		0.0	0.3	1.1	0.0	50.0		0.1	0.6	1.7	0.2	20.0		0.0	0.1	0.2	0.0	25.0		0.0	0.2	0.5	0.0
Clione limacina	16.7		0.0	0.4	1.1	0.0	28.3		0.1	0.7	2.4	0.0	60.0		0.1	0.7	1.0	0.4	62.5		0.1	0.7	1.5	0.4
Beroe forskalii	16.7		0.0	0.2	0.6	0.0	21.7		0.0	0.2	0.4	0.0	20.0		0.0	0.4	0.7	0.0	12.5		0.0	0.1	0.4	0.0
Sipunculids	16.7		0.0	0.2	0.4	0.0	10.9		0.0	0.3	1.3	0.0	20.0		0.0	0.1	0.2	0.0	50.0		0.0	0.6	1.3	0.2
Pegantha martgon	16.7		0.0	0.4	1.1	0.0	8.7		0.0	0.1	0.4	0.0			0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0
Clione antarctica	12.5		0.0	0.1	0.2	0.0	8.7		0.0	0.1	0.3	0.0	60.0		0.1	0.7	0.9	0.4	12.5		0.0	0.1	0.3	0.0
Euphausia crystallorophias	12.5		0.0	0.4	1.4	0.0	8.7		0.0	0.2	0.8	0.0	20.0		0.0	0.1	0.2	0.0	12.5		0.0	0.6	1.6	0.0
Polychaetes (unid.)	12.5		0.0	0.1	0.4	0.0	6.5		0.0	0.1	0.6	0.0	20.0		0.0	0.5	0.9	0.0	6.3		0.0	0.1	0.3	0.0
Notolepis coatsi (L)	8.3		0.0	0.1	0.3	0.0	19.6		0.0	0.3	0.9	0.0	20.0		0.0	0.1	0.2	0.0	31.3		0.0	0.3	0.7	0.0
Euphausia triacantha	8.3		0.1	0.7	3.4	0.0	19.6		0.1	1.0	3.2	0.0			0.0	0.0	0.0	0.0	18.8		0.0	0.1	0.2	0.0
Electrona antarctica	8.3		0.0	0.1	0.3	0.0	13.0		0.0	0.1	0.4	0.0			0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0
Dimophyes arctica	8.3		0.0	0.4	1.6	0.0	4.3		0.0	0.0	0.2	0.0			0.0	0.0	0.0	0.0	31.3		0.0	0.6	1.3	0.0
Lepidonotothen larseni (J)	8.3		0.0	0.1	0.2	0.0	2.2		0.0	0.0	0.1	0.0			0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0
Clio pyramidata antarctica	4.2		0.0	0.0	0.1	0.0	8.7		0.0	0.1	0.6	0.0	40.0		0.0	0.3	0.4	0.0	18.8		0.0	0.1	0.2	0.0
Gammarids (unid.)	4.2		0.0	0.0	0.1	0.0	8.7		0.0	0.1	0.4	0.0	40.0		0.0	0.2	0.2	0.0			0.0	0.0	0.0	0.0
Hydromedusae (unid.)	4.2		0.0	0.0	0.1	0.0	8.7		0.0	0.1	0.3	0.0	20.0		0.0	0.2	0.4	0.0			0.0	0.0	0.0	0.0
Amphipods (unid.)	4.2		0.0	0.0	0.1	0.0	6.5		0.0	0.2	1.0	0.0			0.0	0.0	0.0	0.0	18.8		0.0	0.2	0.5	0.0
Beroe cucumis	4.2		0.0	0.0	0.1	0.0	6.5		0.0	0.0	0.1	0.0			0.0	0.0	0.0	0.0	6.3		0.0	0.0	0.1	0.0
Epimeriella macronyx	4.2		0.0	0.0	0.1	0.0	4.3		0.0	0.0	0.2	0.0	20.0		0.0	0.1	0.2	0.0			0.0	0.0	0.0	0.0
Nototheniops nudifrons (L)	4.2		0.0	0.1	0.5	0.0	4.3		0.0	0.1	0.4	0.0	20.0		0.0	0.2	0.4	0.0			0.0	0.0	0.0	0.0
Acanthophyra pelagica	4.2		0.0	0.0	0.1	0.0	2.2		0.0	0.0	0.1	0.0	40.0		0.0	0.4	0.6	0.0	6.3		0.0	0.0	0.1	0.0
Spongiobranchaea sp.	4.2		0.0	0.1	0.4	0.0	2.2		0.0	0.0	0.1	0.0			0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0

Table 4.5 (Contd.)

TAXON	WEST AREA (N = 24)						ELEPHANT ISLAND AREA (N = 46)						JOINVILLE ISLAND AREA (N = 5)						SOUTH AREA (N = 160					
	F(%)	R	%	MEAN	STD	MED	F(%)	R	%	MEAN	STD	MED	F(%)	R	%	MEAN	STD	MED	F(%)	R	%	MEAN	STD	MED
Decapods (unid.)	4.2		0.0	0.0	0.2	0.0	2.2		0.0	0.0	0.1	0.0			0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0
Chionodraco rastrospinosus (L)	4.2		0.0	0.0	0.1	0.0			0.0	0.0	0.0	0.0	20.0		0.0	0.1	0.2	0.0	18.8		0.0	0.1	0.2	0.0
Orchomene plebs	4.2		0.0	0.1	0.3	0.0			0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0	6.3		0.0	0.0	0.1	0.0
Orchomene rossi	4.2		0.0	0.0	0.1	0.0			0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0
Hyperiella antarctica	4.2		0.0	0.1	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	0.0
Rhynchonereella bongraini			0.0	0.0	0.0	0.0	13.0		0.0	0.3	1.0	0.0	20.0		0.0	0.5	0.9	0.0	12.5		0.0	0.1	0.2	0.0
Lepidonotothen kempi (L)			0.0	0.0	0.0	0.0	10.9		0.0	0.1	0.3	0.0	20.0		0.0	0.1	0.2	0.0	25.0		0.1	1.1	3.5	0.0
Eusirus antarcticus			0.0	0.0	0.0	0.0	6.5		0.0	0.1	0.5	0.0	60.0		0.0	0.4	0.5	0.4	37.5		0.0	0.2	0.2	0.0
Cumaceans			0.0	0.0	0.0	0.0	4.3		0.0	0.2	0.8	0.0	20.0		0.0	0.2	0.3	0.0			0.0	0.0	0.0	0.0
Euphausia frigida (L)			0.0	0.0	0.0	0.0	4.3		0.0	0.4	1.9	0.0			0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0
Bolinopsis infundibulus			0.0	0.0	0.0	0.0	4.3		0.0	0.0	0.1	0.0			0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0
Calycopsis borchgrevinki			0.0	0.0	0.0	0.0	2.2		0.0	0.0	0.1	0.0	20.0		0.0	0.1	0.2	0.0	6.3		0.0	0.0	0.1	0.0
Clio pyramidata sulcata			0.0	0.0	0.0	0.0	2.2		0.0	0.1	1.0	0.0	20.0		0.0	0.1	0.2	0.0			0.0	0.0	0.0	0.0
Artedidraco mirus (L)			0.0	0.0	0.0	0.0	2.2		0.0	0.0	0.2	0.0	20.0		0.0	0.1	0.2	0.0			0.0	0.0	0.0	0.0
Limacina spp.			0.0	0.0	0.0	0.0	2.2		0.0	0.0	0.1	0.0			0.0	0.0	0.0	0.0	6.3		0.1	1.3	5.0	0.0
Pelagobia longicirrata			0.0	0.0	0.0	0.0	2.2		0.0	0.0	0.1	0.0			0.0	0.0	0.0	0.0	6.3		0.0	0.0	0.1	0.0
Hyperoche medusarum			0.0	0.0	0.0	0.0	2.2		0.0	0.0	0.1	0.0			0.0	0.0	0.0	0.0	6.3		0.0	0.0	0.1	0.0
Ctenophora (unid)			0.0	0.0	0.0	0.0	2.2		0.0	0.0	0.1	0.0			0.0	0.0	0.0	0.0	6.3		0.0	0.0	0.1	0.0
Pleurobrachia pileus			0.0	0.0	0.0	0.0	2.2		0.0	0.0	0.1	0.0			0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0
Hyperiella spp.			0.0	0.0	0.0	0.0	2.2		0.0	0.0	0.1	0.0			0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0
Gymnoscopelus braueri			0.0	0.0	0.0	0.0	2.2		0.0	0.1	0.4	0.0			0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0
Hyperiids (unid.)			0.0	0.0	0.0	0.0	2.2		0.0	0.1	0.5	0.0			0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0
Isopods (unid.)			0.0	0.0	0.0	0.0	2.2		0.0	0.0	0.2	0.0			0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0
Travisiopsis levinseni			0.0	0.0	0.0	0.0	2.2		0.0	0.0	0.1	0.0			0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0
Notolepis annulata (L)			0.0	0.0	0.0	0.0	2.2		0.0	0.0	0.1	0.0			0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0
Hyperiella macronyx			0.0	0.0	0.0	0.0	2.2		0.0	0.0	0.1	0.0			0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0
Cephalopods			0.0	0.0	0.0	0.0	2.2		0.0	0.0	0.1	0.0			0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0
Periphylla periphylla			0.0	0.0	0.0	0.0	2.2		0.0	0.0	0.1	0.0			0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0
Larvaceans			0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0	20.0		0.0	0.1	0.2	0.0	12.5		0.0	0.0	0.1	0.0
Travisiopsis coniceps			0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0	20.0		0.0	0.1	0.2	0.0	6.3		0.0	0.0	0.1	0.0
Pasiaphaea spp. (L)			0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0	20.0		0.0	0.1	0.2	0.0			0.0	0.0	0.0	0.0
Eusirus perdentatus			0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0	20.0		0.0	0.1	0.2	0.0			0.0	0.0	0.0	0.0
Trematomus scotti (L)			0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0	20.0		0.0	0.1	0.2	0.0			0.0	0.0	0.0	0.0
Siphonophora (unid.)			0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0	25.0		0.0	0.3	0.7	0.0
Euphausia crystallorophias (L)			0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0	18.8		0.0	0.2	0.4	0.0
Notothenia kempi (L)			0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0	12.5		0.0	0.4	1.3	0.0
Trematomus lepidorhinus (L)			0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0	6.3		0.0	0.0	0.2	0.0
Notolepis spp. (L)			0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0	6.3		0.0	0.1	0.3	0.0
Cryodraco antarctica (L)			0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0	6.3		0.0	0.0	0.1	0.0
Clio pyramidata martensi?			0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0	6.3		0.0	0.0	0.1	0.0
TOTAL	24			912.1	519.1	717.8	46			981.7	1010.6	728.9	5			1029.0	299.0	1025.7	16			1364.0	1065.0	1047.8
TAXA	53			18.0	3.9	17	71			22.3	3.6	22	51			25.8	4.2	25	60			23.8	3.5	23

Table 4.5 (Contd.)
B. AMLR 2004 SURVEY D

TAXON	WEST AREA (N=25) F(%)	R	%	MEAN	STD	MED	ELEPHANT ISLAND AREA (N=47) F(%)	R	%	MEAN	STD	MED	JOINVILLE ISLAND AREA (N=8) F(%)	R	%	MEAN	STD	MED	SOUTH AREA (N=17) F(%)	R	%	MEAN	STD	MED
Copepods	100.0	1	68.5	3514.3	6767.5	1562.2	100.0	1	74.2	6303.1	17739.5	2233.5	100.0	1	76.8	2790.3	1785.6	2049.4	100.0	1	57.2	1270.0	846.3	1261.7
Calanoides acutus	100.0		20.9	1070.1	3578.0	221.0	100.0		21.5	1821.7	7439.2	277.0	100.0		16.0	579.8	131.2	613.9	100.0		9.3	207.2	134.0	172.2
Metridia gerlachei	100.0		19.0	976.3	1651.1	288.5	100.0		21.1	1791.8	3902.9	368.9	100.0		45.5	1653.3	1783.2	771.4	100.0		29.6	657.7	737.2	208.7
Calanus propinquus	96.0		12.5	640.9	1567.7	185.5	100.0		13.1	1113.3	3524.0	324.3	100.0		8.5	309.5	208.2	266.7	100.0		11.6	256.8	291.9	193.4
Rhincalanus gigas	96.0		8.7	444.1	796.8	119.7	95.7		14.2	1209.3	5315.2	117.3	100.0		1.9	67.4	35.5	63.6	82.4		2.8	63.0	74.8	28.8
Paraeuchaeta antarctica	92.0		3.3	168.9	195.3	68.4	97.9		1.9	163.0	275.2	101.3	100.0		4.8	173.0	166.2	91.7	94.1		3.1	67.8	64.3	43.6
Other copepods	84.0		2.2	111.8	193.7	45.9	61.7		1.1	89.7	195.0	5.9	12.5		0.1	3.4	9.1	0.0	23.5		0.3	5.9	18.9	0.0
Pleuromamma robusta	60.0		1.8	92.2	159.4	8.5	21.3		0.1	7.7	25.3	0.0	12.5		0.1	1.9	5.0	0.0	11.8		0.2	3.3	11.4	0.0
Haloptilus ocellatus	20.0		0.2	9.9	31.2	0.0	19.1		0.2	15.1	53.6	0.0	0.0		0.0	0.0	0.0	0.0	11.8		0.0	0.8	2.2	0.0
Heterorhabdus sp.	0.0		0.0	0.0	0.0	0.0	25.5		1.0	88.2	552.6	0.0	12.5		0.1	1.9	5.0	0.0	35.3		0.3	7.0	13.4	0.0
Paraeuchaeta simillus	0.0		0.0	0.0	0.0	0.0	2.1		0.0	3.1	20.8	0.0	0.0		0.0	0.0	0.0	0.0	5.9		0.0	0.4	1.7	0.0
Copepodites	0.0		0.0	0.0	0.0	0.0	2.1		0.0	0.3	2.2	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Thysanoessa macrura	100.0	4	4.5	229.2	390.8	39.4	95.7	7	1.6	138.9	205.7	59.8	87.5	3	3.8	136.2	93.8	140.6	94.1	2	18.4	409.3	457.6	145.7
Themisto gaudichaudii	100.0		0.2	10.3	9.8	6.8	89.4		0.0	2.6	2.8	1.4	37.5		0.0	0.4	0.8	0.0	94.1		0.1	3.0	2.7	2.5
Chaetognaths	96.0	5	4.4	227.1	231.7	136.3	97.9	3	5.3	446.8	1114.1	127.3	100.0	2	9.0	327.4	278.9	190.4	100.0	3	7.9	175.3	217.2	78.8
Salpa thompsoni	96.0	6	2.7	140.3	289.1	33.8	97.9	6	1.9	159.1	252.2	45.5	75.0	10	0.6	21.4	29.2	3.7	64.7	5	2.2	47.9	83.2	1.2
Primno macropa	84.0		0.7	33.8	46.7	21.5	76.6		0.1	10.1	12.5	4.7	50.0		0.2	6.0	8.0	1.1	76.5		0.5	11.6	14.8	6.9
Spongiobranchaea australis	84.0		0.1	5.3	7.1	2.5	72.3		0.1	8.3	21.9	0.6	75.0		0.0	1.7	3.5	0.4	47.1		0.1	1.8	5.2	0.0
Euphausia superba (L)	76.0	10	0.8	41.0	79.7	15.1	91.5	5	2.1	177.3	741.5	38.9	100.0	4	2.4	87.2	86.4	40.7	88.2	8	1.0	23.2	31.6	5.2
Cyllopus lucasii	76.0		0.1	2.9	4.4	0.8	83.0		0.1	4.4	5.1	3.0	62.5		0.1	2.9	4.9	0.4	64.7		0.1	1.9	3.8	0.4
Thysanoessa macrura (L)	76.0	2	9.6	489.9	1387.3	10.5	80.9	4	4.6	386.8	989.5	39.0	37.5		0.2	8.2	10.9	0.0	41.2		0.2	4.2	9.5	0.0
Cyllopus magellanicus	68.0		0.0	1.2	1.8	0.4	68.1		0.0	1.0	1.3	0.6	50.0		0.0	0.4	0.5	0.2	35.3		0.0	0.6	1.2	0.0
Radiolaria	64.0	3	4.5	232.1	790.7	4.1	44.7	2	7.3	623.3	4018.5	0.0	50.0		0.0	1.3	2.6	0.2	23.5		0.0	1.0	2.5	0.0
Euphausia superba	60.0	9	1.0	52.5	237.9	0.4	91.5	8	0.6	50.9	91.0	10.4	87.5	5	2.0	71.7	120.7	9.3	58.8	4	7.6	167.7	541.3	0.8
Limacina helicina	60.0	8	1.1	57.0	96.0	2.1	74.5	9	0.6	49.8	172.1	1.0	100.0	8	0.9	31.5	30.0	23.8	76.5		0.3	6.4	11.3	0.8
Euphausia frigida	52.0	7	1.2	59.1	98.4	2.0	53.2		0.3	26.8	45.8	0.6	75.0	9	0.6	23.1	18.5	31.4	82.4	6	1.3	29.7	46.6	6.0
Electrona spp. (L)	48.0		0.0	2.3	4.9	0.0	25.5		0.0	0.7	2.8	0.0	37.5		0.0	0.2	0.3	0.0	47.1		0.1	1.5	2.6	0.0
Hyperiella dilatata	40.0		0.1	7.2	30.5	0.0	53.2		0.0	2.9	10.7	0.4	62.5		0.1	2.8	5.6	0.4	35.3		0.0	0.3	0.5	0.0
Vibilia antarctica	40.0		0.0	1.4	3.7	0.0	53.2		0.0	1.1	2.2	0.4	25.0		0.0	0.1	0.2	0.0	23.5		0.0	0.6	1.5	0.0
Ostracods	36.0		0.2	9.1	18.9	0.0	53.2	10	0.4	33.6	111.3	0.4	50.0	7	1.2	44.1	58.3	8.6	76.5	7	1.2	26.3	42.1	6.1
Tomopteris spp.	36.0		0.0	1.8	5.2	0.0	38.3		0.0	2.0	3.8	0.0	25.0		0.0	0.3	0.5	0.0	35.3		0.0	0.7	2.0	0.0
Ihlea racovitzai	32.0		0.0	2.3	7.9	0.0	51.1		0.4	32.3	60.4	1.7	75.0	6	1.3	46.6	45.5	32.9	76.5	10	0.6	12.4	20.9	1.0
Clione limacina	24.0		0.0	0.3	0.7	0.0	25.5		0.0	0.5	1.4	0.0	50.0		0.0	1.3	1.3	1.2	35.3		0.0	0.2	0.3	0.0
Lepidonotothen kempi (L)	24.0		0.0	1.4	4.6	0.0	25.5		0.0	0.7	1.8	0.0	50.0		0.0	0.5	0.6	0.2	35.3		0.0	0.4	0.7	0.0
Euphausia triacantha	24.0		0.0	1.2	3.9	0.0	23.4		0.0	2.0	5.6	0.0	25.0		0.0	0.1	0.2	0.0	5.9		0.0	0.0	0.1	0.0
Sipunculids	16.0		0.0	0.6	1.7	0.0	31.9		0.0	1.1	5.8	0.0	62.5		0.2	6.3	10.7	0.9	23.5		0.0	0.5	1.5	0.0
Orchomene plebs	16.0		0.0	0.1	0.3	0.0	23.4		0.0	0.1	0.3	0.0	0.0		0.0	0.0	0.0	0.0	5.9		0.0	0.1	0.4	0.0
Beroe forskalii	12.0		0.0	0.3	1.4	0.0	10.6		0.0	0.1	0.2	0.0	12.5		0.0	0.2	0.6	0.0	5.9		0.0	0.0	0.2	0.0
Calycopsis borchgrevinki	12.0		0.0	0.1	0.1	0.0	10.6		0.0	0.1	0.2	0.0	0.0		0.0	0.0	0.0	0.0	5.9		0.0	0.0	0.0	0.0
Vanadis antarctica	12.0		0.0	0.1	0.3	0.0	2.1		0.0	0.0	0.1	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Euphausia frigida (L)	8.0		0.0	1.4	4.8	0.0	38.3		0.1	9.2	28.0	0.0	25.0		0.2	8.2	18.0	0.0	11.8		0.1	1.2	3.9	0.0
Lepidonotothen larseni (L)	8.0		0.0	0.1	0.2	0.0	25.5		0.0	0.7	2.9	0.0	62.5		0.0	0.7	1.0	0.4	29.4		0.0	0.3	0.7	0.0
Electrona antarctica	8.0		0.0	0.1	0.2	0.0	17.0		0.0	0.1	0.2	0.0	12.5		0.0	0.1	0.1	0.0	5.9		0.0	0.0	0.2	0.0
Hydromedusae (unid.)	8.0		0.0	0.1	0.6	0.0	12.8		0.0	0.1	0.3	0.0	12.5		0.0	0.0	0.1	0.0	11.8		0.0	0.1	0.3	0.0
Notolepis coatsi (L)	8.0		0.0	0.1	0.3	0.0	10.6		0.0	0.1	0.4	0.0	0.0		0.0	0.0	0.0	0.0	29.4		0.0	0.2	0.4	0.0
Dimophyes arctica	8.0		0.0	0.1	0.6	0.0	8.5		0.0	0.1	0.2	0.0	25.0		0.0	0.4	0.7	0.0	23.5		0.1	2.1	8.0	0.0
Gymnoscopelus braueri	8.0		0.0	0.1	0.2	0.0	8.5		0.0	0.1	0.3	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Scina spp.	8.0		0.0	0.7	2.3	0.0	6.4		0.0	0.2	0.9	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Euphausia triacantha (L)	8.0		0.0	0.2	1.1	0.0	6.4		0.0	0.4	2.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Hyperiella spp.	8.0		0.0	0.1	0.2	0.0	6.4		0.0	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
Clione antarctica	8.0		0.0	0.1	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		0.0	0.0	0.0	0.0
Diphyes antarctica	4.0		0.0	0.0	0.1	0.0	29.8		0.0	0.3	0.6	0.0	87.5		0.0	0.6	0.5	0.4	41.2		0.0	0.2	0.3	0.0
Cyllopus spp.	4.0		0.0	0.0	0.1	0.0	10.6		0.0	0.1	0.3	0.0	12.5		0.0	0.0	0.1	0.0	0.0		0.0	0.0	0.0	0.0
Rhynchonereella bongraini	4.0		0.0	0.6	3.0	0.0	6.4		0.0	0.8	3.3	0.0	50.0		0.1	4.2	5.0	2.0	11.8		0.0	0.6	2.0	0.0
Siphonophora (unid.)	4.0		0.0	0.4	1.9	0.0	6.4		0.0	0.3	1.4	0.0	0.0		0.0	0.0	0.0	0.0	11.8		0.1	2.0	7.5	0.0
Ctenophora (unid.)	4.0		0.0	0.0	0.2	0.0	6.4		0.0	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

Table 4.5 (Contd.)

TAXON	WEST AREA (N=25) F(%)	R	%	MEAN	STD	MED	ELEPHANT ISLAND AREA (N=47) F(%)	R	%	MEAN	STD	MED	JOINVILLE ISLAND AREA (N=8) F(%)	R	%	MEAN	STD	MED	SOUTH AREA (N=17) F(%)	R	%	MEAN	STD	MED
Beroe cucumis	4.0		0.0	0.0	0.1	0.0	4.3		0.0	0.0	0.1	0.0	0.0		0.0	0.0	0.0	0.0	5.9		0.0	0.0	0.1	0.0
Pegantha martgon	4.0		0.0	0.0	0.1	0.0	4.3		0.0	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
Cephalopods	4.0		0.0	0.0	0.1	0.0	4.3		0.0	0.0	0.1	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Clio pyramidata antarctica	4.0		0.0	0.0	0.1	0.0	2.1		0.0	0.0	0.2	0.0	12.5		0.0	0.0	0.1	0.0	0.0		0.0	0.0	0.0	0.0
Euphausia crystallorophias (L)	4.0		0.0	0.2	1.1	0.0	2.1		0.0	1.3	9.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Hyperiella macronyx	4.0		0.0	0.0	0.1	0.0	2.1		0.0	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
Orchomene rossi	4.0		0.0	0.0	0.1	0.0	2.1		0.0	0.0	0.1	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Harpagifer antarcticus (L)	4.0		0.0	0.0	0.1	0.0	2.1		0.0	0.0	0.1	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Gymnoscopelus nicholsi	4.0		0.0	0.0	0.1	0.0	0.0		0.0	0.0	0.0	0.0	12.5		0.0	0.0	0.1	0.0	11.8		0.0	0.0	0.1	0.0
Cyphocaris richardi	4.0		0.0	0.0	0.1	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Isopods (unid.)	4.0		0.0	0.0	0.1	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	11.8		0.0	0.1	0.4	0.0
Larval Fish (unid.)	4.0		0.0	0.1	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		0.0	0.0	0.0	0.0
Hyperia macrocephala	4.0		0.0	0.0	0.1	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Lepidonotothen larseni (J)	4.0		0.0	0.0	0.1	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Hyperia antarctica	4.0		0.0	0.0	0.1	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Leusia spp.	0.0		0.0	0.0	0.0	0.0	6.4		0.0	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
Polychaetes (unid.)	0.0		0.0	0.0	0.0	0.0	4.3		0.0	0.6	2.9	0.0	25.0		0.0	1.6	2.9	0.0	0.0		0.0	0.0	0.0	0.0
Limacina spp.	0.0		0.0	0.0	0.0	0.0	4.3		0.0	1.4	8.7	0.0	25.0		0.1	3.1	8.0	0.0	5.9		0.0	0.5	1.9	0.0
Gammarids (unid.)	0.0		0.0	0.0	0.0	0.0	4.3		0.0	0.2	0.8	0.0	12.5		0.0	0.1	0.1	0.0	5.9		0.0	0.8	3.0	0.0
Euphausia crystallorophias	0.0		0.0	0.0	0.0	0.0	4.3		0.0	0.0	0.1	0.0	0.0		0.0	0.0	0.0	0.0	23.5	9	0.6	13.8	36.2	0.0
Bathylagus antarcticus	0.0		0.0	0.0	0.0	0.0	4.3		0.0	0.0	0.1	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Krefflichthys anderssoni (L)	0.0		0.0	0.0	0.0	0.0	4.3		0.0	0.0	0.1	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Clio pyramidata sulcata	0.0		0.0	0.0	0.0	0.0	4.3		0.0	0.0	0.1	0.0	0.0		0.0	0.0	0.0	0.0	5.9		0.0	0.0	0.1	0.0
Schyphomedusae (unid.)	0.0		0.0	0.0	0.0	0.0	4.3		0.0	0.0	0.1	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Electrona carlsbergi	0.0		0.0	0.0	0.0	0.0	4.3		0.0	0.1	0.3	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Eusirus antarcticus	0.0		0.0	0.0	0.0	0.0	2.1		0.0	0.0	0.1	0.0	12.5		0.0	0.0	0.1	0.0	17.6		0.0	0.4	1.3	0.0
Hyperoche medusarum	0.0		0.0	0.0	0.0	0.0	2.1		0.0	0.0	0.1	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Trematomus scotti (L)	0.0		0.0	0.0	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	0.0
Periphylla periphylla	0.0		0.0	0.0	0.0	0.0	2.1		0.0	0.0	0.1	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Spongiobranchaea sp.	0.0		0.0	0.0	0.0	0.0	2.1		0.0	0.0	0.2	0.0	0.0		0.0	0.0	0.0	0.0	11.8		0.0	0.0	0.1	0.0
Clio pyramidata martensi?	0.0		0.0	0.0	0.0	0.0	2.1		0.1	7.3	49.6	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Travisiopsis coniceps	0.0		0.0	0.0	0.0	0.0	2.1		0.0	0.2	1.5	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Larvaceans	0.0		0.0	0.0	0.0	0.0	2.1		0.0	0.0	0.1	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Eusirus perdentatus	0.0		0.0	0.0	0.0	0.0	2.1		0.0	0.0	0.1	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Staurophora mertensi?	0.0		0.0	0.0	0.0	0.0	2.1		0.0	0.0	0.1	0.0	0.0		0.0	0.0	0.0	0.0	5.9		0.0	0.0	0.1	0.0
Thyphloscolex muelleri	0.0		0.0	0.0	0.0	0.0	2.1		0.0	0.2	1.5	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Amphipods (unid.)	0.0		0.0	0.0	0.0	0.0	2.1		0.0	0.2	1.5	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Chromatonema rubra?	0.0		0.0	0.0	0.0	0.0	2.1		0.0	0.0	0.1	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Notolepis annulata (L)	0.0		0.0	0.0	0.0	0.0	2.1		0.0	0.0	0.1	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Gobionotothen gibberifrons (L)	0.0		0.0	0.0	0.0	0.0	2.1		0.0	0.1	0.4	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Acanthophyra pelagica	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	25.0		0.0	0.1	0.2	0.0	5.9		0.0	0.0	0.1	0.0
Pleuragramma antarcticum (L)	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	12.5		0.0	0.0	0.1	0.0	0.0		0.0	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	12.5		0.0	0.0	0.1	0.0	0.0		0.0	0.0	0.0	0.0
Macrourid (L)	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	12.5		0.0	0.0	0.1	0.0	0.0		0.0	0.0	0.0	0.0
Harpagrifer spp. (L)	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	5.9		0.0	0.0	0.1	0.0
Bathydraco antarcticus (L)	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	11.8		0.0	0.0	0.1	0.0
Epimeriella macronyx	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	5.9		0.0	0.0	0.1	0.0
Pelagobia longicirrata	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	5.9		0.0	0.0	0.1	0.0
Hyperiids (unid.)	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	11.8		0.0	0.2	0.5	0.0
Gastropods (unid.)	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	5.9		0.0	0.2	0.7	0.0
TOTAL	100.0			5128.7	7886.5	2101.7	100.0			8490.8	24186.5	3050.8	100.0			3631.6	1840.0	3089.8	100.0			2219.8	1423.2	1771.9
TAXA	67			22.8	4.1	22	87			24.6	3.7	24	51			24.5	5.1	24	62			22.5	3.4	23

Table 4.6. Taxonomic composition of zooplankton clusters during (A) January and (B) February-March, 2004. R and % are rank and proportions of total abundance represented by each taxon. Asterisks denote significant abundance differences between the two clusters: *** P<0.001; **P<0.01; *P<0.05.

A. SURVEY A

JANUARY 2004	CLUSTER 1 (COASTAL) N = 44					CLUSTER 2 (OFFSHORE) N = 47				
TAXA	R	%	MEAN	STD	MED	R	%	MEAN	STD	MED
Salpa thompsoni	2	10.3	143.0	187.4	63.8	1	31.0	212.8	344.3	105.5
Thysanoessa macrura	4	9.7	135.4	136.5	101.9	2	25.6	176.1	287.9	43.7
Calanoides acutus	3	10.1	140.4	189.5	75.7	3	13.4	91.8	167.6	35.2
Calanus propinquus	5	6.7	93.3 ***	78.3	62.5	4	6.6	45.4	42.4	38.4
Euphausia superba	7	4.5	62.3	175.7	1.4	5	4.1	28.2	68.1	3.1
Limacina helicina		1.5	20.3	37.1	7.7	6	3.5	23.9	37.1	4.2
Chaetognaths	8	3.7	52.1 *	82.4	18.5	7	3.1	21.1	33.1	10.4
Thysanoessa macrura (L)		0.5	6.3	11.9	0.2	8	2.9	19.7	87.5	2.1
Euphausia frigida		1.4	18.9	34.4	1.9	9	2.0	13.4	62.3	0.0
Metridia gerlachei	1	35.1	488.9 ***	900.5	142.3	10	1.2	8.5	19.7	1.2
Primno macropa		0.2	3.2	5.2	1.4		1.1	7.4	13.2	3.3
Pleuromama robusta	10	2.2	30.0 *	62.2	9.1		0.9	6.2	21.6	0.0
Pareuchaeta antarctica	9	3.7	51.7 ***	88.8	18.4		0.8	5.7	12.4	0.0
Euphausia superba (L)		0.6	8.8	13.4	2.2		0.8	5.3	15.4	0.0
Radiolaria		0.3	3.6	8.4	0.5		0.5	3.6	7.4	0.8
Themisto gaudichaudii		0.2	2.2	4.2	0.6		0.5	3.5	4.8	2.0
Ostracods		2.0	27.5 **	62.7	2.1		0.4	2.6	5.5	0.4
Spongiobranchaea australis		0.2	2.4	4.3	0.8		0.4	2.5	2.1	2.2
Ihlea racovitzai	6	5.3	74.4 **	148.7	12.4		0.3	2.0	8.6	0.0
Cyllopus lucasii		0.3	4.4 **	6.7	2.5		0.2	1.7	1.9	1.3
Rhincalanus gigas		1.2	16.8 ***	24.6	5.7		0.2	1.4	4.3	0.0
Lepidonotothen larseni (L)		0.1	0.8	1.4	0.0		0.1	0.9	2.7	0.0
Tomopteris spp.		0.1	2.1 **	3.3	0.4		0.1	0.7	1.2	0.4
Vibilia antarctica		0.1	0.9	1.3	0.4		0.1	0.5	0.8	0.0
Hyperiella dilatata		0.0	0.4	1.0	0.0		0.1	0.4	0.6	0.0
Sipunculids		0.0	0.3	0.6	0.0		0.1	0.4	1.4	0.0
Cyllopus magellanicus		0.0	0.6	1.7	0.0		0.0	0.3	0.9	0.0
Clione limacina		0.1	0.9	2.6	0.0		0.0	0.3	0.8	0.0
Diphyes antarctica		0.0	0.4	0.8	0.0		0.0	0.2	0.7	0.0
TOTAL		29	1392.5 ***	1105.2	1038.7		29	686.5	440.5	577.7
TAXA			24.3 ***	3.6	24			19.1	3.6	20

B. SURVEY D

FEBRUARY-MARCH 2004	CLUSTER 1 (COASTAL) N = 82					CLUSTER 2 (OFFSHORE) N = 15				
TAXA	R	%	MEAN	STD	MED	R	%	MEAN	STD	MED
Calanoides acutus	2	9.4	286.7	208.3	227.5	1	28.1	6468.4 ***	12836.5	1078.2
Rhincalanus gigas	7	3.7	113.2	130.8	74.0	2	17.5	4017.9 ***	8842.8	768.5
Calanus propinquus	3	9.1	278.0	248.2	204.0	3	15.2	3492.9 ***	5904.4	1286.4
Radiolaria		0.1	3.2	7.6	0.0	4	10.1	2323.9 **	6895.4	126.2
Thysanoessa macrura (L)		1.0	31.5	66.8	6.7	5	8.1	1865.3 ***	1906.6	1368.8
Metridia gerlachei	1	43.1	1311.0	3043.3	398.2	6	7.4	1702.2	2293.3	240.2
Chaetognaths	5	7.2	218.5	239.9	113.3	7	4.2	957.3 *	1839.9	291.3
Euphausia superba (L)	10	1.4	42.0	60.0	18.8	8	2.0	467.1 **	1263.6	107.8
Other copepods		0.9	26.1	59.2	0.7	9	1.5	333.5 ***	306.9	234.6
Pareuchaeta antarctica	6	3.8	115.1	134.6	69.0	10	1.4	332.0 **	436.6	135.7
Heterorhabdus sp.		0.1	3.7	10.7	0.0		1.2	265.1 *	954.1	0.0
Salpa thompsoni	8	3.3	98.9	166.2	30.3		1.1	257.6 *	437.2	91.5
Limacina helicina		0.4	13.5	41.6	0.8		0.9	201.2 ***	267.5	78.6
Pleuromama robusta		0.9	27.7	90.0	0.0		0.1	31.1	96.8	0.0
Primno macropa		0.5	13.7	17.3	7.7		0.1	29.5 *	57.3	3.6
Spongiobranchaea australis		0.1	2.1	4.7	0.4		0.1	26.4 ***	32.5	15.6
Euphausia superba	9	2.7	82.7	292.6	2.5		0.1	23.7	39.8	2.1
Euphausia frigida (L)		0.1	2.6	7.9	0.0		0.1	22.6 ***	45.8	8.0
Hyperiella dilatata		0.1	1.7	8.1	0.0		0.1	13.5 *	38.6	0.8
Euphausia frigida		1.3	39.7	67.4	5.6		0.1	11.6	33.3	0.0
Ostracods		1.0	30.0	89.0	1.0		0.0	9.7	19.0	0.0
Thysanoessa macrura	4	8.1	246.1 **	343.6	117.3		0.0	8.3	10.9	2.4
Tomopteris spp.		0.0	1.1	3.0	0.0		0.0	3.9 **	6.5	0.4
Cyllopus lucasii		0.1	3.4	4.9	1.3		0.0	3.7	4.2	2.0
Themisto gaudichaudii		0.2	4.7	6.9	2.5		0.0	3.2	2.6	2.4
Euphausia triacantha		0.0	1.2	4.3	0.0		0.0	2.0	5.1	0.0
Electrona spp. (L)		0.0	1.1	2.9	0.0		0.0	1.9	5.5	0.0
Cyllopus magellanicus		0.0	0.8	1.1	0.4		0.0	1.9 **	2.2	1.2
Lepidonotothen kempi (L)		0.0	0.6	1.5	0.0		0.0	1.6	5.8	0.0
Clione limacina		0.0	0.3	0.7	0.0		0.0	1.5 ***	2.3	0.4
Vibilia antarctica		0.0	0.9	2.5	0.0		0.0	1.3	2.8	0.0
Sipunculids		0.1	1.6	5.9	0.0		0.0	0.0	0.1	0.0
Ihlea racovitzai		0.9	26.3 *	50.5	1.3		----	----	----	----
Diphyes antarctica		0.0	0.3 *	0.5	0.0		----	----	----	----
Lepidonotothen larseni (L)		0.0	0.5	2.2	0.0		----	----	----	----
TOTAL		35	3041.2	3371.8	2165.8		32	22979.7 ***	39778.2	8577.6
TAXA			20.9	3.4	21			22.1	2.2	21

Table 4.7. Abundance of krill and other dominant zooplankton taxa collected in the Elephant Island area during January-February and February-March surveys, 1992-2004. Zooplankton data are not available for February-March 1992 or January 2000.

