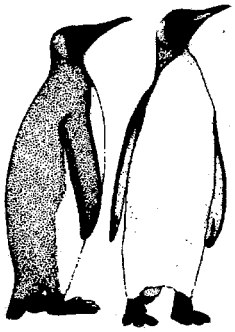

UNITED STATES AMLR ANTARCTIC MARINE LIVING RESOURCES PROGRAM

AMLR 1998/99 FIELD SEASON REPORT

Objectives, Accomplishments and Tentative Conclusions

Edited by
Jane Martin

September 1999

ADMINISTRATIVE REPORT LJ-99-10

Southwest Fisheries Science Center
Antarctic Ecosystem Research Group

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

Inquiries should be addressed to:

Antarctic Ecosystem Research Group
Southwest Fisheries Science Center
P.O. Box 271
La Jolla, California, USA 92038

Telephone Number: (858) 546-5600

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Bioacoustic studies revealed highest concentrations of krill during Leg I were along the shelf-break north of Livingston and King George Islands and southwest of Elephant Island. During Leg II, highest concentrations were again mapped along the shelf-break north of Livingston and King George Islands, but near Elephant Island the high concentrations were mapped to the northwest and southeast of the island. Krill biomass density estimates were calculated from total integrated volume backscattering and from visually classified scattering that was attributed to krill. The results indicate that the volume backscattering attributed to krill was approximately 27% of the total volume backscattering during Leg I and 14% during Leg II. This suggests a substantially larger contribution of scatterers other than krill and/or substantially higher noise levels than has been experienced in previous surveys. Krill biomass density estimates were the second lowest in the 7-year time series and were also consistent with krill abundance trends derived from net sampling.

The 1999 Isaacs-Kidd Midwater Trawl (IKMT) tows revealed three salient observations: (1) krill abundance was near the lowest level ever recorded during AMLR program surveys, which likely was the result of three successive years of poor reproductive and recruitment success; (2) the remaining krill population was dominated by older age classes that had been actively spawning since mid- to late December, which contrasts with the last three years when spawning was reduced in intensity and occurred unfavorably late in the season; and (3) a reduction in the abundance of salps and a dramatic increase in the numbers of copepods, chaetognaths, *Thysanoessa macrura* larvae, *Euphausia frigida*, and several other zooplankton taxa was noted. These results confirm the predicted failure of the 1997/98 krill year class, as well as the prediction that the 1998/99 austral summer would be a transition period based on the cyclic trend of environmental conditions in the study area over the past 11 years.

This was the second full season of seabird research at Cape Shirreff. The breeding populations of chinstrap and gentoo penguins this season were determined to be 7581 chinstrap penguin pairs and 830 gentoo penguin pairs. This represents a slight change from the 1997/98 season when there were 7617 and 810 breeding pairs, respectively. Reproductive success of chinstrap penguins was higher and gentoo penguins lower in the 1998/99 season than in the previous season. The mean fledging weight of 217 chinstrap penguin chicks was 3200 grams (g), compared with weights of 3180g for the 1997/98 cohort and 3270g in 1996/97. The mean weight of 200 gentoo chicks was 4450g, an increase of 250g from the 1997/98 season. As in the 1997/98 season, the length frequency distribution of krill in the chinstrap and gentoo penguin's diets this season was dominated by three CCAMLR size classes [36-40, 41-45, and 46-50 millimeters (mm)], which accounted for 95% of all krill in the samples. As in the 1997/98 season, foraging trips exhibited a bimodal distribution. The two main peaks for trip duration, however, were shorter during the 1998/99 season with a major peak around 8 hours and a second peak near 14 hours in duration.

Pinniped studies at Cape Shirreff indicated that Antarctic fur seal pup production increased in 1998/99 over last year. Return rates for adult female fur seals and yearling pups appeared to indicate good over-winter survival. Adult female trip duration for the first six trips to sea was significantly greater in 1998/99, possibly indicating reduced prey resources early in the season

over the 1997/98 field season. The difference, however, was confined to the first two trips to sea and may have been a result of a difference in arrival condition. Females of the same length had a greater mass at one day postpartum in 1997/98 than in 1998/99. The mean parturition date for females in 1997/98 was also later than in 1998/99 and subsequently foraging cycles in 1998/99 were started earlier than in 1997/98. Any differences in females (or arrival condition) between the two years did not appear to affect later foraging trips as there were no differences between years in trips 3-6. Foraging locations and trip duration change from January to February. Females foraged much closer to Cape Shirreff in February than in January. Trip duration was also shorter in February than in January. At the same time fur seals shifted prey species from primarily krill to a diet with a higher percentage of fish and squid. Fur seals in 1997/98 showed a similar shift in diet and reduction in trip duration in February. However, no foraging location data for January 1998 are available, so comparison of this year's foraging location data is limited to February only.

A total of 16167.5 kilograms (kg) (38,356 individuals) of 42 different fish species were processed from all hauls of the bottom trawl survey of the South Orkney Islands. Species that were caught in substantial numbers, defined as >500kg or >500 individuals, included *Gobionotothen gibberifrons, Lepidonotothen squamifrons, Chionodraco rastrospinosus, Chaenocephalus aceratus, Pseudochaenichthys georgianus, Electrona antarctica, Gymnoscopelus nicholsi, Champsocephalus gunnari, and Lepidonotothen larseni.* The greatest yields of fish in terms of both numbers and total weight were for the nototheniids *G. gibberifrons* (5062kg, 18,745 individuals), followed by *L. squamifrons* (5023kg, 6875 individuals). There was substantial variation in catches between stations. In general, highest yields were to the west and north of the island chain. This region is also generally more patchy than the southern or eastern sectors of the South Orkney Islands. Although there were a total of 42 different species encountered (with representatives within the genus *Pogonophryne* considered one species), the number of species present in each haul ranged from 6 to 16, with an average of 10 species per haul. In general, there was greater variability in species richness per haul in the near shore sectors and more stable and diverse species assemblages in the offshore regions to the south and east of the island chain. The most frequently encountered species was *C. rastrospinosus,* which was found within catches at all 64 stations. Other species encountered frequently were *G. gibberifrons* (97%), *C. aceratus* (94%), *L. larseni* (89%), *C. gunnari* (69%), *L. squamifrons* (67%), *P. georgianus* (67%), and *T. eulepidotus* (67%).

At Palmer Station, Adélie penguin breeding success in 1998/99 decreased, with 1.49 chicks crèched per pair compared to 1.58 during the 1997/98 season. Of the 2082 broods censused in January 1999, 61.9% contained two chicks, which was almost no change from the 60.9% reported in January 1998. Chick production totaled 5469 chicks this season, a 4.4% decrease relative to the 5722 chicks reported from these colonies in January and February 1998. Chick fledgling weights in February 1999 averaged 3.01kg as opposed to 3.05kg in February 1998. Diet studies revealed a mix of prey items, with krill as the dominant component. The krill in the diet samples were mainly comprising the size class 40-45mm, which was generally larger than the size classes observed last season.

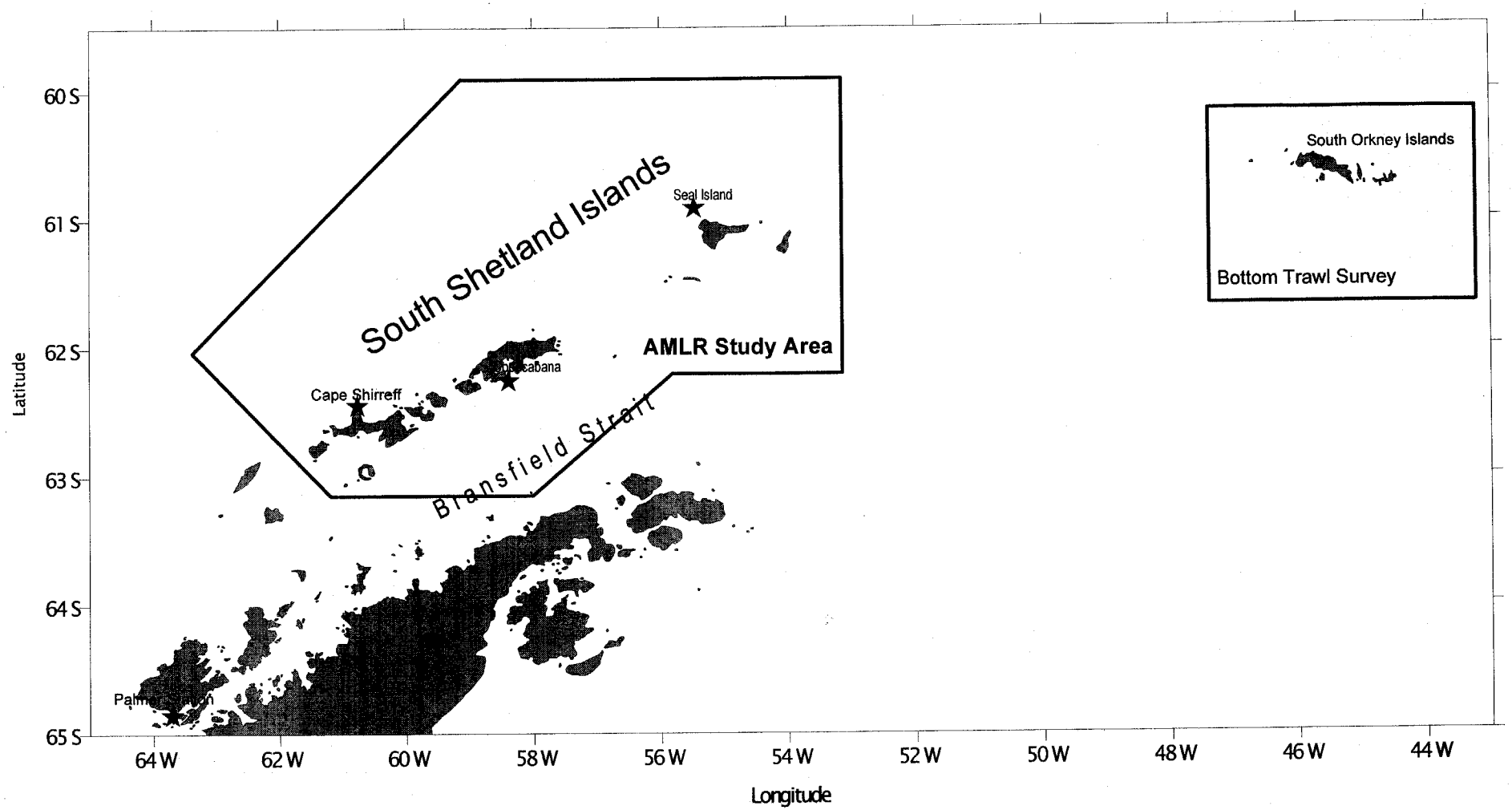


Figure 1. Locations of the U.S. AMLR field research program: AMLR study area, Cape Shirreff, Palmer Station, and the South Orkney Islands.

OBJECTIVES

Shipboard Research:

1. Map meso-scale (10's of kilometers) features of water mass structure, phytoplankton biomass and productivity, and zooplankton constituents (including krill) in the AMLR study area.
2. Estimate the abundance and dispersion of krill in the AMLR study area.
3. Calibrate acoustic system at the beginning of Leg I and again after the large-area survey on Leg II.
4. Collect continuous measurements of ship's position and heading, water depth, sea temperature, salinity, water clarity, chlorophyll, air temperature, barometric pressure, relative humidity, wind speed and direction, and solar radiation.
5. Provide logistical support to three land-based field sites: Copacabana field camp (Admiralty Bay, King George Island); Cape Shirreff (Livingston Island); and Seal Island.
6. Conduct a bottom trawl survey to provide baseline estimates of abundance, species composition, size composition, and demographic structure of fish species within the 500 meter isobath of the South Orkney Islands.

Land-based Research:

Cape Shirreff

1. Estimate chinstrap and gentoo penguin breeding population size.
2. Band 1000 chinstrap and 200 gentoo penguin chicks for future demographic studies.
3. Determine chinstrap penguin foraging trip durations during the chick rearing stage of the reproductive cycle.
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. Document Antarctic fur seal pup production for Cape Shirreff and assist Chilean colleagues with censuses of fur seal pups for the entire Cape and the San Telmo Islands.
9. Monitor female Antarctic fur seal attendance behavior.
10. Assist Chilean researchers in collecting Antarctic fur seal pup length, girth, and mass for 100 pups every two weeks through the season.
11. Collect 20 Antarctic fur seal scat samples every two weeks for diet studies.
12. Collect a milk sample at each female Antarctic fur seal capture for fatty acid signature analysis and diet studies.
13. Record at-sea foraging locations for female Antarctic fur seals using ARGOS satellite-linked transmitters.
14. Deploy time-depth recorders on female Antarctic fur seals for diving studies.

15. Measure at-sea metabolic rates and foraging energetics of lactating Antarctic fur seals using doubly-labeled water.
16. Measure milk intake using deuterated water on the pups of foraging energetics study females.
17. Measure milk intake and energetics for 20 Antarctic fur seal pups using doubly-labeled water.
18. Tag 500 Antarctic fur seal pups for future demographic studies.
19. Measure total blood volume for adult female and juvenile Antarctic fur seals.
20. Measure metabolic rates and thermo-neutral zones of pups and juvenile Antarctic fur seals using a metabolic chamber.
21. Deploy a weather station for continuous recording of wind speed, wind direction, ambient temperature, humidity, and barometric pressure.
22. Construct an emergency shelter/bird observation blind at the northern end of Cape Shirreff.

Seal Island

1. Demolish and remove all remaining building materials, refuse, and equipment from the site of the former field camp.

Palmer Station

1. Determine Adélie penguin breeding population size.
2. Determine Adélie penguin breeding success.
3. Obtain information on Adélie penguin diet composition and meal size.
4. Determine Adélie penguin chick weights at fledging.
5. Determine adult Adélie penguin foraging trip durations.
6. Band 500 Adélie penguin chicks for future demographic studies.
7. Determine Adélie penguin breeding chronology.

DESCRIPTION OF OPERATIONS

Shipboard Research:

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

Itinerary

Leg I:	Depart Punta Arenas	10 January 1999
	Drop off personnel/supplies at Cape Shirreff	13 January
	Drop off personnel/supplies at Copacabana	14 January
	Transducer calibration	15 January
	Large-area survey (Survey A)	15-28 January
	Drop off supplies at Cape Shirreff	18 January
	Transfer personnel, Copacabana to Cape Shirreff	29 January
	Transfer personnel, Cape Shirreff to Seal Island	29-30 January
	Arrive Punta Arenas	02 February
Leg II:	Depart Punta Arenas	05 February
	Transfer personnel, Seal Island to Cape Shirreff	08-10 February
	Large-area survey (Survey D)	10-26 February
	Seal Island operations	17 and 21 February
	Close Copacabana	24 February
	Transducer calibration	25 February
	Close Cape Shirreff	26 February
	Arrive Punta Arenas	01 March
Leg III:	Depart Punta Arenas	05 March
	Bottom trawl survey/CTDs	09-25 March
	Arrive Punta Arenas	29 March

Leg I.

1. The R/V *Yuzhmorgeologiya* departed Punta Arenas, Chile via the eastern end of the Strait of Magellan. Landfall was made at Cape Shirreff, Livingston Island, and personnel and supplies were transferred ashore.

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

3. A large-area survey of 78 Conductivity-Temperature-Depth (CTD)/carousel and net sampling stations, separated by acoustic transects, was conducted in the vicinity of Elephant, Clarence, King George, and Livingston Islands (Survey A, Figure 2). Stations are located in three areas: stations to the west of Livingston and King George Islands are designated the "West area," those to the south of King George Island are designated the "South area," and those around Elephant Island are called the "Elephant Island area." Acoustic transects were conducted at 10 knots, using hull-mounted 38kHz, 120kHz, and 200kHz down-looking transducers. Operations at each station included: (a) vertical profiles of temperature, salinity, oxygen, photosynthetically available radiation, light transmission, and fluorescence; (b) collection of discrete water samples at standard depths for analysis of chlorophyll-a concentration, primary production rates, inorganic nutrients, dissolved oxygen, phytoplankton cell size and species composition, and phytoplankton biomass; and (c) deployment of an IKMT to obtain samples of zooplankton and micronekton. The IKMT was not deployed at two of the planned stations (A188 and A111) due to the net being lost during a previous deployment; the IKMT was also not deployed at Station A189.

4. Field team personnel were retrieved from the Copacabana field camp and transferred to Cape Shirreff. Other personnel were then transferred from Cape Shirreff to Seal Island.

5. Twenty-four days of continuous underway measurements of ship's position and heading, water depth, sea temperature, salinity, water clarity, chlorophyll, air temperature, barometric pressure, relative humidity, wind speed and direction, and solar radiation were recorded.

Leg II.

1. The R/V *Yuzhmorgeologiya* departed Punta Arenas, Chile via the eastern end of the Strait of Magellan and arrived at Seal Island; the field team and some retrograded material were recovered. The ship then transited to Cape Shirreff to deliver and retrieve personnel and also to re-provision the field camp.

2. A large-area survey, similar to Survey A, was conducted in the vicinity of Elephant, Clarence, King George, and Livingston Islands (Survey D, Figure 2). Due to bad weather, nine planned stations (D151, D152, D123, D124, D42, D121, D3, D133, and D109) were canceled. The CTD cast was not done at Stations D58 and D57 due to equipment problems; however, an IKMT was conducted at these two stations.

3. Survey D was suspended twice to visit Seal Island in order to remove retrograded materials. Toward the end of Survey D, the ship transited to Admiralty Bay to close Copacabana field station, retrieve personnel, and calibrate the acoustic transducers. Following the completion of the survey, the ship transited to Cape Shirreff to close the field camp and retrieve personnel.

4. Similar to Leg I, twenty-five days of continuous underway measurements were recorded.

Leg III.

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

2. A total of 64 bottom trawls were conducted around the South Orkney Islands (Figure 1). The trawl gear consisted of a two-warp/four-panel bottom trawl and a third-wire linked net sonde.

3. Other scientific operations included continuous acoustic data collection, 24 days of continuous underway measurements of meteorological and sea surface conditions, and CTD casts at selected sites.

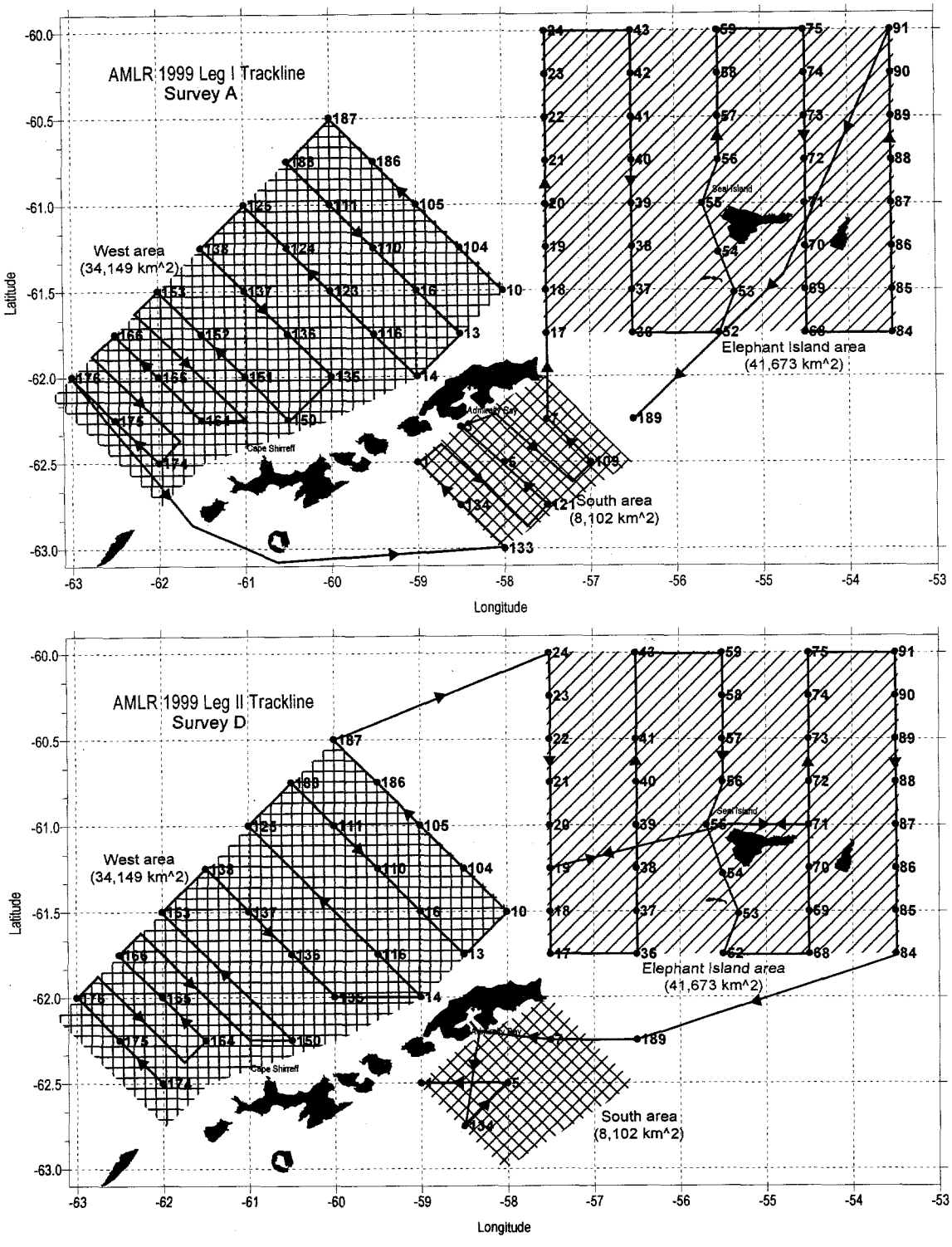


Figure 2. The large-area surveys for AMLR 99 (Surveys A and D) in the vicinity of Elephant, Clarence, King George, and Livingston Islands. Stations located to the west of Livingston and King George Islands are designated the "West area," those to the south of King George Island are designated the "South area," and those around Elephant Island are designated the "Elephant Island area."

Land-based Research:

Cape Shirreff

1. A four-person field team (M. Goebel, J. Sterling, T. Carten, and R. Capitan) arrived at Cape Shirreff, Livingston Island, on 25 November 1998 via the M/V *Explorer*. Equipment and provisions were transferred from the M/V *Explorer* to Cape Shirreff.

2. Two additional personnel (R. Holt and D. Costa), along with supplies and equipment, arrived at Cape Shirreff via the R/V *Yuzhmorgeologiya* on 13 January 1999. Due to bad weather, offloading operations were suspended prior to completion. The ship returned on 18 January to complete the cargo transfer. Two other personnel (W. Trivelpiece and M. Rutishauser) arrived at Cape Shirreff via the R/V *Yuzhmorgeologiya* on 29 January 1999.

3. An emergency shelter/bird observation blind was constructed at the northern end of Cape Shirreff.

4. Chinstrap and gentoo penguin populations were censused on 30 November 1998. All colonies were counted, and the number of breeding pairs was determined. Reproductive success was studied by following a sample of 100 chinstrap penguin pairs and 60 gentoo penguin pairs from egg laying to crèche formation.

5. Radio transmitters were attached to 24 chinstrap penguins feeding 2-3 week old chicks on 11 and 12 January 1999; foraging trip length and frequency data were collected through mid-February.

6. Seven satellite-linked transmitters were deployed on adult chinstrap penguins during check rearing phase to determine foraging location.

7. Diet studies of chinstrap and gentoo penguins during the chick rearing phase were initiated on 4 January 1999 and continued through 11 February 1999. Forty chinstrap and 20 gentoo adult penguins were captured upon returning from foraging trips, and their stomach contents were removed by lavaging.

8. A count of all chinstrap and gentoo penguin chicks was conducted on 8 February 1999. Fledging weights of chinstrap penguin chicks were collected 17-24 February 1999. Two hundred gentoo penguin chicks were also weighed on 14 February 1999.

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

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

11. Time-depth recorders (TDRs) were deployed on chinstrap and gentoo penguins for 7-10 day foraging periods to study diving behavior.

12. Antarctic fur seal pups and female fur seals were counted at four main breeding beaches every other day from 30 November 1998 through 6 January 1999.

13. Attendance behavior of female Antarctic fur seals was measured using radio transmitters. Thirty-three lactating female seals were instrumented 5-15 December 1998, and their pups were captured, weighed, and measured.