	Euphausia superba												
	January-February												
YEAR	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
N	63	70	63	71	72	71	61	40	n.a.	60	44	38	46
Mean	23.7	28.8	34.5	9.5	82.1	29.6	27.1	5.3	—	18.9	39.0	318.8	59.8
SD	78.0	64.4	94.2	20.6	245.1	80.5	42.3	8.1	—	32.7	93.3	1386.0	170.5
Med	5.7	8.2	3.1	3.6	11.4	5.6	10.2	1.7	—	6.0	7.5	30.9	3.1
Max	594.1	438.9	495.9	146.1	1500.6	483.2	175.0	35.1	—	217.7	458.6	8683.2	852.2
	February-March												
YEAR	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
N	67	67	70	71	72	16	61	39	60	57	44	48	47
Mean	38.0	35.0	17.1	5.2	133.2	30.4	162.6	35.5	14.4	80.5	10.1	94.9	50.9
SD	77.4	89.7	63.5	12.0	867.7	56.4	768.3	155.7	35.3	374.0	25.4	240.2	91.0
Med	7.1	3.0	0.4	1.2	4.1	4.6	4.5	0.8	3.3	4.6	0.4	8.7	10.4
Max	389.9	542.0	371.1	90.0	7385.4	204.2	5667.0	978.6	253.5	2817.0	112.1	1309.1	425.2

	Salpa thompsoni												
	January-February												
YEAR	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
N	63	70	63	71	72	71	61	40	n.a.	60	44	38	46
Mean	94.3	1213.4	931.9	20.2	25.5	223.2	939.7	197.5	—	622.8	410.0	61.9	176.6
SD	192.3	2536.7	950.2	46.5	36.3	336.4	1556.3	191.6	—	576.4	614.6	132.7	166.7
Med	14.0	245.8	582.3	1.6	10.5	87.1	348.9	159.1	—	449.3	85.8	8.7	134.1
Max	1231.1	16078.8	4781.7	239.9	161.6	2006.3	8030.4	873.4	—	3512.4	2816.8	709.2	754.8
	February-March												
YEAR	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
N	n.a.	67	70	71	72	16	61	39	60	57	44	48	47
Mean	—	1585.9	495.1	20.6	33.2	1245.5	977.3	309.1	912.8	452.4	570.4	60.7	159.1
SD	—	2725.5	579.4	66.5	85.7	1224.6	1496.5	376	3395.1	501.2	782.3	119.7	252.2
Med	—	605.9	242.6	0.7	5.6	521.0	553.8	160.7	262.9	312.1	250.9	7.0	45.5
Max	—	16662.5	2377.5	391.9	659.4	4348.3	10712.9	1550.2	24031.9	2416.8	2903.7	475.4	1216.3

	Thysanoessa macrura												
	January-February												
YEAR	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
N	63	70	63	71	72	71	61	40	n.a.	60	44	38	46
Mean	48.1	48.6	74.6	104.1	103.4	101.0	135.3	46.6	—	46.2	200.9	239.0	108.2
SD	57.0	60.1	144.3	231.9	118.1	127.2	150.8	54.1	—	49.2	784.8	405.3	161.5
Med	22.5	27.5	25.4	36.1	52.3	52.8	98.0	23.2	—	32.2	33.1	103.9	55.4
Max	233.7	307.1	901.6	1859.0	500.1	616.2	992.3	215.8	—	251.7	5302.0	2134.8	971.4
	February-March												
YEAR	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
N	n.a.	67	70	71	72	16	61	39	60	57	44	48	47
Mean	—	128.9	77.1	79.7	116.1	181.3	140.6	95.2	35.1	1040.9	56.4	232.6	138.9
SD	—	235.1	132.6	138.5	147.4	168.0	232.3	131.9	61.5	7262.6	132.5	271.3	205.7
Med	—	22.1	23.8	22.2	53.6	122.6	70.0	18.0	14.0	44.1	3.5	156.0	59.8
Max	—	1141.5	815.9	664.9	679.4	538.9	1638.5	589.2	291.6	55381.1	662.7	1441.5	963.6

Table 4.7 (Contd.)

	Copepods January-February												
YEAR	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
N	n.a.	70	63	71	72	71	61	40	n.a.	60	44	38	46
Mean	—	73.5	32.4	741.0	897.5	656.4	41.2	928.2	—	1003.2	5484.3	541.0	494.5
SD	—	302.7	92.2	1061.3	1726.4	799.1	55.1	1590.8	—	1582.4	14585.6	798.6	796.1
Med	—	0.0	0.0	346.0	338.2	399.7	21.5	333.0	—	252.2	2174.9	317.0	208.7
Max	—	2312.6	465.3	7047.5	10598.0	4090.0	276.0	7524.8	—	6909.7	96514.5	4390.2	3554.4
	February-March												
YEAR	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
N	n.a.	n.a.	70	71	72	16	61	39	60	57	44	48	47
Mean	—	—	3453.3	3707.3	1483.7	1267.8	110.4	1558.4	8019.1	4501.5	17473.4	1674.3	6303.1
SD	—	—	8190.8	5750.3	2209.2	1755.6	170.3	2337.5	11824.4	8072.4	20036.9	2593.6	17739.5
Med	—	—	172.4	1630.9	970.2	659.8	50.9	621.6	3478.0	1518.0	7563.8	737.5	2233.5
Max	—	—	37987.2	40998.5	16621.0	7289.2	901.1	10786.6	57498.5	39800.7	90224.5	15990.9	120411.5

	Euphausia superba Larvae January-February												
YEAR	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
N	n.a.	n.a.	n.a.	71	72	71	61	40	n.a.	60	44	38	46
Mean	—	—	—	172.1	3.4	19.3	0.4	175.1	—	32.8	35.8	4.7	9.8
SD	—	—	—	969.4	8.3	27.0	1.6	795.5	—	86.2	64.6	16.8	18.5
Med	—	—	—	0.0	0.0	6.4	0.0	4.3	—	9.0	0.0	0.0	0.4
Max	—	—	—	8076.1	42.7	96.5	11.4	5083.2	—	654.0	356.3	95.5	95.7
	February-March												
YEAR	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
N	n.a.	n.a.	n.a.	71	72	16	61	39	60	57	44	48	47
Mean	—	—	—	4593.4	14.1	25.0	2.5	67.2	3423.2	71.9	49.9	6.1	177.3
SD	—	—	—	20117.0	44.0	81.4	18.3	146.0	8974.1	176.9	140.9	13.0	741.5
Med	—	—	—	268.6	3.3	0.0	0.0	12.3	248.7	5.1	0.0	0.0	38.9
Max	—	—	—	167575.6	368.5	339.0	144.1	692.5	44478.2	1197.7	728.6	56.1	5160.5

	Euphausia frigida January-February												
YEAR	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
N	63	70	63	71	72	71	61	40	n.a.	60	44	38	46
Mean	5.4	4.2	4.7	12.1	2.0	9.6	0.3	15.9	—	23.4	28.0	10.6	19.2
SD	14.9	18.4	14.9	32.1	4.5	21.4	1.4	29.1	—	55.9	56.1	27.3	44.5
Med	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	—	0.0	0.4	0.0	0.0
Max	76.7	143.0	76.7	175.6	22.5	91.4	10.0	116.0	—	315.6	256.1	135.2	223.7
	February-March												
YEAR	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
N	n.a.	67	70	71	72	16	61	39	60	57	44	48	47
Mean	—	1.0	28.9	19.7	9.5	44.8	9.0	23.0	43.1	37.7	78.4	50.9	26.8
SD	—	4.7	62.0	36.7	12.7	54.2	26.0	38.7	73.0	82.0	192.3	92.0	45.8
Med	—	0.0	5.5	2.9	1.2	21.0	0.0	7.6	6.8	0.0	5.1	11.5	0.6
Max	—	32.6	439.7	216.1	48.8	176.2	178.4	159.1	307.2	319.2	1149.9	478.7	162.7

Table. 4.7 (Contd.)

	Thysanoessa macrura larvae January-February												
YEAR	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
N	n.a.	n.a.	n.a.	71	72	71	61	40	n.a.	60	44	38	46
Mean	—	—	—	20.2	372.0	21.5	0.0	116.5	—	269.3	773.3	1.2	6.7
SD	—	—	—	75.2	858.1	38.4	0.0	348.8	—	608.8	1379.1	2.7	11.0
Med	—	—	—	0.0	32.1	1.5	0.0	2.8	—	42.7	181.7	0.0	2.1
Max	—	—	—	441.5	4961.8	159.9	0.0	1519.6	—	3621.0	8984.2	14.5	45.3
	February-March												
YEAR	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
N	n.a.	n.a.	70	71	72	16	61	39	60	57	44	48	47
Mean	—	—	31.7	344.3	511.5	10.8	0.5	185.9	1084.8	613.3	1444.9	1.3	386.8
SD	—	—	111.1	594.2	1432.5	24.9	2.0	535.7	4147.3	1009.5	2665.1	3.0	989.5
Med	—	—	0.0	79.9	36.1	1.0	0.0	10.0	26.8	265.3	364.0	0.0	39.0
Max	—	—	809.1	3735.5	10875.0	104.7	12.1	2990.8	31132.5	5461.9	12270.6	18.1	4637.7

	Chaetognaths January-February												
YEAR	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
N	n.a.	70	63	71	72	71	61	40	n.a.	60	44	38	46
Mean	—	3.1	0.2	84.7	11.9	20.1	3.3	63.9	—	57.4	139.8	119.3	35.3
SD	—	7.9	0.5	159.5	25.1	26.1	5.2	159.1	—	110.9	221.1	33.6	78.5
Med	—	0.0	0.0	30.0	4.2	10.3	0.9	14.7	—	11.3	76.6	5.3	9.3
Max	—	41.3	2.2	781.8	184.9	120.4	24.7	960.2	—	660.7	1283.4	130.2	385.3
	February-March												
YEAR	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
N	n.a.	67	70	71	72	16	61	39	60	57	44	48	47
Mean	—	0.7	21.8	330.2	58.4	18.4	8.9	147.4	792.3	93.5	1073.1	103.2	446.8
SD	—	4.2	87.7	404.6	72.3	23.9	23.3	261.4	1543.7	173.4	1210.4	130.6	1114.1
Med	—	0.0	0.0	161.0	31.8	5.5	1.0	48.7	229.4	10.5	435.6	56.3	127.3
Max	—	34.9	578.9	1769.9	383.8	77.9	124.7	1146.6	8221.0	836.9	5052.6	579.9	7568.7

Table 4.8. Maturity stage composition of krill collected in the Elephant Island area during 2003 compared to 1992-2002. Advanced maturity stages ar 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, 2

A. SURVEY A	*Euphausia superba* JANUARY-FEBRUARY												
	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Stage	%	%	%	%	%	%	%	%	n.a.	%	%	%	%
Juveniles	37.1	7.2	4.0	4.6	55.0	15.2	18.4	0.4	---	9.7	46.3	42.4	1.8
Immature	19.1	30.7	18.8	4.0	18.3	30.6	31.7	11.7	---	6.2	9.0	39.1	38.5
Mature	43.9	62.2	77.2	91.4	26.7	54.2	49.9	87.9	---	84.1	44.7	18.5	59.7
Females:													
F2	0.8	7.8	2.3	0.1	1.1	6.3	9.1	1.6	---	0.2	0.4	12.3	4.3
F3a	0.6	11.7	18.0	0.2	0.0	3.5	21.4	1.7	---	0.9	0.5	11.7	18.1
F3b	12.3	14.3	19.3	1.2	0.2	0.6	9.0	1.8	---	14.6	2.3	1.3	7.5
F3c	9.2	5.1	20.1	15.3	1.9	6.9	1.0	14.7	---	13.2	13.7	1.6	11.2
F3d	0.4	1.2	2.3	17.7	0.7	6.1	0.3	23.9	---	7.4	10.0	0.0	0.1
F3e	0.0	0.0	0.0	3.7	11.6	7.4	0.7	9.2	---	1.3	6.2	0.0	0.6
Advanced Stages	42.7	19.5	37.5	96.3	98.3	83.2	6.2	93.2	---	58.5	91.6	11.2	11.8
Males:													
M2a	8.7	6.8	0.3	0.9	14.6	14.6	8.5	2.2	---	2.1	3.0	13.6	7.4
M2b	7.3	11.9	9.4	1.5	2.1	8.2	8.4	3.9	---	2.1	4.0	10.2	14.7
M2c	2.3	4.2	6.8	1.5	0.5	1.5	5.7	4.1	---	1.7	1.5	3.1	12.2
M3a	2.8	3.7	4.3	4.4	1.4	1.5	3.1	1.7	---	2.1	1.7	1.1	11.5
M3b	18.7	26.2	13.2	48.9	10.9	28.1	14.4	34.9	---	44.6	10.4	2.9	10.8
Male:Female ratio	1.7	1.3	0.5	1.5	1.9	1.8	1.0	0.9	---	1.4	0.6	1.2	1.4
No. measured	2472	4283	2078	2294	4296	3209	3600	751	---	2063	1437	2466	1410

B. SURVEY D	FEBRUARY-MARCH												
	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Stage	%	%	%	%	%	%	%	%	%	%	%	%	%
Juveniles	33.6	3.5	3.7	1.1	20.8	8.0	3.6	0.0	0.1	13.4	38.9	20.6	0.1
Immature	27.1	51.4	6.2	2.5	9.9	19.7	25.4	1.3	2.3	14.7	17.3	52.4	16.3
Mature	39.2	45.1	90.1	96.4	69.3	72.3	71.0	98.7	97.5	71.9	43.8	27.0	83.6
Females:													
F2	0.8	21.8	0.7	0.3	0.6	1.1	6.9	0.0	0.2	0.7	3.3	21.4	2.9
F3a	10.3	12.4	3.5	0.0	0.0	0.1	10.9	0.4	1.0	2.4	0.9	13.4	3.7
F3b	10.2	6.2	7.8	0.0	0.0	0.0	11.8	0.0	0.7	0.2	0.2	2.5	0.3
F3c	4.3	3.7	4.3	2.0	5.0	1.8	3.0	11.1	6.5	1.5	2.2	2.3	2.2
F3d	1.2	1.1	4.6	21.8	10.9	29.1	1.3	47.3	21.9	3.8	14.7	0.3	17.0
F3e	<0.01	1.2	0.9	20.4	4.9	7.3	0.1	4.8	22.0	42.6	3.6	0.6	13.0
Advanced Stages	4.6	9.3	26.1	95.5	76.0	95.0	5.2	81.8	84.2	91.8	85.2	4.7	82.9
Males:													
M2a	4.3	6.9	0.2	0.7	6.5	8.6	1.9	0.0	0.1	4.1	8.8	12.0	2.4
M2b	19.8	19.1	1.2	0.4	1.2	8.8	6.6	0.7	0.7	2.7	3.6	14.9	7.3
M2c	2.2	3.6	4.2	1.1	1.6	1.2	10.0	0.6	1.3	7.3	1.6	4.2	3.7
M3a	2.5	2.1	24.1	4.4	5.3	3.7	17.5	2.6	7.4	2.2	0.3	2.0	4.8
M3b	10.7	18.4	44.7	47.8	43.2	30.3	26.2	32.4	38.0	19.2	22.1	5.8	42.7
Male:Female ratio	1.5	1.1	3.4	1.2	2.7	1.3	1.9	0.6	0.9	0.7	1.5	0.9	1.6
No. measured	3646	3669	1155	1271	2984	560	3153	1176	1371	1739	558	1936	2081

Table 4.9. Salp and krill carbon biomass (mg C per m^2) in the Elephant Island area during 1995-2004 surveys. N is number of samples. Salp:Krill Ratio is based on median values.

	JANUARY-FEBRUARY																			
	1995		1996		1997		1998		1999		2000		2001		2002		2003		2004	
BIOMASS	Salps	Krill	Salps	Krill	Salps	Krill	Salps	Krill	Salps	Krill	Salps	Krill	Salps	Krill	Salps	Krill	Salps	Krill	Salps	Krill
Mean	7.8	242.3	20.2	337.3	334.5	229.0	430.8	173.1	151.8	48.6	---	---	334.5	248.5	287.4	218.6	35.9	1426.0	120.5	472.7
SD	16.1	201.1	30.9	756.1	1115.6	522.1	565.3	290.6	166.1	66.1	---	---	272.8	425.3	418.3	552.0	69.8	6818.3	135.8	1403.2
Median	1.3	43.5	10.0	72.2	108.9	45.1	187.0	46.7	93.2	14.5	---	---	251.7	81.0	127.0	37.6	4.5	137.7	84.9	28.2
Maximum	75.3	1545.2	134.2	4721.0	9434.6	3115.5	2699.0	1488.4	882.7	304.4	---	---	1395.1	2561.2	1855.4	3509.2	388.6	42745.4	628.0	7254.5
N	57	71	72	72	71	71	61	60	40	40	---	---	60	60	44	44	38	38	46	46
Salp:Krill Ratio	0.03		0.1		2.4		4.0		6.4		n.a.		3.1		3.4		0.03		3.0	

	FEBRUARY-MARCH																			
	1995		1996		1997		1998		1999		2000		2001		2002		2003		2004	
BIOMASS	Salps	Krill	Salps	Krill	Salps	Krill	Salps	Krill	Salps	Krill	Salps	Krill	Salps	Krill	Salps	Krill	Salps	Krill	Salps	Krill
Mean	13.1	59.2	50.7	1702.3	1139.7	313.1	694.6	1555.8	321.9	451.0	741.2	204.4	333.9	890.3	738.4	62.3	62.0	451.9	123.7	559.1
SD	47.3	149.1	146.5	12441.6	1269.8	655.2	1121.2	8218.7	335.1	2082.6	2314.9	507.6	352.4	4116.8	2129.0	179.5	122.9	1082.7	219.1	1037.1
Median	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	327.1	2.7	6.2	27.4	42.5	82.9
Maximum	325.2	1107.1	954.0	106458.5	4645.4	2638.7	8543.0	62155.8	1698.1	13133.1	16400.1	3634.6	1702.8	30967.9	14362.1	1062.6	550.4	5165.6	1201.3	5221.1
N	71	71	72	72	16	16	61	60	39	39	60	60	57	57	44	44	48	48	47	47
Salp:Krill Ratio	0.1		0.1		10.1		12.0		28.0		5.6		4.7		121.1		0.2		0.5	

Table 4.10. Zooplankton and nekton taxa present in the large survey area samples during (A) January 2004 and (B) February-March 2004 compared to 1995-2003 surveys. F is the frequency of occurrence (%) in (N) tows. Mean is number per 1000 m^3. Dashes indicate that taxon were not yet identified and/or enumerated. (L) and (J) denote larval and juvenile stages.

	JANUARY-FEBRUARY																			
	2004 N=91		2003 N=83		2002 N=95		2001 N=101		2000 n.a.		1999 N=75		1998 N=105		1997 N=105		1996 N=91		1995 N=90	
TAXON	F(%)	Mean	F(%)	Mean	F(%)	Mean	F(%)	Mean	F(%)	Mean	F(%)	Mean	F(%)	Mean	F(%)	Mean	F(%)	Mean	F(%)	Mean
Copepods	98.9	479.9	100.0	609.2	100.0	7536.2	100.0	2247.1	-----	-----	100.0	711.6	94.2	56.5	100.0	582.6	100.0	794.4	98.9	652.7
Thysanoessa macrura	95.6	156.4	100.0	243.5	92.6	222.6	93.1	73.5	-----	-----	93.3	135.1	100.0	180.8	97.1	104.4	98.9	106.9	91.1	96.4
Salpa thompsoni	93.4	179.1	81.9	63.0	88.4	267.7	100.0	520.7	-----	-----	100.0	163.3	100.0	808.2	97.1	181.4	64.8	20.4	66.7	16.0
Chaetognaths	84.6	36.1	94.0	31.3	81.1	170.9	84.2	174.2	-----	-----	49.3	47.8	42.3	8.9	74.3	22.9	68.1	12.5	98.9	79.7
Limacina helicina	83.5	22.1	68.7	31.9	12.6	0.8	51.5	4.9	-----	-----	61.3	2.4	73.1	8.1	47.6	2.9	74.7	33.7	43.3	1.9
Euphausia superba	83.5	44.7	92.8	193.0	74.7	65.5	89.1	27.7	-----	-----	60.0	6.1	92.3	36.8	93.3	40.4	96.7	112.5	87.8	14.5
Spongiobranchaea australis	79.1	2.5	57.8	1.4	69.5	1.9	68.3	2.1	-----	-----	69.3	1.4	45.2	0.9	67.6	2.2	47.3	1.8	64.4	0.5
Cyllopus lucasii	78.0	3.0	31.3	0.5	34.7	1.4	87.1	22.4	-----	-----	6.7	0.0	20.2	0.5	49.5	0.4	11.0	0.1	22.2	0.5
Themisto gaudichaudii	72.5	2.9	74.7	7.8	86.3	32.5	66.3	4.0	-----	-----	32.0	0.3	31.7	0.3	92.4	3.6	92.3	4.9	76.7	4.9
Primno macropa	67.0	5.4	85.5	5.2	52.6	6.3	7.9	0.1	-----	-----	69.3	2.5	26.0	0.7	63.8	4.3	20.9	0.1	20.0	0.1
Radiolaria	65.9	3.6	47.0	2.2	42.1	1030.2	19.8	46.1	-----	-----	40.0	8.9	27.9	0.7	41.0	1.8	12.1	0.1	-----	-----
Ostracods	63.7	14.6	45.8	6.8	28.4	111.0	37.6	6.7	-----	-----	49.3	2.8	51.0	4.8	41.0	5.5	53.8	4.9	56.7	9.7
Thysanoessa macrura (L)	57.1	13.3	21.7	1.0	90.5	1428.1	85.1	458.0	-----	-----	69.3	72.5	1.9	0.0	44.8	17.0	90.1	308.5	36.7	15.9
Vibilia antarctica	54.9	0.7	74.7	2.3	66.3	3.9	98.0	16.3	-----	-----	94.7	3.8	96.2	13.2	70.5	2.5	48.4	0.5	22.2	0.2
Tomopteris spp.	53.8	1.4	74.7	3.4	46.3	3.0	45.5	1.9	-----	-----	56.0	2.0	31.7	1.3	54.3	1.9	60.4	0.9	84.4	4.2
Euphausia superba (L)	50.5	7.0	32.5	3.4	28.4	19.4	68.3	160.2	-----	-----	65.3	103.1	11.5	1.0	55.2	15.2	22.0	2.7	22.2	135.8
Hyperiella dilatata	47.3	0.4	65.1	0.8	53.7	1.3	24.8	0.4	-----	-----	52.0	0.5	39.4	0.4	56.2	2.2	41.8	0.6	54.4	0.3
Ihlea racovitzai	42.9	37.0	13.3	0.2	12.6	1.1	12.9	1.1	-----	-----	25.3	3.3	5.8	41.5	n.a	n.a	n.a	n.a	n.a	n.a
Lepidonotothen larseni (L)	36.3	0.9	48.2	1.5	18.9	3.8	10.9	0.7	-----	-----	20.0	0.2	23.1	0.5	27.6	1.8	22.0	0.2	40.0	1.1
Euphausia frigida	36.3	16.1	39.8	10.9	42.1	20.5	45.5	28.8	-----	-----	32.0	9.0	5.8	0.2	41.9	14.8	30.8	1.9	50.0	9.8
Cyllopus magellanicus	35.2	0.4	37.3	0.5	44.2	3.3	30.7	0.5	-----	-----	78.7	2.0	64.4	1.9	76.2	3.8	41.8	1.6	24.4	0.2
Clione limacina	33.0	0.6	54.2	2.9	40.0	2.3	26.7	0.9	-----	-----	17.3	0.1	38.5	0.9	21.9	0.3	56.0	2.1	41.1	0.5
Diphyes antarctica	23.1	0.3	33.7	0.5	15.8	0.4	23.8	0.5	-----	-----	34.7	0.5	37.5	1.1	9.5	0.2	17.6	0.1	58.9	1.0
Sipunculids	19.8	0.3	26.5	0.2	3.2	0.0	3.0	0.0	-----	-----	10.7	0.0	11.5	0.1	10.5	0.1	7.7	0.0	24.4	0.1
Notolepis coatsi (L)	18.7	0.2	16.9	0.1	4.2	0.0	1.0	0.0	-----	-----	5.3	0.0	3.8	0.0	6.7	0.0	8.8	0.0	27.8	0.1
Beroe forskalii	18.7	0.2	30.1	0.4	0.0	0.0	17.8	0.2	-----	-----	2.7	0.0	1.0	0.0	0.0	0.0	1.1	0.0	-----	-----
Electrona spp. (L)	16.5	0.3	44.6	1.5	3.2	0.0	10.9	0.4	-----	-----	24.0	0.2	10.6	0.2	37.1	1.4	27.5	0.7	61.1	2.5
Euphausia triacantha	15.4	0.7	10.8	0.7	7.4	0.8	13.9	1.6	-----	-----	17.3	0.4	7.7	0.3	18.1	1.4	15.4	0.5	33.3	1.5
Clione antarctica	13.2	0.1	0.0	0.0	1.1	0.0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Eustrus antarcticus	13.2	0.1	4.8	0.0	1.1	0.0	-----	-----	-----	-----	0.0	0.0	1.0	0.0	0.0	0.0	1.1	0.0	0.0	0.0
Clio pyramidata antarctica	11.0	0.1	15.7	1.7	2.1	0.0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Euphausia crystallorophias	11.0	0.3	30.1	29.7	12.6	16.5	1.0	0.0	-----	-----	9.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	4.4	0.0
Lepidonotothen kempi (L)	11.0	0.3	15.7	0.2	8.4	0.3	7.9	0.4	-----	-----	6.7	0.0	13.5	0.3	32.4	0.6	30.8	0.3	20.0	0.1
Dimophyes arctica	9.9	0.2	16.9	0.1	13.7	0.6	10.9	0.2	-----	-----	6.7	0.1	2.9	0.1	19.0	0.3	15.4	0.1	25.6	0.8
Rhynchonereella bongraini	9.9	0.2	18.1	0.5	0.0	0.0	1.0	0.0	-----	-----	33.3	0.8	9.6	0.2	4.8	0.1	2.2	0.0	3.3	0.1
Pegantha martagon	8.8	0.2	7.2	0.0	1.1	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
Polychaetes	8.8	0.1	0.0	0.0	15.8	6.7	7.9	0.7	-----	-----	20.0	0.6	28.8	1.5	1.0	0.0	1.1	0.0	-----	-----
Electrona antarctica	8.8	0.1	1.2	0.0	3.2	0.0	5.9	0.0	-----	-----	1.3	0.0	3.8	0.1	9.5	0.0	13.2	0.0	13.3	0.1
Gammarids	7.7	0.1	3.6	0.4	1.1	0.0	0.0	0.0	-----	-----	2.7	0.0	1.0	0.0	0.0	0.0	1.1	0.0	-----	-----
Hydromedusae	6.6	0.0	0.0	0.0	15.8	0.4	14.9	0.4	-----	-----	37.3	0.2	0.0	0.0	20.0	0.1	4.4	0.0	6.7	0.1
Acanthophyra pelagica (L)	5.5	0.0	10.8	0.1	2.1	1.5	0.0	0.0	-----	-----	17.3	0.2	3.8	0.0	9.5	0.1	0.0	0.0	22.2	0.1
Beroe cucumis	5.5	0.0	8.4	0.1	2.1	0.0	20.8	0.3	-----	-----	4.0	0.0	3.8	0.0	15.2	0.1	7.7	0.0	12.2	0.0
Chionodraco rastrospinosus (L)	5.5	0.0	4.8	0.0	2.1	0.0	-----	-----	-----	-----	1.3	0.0	1.9	0.0	1.0	0.0	-----	-----	-----	-----
Lepidonotothen nudifrons (L)	4.4	0.1	0.0	0.0	5.3	0.1	0.0	0.0	-----	-----	0.0	0.0	0.0	0.0	0.0	0.0	2.2	0.0	8.9	0.1
Siphonophora	4.4	0.1	3.6	0.1	2.1	0.0	3.0	0.3	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Epimeriella macronyx	4.4	0.0	1.2	0.0	0.0	0.0	1.0	0.0	-----	-----	0.0	0.0	5.8	0.2	1.9	1.4	1.1	0.0	8.9	0.0
Cumaceans	3.3	0.1	2.4	0.3	2.1	2.7	1.0	0.0	-----	-----	-----	-----	-----	-----	3.8	0.4	1.1	0.0	-----	-----
Euphausia crystallorophias (L)	3.3	0.0	4.8	0.2	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Lepidonotothen larseni (J)	3.3	0.0	0.0	0.0	1.1	0.0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Calycopsis borchgrevinki	3.3	0.0	2.4	0.0	1.1	0.0	4.0	0.2	-----	-----	2.7	0.0	1.0	0.0	2.9	0.0	2.2	0.0	1.1	0.0
Larvacean	3.3	0.0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Limacina spp.	2.2	0.2	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Euphausia frigida (L)	2.2	0.2	8.4	0.4	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Clio pyramidata sulcata	2.2	0.1	7.2	0.1	75.8	53.4	32.7	5.9	-----	-----	9.3	0.1	4.8	0.3	2.9	0.0	6.6	0.1	72.2	5.3
Spongiobranchaea sp.	2.2	0.0	0.0	0.0	1.1	0.0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Orchomene plebs	2.2	0.0	2.4	0.0	1.1	0.0	-----	-----	-----	-----	-----	-----	1.0	0.0	2.9	0.0	1.1	0.0	4.4	0.0
Artededraco mirus (L)	2.2	0.0	1.2	0.0	1.1	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
Decapods (L)	2.2	0.0	2.4	0.0	3.2	1.7	0.0	0.0	-----	-----	1.3	0.0	2.9	0.0	0.0	0.0	2.2	0.2	-----	-----
Pelagobia longicirrata	2.2	0.0	0.0	0.0	1.1	0.0	3.0	0.0	-----	-----	0.0	0.0	0.0	0.0	1.0	0.0	1.1	0.0	-----	-----
Bolinopsis infundibulus	2.2	0.0	4.8	0.0	1.1	0.0	-----	-----	-----	-----	5.3	0.0	1.9	0.0	-----	-----	-----	-----	-----	-----
Ctenophora	2.2	0.0	3.6	0.0	1.1	0.0	5.0	0.1	-----	-----	6.7	0.0	3.8	0.1	16.2	0.1	-----	-----	6.7	0.0
Travisiopsis coniceps	2.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-----	-----	0.0	0.0	0.0	0.0	1.0	0.0	-----	-----	-----	-----
Hyperoche medusarum	2.2	0.0	6.0	0.0	1.1	0.0	5.0	0.1	-----	-----	5.3	0.0	1.0	0.0	1.0	0.0	3.3	0.0	18.9	0.0
Hyperiids	1.1	0.0	6.0	0.1	4.2	0.5	12.9	0.7	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Gymnoscopelus braueri	1.1	0.0	1.2	0.0	1.1	0.0	1.0	0.0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Notolepis spp. (L)	1.1	0.0	2.4	0.0	0.0	0.0	2.0	0.0	-----	-----	0.0	0.0	1.0	0.0	-----	-----	-----	-----	-----	-----
Hyperiella antarctica	1.1	0.0	0.0	0.0	1.1	0.0	0.0	0.0	-----	-----	0.0	0.0	0.0	0.0	0.0	0.0	2.2	0.0	2.2	0.0
Hyperiella macronyx	1.1	0.0	6.0	0.1	3.2	0.0	-----	-----	-----	-----	2.7	0.0	2.9	0.1	8.6	0.1	5.5	0.0	23.3	0.1

Table 4.10 (Contd.)

A. SURVEY A	JANUARY-FEBRUARY																			
	2004		2003		2002		2001		2000		1999		1998		1997		1996		1995	
TAXON	F(%)	Mean	F(%)	Mean	F(%)	Mean	F(%)	Mean	F(%)	Mean	F(%)	Mean	F(%)	Mean	F(%)	Mean	F(%)	Mean	F(%)	Mean
Notolepis annulata (L)	1.1	0.0	2.4	0.0	0.0	0.0	0.0	0.0	-----	-----	2.7	0.0	0.0	0.0	1.0	0.0	0.0	0.0	13.3	0.0
Trematomus lepidorhinus (L)	1.1	0.0	0.0	0.0	1.1	0.1	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Eusirus perdentatus	1.1	0.0	0.0	0.0	0.0	0.0	1.0	0.0	-----	-----	1.3	0.0	0.0	0.0	0.0	0.0	1.1	0.0	22.2	0.1
Trematomus scotti (L)	1.1	0.0	0.0	0.0	1.1	0.0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Periphylla periphylla	1.1	0.0	1.2	0.0	0.0	0.0	0.0	0.0	-----	-----	1.3	0.0	0.0	0.0	0.0	0.0	1.1	0.0	1.1	0.0
Travisiopsis levinseni	1.1	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	1.1	0.0
Cephalopods	1.1	0.0	1.2	0.0	0.0	0.0	1.0	0.0	-----	-----	1.3	0.0	1.0	0.0	0.0	0.0	0.0	0.0	2.2	0.0
Pasiphaea sp. (L)	1.1	0.0	0.0	0.0	1.1	0.0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Orchomene rossi	1.1	0.0	6.0	0.0	0.0	0.0	1.0	0.0	-----	-----	4.0	0.0	0.0	0.0	8.6	0.0	0.0	0.0	5.6	0.0
Cryodraco antarctica (L)	1.1	0.0	1.2	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	-----	-----
Hyperiella spp.	1.1	0.0	6.0	0.0	11.6	0.1	5.9	0.1	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Clio pyramidata martensi?	1.1	0.0	0.0	0.0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Pleurobranchia pileus	1.1	0.0	0.0	0.0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Pleuragramma antarcticum (L)	0.0	0.0	15.7	0.4	1.1	0.0	4.0	0.1	-----	-----	1.3	0.1	4.8	0.0	2.9	0.0	1.1	0.0	2.2	0.0
Callianira antarctica	0.0	0.0	14.5	0.1	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Larval Fish	0.0	0.0	12.0	0.4	8.4	3.3	18.8	0.6	-----	-----	9.3	0.1	8.7	0.1	0.0	0.0	1.1	0.0	0.0	0.0
Cyllopus spp.	0.0	0.0	10.8	0.2	3.2	0.0	2.0	0.0	-----	-----	28.0	0.4	1.0	0.0	1.0	0.0	-----	-----	-----	-----
Euphausia triacantha (L)	0.0	0.0	4.8	2.8	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Atolla wyvillei	0.0	0.0	4.8	0.0	0.0	0.0	0.0	0.0	-----	-----	0.0	0.0	0.0	0.0	2.9	0.0	1.1	0.0	7.8	0.0
Notocrangon antarcticus(?)	0.0	0.0	3.6	0.1	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Gastropods	0.0	0.0	3.6	0.1	2.1	0.0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Fish Eggs	0.0	0.0	3.6	0.1	0.0	0.0	0.0	0.0	-----	-----	1.3	0.0	1.0	0.0	2.9	0.1	1.1	0.0	4.4	0.0
Orchomene spp.	0.0	0.0	2.4	0.1	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Pleurobrachia pileus	0.0	0.0	2.4	0.0	2.1	0.0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Mitrocomella brownei	0.0	0.0	1.2	0.0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Russelia mirabilis	0.0	0.0	1.2	0.0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Leusia sp.	0.0	0.0	1.2	0.0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Atolla sp.	0.0	0.0	1.2	0.0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Bathylagus sp. (L)	0.0	0.0	1.2	0.0	3.2	0.3	0.0	0.0	-----	-----	0.0	0.0	1.0	0.0	1.0	0.0	2.2	0.0	8.9	0.0
Modeeria rotunda	0.0	0.0	1.2	0.0	2.1	0.2	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Electrona carlsbergi	0.0	0.0	1.2	0.0	2.1	0.0	2.0	0.0	-----	-----	2.7	0.0	1.0	0.0	10.5	0.1	-----	-----	-----	-----
Staurophora mertensi ?	0.0	0.0	1.2	0.0	1.1	0.0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Hyperia antarctica	0.0	0.0	1.2	0.0	1.1	0.0	1.0	0.0	-----	-----	0.0	0.0	0.0	0.0	1.9	0.0	-----	-----	-----	-----
Krefftichthys anderssoni (L)	0.0	0.0	1.2	0.0	1.1	0.0	0.0	0.0	-----	-----	0.0	0.0	0.0	0.0	1.9	0.0	-----	-----	-----	-----
Maupasia coeca	0.0	0.0	1.2	0.0	0.0	0.0	1.0	0.0	-----	-----	1.3	0.0	0.0	0.0	1.9	0.0	1.1	0.0	-----	-----
Scina spp.	0.0	0.0	1.2	0.0	0.0	0.0	1.0	0.1	-----	-----	0.0	0.0	0.0	0.0	4.8	0.1	-----	-----	-----	-----
Vogtia serrata	0.0	0.0	1.2	0.0	0.0	0.0	0.0	0.0	-----	-----	1.3	0.0	0.0	0.0	3.8	0.1	-----	-----	-----	-----
Eusirus spp.	0.0	0.0	1.2	0.0	0.0	0.0	0.0	0.0	-----	-----	0.0	0.0	1.0	0.0	-----	-----	-----	-----	-----	-----
Euphausia spp. (L)	0.0	0.0	0.0	0.0	11.6	93.5	0.0	0.0	-----	-----	10.7	11.1	0.0	0.0	0.0	0.0	1.1	0.0	-----	-----
Prionodraco evansii (J)	0.0	0.0	0.0	0.0	4.2	0.0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Trematomus newnesi (L)	0.0	0.0	0.0	0.0	4.2	0.1	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Mysids	0.0	0.0	0.0	0.0	3.2	0.1	1.0	0.0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Chromatonema rubra	0.0	0.0	0.0	0.0	2.1	0.1	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Zanclonia weldoni	0.0	0.0	0.0	0.0	2.1	0.0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Notothenia spp. (L)	0.0	0.0	0.0	0.0	2.1	0.0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Vanadis antarctica	0.0	0.0	0.0	0.0	2.1	0.0	5.0	0.1	-----	-----	5.3	0.1	4.8	0.1	1.0	0.0	4.4	0.0	15.6	0.1
Schyphomedusae	0.0	0.0	0.0	0.0	2.1	0.0	2.0	0.0	-----	-----	1.3	0.0	1.9	0.0	1.0	0.0	13.2	0.1	-----	-----
Crustacean larvae	0.0	0.0	0.0	0.0	1.1	0.8	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Parachaenichthys charcoti (L)	0.0	0.0	0.0	0.0	1.1	0.0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Schizobrachium polycotylum	0.0	0.0	0.0	0.0	1.1	0.0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Electrona subaspera	0.0	0.0	0.0	0.0	1.1	0.0	1.0	0.0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Gobionotothen gibberifrons (L)	0.0	0.0	0.0	0.0	1.1	0.0	0.0	0.0	-----	-----	1.3	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.1	0.0
Gymnoscopelus nicholsi	0.0	0.0	0.0	0.0	1.1	0.0	0.0	0.0	-----	-----	0.0	0.0	0.0	0.0	1.9	0.0	1.1	0.0	1.1	0.0
Chaenodraco wilsoni (L)	0.0	0.0	0.0	0.0	0.0	0.0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Botrynema brucei	0.0	0.0	0.0	0.0	0.0	0.0	5.0	0.1	-----	-----	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.0
Patagonotothen b. guntheri (J)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-----	-----	1.3	0.0	-----	-----	-----	-----	-----	-----	-----	-----
Bylgides pelagica	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-----	-----	1.3	0.0	0.0	0.0	2.9	0.1	0.0	0.0	5.6	0.0
Notothenia coriiceps (L)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-----	-----	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.0
Euphysora gigantea	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	0.0	2.2	0.0
Arctapodema ampla	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	1.1	0.0	-----	-----
Cyphocaris richardi	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-----	-----	0.0	0.0	0.0	0.0	1.9	0.0	0.0	0.0	4.4	0.0
Bolinopsis sp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-----	-----	0.0	0.0	1.0	0.0	-----	-----	-----	-----	-----	-----
Eusirus microps	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-----	-----	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.4	0.0
Chaenocephalus aceratus (L)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-----	-----	0.0	0.0	3.8	0.0	-----	-----	-----	-----	-----	-----
Harpagifer antarcticus (L)	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	1.1	0.0	-----	-----
Artededraco skottsbergi (L)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-----	-----	0.0	0.0	1.0	0.0	1.0	0.0	-----	-----	-----	-----
Gosea brachyura	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	0.0	3.3	0.0
Oediceroides calmani	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-----	-----	0.0	0.0	0.0	0.0	1.0	0.0	-----	-----	-----	-----
Gymnodraco acuticeps (L)	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	0.0	1.1	0.0
Phalacrophorus pictus	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	1.1	0.0	-----	-----
Thyphloscolex muelleri	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-----	-----	0.0	0.0	0.0	0.0	1.0	0.0	4.4	0.0	-----	-----
Chorismus antarcticus (L)	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	1.1	0.0	-----	-----

Table 4.10 (Contd.)

A. SURVEY A	JANUARY-FEBRUARY																			
	2004		2003		2002		2001		2000		1999		1998		1997		1996		1995	
TAXON	F(%)	Mean	F(%)	Mean	F(%)	Mean	F(%)	Mean	F(%)	Mean	F(%)	Mean	F(%)	Mean	F(%)	Mean	F(%)	Mean	F(%)	Mean
Artededraco sp. B (L)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-----	-----	0.0	0.0	0.0	0.0	1.0	0.0	-----	-----	-----	-----
Hyperia macrocephala	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-----	-----	0.0	0.0	1.0	0.1	1.0	0.0	0.0	0.0	3.3	0.0
Krefftichthys anderssoni	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-----	-----	0.0	0.0	0.0	0.0	1.0	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	0.0	0.0	3.8	0.0	2.2	0.0	7.8	0.0
TOTAL		1033.1		1264.924		11143.1		3812.2		---		1282.4		1172.7		1015.2		1408.9		1052.2
TAXA	89		88		89		63		---		65		63		70		66		68	

B. SURVEY D	FEBRUARY-MARCH																			
	2004 N=97		2003 N=95		2002 N=94		2001 N=97		2000 N=97		1999 N=67		1998 N=104		1997 N=16		1996 N=91		1995 N=89	
TAXON	F (%)	Mean	F (%)	Mean	F(%)	Mean	F(%)	Mean	F(%)	Mean	F(%)	Mean	F(%)	Mean	F(%)	Mean	F(%)	Mean	F(%)	Mean
Copepods	100.0	4412.5	100.0	1533.7	100.0	15904.8	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
Chaetognaths	96.9	332.7	96.8	83.1	97.9	880.1	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
Thysanoessa macrura	95.9	209.4	100.0	293.3	79.8	112.8	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
Salpa thompsoni	90.7	123.4	76.8	77.8	80.9	621.6	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
Euphausia superba (L)	87.6	107.7	27.4	3.9	28.7	61.0	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
Themisto gaudichaudii	87.6	4.5	93.7	6.4	97.9	30.2	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
Euphausia superba	76.3	73.5	90.5	151.5	57.4	281.6	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
Primno macropa	76.3	16.1	73.7	6.7	57.4	28.2	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
Cyllopus lucasii	76.3	3.4	17.9	0.2	30.9	3.0	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
Limacina helicina	73.2	42.6	36.8	1.5	5.3	0.6	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
Spongiobranchaea australis	71.1	5.9	54.7	1.3	47.9	1.3	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
Thysanoessa macrura (L)	68.0	315.1	25.3	1.1	96.8	1111.5	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
Euphausia frigida	59.8	35.3	58.9	31.3	66.0	80.0	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
Cyllopus magellanicus	59.8	0.9	45.3	2.2	34.0	2.8	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
Ostracods	52.6	26.9	48.4	9.0	22.3	42.6	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
Ihlea racovitzai	52.6	22.3	10.5	0.5	5.3	0.3	3.1	0.3	13.4	0.6	26.9	5.1	61.5	51.5	-----	-----	-----	-----	-----	-----
Hyperiella dilatata	47.4	3.5	37.9	0.4	38.3	2.6	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
Radiolaria	46.4	362.1	46.3	2.3	36.2	7918.3	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
Vibilia antarctica	42.3	1.0	63.2	1.9	46.8	22.2	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
Tomopteris spp.	36.1	1.6	49.5	1.9	18.1	1.1	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
Electrona spp. (L)	36.1	1.2	55.8	2.5	20.2	2.2	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
Diphyes antarctica	29.9	0.2	29.5	0.4	8.5	0.2	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
Sipunculids	28.9	1.3	15.8	0.1	4.3	1.5	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
Lepidonotothen kempi (L)	28.9	0.8	35.8	0.6	18.1	0.3	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
Clione limacina	28.9	0.5	18.9	0.3	4.3	0.1	16.7	0.9	5.2	0.0	3.0	0.0	10.6	0.1	12.5	0.0	15.4	0.2	-----	-----
Euphausia frigida (L)	24.7	5.7	18.9	1.0	19.1	53.4	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Lepidonotothen larseni (L)	24.7	0.5	15.8	0.5	11.7	1.8	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
Euphausia triacantha	20.6	1.3	20.5	1.8	22.3	2.2	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
Orchomene plebs	15.5	0.1	3.2	0.0	2.1	0.0	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
Dimophyes arctica	12.4	0.5	9.5	0.1	8.5	0.1	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
Notolepis coatsi (L)	12.4	0.1	23.2	0.2	12.8	0.2	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
Electrona antarctica	12.4	0.1	9.5	0.1	12.8	0.1	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
Rhynchonereella bongraini	10.3	1.0	16.8	1.0	0.0	0.0	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
Beroe forskalii	10.3	0.1	3.2	0.0	0.0	0.0	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
Calycopsis borchgrevinki	8.2	0.0	6.3	0.0	4.3	0.0	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
Cyllopus spp.	7.2	0.0	9.5	0.4	13.8	0.9	0.0	0.0	25.8	2.9	0.0	0.0	24.0	0.7	24.0	0.7	-----	-----	-----	-----
Euphausia crystallorophorias	6.2	2.4	31.6	4.9	11.7	65.3	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Siphonophora	6.2	0.6	1.1	0.0	0.0	0.0	2.1	0.0	10.3	2.3	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Gymnoscopelus braueri	6.2	0.0	7.4	0.1	6.4	0.1	7.3	0.0	8.2	0.1	7.5	0.1	-----	-----	-----	-----	-----	-----	-----	-----
Limacina spp.	5.2	1.0	0.0	0.0	1.1	0.2	1.0	0.0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Scina spp.	5.2	0.3	4.2	0.1	1.1	0.0	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
Euphausia triacantha (L)	5.2	0.3	2.1	0.0	1.1	0.8	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Eusirus antarcticus	5.2	0.1	3.2	0.0	2.1	0.0	5.2	0.1	1.0	0.0	1.5	0.0	1.9	0.0	-----	-----	-----	-----	-----	-----
Hyperiella spp.	5.2	0.0	5.3	0.2	12.8	0.2	0.0	0.0	9.3	0.3	9.0	0.1	1.0	0.0	-----	-----	-----	-----	-----	-----
Bathylagus sp. (L)	4.2	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	6.3	0.0	1.1	0.0	14.6	0.0
Polychaetes	4.1	0.4	5.3	0.3	1.1	0.0	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
Gammarids	4.1	0.2	1.1	0.1	4.3	2.3	4.2	0.4	1.0	0.0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Ctenophora	4.1	0.1	4.2	0.0	0.0	0.0	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
Vanadis antarctica	4.1	0.0	0.0	0.0	2.1	0.0	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
Beroe cucumis	4.1	0.0	4.2	0.0	1.1	0.0	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
Gymnoscopelus nicholsi	4.1	0.0	1.1	0.0	2.1	0.0	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
Cumaceans	3.1	0.0	0.0	0.0	1.1	0.0	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.0	-----	-----
Spongiobranchaea sp.	3.1	0.0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Clio pyramidata antarctica?	3.1	0.0	6.3	0.2	4.3	0.1	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Peganthu margaton	3.1	0.0	8.4	0.1	3.2	0.1	27.1	0.3	13.4	0.2	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Leusia spp.	3.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.1	0.0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Clio pyramidata sulcata	3.1	0.0	1.1	0.0	5.3	0.2	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

Table 4.10 (Contd.)

D. SURVEY D	FEBRUARY-MARCH																			
	2004		2003		2002		2001		2000		1999		1998		1997		1996		1995	
TAXON	F (%)	Mean	F (%)	Mean	F(%)	Mean	F(%)	Mean	F(%)	Mean	F(%)	Mean	F(%)	Mean	F(%)	Mean	F(%)	Mean	F(%)	Mean
Acanthophyra pelagica	3.1	0.0	3.2	0.1	1.1	0.0	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
Cephalopods	3.1	0.0	2.1	0.0	2.1	0.0	1.0	0.0	2.1	0.0	4.5	0.0	1.9	0.0	0.0	0.0	9.9	0.0	-----	-----
Euphausia crystallorophorias (L)	2.1	0.7	2.1	0.0	6.4	14.1	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Electrona carlsbergi	2.1	0.0	0.0	0.0	1.1	0.0	6.3	0.0	1.0	0.0	4.5	0.0	1.9	0.0	-----	-----	-----	-----	-----	-----
Hyperiids	2.1	0.0	1.1	0.0	0.0	0.0	5.2	0.3	8.2	2.2	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Clione antarctica	2.1	0.0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Hyperiella macronyx	2.1	0.0	1.1	0.0	1.1	0.0	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
Orchomene rossi	2.1	0.0	4.2	0.2	1.1	0.0	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
Staurophora mertensi ?	2.1	0.0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Krefftichthys anderssoni (L)	2.1	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	-----	-----	-----	-----	-----	-----
Clio pyramidata martensi?	1.0	3.5	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Thyphloscolex muelleri	1.0	0.1	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Larval Fish	1.0	0.0	17.9	0.7	1.1	0.0	1.0	0.0	6.2	0.6	14.9	0.7	1.9	0.1	0.0	0.0	1.1	0.0	-----	-----
Gastropods	1.0	0.0	2.1	0.2	0.0	0.0	0.0	0.0	4.1	17.6	6.0	0.5	1.9	0.0	-----	-----	-----	-----	-----	-----
Gobionotothen gibberifrons (L)	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.1	0.0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Eusirus perdentatus	1.0	0.0	0.0	0.0	0.0	0.0	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
Notolepis annulata (L)	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	6.3	0.0	5.5	0.0	3.4	0.0
Hyperia macrocephala	1.0	0.0	0.0	0.0	0.0	0.0	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
Chromatonema rubra?	1.0	0.0	0.0	0.0	3.2	0.3	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Lepidonotothen larseni (J)	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	0.0	0.0	1.1	0.0
Hyperoche medusarum	1.0	0.0	4.2	0.0	3.2	0.0	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
Periphylla periphylla	1.0	0.0	0.0	0.0	1.1	0.0	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
Epimeriella macronyx	1.0	0.0	2.1	0.1	0.0	0.0	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
Cyphocaris richardi	1.0	0.0	3.2	0.0	2.1	0.0	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
Hyperia antarctica	1.0	0.0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Pelagobia longicirrata	1.0	0.0	0.0	0.0	1.1	0.0	0.0	0.0	5.2	0.6	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Macrourid (L)	1.0	0.0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Pleuragramma antarcticum (L)	1.0	0.0	15.8	0.2	5.3	0.2	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
Larvaceans	1.0	0.0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Schyphomedusae	1.0	0.0	0.0	0.0	0.0	0.0	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
Atolla wyvillei	1.0	0.0	4.2	0.0	1.1	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	-----	-----
Trematomus scotti (L)	1.0	0.0	0.0	0.0	4.3	0.0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Bathydraco antarcticus (L)	0.0	0.0	0.0	0.0	1.1	0.0	0.0	0.0	0.0	0.0	3.0	0.0	-----	-----	-----	-----	-----	-----	-----	-----
Callianira antarctica	0.0	0.0	13.7	0.3	0.0	0.0	5.2	0.0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Notolepis spp. (L)	0.0	0.0	6.3	0.1	1.1	0.0	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
Fish Eggs	0.0	0.0	5.3	0.2	0.0	0.0	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
Euphausia spp. (L)	0.0	0.0	5.3	0.1	3.2	4.4	1.0	0.4	11.3	4.3	13.4	1.5	-----	-----	-----	-----	-----	-----	-----	-----
Euphausia spp.	0.0	0.0	4.2	0.2	0.0	0.0	0.0	0.0	4.1	0.7	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Protomyctophum bolini	0.0	0.0	2.1	0.0	0.0	0.0	0.0	0.0	1.0	0.0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Eusirus properdentatus	0.0	0.0	2.1	0.0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Champsocephalus gunnari (L)	0.0	0.0	2.1	0.0	1.1	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	1.1	0.0
Mysids	0.0	0.0	1.1	0.0	2.1	0.1	1.0	0.1	1.0	0.0	1.5	0.0	-----	-----	-----	-----	-----	-----	-----	-----
Pleurobrachia pileus	0.0	0.0	1.1	0.0	0.0	0.0	5.2	0.0	0.0	0.0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Cryodraco antarctica (L)	0.0	0.0	1.1	0.0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Orchomene spp.	0.0	0.0	1.1	0.0	0.0	0.0	0.0	0.0	1.0	1.3	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Chionodraco rastrospinosus (L)	0.0	0.0	1.1	0.0	0.0	0.0	1.0	0.0	1.0	0.0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Bylgides pelagica	0.0	0.0	1.1	0.0	0.0	0.0	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
Botrynema brucei	0.0	0.0	1.1	0.0	0.0	0.0	1.0	0.0	0.0	0.0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Clytia sp.?	0.0	0.0	0.0	0.0	4.3	0.1	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Bolinopsis spp.	0.0	0.0	0.0	0.0	2.1	0.0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Modeeria rotunda?	0.0	0.0	0.0	0.0	2.1	0.0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Arctapodema ampla	0.0	0.0	0.0	0.0	1.1	0.1	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Pyrasoma atlanticum	0.0	0.0	0.0	0.0	1.1	0.0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Parachaenechthys charcoti (L)	0.0	0.0	0.0	0.0	1.1	0.0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Mitrocomella brownei?	0.0	0.0	0.0	0.0	1.1	0.0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Gerlache australis (L)	0.0	0.0	0.0	0.0	1.1	0.0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Gymnoscopelus bolini	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Bolinopsis infundibulus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.1	0.0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Chorismus antarcticus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	0.0	-----	-----	-----	-----	-----	-----	-----	-----
Laodicea undulata	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Chaenodraco wilsoni (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	1.0	0.0	-----	-----	-----	-----	-----	-----
Solomondella spp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Gymnoscopelus opisthopteris	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.3	0.0	10.1	0.0
Notothenia coriiceps (L)	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Artedidraco skottsbergi (L)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	-----	-----	-----	-----	-----	-----

Table 4.10 (Contd.)

B. SURVEY D	FEBRUARY-MARCH																			
	2004		2003		2002		2001		2000		1999		1998		1997		1996		1995	
TAXON	F (%)	Mean	F (%)	Mean	F(%)	Mean	F(%)	Mean	F(%)	Mean	F(%)	Mean	F(%)	Mean	F(%)	Mean	F(%)	Mean	F(%)	Mean
Decapods (L)	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	0.0	1.1	0.0	-----	-----
Euphausiid eggs	0.0	0.0	0.0	0.0	0.0	0.0	19.8	9.3	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Eusirus microps	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	0.0	3.3	0.0	-----	-----
Pasiphaea sp. (L)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.8	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Electrona subaspera	0.0	0.0	0.0	0.0	0.0	0.0	2.1	0.0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Hyperiella antarctica	0.0	0.0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Hydromedusae	0.0	0.0	5.3	0.1	5.3	0.0	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
Harpagifer antarcticus (L)	0.0	0.0	3.2	0.0	2.1	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.0	-----	-----
Pseudochaenichthys georgianus (J)	0.0	0.0	1.1	0.0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Zanclonia weldoni?	0.0	0.0	0.0	0.0	6.4	0.0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Lepidonotothen nudifrons (L)	0.0	0.0	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	1.1	0.0	3.4	0.0
Trematomus newnesi (L)	0.0	0.0	0.0	0.0	1.1	0.0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Trematomus centronotus (L)	0.0	0.0	0.0	0.0	1.1	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	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.0
Pagothenia brachysoma	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.9	0.0	-----	-----	-----	-----	-----	-----
Rhynchonereella sp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	-----	-----	-----	-----	-----	-----
Gymnoscopelus sp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.9	0.0	-----	-----	-----	-----	-----	-----
Travisiopsis coniceps	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	0.0	1.1	0.0	1.1	0.0
Hyperia spp.	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	0.0	1.1	0.1	-----	-----
TOTAL		6124.5		2228.5		27260.8		8910.2		12378.9		2207.6		1224.4		2854.0		2196.4		7713.3
TAXA	89		82		84		72		72		58		60		37		63		62	

Table 4.11. Abundance of biomass dominant copepod species in the Elephant Island Area during various cruises 1981-2003. 1981-1990 data provided by John Wormuth. Abundance is numbers per 1000 m^3. Dashes indicate that data are not available.

SURVEY PERIOD	TAXON	*Calanoides acutus*	*Calanus propinquus*	*Metridia gerlachei*	*Rhincalanus gigas*	*Pleuromamma robusta*	*Paraeuchaeta antarctica*	*Haloptilus ocellatus*	*Heterorhabdus sp.*	Copepodites	Other Copepods	Total Copepods
Jan-Feb 89 N=48	Mean	429.7	93.6	1639.0	---	---	---	---	---	---	---	---
	STD	676.8	104.3	3488.0	---	---	---	---	---	---	---	---
	Median	80.5	45.5	57.0	---	---	---	---	---	---	---	---
Jan 90 N=23	Mean	302.5	354.4	981.3	---	---	---	---	---	---	---	1700.2
	STD	405.8	365.8	1620.7	---	---	---	---	---	---	---	2003.7
	Median	170.1	243.6	192.3	---	---	---	---	---	---	---	656.7
Jan 99 N=40	Mean	335.4	109.1	340.5	---	---	---	---	---	---	---	927.0
	STD	1009.5	161.9	512.7	---	---	---	---	---	---	---	1590.8
	Median	28.9	52.0	66.0	---	---	---	---	---	---	---	332.9
Jan 01 N=60	Mean	241.0	50.4	488.4	20.2	5.5	0.2	0.0	---	---	197.5	1003.2
	STD	392.0	85.9	1103.3	74.8	21.0	0.6	0.0	---	---	527.3	1582.4
	Median	117.7	12.5	45.5	0.0	0.0	0.0	0.0	---	---	41.8	252.2
Jan 02 N=44	Mean	2931.3	1862.2	350.8	141.6	1.4	122.7	0.0	---	30.2	44.2	5484.3
	STD	8293.0	5659.2	467.6	381.0	6.3	185.6	0.0	---	154.1	89.0	14585.6
	Median	876.4	502.7	130.3	16.4	0.0	57.7	0.0	---	0.0	11.0	2174.9
Jan 03 N=38	Mean	75.6	80.1	241.2	11.1	1.8	0.0	0.2	---	0.1	41.0	541.0
	STD	67.9	65.0	639.3	23.4	10.9	0.0	1.0	---	0.9	34.9	798.6
	Median	52.0	55.1	6.7	1.9	0.0	0.0	0.0	---	0.0	27.8	317.0
Jan 04 N=46	Mean	77.4	73.2	293.6	9.7	24.1	16.4	0.0	---	0.1	0.0	494.5
	STD	97.2	63.8	706.6	19.0	41.0	25.0	0.0	---	0.9	0.0	796.1
	Median	42.7	57.1	25.4	0.2	7.8	7.6	0.0	---	0.0	0.0	208.7

SURVEY PERIOD	TAXON	*Calanoides acutus*	*Calanus propinquus*	*Metridia gerlachei*	*Rhincalanus gigas*	*Pleuromama robusta*	*Pareuchaeta antarctica*	*Haloptilus ocellatus*	*Heterorhabdus sp.*	Copepodites	Other Copepods	Total Copepods
Mar 81 N=10	Mean	4786.9	5925.8	2402.5	---	---	---	---	---	---	---	---
	STD	5482.2	6451.6	3321.4	---	---	---	---	---	---	---	---
	Median	2197.7	2048.7	609.5	---	---	---	---	---	---	---	---
Feb-Mar 84 N=13	Mean	25.5	121.7	1154.4	---	---	---	---	---	---	---	---
	STD	29.6	134.4	2999.9	---	---	---	---	---	---	---	---
	Median	16.2	51.4	23.1	---	---	---	---	---	---	---	---
Feb 89 N=25	Mean	161.4	194.9	3189.3	---	---	---	---	---	---	---	---
	STD	240.9	151.5	4017.2	---	---	---	---	---	---	---	---
	Median	88.0	162.0	1051.0	---	---	---	---	---	---	---	---
Feb 99 N=39	Mean	511.8	300.9	521.1	---	---	---	---	---	---	---	1557.9
	STD	1395.6	630.6	699.0	---	---	---	---	---	---	---	2337.8
	Median	70.7	70.8	216.9	---	---	---	---	---	---	---	621.6
Feb 00 N=60	Mean	1846.3	741.8	3051.7	1089.0	100.0	107.3	1.5	---	---	1171.4	8019.1
	STD	3177.2	1546.5	4783.5	2456.5	34.7	249.1	7.8	---	---	28232.0	11824.4
	Median	225.2	193.3	1249.7	79.9	0.0	11.0	0.0	---	---	297.6	3478.0
Feb-Mar 01 N=57	Mean	2540.2	247.1	1450.0	32.4	3.7	74.7	0.4	---	116.1	37.0	4501.5
	STD	6921.6	402.9	2966.0	129.1	13.6	137.9	2.7	---	343.8	188.4	8072.4
	Median	111.5	122.2	140.1	0.0	0.0	20.8	0.0	---	23.2	0.0	1518.0
Feb-Mar 02 N=44	Mean	9569.2	3827.4	2515.1	1226.4	30.0	169.3	14.8	---	5.2	116.0	17473.4
	STD	12553.1	4288.9	3124.5	1952.7	97.2	269.2	66.0	---	22.5	337.2	20036.9
	Median	4855.6	2037.2	1183.6	346.2	0.0	52.5	0.0	---	0.0	0.0	7563.8
Feb 03 N=48	Mean	138.1	68.2	1092.8	39.0	5.9	3.8	0.5	---	0.0	205.0	1674.3
	STD	114.2	70.2	2239.6	45.9	17.5	10.0	1.7	---	0.0	235.4	2593.6
	Median	119.3	47.9	197.3	17.9	0.0	0.0	0.0	---	0.0	130.2	737.5
Feb 04 N=47	Mean	1821.7	1113.3	1791.8	1209.3	7.7	168.9	15.1	88.2	0.3	89.7	6303.1
	STD	7439.2	3524.0	3902.9	5315.2	25.3	195.3	53.6	552.6	2.2	195.0	17739.5
	Median	277.0	324.3	368.9	117.3	0.0	68.4	0.0	0.0	0.0	5.9	2233.5

Table 4.12. 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, 1994-2004. Includes the 10 most abundant taxa each year. Radiolarian excluded as a taxonomic category. No samples were collected January-F Dashes indicate that the taxon was not enumerated during that survey.

A.	JANUARY-FEBRUARY																					
	2004		2003		2002		2001		2000		1999		1998		1997		1996		1995		1994	
TAXON	%	R	%	R	%	R	%	R	n.a.		%	R	%	R	%	R	%	R	%	R	%	R
Copepods	50.37	1	42.52	1	75.69	1	46.76	1	---	---	58.05	1	4.80	3	57.16	1	56.18	1	61.54	1	4.08	3
Salpa thompsoni	17.94	2	4.87	4	5.66	3	29.03	2	---	---	12.35	2	68.76	1	17.79	2	1.45	6	1.51	5	80.83	1
Thysanoessa macrura	11.02	3	18.79	3	2.77	4	2.15	5	---	---	2.92	6	15.38	2	10.24	3	7.56	4	9.09	3	7.87	2
Euphausia superba	6.10	4	25.06	2	0.54	6	0.88	10	---	---	0.33	8	3.13	5	3.96	4	7.95	3	1.37	7	2.68	4
Chaetognaths	3.60	5	1.51	6	1.93	5	2.68	4	---	---	4.00	5	0.92	7	2.28	5	0.90	7	7.84	4	0.04	
Euphausia frigida	1.96	6	0.84	7	0.39	9	1.09	7	---	---	1.00	7	0.02		1.45	8	0.14		0.92	8	0.38	9
Ostracods	1.74	7	0.53	8	0.09		0.25		---	---	0.13		0.41	9	0.54	9	0.35	8	0.91	9	---	
Ihlea racovitzai	1.63	8	0.03		0.02		0.02		---	---	0.15		3.53	4	---		---		---		---	
Limacina helicina	1.30	9	2.55	5	0.03		0.14		---	---	0.07		0.69	8	0.28		2.38	5	0.18		0.03	
Euphausia superba (L)	0.99	10	0.37	10	0.49	7	1.53	6	---	---	10.95	3	0.09		1.49	7	0.19	10	12.80	2	---	
Thysanoessa macrura (L)	0.69		0.09		10.67	2	12.55	3	---	---	7.29	4	0.00		1.67	6	21.82	2	1.50	6	---	
Primno macropa	0.40		0.44	9	0.12		0.10		---	---	0.13		0.06		0.42	10	0.01		0.01		0.05	
Cyllopus lucasii	0.38		0.06		0.02		0.98	9	---	---	0.15		0.16	10	0.37		0.11		0.02		0.62	7
Spongiobranchaea australis	0.29		0.15		0.02		0.09		---	---	0.09		0.07		0.22		0.13		0.05		0.01	
Themisto gaudichaudii	0.24		0.35		0.32	10	0.17		---	---	0.02		0.03		0.35		0.34	9	0.46		1.05	6
Tomopteris spp.	0.11		0.20		0.03		0.11		---	---	0.15	10	0.11		0.19		0.06		0.40		0.25	10
Euphausia triacantha	0.10		0.05		0.02		0.10		---	---	0.03		0.02		0.14		0.04		0.14		0.12	
Vibilia antarctica	0.07		0.19		0.06		0.98	8	---	---	0.32	9	1.12	6	0.24		0.04		0.02		1.17	5
Clio pyramidata sulcata	0.01		0.01		0.46	8	0.08		---	---	0.01		0.02		0.00		0.01		0.50	10	0.53	8
TOTAL	98.94		98.61		99.34		99.68		---		98.15		99.32		98.79		99.64		99.26		99.69	

B.	FEBRUARY-MARCH																					
	2004		2003		2002		2001		2000		1999		1998		1997		1996		1995		1994	
TAXON	%	R	%	R	%	R	%	R	%	R	%	R	%	R	%	R	%	R	%	R	%	R
Copepods	80.19	1	73.70	1	83.13	1	64.68	1	54.20	1	62.77	1	7.38	4	44.46	1	62.07	1	40.49	2	82.15	1
Chaetognaths	5.68	2	4.54	3	5.11	3	1.34	5	5.35	5	5.94	4	0.60	8	0.65	7	2.43	5	3.61	4	0.47	6
Thysanoessa macrura (L)	4.92	3	0.06		6.87	2	8.81	3	7.33	3	7.49	3	0.03		0.38	8	21.40	2	3.76	3	---	
Euphausia superba (L)	2.26	4	0.27	8	0.20	8	1.03	7	23.14	2	2.71	6	0.16		0.88	6	0.59	7	50.16	1	---	
Salpa thompsoni	2.02	5	2.67	5	2.71	4	6.50	4	6.17	4	12.46	2	65.31	1	43.62	2	1.39	6	0.22	7	11.78	2
Thysanoessa macrura	1.77	6	10.24	2	0.27	7	14.96	2	0.24	8	3.84	5	9.40	3	6.36	3	4.86	4	0.87	5	1.83	3
Euphausia superba	0.65	7	4.18	4	0.05		1.15	6	0.10		1.43	7	10.87	2	1.07	5	5.57	3	0.06	10	0.41	7
Limacina helicina	0.63	8	0.06		0.00		0.00		2.21	6	0.00		0.03		0.00		0.01		0.00		0.00	
Ostracods	0.43	9	0.24	9	0.06		0.03		0.20	9	0.65	9	0.35	10	0.17	10	0.38	9	0.43	6	---	
Ihlea racovitzai	0.41	10	0.01		0.00		0.00		0.00		0.34	10	2.77	5	---		---		---		---	
Euphausia frigida	0.34		2.24	6	0.37	6	0.54	8	0.29	7	1.00	8	0.60	7	1.57	4	0.40	8	0.21	8	0.69	5
Primno macropa	0.13		0.35	7	0.21	9	0.03		0.02		0.08		0.11		0.02		0.15	10	0.00		0.00	
Euphausia frigida (L)	0.12		0.07		0.40	5	---		---		---		---		---		---		---		---	
Cyllopus lucasii	0.06		0.01		0.01		0.43	9	0.00		0.01		0.14		0.08		0.01		0.01		0.14	10
Themisto gaudichaudii	0.03		0.20	10	0.12		0.07		0.02		0.01		0.01		0.10		0.09		0.01		0.27	8
Euphausia triacantha	0.03		0.09		0.01		0.02		0.01		0.06		0.04		0.03		0.03		0.02		0.03	
Vibilia antarctica	0.01		0.07		0.16	10	0.21	10	0.18	10	0.15		0.71	6	0.28	9	0.05		0.00		0.16	9
Cyllopus magellanicus	0.01		0.09		0.02		0.02		0.07		0.17		0.55	9	0.12		0.10		0.01		0.12	
Electrona spp. (L)	0.01		0.18		0.02		0.02		0.03		0.01		0.01		0.01		0.04		0.07	9	0.75	4
Euphausia spp. (L)	---	---	0.01		0.00		0.01		0.04		0.10		0.00		0.00		0.00		0.00		---	
TOTAL	99.70		99.29		99.72		99.85		99.57		98.93		98.52		99.66		99.43		99.86		97.93	

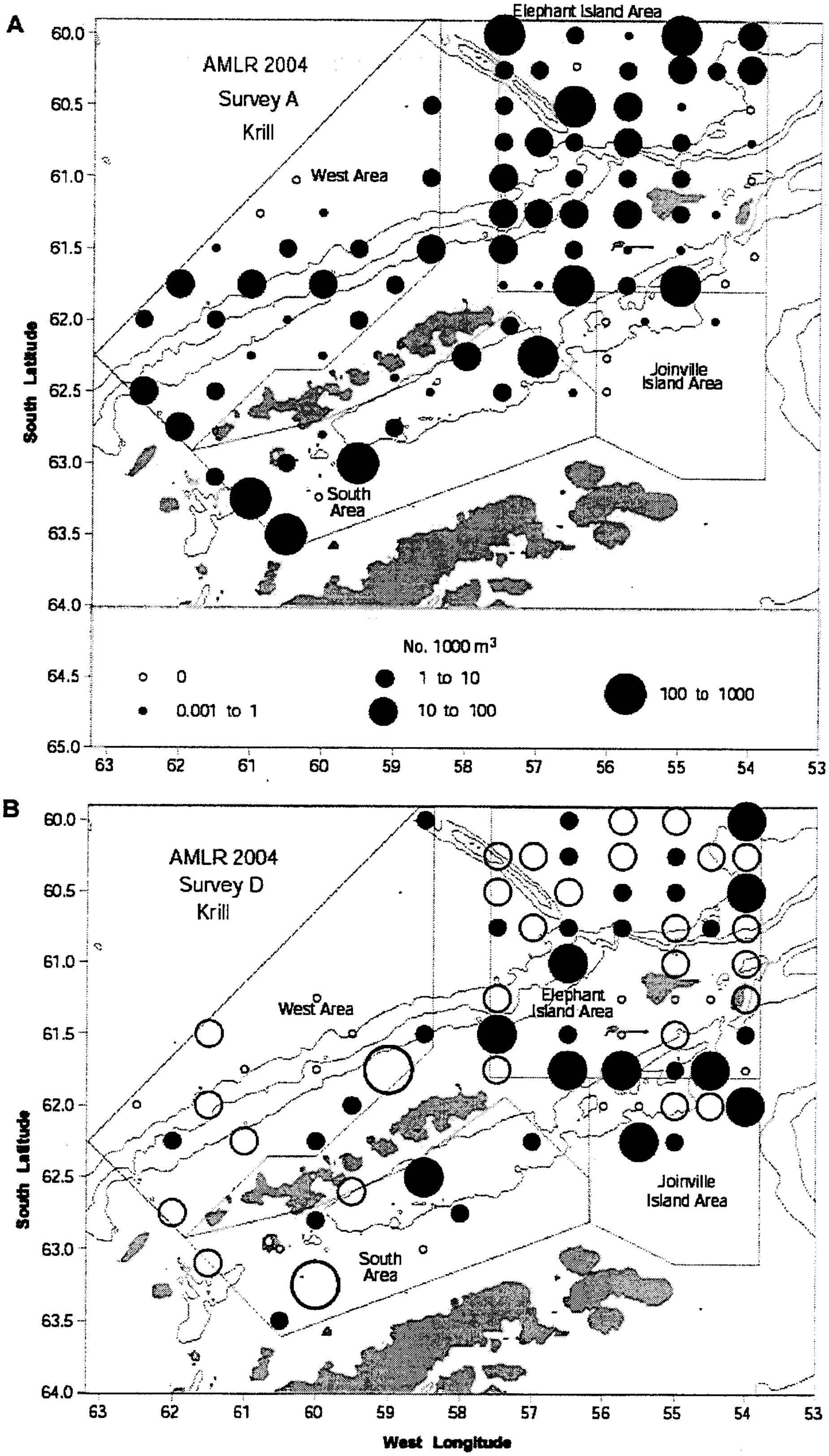


Figure 4.1. Krill abundance in IKMT tows collected during (A) January Survey A and (B) February-March Survey D, 2004. The outlined stations included in the Elephant Island Area are used for between-year comparisons. West, South and Joinville Island Area stations are indicated.

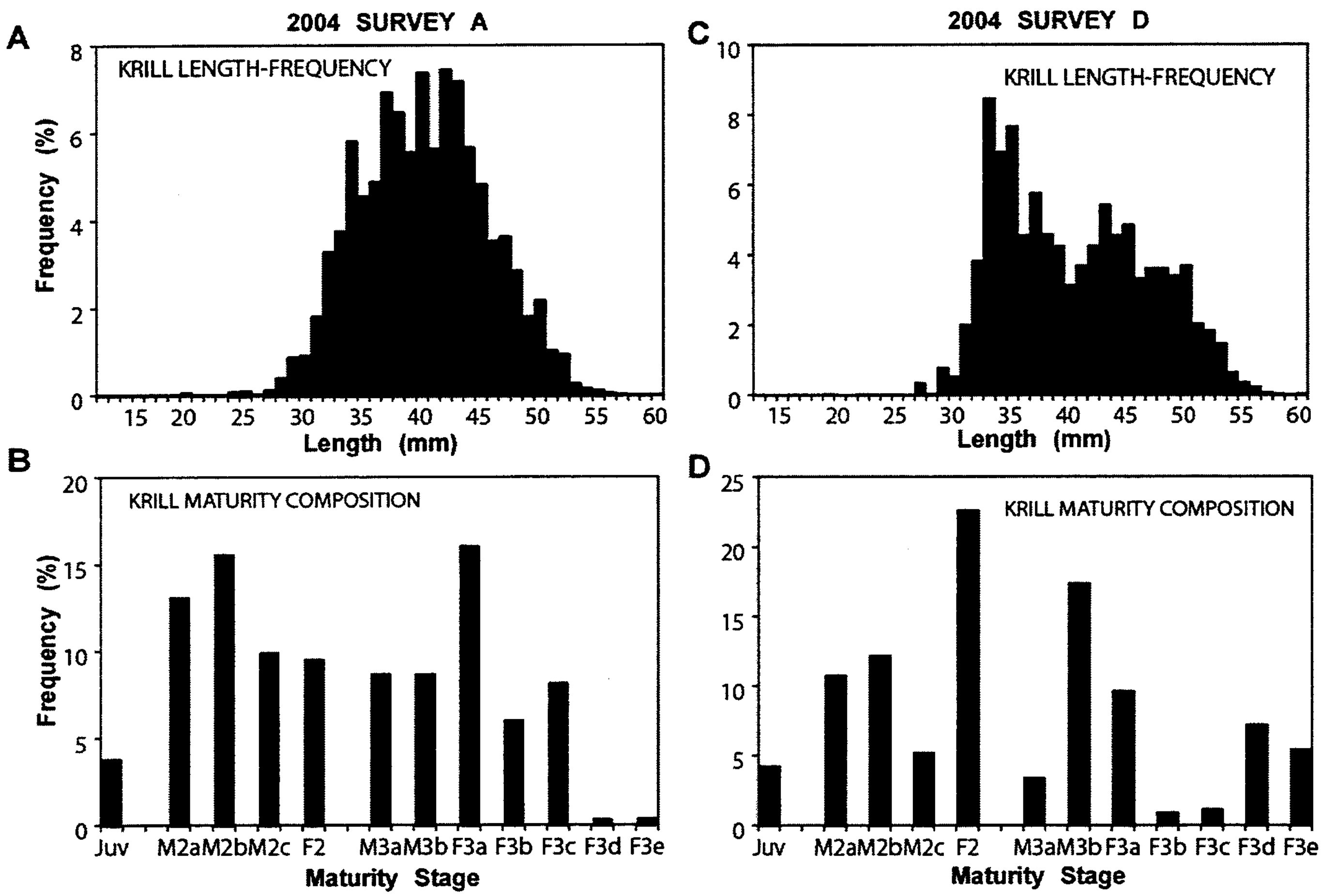


Figure 4.2. Krill length-frequency distribution and maturity stage composition during (A, B) Survey A and (C, D) Survey D.

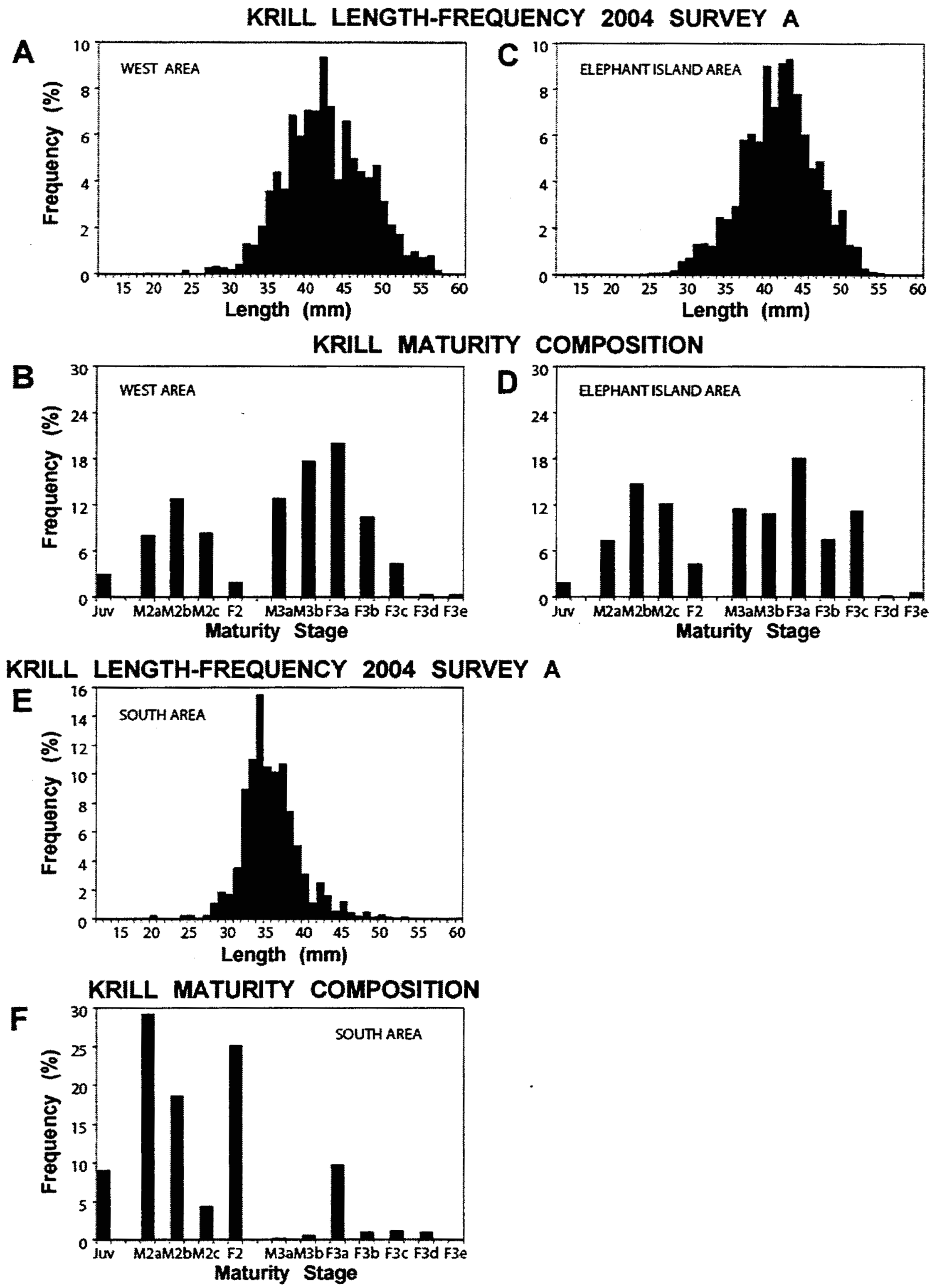


Figure 4.3a. Krill length-frequency distribution and maturity stage composition in the (A,B) West, (C, D) Elephant Island and (E, F) South Areas during Survey A.