14. U.S. researchers assisted Chilean scientists in collecting data on Antarctic fur seal pup growth. Measurements were begun by the Chileans on 16 December 1998 and continued every two weeks until 14 February 1999. An additional 51 weights were collected on 20 February 1999.

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

16. Thirty-two female Antarctic fur seals were instrumented with TDRs for diving behavior studies.

17. Thirty-three female Antarctic fur seals were instrumented with ARGOS satellite-linked transmitters for studies of foraging locations and energetics. Twenty of the 33 fur seals also received injections of doubly-labeled water for measurements of metabolic rate, water flux, and energy expended.

18. Five hundred Antarctic fur seal pups were tagged at Cape Shirreff 20 January-23 February 1999 by U.S. and Chilean researchers for demography studies. Studies of pup milk intake and energetics were conducted on 20 pups. Fifty-two female Antarctic fur seals with pups were also tagged.

19. Total blood volume was determined for 19 Antarctic fur seals using the Evan's blue dye dilution method.

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

21. Two field team members (R. Holt and J. Sterling) were retrieved from Cape Shirreff via the R/V *Yuzhmorgeologiya* on 29 January 1999. Sterling returned home to the U.S. and Holt was transported to Seal Island. Holt returned to Cape Shirreff on 10 February 1999; R. Capitan embarked the ship to work aboard for the remainder of Leg II.

22. The Cape Shirreff field camp was closed for the season on 26 February 1999; all personnel (R. Holt, M. Goebel, D. Costa, T. Carten, W. Trivelpiece, and M. Rutishauser), garbage, and equipment were retrieved by the R/V *Yuzhmorgeologiya*.

Seal Island

1. Four field team members (R. Holt, W. Armstrong, K. Dietrich, and A. Jenkins) arrived at Seal Island on 30 January 1999 via the R/V *Yuzhmorgeologiya*. During their stay, the team dismantled all remaining structures and retrograded materials for the last phase of the field camp deconstruction.

2. The four-person team (R. Holt, W. Armstrong, K. Dietrich, and A. Jenkins) was recovered from Seal Island 8-9 February 1999. Building materials from the dismantled structures, along with additional supplies and equipment, were removed from the island during this visit and also during two subsequent visits on 17 and 21 February 1999.

Palmer Station

1. Field work at Palmer Station was initiated on 29 September 1998 and terminated on 6 April 1999.

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

3. Breeding population size was determined by censusing the number of breeding pairs of Adélie penguins at 54 sample colonies. Censuses were delayed until past the peak egg-laying period (10 December 1998) due to heavy spring sea ice conditions.

4. The proportion of one and two Adélie penguin chick broods was assessed at 54 sample colonies on 6 and 10 January 1999. Chick production was determined by censusing Adélie penguin chicks on 23 and 24 January 1999 at 54 sample colonies when approximately 2/3 of them had entered the crèche stage.

5. Fledging weights of Adélie penguin chicks were obtained at beaches near the Humble Island rookery between 1 and 16 February 1999.

6. Five hundred Adélie penguin chicks were banded on 1 February 1999 as part of continuing demographic studies at selected AMLR colonies on Humble Island.

7. In conjunction with diet studies, 50 adult Adélie penguins were captured and lavaged as they approached their colonies to feed chicks on Torgersen Island.

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

SCIENTIFIC PERSONNEL

Cruise Leader:

Roger P. Hewitt, Southwest Fisheries Science Center (Leg I)
Wesley A. Armstrong, Southwest Fisheries Science Center (Leg II)
Christopher D. Jones, Southwest Fisheries Science Center (Leg III)

Physical Oceanography:

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

Phytoplankton:

Osmund Holm-Hansen, Scripps Institution of Oceanography (Leg I)
Vicente E. Chacon Chade, Instituto de Fomento Pesquero (Leg II)
Guillermo Aravena Cuevas, Escuela la Ciencias del mar (Leg I)
Erwin Guzman, Universidad Austral de Chile (Leg I)
Christopher D. Hewes, Scripps Institution of Oceanography (Legs I and II)
Susana B. Giglio Munoz, Escuela de Ciencias del mar (Leg II)
Hardy R. Wellman Ruiz, Universidad Austral de Chile (Leg II)

Bioacoustic Survey:

Roger P. Hewitt, Southwest Fisheries Science Center (Leg I)
Peter Kappes (Legs II and III)
Jacqueline Popp (Legs I, II, and III)

Krill and Zooplankton Sampling:

Valerie Loeb, Moss Landing Marine Laboratories (Legs I and II)
Wesley A. Armstrong, Southwest Fisheries Science Center (Leg I)
Richard Capitan (Leg II)
Kim Dietrich (Legs I and II)
Michael Force (Legs I and II)
Nancy Gong, Moss Landing Marine Laboratories (Legs I and II)
Adam Jenkins, Wayward Sailor Maritime (Legs I and II)
Darci Lombard, Moss Landing Marine Laboratories (Legs I and II)

Bottom Trawl Survey:

Christopher D. Jones, Southwest Fisheries Science Center (Leg III)
Kim Dietrich (Leg III)
Peter Kappes (Leg III)
Karl-Hermann Kock, Sea Fisheries Research Institute (Leg III)
Darci Lombard, Moss Landing Marine Laboratories (Leg III)
Jacqueline Popp (Leg III)
David Ramm, CCAMLR (Leg III)
Sunhild Wilhelms, Bundesamt fuer Seeschiffahrt und Hydrographie (Leg III)

Pinniped Studies:

Matthew R. Rutishauser, University of California at Santa Cruz (Leg I)

Cape Shirreff Personnel:

Michael E. Goebel, Southwest Fisheries Science Center (11/25/98-2/26/99)
Richard Capitan (11/25/98-2/10/99)
Terence Carten (11/25/98-2/26/99)
Daniel P. Costa, University of California at Santa Cruz (1/13/99-2/26/99)
Rennie S. Holt, Southwest Fisheries Science Center (1/13/99-1/29/99; 2/10/99-2/26/99)
Jeremy T. Sterling, University of California at Santa Cruz (11/25/98-1/29/99)
Wayne Z. Trivelpiece, Southwest Fisheries Science Center (1/29/99-2/26/99)
Matthew R. Rutishauser, University of California at Santa Cruz (1/29/99-2/26/99)

Seal Island Personnel:

Rennie S. Holt, Southwest Fisheries Science Center (1/30/99-2/9/99)
Wesley A. Armstrong, Southwest Fisheries Science Center (1/30/99-2/8/99)
Adam Jenkins, Wayward Sailor Maritime (1/30/99-2/8/99)
Kim Dietrich (1/30/99-2/8/99)

Palmer Station Personnel:

William R. Fraser, Montana State University (12/29/98-4/6/99)
Donna L. Patterson, Montana State University (12/29/98-4/6/99)
Peter Duley, Montana State University (9/29/98-2/15/99)
Matt Irinaga, Montana State University (9/29/98-2/15/99)

DETAILED REPORTS

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

1.1 Objectives: The physical oceanography component of the AMLR program provided the means to identify contributing water masses and environmental influences within the study area, as well as to log meteorological and sea surface conditions annotated by the ship's position. The instrumentation and data collection programs served as host to the other scientific components of the program. AMLR 99 is the tenth field season for the collaboration of physical measurements with biological studies.

1.2 Accomplishments: The large-area survey included an expanded grid of stations extending to the north of Livingston Island. Some of the original 91 large-area survey stations were dropped.

CTD/Carousel Stations: Seventy-eight CTD/carousel casts were made on Leg I (Survey A, Stations A001-A189); an extra cast at Station A019 was also conducted. Sixty-seven casts were made on Leg II (Survey D, Stations D001-D189). Due to rough weather encountered on Leg II, several stations were not occupied. Stations were located in three areas: stations to the west of Livingston and King George Islands were designated the "West area," those to the south of King George Island were designated the "South area," and those around Elephant Island were called the "Elephant Island area." See Figure 2 in the Introduction Section for station locations. Three hundred water samples were collected from the carousel bottles for analyses during Leg I (out of a total of 913 water samples collected). Two hundred eighty water samples were collected for analyses during Leg II (out of a total of 737 water samples collected). The water samples were analyzed for micronutrient concentration, phytoplankton, and chlorophyll-a by the phytoplankton group, and for salinity by the Russian support team. Dissolved oxygen analyses were not conducted. Salinity samples were analyzed aboard using a Guildline Autosal to verify the depth that each bottle tripped and to provide calibration data for the CTD conductivity sensor. The difference between the salinity measured by the Autosal and the CTD sensor was <0.005, confirming the high accuracy of the CTD. Additional sensors on the CTD [fluorometer, transmissometer, and photosynthetically available radiation (PAR) sensor] functioned well.

Underway Environmental Observations: Twenty-four and 25 days of continuously acquired weather, sea temperature, salinity, water clarity, chlorophyll, and solar radiation data were collected during Leg I and Leg II, respectively. Augmented with navigational data from a portable Global Positioning System (GPS) and the ship's gyro compass output, these data provided complete coverage of surface environmental conditions encountered throughout the AMLR study area.

1.3 Methods:

CTD/Carousel: For the large-area surveys on Legs I and II (Surveys A and D), water profiles were collected with a Sea-Bird SBE-9/11 PLUS CTD/carousel water sampler. CTD profiles

were limited to 750 meters (m) depth (or to within a few meters of the ocean floor when the depth was 750m, or less). A Data Sonics altimeter was used to guide the CTD/carousel to within 5m of the bottom on the shallow stations. A Sea-Bird dissolved oxygen sensor, Seatech 25-centimeter (cm) beam transmissometer, Biospherical Instruments PAR sensor, and a Seatech *in situ* fluorometer (interfaced with the CTD/carousel unit) provided additional water column data on each station. Downtrace and uptrace CTD data for each station were recorded separately on 100 Mbyte Zip drives. Data were collected at 24 scans/second on the downtrace and 6 scans/second on the uptrace. All carousel bottles were fired during the upcast.

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

Underway Data: A GPS system (a Trimble NAVPAC II) was used to acquire navigational information without modifying the cable. The cable was run from the computer laboratory to an obstruction-free region near the port lifeboat station, which gave nearly error-free operation during all legs. A Coastal Environmental Company Weatherpak system was installed and used as the primary atmospheric data acquisition system. All of these systems output serial data, as does the Sea-Bird thermosalinograph for sea temperature and salinity data. The PAR sensor, transmissometer and flow-through fluorometer units, which output analog data signals, were connected to a Fluke "Data Bucket" DVM/multi-channel data acquisition system, which itself outputs an RS232 message. A GTEK multi-port card was used to acquire all these data with the Data World computer.

1.4 Results and Tentative Conclusions:

Oceanography: As in past years, we classified and grouped stations with similar vertical temperature/salinity (T/S) characteristics (Figure 1.1). We have identified five water zones, designated I through V. It should be noted that the water zones are based on the T/S curves from the surface to 750m (or to the bottom in water shallower than 750m). For example, Water Zone I (Figures 1.1a and 1.1f) is based on the following characteristics: warm, low salinity surface water; strong sub-surface temperature minimum (called "Winter Water" at approximately -1 °C and salinity of 34.0 ppt.); and a distinct T/S maximum near 500m (called "Circumpolar Deep Water" or CDW). Water Zone I is the oceanic water of the Drake Passage. In the Bransfield Strait and south of Elephant Island, Water Zone IV dominates (Figures 1.1d and 1.1i). Water Zone IV has bottom waters around -1 °C, and subsurface extreme that are far less prominent, although a slight "crook" in the curve is characteristic. In between, there are transition zones where adjacent water zones mix.

In Figure 1.1, each panel shows the envelope (in gray) encompassing the T/S curves of all stations grouped by Water Zones (I through V). The depth-averaged mean of each water zone is shown as a solid black curve. The map inset shows the location of those stations which display the T/S curve characteristic of its water zone. This makes it easier to envision the locations of the five water masses in the AMLR study area. Although considerable care has been taken to classify each station by water zone, these data are still preliminary as some stations are transitional. This particularly applies to Water Zone II, which we identified by the evidence of isopycnal mixing of the CDW with shelf water (Figures 1.1b and 1.1g). Water Zone III was more extensive during Leg I (Survey A, Figure 1.1c) than on Leg II (Survey D, Figure 1.1h). Water Zone V with Weddell Sea influence was only seen at three stations on the extreme eastern edge of the Elephant Island area (Figures 1.1e and 1.1j).

In Figures 1.2a and 1.2b, T/S curves have been plotted for each station in Survey A (Leg I) and Survey D (Leg II), respectively. The two major water divisions can clearly be seen for both surveys. Water Zone I dominated the area northwest of Livingston and King George Islands, which included new AMLR stations occupied for the first time during AMLR 99. Water Zone I extended eastward to Elephant Island where the mixing zone was clearly seen on both Leg I and Leg II (Figure 1.2). The gaps on Leg II were caused by rough weather when CTD stations could not be made (Figure 1.2b). The South area included eight stations south of King George Island on Leg I; only four of these stations could be occupied on Leg II due to bad weather and time constraints. An extra station (189) was added in Bransfield Strait to tie in with the Elephant Island area.

Sea surface temperature data are presented for both legs in Figure 1.3a, and salinity data for both legs are shown in Figure 1.3b; these data were contoured using Surfer software. The data were gathered from the continuous underway record of the thermosalinograph and include all track lines from each leg. Data have been corrected by regression against the CTD temperatures and salinities at each station. On Leg I, water above 2 °C was confined to the northwest corner of the Elephant Island area, making 1999 a "cold year" in comparison with most previous AMLR surveys (Figure 1.3a, top panel). An interesting area >2 °C occurred in the Bransfield Strait on Leg I, but was not found on Leg II by which time the two-degree isotherm had advanced southward towards the islands (Figure 1.3a, bottom panel). Within the large-area survey region, surface temperatures did not exceed 3 °C on Leg II, hence we classify 1999 as a "cold year." In general, surface salinity increased from north to south across the survey area (Figure 1.3b). The frontal boundary separating oceanic from coastal waters can be located by the approximate position of the 34-isohaline at the surface (Figure 1.3b). By February, the front had intensified and moved closer to Elephant Island (Figure 1.3b, lower panel), as has been observed in several other AMLR surveys. North of Livingston Island, a complex region of low salinity surface water was seen, possibly connected to similar water in the Bransfield Strait.

We made extensive use of Ocean Data View (v4.0 or ODV40) during AMLR 99. This software has been developed at the Alfred Wegener Institut in Germany by Dr. Reiner Schlitzer and has recently been reviewed in the oceanographic literature (Brown, 1998). ODV40 allows CTD data

to be visualized during the cruise at several stages by its use of color, creating sections and surfaces, and the ability to calculate many oceanographic parameters. Like other contouring software, ODV40 has its drawbacks and caution should be used in the interpretation of the diagrams produced. For example, a lone point at the edge of a grid interstice can give a potentially false idea of a singularity. The contoured area extends beyond the actual area surveyed and there is as yet no blocking feature (as in Surfer) to eliminate the extended contours. Because color cannot be used here and monochrome renditions of the originals reproduce poorly, we have used only black and white reproductions in the figures. In some cases, such as when the figure includes an inset map, neither shading nor the inset can be removed. The rendition of the South Shetland Islands is crude. We are working on using our more accurate coastlines and topography for future use with ODV40.

Figures 1.4a and 1.4b show surface temperature, density, and the dynamic topography of the surface relative to 300 and 500dbar for Legs I and II, respectively. Data used in the figure were derived from the 1-meter averaged CTD profiles. Potential temperature and density are used in the figures, but at the surface these are equivalent to temperature and Sigma-T. Note that enclosed loops in temperature and density around Livingston Island imply continuity between the oceanic and Bransfield Strait environments. While this may be the case, it is not necessarily so. Density, like salinity, increases at the surface from north to south. The 27.2 isopycnal delineates the surface frontal boundary. The sea surface topography slopes from high to low from the northwest to the southeast as shown by the contouring of dynamic height (Figures 1.4a and 1.4b, right panels). With the high to the left, the contours indicate geostrophic flow which as usual prevailed from southwest to northeast across the entire AMLR study area. The eddy-like feature northwest of Elephant Island represents a bend in the southern limb of the Antarctic Circumpolar Current driven by the West Wind Drift. This dynamic topographic high is a quasi-permanent feature of the flow in the AMLR region and has been present on all AMLR cruises on both legs. The pattern was similar when the surface was referenced to 300m (upper right panels in Figures 1.4a and 1.4b), so it is assumed that these patterns are reasonably representative of the mean flow in the upper water column of interest to AMLR. There were minor reversals in the flow, but we saw no evidence of the East Wind Drift, which while a feature of the flow around most of the continent, is interrupted by the Antarctic Peninsula. The flow was most intense to the northwest of Elephant Island and north of King George Island on both Leg I (January) and Leg II (February). On Leg II, the bend in the flow shifted westward from Elephant Island to King George Island. The unfortunate gap in stations along the 55.5°W meridian confuses the depiction of the flow. The flow was weaker along the South Shetland Islands shelf off Livingston and King George Islands during both surveys. Due to the reduction in station coverage in the Bransfield Strait, flow patterns appear to be less coherent in this region. As in other AMLR cruises, with the exception of the eddies, flow throughout the region is exclusively in a northeasterly to northerly direction.

Using ODV40, sections along the 57°30'W meridian from the Drake Passage into the Bransfield Strait (crossing the oceanic front at its most defined location) are shown in Figures 1.5a and 1.5b for Legs I and II, respectively. Station locations are shown by the vertical lines on each section in

Figures 1.5a and 1.5b and also on the inset map. T/S curves for each of the stations are shown in the panel on the lower right. On Leg I, the Winter Water temperature minimum near 100m was well developed, but the feature abruptly ended just north of King George Island (upper section, Figure 1.5a). However, the reason for the disappearance of this feature was because the underlying warm CDW mass did not continue south into the Bransfield Strait. CDW is characterized by its T/S maximum and oxygen minimum. Both the surface expression of the front and the CDW boundary coincided on Leg I. The deep isotherms abutting the continental slope were nearly vertical as depicted in Figure 1.5a, but the bend at 600m is an artifact of the contouring method. Also, bottom topography is only crudely shown here and is derived from the depth to bottom at the CTD station site. Note that slight changes in station position on the rugged slope may put the same station on different legs over deeper or shallower water (see the difference in "bottom topography" between Figures 1.5a and 1.5b). Despite the dramatic variability in the temperature sections, density is controlled by salinity and exchange of water across the thermal fronts may take place. By Leg II, surface waters had warmed, the mixed layer had deepened, and the thermocline and pycnocline had intensified (Figure 1.5b). Winter Water was still well defined. The kink in the deep isotherms is again an artifact. Only one station along this line in the Bransfield Strait was occupied on Leg II, diminishing the utility of the contoured section. Note the difference in the length of the sections between Leg I and Leg II. We have yet to learn how to effectively scale ODV40 diagrams to avoid misinterpretation due to scaling factors.

We used ODV40 to examine features of chlorophyll-a, light transmission, and downwelling solar radiation in relationship to the stability of the water column. This was inspired by the detection of a phytoplankton bloom during Leg II (see Section 2, Phytoplankton). Taking a section through the Bransfield Strait, we plotted Potential temperature, Brunt-Viasala Frequency, fluorometry, transmissometry, and PAR for Legs I and II (Figures 1.6a and 1.6b, respectively). Brunt-Viasala, or Buoyancy Frequency (BV-Freq.), is a measure of the stability of the water column. It is a displacement function indicating the frequency of oscillation of a water particle displaced from its position in the column. The higher the frequency, the more stable the water column. Generally, the greatest stability is found in the upper pycnocline and this is a factor in constraining planktonic particles to the upper water column where blooms can occur with adequate light and nutrient supply. In this preliminary report, we use the voltage outputs of the three auxiliary CTD sensors devoted to the phytoplankton group's work. Later, the fluorometer output will be converted to phytoplankton chlorophyll; the transmissometer voltage to Beam Attenuation Coefficient (in Figure 1.6, the lower the voltage, the more turbid is the water); and PAR to light extinction levels. On Leg I, there was little chlorophyll in the Bransfield, the thermocline was more diffuse, and BV-Freq. was lower (Figure 1.6a). The oscillatory appearance of the PAR section merely reflects the time of day when stations were made. The extreme eastern station showed little stability as this Water Zone V is nearly isothermal. By Leg II, however, the mixed layer had deepened, the thermocline intensified, and stability increased at around 50m (Figure 1.6b). This coincides exactly with the distribution of chlorophyll and light transmission, providing an explanation for the bloom formation.

Meteorology: During both legs of AMLR 99, strong winds, rough seas, and a nearly constant swell were experienced, making this one of the windiest of the AMLR surveys. This was especially true during Leg II, when nine CTD stations were dropped due to weather. There were few periods of fog, in marked contrast to last year, and very few icebergs were observed. The underway system worked almost without data loss throughout AMLR 99. Some hours of flow-through data were lost due to pump problems in the sea water supply. To illustrate the wind field during AMLR99, Figures 1.7a and 1.7b show the wind vectors plotted at hourly intervals along the cruise track for both legs. The predominance of the westerly flow is obvious both on Leg I (January) and Leg II (February). There were short periods of northeasterly winds during both legs and some strong northerly winds in February. Wind direction was more variable in February. The strong winds of February were probably a factor in deepening the upper mixed layer in the Bransfield Strait.

1.5 Disposition of Data: The CTD/carousel, underway, and weather station data have been stored on 100 Mbyte and 250 Mbyte Zip diskettes. The raw data were taken to the University of Texas Marine Science Institute in Port Aransas, Texas at the end of Leg II with backup copies shipped back with our equipment after Leg III. Final analysis will be under the direction of Anthony F. Amos. Copies of the CTD/carousel 1-meter averages (Legs I and II), and modified 1-minute underway data (Legs I and II) have been distributed on diskettes to the phytoplankton and acoustic groups. Copies of the printed log sheets and plot were provided daily to the phytoplankton group. Special logs listing time, position and weather conditions for each scientific event were provided to the phytoplankton and zooplankton groups.

1.6 Acknowledgments: Once again, we were most impressed by Captain Igor Zhelyabovskiy and the improvement to the ship and crew attributable to his leadership. Special mention must go to the Russian crew who launched, lowered and raised, and recovered the CTD. The 4-hour on, 8-hour off watches with three crews worked out well for the CTD operation. We are especially grateful to Valeriy Kazachenok, whose tireless work, attention to our needs, and rapid response to our problems was much appreciated. Valeriy and Andrey Mikhaylov ran hundreds of salinity samples for the physical oceanography group. The accuracy and consistency of the results was very high, reflecting the care they took doing the measurements.

1.7 Problems and Suggestions: The Sea-Bird CTD operated well throughout the cruise. However, despite frequent inspection of the CTD connectors, pin corrosion was still a problem. The PAR sensor was most prone to pin corrosion. The oxygen sensor worked well on this cruise, although we had no back up dissolved oxygen sampling for in situ calibration. The Sea-Bird carousel water sampler worked well again this year, and we were able to mount the CTD horizontally, which is the recommended method for optimal CTD performance. On Leg II, the CTD suffered damage in rough seas. In the first instance the mishap was due to an error on the part of the operator (Tony Amos), when the CTD touched the ocean bottom and broke several water sampling bottles. The winch was stopped when the CTD was about 7m from the bottom, but the wire angle decreased during the transition between down- and uptrace, causing the unit to fall over on the bottom. Subsequent to that, the CTD was stopped well above the bottom on

shallow stations. The second event occurred when the CTD crashed into the ship's stern on retrieval, breaking the frame and several water sampling bottles. Fortunately, no damage was done to the CTD or any auxiliary sensors in both incidents. The entire Russian deck crew assembled in the middle of the night in awful weather to replace the broken frame. Their effort was most appreciated. Most of the bottles were repaired by Chuck Rowe and were used again, but some were smashed beyond repair.

The Coastal Climate Weatherpak system, which measures wind conditions, air temperature, humidity and barometric pressure, worked well, with the exception of the humidity sensor which again gave frequent readings above 100%. A sling psychrometer was again used to calibrate the sensor at regular intervals. The underway system, its various components, and software functioned well. We only occasionally had the mysterious "Fluke error," which caused the underway recording to halt.

1.8 Reference:

Brown, M. 1998. Ocean Data View 4.0. Oceanography 11(2), 19-21.