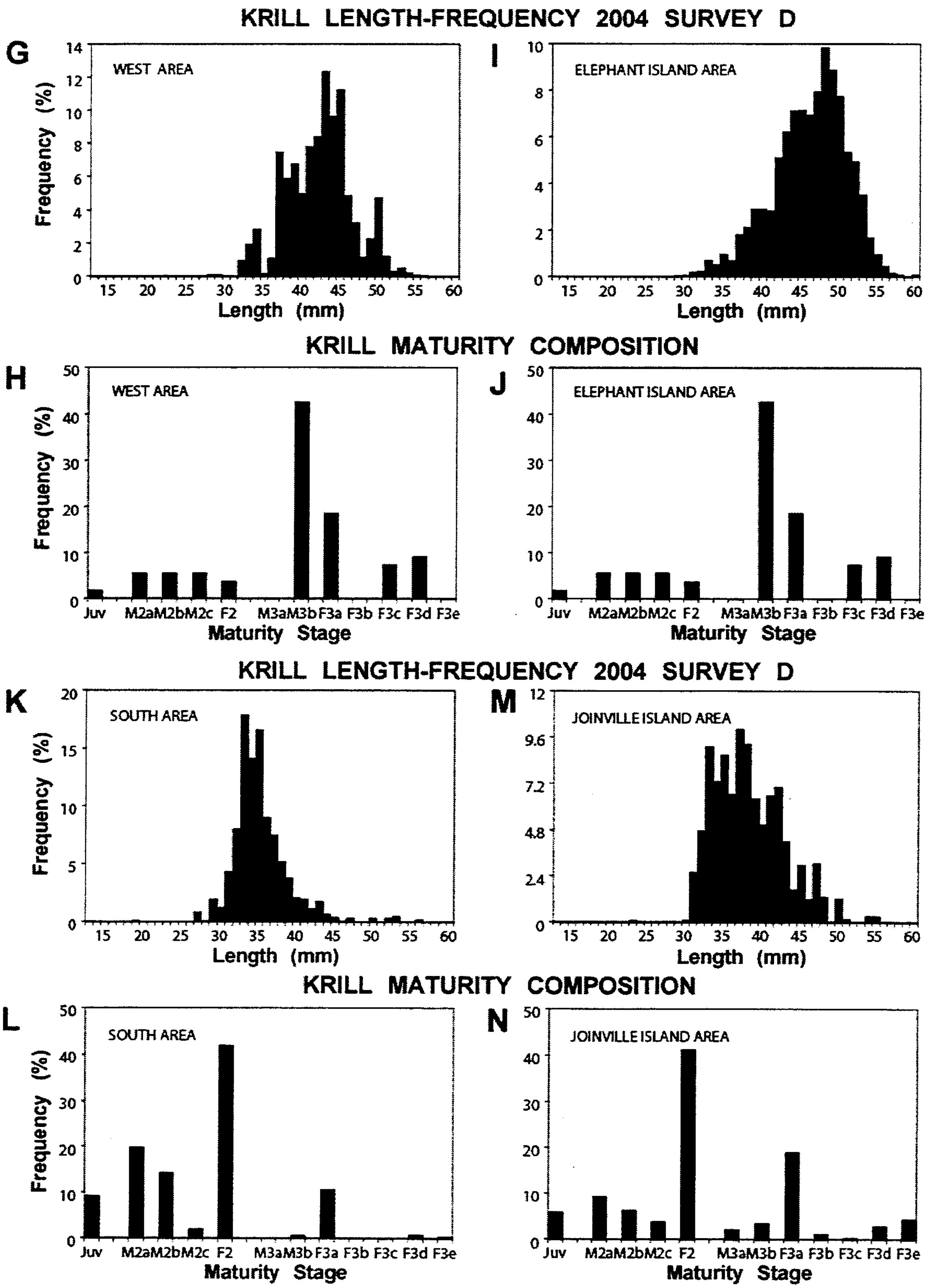


Figure 4.3b. Krill length-frequency distribution and maturity stage composition in the (G, H) West, (I, J) Elephant Island, (K, L) South and (M, N) Joinville Island Areas during Survey D.

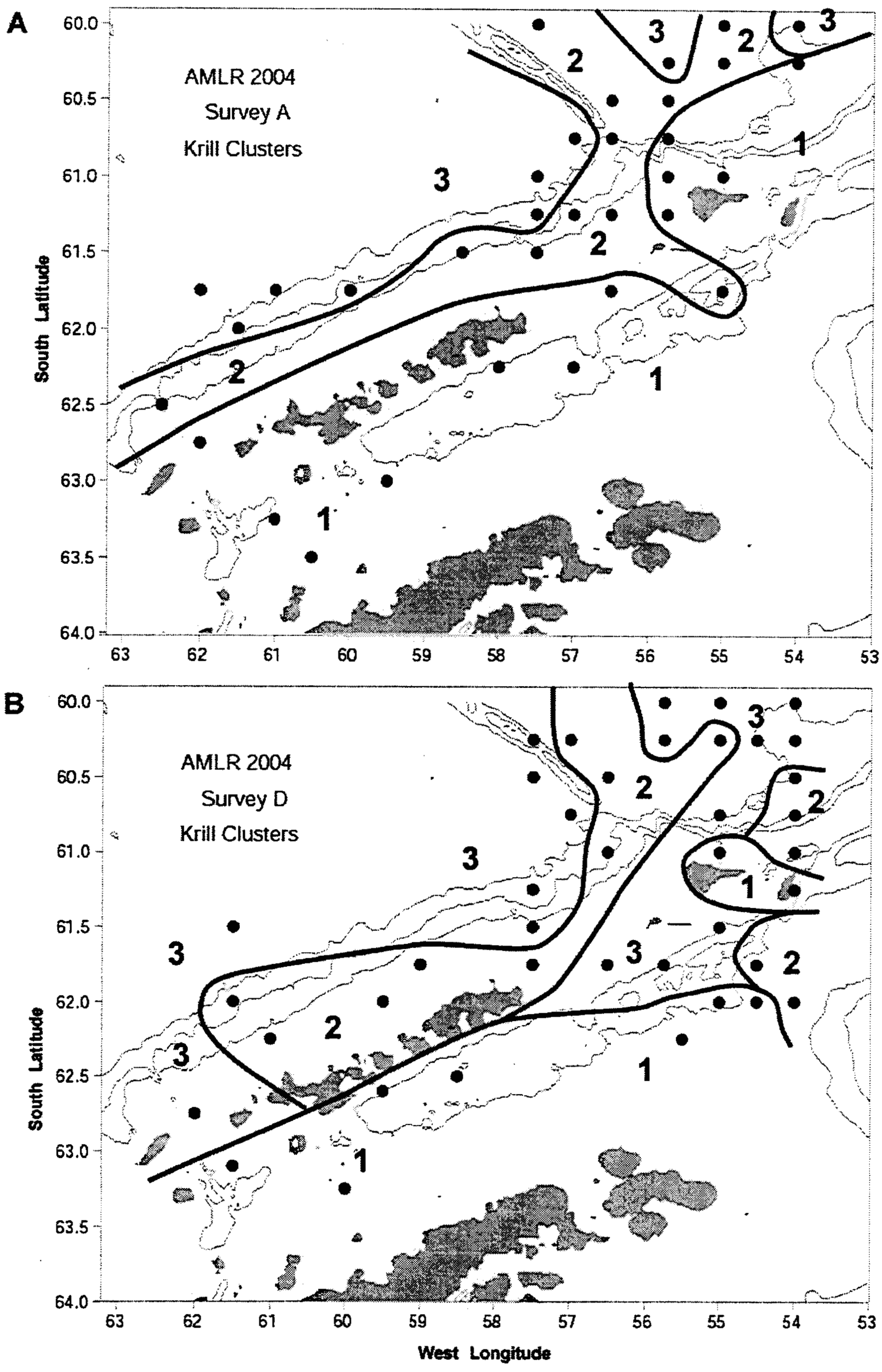


Figure 4.4. Distribution patterns of krill belonging to three length categories (Clusters) during (A) January Survey A and (B) February-March Survey D.

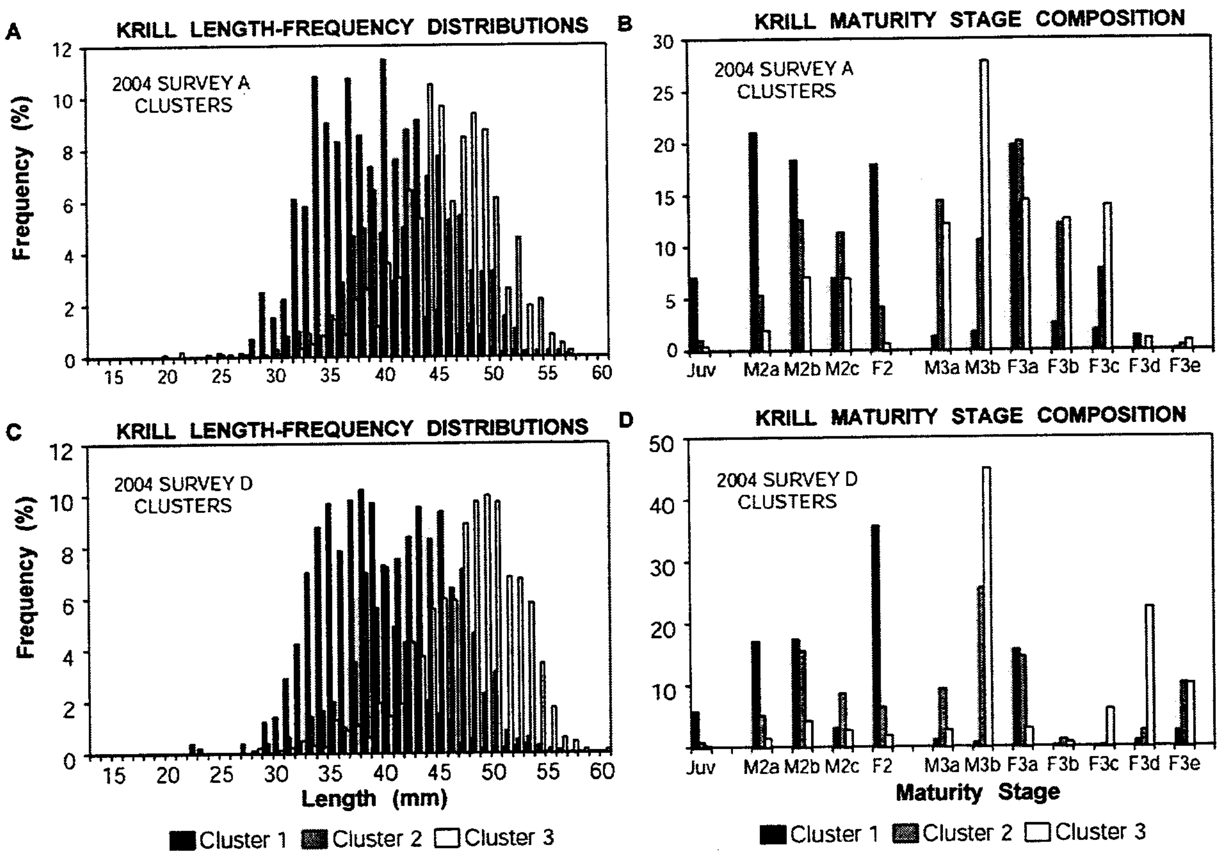


Figure 4.5. Length-frequency distribution and maturity stage composition of krill belonging to Clusters 1-3 during (A,B) January Survey A and (C,D) February-March Survey D.

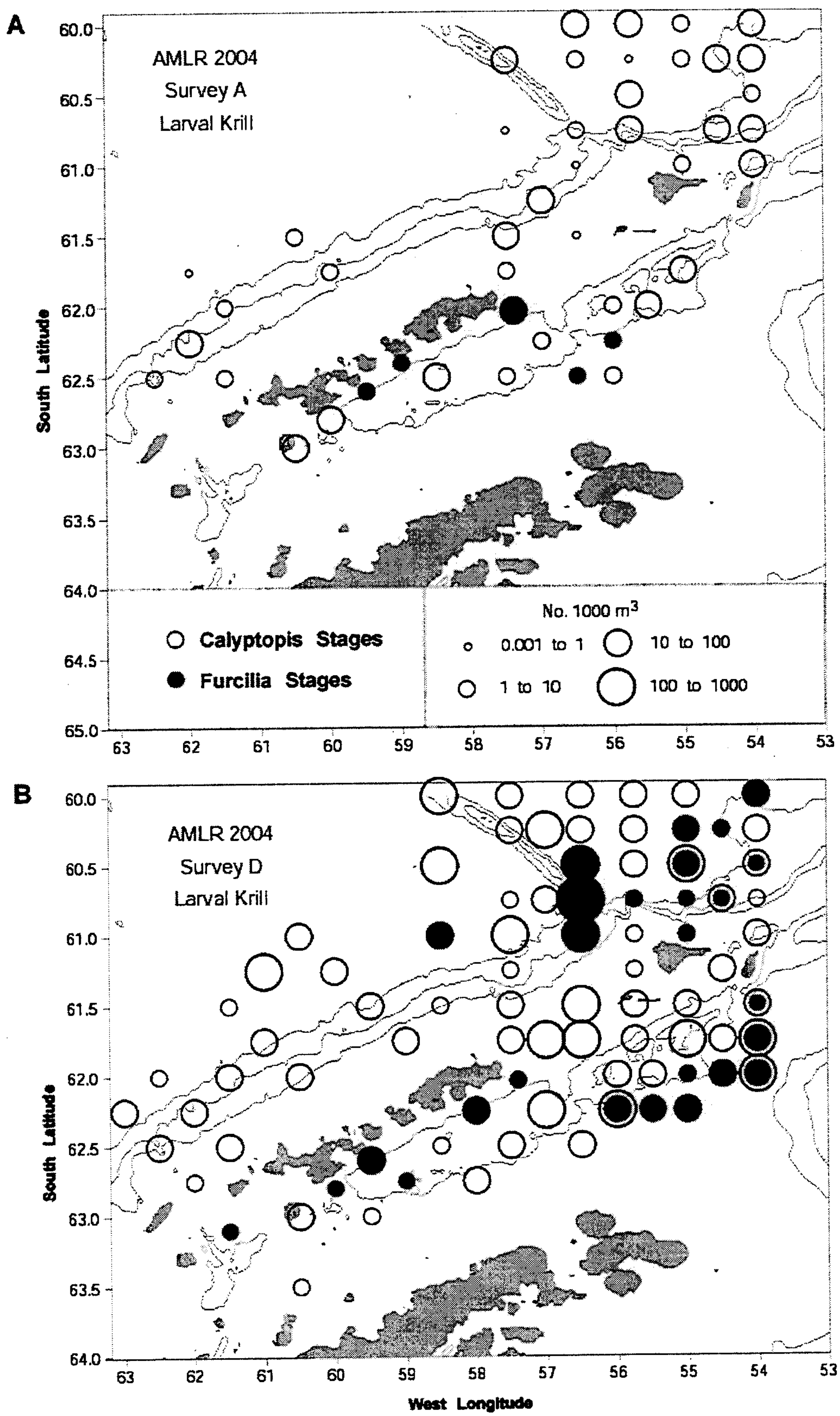


Figure 4.6. Distribution and abundance of Calyptopis and Furcilia stage krill larvae during (A) Survey A and (B) Survey D.

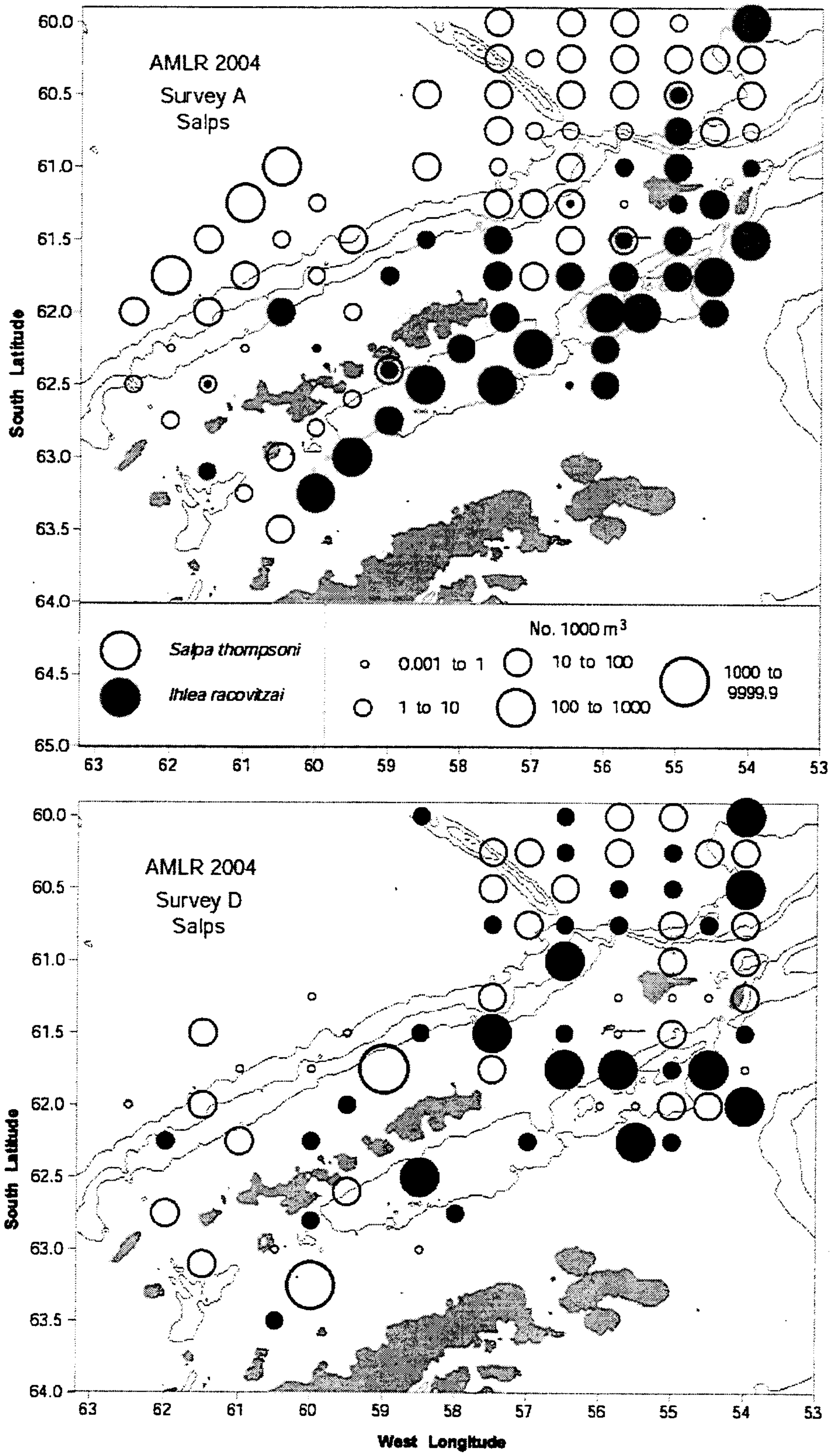


Figure 4.7. Distribution and abundance of *Salpa thompsoni* and *Ihlea racovitzai* during (A) Survey A and (B) Survey D.

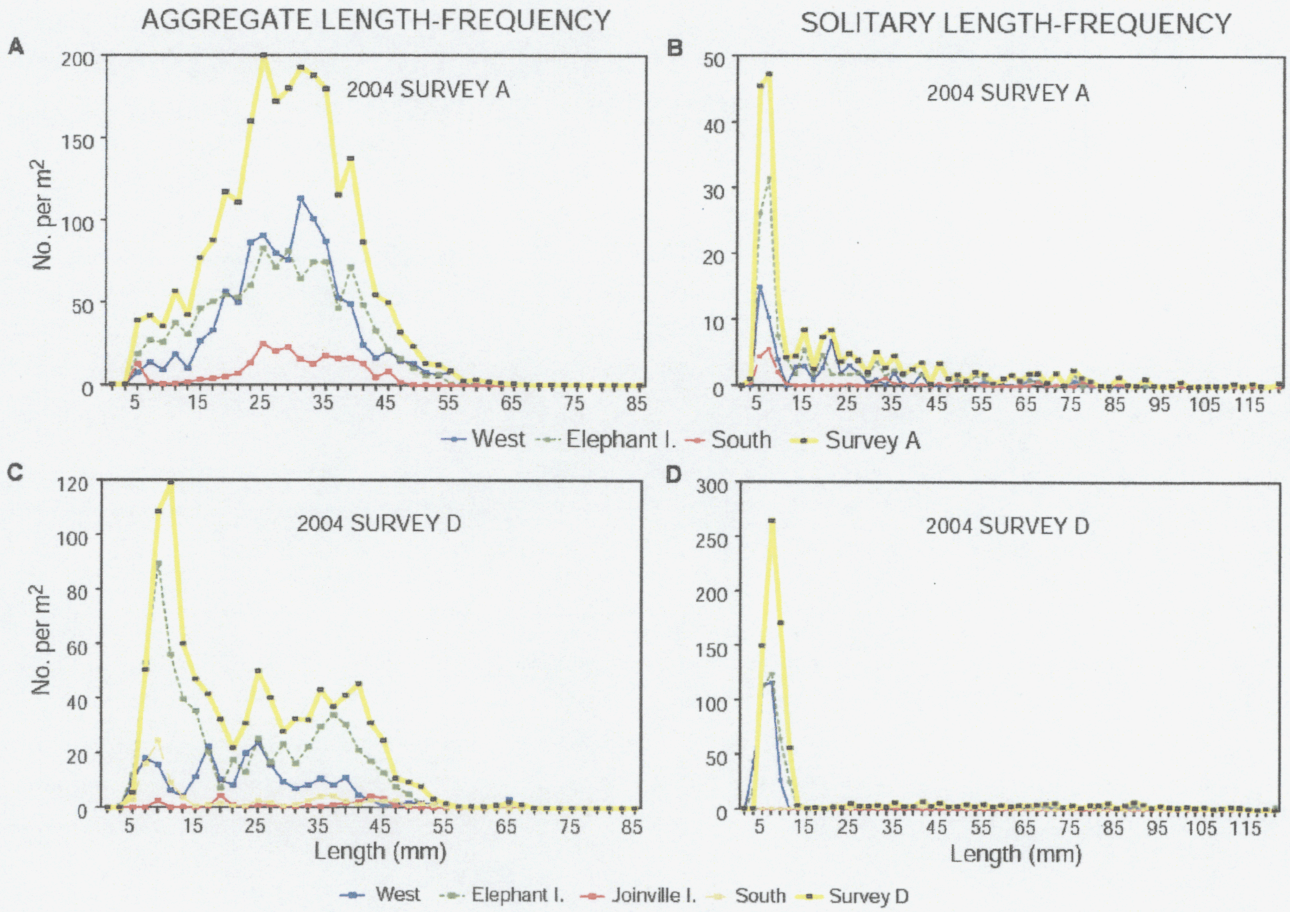


Figure 4.8. Length-frequency distributions of aggregate and solitary stage *Salpa thompsoni* in the large survey area and four subareas during (A, B) January Survey A and (C, D) February-March Survey D.

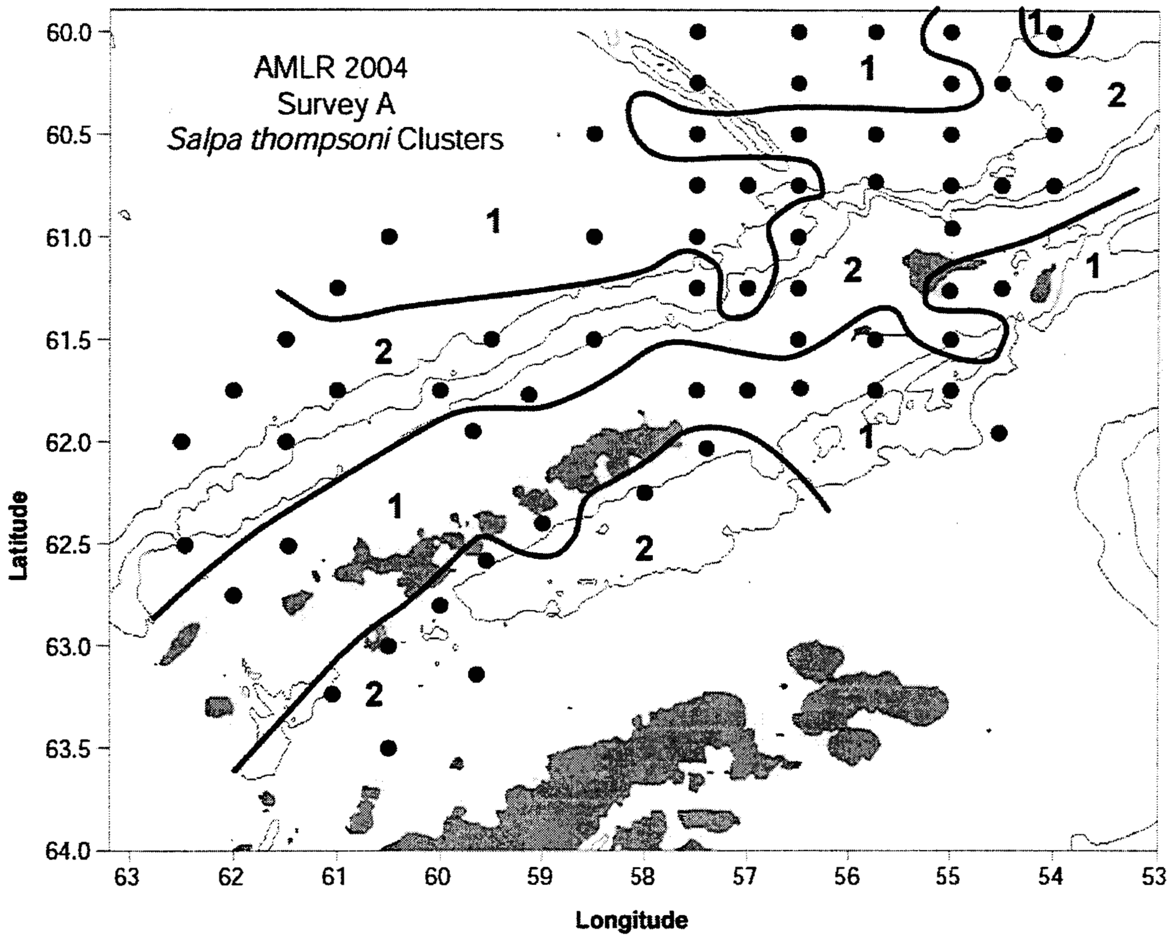


Figure 4.9. Distribution of aggregate salps belonging to two length clusters during Survey A.

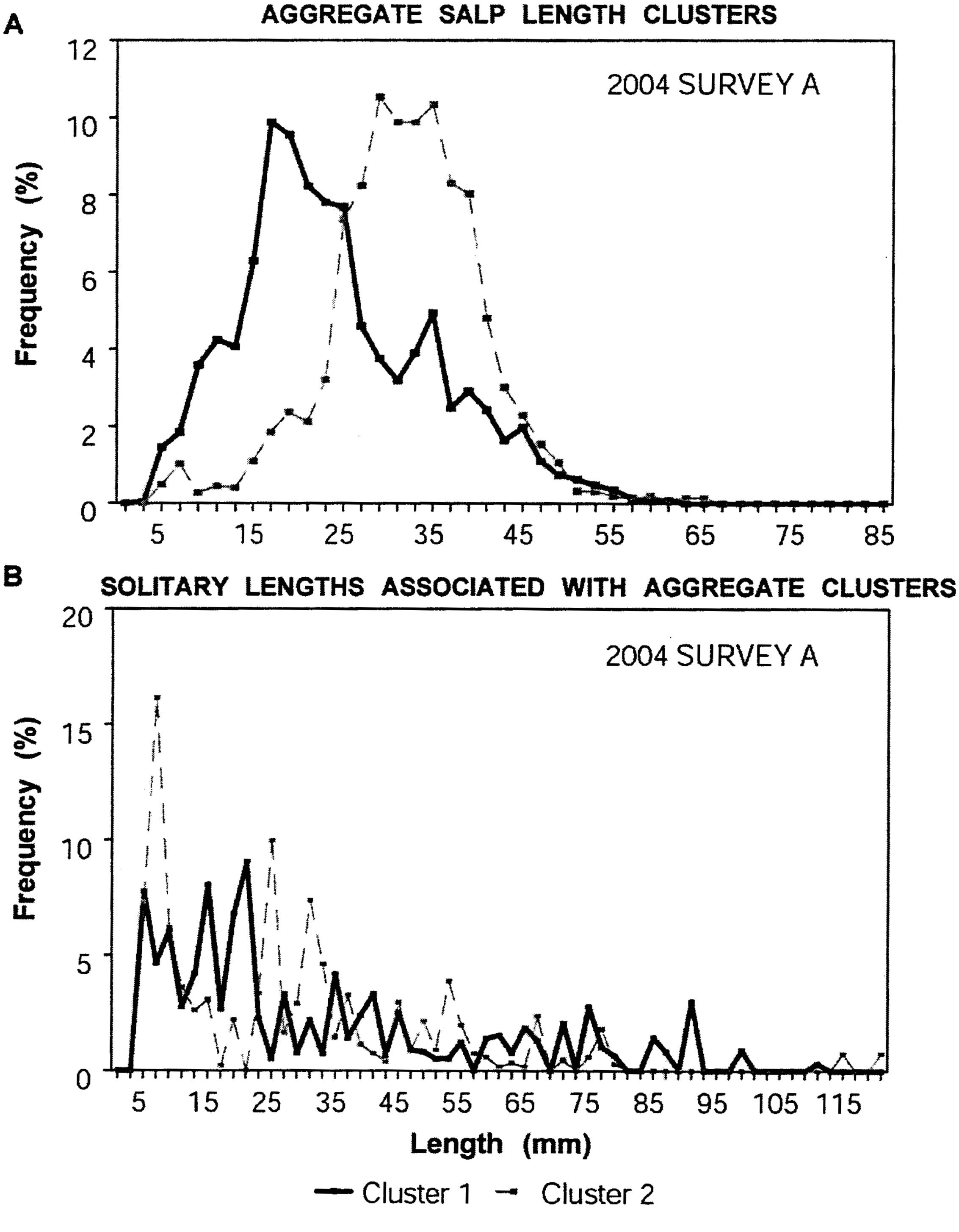


Figure 4.10. Length-frequency distributions of *Salpa thompsoni* (A) aggregate stage individuals belonging to two length clusters during January Survey A and (B) solitary stage individuals associated with these clusters.

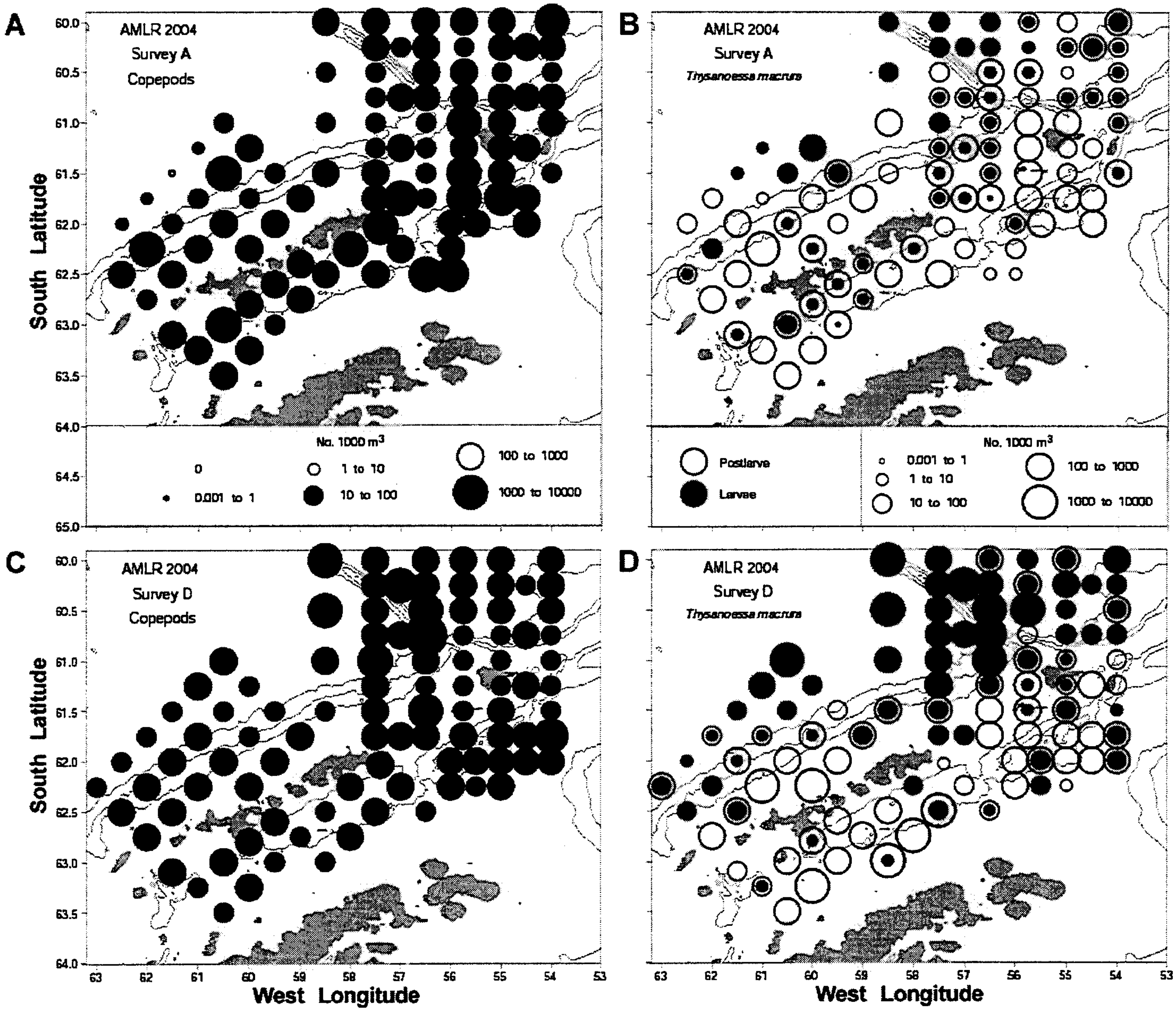
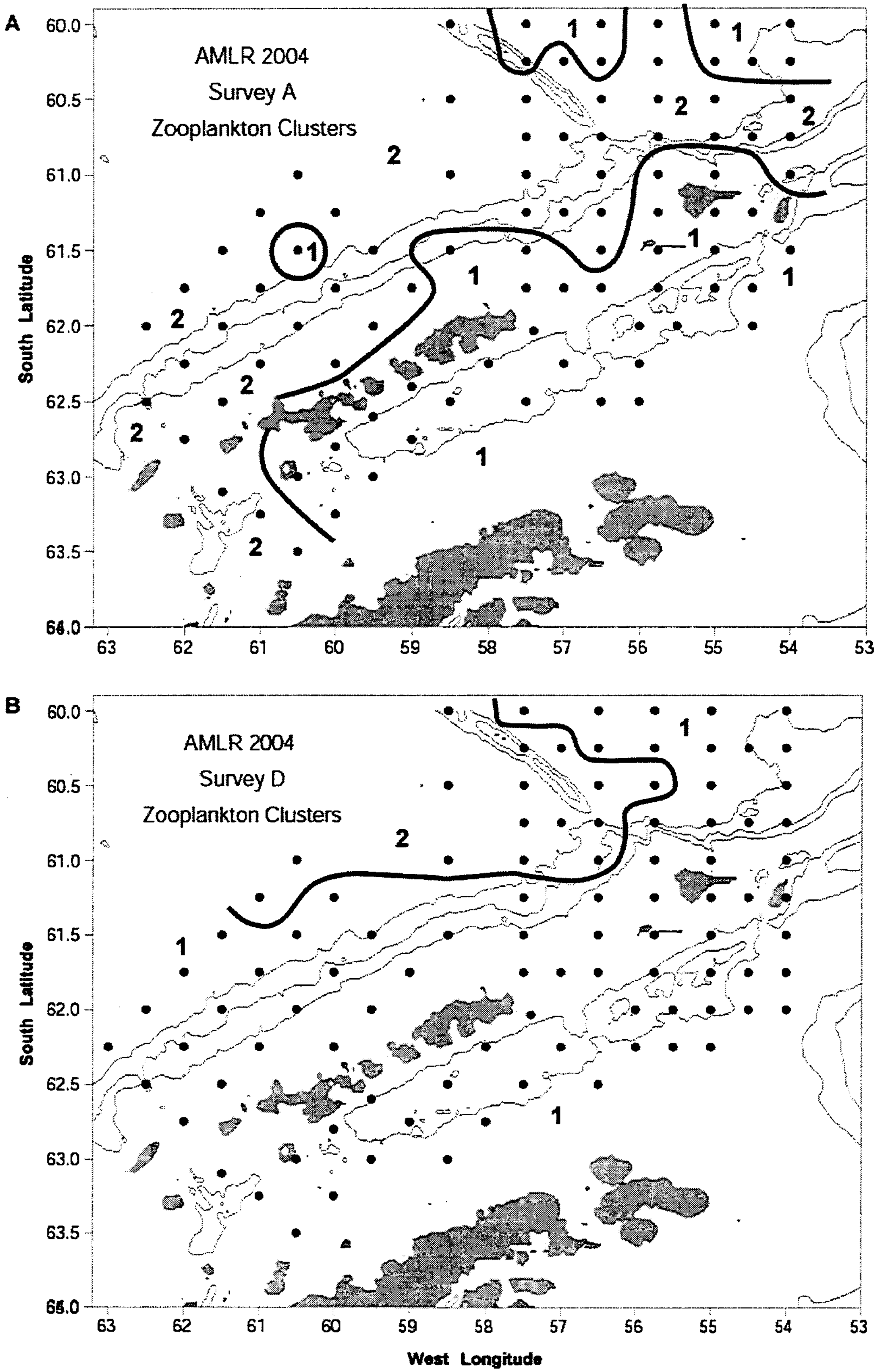


Figure 4.11. Distribution and abundance of (A, C) copepods and postlarval and larval *Thysanoessa macrura* (B, D) in the Survey A and Survey D Areas.

Figure 4.12.



Distribution patterns of zooplankton taxa belonging to different station groupings (Clusters 1 and 2) during (A) January Survey A and (B) February-March Survey D.

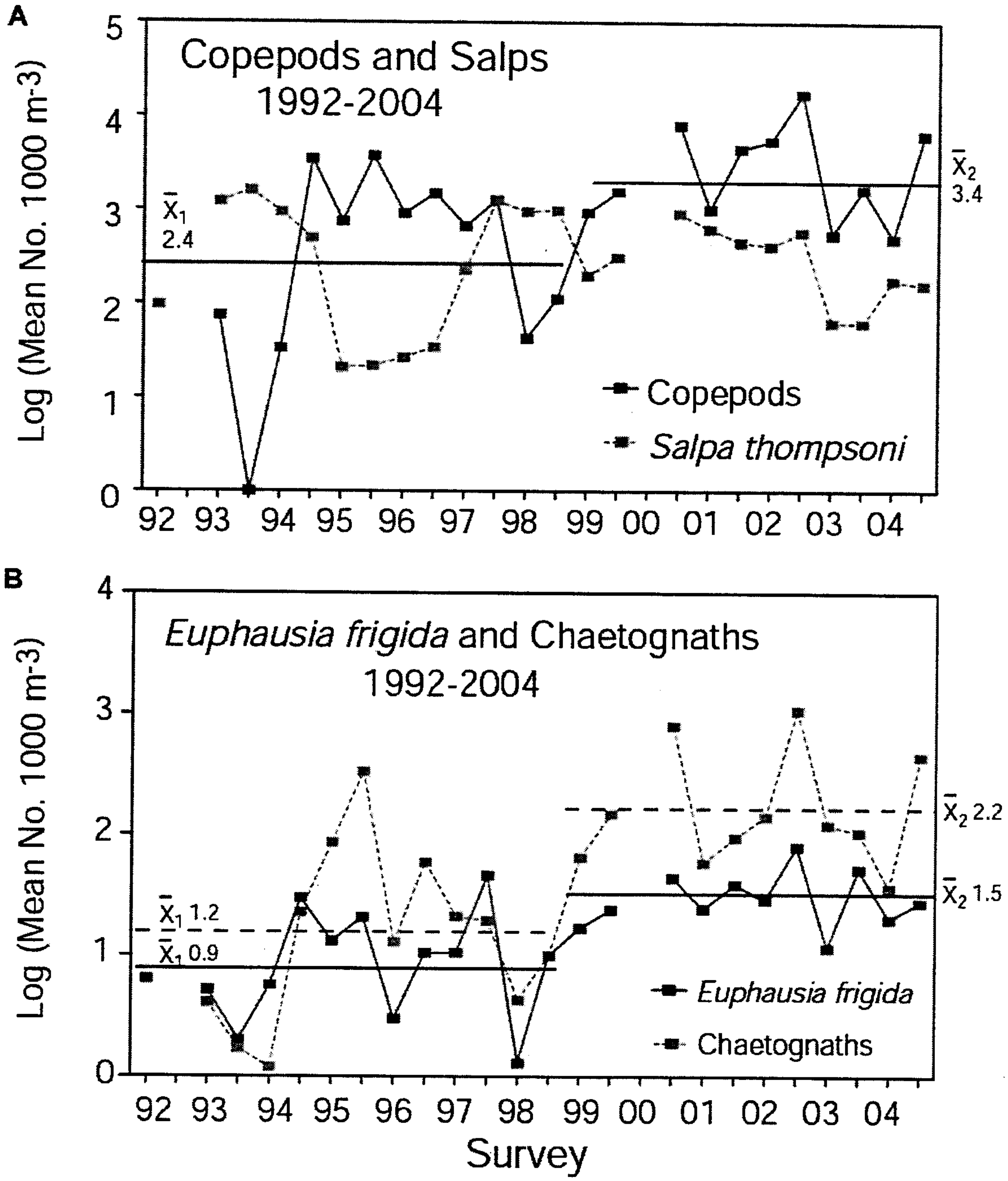


Figure 4.13. Zooplankton abundance fluctuations in the Elephant Island Area, 1992-2004. (A) Copepods and *Salpa thompsoni* and (B) *Euphausia frigida* and Chaetognaths.

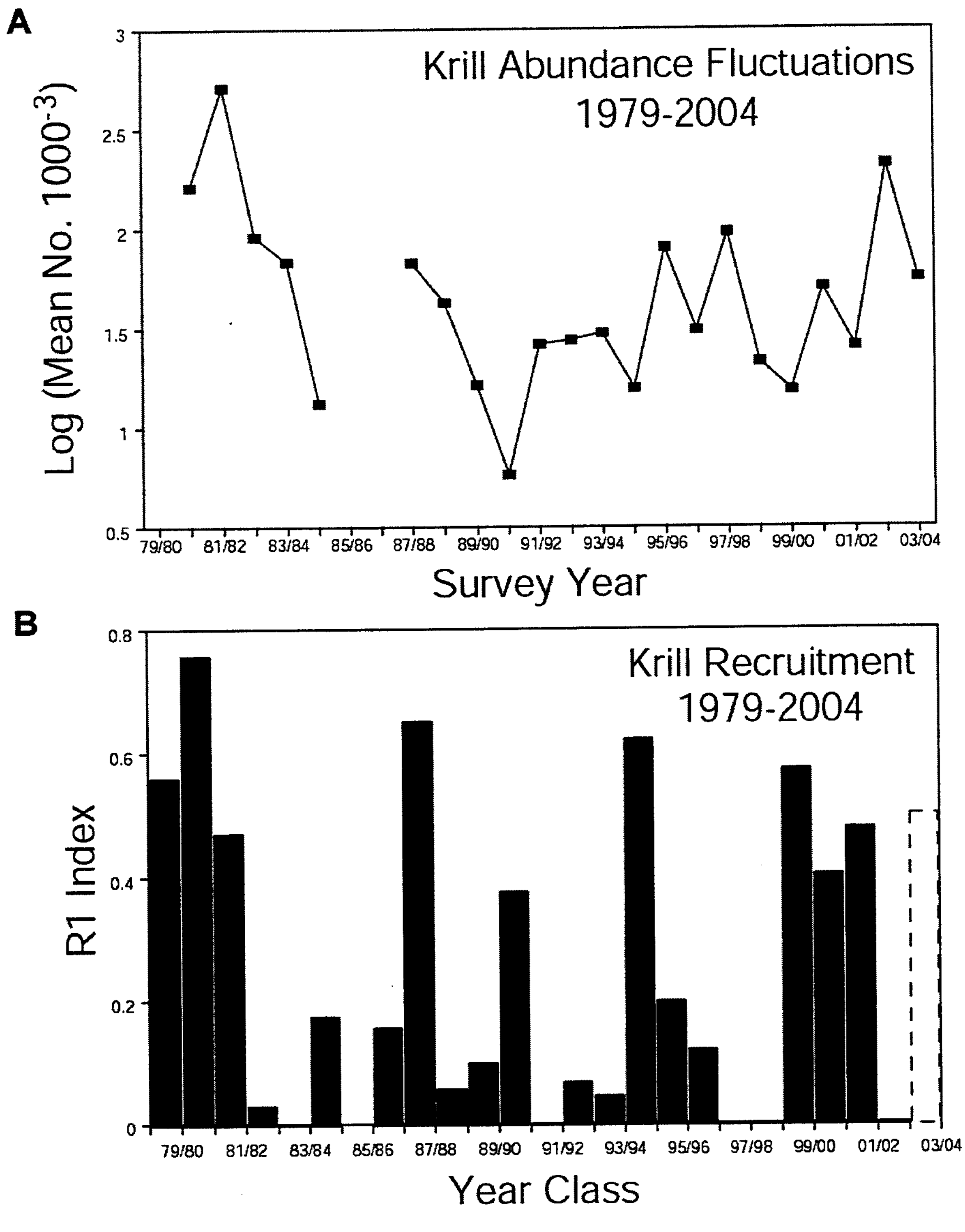


Figure 4.14. Krill recruitment success (A) and mean abundance (B) in the Elephant Island Area, 1979-2004. Estimated R1 value for the 2003/04 year class is based on recruitment success following similar reproductive conditions observed during the 1994/95, 1999/00, 2000/01 and 2000/02 field seasons.

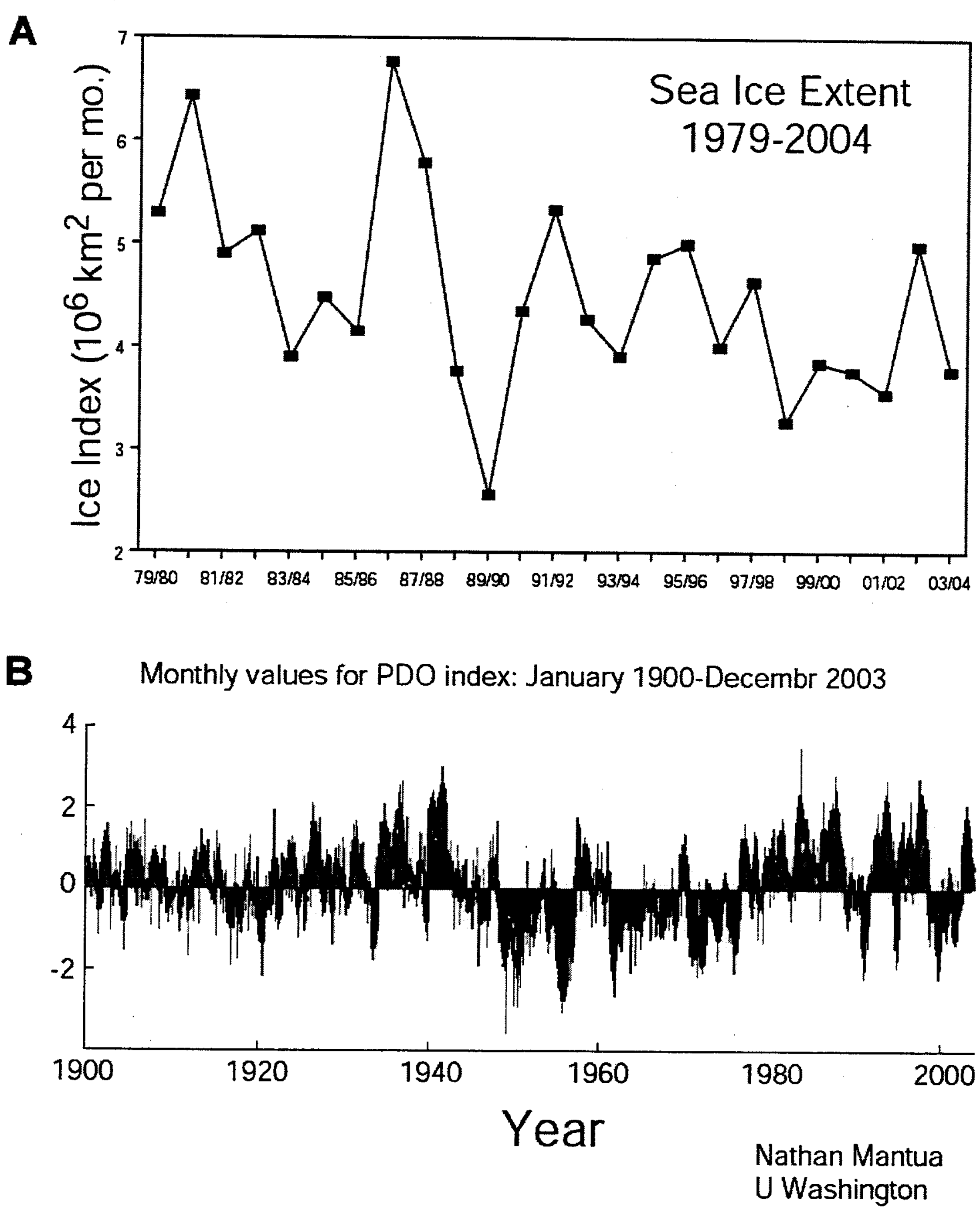


Figure 4.15. (A) Sea ice extent in the Antarctic Peninsula region 1979-2003 and (B) the Pacific Decadal Oscillation index, 1900-2003.

5. Nearshore Acoustical Survey Near Cape Shirreff, Livingston Island, Antarctica; submitted by Joseph D. Warren (Leg I), Adam D. Jenkins (Leg I), Derek J. Needham (Leg I), Marcel van den Berg (Legs I & II), Mike Soule (Leg II), and David A. Demer.

5.1 Objectives: The nearshore area around Cape Shirreff serves as the main feeding ground for the seasonally resident fur seal and penguin populations at Cape Shirreff. These animals feed primarily on Antarctic krill, which aggregates in large swarms and layers in the waters just offshore of the island. Shallow and highly variable bathymetry makes this area unsuitable for study from large ships. Using a specially modified 19-ft Zodiac (R/V *Ernest*), the near-shore region was surveyed, collecting acoustical backscatter and meteorological data. During this time, the R/V *Yuzhmorgeologiya* conducted a complementary survey of the shelf break and eastern canyon areas (Figure 5.1). This survey overlapped coverage with that of *Ernest* and collected hydrographic, meteorological, and net tow data. All of these data sets were analyzed to study the relationships between the oceanography and biology of the area. It is believed that the two submarine canyons flanking Cape Shirreff serve as a source of deep, nutrient-rich water which increases the productivity of this nearshore area. Additionally, three instrumented buoys were deployed in the area near the mouth of the eastern canyon to provide longer time-series measurements of underwater currents and acoustic scattering.

5.2 Methods and Accomplishments: Approximately 69 nautical miles were surveyed using *Ernest* from 7 to 9 February 2004 (Figure 5.1). *Ernest* is a Mark V 19-ft Zodiac powered by two outboard engines: a 9.9-hp Yamaha and a 55-hp Johnson (Figure 5.2). She is equipped with radar, multiple GPS, EPIRB, VHF radio, a WeatherPak 2000 meteorological station (measuring temperature, humidity, barometric pressure, bearing and apparent and true wind speed and direction), and a 120kHz Simrad EY500 echosounder. GPS and meteorological data were recorded on a laptop computer on board the vessel. There is also a downrigger that can be used to deploy additional instrumentation such as a small CTD or video camera system. *Ernest* runs from a bank of four gel cell batteries that can provide up to 20 hours of continuous power, providing 120-VAC power for data logging computers and instrumentation. The boat is also equipped with survival and tool kits, manual and automatic bilge pumps, three survival suits, four fuel tanks, binoculars, and anchorage equipment. Modifications made to the *Ernest* this year include changing the mount point of the acoustic transducer from a port-side armature to a transom mount. This locates the transducer approximately 1m below the water line and allows for transects to be conducted in all directions as opposed to the side-arm mount which tended to rise upward in certain sea states. The transducer can also be raised out of the water for quicker transit or rough sea state.

Ernest was scheduled to be deployed from *Yuzhmorgeologiya* on 05 February 2004. However, large swell and high winds precluded the launching of the vessel until 0600 (local time) on 7 February 2004. *Ernest* was taken into the Cape Shirreff cove anchorage location where mooring tackle was set-up, the WeatherPak installed and data acquisition systems tested. At approximately 0800, survey efforts commenced with running of the two northern-most transect lines of the eastern canyon. Sea conditions were between 2 and 3m swell with some wind chop. The acoustic transducer mount and all other equipment operated without problems. There is normally noise present on the acoustic echogram when the engine is operating. The survey on 7 February used only the 9.9hp electric motor. Survey operations concluded at approximately 1400 local time.

Subsequent operations were based from the field camp on Cape Shirreff. Due to the three days lost for the survey (two from weather preceding the deployment, and the last day (11 Feb) being used to transit to the Copacabana field station), the decision was made to focus survey efforts of the *Ernest* and *Yuzhmorgeologiya* on the eastern canyon. It was decided that multiple transects and stations in a smaller area would provide data to describe the temporal and spatial characteristics of the eastern canyon. The cost of this decision was that the western canyon was not surveyed at all this year.

An additional factor in the decision to forego the western canyon survey was that the *Yuzhmorgeologiya* needed to take an indirect route from the eastern to western canyon areas due to the presence of ice around Livingston Island. Grounded icebergs were prevalent throughout the original survey area, and tended to follow the 150m isobath. There was a fair chance that if the *Yuzhmorgeologiya* was sent west, the *Ernest* (if conditions were poor) would be unable to proceed to the western area and without the presence of the *Yuzhmorgeologiya* as a support ship would also be unable to survey the eastern canyon.

During the evening of 7 February, the *Yuzhmorgeologiya* ran the Y2 (along-canyon) transect line, however weather prevented complete coverage of the sampling locations. During the daytime of 0 February, the *Yuzhmorgeologiya* stood at station at Y2-5 while the *Ernest* surveyed the two southernmost transect lines of the eastern canyon. The *Ernest* encountered substantial iceberg and iceberg detritus lines (possibly wind rows) that made transect coverage difficult in the easternmost portion of the survey grid. Therefore the survey area was reduced in order to return to the anchorage of Cape Shirreff. Before returning to the anchorage, a calibration of the scientific echosounder on the *Ernest* was conducted. A full calibration proved difficult given that the echosounder is pitched slightly forward and the two crew members of the *Ernest* were unable to maintain the calibration sphere in the acoustic beam of the echosounder. However, the sparse results that were obtained were similar to those acquired in 2002.

The evening of 8 February, the *Yuzhmorgeologiya* surveyed the Y3 (along-shelf) transect, arriving back at station Y2-5 on the morning of 9 February. During the day, the *Ernest* ran transects between the two northernmost transect lines of the eastern canyon. Conditions were rougher with more substantial wind and seas up to 5m. At the end of the survey with foreboding weather forecasts, there was discussion of possibly recovering the *Ernest* that evening. In the end, the decision was made to wait out the evening and recover *Ernest* and personnel on the morning of 10 February. The *Ernest* was brought back on board the *Yuzhmorgeologiya* at approximately 1000 local time.

The *Ernest* was able to provide the most substantial and extensive survey of the eastern canyon of Cape Shirreff on Livingston Island. For the first time, proposed cruise tracks were actually followed. There were zero equipment failures and despite the short survey time (three days), the *Ernest* was able to collect acoustic data almost the entire time it was in the water, as opposed to previous years when substantial time was spent transiting between survey transect lines.

Due to the large number of icebergs in the vicinity of the planned buoy deployment sites (Figure 5.1), only one of the three instrumented spar buoys was deployed upon arrival at Cape Sherriff, Livingston Island. The instrumented buoy contained 50 and 200kHz single-beam echosounders, a 300kHz Acoustic Doppler Current Profiler (ADCP), a 900MHz spread-spectrum radio modem, GPS, radar reflector, strobe light, battery, solar panels and power control circuitry (Figure 5.2). The buoy was assembled and successfully deployed from the stern of the ship and moored in 87m of water at the northernmost of the three sites (62°25.76'S 60°44.02'W), on 14 January 2004. The buoy was set to activate itself for five minutes, every fifteen, and successfully established a connection with a logging computer at the Cape Sherriff base. The system provided remote display and record of targets beneath itself until 23 January 2004. On 1 February 2004, this buoy was replaced with another one hosting a 70kHz splitbeam echosounder and a 300kHz ADCP buoy.

Weather and ice conditions also permitted the second planned mooring site (62°27.38'S 60°42.0'W) to be approached by Zodiac, and a buoy with a 38/200kHz echosounder and 300kHz ADCP was successfully moored in 85m of water. A second receiving/logging station was set up at the Cape Sherriff base and the two buoys established communications and continuously logged data until 7 February, when they were recovered, repaired and redeployed. The 70kHz buoy's radio antenna had been snapped off and was replaced with a spare. This could be attributed to the rough sea conditions (6m swells) experienced over the previous two days. The 38/200kHz buoy had sustained ice collision damage and had to have its mast, solar panels, radar reflector and strobe light replaced. Radio communication was lost with this buoy on Saturday afternoon. Most likely cause was that the 300 x 300m iceberg that had moved in line with the buoy and shore station, was blocking the radio signal path. The buoy was tracked with the ship's radar and assumed to be mechanically sound and still gathering ADCP data.

The ship left the Cape Sherriff area on the afternoon of 10 February with the offshore most buoy logging ES60 70kHz, ADCP and GPS data. The control electronics were also reporting that the batteries were being charged by the solar panels. The 38/200kHz buoy at the second mooring had also reestablished contact with its logging computer on 10 February, but it was later discovered that the timing sequence was corrupted and the logging became unpredictable.

When the ship returned to Cape Sherriff on 19 February, risk assessments were made relative to buoy battery voltages and ice collision potential. A decision was made to leave the buoys deployed until sometime during Leg II, as both buoys were still logging, even though the 38/200kHz buoy's asleep/awake timing cycle was erratic.

The 70kHz buoy logged splitbeam and ADCP data until the evening of 20th February, when it finally succumbed to the long periods of overcast weather and the solar panels were not able to recharge the batteries enough to run the ES60 70kHz echosounder. However, the buoy's ADCP kept on collecting data until R/V *Yuzhmorgeologiya* retrieved the buoy, when she returned to Cape Sherriff on 7 March 2004.

The 38/200kHz buoy logged dual frequency echosounder data until 25 February and ADCP data until the buoy was retrieved on 7 March 2004. On retrieval the cause of the erratic timing cycle of the echosounder was discovered. A small amount of water had leaked into the control board housing, possibly through a stuffing tube or cable, damaged when this buoy sustained ice collision damage.

5.3 Results and Tentative Conclusions: The results of the 120kHz echosounder survey from the R/V *Ernest* were similar to the previous two surveys during 2000 and 2002 (Figure 5.3). Volume backscattering coefficients at 120kHz were integrated over the upper water column from 5m below the surface to the shallower of 3m above the bottom or 100m. Backscattering was averaged over 0.1-n.mi. of survey distance to produce Sa values which are believed to be proportional to the density of krill. As was seen in the 2000 and 2002 surveys, the highest concentrations of scatterers were found in the near-shore region southeast and east of Cape Shirreff. High levels of scattering were also found along the canyon walls. Scattering level magnitude was larger than in 2002, however the distribution of scattering patches was similar. From the 2004 nearshore survey net tow data from *Yuzhmorgeologiya*, the acoustical targets are believed to be euphausiids *Thysanoessa macrura* and *Euphausia superba*, although small fish contribute to the scattering as well. During the survey, many penguins and seals and one fin whale were seen in areas that had high acoustic backscatter.

Two large scattering patches were further analyzed (Figure 5.4) to investigate whether the presence of small fish was contributing to the measured scattering level. The strongest scattering level patch found during the nearshore survey occurred on 7 February at 13:06 local time, and the target strength histogram indicates that this swarm likely contained both adult krill (the mode centered around -70dB) as well as small fish (the mode centered around -40dB). Another extremely strong scattering patch was observed at the very end of the survey on 9 February at 17:06 local time. This patch occurred as *Ernest* was heading back into the Cape Shirreff anchorage as we passed very close by to a grounded iceberg. It is not clear whether the strong scattering signal is biological in origin or an artifact from the iceberg itself. However, an examination of the Sv histogram does not rule out a biological scattering source.

CTD results from the *Yuzhmorgeologiya* are shown as along-shore (cross-canyon) and cross-shore (along-canyon) transects (Figure 5.5). Evidence was not as strong this year for the presence of deep, nutrient-rich water in the eastern canyon, however the cross-canyon (along-shore) transect was much further offshore this year relative to the 2002 survey. Ice conditions in and around the canyons prevented the *Yuzhmorgeologiya* from replicating the 2002 survey area. There are slight elevations in the isopycnal surfaces (generally indicative of upwelling) near station Y2-3, however there was not strong evidence for upwelling during this year's survey. Nearshore waters were fresher than offshore waters which could be due to either glacial or iceberg melt.

IKMT net tow data were collected at stations along the Y2 and Y3 transects (Figure 5.1). As expected, euphausiids, copepods, salps, larval fish, and other crustaceans were the most common animals found (Figure 5.6) and occurred in numerical densities up to several animals per cubic meter (copepods, krill, and salps). The most common species for various zooplankton types were: krill (*T. macrura, E. frigida*, and *E. superba)*, copepods (*M. gerlachei, C. acutus, C. propinquus*, and *P. antarctica*), salps (*S. thompsoni*), amphipods (*C. lucasii, P. macropa, and T. gaudichaudii*), chaetognaths, larval fish (*L. larseni* and *Electrona spp.*), and gastropods (*L. helicina, S. australis*, and *C. limacina*). Adult krill (*E. superba*) were approximately 4cm in length.

Euphausiids and salps were found in higher densities in the offshore waters, while larval fish and copepods had higher densities in the eastern canyon in the nearshore areas. Net tows were conducted during both the day and night so these data are biased with regard to animals that vertically or laterally migrate during the day.

One interesting aspect of the zooplankton survey was that Station Y2-5 was occupied seven times during daylight hours over a three day period. The variability in numerical density of the various animals shows that even small temporal changes (of three to four hours) could lead to large (order of magnitude) changes in zooplankton abundance (Figure 5.7).

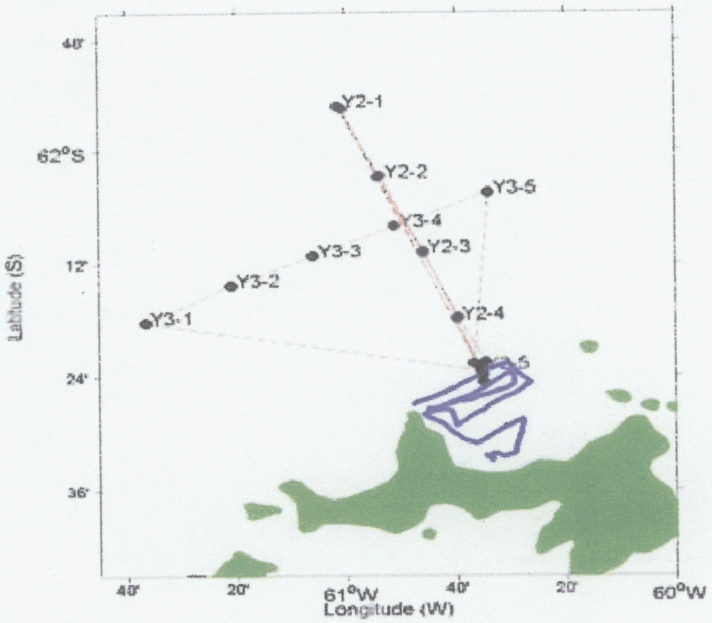
Weather conditions were fair during the 7 – 9 February survey period (Figure 5.8). The meteorological data collected by the WeatherPak 2000 system aboard the *Ernest* shows that wind speeds were generally in excess of 5m/s. Wind direction was variably but most often from the northwest. True wind speed and direction were calculated from the apparent wind speed and direction and the speed and course of the R/V *Ernest*. The humidity sensor often gave readings > 100% and is believed to have a 10-15% offset. Temperature was generally between 2°C and 4°C. The sea state was typically 2-3m and occasionally up to 4-6m. Typical survey speeds were 5-kts and an average of 6 hours per day were spent on the water.

The only objective that was not completed during the survey was the deployment of the video camera system to identify scatterers. When sea state was suitable for deployment, the *Ernest* was often in shallow water with no large scattering aggregations. When aggregations were seen in the echogram, either they were located too deep (below 30m, the length of cable of the video camera) or the sea state was too large to safely deploy the equipment. Given that the *Yuzhmorgeologiya* was obtaining net tow data in this area during the same time as the *Ernest* survey, we feel confident that the acoustic scattering sources are primarily krill and small fish.

The instrumented buoys provided real-time observations of krill abundance and dynamics and currents in the nearshore region of the Cape. The light-weight, spar-buoy design is proving to be stable and reliable in an unpredictable and hostile environment.

5.4 Disposition of Data: Data are available from David A. Demer, Southwest Fisheries Science Center, 8604 La Jolla Shores Drive, La Jolla, CA 92037, USA; phone/fax 858-546-5603/5608; email: ddemer@ucsd.edu or Joseph D. Warren, Southampton College, 239 Montauk Hwy, Southampton, NY 11968, phone/fax 631-287-8390/631-287-8419; email: joe.warren@liu.edu.

5.5 Acknowledgments: We are indebted to the scientists and crew aboard R/V *Yuzhmorgeologiya* for keeping a watchful eye over R/V *Ernest* and crew, and for collecting CTD, acoustical, and net tow data during the survey. We would also like to thank the personnel of the Cape Shirreff field camp for their hospitality during our stay at their home. Derek Needham and Sea Technology Services designed and built the transom mount for the scientific echosounder. Under contract from the Advanced Survey Technologies Program at SWFSC, R/V *Ernest* was cleverly designed and solidly built by Leif Knutsen of Port Townsend Shipwrights, Inc. Joseph D. Warren was supported in part by Southampton College of Long Island University.



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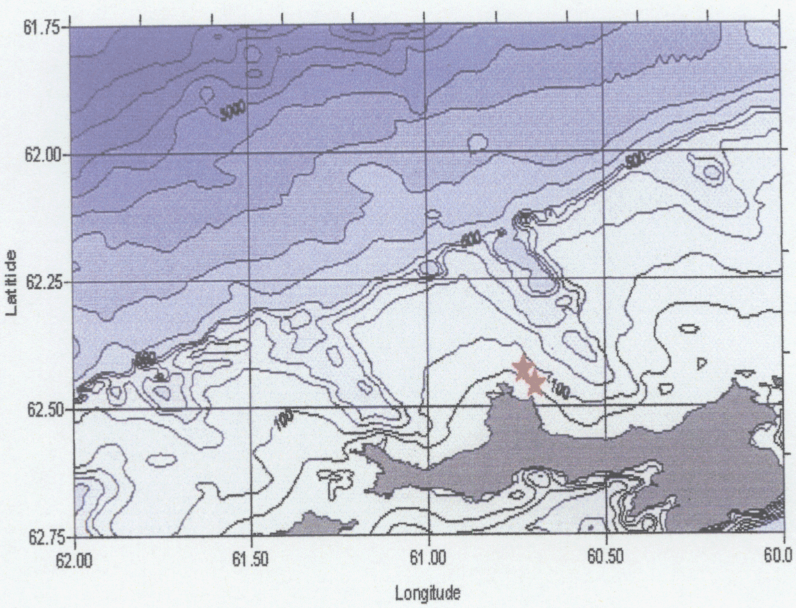
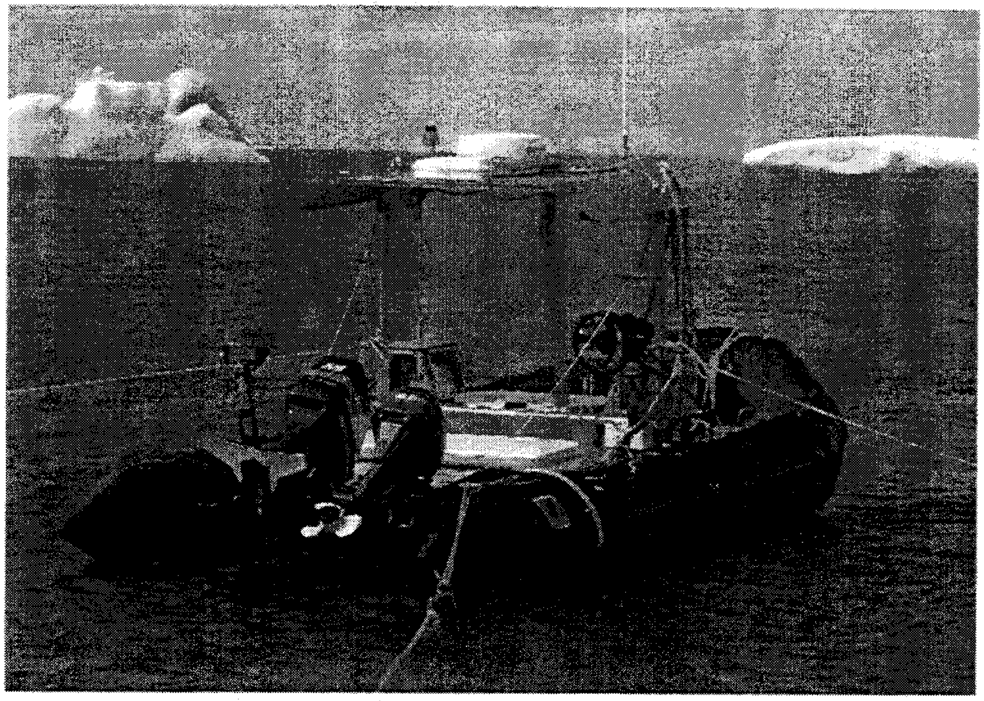
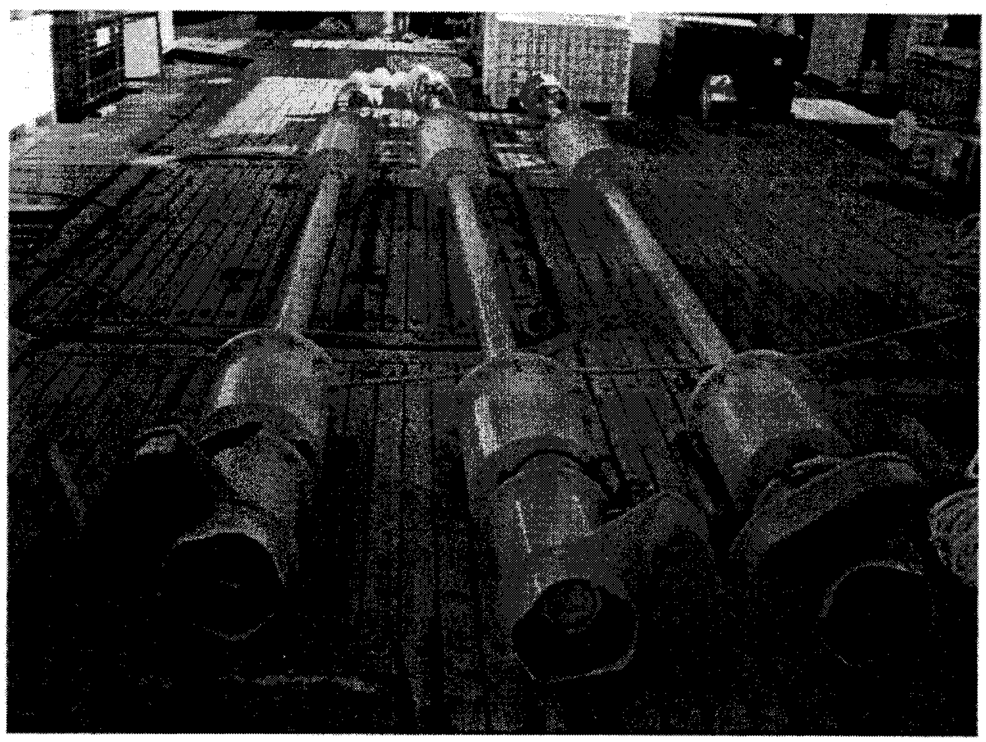


b.

Figure 5.1. (a) Completed track lines of the R/V *Yuzhmorgeologiya* (red) and R/V *Ernest* (blue) during the 2003 AMLR Nearshore Survey of Cape Shirreff. Red circles indicate the locations of CTD and IKMT stations. (b) Stars indicate the mooring locations of instrumented buoys.



a.



b.

Figure 5.2. (a) R/V *Ernest* moored at the protected beach immediately north of the Cape Shirreff field camp with transect line obstacles shown in the background. (b) The instrumented spar buoys readied for deployment.

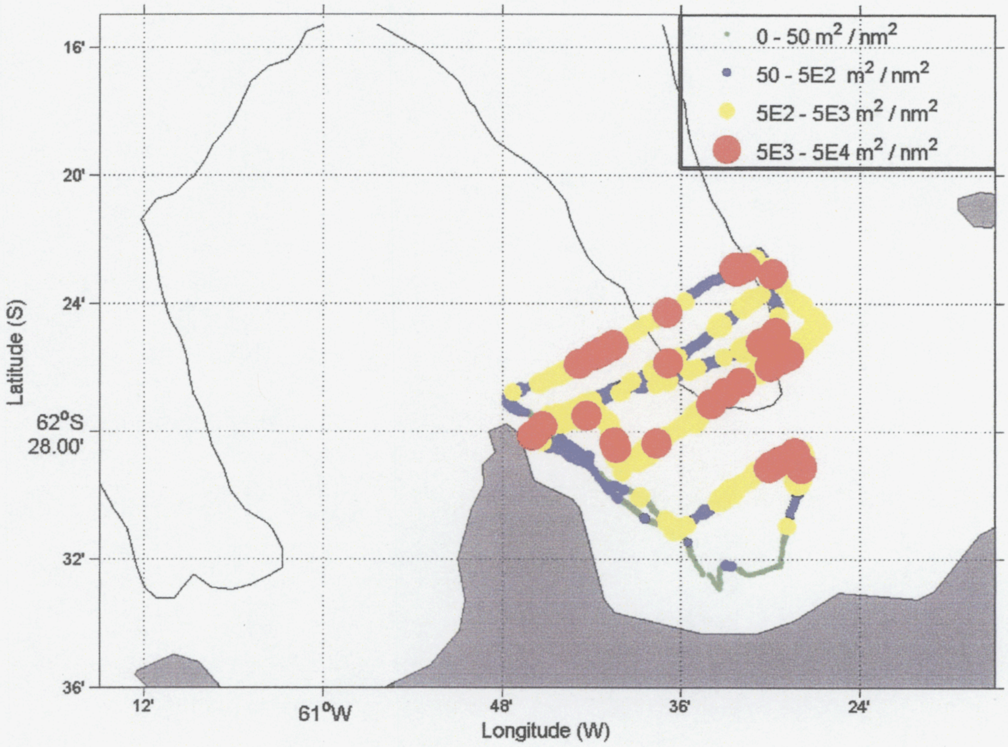


Figure 5.3. Volume backscattering coefficients at 120kHz integrated from 5m depth to the lesser of 3m above the bottom or 100m depth and averaged over 0.1 n.mi. bins (Sa). Overall values of Sa are larger compared to 2000 and 2002 surveys. Elevated backscatter (indicative of the presence of krill) occurred in the areas immediately east and southeast of Cape Shirreff and throughout the canyon region particularly along the canyon boundaries. The 200m isobath is shown in black.