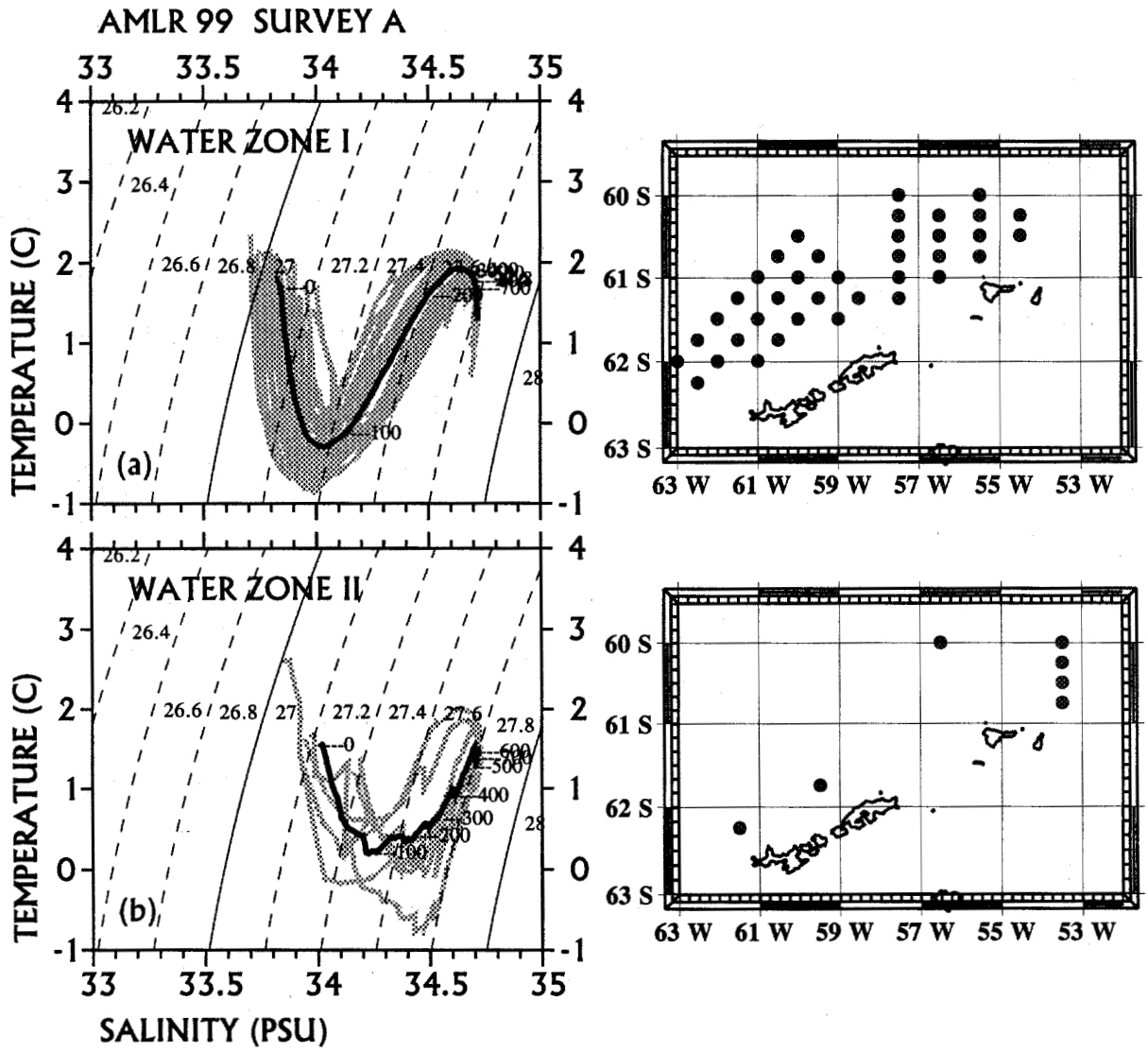


Figure 1.1 Temperature/Salinity (T/S) curves for various water zones in the AMLR study area. The gray area is the T/S envelope of all stations identified as having the water zone characteristics. The heavy black curve is the mean T/S curve for each water zone. Inset maps show the location and numbers of stations belonging to each water zone. (A) Survey A, Water Zone I; (b) Survey A, Water Zone II.

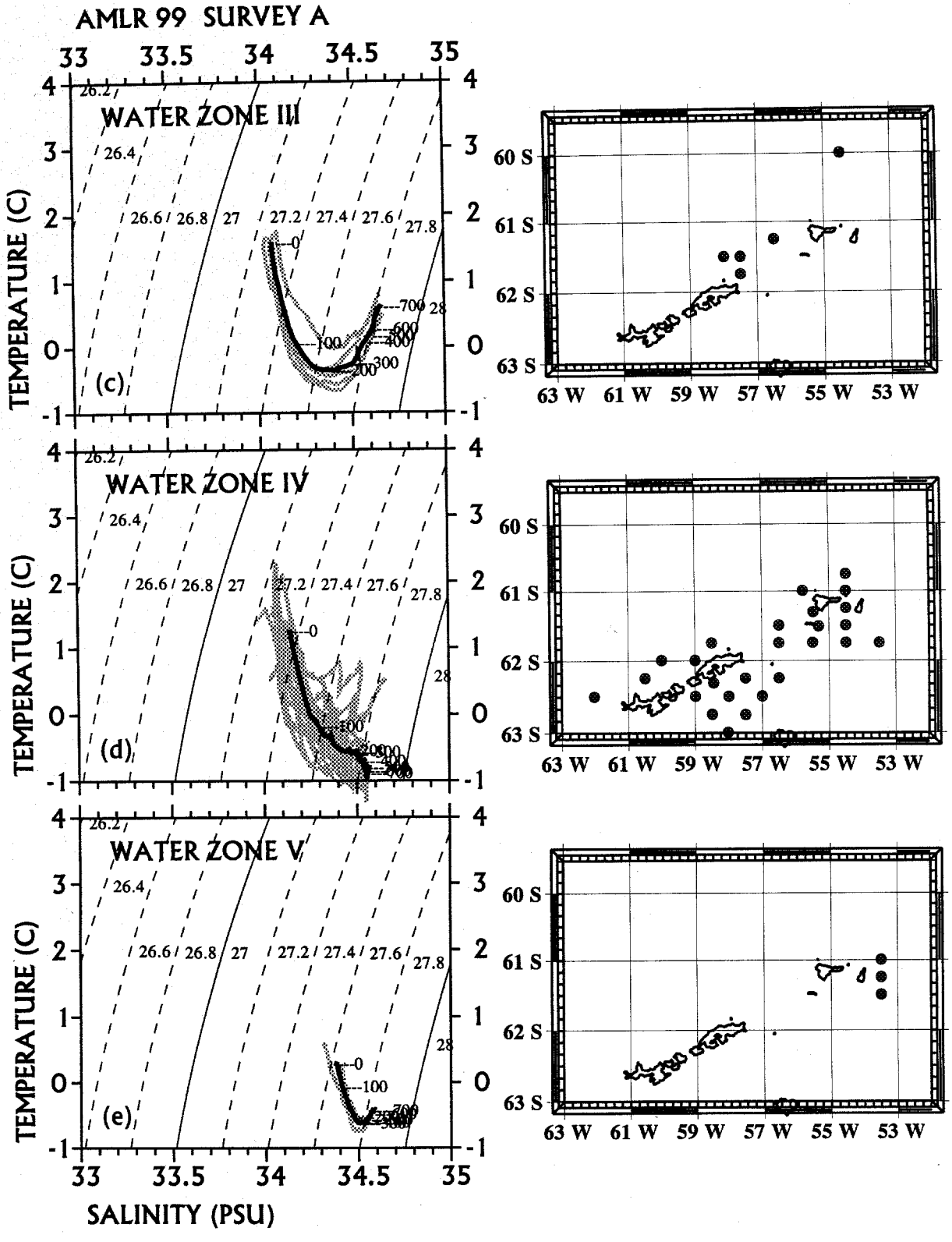


Figure 1.1 (cont.) (c) Survey A, Water Zone III; (d) Survey A, Water Zone IV; (e) Survey A, Water Zone V.

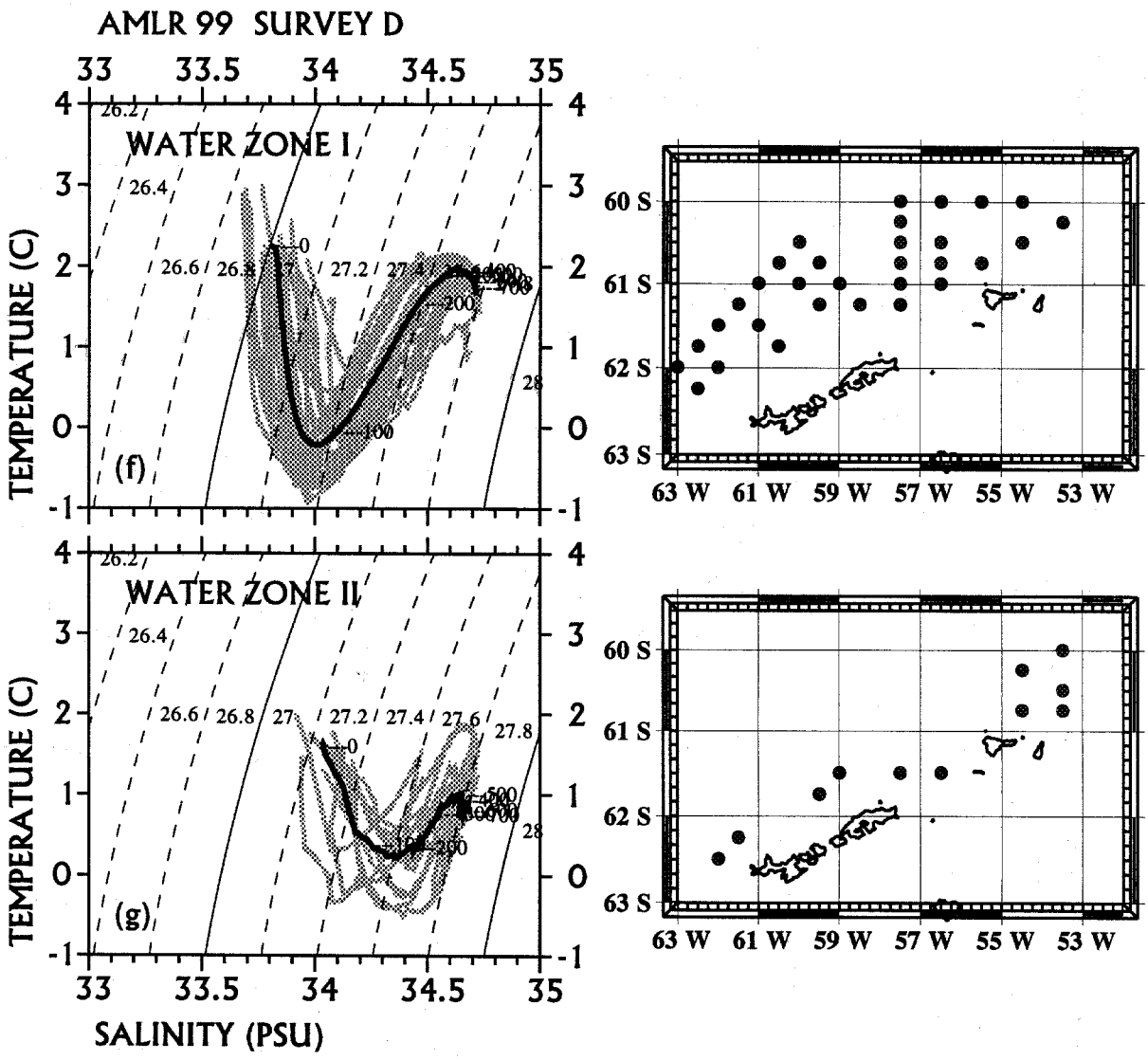


Figure 1.1 (cont.) (f) Survey D, Water Zone I; (g) Survey D, Water Zone II.

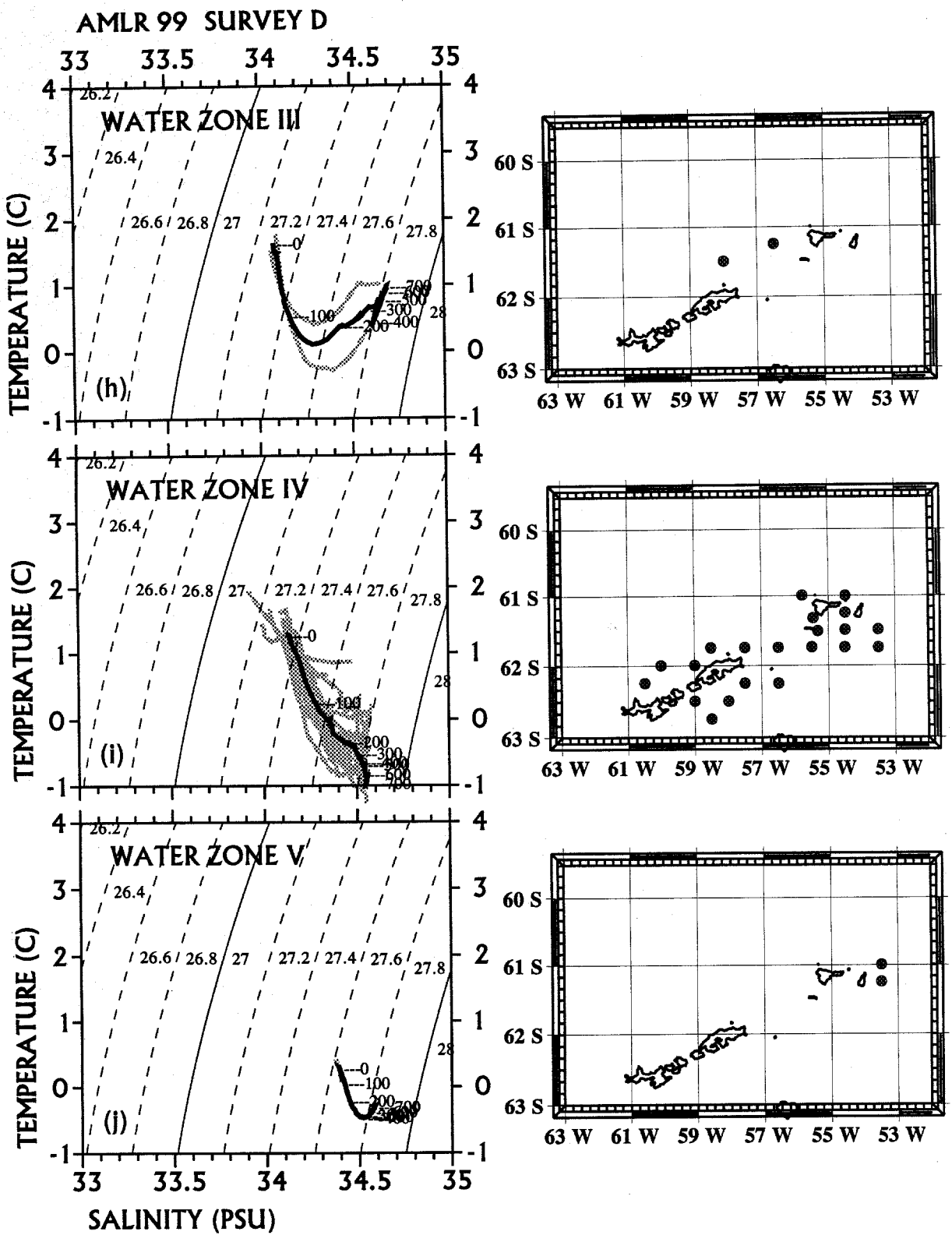


Figure 1.1 (cont.) (h) Survey D, Water Zone III; (i) Survey D, Water Zone IV; (j) Survey D, Water Zone V.

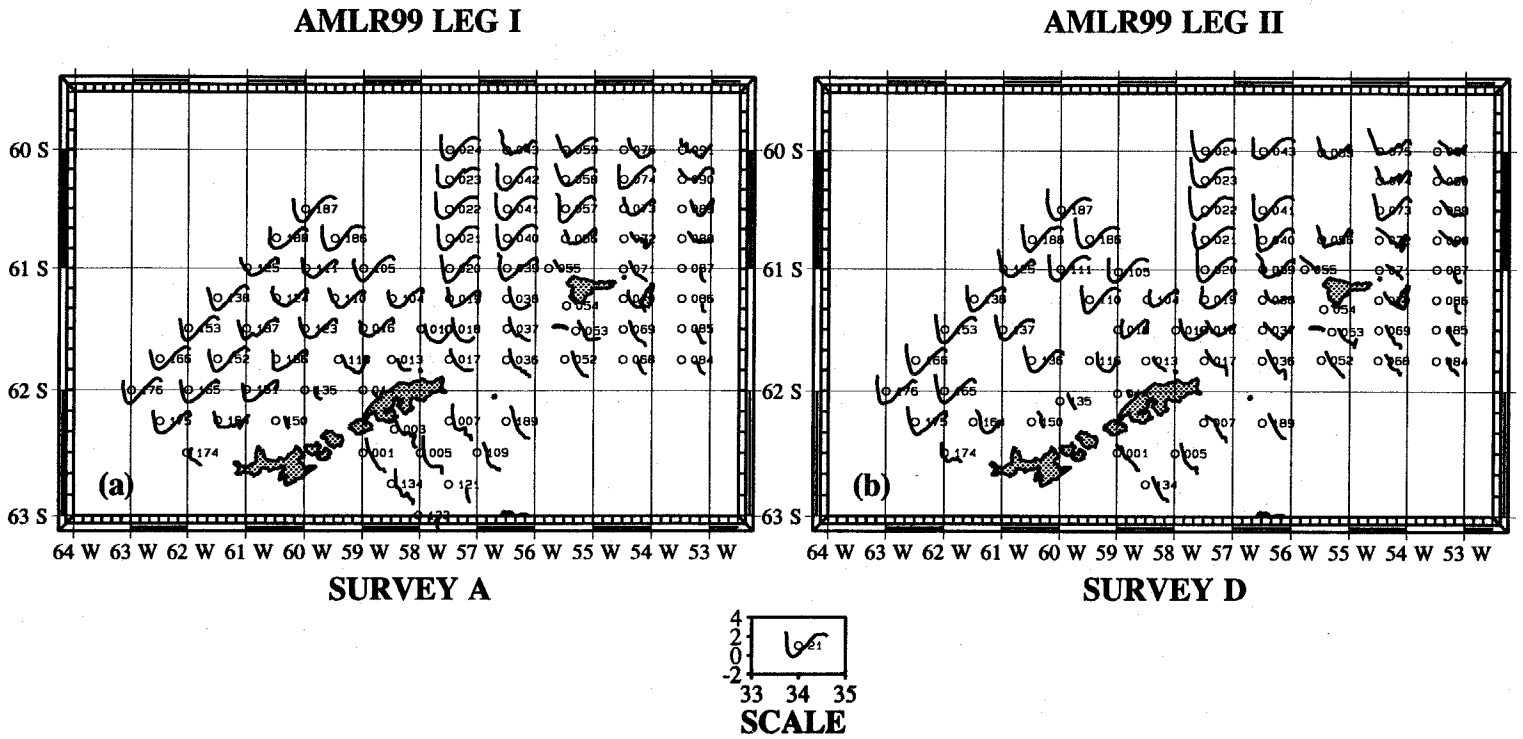
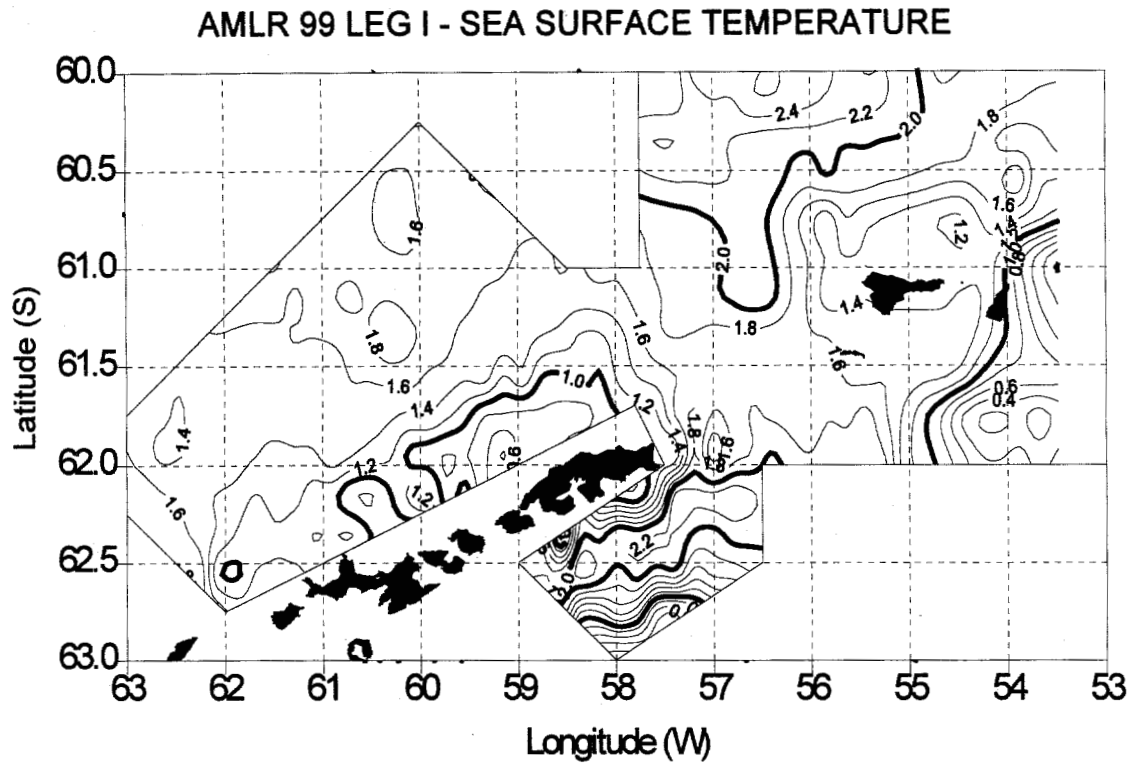


Figure 1.2 Temperature/Salinity curves for individual stations plotted at the station locations. The circle representing station location is plotted at S=34, T=+0.5 (see scale inset). (a) Survey A, Leg I; (b) Survey D, Leg II.