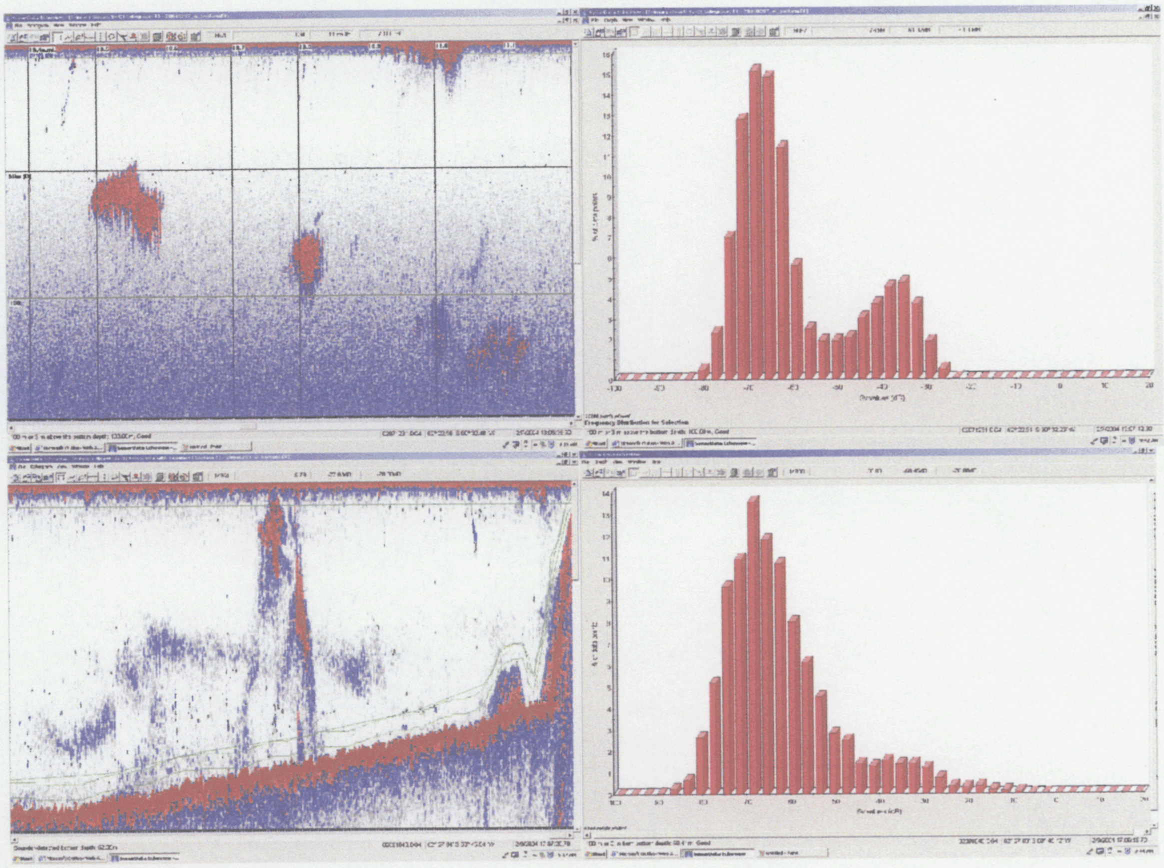


Figure 5.4. Echograms (left) and target strength histograms (right) for two large scattering patches observed during the survey. The strongest patch (top) was seen on 7 February at 13:06 local time. The histogram of target strength suggests that his patch is composed of both strong (larval fish) and weak (krill) scatterers. The other strong patch (bottom) was observed on 9 February at 17:06 local time as the R/V *Ernest* was returning to the Cape Shirreff anchorage. This patch was located next to a grounded iceberg. While it is possible that the scattering is an artifact from sidelobes from the transducer striking the submerged iceberg, the histogram suggests that this patch is possibly krill.

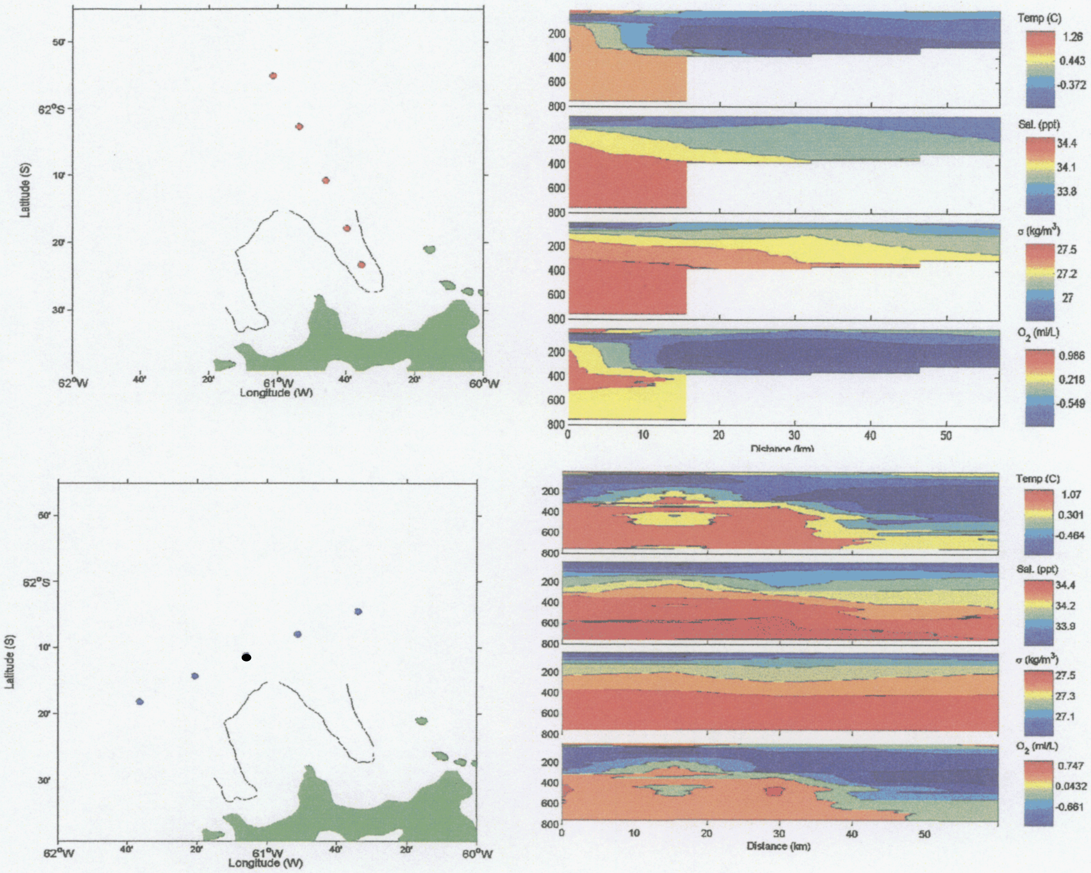


Figure 5.5. Along-canyon (upper figures) and cross-canyon (lower figures) hydrographic transects from the R/V *Yuzhmorgeologiya* during the nearshore survey. The along-canyon transect shows distance from the furthest off-shore station, while the cross-canyon transect shows distance from the furthest west station. Due to the presence of icebergs along the canyon, we were unable to replicate the hydrographic stations from the 2002 survey which indicated that deep, nutrient-rich water was being transported up the canyons into the nearshore region.

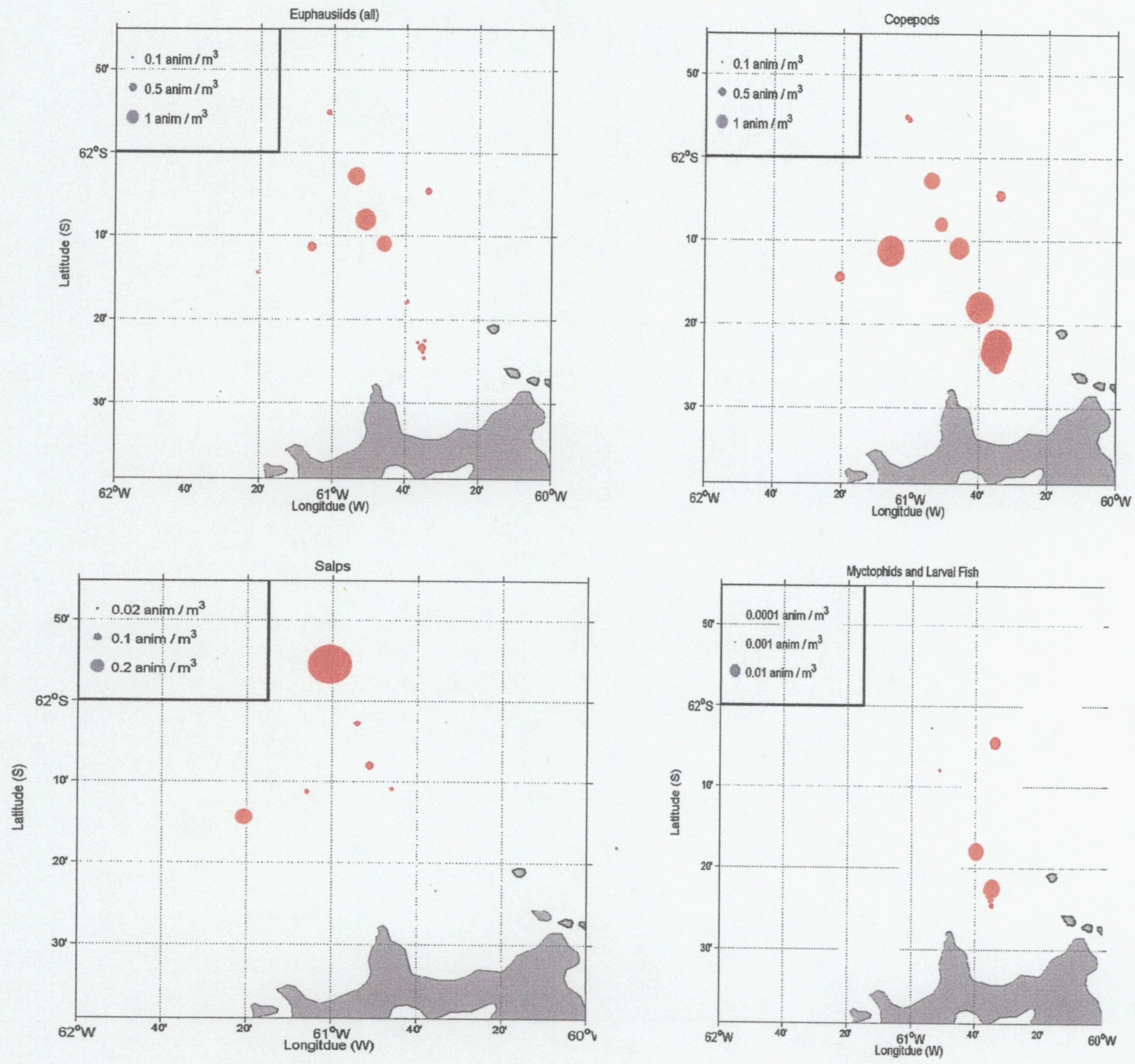


Figure 5.6. Distribution of zooplankton from IKMT new samples collected by the R/V *Yuzhmorgeologiya* during the 2004 nearshore survey. The diameter of the circles correspond to numerical densities of animals per m^3, but are different for each image. Salps and euphausiids were found in higher densities off-shore, while fish and copepods had higher densities in the eastern canyon. A complicating factor is that the net surveys are likely biased since the net tows occurred during both day and night during the nearshore survey.

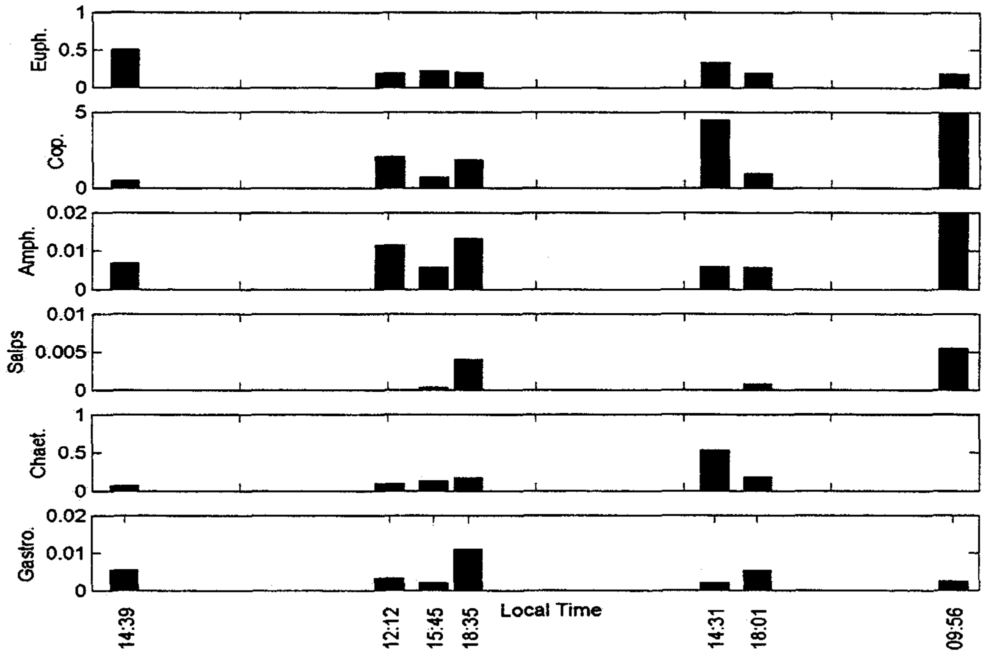


Figure 5.7. Zooplankton numerical density data from Station Y2-5 which was occupied seven times during the nearshore survey (7-10 Feb.). Zooplankton shown are (from top to bottom) euphausiids, copepods, amphipods, salps, chaetognaths, and gastropods. Large variations can be seen in the data over relatively small time scales (~ four hours). While many of the zooplankton species are vertical migrators, it is possible that lateral advection or migration may also account for these variations.

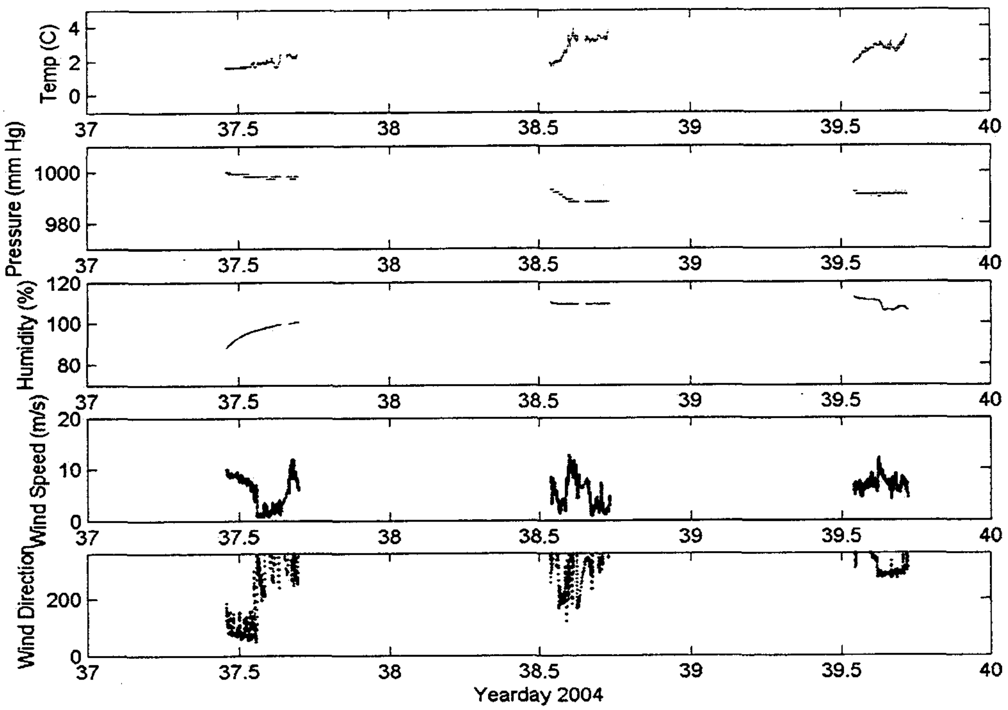


Figure 5.8. Meteorological data from R/V *Ernest* during the nearshore survey. The humidity sensor readings are likely offset 10-15% high. Mean wind speed was 6m/s with a peak gust recorded of 14m/s. Most frequent wind direction was from the NW. The humidity readings are 10-15% higher than actual conditions.

6. Pinniped research at Cape Shirreff, Livingston Island, Antarctica, 2003/04; submitted by Michael E. Goebel, Scott L. Freeman, Douglas J. Krause, Jessica D. Lipsky (Leg I), Lindsay K. Smith (Leg II), and Rennie S. Holt.

6.1 Objectives: As upper trophic level predators, pinnipeds are a conspicuous component of the marine ecosystem around the South Shetland Islands. They respond to spatio-temporal changes in physical and biological oceanography and are directly dependent upon availability of krill (*Euphausia superba*) for maintenance, growth, and reproduction during the austral summer. Because of their current numbers and their pre-exploitation biomass in the Antarctic Peninsula region and Scotia Sea, Antarctic fur seals, are recognized to be an important "krill-dependent" upper trophic level predator. The general objectives for U.S. AMLR pinniped research at Cape Shirreff (62°28'S, 60°46'W) are to monitor population demography and trends, reproductive success, and status of pinnipeds throughout the summer months. The Antarctic fur seal, *Arctocephalus gazella*, is the most abundant pinniped at Cape Shirreff and our studies are focused to a large degree on this species. Our studies focus on foraging ecology, diving, foraging range, energetics, diet, and reproductive success of fur seals rearing offspring.

The 2003/04 field season began with the arrival at Cape Shirreff of a four person field team via the R/V *Laurence M. Gould* on 11 November 2003. Research activities were initiated soon after and continued until closure of the camp on 7 March 2004. Our specific research objectives for the 2003/04 field season were to:

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

B. Monitor pup growth in cooperation with Chilean researchers collecting mass measures for a random sample of 100 fur seal pups every two weeks throughout the research period beginning 30 days after the median date of births;

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

D. Collect and analyze fur seal scat contents on a weekly basis for diet studies;

E. Collect a milk sample at each adult female fur seal capture for fatty acid signature analysis for 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 (with most deployments coinciding with the U.S.-AMLR Oceanographic Survey cruises);

H. Tag 500 fur seal pups for future demographic studies;

I. Re-sight animals tagged as pups in previous years for population demography studies;

J. Monitor survival and natality of the tagged adult female population of fur seals;

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

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

M. Record other tagged pinnipeds observed and any pinnipeds carrying marine debris (i.e. entanglements).

6.2 Methods, Accomplishments, and Results (by objective):

A. Female Fur Seal Attendance Behavior: Lactation in Otariid females is characterized by a cyclical series of trips to sea and visits to shore to suckle their offspring. The sequential sea/shore cycles are commonly referred to as attendance behavior. Measuring changes in attendance behavior (especially the duration of trips to sea) is one of the standard indicators of a change in the foraging environment and availability of prey resources. Generally, the shorter the duration of trips to sea, the more resources a female can deliver to her pup during the period from birth to weaning.

We instrumented 28 lactating females from 5-12 December 2003. 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). Standard Method C1.2 calls for monitoring of trip durations for the first six trips to sea. 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 were weighed, measured, and marked with an identifying bleach mark. The general health and condition of the pups was monitored throughout the study by making daily visual observations. The presence/absence was recorded for each female for the first six trips to sea using a remote VHF receiving station with an automated data collection and storage device. Data were downloaded weekly. Daily visual observations of instrumented females were conducted to confirm proper functioning of the remote system.

The first female in our study to begin her foraging cycles did so on 9 December and last female to complete six trips to sea did so on 23 January. Only one female (3.6%) failed to complete six trips (i.e. her pup perished before completion of six trips) and was never observed (live or dead) after the fourth trip to sea, ~11 January. The cause of failure was likely leopard seal predation as the timing of the disappearance coincided with the timing of the first pups entering the water and sightings of the first leopard seal predation.

The mean trip duration for the combined first six trips to sea this year was 3.61 (±0.10, N=166, range: 0.58-6.97). Last year (2002/03) the mean trip duration (1st six trips) was 6.83 days (±0.73, N=90, range: 2.83-10.78) the longest mean trip duration since data collection began at Cape Shirreff in 1997/98 (Table 6.1, Figure 6.1; ANOVA, $F_{6,1087}$=116.26, P<0.0005). Trip durations were normally distributed (Table 6.1, Figure 6.2).

Mean duration for the first six, non-perinatal visits was 1.55 days (±0.05, N=163, range: 0.23-3.99) (Table 6.1, Figure 6.1; ANOVA, $F_{6,1075}$=23.99, P<0.0005).

We use female post-partum mass as an index of condition at start of the breeding season. Arrival condition was better in 2003/04 than in previous years. Mean post-partum mass was 48.9kg (±1.04, N=28). There was no difference in the postpartum mass of females at arrival from 1998/99 to 2002/03 (ANOVA, $F_{4,138}$, P=0.34). However, females in 2003/04 had a greater mass at arrival than females in the previous four years (ANOVA, $F_{5,165}$, P=0.023; (Figure 6.3a). Females from 1997/98, the first year of our studies, were excluded from this analysis because they had a later mean date of parturition (22 Dec, ±0.60; range: 15-28 Dec) than females in subsequent years. This was due to late arrival of researchers in the first year of monitoring studies. Females in all other years did not differ in their mean date of parturition (8 Dec, ±0.23, range: 3-15 Dec; ANOVA, $F_{5,165}$, P=0.22).

The mass-to-length ratio (arc-sin transformed), a better measure of condition did not change from 1998/99-2002/03 (ANOVA, $F_{4,138}$=0.702, P=0.592; 98/99: Mean=0.347 ±0.041, N=32; 99/00: Mean=0.346 ±0.034, N=23; 00/01: Mean=0.35 ±0.026, N=28; 02/03: Mean=0.334 ±0.024, N=28). However, females at arrival in 2003/04 had a greater mass-to-length ratio, 0.366 ±0.007 (ANOVA, $F_{5,165}$=2.63, P=0.026; Figure 6.3b).

B. Fur Seal Pup Growth: Measures of fur seal pup growth were a collaborative effort between the U.S. research team and Chilean researchers. Data on pup weights and measures were collected every two weeks beginning 30 days after the median date of pupping (9 Dec 2003) and ending 24 February (four bi-weekly samples; collection dates: 10 Jan, 25 Jan, 9 February, and 24 February). 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 U.S. 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 17 November 2003 through 10 January 2004. The maximum number counted (live plus cumulative dead) at the combined four beaches in 2003/04 was 2285 on 4 January 2004 (Figure 6.4), a 5.9% increase over the maximum count for the same area last year (02/03: 2157 on 8 January 2003; 01/02: 2,435 on 6 January 2002; 00/01: 2,248 on 29 December 2000; 99/00: 2,104 on 3 January 2000). The median date of parturition was 9 December, the same date as last year. Since 1997/98 the median date of parturition has varied by four days (7-10 Dec).

Neonate mortality was lower than in previous years. We record the number of new pup carcasses on our census beaches at each count and calculate a cumulative mortality every other day (i.e. at each census) from around the start of births (17 November this year) until the last of pupping (10 January this year). Pup mortality for 2002/03 was 9.0%; this year pup mortality was 4.9 percent. Pup mortality for the same time period for past years was: 97/98: 1.8%; 98/99: 2.5%; 99/00: 2.8%; 00/01: 3.0%; and 01/02: 5.5%.

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 containing dietary information. In addition to diet information from captive animals, ten scats were collected opportunistically from female suckling sites every week beginning 20 December. The weekly scat sample is collected by systematically walking transects of female suckling areas and collecting any fresh scats within a short range of the observer. This method prevents any bias associated with the difference in visibility between krill laden scats, which are bright pink, and fish laden scats, which are gray to brown, and blend in with the substrate more easily.

In total, we collected and processed 112 scats from 20 December 2003-2 March 2004. Diet samples that could not be processed within 24 hours of collection were frozen. All samples were processed by 6 March. Up to 25 krill carapaces were measured from each sample that contained krill. Otoliths were sorted, dried, identified to species. The number of squid beaks were counted and preserved in 70% alcohol for later identification. A total of 2337 krill carapaces were measured. Most scats, 87.5% (98/112) collected contained krill. In addition, 6,424 otoliths were collected from 58.9% of the scats collected. Ninety percent (5,780) were from three species of myctophid fish (*Electrona antarctica*, n=952; *Electrona carlsbergi*, n=1176; *Gymnoscopelus nicholsi*, n=2,205; plus an additional 2,091 eroded and unidentified otoliths). A total of 76 squid beaks (*Brachioteuthis picta*) were collected from 17.9% of the scats.

The proportions of krill, fish and squid were different every year (Table 6.2, X^2=31.7, d.f.=8, P<0.0005). Results for 2003/04 were similar to 2002/03 which indicated less krill more fish and squid in the diet than in 2000/01 and 2001/02. Proportions were more similar to those encountered in 1998/99-1999/00. In fact, for February samples unlike prior to 2002/03, fish was in greater proportion than krill (Figure 6.5). The weekly occurrence of five primary prey species in fur seal diet varies inter- and intra-seasonally (Figure 6.6). As in years past, the proportions of fish and squid increases over time (from Dec-Feb).

The length and width of krill carapaces found in fur seal scats were measured in order to determine length distribution of krill consumed. Up to twenty-five 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 2,337 carapaces were measured from 98 scats in 2003/04. Summary statistics are presented in Table 6.3. Data from 1999/00 through 2002/03 are also presented for comparison. Krill consumed by fur seals in 2003/04 was on average larger than last year (Table 6.3; ANOVA, $F_{3,10383}$ = 3,043.3, P<0.0005). The length distributions (in 2mm increments) for the last four years are presented in Figure 6.7. Smaller krill (<50mm) were present in fur seal diet throughout the sampling period and weekly comparisons showed changes in length-frequency distributions (Figure 6.8).

E. Fatty Acid Signature Analysis of Milk: In addition to scats, we collected 104 milk samples from 49 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 returned (within several hours) to the lab where two 0.25mL aliquots were collected and each stored in a solvent-rinsed glass tube with 2mL of chloroform with 0.01% butylated hydroxytoluene (BHT, an antioxidant). Samples were flushed with nitrogen, sealed, and stored frozen until later extraction of lipid and trans-esterification of fatty acids. Of the 104 samples, 26 were collected from perinatal females and 22 were collected from females that 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 9s, 66 x 18 x 18mm, 31g) on their first visit to shore. Five of the ten carried their TDR for at least their first six trips to sea. In addition, all other females captured for studies of at-sea foraging locations also received a TDR. A total of 32 dive records were collected from 22 females in 2003/04.

G. Adult Female Foraging Locations: We instrumented 18 females with satellite-linked transmitters (ARGOS-linked Platform Terminal Transmitters or PTTs) from 21 December – 22 February. Thirteen of the 18 were deployed to coincide with the U.S.-AMLR large-scale oceanographic survey. Six females successfully carried a PTT for two trips to sea and nine females carried a PTT for a single trip. Results of fur seal foraging location data analysis and interannual comparisons are pending.

H-J. Demography and Tagging: Together Chilean and U.S. researchers tagged 499 fur seal pups (245 females, 254 males) from 23 January – 20 February 2004. 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. Series numbers for 2002/03 were 3501-3999. Most pups (449 or 90.0%) were tagged on the east side of the Cape from Playa Marko to Ballena Norte beach. A total of 50 pups (40 females, 10 males) were tagged at Loberia beach on the northwest side of the Cape.

In addition to the 499 pups tagged, we also tagged 32 adult lactating (26 had been previously untagged females [315-340] and 6 that had previously been tagged but had lost one tag [001,301,311,336,1555,1681,1832]. The latter three females were tagged as pups at Cape Shirreff and gave birth for the first time this year. All tags were placed on females with parturition sites on east side beaches (Copihue, Maderas, Cachorros, and Chungungo beaches).

Last year we added 28 adult females to our tagged population. These 28, when added to the females that returned in the previous season (N=199), gave an expected known tagged population of 227 for 2003/04 (Table 6.4). Of these, 209 (92.1%) returned in 2003/04 to Cape Shirreff and 186 (89.0%) returned pregnant (Figure 6.9). The return rate was higher than last year and above the long-term mean (mean for six years, 1998/99-2003/04: 90.2% ±2.1) and the natality rate was only slightly (0.3%) below the long-term mean (89.3% ±1.0). (Return rates by year: 98/99: 83.8%, 99/00: 94.0%, 00/01: 90.4%, 01/02: 97.9%, 02/03: 85.8%; Natality rates: 98/99: 90.3%, 99/00: 92.3%, 00/01: 87.2%, 01/02: 91.1%, 02/03: 85.8%; Figure 6.9).

Our tagged population of females returned (on average) one day later than last year. Last year (2002/03) the mean date of pupping for tagged females (which had a pup in both years, 2002/03 and 2003/04) was 7 December (±0.67, N=114) and in 2003/04, for the same females, it was 8 December (±0.67, N=114).

We observed 12 yearlings (four males, eight females; 2.4% return rate) tagged as pups this year compared to 23 last year (12 males and 11 females, 4.6%; Table 6.5). The yearling return rate for this year was higher than last year but lower than the 6-year mean (3.3% ±0.68). Table 6.5 presents observed tag returns for four cohorts in their first year. Tag deployment, the total number placed and re-sighting effort for all six cohorts were similar and the variance is likely due to differences in the post-weaning physical and/or biological environment. The differences in return rates are not necessarily due to survival alone 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 for year one based upon tag re-sights for the first two years following tagging (Table 6.6). 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, *etcetera* may vary for different cohorts. Given similar re-sighting effort the five cohorts presented have return rates in the first two years that are very different (Figure 6.10). Most notable is that the 1999/00 cohort appears exceptional in its rate of return in both its first year and its second. The minimum survival to age-1 for the 1999/00 cohort was 25.0%. If the transition to nutritional independence and foraging conditions their first winter are critical to juvenile otariid survival (as suggested by York, 1994) then 1999/00 cohort experienced exceptionally good conditions at weaning and for their first winter at sea. The observed cohort differences are important whether due to survival or differences in dispersal that result in a different rate of return. This year's tag returns were again dominated by the 99/00 cohort and to a lesser degree by the 2001/02 cohort which had 16.1% minimum survival in its first year.

K. 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-9 February, we took a single post-canine tooth from 36 previously tagged females at Cape Shirreff. Females ranged in size from a mass of 30.2-49.2kg and length of 120-140cm. The mean total time captive was 16.0 min (±0.67) and the mean total time under anesthesia was 13.0 min (± 0.64, n=36). The time captive and the time under anesthesia were not significantly different over last year. (Time captive: ANOVA, $F_{1,79}$=3.03, P=0.09; time on gas anesthesia: ANOVA, $F_{1,79}$=0.24, P=0.63)

This year we attempted to increase the number of validation teeth (i.e. teeth from animals of known-age (tagged as pups)). Since tagging studies at Cape Shirreff were only begun in 1998, the teeth collected for validating ageing techniques and reliability of counters has been restricted to very young animals and two immigrant females from Seal Island. In order to increase our sample size and age distribution of validation teeth we went to Seal Island where from 1987-1995 the U.S. AMLR Program tagged fur seal pups.

From 2-4 February we made daily landings on Seal Island where we found many more known-aged tagged adult fur seals than we anticipated (since pups at Seal Island (North Cove) experience high leopard seal mortality). We were easily able to collect our permitted take of 15 teeth. Most notable of our visit to Seal Island was not just the number of tagged individuals found but the exceptionally large size of females. Female mass was on average 7.4kg greater than at Cape Shirreff (39.4kg ±0.72, Seal I.: 46.9kg ±1.3; ANOVA, $F_{1,49}$=28.40, P<0.0005) and length was 5.5cm greater (Cape Shirreff: 131.4cm ±0.81, Seal I.: 136.9cm ±1.4; ANOVA, $F_{1,49}$=12.71, P=0.001). The difference can in part be explained because Seal Island sample was likely, on average, older.

L. Weather at Cape Shirreff: A weather data recorder (Davis Weather Monitor II) was set up at the U.S.-AMLR field camp at Cape Shirreff from 12 November 2003 to 28 February 2004. 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.

M. Miscellaneous: Tagged Elephant Seals. No tagged elephant seals were recorded this year. Entangled pinnipeds. We did not observe any entangled pinnipeds this season.

6.3 Preliminary Conclusions: The 2003/04 season was in many respects an improvement over the 2002/03 season for Antarctic fur seals at Cape Shirreff. Fur seal pup production at U.S.-AMLR study beaches increased by 5.9% over last year (though pup numbers still remain below the pre-2002/03 numbers). Neonate mortality (4.9%) was nearly half what it was in 2002/03. The median date of pupping based on pup counts did not change over last year and our tag returns of adult females confirm no change in the parturition date. Over winter survival for adult females was better than last year (92.1 vs. 85.8%). The natality rate (89.0%) also improved over last year. Foraging trip duration was below the long-term mean indicating better than average foraging conditions (mean: 3.61d ±0.10) and visit duration above the long-term mean (1.55d ±0.05; long-term mean: 1.45d ±0.10). The 1999/00 and the 2001/02 cohorts continued to dominate tag returns as in previous years.

6.4 Disposition of Data: All raw and summarized data are archived by the Antarctic Ecosystem Research Division of the National Marine Fisheries Service, Southwest Fisheries Science Center, La Jolla, CA. Efforts are being made to archive much of the data in a web/password accessible database.

6.5 Problems and Suggestions: The monitoring program at Cape Shirreff is confined to measuring parameters during the first three months of fur seal pup rearing. Only a few of the summer-measured parameters (e.g. adult female over-winter survival, pregnancy rates, and cohort survival) reflect ecological processes over a broader temporal spatial scale. Yet these data clearly show that post-weaning environments are crucial for survival, recruitment, and sustainability of pinniped and seabird populations. The dominance of the 99/00 cohort in tag return data and differential cohort strength (Table 6.6, Figure 6.10) offer one of the best examples of this. Recent technology in miniaturization and programmability of satellite-linked transmitters provide the means by which to develop an understanding of post-weaning environments, dispersal of females and pups post-weaning. These instruments can not only provide information on dispersal but can measure the physical environment encountered by individuals. Future studies should use this technology to measure dispersal, survival and various parameters of the physical environment in order to identify factors leading to increased survival and recruitment of juvenile pinnipeds and seabirds.

6.6 Acknowledgements: The National Science Foundation provided support and transportation to the Cape Shirreff field site for the opening camp crew. We thank the captain, crew and science staff of the November cruise of the R/V *Laurence M. Gould.* We would especially like to thank Roger Hewitt and Ethan Daniels, who participated in zodiac support for Seal Island operations, and Anthony Cossio for his able assistance in captures at Seal Island. We are grateful to our Chilean colleagues: Romeo Vargas, Daniel Torres, Victoria Valdenegro, Claudio Vera and Daniel Torres, Jr. for their assistance in the field 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 Michelle Antolos and Aileen Miller for their help with pinniped studies. 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. All pinniped research at Cape Shirreff was conducted under Marine Mammal Protection Act Permit No. 774-1649 granted by the Office of Protected Resources, National Marine Fisheries Service.

6.7 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.

York, A.E. 1994. The population dynamics of northern sea lions, 1975-1985. Marine Mammal Science 10(1): 38-51.

Table 6.1. 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 – 2003/04.

Year	Female N	N	Range	Median	Mean	St.Dev.	Skew[1]	SE Skew	S[1]	(+/-)
Trip Durations:										
1997/98	30	180	0.50 -9.08	4.07	4.19	1.352	0.083	0.181	0.459	-
1998/99	31	186	0.48 -11.59	4.23	4.65	1.823	0.850	0.178	4.775	+
1999/00	23	138	0.60 -8.25	3.25	3.47	0.997	1.245	0.206	6.044	+
2000/01	28	168	0.75 -5.66	2.69	2.71	0.828	0.874	0.187	4.674	+
2001/02	28	166	0.50 -7.85	2.87	3.18	1.207	0.740	0.188	3.936	+
2002/03	15	90	2.83 -10.78	6.89	6.83	0.731	-0.072	0.254	0.283	-
2003/04	28	166	0.58 -6.97	3.60	3.61	1.241	0.365	0.188	1.94	-
Visit durations:										
1997/98	30	179	0.46 -2.68	1.25	1.35	0.462	0.609	0.182	3.346	+
1998/99	31	186	0.21 -3.49	1.27	1.33	0.535	0.947	0.178	5.320	+
1999/00	23	138	0.10 -4.25	1.51	1.72	0.635	1.088	0.206	5.282	+
2000/01	28	168	0.44 -3.15	1.52	1.68	0.525	0.485	0.187	2.594	+
2001/02	28	166	0.19 -4.84	1.43	1.55	0.621	1.328	0.188	7.094	+
2002/03	15	82	0.23 -2.18	0.98	0.98	0.051	0.447	0.266	1.680	-
2003/04	28	163	0.23 -3.99	1.43	1.55	0.579	0.870	0.190	4.58	+

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

Table 6.2. 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 the last five years of collections, 1999/00 through 2003/04 (X^2=31.7, d.f.=8, P<0.0005). Reject H_o: The proportions of krill, fish, and squid in the diet are homogeneous in the five years of study. (Column headings: Obs. = Observed, Exp. = Expected)

	1999/00		2000/01		2001/02		2002/03		2003/04	
Prey	Obs,	Exp.	Obs.	Exp.	Obs.	Exp.	Obs.	Exp.	Obs.	Exp.
Krill	94	98.8	104	78.7	111	121.0	78	87.4	98	99.9
Fish	71	67.9	39	54.1	97	83.2	61	60.1	66	68.7
Squid	17	15.3	2	12.2	15	18.7	21	13.5	20	15.4

Table 6.3. Krill length (mm) in fur seal diet from 1999/00 - 2003/04. Data are derived from measuring length and width of krill carapaces found in fur seal scats and applying a discriminant function to first determine sex before applying independent regression equations to calculate total length.

Krill Length (mm)	1999/00:	2000/01:	2001/02:	2002/03	2003/04
N:	2,528	2,941	2,826	2,091	2,337
Median:	50.8	52.9	55.0	42.5	46.6
Mean:	50.6	53.1	53.8	43.0	47.0
St.Dev.:	4.46	3.82	4.44	4.17	5.52
Maximum:	59.7	64.3	64.3	59.7	62.0
Minimum:	13.9	39.1	36.8	34.1	34.1
Sex Ratio (M:F):	1:1.8	1:1.2	1:2.4	1:8.3	1:1.4

Table 6.4. Tag returns and natality rates for adult female fur seals at Cape Shirreff, Livingston Island, 1998/99 – 2003/04.

Year	Known Tagged Population[1]	Returned	Pregnant	% Return	% Natality	Tags Placed	Primaparous females tagged as pups
1997/98						37[2]	0
1998/99	37	31	28	83.8	90.3	52	0
1999/00	83	78	72	94.0	92.3	100	0
2000/01	173	156	136	90.4	87.2	35	0
2001/02	195[3]	191	174	97.9	91.1	42	2
2002/03	226	194	168	85.8	86.6	28	6
2003/04	227	209	186	92.1	89.0	26	14

[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.

[3]Includes one female tagged as an adult with a pup in 1998/99, which was present in 1999/00 but was never observed in 2000/01.

Table 6.5. A comparison of first year tag returns for four cohorts: 1997/98 – 2001/02. Values in parentheses are percent total tagged.

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)
2000/01	499	9 (1.8)	6 (2.6)	3 (1.1)
2001/02	499	23 (4.6)	12 (4.8)	11 (4.0)
2002/03	498	12 (2.4)	4 (1.7)	8 (3.0)

Table 6.6. Tag returns and minimum percent survival for five cohorts, 1997/98 – 2001/02 using only the first two years of re-sight data for each cohort. Assuming cohort return rates correlate with survival and are similar for each cohort, our data show survival to age-1 varies considerably.