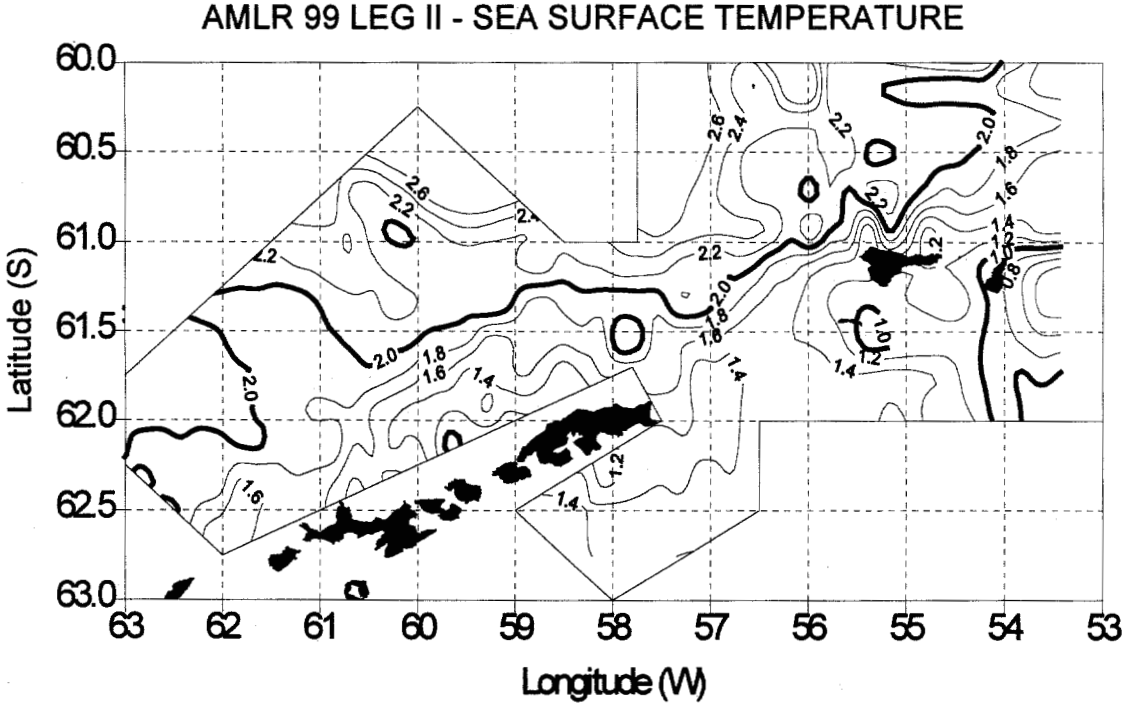
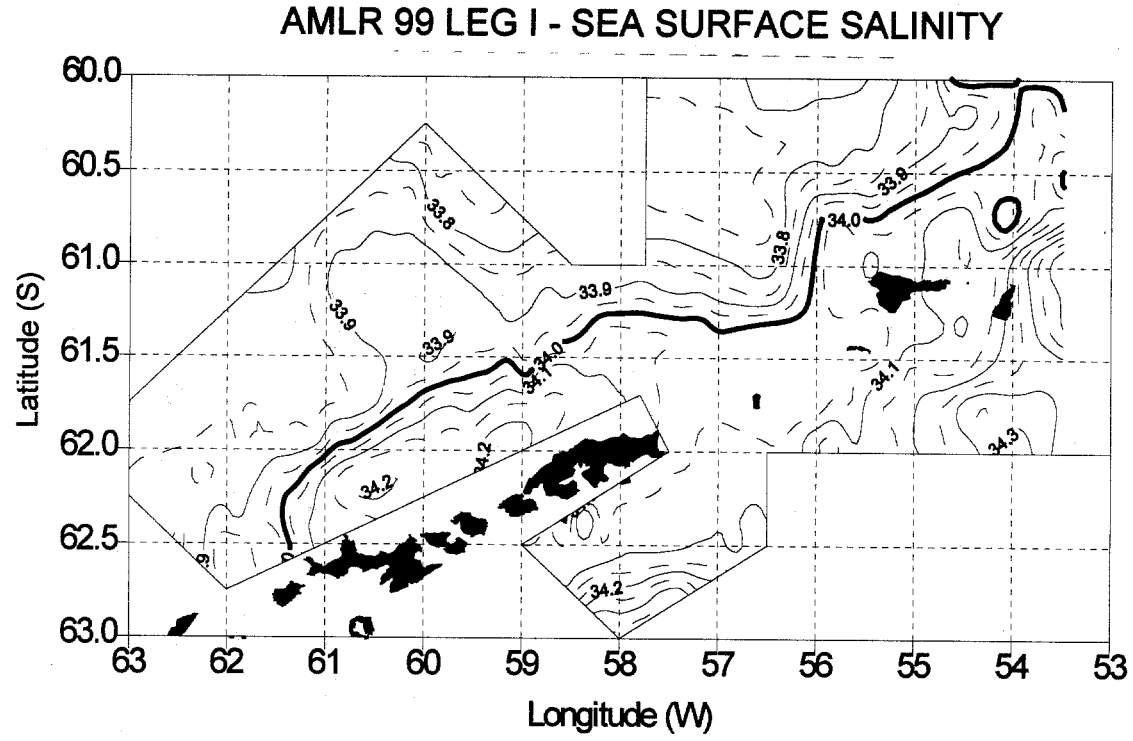


Figure 1.3a Horizontal maps of near surface oceanographic conditions (temperature) in the AMLR study area during Legs I and II. Data are from the continuously recorded underway environmental system.



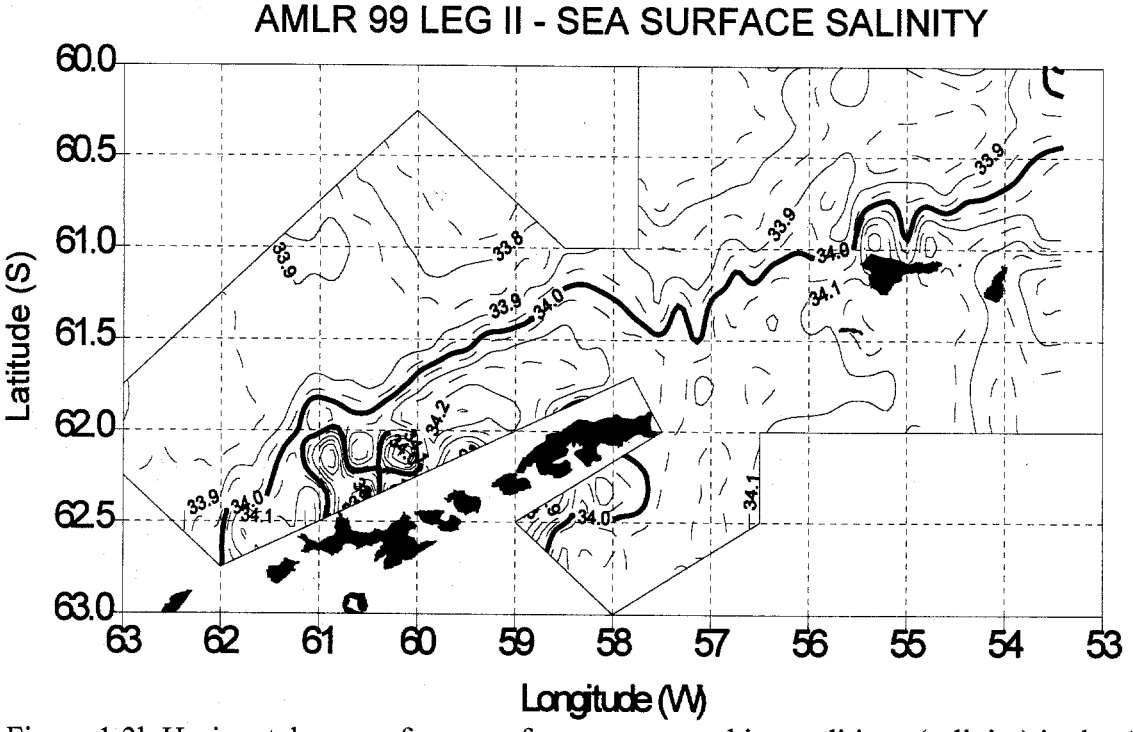


Figure 1.3b Horizontal maps of near surface oceanographic conditions (salinity) in the AMLR study area during Legs I and II. Data are from the continuously recorded underway environmental system.

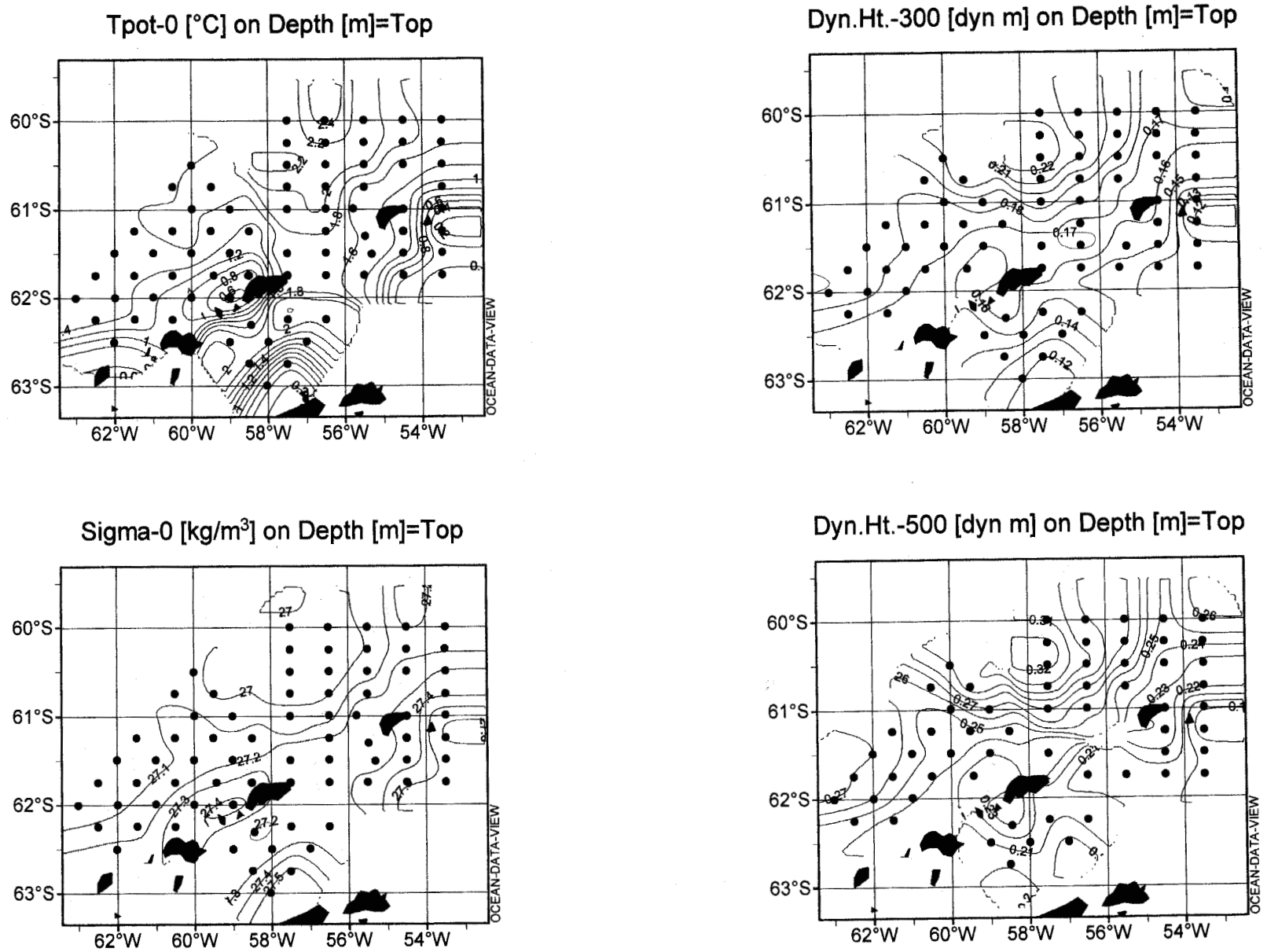


Figure 1.4a Surface temperature, density, and the dynamic topography of the surface relative to 300 and 500dbar during Leg I.

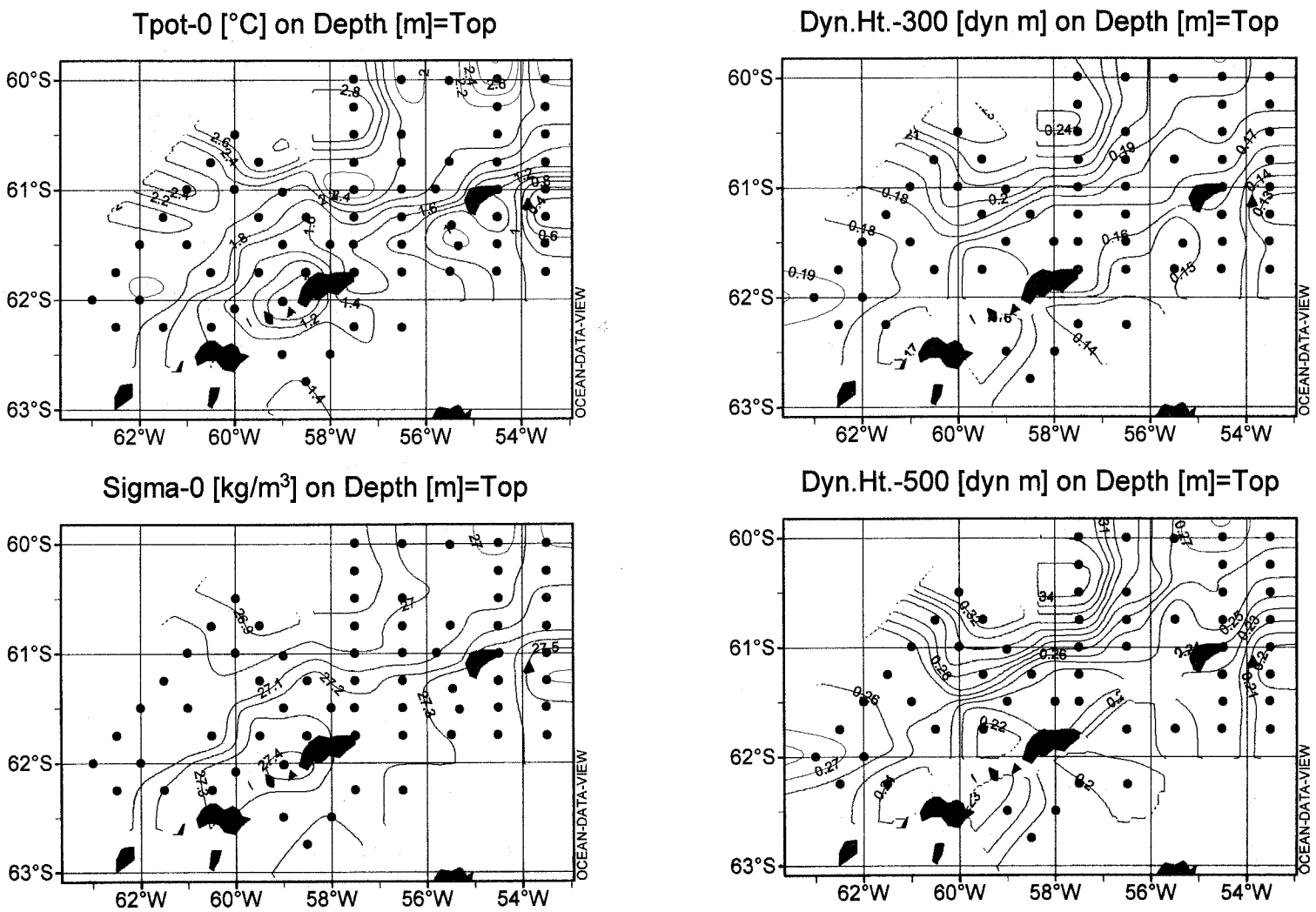
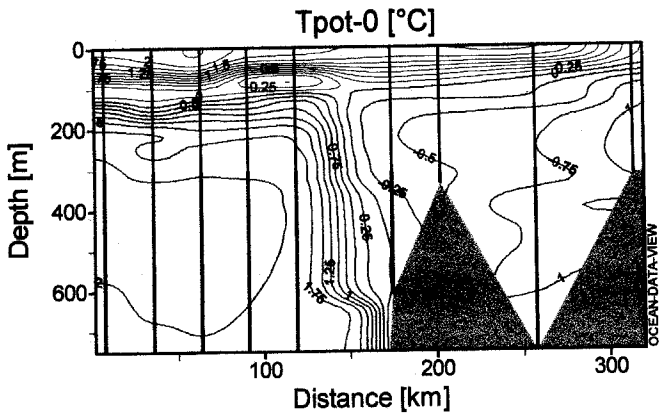
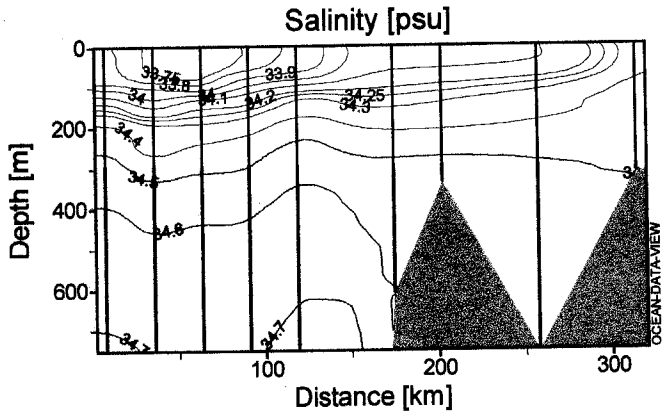
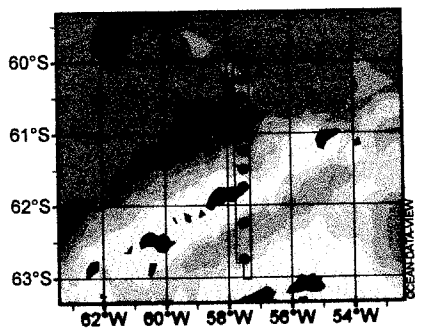
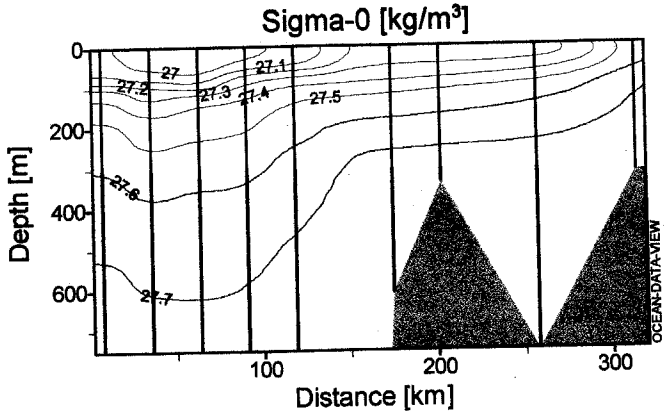


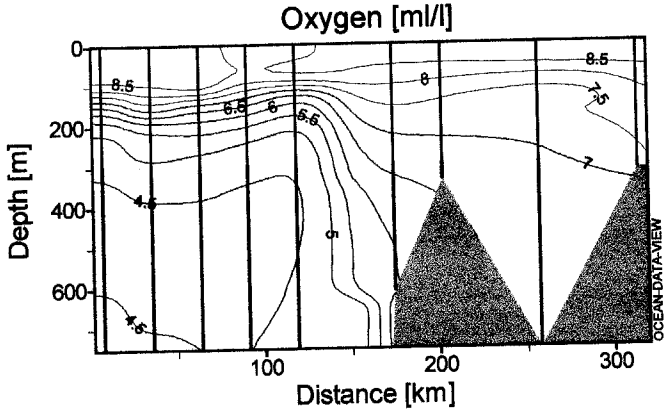
Figure 1.4b Surface temperature, density, and the dynamic topography of the surface relative to 300 and 500dbar during Leg II.











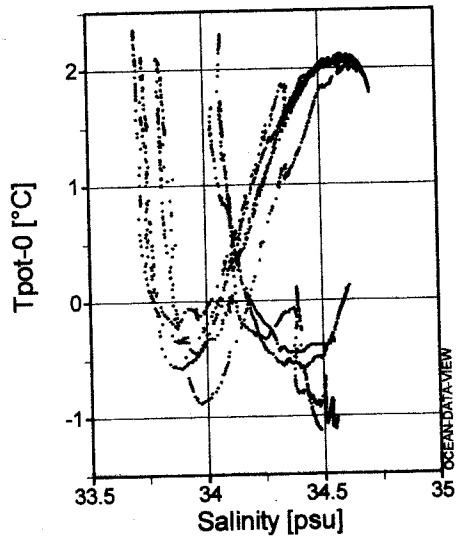


Figure 1.5a Section along 57°30'W meridian during Leg I.

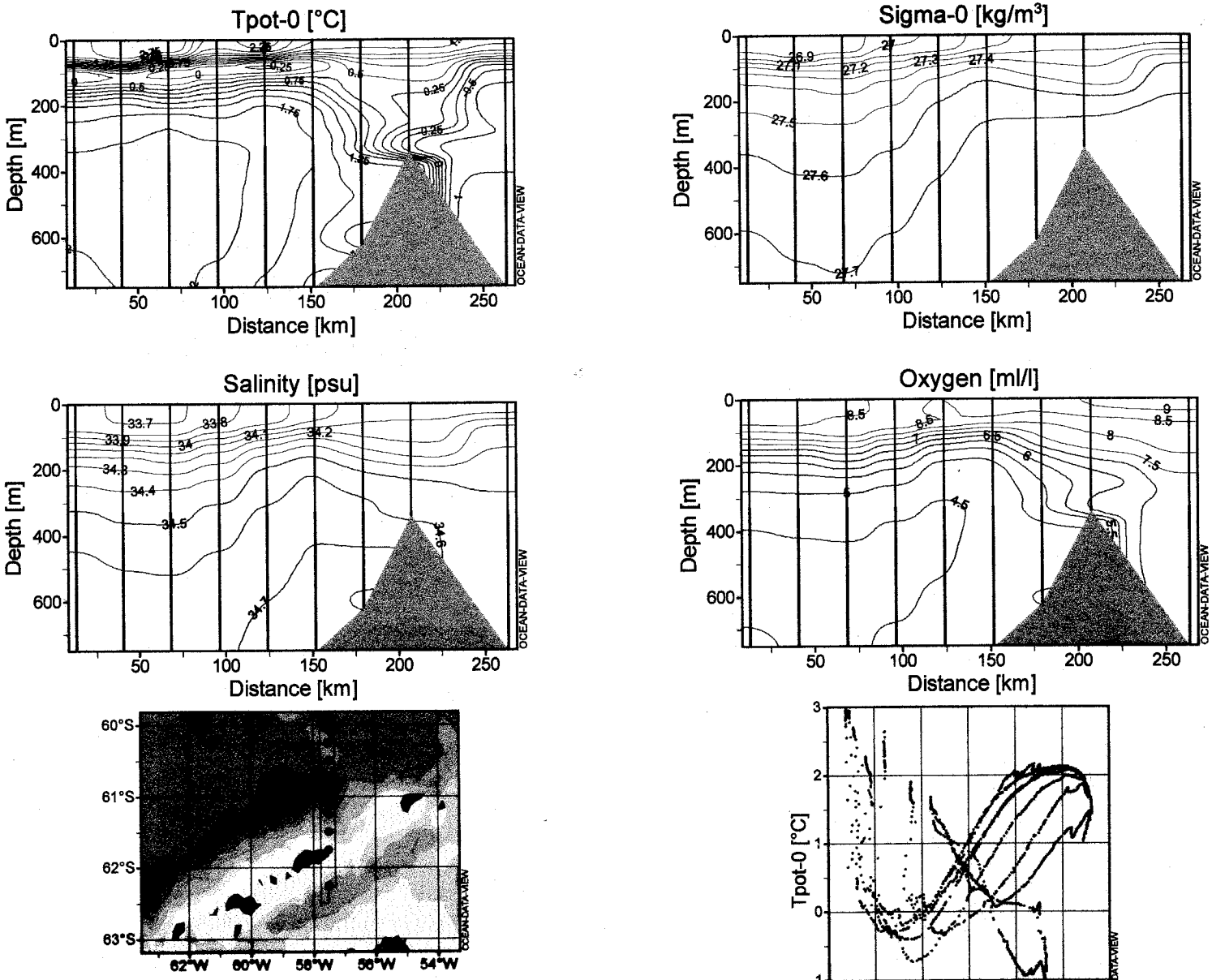


Figure 1.5b Section along 57°30'W meridian during Leg II.

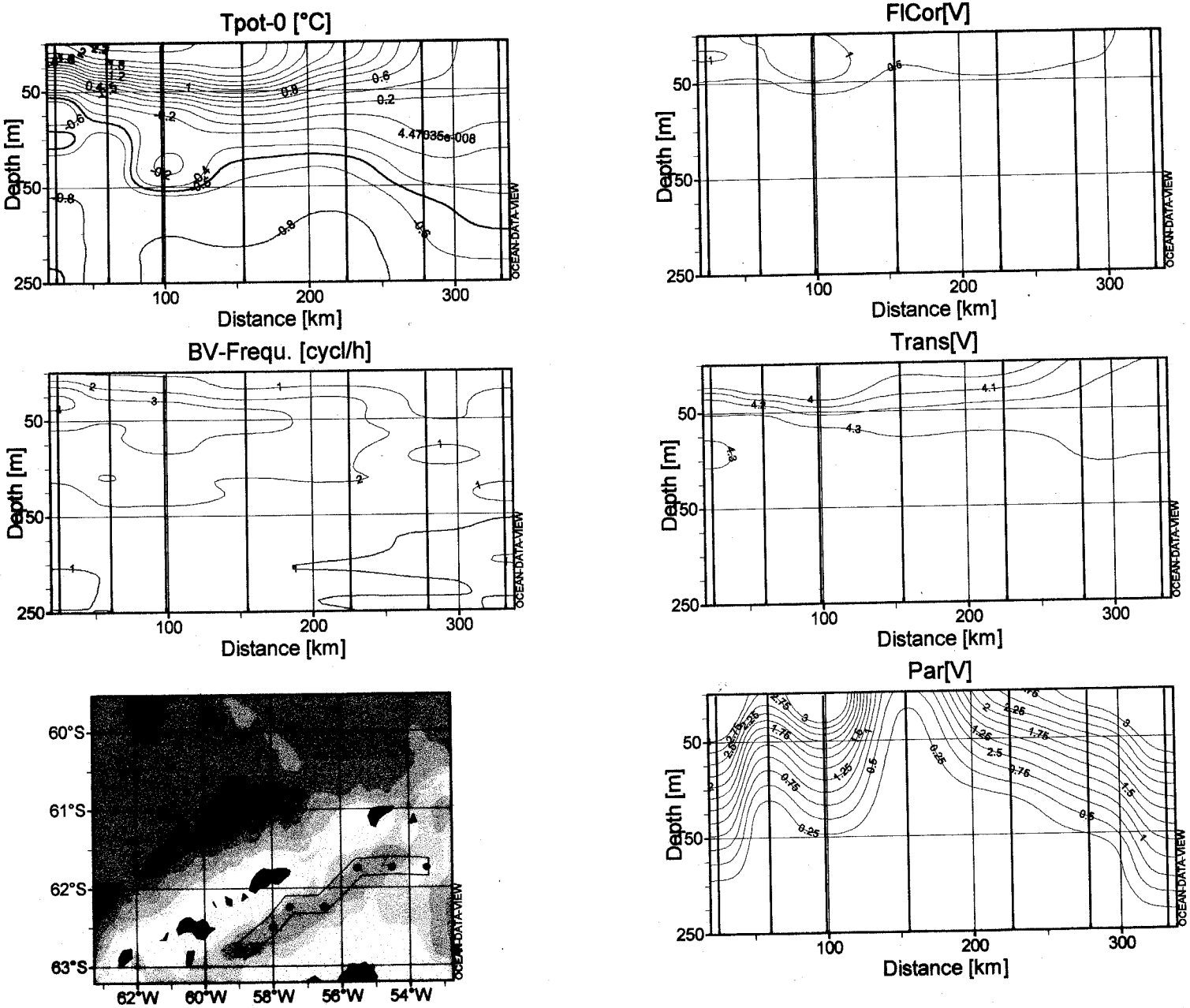


Figure 1.6a Bransfield Strait section during Leg I.