	1997/98			**1998/99**			**1999/00**			**2000/01**			**2001/02**		
	♀	♂	**Total**	♀	♂	**Total**	♀	♂	**Total**	♀	♂	**Total**	♀	♂	**Total**
Sightings:															
Sighted in Year 1:	12	10	22	1	5	6	11	15	26	3	6	9	12	11	23
Additional Tags Sighted in Year 2:	20	10	32	6	7	13	53	40	93	13	2	15	28	26	54
Minimum survival in year 1:	32	20	54[1]	7	12	19	64	55	119	16	8	24	40	37	77
Tag loss:															
Unknown tag status:	2	1	3	0	2	2	1	3	4	0	1	1	4	2	6
Both tags present:	14	13	29	6	6	12	48	42	90	11	5	16	29	27	56
Missing 1 tag:	16	6	22	3	2	5	15	10	25	5	2	7	7	8	15
Probability of missing one tag:	0.53	0.32	0.43	0.33	0.25	0.29	0.24	0.19	0.22	0.29	0.29	0.30	0.19	0.23	0.21
Probability of missing both tags[2]:	0.28	0.10	0.19	0.11	0.06	0.09	0.06	0.04	0.05	0.08	0.08	0.09	0.04	0.05	0.04
Survival estimates:															
Minimum % Survival 1st year:	12.80	8.00	10.8	2.8	4.8	3.8	27.6	20.6	23.8	6.0	3.4	4.8	15.3	15.5	15.4
Adj. Min. % Survival for year 1[3]:	16.44	8.80	**12.8**	3.1	5.1	**4.1**	29.2	21.4	**25.0**	6.6	3.8	**5.3**	15.9	16.4	**16.1**

[1]Includes two sightings of seals of unknown sex.

[2]Assumes tag loss is independent for right and left tags.

[3]Minimum percent survival adjusted for double tag loss.

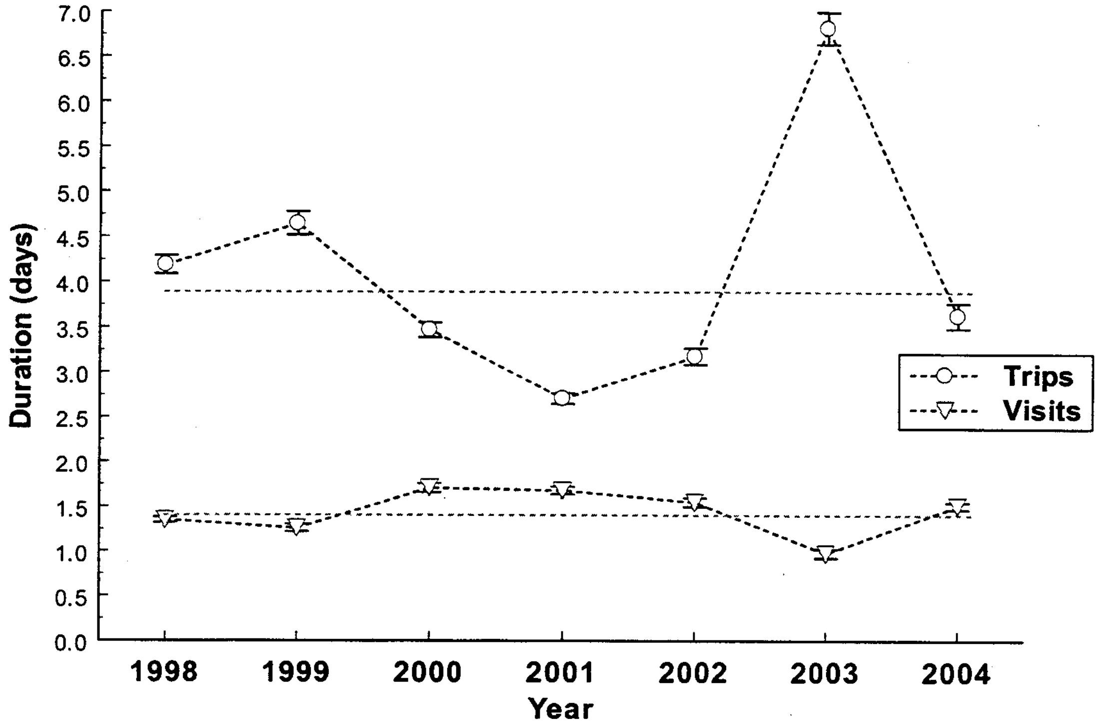


Figure 6.1. Antarctic fur seal mean trip and visit durations (with standard error) for females rearing pups at Cape Shirreff, Livingston Island. Data plotted are for the first six trips to sea and the first six non-perinatal visits following parturition for six years (See Table 6.1 for sample sizes). Long-term means are plotted as dashed gray lines (long-term means: Trips: 3.96 (±0.05); Visits: 1.48 (±0.02)).

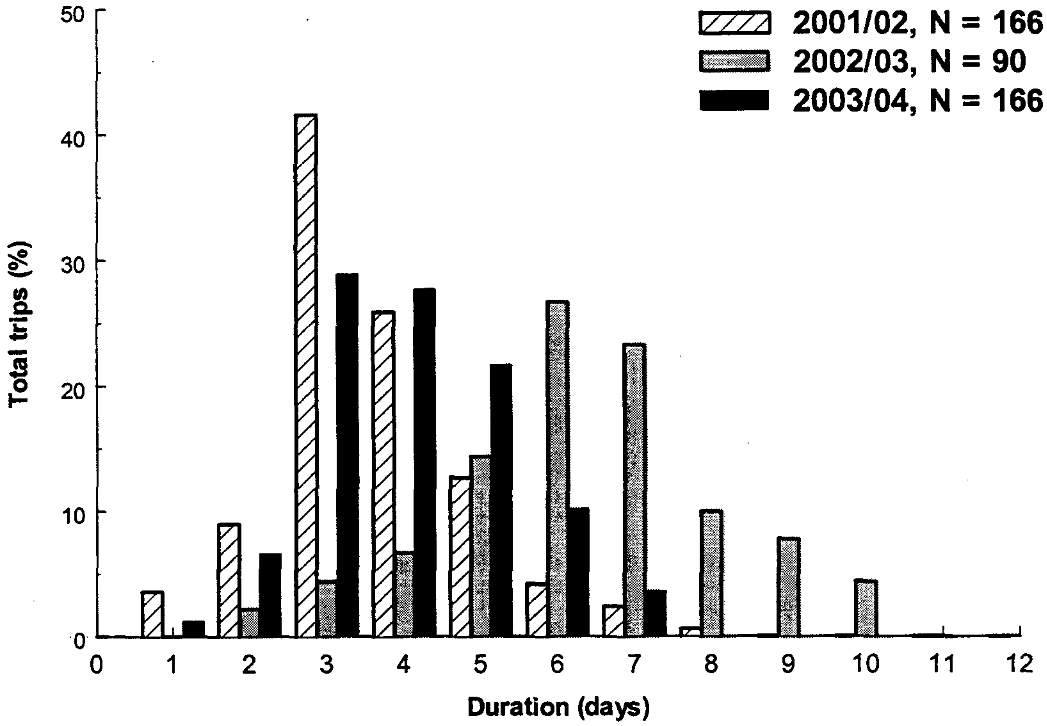


Figure 6.2. The distribution of Antarctic fur seal trip durations at Cape Shirreff, Livingston Island for the last three years (2001/02-2003/04).

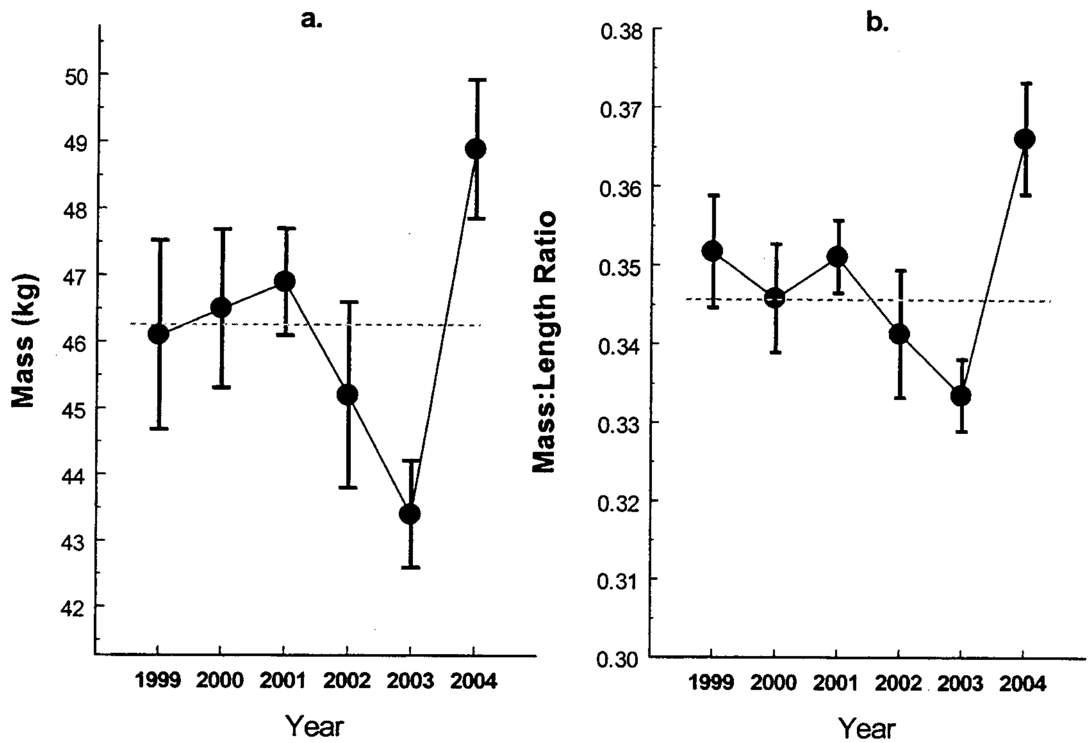


Figure 6.3. The mean mass (a.) and mass:length ratio (b.) for females at parturition 1998/99 – 2003/04 (**98/99**: N=32, **99/00**: N=23, **00/01**: N=29, **01/02-03/04**: N=28 for each year). Long-term average is plotted as a gray dashed line, mass: 45.9 ±0.45; mass:length ratio: 0.346 ±0.03.

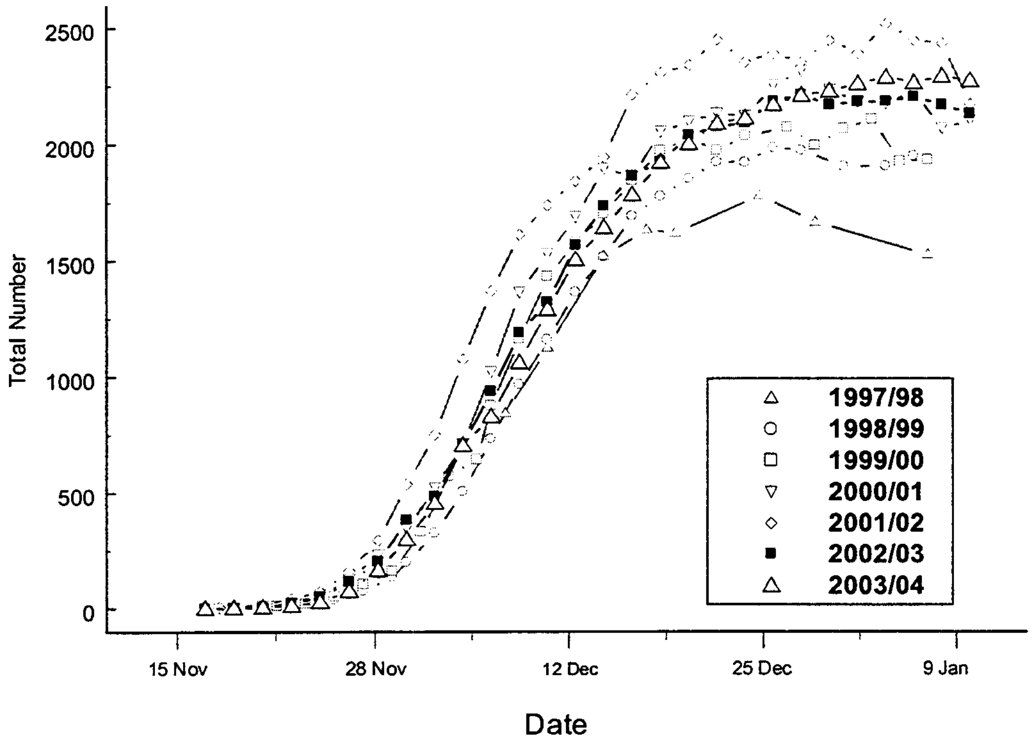


Figure 6.4. Antarctic fur seal pup production at U.S.-AMLR study beaches, Cape Shirreff, Livingston Island, 1997/98-2003/04.

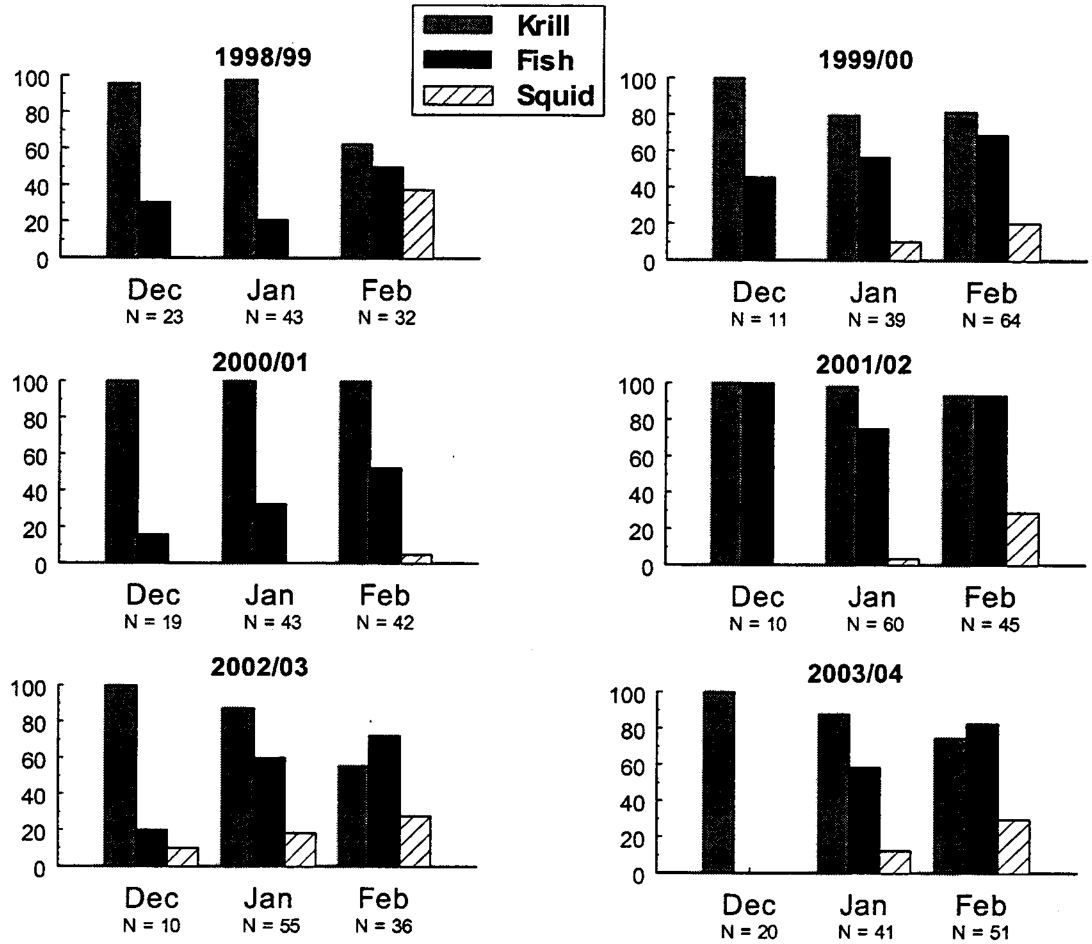


Figure 6.5. The percent occurrence of primary prey types (krill, fish, and squid) from December through February for Antarctic fur seal scats collected from female suckling areas and enemas from females carrying time-depth recorders at Cape Shirreff, Livingston Island for 1998/99 through 2003/04.

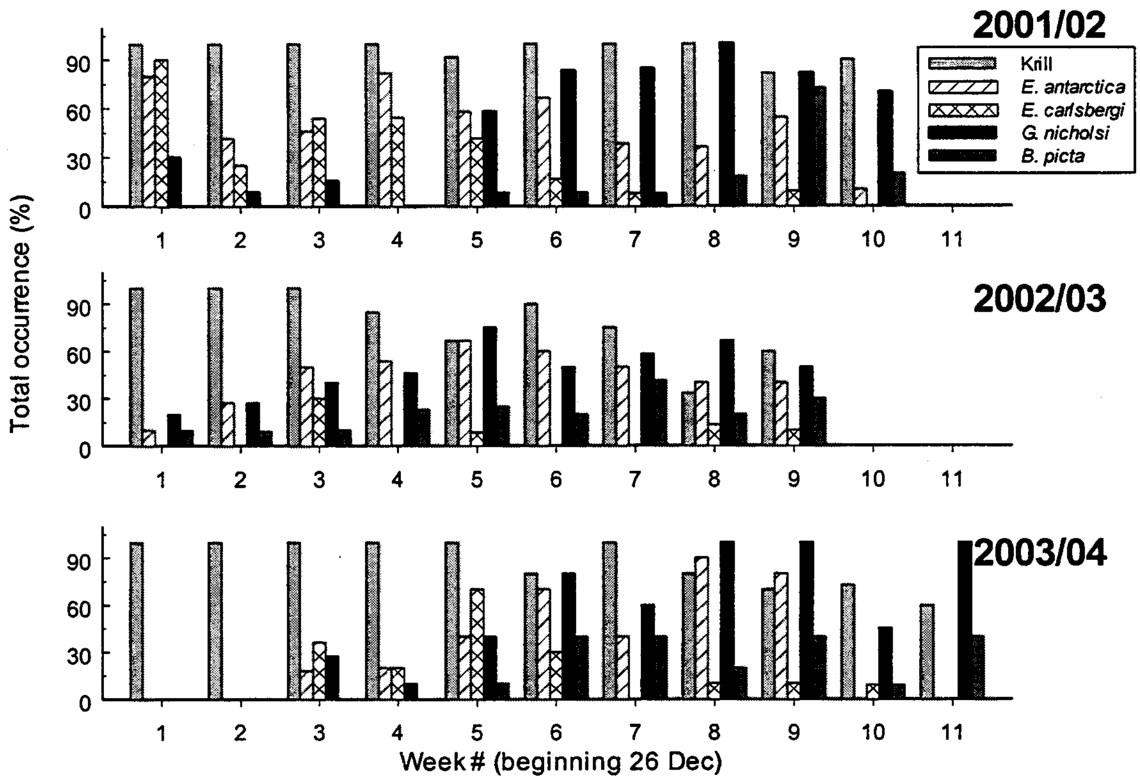


Figure 6.6. The weekly percent occurrence of five primary prey species found in fur seal diets at Cape Shirreff, Livingston Island from 2001/02-2003/04. The five species are krill (*Euphausia superba*), *Electrona antarctica*, *Electrona carlsbergi*, *Gymnoscopelus nicholsi*, and *Brachioteuthis picta*. The first three non-krill species are myctophid fish (lantern fish) and the fourth species is a cephalopod (squid).

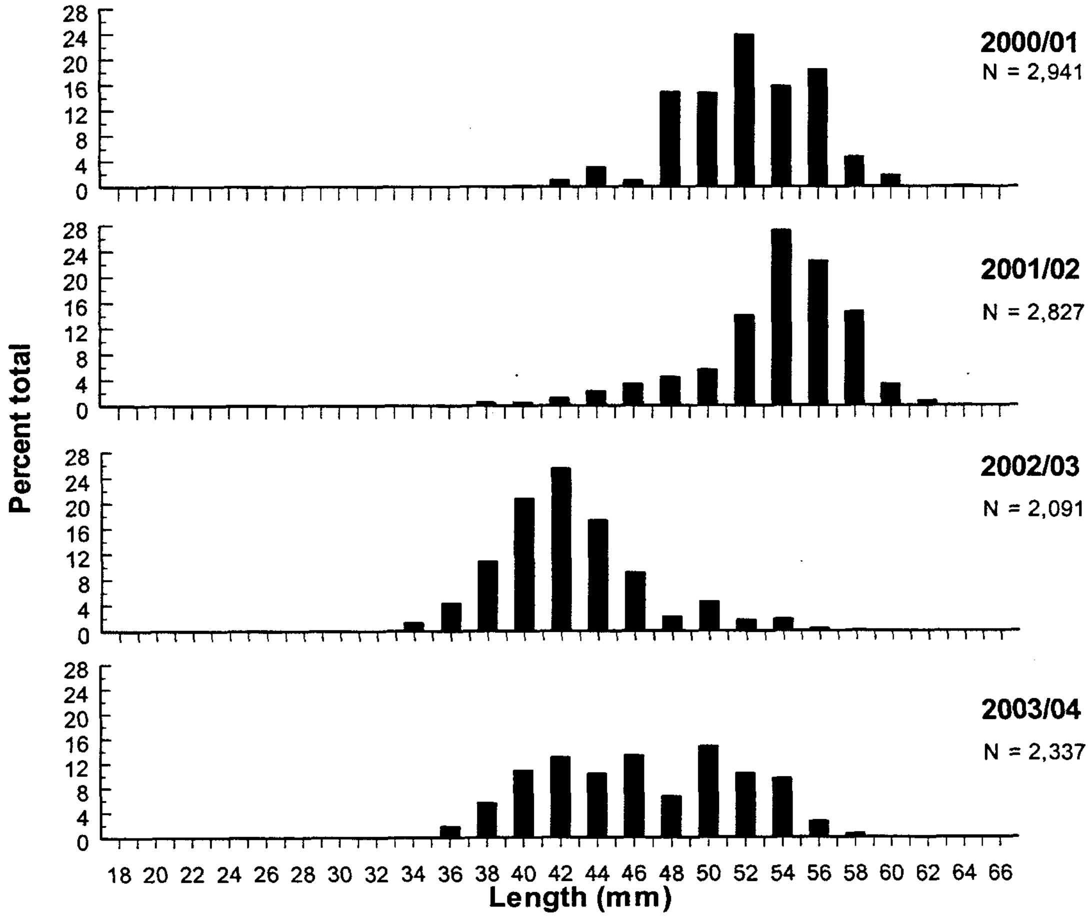


Figure 6.7. The size distribution of krill in Antarctic fur seal diet at Cape Shirreff, Livingston Island from 2000/01 through 2003/04.

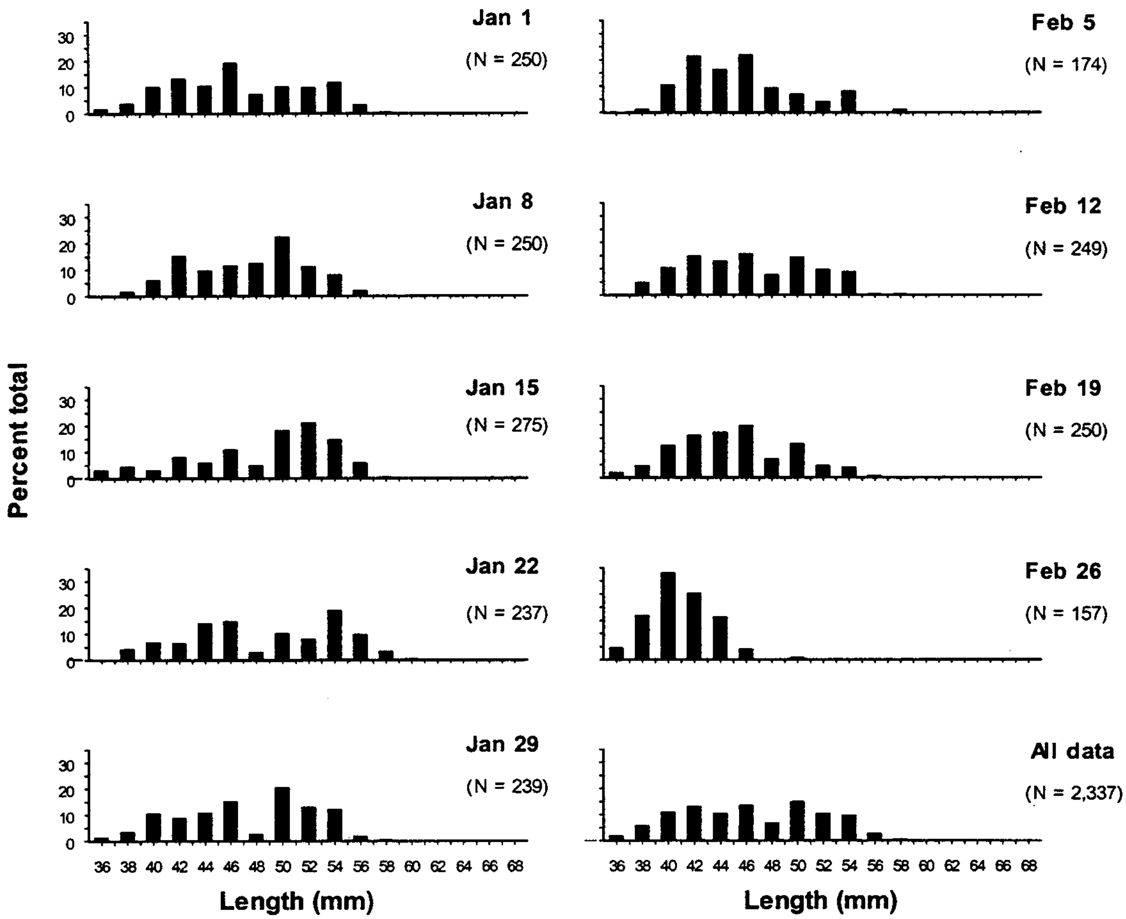


Figure 6.8. Weekly size distribution of krill (*Euphausia superba*) in Antarctic fur seal diet at Cape Shirreff, Livingston Island in 2003/04. Each plot represents one week of krill carapace measurements. The date on each plot is the last day of the week (e.g. Jan 1: the week 26 Dec 2001-1 Jan 2002). The number of krill carapaces measured for each week is given in parentheses.

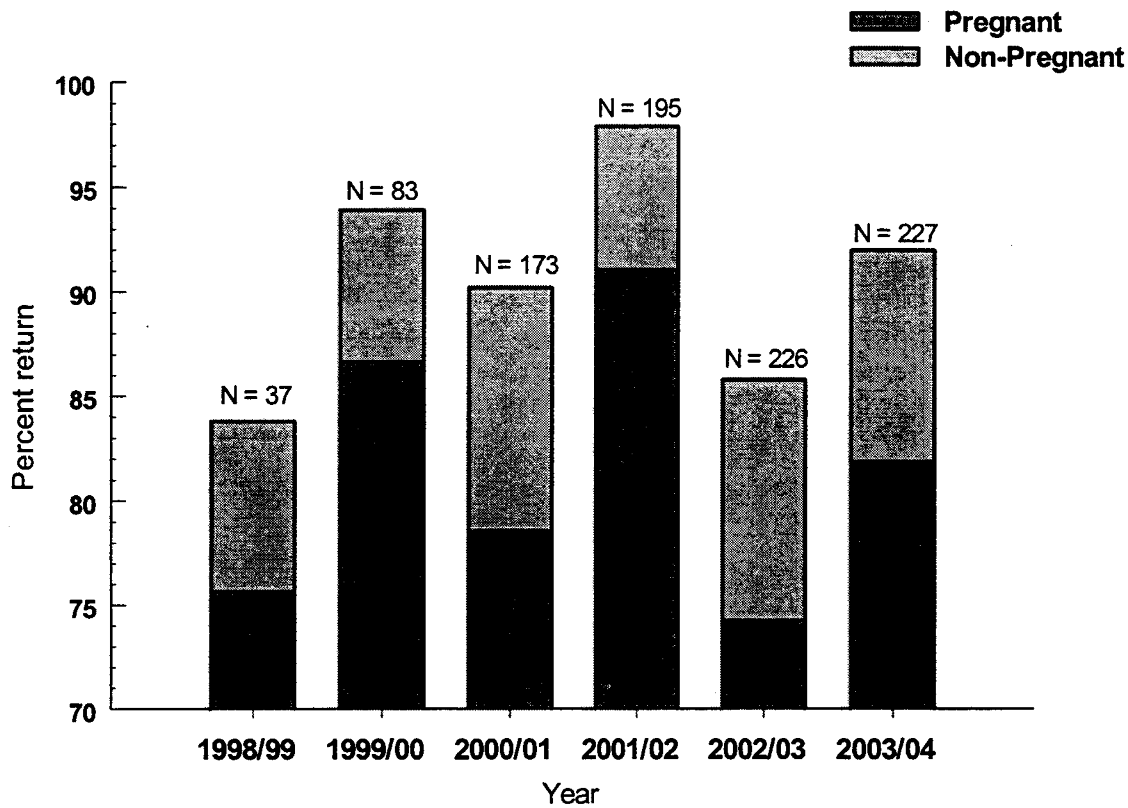


Figure 6.9. Adult female Antarctic fur seal tag returns for six years (1998/99-2003/04) of study at Cape Shirreff, Livingston Island.

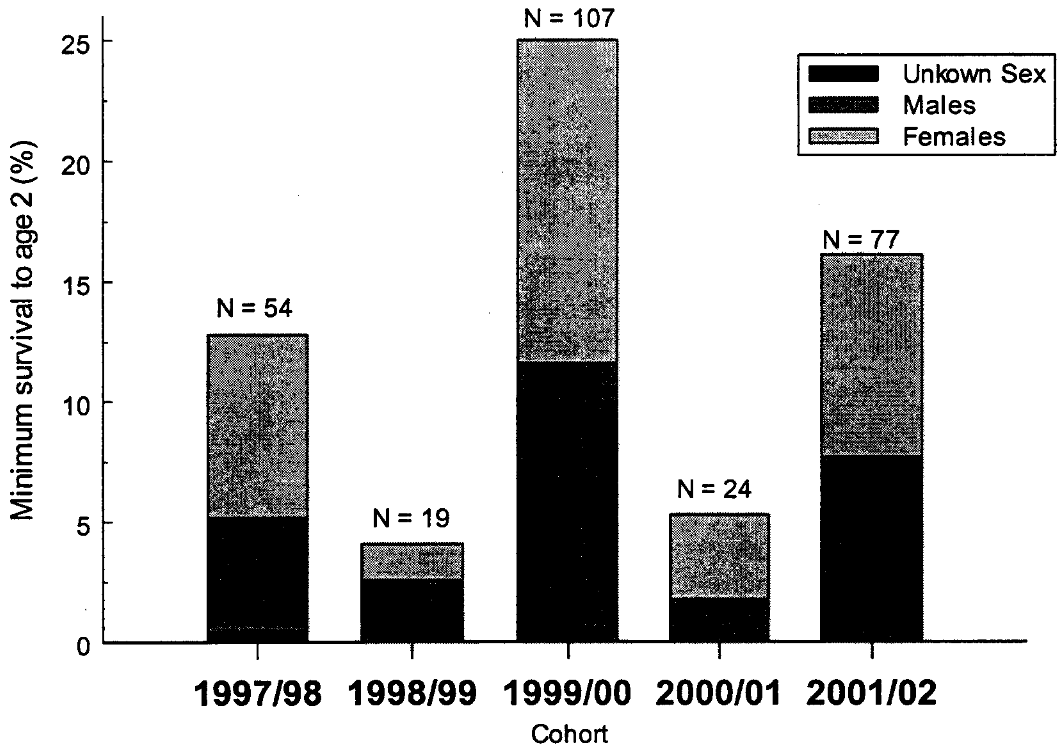


Figure 6.10. Minimum survival to age-1 based on tag returns for the first two years for four cohorts (97/98-01/02) of fur seals tagged as pups at Cape Shirreff, Livingston Island. Not all pups that survive their first year return as yearlings or two year olds, thus our estimates represent a minimum survival. There were no differences in tag re-sight effort among years.

7. Seabird Research at Cape Shirreff, Livingston Island, Antarctica, 2003-2004; submitted by Michelle Antolos, Aileen K. Miller and Wayne Z. Trivelpiece.

7.1 Objectives: The U.S. Antarctic Marine Living Resources (AMLR) program conducted its seventh field season of land-based predator research at the Cape Shirreff field camp on Livingston Island, Antarctica (62° 28'S, 60° 46'W), during the austral summer of 2003-2004. Cape Shirreff is a Site of Special Scientific Interest and long-term monitoring of predator populations are conducted there in support of U.S. participation in CCAMLR (Convention for the Conservation of Antarctic Marine Living Resources). Four scientists arrived at Cape Shirreff on 11 November 2003 via the National Science Foundation research vessel R/V *Laurence M. Gould*. Research continued until camp closure on 7 March 2004. The AMLR chartered vessel R/V *Yuzhmorgeologiya* provided logistical support and transit back to Punta Arenas, Chile, at the field season's conclusion. The objectives of the seabird research for the 2003/04 season were to collect the following long-term monitoring data:

1. To estimate chinstrap *(Pygoscelis antarctica)* and gentoo penguin *(P. papua)* breeding population size (Standard Method A3);
2. To band 500 chinstrap and 200 gentoo penguin chicks for future demography studies (Std. Method A4);
3. To determine chinstrap penguin foraging trip durations during the chick rearing stage of the reproductive cycle (Std. Method A5);
4. To determine chinstrap and gentoo penguin breeding success (Std. Methods 6a,b&c);
5. To determine chinstrap and gentoo penguin chick weights at fledging (Std. Method 7c);
6. To determine chinstrap and gentoo penguin diet composition, meal size, and krill length-frequency distributions (Std. Methods 8a,b&c); and
7. To determine chinstrap and gentoo penguin breeding chronologies (Std. Method 9).

7.2 Results and Conclusions:

7.2.1 Breeding Biology Studies: The Cape Shirreff penguin rookery consisted of 25 breeding sub-colonies of chinstrap and gentoo penguins during the 200/-04 breeding season. Chinstrap penguin nests were censused on 29 and 30 November 2003, and gentoo penguin nests on 4 December 2003, approximately one week after the peak of clutch initiation in each species. All colonies were counted in their entirety. Total breeding numbers during the 2003/04 breeding season were determined to be 5,636 chinstrap penguin pairs and 751 gentoo penguin pairs. The number of chinstrap breeding pairs declined 3% from the 2002/03 breeding season, marking the fifth consecutive year of decline. The chinstrap penguin breeding population is at its lowest size in seven years of study at Cape Shirreff (Figure 7.1). Although the number of gentoo breeding pairs increased 4% from the 2002/03 breeding season, the gentoo breeding population is at its second lowest size in our seven years of study on the Cape (Figure 7.2).

We conducted the annual penguin chick census for chinstrap penguins on 2 and 3 February 2004, and the chick census for gentoo penguins on 4 February 2004. We counted a total of 5,619 chinstrap penguin chicks and 916 gentoo penguin chicks. The total number of chicks was roughly 30% greater in both species compared to the 2002/03 breeding season (Figures 7.1 and 7.2). Based on census data, chinstraps fledged 1.00 chicks per nest, and gentoo penguins fledged

1.22 chicks per nest. This represents an increase in fledging success of 31% for chinstrap and 27% for gentoo penguins compared to the 2002/03 breeding season. Compared to the seven-year mean between 1997-98 and 2003-04, chinstrap penguin fledging success was 9% lower in 2003/04; gentoo penguin fledging success was 3% greater. We also measured penguin reproductive success by following a sample of 100 breeding pairs of chinstrap penguins and 49 pairs of gentoo penguins from clutch initiation through crèche formation (Std. Methods 6a, b & c). Chinstrap penguins fledged 0.87 chicks per nest; gentoo penguins fledged 1.20 chicks per nest during 2003/04. According to this method, chinstrap penguin fledging success was 10% lower in 2003-04; gentoo penguin fledging success in 2003/04 was the same as the seven-year mean.

We banded a sample of 500 chinstrap and 200 gentoo penguin chicks for future demographic studies. Banded chicks that survive and return to the colony as adults will be observed for age-specific survival and reproductive success in future years.

We collected chinstrap chick fledging weights between 21 and 27 February 2004, during the peak fledging period. We captured and weighed 253 chinstrap fledglings on the beaches surrounding the penguin rookery, as fledglings departed to sea (Standard Method 7c). Mean chinstrap fledging weight during the 2003/04 season was 3,128g (S.E. = 22.1), 3.9% greater than last year's mean, and 1.5% lower than the eight-year mean (data collection for this measure began during the 1996/97 austral summer). We also collected a sample of gentoo penguin chick weights. Because gentoo chicks retain parental care after they begin making trips to sea, it is not possible to get a definitive fledging weight by the same method used for chinstrap fledglings. Instead, a sample of chicks are captured and weighed at 85 days after average gentoo clutch initiation date. This approximates the age at which other *Pygoscelis* penguin chicks fledge. We collected 202 gentoo chick weights on 18 February; mean gentoo chick weight was 4,208g (S.E. = 39.9), 6% greater than last year's mean. Average gentoo chick weight during the 2003/04 season was 1.4% lower than the eight-year mean.

7.2.2 Foraging Ecology Studies: We conducted diet studies of chinstrap and gentoo penguins rearing chicks between 9 January and 8 February 2004. The majority of the sampling coincided with the AMLR oceanographic survey. Forty chinstrap and 20 gentoo breeding adults were captured at their nest sites upon returning from foraging trips, and total stomach contents were collected using the wet-offloading technique. Antarctic krill (*Euphausia superba*) was present in all samples, and comprised the majority of the diet in 97% of samples. Fish comprised the next largest component of the diet; < 1% of the diet was comprised of squid and other marine invertebrates.

The chinstrap penguin diet samples consisted of 2% fish by mass during the 2003/04 breeding season, similar to the past seven years of study where the chinstrap penguin diet has consisted of a mean 0.5% fish. However, the gentoo penguin diet consisted of only 4% fish by mass during the 2003/04 breeding season; significantly below the seven-year average of 27% fish. During the 2003/04 breeding season, 60% of the diet samples in both species contained some evidence of fish. This compares to a mean frequency of occurrence of fish over the past seven years of 28% for chinstraps and 78% for gentoos. Average total chick meal mass was 659g for chinstraps and 624g for gentoos. Compared to the seven-year mean, chinstrap chick meals were 6% larger during the 2003/04 breeding season; gentoo chick meals were 9% larger.

A sub-sample of 50 individual Antarctic krill from each diet sample were measured and sexed in order to determine krill sex ratios and length distribution in penguin diets. Krill found in penguin diets during the 2003/04 breeding season consisted of 45% males, 46% females, and 9% juveniles. The proportion of juvenile krill in the diet decreased from 28% during the 2002/03 breeding season (Figure 7.3). The majority of the krill in chinstrap diets were in the 36-45mm range; the majority of krill in gentoo diets were in the 41-55mm range (Figure 7.4). This is the first season where the two penguin species have selected different sized krill during the chick-rearing period. We are currently plotting the foraging locations of the two species, derived from satellite tags, to examine the foraging locations used by chinstrap and gentoo penguins during this period.