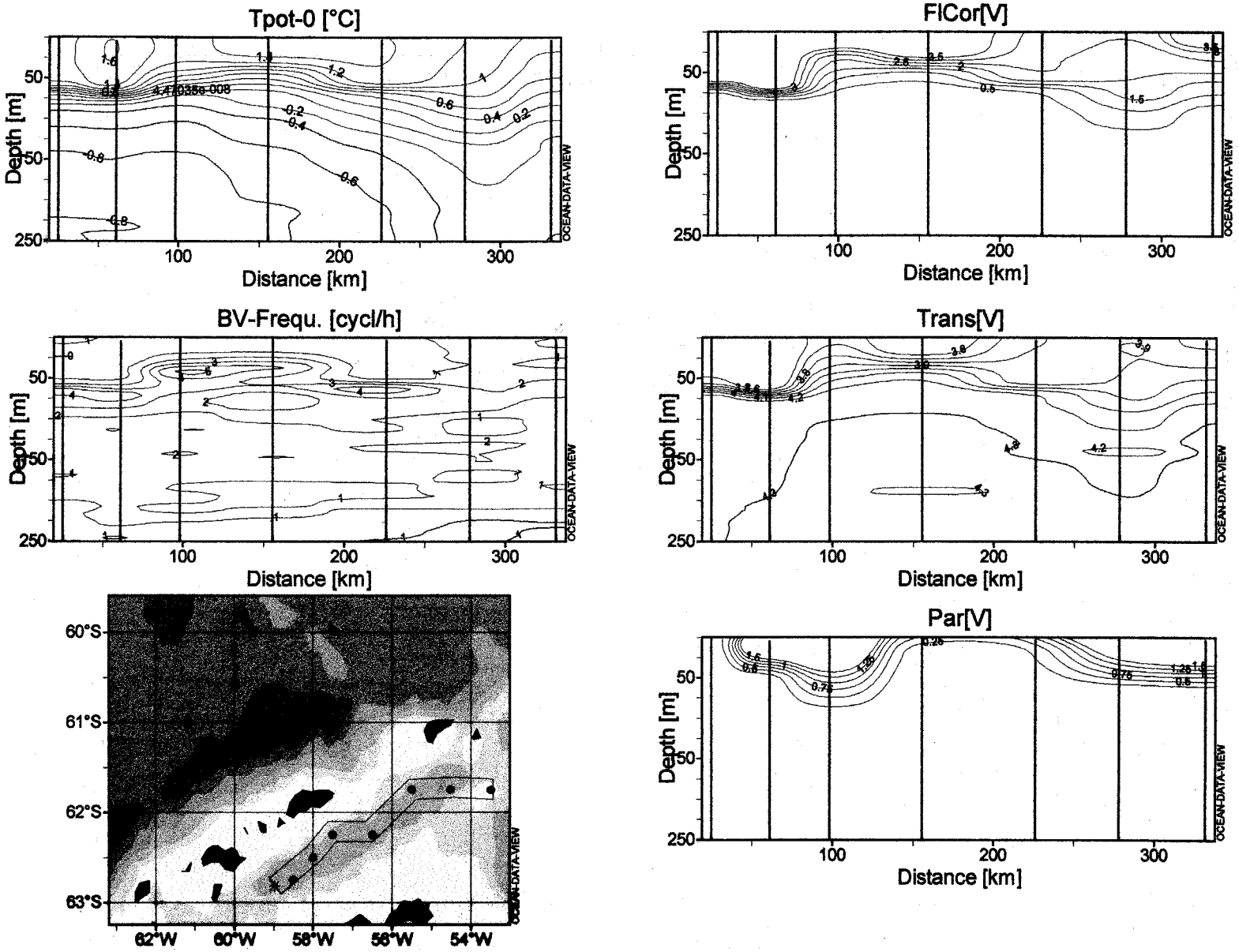


Figure 1.6b Bransfield Strait section during Leg II.

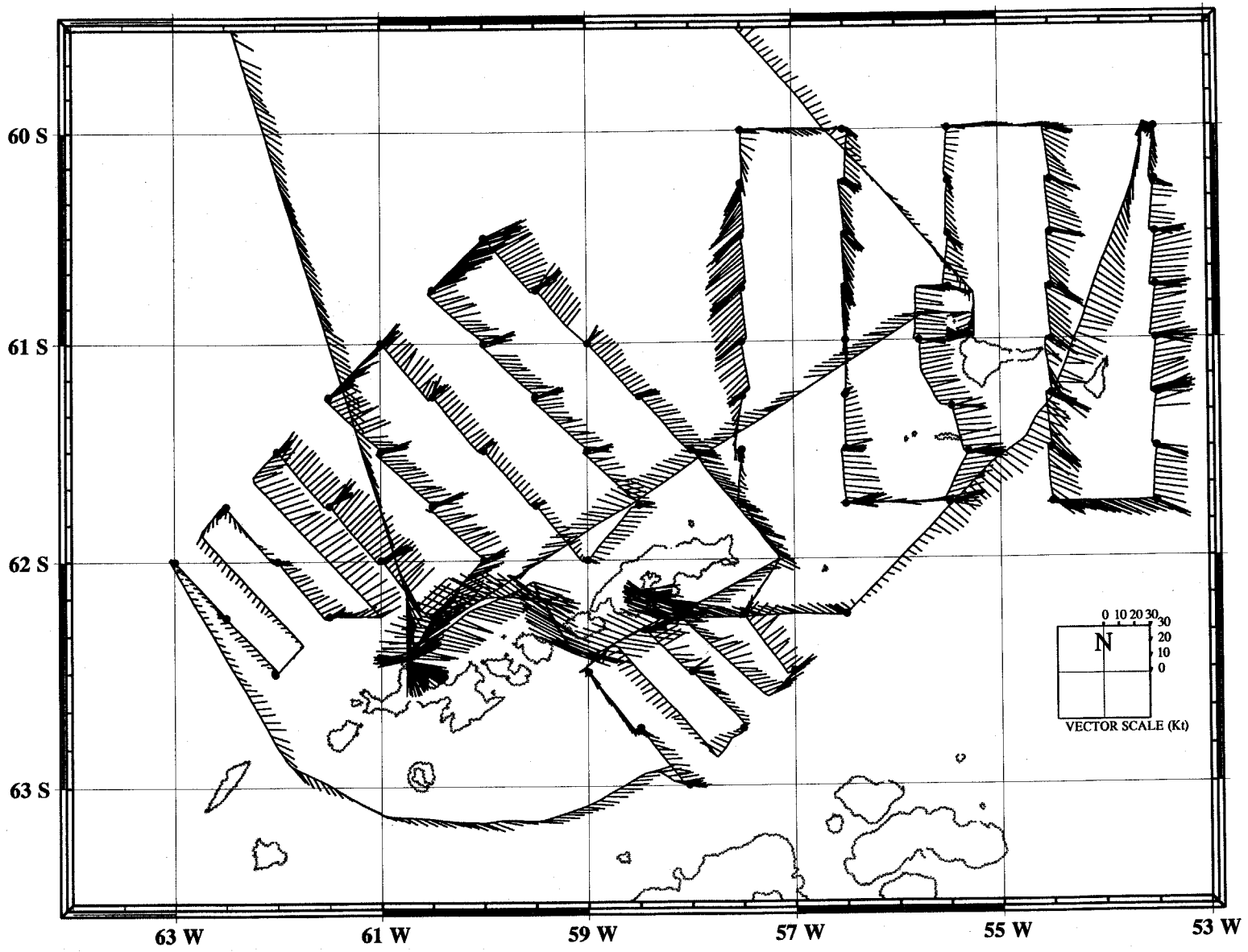


Figure 1.7a Wind vectors at hourly intervals along the survey track lines during Leg I.

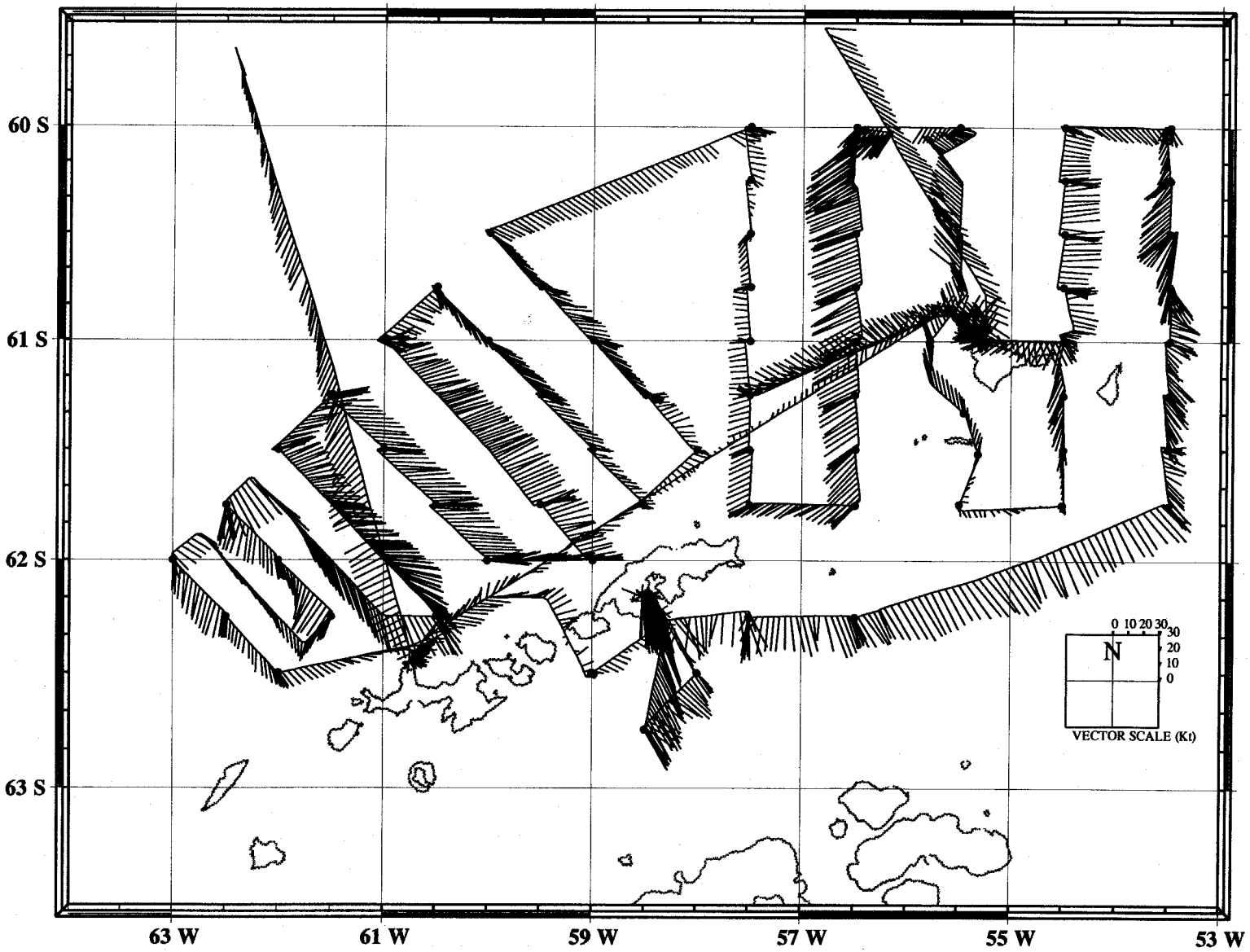


Figure 1.7b Wind vectors at hourly intervals along the survey track lines during Leg II.

2. Phytoplankton; submitted by Osmund Holm-Hansen (Leg I), Christopher D. Hewes (Legs I and II), Erwin Guzman (Leg I), Guillermo Aravena Cuevas (Leg I), Vicente E. Chacon Chade (Leg II), Susana B. Giglio Munoz (Leg II), and Hardy R. Wellmann Ruiz (Leg II).

2.1 Objectives: The overall objective of our research project was to assess the distribution and concentration of food reservoirs available to the herbivorous zooplankton populations throughout the AMLR study area during the austral summer. Specific objectives of our work included: (1) to determine the distribution and biomass of phytoplankton in the upper water column [surface to 750 meters (m)], with emphasis on the upper 100m; (2) to determine the rate of primary production throughout the euphotic zone; (3) to determine the species and size-class distributions of the phytoplankton; and (4) to examine the importance of physical, chemical, and optical characteristics in the upper water column as controlling factors for the distribution and photosynthetic activity of phytoplankton.

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

(A) Sampling Strategy:

The protocol relied on the following ways to obtain water samples for analyses or to acquire data from various sensors: (1) Water samples were obtained from 10-liter Niskin bottles (with Teflon covered springs), which were closed at eleven standard depths (5, 10, 15, 20, 30, 40, 50, 75, 100, 200, and 750m or within 10m of the bottom at the shallow stations) from every upcast of the CTD/carousel unit. Leg I occupied 78 stations and Leg II occupied 67 stations. These water samples were used for measurements described below. (2) Water from the ship's clean water intake line (approximately 4m depth) was used to monitor phytoplankton concentrations continuously during the entire cruise (see Section 1, Physical oceanography) and also to obtain samples for extraction of chlorophyll-a (chl-a) between some CTD/carousel stations. (3) The sensors used for acquiring data included instruments to record solar irradiance (both incident and *in situ*), fluorometers to record *in vivo* chl-a fluorescence, and transmissometers to determine the attenuation of collimated light by both scattering and absorption.

(B) Measurements and Data Acquired:

(1) Chlorophyll-a concentrations: Chl-a concentrations in the water samples (10 depths from 5 to 200m) from the Niskin bottles at every CTD/carousel station were determined by measurement of chl-a fluorescence after extraction in an organic solvent. Sample volumes of 100 milliliters (ml) were filtered through glass fiber filters [Whatmann GF/F, 25 millimeters (mm)] 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 polyethylene centrifuge tubes (with leak proof screw caps), and the photosynthetic pigments allowed to extract at 4°C for at least 12 hours. The samples were then shaken, centrifuged, and the clear supernatant poured into cuvettes

(13 x 100mm) for measurement of chl-a fluorescence before and after addition of two drops of 1.0 N HCl. Fluorescence was measured in a Turner Designs Fluorometer (model #700), which had been calibrated using spectrophotometrically determined chl-a concentrations. Stability of the fluorometers was verified daily by use of a sealed, solid fluorescence standard (Turner Designs, Inc). Data from the fluorometer mounted on the carousel were used to provide a continuous profile of chl-a concentrations in the upper water column. However, as the fluorescence yield per unit chl-a is decreased by solar radiation, these data were corrected by use of an algorithm relating *in vivo* chl-a fluorescence to chl-a concentrations. This algorithm was developed from analysis of data we acquired on previous AMLR cruises.

(2) Primary production: Rates of primary production were measured daily during Leg I whenever there was a CTD/carousel station between 07:00 and 10:00. Water samples from eight depths (from 5 to 75m) were poured into 50ml clear polycarbonate screw-cap tubes and inoculated with 5 microcuries (μCi) of ^{14}C-labeled sodium bicarbonate. Duplicate tubes were used for each depth, in addition to one tube from 5m and one from 75m which were kept in the dark and were used to estimate the rate of dark-fixation of CO_2. These tubes were attached to a Plexiglas frame with sections of neutral density screening to simulate the irradiance at the depths from which the phytoplankton had been sampled. The frame with the tubes was placed in a wooden incubator with pumped surface sea water (which just covered the tubes) for temperature control. The incubator was in a relatively shade-free area on the ship's upper deck. The irradiance incident upon the samples ranged from 95% of incident radiation for the 5m sample to 0.5% for the sample from 75m. At the end of the incubation period (8-10 hours), the samples were filtered through GF/F glass fiber filters (25mm). The filters were placed in 7ml glass scintillation vials and any inorganic ^{14}C eliminated by fuming with HCl fumes for at least 10 hours. The filters and vials were dried at 35°C and then sealed and stored until analysis. Fixed radioactivity in the samples was determined by conventional liquid scintillation techniques, using a Wallac 1215 liquid scintillation counter in J.L. Iriarte's laboratory at the Universidad De Magallanes, Punta Arenas.

(3) Photo-physiological state of the phytoplankton: Simultaneous with the primary production measurements, water samples from high-light conditions (5m) and from low-light conditions (between 50 to 100m) were treated in a similar fashion except that replicate water samples from each of the above depths were exposed to the eight different irradiances (95 to 0.5% of incident solar radiation). The resulting photosynthesis vs irradiance data will be analyzed together with the physical and optical characteristics of the upper water column to determine the degree of acclimation of the phytoplankton to variable conditions of irradiance.

(4) Inorganic nutrients: Water samples for measurement of nitrite + nitrate, phosphate, and silicic acid were taken from 5m depth at every station during Leg I, in addition to detailed profiles of these nutrients at a few of the productivity stations. Using the valve close to the bottom of the Niskin bottle, approximately 40ml were poured directly into acid-cleaned 50ml polyethylene screw-cap bottles. The samples were frozen immediately at -20°C and later transported with dry

ice to N. Silva's laboratory at the Universidad Catolica de Valparaiso, Chile, where all analyses were performed with an autoanalyzer.

(5) Phytoplankton cell size and species composition: For both Legs I and II, a water sample (100ml) from 5m depth at every CTD/carousel station was preserved with borate-buffered formalin. These preserved samples will be returned to our home laboratories for floristic examination by inverted microscope techniques which will provide information on species composition, cell size and numbers, and cell volumes. Additionally, data on cell size distributions were acquired by using membrane polycarbonate filters (1.0, 2.0, 5.0, 8.0, 10 and 20μm pore size) to determine the percentage of chl-a that passed through these various pore dimensions. Differences between using low vacuum (1/3 atmosphere) and gravity to obtain the filtrates were also examined. The filtrates from these fractionations were put through a GF/F filter, which supposedly retains all phytoplankton, including the picoplankton. Chlorophyll concentrations in the various fractions were measured as described in (1) above. Some of the filtrates from the above filtrations using the polycarbonate filters were also incubated with ^{14}C to measure rates of primary production in each of the size fractions.

(6) Biomass and organic carbon concentrations: Three methods will be used to estimate phytoplankton biomass expressed as cellular organic carbon. (a) The data obtained from the microscopic observations (see above) will be used to calculate cellular organic carbon by standard equations relating cell volumes to cellular organic carbon. (b) Data on chlorophyll concentrations from both extracted and *in situ* measurements will be used to estimate phytoplankton biomass using published algorithms of carbon:chlorophyll ratios. (c) Data on beam attenuation coefficients (C_t) as obtained with the transmissometer on the CTD/carousel unit and also the one on the pumped sea water line will be used to estimate particulate organic carbon by use of an algorithm that was developed from data previously obtained in the AMLR program.

(7) Solar radiation measurements: Sensors used to measure solar irradiance included: (a) continuous recording (every minute) of Photosynthetically Available Radiation [PAR; 400 to 700 nanometers (nm)] using a 2-pi sensor (model #QSR-240, Biospherical Instruments, Inc.) which was mounted in a shade-free location close to the primary production incubators; (b) attenuation of PAR in the water column using a light sensor with a cosine response (model # QCP-200L, Biospherical Instruments, Inc.) mounted on the CTD/carousel unit.

2.3 Results and Tentative Conclusions:

(A) Phytoplankton biomass at 5m depth during Leg I was lowest [<0.2 milligrams chl-a per cubic meter (mg m^{-3})] in the pelagic waters to the northwest of the South Shetland Islands and Elephant Island, and highest (>1.0mg m^{-3}) in the coastal waters north of Livingston Island and Elephant Island and in pelagic waters to the northeast of Elephant Island (Figure 2.1A). During Leg II, chl-a concentrations increased to over 2.0mg m^{-3} in Bransfield Strait waters (Figure 2.1B). The mean chl-a concentrations at 5m depth during Legs I and II were 0.63 and 1.30mg m^{-3}, respectively.

(B) The patterns of integrated chl-a values in the upper water column during both legs were similar to the patterns of chl-a concentrations at 5m (Figure 2.2). At the low chl-a stations the integrated values for chl-a were generally <20 milligrams per square meter (mg m^{-2}) (0 to 100m), as compared to the chl-a rich stations where the values exceeded 200mg m^{-2}. The most dramatic changes in integrated chl-a values from Leg I to Leg II were in Bransfield Strait waters (compare Figures 2.2A with 2.2B). The mean integrated values for chl-a during Legs I and II were 44.5 and 83.1mg m^{-2}, respectively.

(C) Profiles of chl-a concentrations in the upper water column differed in various regions of the survey grid as described in past reports. Stations with the lowest chl-a concentrations in surface waters generally have a deep chl-a maximum at approximately 80m depth and are found in Drake Passage waters (Water Zone I, as described in Section 1, Physical oceanography). Stations in the other water zones generally have higher chl-a values in the upper 20-30m of the water column and no deep chl-a maximum. At some of the stations in Water Zone I there were elevated chl-a concentrations in the upper 20-30m of the water column in addition to the characteristic deep chl-a maximum. In past years such stations have shown higher than usual concentrations of silicic acid in the upper mixed layer, suggesting some input of nurients from contiguous water masses. The number of such stations this year was higher than in recent years.

(D) Data from the primary productivity incubations show that the phytoplankton were very efficient at fixing carbon dioxide at low light levels (at approximately 1% of surface irradiance the assimilation numbers were consistently >0.5mg carbon fixed per mg chl-a per hour); reach maximal photosynthetic rates at relatively low irradiances; and show considerable photoinhibition of photosynthesis with increasing irradiance (Figure 2.3). The photosynthetic parameters derived from the data in Figure 2.3 are shown in Table 2.1. Additional productivity vs irradiance experiments were also performed using replicate water samples from 5m and from 50-100m depths and subjecting them to the eight different irradiances ranging from 0.5% to 100% of incident radiation (data for these experiments are not shown). The marked inhibition of photosynthetic rate at high light levels seen in these experiments, coupled with the data in Figure 2.3, indicate that the phytoplankton throughout the AMLR survey grid have characteristics of dark adapted cells. There were no obvious differences in the photosynthetic parameters for the phytoplankton from Water Zone I as compared to samples from the other water zones.

(E) Profiles of the rate of primary production with depth in the water column differed appreciably, depending upon the incident solar irradiance and the distribution of phytoplankton with depth (Figure 2.4). When the phytoplankton were predominantly in the upper mixed layer, the profiles for rate of production were fairly similar to the profiles of chl-a concentrations, except for the photoinhibition of photosynthesis noted in the upper 20m (Figures 2.4A and 2.4B). The mean irradiance for the samples in Figure 2.4A was very high (>1600 microEinsteins per square meter per second), resulting in a marked decrease in photosynthetic rate for the samples from 5 and 10m depths. The data in Figure 2.4C are from a typical Water Zone I station. The mean irradiance for the samples during this incubation was low (700 microEinsteins per square meter per second), and hence no photoinhibition was noted. The decrease in rate of production

from 5m down to 40m was due to light limitation as solar radiation is attenuated with depth. The increases in production at 50 and 75m were due to the increasing biomass at these depths as they lie within the sub-surface chl-a maximum which characterizes Water Zone I stations. Station A136 was classified as being in Water Zone I, but it was one of those aberrant Water Zone I stations which show relatively high phytoplankton biomass in the upper water column in addition to having enhanced chl-a values at 75m depth (Figure 2.4D). The integrated primary production at such stations was high due to the substantial phytoplankton biomass throughout the upper 75m of the water column. The light level was high during this incubation (1190 microEinsteins per square meter per second), which resulted in the inhibition of photosynthesis as noted in Figure 2.4D.

(F) Chl-a concentrations at Bransfield Strait stations were moderate (<1.0mg m^{-3}) during Leg I (Figure 2.5A). During the 35 days that elapsed before these same stations were sampled in Leg II, a massive bloom developed that extended from approximately south of Admirality Bay (Station 134) to northeast of Elephant Island (Station 084; Figure 2.5B). The greatest concentrations of chl-a were found at Station D005, which had fairly uniform concentrations of chl-a (7-8mg m^{-3}) down to ~60m. Integrated chl-a at this station was 460mg m^{-2} (0 to 100m) . This is the highest integrated chl-a value that we have measured during the 10 years of the AMLR surveys. The only other year that showed near-comparable concentrations of chl-a in Bransfield Strait was in February of 1994. Physical oceanographic characteristics of the water column for the Bransfield Strait transect are discussed in the Physical oceanography section of this report.

(G) Our preliminary experiments showed that vacuum filtration was not a suitable method for the determination of small nanoplankton and picoplankton (Table 2.2). The results from both productivity and chlorophyll experiments showed that gravity filtration yielded similar percent concentrations of total values, whereas vacuum resulted with very high values of chlorophyll concentration and lower productivity values. Although picoplankton [<2 micrometers (μm)] biomass was found to be high, we believe that most of the reports found in the literature indicating high picoplankton values in Antarctic waters are over-estimates since vacuum filtration has been a standard routine method for obtaining such data. All results discussed below refer to size fraction data obtained through gravity filtration.

During both legs, most of the phytoplankton biomass analyzed was contained in the nanoplankton (<20μm) as compared with the microplankton (>20μm) size fraction (Table 2.3). During Leg I, the 2-5μm size class contained the greatest fraction of total chlorophyll, with the 1-2μm size class having the next highest percentage. Total chlorophyll biomass increased in the AMLR survey area between Legs I and II, reflecting the seasonal increase during February as noted from previous years. For the size fractions, the greatest increase in biomass occurred for the microplankton (128%) and 10-20μm (47%) size classes, while the picoplankton (1-2μm) size class showed a decrease. For convenience, we group the microplankton and 10-20μm size classes into the >10μm category.

In general for the Antarctic, nanoplankton are considered to dominate low biomass containing waters, and microplankton dominate blooms. Our data support this idea (Table 2.3), and implies that a kinetic-like relationship occurs between the relative contribution of large-sized phytoplankton and the concentration of chlorophyll (Figure 2.6). We have learned this year that there may be differences for this relationship dependent upon physical characteristics of the environment. For Drake Passage waters (Water Zone I), >10μm cell dominance occurred when chl-a concentrations approach 0.4mg m^{-3} (Figure 2.6A). For Bransfield Strait waters (Water Zone IV), >10μm cell dominance maximized at approximately 3.0mg m^{-3} (Figure 2.6B). The reason that the size spectrum of phytoplankton changes between low and high chlorophyll concentrations is believed to be a function of protozoan grazing. This was demonstrated indirectly by our long-term natural culture experiment (Figure 2.7). After a lag phase of 3-4 days (0.46 doublings day^{-1}), total chlorophyll concentrations increased exponentially (0.78 doublings day^{-1}; Table 2.4) reaching a total concentration of 36mg m^{-3} after 10 days, and reflect rates similar to those reported in the literature. It should be noted that this concentration of phytoplankton grown from unenriched natural seawater is higher by a factor of 4-5 than rich blooms usually found in the Bransfield Strait (see Figure 2.5). Total phaeopigments (a degredation product of chlorophyll) also increased (0.32 doublings day^{-1} during the lag phase, 0.49 doublings day^{-1} post lag phase; Figure 2.7A, Table 2.4).

Size fraction data revealed that the lag phase for total chlorophyll concentration was actually a phenomena of changing size distributions of the culture as it developed (Figure 2.7B), since most size classes >1μm increased exponentially, but at different rates (Table 2.4). At the start of the culture, the >10μm size fraction comprised only 22% of the total chlorophyll, while it comprised 97% on day 10. Carbon fixation was measured for the culture on day 7, and indicated that the nanoplankton fraction had Assimilation Numbers about 60% [1.3mg C $(mg\ chl)^{-1}\ h^{-1}$] that of the total [2.1mg C $(mg\ chl)^{-1}\ h^{-1}$]. The reason for these differences between nanoplankton and microplankton rates was probably protozoan grazing upon nanoplankton, and thereby controlling the increase of nanoplankton biomass. There is little microbial grazing control of microplankton biomass; this size class is thought to be controlled via macrozooplankton grazing. The shift from "lag phase" to exponential growth for total chlorophyll therefore occurred when the >10μm size classes contributed >50% of the total biomass (between days 3 and 4) (Figure 2.7A). The rate of increase in phaeopigments probably reflects the rate of increase in protozoan biomass, since most protozoan fecal matter cannot be retained by the filters used.

2.4 Disposition of the Samples and Data: The nutrient samples will be processed at the Universidad Catolica de Valparaiso (Chile). The radiocarbon samples were processed at the Universidad de Magallanes in Punta Arenas. All other samples will be returned to SIO for processing. All data obtained during the cruises have been stored on 1 Gbyte Jaz disks. After compilation of the final data sets, a copy of all data will be deposited with the AERG office in La Jolla, CA. Copies of any of our data sets are available to all other AMLR investigators upon request.

2.5 Problems and Suggestions: There were no serious shortcomings this year in regard to facilities or equipment needed on the ship to do our work satisfactorily.

2.6 Acknowledgments: We want to express our gratitude and appreciation to the entire complement of the R/V *Yuzhmorgeologiya* for their generous and valuable help during the entire cruise. They not only aided immeasurably in our ability to obtain the desired oceanographic data, but they also made the cruise most enjoyable and rewarding in many ways. We also thank all other AMLR personnel for help and support which was essential to the success of our program, especially to the Physical Oceanography group who meshed some of our instruments and sensors with their data acquisition systems.

Table 2.1 Photosynthetic vs. Irradiance curve parameters of the photosynthetic response curve to light intensity incorporating photoinhibition (Platt and Jasby),

$$P^B = P_s^B (1-e^{-(\alpha I/PsB)}) e^{-(1-e-(\beta I/PsB)}$$

where α is the positive and β the negative rates of response to light, P_s^B is the theoretical maximal response, P_{max}^B is the maximal production rate obtained at light intensity I_m, I_k is the conventional index of light adaptation, and I_s is an analogous parameter when the photoinhibition model is used.

Parameter	Value
α	0.055mg C (mg CHL)$^{-1}$ hr^{-1} (μEins m^{-2} s^{-1})$^{-1}$
β	0.00179mg C (mg CHL)$^{-1}$ hr^{-1} (μEins m^{-2} s^{-1})$^{-1}$
P_S^B	3.25mg C (mg CHL)$^{-1}$ hr^{-1}
P_{max}^B	2.82mg C (mg CHL)$^{-1}$ hr^{-1}
I_k	51μEins m^{-2} s^{-1}
I_s	59μEins m^{-2} s^{-1}
I_m	210μEins m^{-2} s^{-1}

Table 2.2 Comparison of the percent of total chlorophyll and carbon fixation contained in size fractions when using gravity or vacuum filtration. Vacuum filtration resulted in high percentage yields of chlorophyll and low percentage yields of carbon fixation. Gravity filtration resulted in similar percentage yields for both chlorophyll and carbon fixation.

Station	Gravity Filtration			Vacuum Filtration		
	5 μm	2 μm	1 μm	5 μm	2 μm	1 μm
	CHL			CHL		
A133	57%	31%	1%	80%	55%	45%
A003	62%	36%	1%	66%	54%	54%
A166	58%	42%	6%	82%	87%	68%
A116	71%	------	------	------	47%	51%
A152	------	------	17%	------	------	33%
A136	66%	25%	1%	------	------	------
A019a	67%	9%	0%	------	------	------
A053	64%	30%	0%	------	------	------
	Carbon Fixation			Carbon Fixation		
A133	66%	29%	2%	66%	5%	2%
A116	53%	------	------	------	6%	1%
A152	------	------	13%	------	------	5%
A136	66%	14%	0%	------	------	------
A019a	79%	9%	6%	------	------	------
A053	52%	26%	0%	------	------	------

Table 2.3 Summary of results for size classed chlorophyll concentrations from Leg I and Leg II. Average percentage and concentration, the seasonal difference (from Leg I to Leg II) and percent change from Leg I, are listed for the various categories as discussed.

Size Fraction	% Total CHL		Average mg CHL m^{-3}		Seasonal Change	
	Leg I	Leg II	Leg I	Leg II	mg CHL m^{-3}	% of Leg I Total
n =	12	21	12	21	-----	-----
Total			0.63	2.02	1.39	221
>20 µm	19	46	0.07	0.87	0.81	128
10-20 µm	7	13	0.04	0.34	0.29	47
5-10 µm	18	14	0.13	0.37	0.24	38
2-5 µm	32	16	0.23	0.31	0.08	13
1-2 µm	21	7	0.14	0.09	-0.05	-8
<1 µm	3	2	0.01	0.04	0.03	5

Table 2.4 Growth rate data (in specific growth and doublings day^{-1}) and significance of exponential regressions (see Figure 2.7) for total and size classed pigments measured during the course of a natural culture. Rates of increase not found significant are indicated by NS.

Size Class	Specific Growth, d^{-1}	Doublings per day	r^2
Total (lag)	0.32	0.46	0.998
Total (post lag)	0.54	0.78	0.990
>10 µm	0.71	1.02	0.998
5-10 µm	NS	NS	NS
2-5 µm	0.16	0.23	0.945
1-2 µm	0.26	0.38	0.942
<1 µm	NS	NS	NS
Total Phaeopigment (lag)	0.223	0.32	0.963
Total Phaeopigment (post lag)	0.343	0.49	0.976

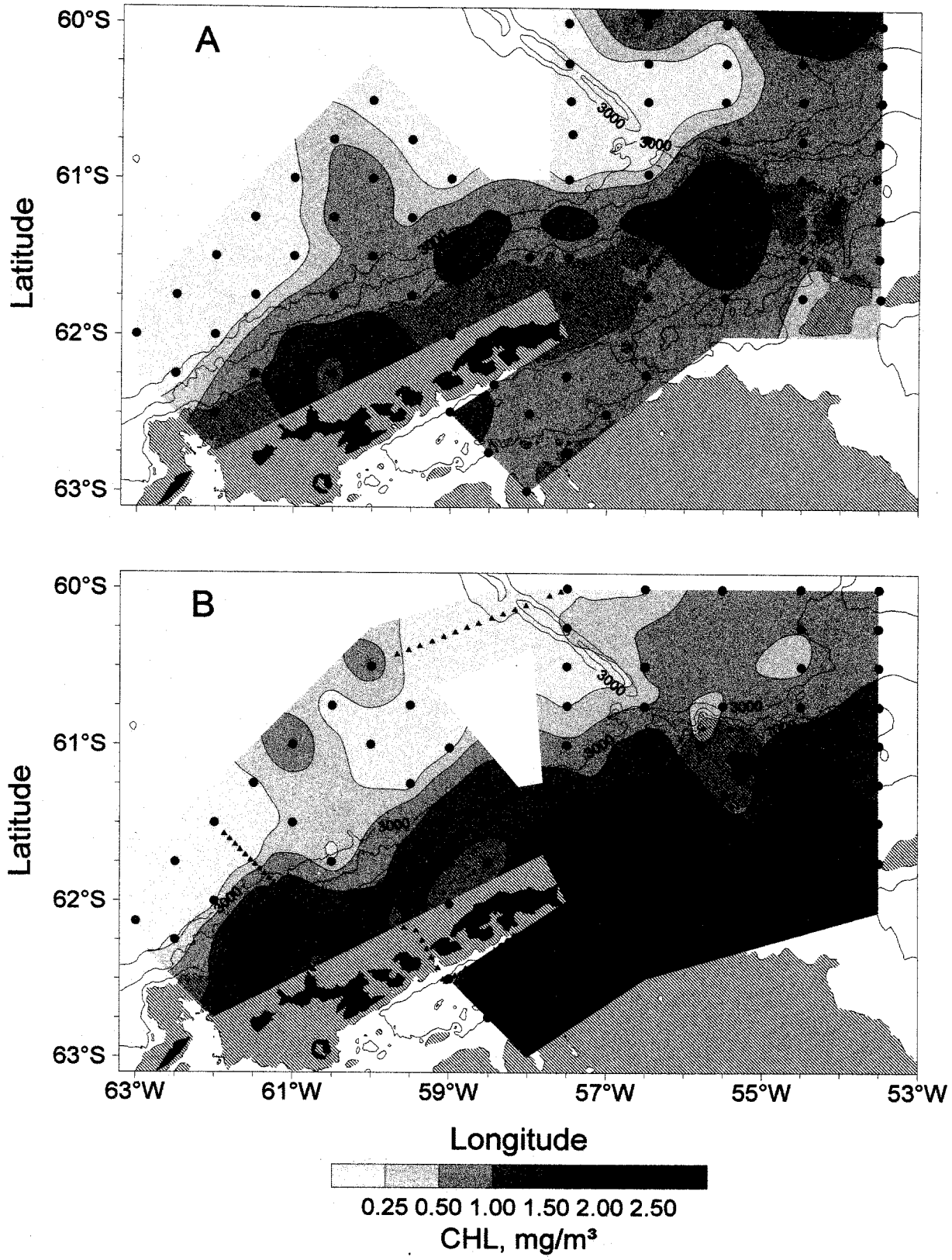


Figure 2.1 Concentration of chl-a at 5m depth throughout the large-area survey grid. (A) Survey A, Leg I; (B) Survey D, Leg II. The scale at the bottom refers to the chl-a concentrations in mg m^{-3}. Depth isopleths for 1000, 2000, and 3000m are shown as continuous lines; cross-hatched areas indicate depths less than 500m. Filled circles indicate station locations, filled triangles indicate location of samples taken from the continuous flow system.

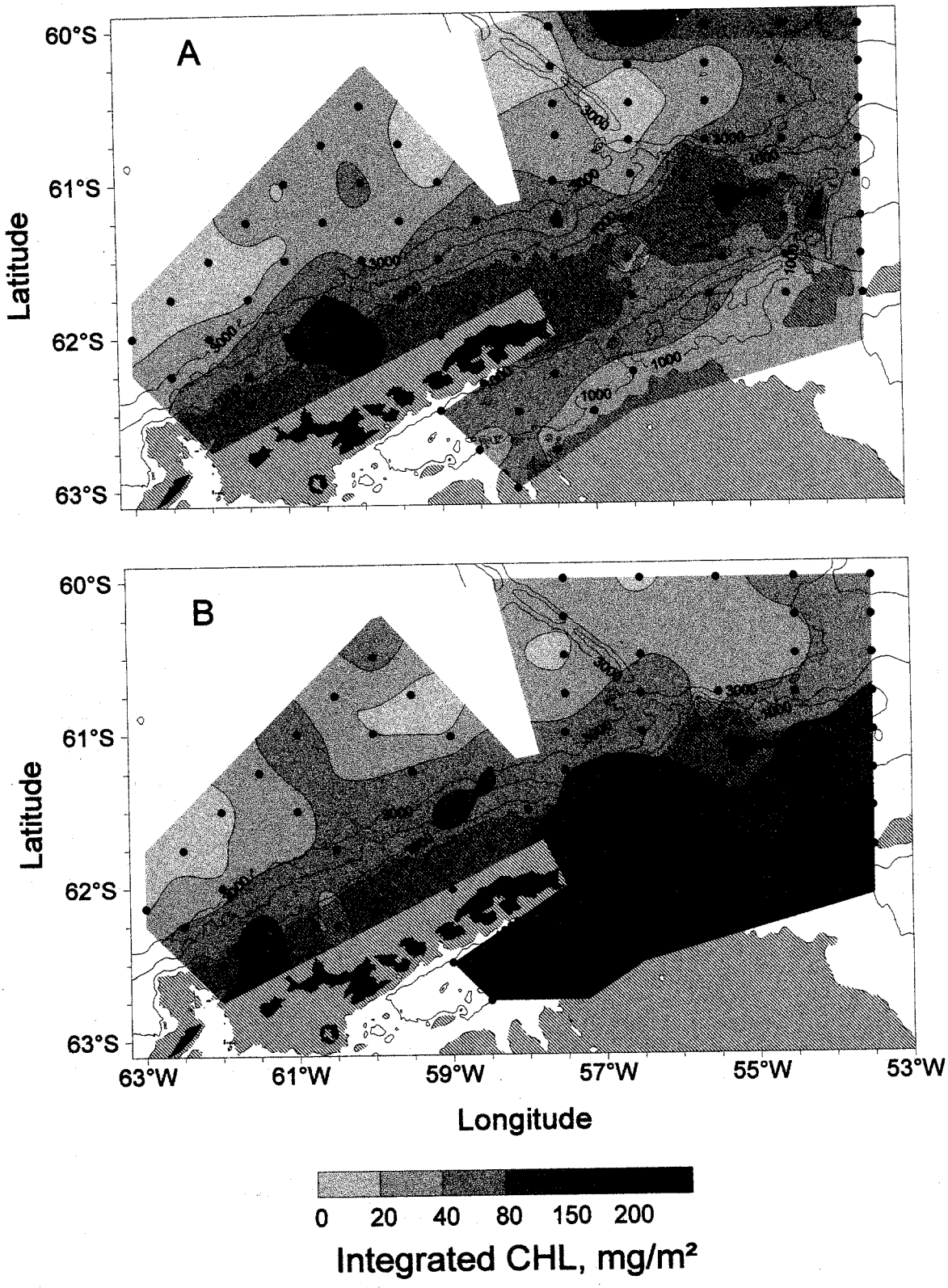


Figure 2.2 Integrated chl-a (0 to 100m) values throughout the large-area survey grid. (A) Survey A, Leg I; (B) Survey D, Leg II. The scale refers to the chl-a concentrations in mg m^{-2}; cross-hatched areas indicate depths less than 500m.

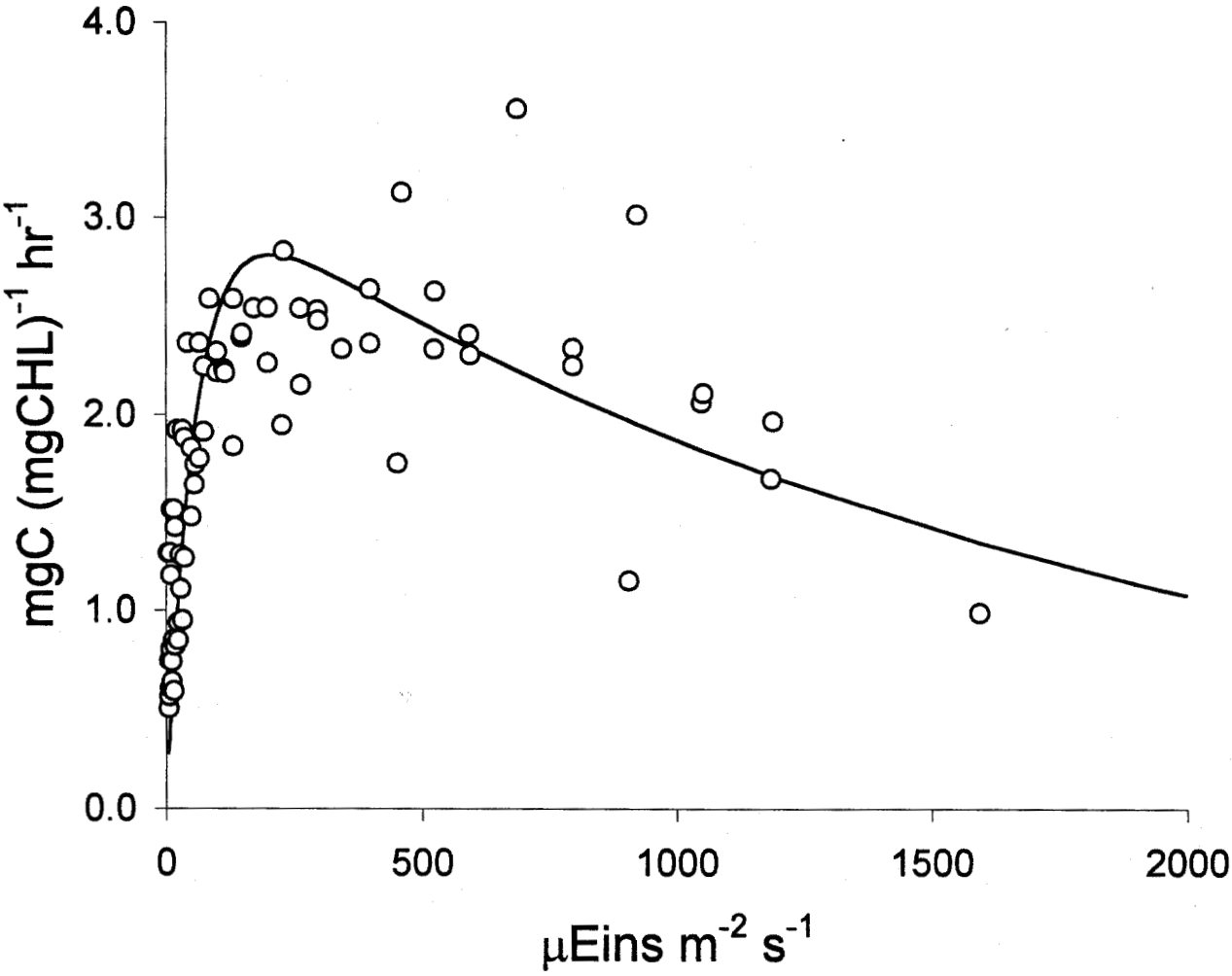


Figure 2.3 Rate of primary production (mg carbon fixed per mg chl-a per hour) as a function of the mean solar irradiance (microEinsteins per square meter per second) to which the samples were exposed during the on-deck incubation. The line represents the best fit of the experimental points assuming a photoinhibition effect. The photosynthetic parameters calculated from these data are listed in Table 2.1.