We attached 19 radio transmitters to adult chinstrap penguins during the chick-provisioning period on 7 and 8 January 2004 and logged their signals until 1 March using a remote receiver and Data Collection Computer at our observation blind. Detections of penguins onshore were used to calculate foraging trip durations. The majority of foraging trips (53%) were between 10 and 18 hours long, and average trip duration was 18.6 hours (S.E. = 1.25 h). This compares to mean trip durations in 2002-03 of 12.8 hours.

Time-depth recorders (TDRs) were epoxied to Chinstrap and gentoo penguins in two deployments in early and mid-January to collect penguin diving behavior data during the chick-rearing period. The second deployment coincided with the AMLR oceanographic survey. During each deployment, four TDRs were placed on chinstrap penguins and four on gentoo penguins; all TDRs remained on for 7-10 days before being removed and downloaded. Dive data are awaiting analysis.

PTTs (satellite-linked transmitters) were also deployed on chinstrap and gentoo penguins during the chick-rearing phase in order to provide geographic data on penguin foraging locations during this period. Five PTTs were deployed on both chinstrap and gentoo penguins in early January, then redeployed on a second set of penguins in mid-January to coincide with the AMLR oceanographic survey. A third deployment of PTTs were placed on two chinstrap penguins and five gentoo penguins in early February, in order to coincide with the AMLR Nearshore hydroacoustic survey.

We monitored reproductive success of all breeding brown skuas (*Catharacta lonnbergi*) on Cape Shirreff, as well as at an additional breeding site on Punta Oeste. A total of 20 brown skua pairs initiated nests during the 2003/04 season; 40% of these breeding attempts failed during the incubation stage. Overall fledging success was 0.65 fledglings/pair, a 24% increase in fledging success from the 2002/03 breeding season, but 19% below the seven-year mean. Reproductive performance of kelp gulls (*Larus dominicanus*) was followed opportunistically throughout the season. Overall fledging success was 0.83 fledglings/pair, a 33% increase from the 2002/03 breeding season, and 15% below the four-year mean.

The seventh consecutive season of data collection at Cape Shirreff has enabled us to examine trends in penguin populations, as well as inter-annual variation in reproductive parameters, penguin diet, and foraging behavior. The chinstrap breeding population at Cape Shirreff has continued to decline over the past five years, and is at its lowest size in the past seven years of study. While the gentoo breeding population increased slightly from last year, it is at its second lowest size in the past seven years. Chinstrap fledging success was higher during the 2003/04 breeding season than in the previous season, but lower than the average for the past seven years. Gentoo fledging success in 2003/04 was greater than in 2002/03, and was either similar to or greater than the seven-year mean, depending on methodology used. Fledging weights of both species increased from last year, but were below the eight-year mean for this parameter. Chinstrap penguin diet contained more fish than in other years on average, while gentoo diets contained less fish. Total chick meal mass was larger in both species compared to the past seven years of study. Foraging trip durations were on average longer than during the 2002/03 breeding season, the interpretation of which may be aided by analysis of foraging location and diving behavior data.

7.3 Acknowledgements: We would like to sincerely thank the efforts of Mike Goebel, Scott Freeman, Douglas Krause, and Rennie Holt for their invaluable assistance and guidance in the field. We would also like to thank the Chilean research team; Romeo Vargas, Victoria Valdenegro, Claudio Vero, Daniel Torres, Daniel Torres Jr., and the Chilean logistics team; Cesar Cifuentes and Denis Hinojosa Prado, for their assistance in the field, as well as their personal camaraderie. We are grateful to the crew of the NSF research vessel *Laurence M. Gould* for our smooth transit to Cape Shirreff and for their help with camp opening, and to the crew of the AMLR chartered research vessel *Yuzhmorgeologiya* for their efforts in resupplying our camp and for providing transit back to Punta Arenas, Chile.

Figure 7.1. Chinstrap penguin population size based on census data at Cape Shirreff, Livingston Island, Antarctica, 1996-2004.

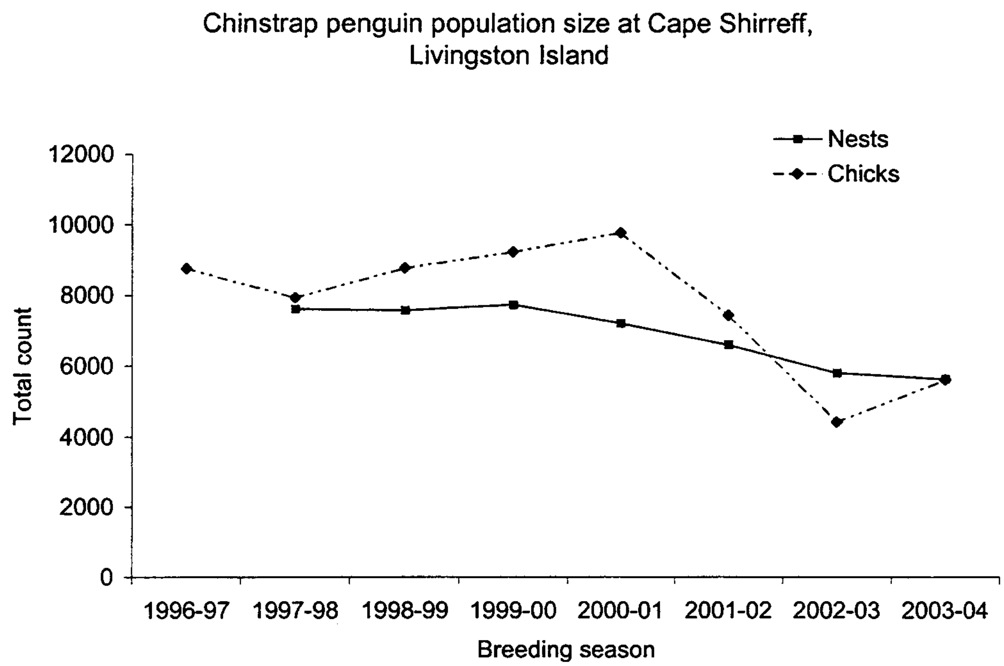


Figure 7.2. Gentoo penguin population size based on census data at Cape Shirreff, Livingston Island, Antarctica, 1996-2004.

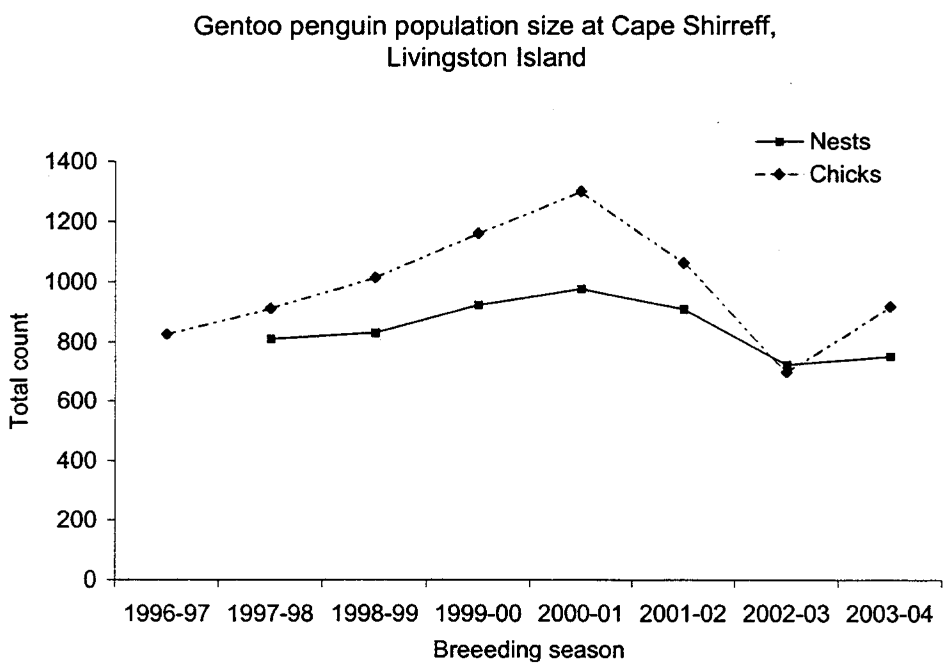


Figure 7.3. Percent composition of Antarctic krill (*E.superba*) in penguin diets at Cape Shirreff, Livingston Island, Antarctica, 1997-2004.

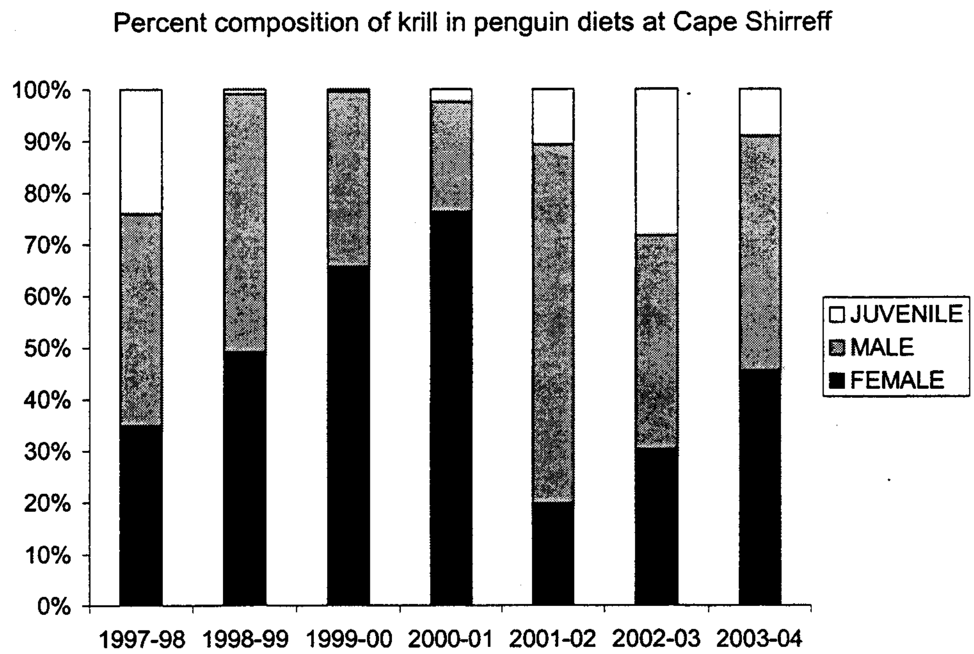
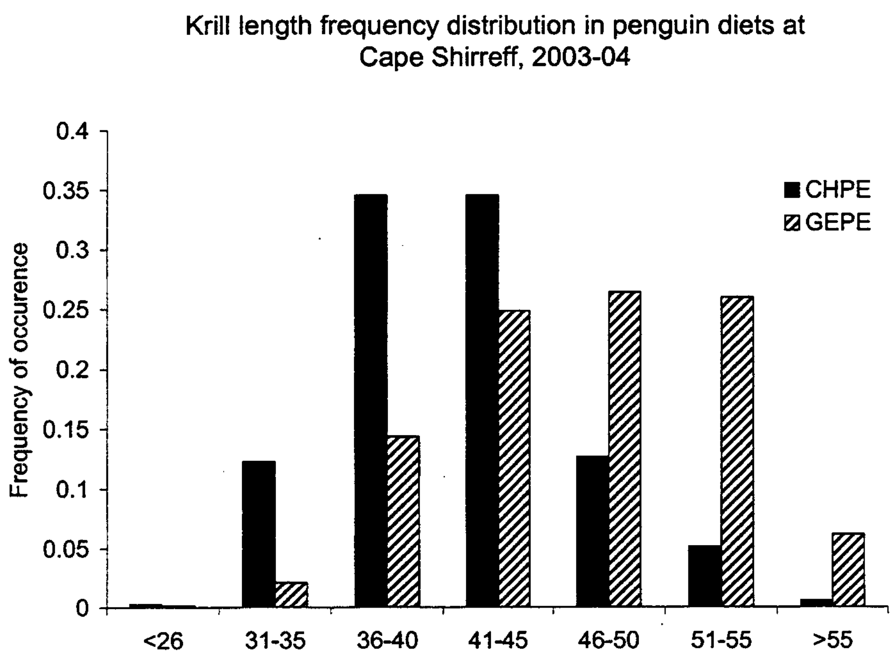


Figure 7.4. Krill length-frequency distribution in penguin diet samples at Cape Shirreff, Livingston Island, Antarctica, 2003-04.



8. Distribution, Abundance, and Behavior of Seabirds and Mammals at sea, during the 2003/04 AMLR Survey; submitted by Jarrod A. Santora (Leg I).

8.1 Objectives: Understanding how seabirds and their prey form aggregations at sea is crucial to the design and implementation of conservation policy. Multi-scale investigations of predator abundance at sea near the South Shetland Islands and Antarctic Peninsula are lacking and are usually not concurrent with continuous year to year surveys. This investigation focuses on the at sea abundance and behavior of pelagic predators in collaboration with other marine operations. The primary objectives were to map the behavior and abundance of seabirds and mammals at sea during Leg I, and use the resulting data set to investigate:

a) Foraging behavior of Antarctic seabirds and the scale (100m to 1000's of km) at which feeding predators and krill aggregations occur.
b) Patterns of predator behavior and abundance in response to depth stratified krill abundance.
c) Community structure and habitat selection by predator groups.
d) Seasonal change in dispersion of foraging seabirds at sea.

8.2 Methods:

8.2.1 Seabird and Mammal Observations: Data on predator abundance and behavior were collected using binoculars while underway between stations during daylight hours. Surveys followed strip transect methods (Tasker *et al.*, 1984) and counts were made within an arc of 300m directly ahead and to one side of the ship. In this report, transects are referred to as the duration of travel time and space coverage while the vessel was underway between stations. Data were entered into a computer program designed for mapping observations in space and in real time. Each record was immediately assigned a time and a position directly fed by the ships navigational computer. The computer clock was synchronized with the ships data acquisition computer and the hydro-acoustic system used to collect krill biomass estimates. Individual birds, or flocks of birds, were assigned a behavioral code. The behaviors were: flying, sitting on water, milling (circling), feeding, porpoising (penguins, seals, and dolphins), and ship-following. Ship-followers were entered when encountered and were ignored thereafter. Predators which were flying or porpoising were assigned a direction. Data recorded for mammals included traveling direction, distance from ship and behavior.

8.3 Accomplishments: In total, 74 transects were collected during the Leg I and the amount of area surveyed in each stratum is contained in Table 8.1. In total, 27 seabird species and 10 species of marine mammals were encountered during the AMLR 2003/04 survey, and they are presented in Tables 8.2 and 8.3 as estimates of densities calculated by the dividing the total abundance, by the total kilometers surveyed in each stratum (i.e. Elephant Island). Overall, 203 one hour blocks (≈10 km), of seabird observations were collected. Mean seabird abundance per block was 58.3 birds/hour with a standard deviation of 65 birds/hour, and the maximum observation recorded 592 birds/hour (Figure 8.1). In Figure 8.2, total seabird abundance is mapped for transits between stations, and seabird abundance is depicted as gradated circles representing number observed per hour, or approximately 10km. Figure 8.2 illustrates where major aggregations of seabirds were encountered during daylight survey hours, and does not accurately depict total seabird dispersion because of missed transits during dark hours. Figure

8.3 illustrates (A) Humpback Whale (*Megaptera novaeangliae*), and (B) Antarctic Fur Seal (*Arctocephalus gazella*) dispersion in the study area, represented by the abundance of animals encountered during a one hour period while underway between stations during daylight hours.

8.4 Results and Tentative Conclusions:

8.4.1 Elephant Island Area: The total amount of space surveyed between stations was 1275.2km. The greatest penguin abundance observation was on the east side of Elephant Island over the shelf region (500m). Chinstrap penguins (*Pygocelis antarctica*) were the most common seabird followed by Cape petrel (*Daption capense*), Black-bellied storm petrel (*Fregetta tropica*), Antarctic Prion (*Pachyptila desolata*), Southern Fulmar (*Fulmarus glacialoides*), and Black-browed Albatross (*Thalassarche melanophrys*), (Table 8.1). Cape Petrels were the most conspicuous aerial predator in the Elephant Island Area and were observed in dense feeding aggregations. Groups of Cape Petrels were monitored for behavior changes and association with diving predators (i.e. penguins and fur seals). Small groups of Macaroni penguins (group size: 8-10), were observed near the Seal Islets and between Elephant and Clarence Islands. Black-bellied storm petrels and Southern Fulmars, (hundreds observed sitting on water) were most abundant near Aspland and Gibbs Islands. Interestingly, Antarctic Prions were more abundant in the Elephant Island area during the AMLR 2003/04 than in the AMLR 2002/03 survey(460 birds in 2003/04, and 21 birds in 2002/03), (Santora and Mitra, 2003). A total of 16 Soft-plumaged Petrels (*Pterodroma mollis*) were recorded in the northwest section of the Elephant Island Area. This species was not detected within the survey area in Leg I of AMLR 2002/03. Other unusual species include Slender-billed Prions (*Pachyptila belcheri*), Common Diving Petrel (*Pelacanoides urinatrix*) and Arctic Tern (*Sterna paradisaea*). Wandering (*Diomedea exulans*), and Royal Albatrosses (*D. epomorpha*) were regular ship followers, and on many occasions individual birds have been observed following for over 12 hours. Two Royal albatrosses were observed while on station near Clarence Island (per comms. M. Force). White-chinned petrels (*Procellaria aequinoctialis*) were more common in the Elephant Island Area during 2003/04 season (n= 185) than in 2002/03 (n=20). This species was encountered sitting on the water in large (20-40 birds) aggregations. Fur seals were observed in small groups (2-5), primarily in the offshore waters on the Elephant Island transects (Figure 8.3B). During transit between stations 04-05 and 04-06, two Killer Whales (*Orcinus orca*) were observed in the vicinity of Clarence and Cornwallis Islands.

8.4.2 Seal Island Observations: An opportunistic seabird survey was conducted around the Seal Islets. A photograph of a Macaroni Penguin colony was taken at North Anex, Seal Island. A review of the picture yielded an estimate of approximately 57 adults and 37 chicks. A total of 77 Pale-faced Sheathbills were also observed. Other birds observed nesting in dense numbers on the Seal Islets included: Chinstrap Penguin (*Pygocelis antarctica*), Cape Petrel (*Daption capense*), Southern Giant Petrel (*Macronectes giganteus*), and Kelp Gull (*Larus dominicanus*). Leopard Seals (*Hydrurga leptonyx*) were observed in the waters near Seal Island. A Leopard Seal was observed pursuing and capturing Chinstrap penguins, and digital video footage was collected. Once a penguin was captured, the seal consumed the head and upper chest portion, and discarded the rest. Interestingly, after the seal was finished, other seabirds opportunistically foraged on the carcass. Southern Giant Petrels, Cape Petrels, and Wilson Storm Petrels (*Oceanites oceanicus*) were immediately on the scene, and small multi-species feeding aggregations were observed. The most interesting species group behavior observed was that of the Southern Giant Petrel. Digital video of the Giant Petrel feeding behavior was recorded (R. Hewitt), and closer examination of the intra-specific behavior is pending.

8.4.3 Joinville Island Area: The amount of area survey in this stratum was far less than the other strata (76km). However, the largest Southern Fulmar abundance (811 birds) for the entire survey was recorded there in a series of observed aggregations of birds sitting on the water.

8.4.4 South Area: The amount of area surveyed was 326km. Chinstrap Penguins, Southern Fulmars, Wilson's Storm Petrels (*Oceanites oceanicus*), and Gentoo Penguins (*Pygocelis papau*) were numerically dominant members of the South area survey. Cape Petrels were relatively absent from this strata and were more abundant north of the South Shetlands. Interestingly, the abundance of Black-bellied Storm Petrels (n=39) was far less then the observed amount in the Elephant Island area (n=358), whereas Wilson's Storm Petrel was greater in the South Area than at Elephant Island. These two species are quite similar and the apparent difference in dispersion in the study area may reflect habitat and prey preference. Humpback whales were more abundant in the South then in any other strata (Table 8.1, Figure 8.3).

8.4.5 West Area: The amount of area surveyed was 1044.5km. Cape Petrels, Chinstrap Penguins, Black-browed Albatrosses, Antarctic Prions, Blue Petrels (*Halobaena caerulea*), and Black-bellied Storm Petrels were the most numerically dominant community members (Table 8.1). The densest seabird aggregations (# of birds/10km) were encountered either in the shelf or slope zone of the West Area (Figure 8.2). The largest densities of Antarctic Fur Seals observed during the West Area were north of Cape Sherriff, Livingston Island, and likely due to the proximity of the breeding colony and localized prey aggregations. Blue Petrels and Antarctic Prions were very common during transits over the South Shetland Trough. These small petrels are usually more abundant in proximity to the convergence zone in the Drake Passage (pers obs), but were more abundant and spatially contagious this year than in either Leg of AMLR 2002/03 (Santora and Mitra, 2003).

8.5 Disposition of Data: After all data have been thoroughly proofed, a copy will be retained and available from Jarrod Santora, College of Staten Island, Biology Department, 2800 Victory Boulevard, Staten Island, NY, 10314; phone: (718) 982-3862; email: jasantora@yahoo.com

8.6 Acknowledgements: Andrew J. Bernick assisted in data collection. Mike Force assisted in data collection while at stations. Jessica Lipsky assisted in data collection of marine mammals during the Nearshore Survey. Richard R. Veit provided financial assistance and use of a laptop computer for data collection. Roger Hewitt and Anthony Cossio provided assistance in sequencing krill series to be aligned with predator abundance. Thank you to the crew of the R/V *Yuzhmorgeologiya* for assistance in the bridge and supplying a GPS feed.

8.7 Reference:

Tasker, M.L., Jones, P.H., Dixon, T., and Blake, B.F. 1984. Counting seabirds at sea from ships: A review of methods employed and a suggestion for a standardized approach. *Auk* 101: 567-577.

Santora, J.A., and Mitra, S.M. 2003. Distribution, abundance, and behavior of seabirds and mammals at sea, in response to variability of Antarctic krill and physical oceanography during the 2003 AMLR marine survey. Lipsky, J. (ed.) NOAA-TM-NMFS-SWFSC-355. pp 204-217.

Table 8.1. Survey effort for seabird and mammal observations during AMLR 2003/04 presented here in kilometers.

Stratum	Survey A
Elephant	1275.2
West	1044.5
South	326
Joinville	76
Nearshore	244.9
TOTAL	2721.7

Table 8.2. Seabird-Mammal densities recorded for Leg I AMLR 2003/04. Densities are presented as # / Km per strata

Common Name	Latin Name	Elephant	West	South	Joinville	Total
Gentoo Penguin	*Pygocelis papua*	0.0086	0	1.1012	0	1.1098
Adelie Penguin	*Pygocelis adelie*	0	0	0.0031	0	0.0031
Chinstrap Penguin	*Pygocelis antarctica*	1.2853	0.5132	2.635	0.6974	5.1309
Macaroni Penguin	*Eudyptes chrysolophus*	0.011	0	0	0	0.011
Wandering Albatross	*Diomedea exulans*	0.0157	0.0191	0	0	0.0348
Royal Albatross	*Diomedea epomorpha*	0.0031	0	0	0	0.0031
Black-browed Albatross	*Thalassarche melanophrys*	0.2807	0.2422	0.092	0.1053	0.7202
Grey-headed Albatross	*Thalassarche chrysostoma*	0.0282	0.0201	0.0092	0.0132	0.0707
Light-mantled Sooty Albatross	*Phoebetria palpebrata*	0.0039	0.001	0	0	0.0049
Southern Giant Petrel	*Macronectes giganteus*	0.058	0.0469	0.1043	0.1842	0.3934
Northern Giant Petrel	*Macronectes halli*	0.0212	0	0.0153	0	0.0365
Southern Fulmar	*Fulmarus glacialoides*	0.3309	0	1.7607	10.6711	12.7627
Antarctic Petrel	*Thalassoica antarctica*	0	0	0.0521	0	0.0521
Cape Petrel	*Daption capense*	1.072	0.8473	0.4325	0.5395	2.8913
Soft-plumaged Petrel	*Pterodroma mollis*	0.0118	0.001	0	0	0.0128
White-chinned Petrel	*Procellaria aequinoctialis*	0.1451	0.0402	0	0	0.1853
Antarctic Prion	*Pachyptila desolata*	0.298	0.1561	0	0	0.4541
Slender-billed Prion	*Pachyptila belcheri*	0.0024	0	0	0	0.0024
Blue Petrel	*Halobaena caerulea*	0.0831	0.203	0	0	0.2861
Wilson's Storm Petrel	*Oceanites oceanicus*	0.1561	0.0948	1.1779	0.3947	1.8235
Black-bellied Storm Petrel	*Fregetta tropica*	0.407	0.1752	0.1196	0.0263	0.7281
Common Diving Petrel	*Pelacanoides urinatrix*	0.0008	0.001	0	0	0.0018
Brown Skua	*Catharacta antarctica*	0.0031	0.001	0	0.0132	0.0173
South Polar Skua	*Catharacta maccormicki*	0.0078	0.0048	0.0429	0	0.0555
Kelp Gull	*Larus dominicanus*	0.0008	0	0	0	0.0008
Arctic Tern	*Sterna paradisaea*	0.0008	0	0	0	0.0008
Antarctic Tern	*Sterna vittata*	0.0118	0.0048	0.0368	0.0132	0.0666
Antarctic Fur Seal	*Arctocephalus gazella*	0.1419	0.0211	0.0184	0.0395	0.2209
Leopard Seal	*Hydrurga leptonyx*	0	0	0.0092	0	0.0092
Southern Bottlenose Whale	*Hyperoodon planifrons*	0.0031	0.0029	0	0	0.006
Southern Right Whale	*Eubalaena australis*	0	0	0.0061	0	0.0061
Antarctic Minke Whale	*Balaenoptera bonaerensis*	0.0345	0.0038	0	0.0132	0.0515
Fin Whale	*Balaenoptera physalus*	0.0173	0.0057	0	0	0.023
Humpback Whale	*Megaptera novaeangliae*	0.0431	0.0306	0.1472	0.0789	0.2998
Sei Whale	*Balaenoptera borealis*	0.0008	0	0	0	0.0139
Killer Whale	*Orcinus orca*	0.0016	0	0.0123	0	0.0008
Un-identified Whale	*Balaenoptera species*	0.0024	0.0048	0.0031	0	0.0103

Table 8.3. Seabird-Mammal densities recorded for Nearshore survey. Densities are presented as # / Km

Common Name	Latin Name	Nearshore Survey
Gentoo Penguin	*Pygocelis papua*	**0.0163**
Chinstrap Penguin	*Pygocelis antarctica*	**3.8751**
Wandering Albatross	*Diomedea exulans*	**0.0245**
Black-browed Albatross	*Thalassarche melanophrys*	**0.3348**
Grey-headed Albatross	*Thalassarche chrysostoma*	**0.0939**
Light-mantled Sooty Albatross	*Phoebetria palpebrata*	**0.0163**
Southern Giant Petrel	*Macronectes giganteus*	**0.1307**
Northern Giant Petrel	*Macronectes halli*	**0.0367**
Unknown Giant Petrel	*Macronectes species*	**0.2001**
Southern Fulmar	*Fulmarus glacialoides*	**0.0204**
Cape Petrel	*Daption capense*	**2.7848**
White-chinned Petrel	*Procellaria aequinoctialis*	**0.1062**
Antarctic Prion	*Pachyptila desolata*	**0.4247**
Blue Petrel	*Halobaena caerulea*	**0.2777**
Wilson's Storm Petrel	*Oceanites oceanicus*	**0.8779**
Black-bellied Storm Petrel	*Fregetta tropica*	**0.5022**
Common Diving Petrel	*Pelacanoides urinatrix*	**0.0041**
South Polar Skua	*Catharacta maccormicki*	**0.0041**
Kelp Gull	*Larus dominicanus*	**0.0163**
Arctic Tern	*Sterna paradisaea*	**0.2123**
Antarctic Tern	*Sterna vittata*	**0.0082**
Antarctic Fur Seal	*Arctocephalus gazella*	**0.3471**
Leopard Seal	*Hydrurga leptonyx*	**0.0041**
Antarctic Minke Whale	*Balaenoptera bonaerensis*	**0.0204**
Fin Whale	*Balaenoptera physalus*	**0.0327**
Humpback Whale	*Megaptera novaeangliae*	**0.0939**
Un-identified Whale	*Balaenoptera species*	**0.0041**

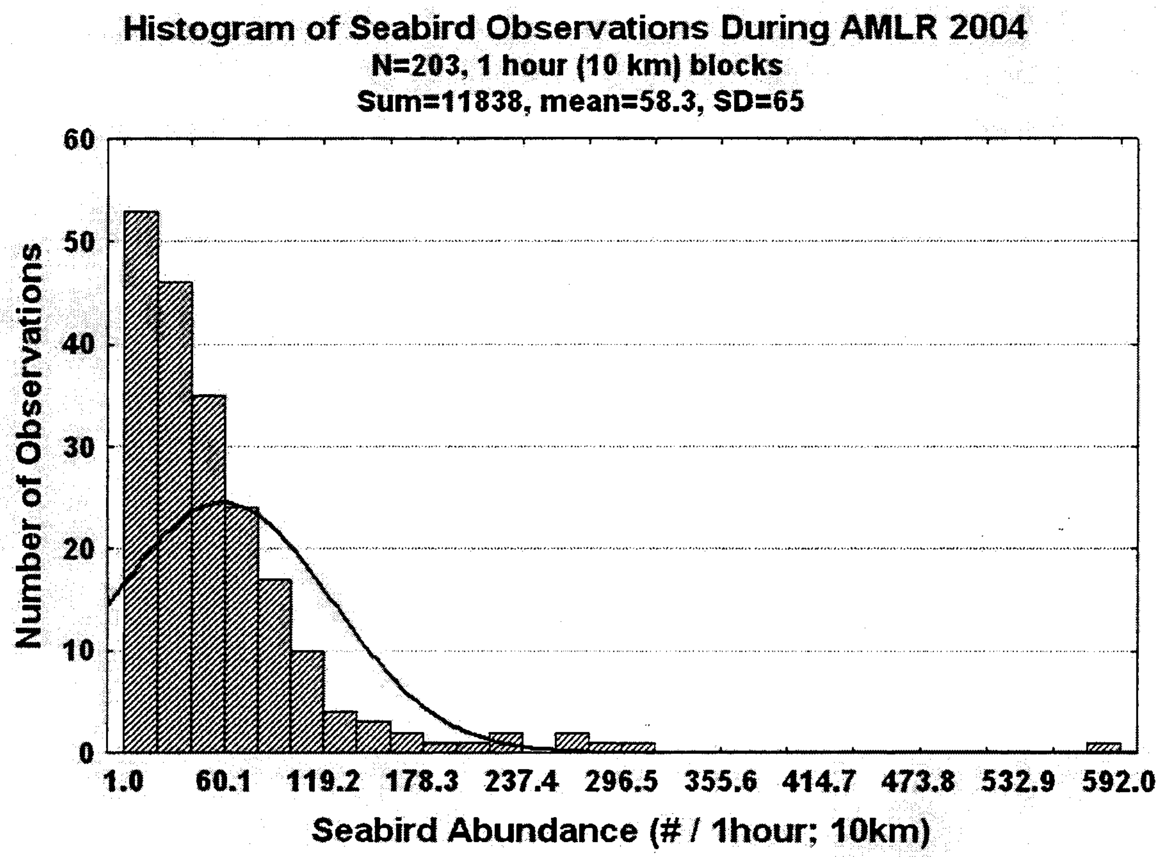


Figure 8.1. Histogram of total seabird abundance recorded during AMLR 2003/04.

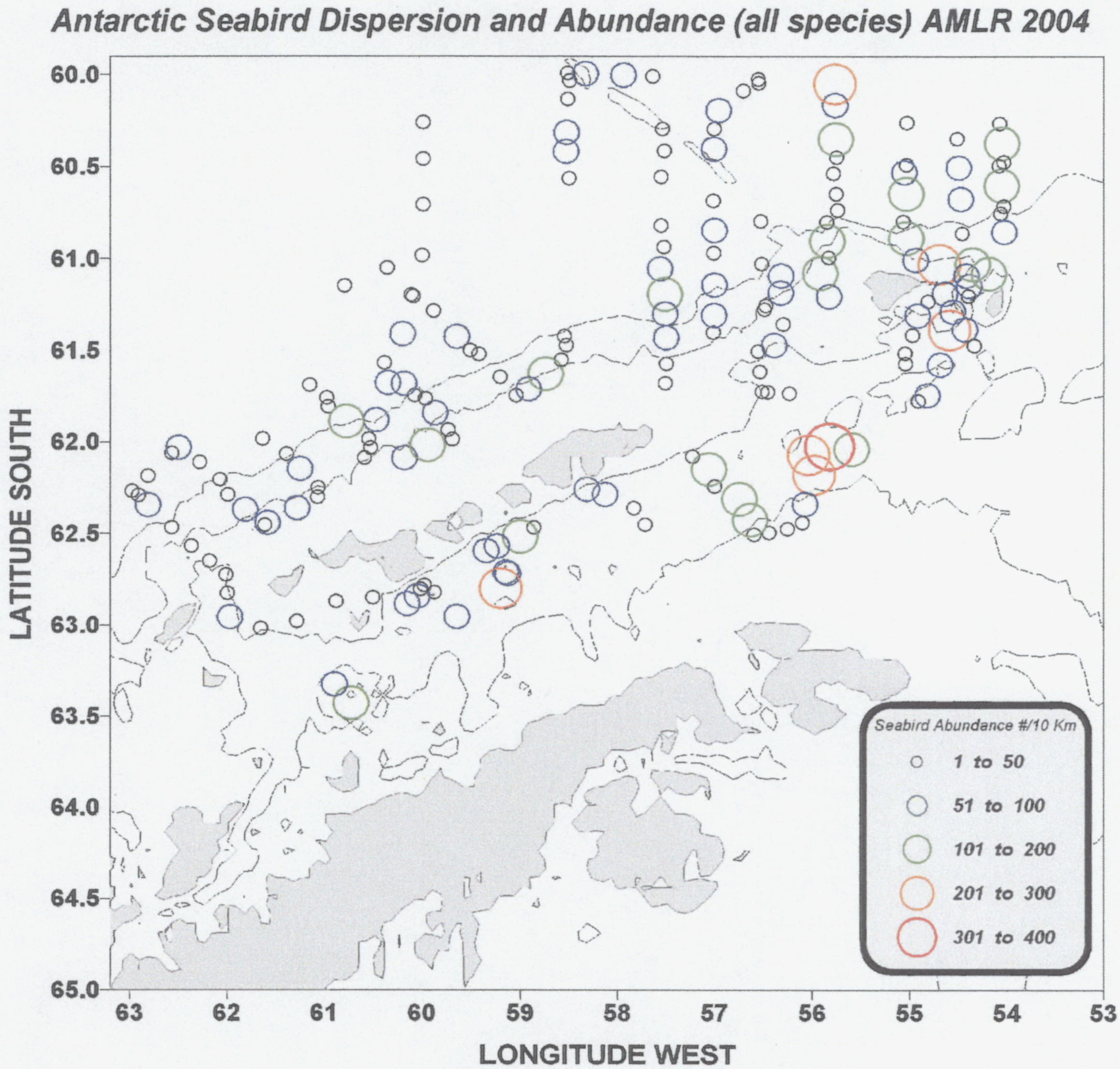


Figure 8.2. Antarctic seabird dispersion and abundance map during Leg I of AMLR 2003/04.

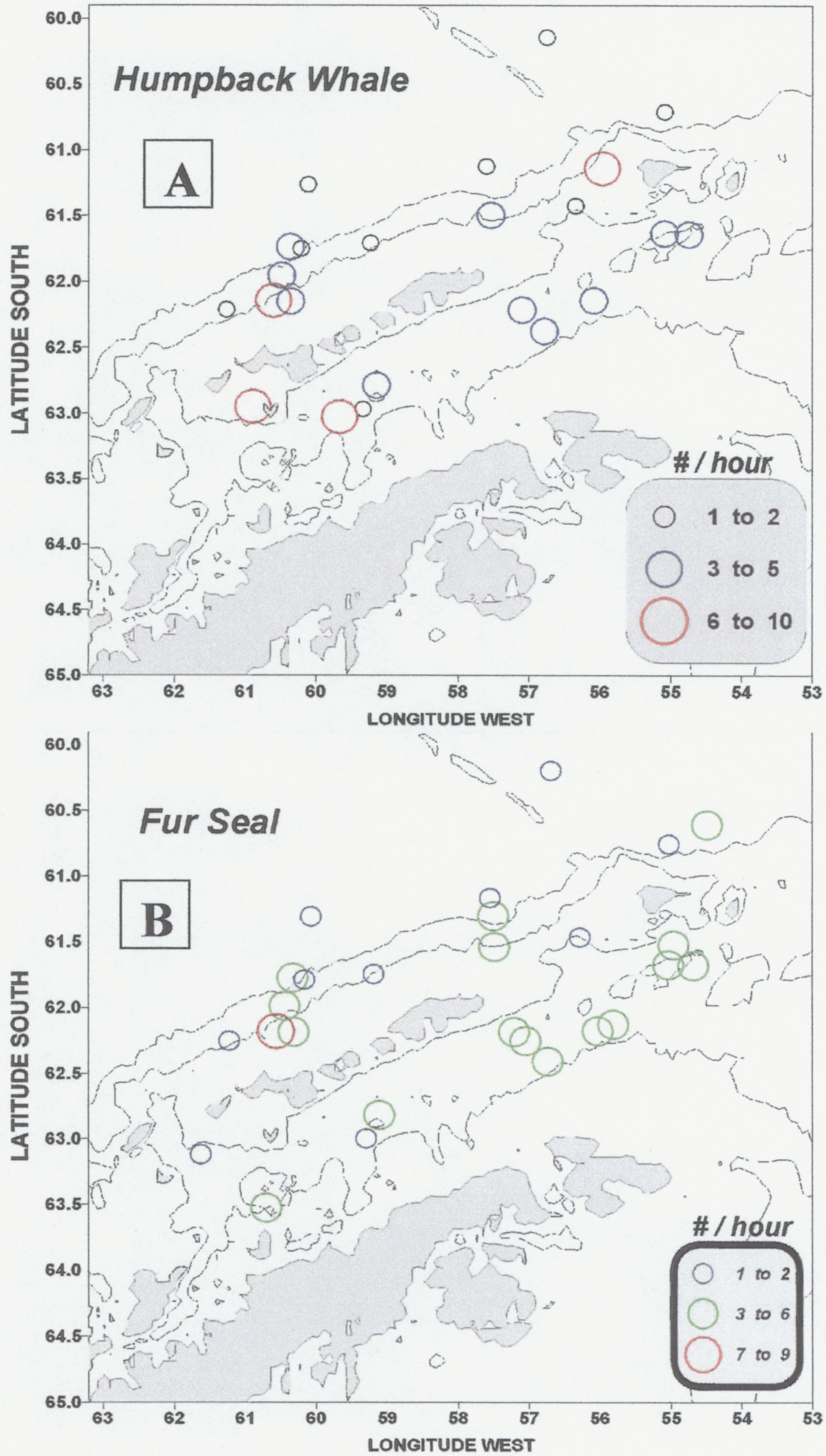


Figure 8.3. A) Humpback whale (*Megaptera novaeangliae*) abundance and dispersion (#/hour), and (B) Antarctic fur seal abundance and dispersion during Leg I AMLR 2003/04 survey.

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