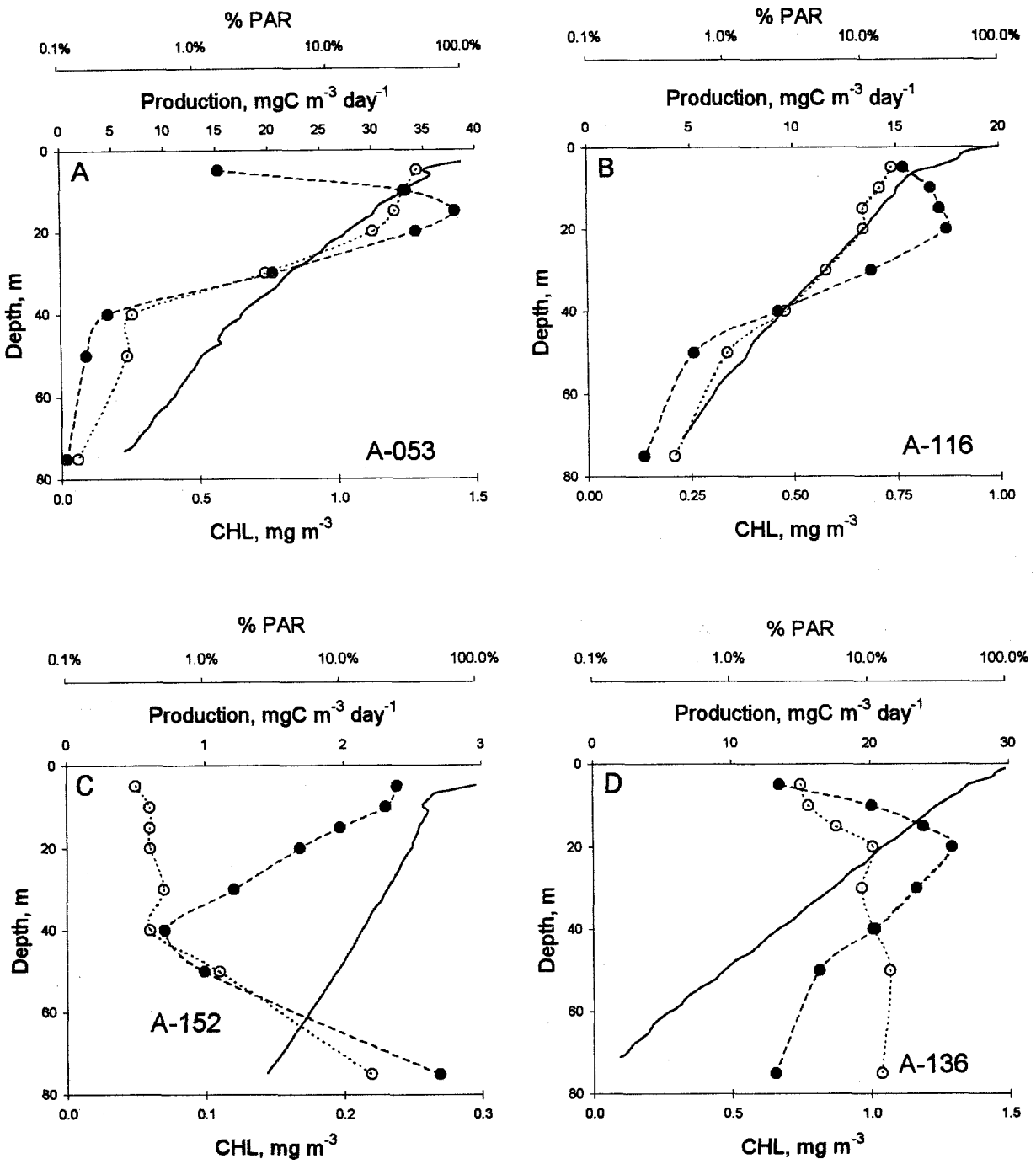


Figure 2.4 Profiles of rates of primary production and rates of sunlight attenuation in the upper water column (5 to 75m) at four stations as influenced by chl-a concentrations. Photosynthetically available radiation (PAR) has been set to 100% at the surface to facilitate visualizing the depth of the euphotic zone, which is assumed to be where the irradiance was 1% of incident PAR. Rates of primary production are shown as solid circles. Chl-a concentrations are shown as empty circles. Note change of scales for production and for chl-a concentrations. (A) Station A053, Water Zone IV; (B) Station A116, Water Zone II; (C) Station A152, Water Zone I; (D) Station A136, Water Zone I. The mean incident solar irradiances for the samples shown in A, B, C, and D were 1612, 1050, 700, and 1190 microEinsteins per square meter per second, respectively.

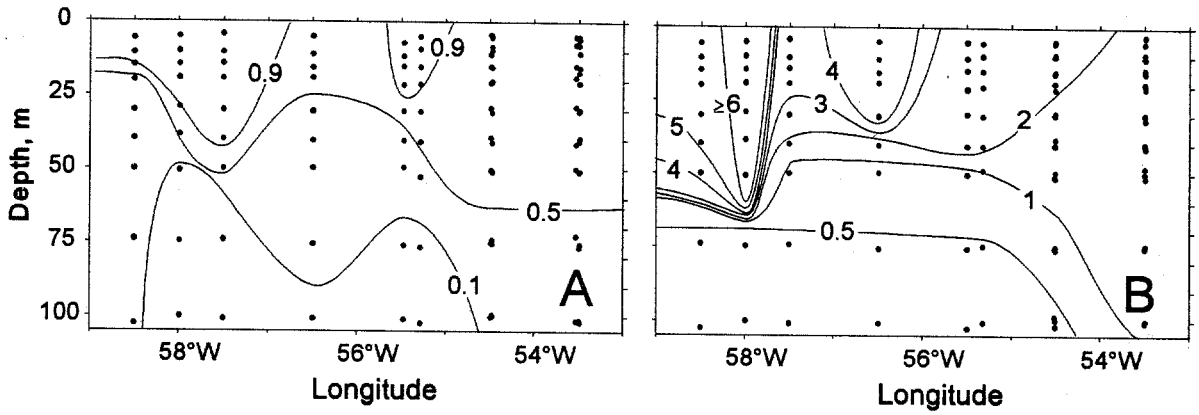


Figure 2.5 Profile of chlorophyll concentrations in Bransfield Strait for Leg I (A) and Leg II (B). Isolines and values are in mg chl-a m^{-3}; dots represent depths from which samples were taken. Values at 54.5°W represent averages between two stations (068 and 069), and those from 53.5°W represent averages between three stations (085, 086, and 087).

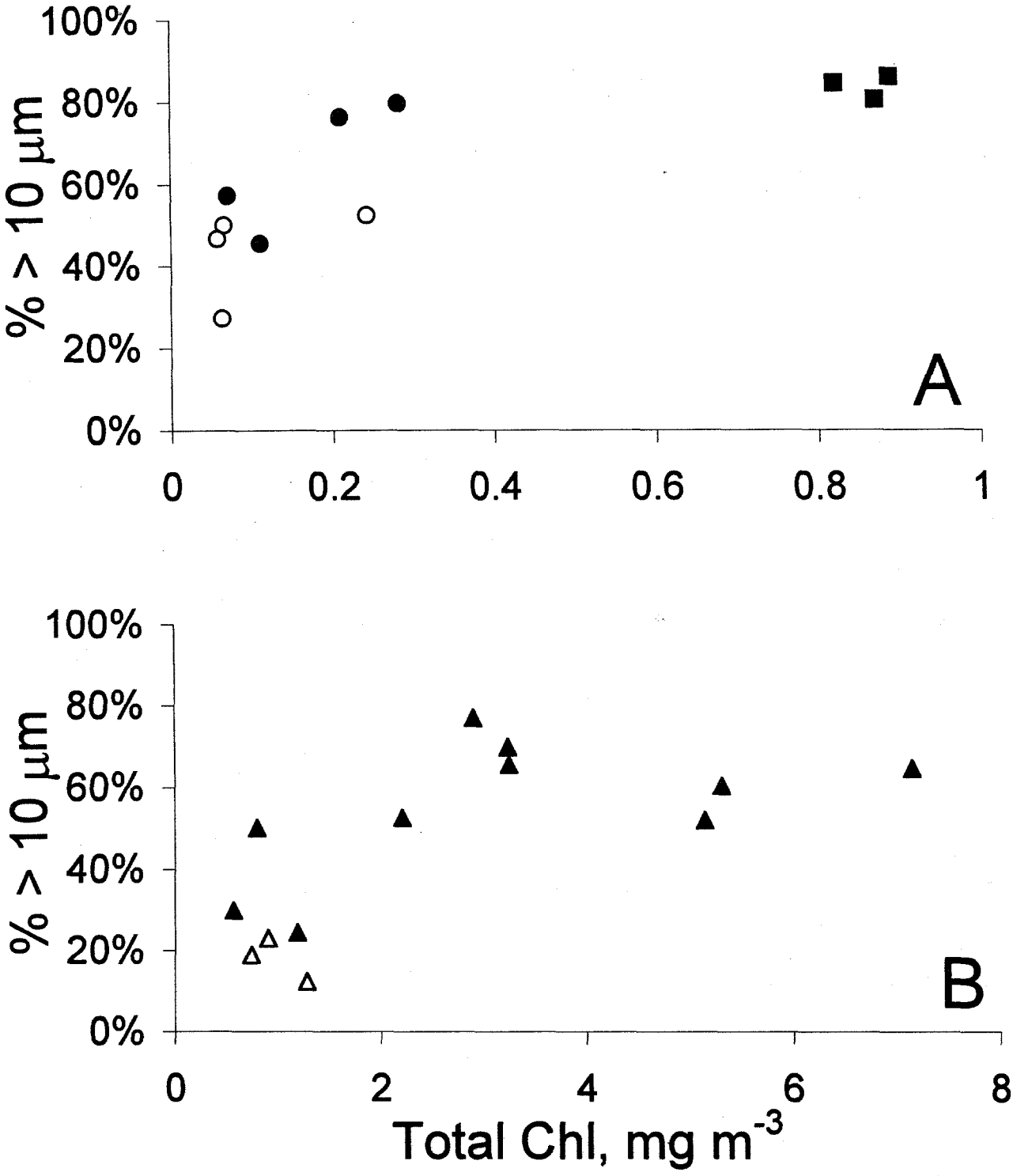


Figure 2.6 Relationship between percentage of chlorophyll contained in the >10µm size class with changing total chlorophyll concentration in (A) Drake Passage waters (Water Zone I); and (B) Bransfield Strait waters (Water Zone II). Note that the scale in A and B are different by a factor of 8. Drake Passage waters become microplankton dominated at lower chlorophyll concentrations than Bransfield Strait waters. Open symbols represent Leg I samples, closed symbols represent Leg II samples.

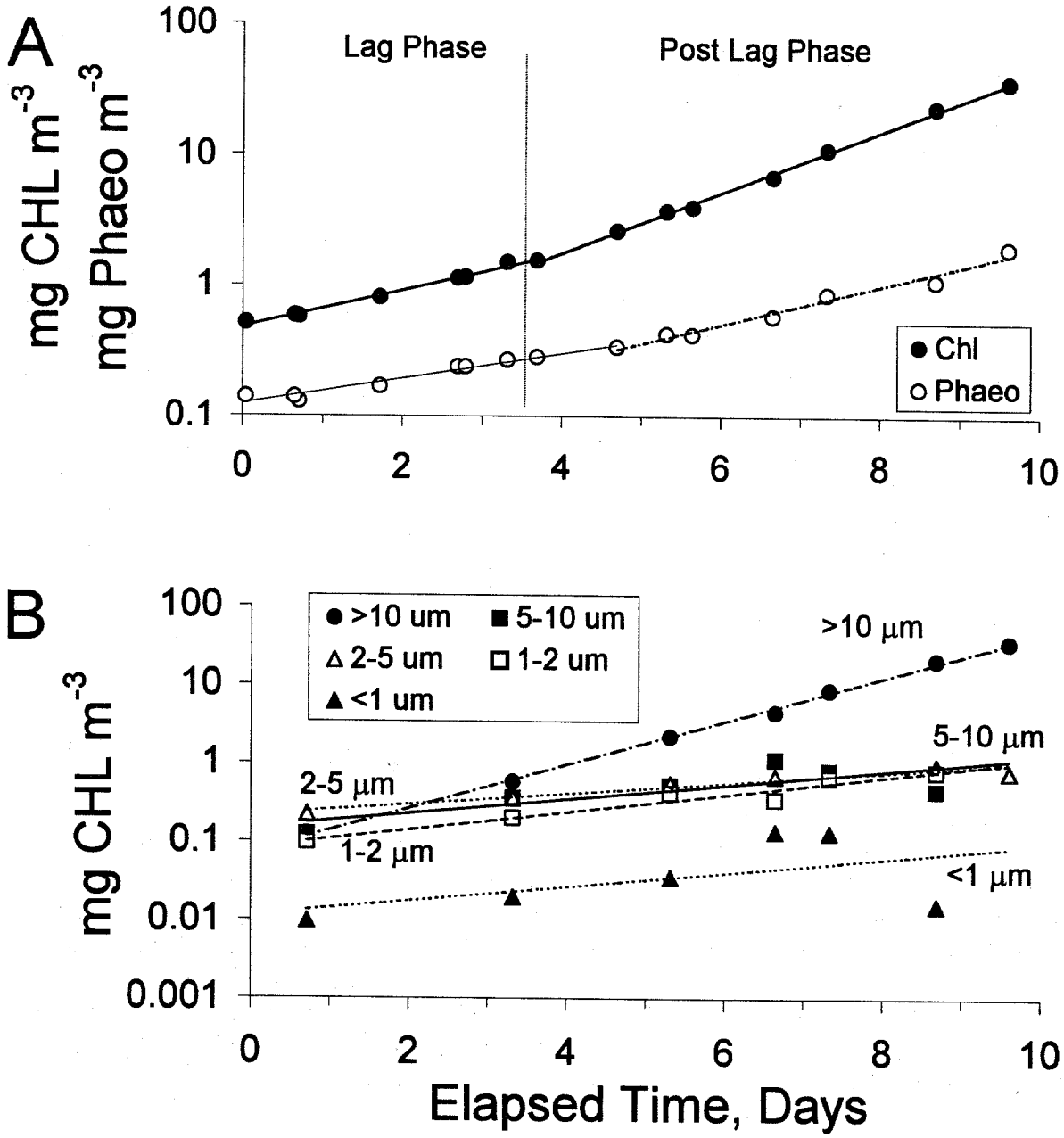


Figure 2.7 Growth characteristics of our natural culture grown during Leg I in terms of (A) total pigments; and (B) various size classes of chlorophyll containing particulates. Lines represent exponential regressions, with growth rates and statistical significance for each line found in Table 2.3. This culture was initiated from 5m water obtained by Nisken bottle at Station A121.

3. Bioacoustic survey; submitted by Jacqueline Popp (Legs I, II, and III), Roger P. Hewitt (Leg I), Peter Kappes (Legs II and III) and David Demer.

3.1 Objectives: The primary objectives of the bioacoustic sampling program during Legs I and II were to map the meso-scale [10's of kilometers (km)] dispersion of krill (*Euphausia superba*) in the vicinity of the South Shetland Islands; to estimate their biomass; and to determine their association with predator foraging patterns, water mass boundaries, spatial patterns of primary productivity, and bathymetry. During the bottom trawl survey (Leg III), the objectives were to acoustically detect any epibenthic scatterers; qualitatively assess their distribution; judge the type of bottom habitat (e.g. mud, sand, rock, etc.); and collect bathymetric data in the vicinity of the South Orkney Islands.

3.2 Methods and Accomplishments: Acoustic data were collected using a multi-frequency echo sounder (Simrad EK500) configured with down-looking 38, 120, and 200 kilohertz (kHz) transducers mounted in the hull of the ship. System calibrations were conducted before and after the surveys using standard sphere techniques while the ship was at anchor in Ezcurra Inlet, 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, a Windows NT workstation, and a UNIX workstation. The Windows NT workstation, running SonarData EchoLog and EchoView software, was used for primary system control, and data logging, processing and archiving. The UNIX workstation, running Simrad BI500 software, was used in parallel for data logging, limited processing, and archiving.

An acoustic survey of the waters surrounding the South Shetland Islands was conducted on each of the first two cruise legs (Surveys A and D, Figure 2, Introduction Section). The surveys were divided into three areas: (1) a 41,673 km^2 area centered on Elephant Island (Elephant Island area) was sampled with five north-south transects; (2) a 34,149 km^2 area along the north side of the southwestern portion of the South Shetland archipelago (West area) was sampled with nine transects oriented northwest-southeast; and (3) a 8,102 km^2 area south of King George Island in the Bransfield Strait (South area) was sampled during the first leg with five transects oriented northwest-southeast; poor weather and scheduling conflicts during Leg II precluded complete sampling of the South area on Survey D. Intensified sampling in the western portion of the West area and in the South area was intended to complement studies of krill predator foraging and reproductive performance conducted at Cape Shirreff and Admiralty Bay.

For the purposes of generating distribution maps, the bottom return, surface turbulence and system noise were eliminated from the echograms. The remaining volume backscatter was attributed to biological scatterers and was integrated over depth [from 15-250 meters (m) for the 38kHz data, 15-225m for the 120kHz data, and 15-175m for the 200kHz data] and averaged over

185.2m [0.1 nautical miles (n.mi.)] distance intervals.[1] These data were processed on the Windows NT workstation using SonarData EchoView software. The integrated volume backscattering strength data were then gridded and contoured. A 30x20 cell grid was imposed on the survey area and integrated volume backscattering values were interpolated at grid nodes using the method of krigging interpolation. An anisotropic ratio of 2 was used to normalize the x and y axes during the krigging of the data.

Two estimates of krill biomass density were generated. The first estimate assumes that all volume backscattering at 120kHz is from krill. The second estimate was generated by integrating only those portions of the echogram that were visually classified as krill. Visual classification was accomplished by scanning the 120kHz echograms for scattering forms that have been attributed to krill (Kalinowski and Witek 1985). The guidelines for classifying aggregations and sound scattering layers were as follows:

(1) Aggregations (also referred to as schools or swarms) were classified as krill if the scatterers coalesced into a discrete, dense target above 225m in the water column.

(2) Sound scattering layers were classified as krill if the edges or boundaries in the horizontal dimension were distinct (not diffuse) above 225m in the water column.

Overall, a conservative approach was used to classify the structures of the scatterers as krill and, as such, a bias may exist toward underestimation of krill biomass density based on visual classification of this data. In addition, sound scattering layers that may have contained krill were excluded because they did not exhibit a distinct edge. On the other hand, because all aggregations were included there is the possibility that some of these may have been nekton and not krill, which would contribute to an overestimate of the krill biomass density. On the whole, however, the visual classification of krill aggregations prior to integration most likely resulted in a slight underestimate of krill biomass density.

The two methods were employed because it was suspected that relatively high levels of system noise were recorded as part of the echogram causing bias in the measurements of volume backscattering strength. In order to test whether noise was related to ship's speed, sections of the acoustic record including relatively few scatterers were integrated over 185m intervals.

Integrated volume backscattering strength per unit sea surface area (s_a) was converted to estimates of krill biomass density (ρ) by applying a factor equal to the quotient of the weight of an individual krill and its backscattering cross-sectional area, both expressed as a function of body length and summed over the sampled length frequency distribution for each survey (Hewitt and Demer, 1993):

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[1] During Survey D, rough sea conditions were encountered which introduced unusually deep surface turbulence in the water column. Therefore, at times the upper level of the integration layer was set deeper (>15m but <20m) in order to exclude surface turbulence before integrating.

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

Where s_a is expressed in units of m^2(n.mi.)$^{-2}$ and f_i = the relative frequency of krill of standard length l_i such that

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

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

For each area in each survey, mean biomass density 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).

In-situ target strength measurements were recorded throughout the surveys using a new multiple-frequency method (Demer et al., 1999). The algorithm reduces the number of measurements of unresolvable multiple targets by rejecting echoes that are not detected at the same location by two or more echosounder frequencies. Differences in these three-frequency target strength measurements will be used to characterize acoustic signatures of various scattering types for the purpose of taxa delineation. The data will also be used to more accurately convert the s_a data to animal density as it accounts for the actual variability in the distributions of animal size, shape, morphology, and orientation.

3.3 Tentative Conclusions: During Survey A, the highest concentration of scatterers was mapped southwest of Elephant Island in a canyon-like area south of the continental ridge that lies between the islands in this northern area of the archipelago (Figure 3.1). Other areas of high concentration were off the shelf-break northwest of Cape Shirreff, Livingston Island and outside of Nelson's passage between Nelson Island and Robert Island. In the latter region, tentative conclusions from the hydrography and primary productivity data indicate that this is an area of upwelling. The distribution of total volume integrated volume backscattering strength by the 38kHz indicates possible distributions of nekton, which are associated with a front that is typically offshore. This was consistent between Survey A and Survey D (Figure 3.2). Broad scattering layers usually extending below 125m to depths ≥250m, which have been associated with myctophids, were especially evident during Survey D to the north of Elephant Island. During Survey D there appeared to be a westward shift in the distribution of scatterers. The highest concentrations were north-northwest of Elephant Island. Other areas of elevated concentrations were in the convergence area north of King George Island and the shelf areas surrounding Elephant and Gibbs Islands.

The highest concentrations of krill during Survey A, based on visual classification, were along the shelf-break north of Livingston and King George Islands and southwest of Elephant Island

(Figure 3.3). During Survey D, highest concentrations were again mapped along the shelf-break north of Livingston and King George Islands; but near Elephant Island the high concentrations were mapped to the northwest and southeast of the island (Figure 3.3).

Krill biomass density estimates were calculated from total integrated volume backscattering and from visually classified scattering that was attributed to krill. The results indicate that the volume backscattering attributed to krill was approximately 27% of the total volume backscattering during Survey A and 14% during Survey D. This suggests a substantially larger contribution of scatterers other than krill and/or substantially higher noise levels than has been experienced in previous surveys. The lower values are reported here (Table 3.1) and are consistent with those predicted from a model of the variability of acoustic estimates of krill in the Elephant Island area (Figure 3.4, Hewitt and Demer, in press). These values are the second lowest in the 7-year time series and are also consistent with krill abundance trends derived from net sampling.

Underway measurements of noise were made on 22 February 1999 with the echo sounder in passive mode, ship's speed at 10.3 knots, 1-2m ground swell and 0.5m wind chop:

Transceiver 1 (38kHz) = -135 ±1.5 dB
Transceiver 2 (120kHZ) = -145 ±1.0 dB
Transceiver 3 (200kHz) = -147 ±0.5 dB

These values are consistent with measurements made during previous surveys; however, they do not rule out enhanced noise levels during the 1999 surveys relative to previous years. It was noted that the ship had spent several months at anchor in tropical waters and had accumulated a considerable amount of biological growth on the hull. Although the system calibrations were within expected values, the accumulated growth could have caused turbulence while underway. It was expected that the 120kHz transducer would have been most affected because it is the foremost transducer in the hull-mounted blister. Volume backscattering was integrated from 15 to 225m over sections of the 120kHz acoustic record that were relatively clear of scatterers while the ship was moving at various speeds. During Survey A, noise increased dramatically with speed. This behavior was not noted at the beginning of Survey D, but after a break in the survey to recover cargo at Seal Island, noise was noted to again increase sharply with ship's speed (Figure 3.5). Another source of noise may have been a computer monitor placed adjacent to the echosounder which appeared to increase the noise displayed on the 200kHz display; this source may have also introduced noise in the 120kHz and 38kHz records as well. The interference was only apparent when the monitor was in graphics mode as opposed to text mode. Increased noise from the ship's propulsion engines and increased sea surface turbulence could have also contributed to enhanced noise during the 1999 surveys relative to previous years. With regard to engine noise, records were maintained as to when the main engines were brought on- and off-line; comparisons will be made with the acoustic record in an effort to rule out this possibility. With regard to surface turbulence, care was taken not to include turbulence in the regions that were integrated. Increased surface turbulence may also cause some attenuation of the acoustic signal resulting in reduced rather than increased integrated volume backscattering.

Visual classification of krill aggregations also afforded an opportunity to examine the possible relationship between demographic parameters of krill and the shapes and positions of their

aggregations. Preliminary results (five out of five cases during Survey D) suggest that gravid females may have been encountered most often in surface swarms. These results suggest that there may be a potential benefit to examining the acoustic records of previous surveys in conjunction with demographic descriptions of krill obtained from contemporaneous net samples.

One of the immediate results of acoustic data collected during the bottom trawl survey of the South Orkney Islands area on Leg III is an improved bathymetric map of the area (see Figure 9.1 in Section 9, Bottom trawl survey). The general features of the area are a broad coastal plain which extends to the east, west and extensively to the south of these islands and the steep bathymetry outside of the 500m isobath, which delineates the coastal shelf except to the southeast where the shelf gently slopes downward. A noticeable modification to previous bathymetric maps is the extension of the 500m isobath to 42° east. The shelf is very narrow to the north of the islands and is characterized by a very steep change in bathymetry. Although the trawl survey was designed to sample within the 50-500m isobaths, heavy concentrations of ice often precluded sampling at depths shallower than 150m. As a result, the described bathymetry at these depths is less certain. In addition, prevailing wind and sea conditions caused most of the reconnaissance and trawls to have a strong east-to-west component; thus, there is a bias towards improvements in the data across longitudes.

3.4 Disposition of Data: Integrated volume backscattering data are available to other U.S. AMLR investigators in ASCII format files. The analyzed echo-integration data consume approximately 10 Mbyte. The data are available from Dr. David Demer, Southwest Fisheries Science Center, 8604 La Jolla Shores Drive, La Jolla, CA 92037; phone/fax - (858) 546-5603/546-5608; internet: ddemer@ucsd.edu.

3.5 Acknowledgments: We would like to express our appreciation to the officers and crew of the *R/V Yuzhmorgeologiya* for their enthusiastic assistance during the cruise, which contributed to the success of our work. Thanks to Dr. Valerie Loeb for the use of krill demographic data from Survey D for tentative comparisons with sound scattering forms. We would like to thank all members who assisted with calibrations (special note of appreciation to A. Jenkins for constructing a new monfilament harness and basket for the post calibration) and to all for their patience during this operation. Thanks to Denny Sutton who provided excellent technical assistance as we prepared for departure from Punta Arenas.

3.6 References:

Demer, D.A., M.A. Soule, and R.P. Hewitt, 1999. *Jour. Acoust. Soc. Am.*, 105(4) 2359-2376.
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Jolly, G.M. and I. Hampton. 1990. *Can. J. Fish Aquat. Sci.* 47:1282-1291.
Kalinowski, J. and Witek, Z. 1985. *Biomass Handbook 27: Scheme for Classifying Aggregations of Antarctic Krill.*

Table 3.1 Mean krill biomass density for surveys conducted from 1992 to 1999. Coefficients of variation (CV) are calculated by the methods described in Jolly and Hampton, 1990, and describe measurement imprecision due to the survey design. Other contributions to measurement uncertainty (i.e. calibration, diel vertical migration, target strength estimation, species delineation, etc.) are not included in these values. 1993 estimates were omitted due to system calibration uncertainties; only one survey was conducted in 1997; 1999 South area values are not available (NA) due to the lack of data. See Figure 2 in the Introduction Section for descriptions of each survey area.

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

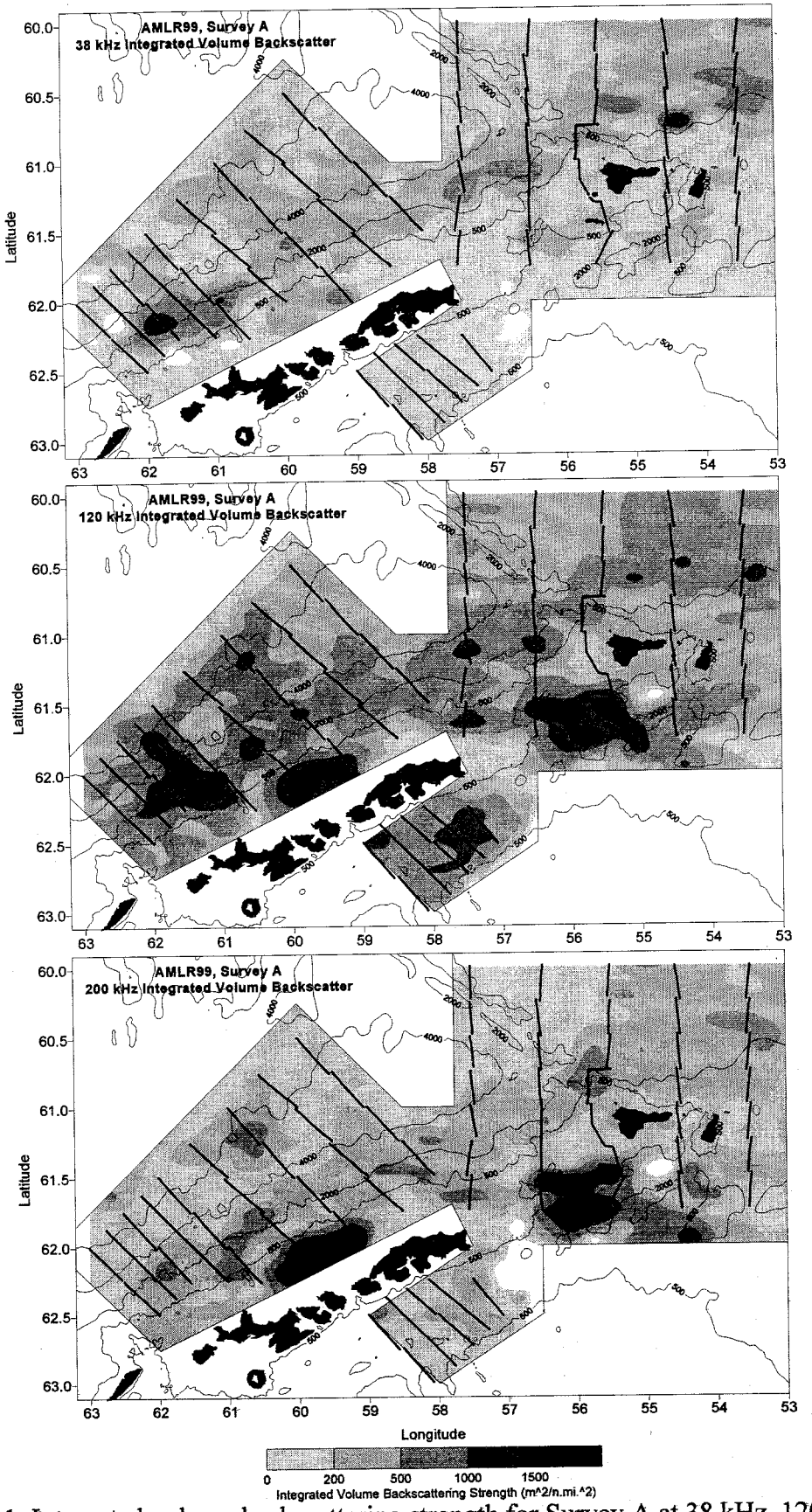


Figure 3.1 Integrated volume backscattering strength for Survey A at 38 kHz, 120 kHz, and 200 kHz. Transect lines are indicated but not station positions.

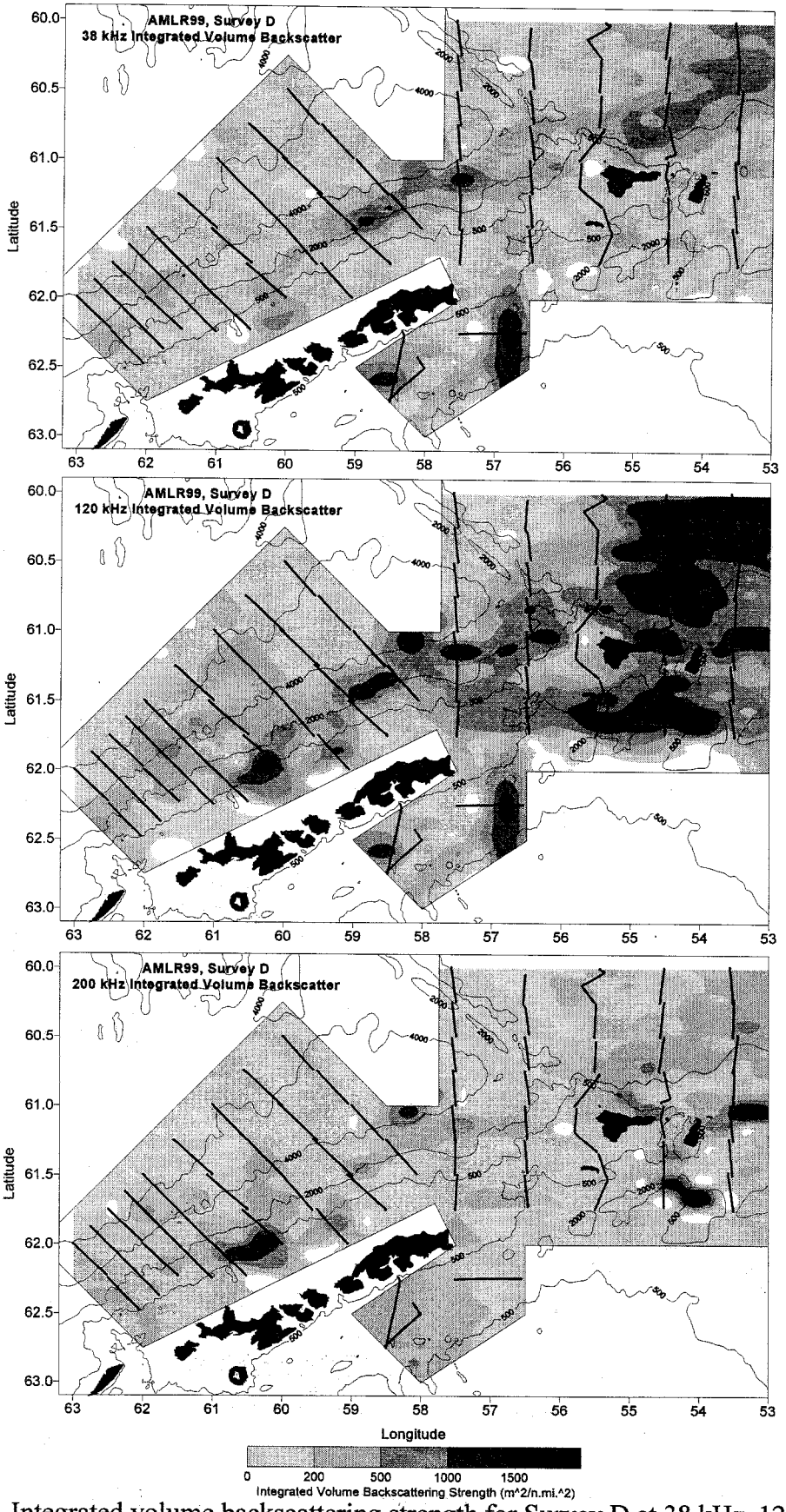


Figure 3.2 Integrated volume backscattering strength for Survey D at 38 kHz, 120 kHz, and 200 kHz. Transect lines are indicated but not station positions.

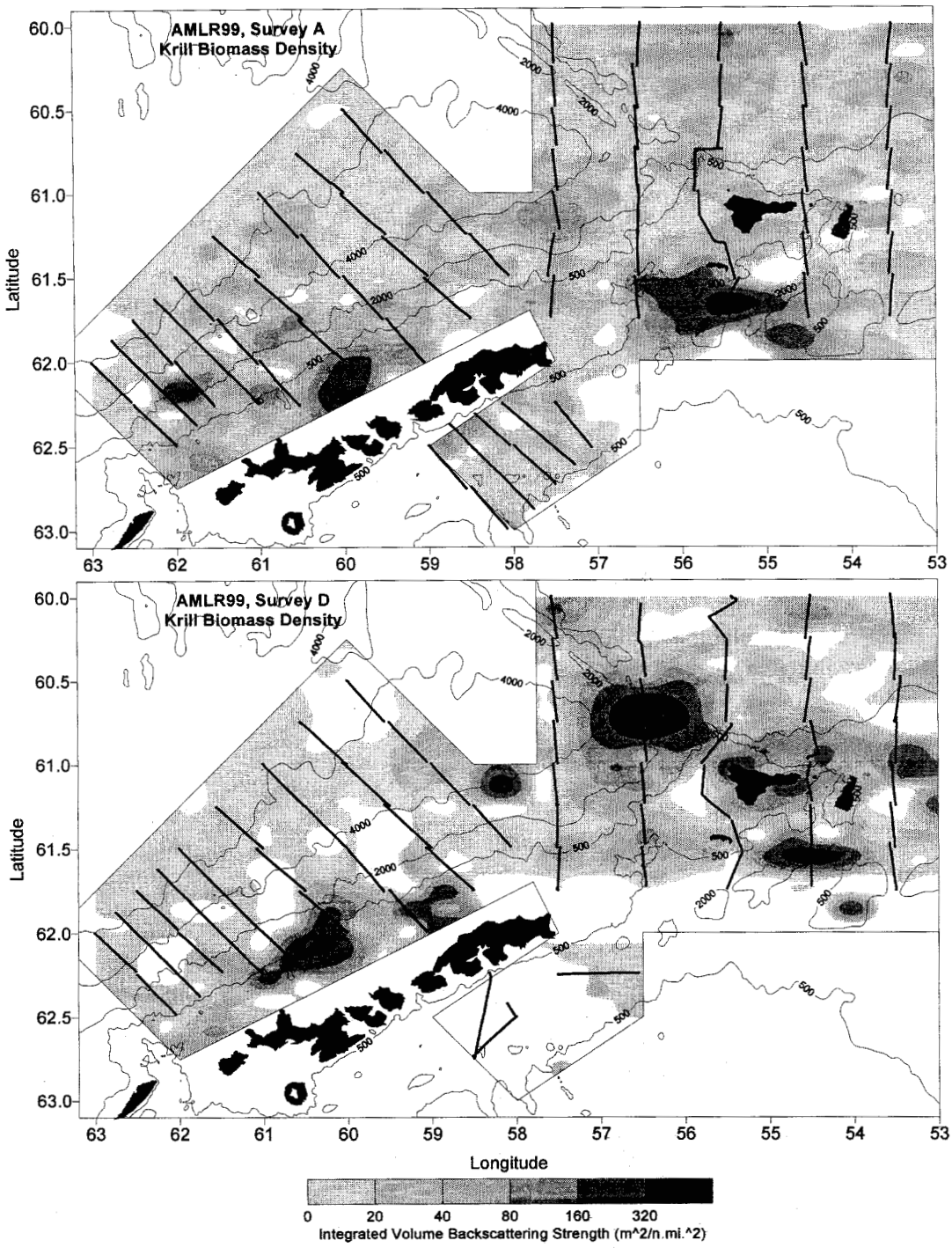


Figure 3.3 Krill biomass density based on visual classification of data at 120kHz.

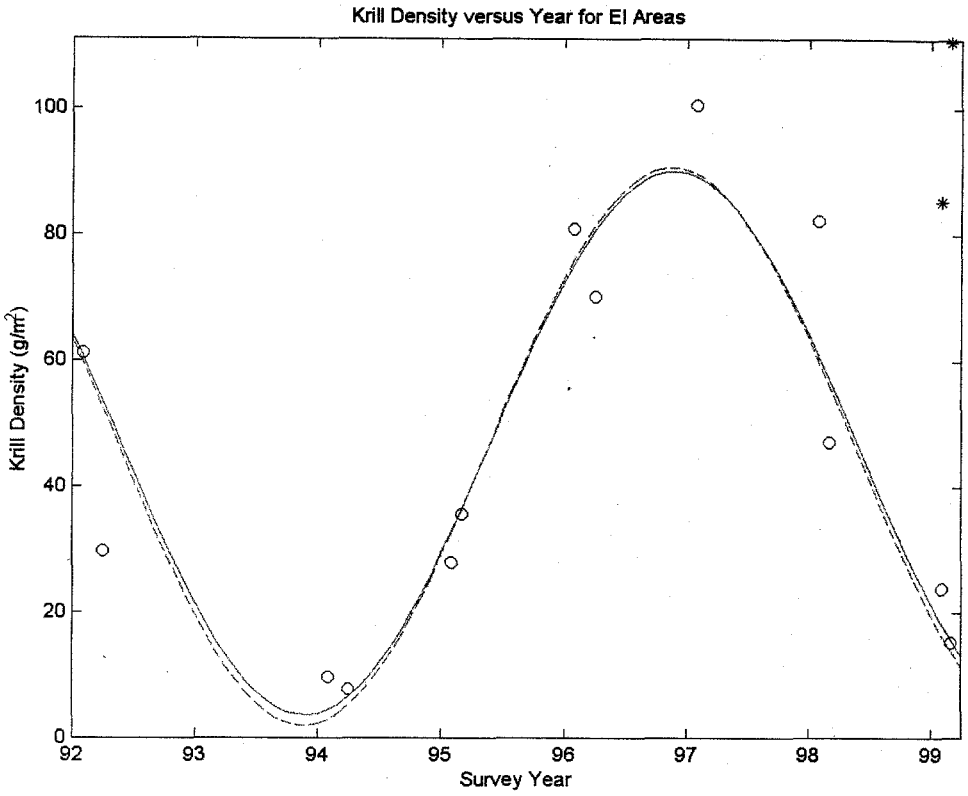
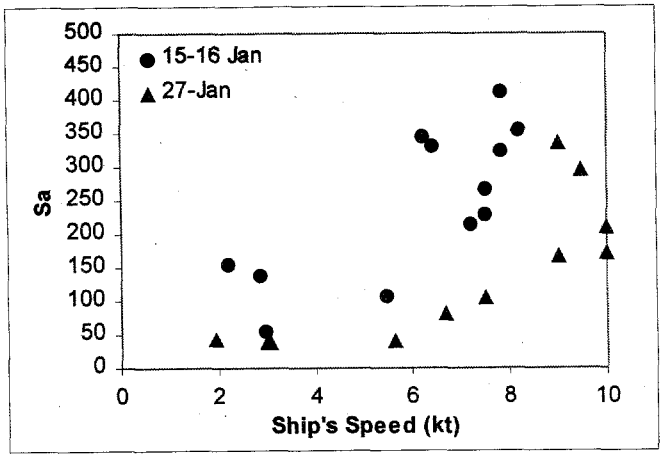
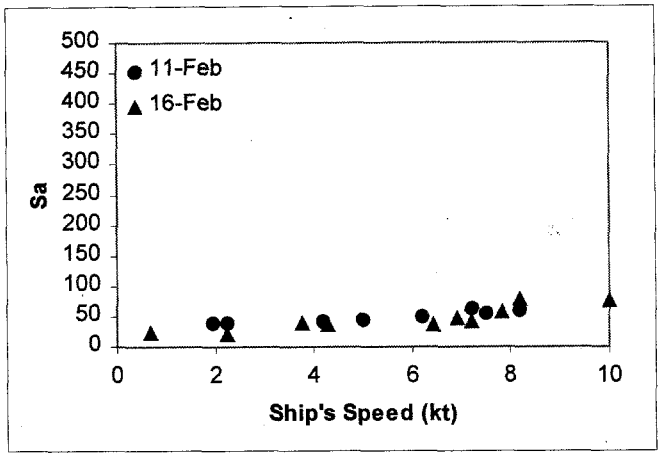


Figure 3.4 Time series of krill density in the Elephant Island area from austral summer 1991/92 to 1998/99. The curves were fitted according to $\rho(t) = A + B\cos\left(\frac{2\pi t}{6\text{ yrs}} + \phi_1\right)$ where t is time (years), and A is the mean value of the series and B and Φ_1 are the amplitude (g/m2) and the phase (radians) of the 6-year cyclical component. The solid line represents the curve fitted to 1992-1998 data; the dashed line represents the curve fitted to 1992-1999 data. Data from 1993 were omitted due to uncertainty in the system calibration and other equipment parameters. For 1999, circles indicate krill biomass density estimates as determined after visual classification of krill aggregations; * indicate krill biomass density estimates assuming all volume backscattering is from krill.





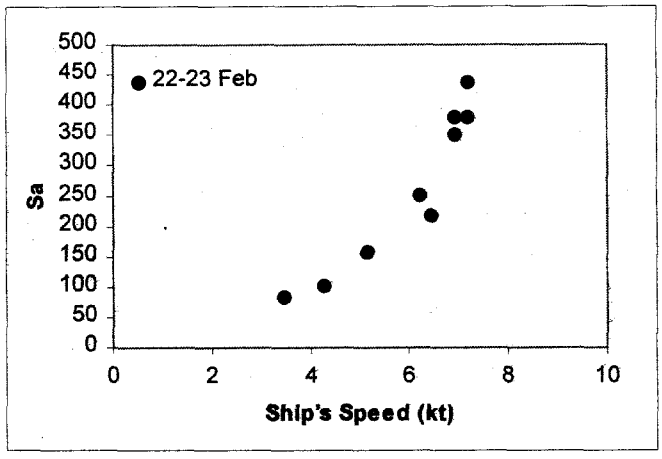


Figure 3.5 Trends in 120kHz volume backscattering integrated from 15 to 225m (s_a) with ship's speed. The top graph was generated from data collected 15-16 and 27 January during Survey A. Data presented in the middle graph were collected on 11 and 16 February during the first part of Survey D. Data in the bottom graph were collected 22-23 February during the latter part of Survey D.

4. Net sampling: krill and zooplankton; submitted by Valerie Loeb (Legs I and II), Wesley A. Armstrong (Legs I and II), Kim Dietrich (Legs I, II, and III), Michael Force (Legs I and II), Nancy Gong (Legs I and II), Adam Jenkins (Legs I and II), and Darci Lombard (Legs I, II, and III).

4.1 Objectives: We provide information on the demographic structure of Antarctic krill (*Euphausia superba*) and the abundance and distribution of salps (*Salpa thompsoni*) 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/carousel stations within the large-area survey. As in previous years, the salp receives special attention because of its hypothesized influence on the distribution, behavior, and recruitment success of krill. Increased emphasis is also placed on copepods (see Section 5, Copepods) as interannual variations in copepod abundance and species composition 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 1992-1999 period.

4.2 Accomplishments:

Large-Area Survey Samples.

Krill and zooplankton were obtained from a 6-foot Isaacs-Kidd Midwater Trawl (IKMT) fitted with a 505 micrometer (μm) 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 170 meters (m) or to ca. 10m above bottom in shallower waters. Real-time tow depths were derived from a depth recorder mounted on the trawl bridle. Tow speeds were ca. 2 knots. Samples were collected at large-area survey stations during both cruise legs (see Figure 2, Introduction Section). Three regionally distinct groups of stations are considered here (Figures 4.1A and 4.1B). "Elephant Island area" stations represent the historically sampled area used for long-term analyses of the Antarctic Peninsula marine ecosystem. "West area" stations, northwest of King George and Livingston Islands, form a data base 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. "South area" stations, located in Bransfield Strait, are used to monitor krill supplies available to predator populations in Admiralty Bay, King George Island.

Shipboard Analyses.

All samples were processed on board. Krill demographic analyses were made using fresh or freshly frozen specimens. The 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 m^3 water filtered; krill abundance is also expressed as numbers per m^2 sea surface to allow comparisons with other data sets. Abundance information is presented for the Elephant Island, West, and South areas, and for the total survey area.

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

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

(3) Fish: All adult myctophids were removed, identified, measured to the nearest millimeter (Standard Length), and frozen.

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

4.3 Results and Preliminary Conclusions:

(A) Leg I, Survey A, 15-28 January 1999

(1) Krill

Abundance

Primarily small numbers of postlarval krill were represented in Survey A samples. A total of 1657 individuals were collected by 44 of the 75 tows (59%) with mean and median overall abundance of 6.1 and 1.3 per 1000 m^3, respectively (Table 4.1A). Most krill were obtained over, or immediately adjacent to, island shelf regions (Figure 4.1A). The largest catch (291 individuals, 80.3 per 1000 m^3) occurred in Bransfield Strait adjacent to Robert and Nelson Islands. Due to this catch, the South area had highest overall krill abundance (13.3 per 1000 m^3 mean and 3.3 per 1000 m^3 median). Abundance estimates from 40 Elephant Island area samples

were about half as large (5.3 mean and 1.7 per 1000 m^3 median). Krill were least abundant in the West area (27 samples; 5.0 per 1000 m^3 mean and 0.0 per 1000 m^3 median).

Length Composition

Virtually all of the krill were longer than 35mm; length modes within 36-39mm and 41-45mm size ranges were apparent in all three areas (Figures 4.2A-4.2D). These represent mixtures of 2 and 3 year old krill (1996/97 and 1995/96 year classes; Siegel, 1987). Generally smaller sizes were collected in the South area, and a 36-38mm (2 year old) length mode dominated there compared to 44-45mm (3 year old) modes in the Elephant Island and West areas. The different length frequency distributions in the West and South areas are clearly reflected in the diets of Adélie penguins at Cape Shirreff (N = 2454 krill; Figure 4.2C) and Copacabana (N = 1761 krill; Figure 4.2D). Greatest numbers of older krill (i.e., ≥50mm), remnants of the highly successful 1994/95 year class, were in the Elephant Island area where they made up 11% of the catch.

Maturity Stage Composition

In accordance with the virtual absence of krill lengths <35mm, juveniles contributed only 3% of the total, while mature stages contributed 67% and immature stages 30% (Table 4.2). Juvenile and immature stages were mostly represented by the small individuals in the South area where they respectively made up 8% and 56% of the catch. Although similar proportions of immature and mature krill were represented in the West and Elephant Island areas, there were large differences between the female maturity condition in the two areas, with substantially greater proportions of advanced stages present in the Elephant Island area. Among mature females in the West area, 76% had not mated and 11% had recently mated but not yet undergone ovarian development (stages F3a and F3b). In contrast, most females in the Elephant Island area had maturing eggs (F3c, 29%), were gravid (F3d, 47%), or spent (F3e, 18%). The frequent presence (65% of samples) and relatively high abundance of stage 1 and 2 calyptopis larvae (mean abundance 103 per 1000 m^3) across the survey area indicates that active spawning was initiated within the past month (i.e., mid-December to early January).

Distribution Patterns

Cluster analysis applied to length frequency distributions from samples with ≥15 krill yielded two groups (Figure 4.3A). Cluster 1 occurred at four stations in the King George-Livingston Island shelf area and one station southeast of Elephant Island. Cluster 2 occurred at 21 stations distributed across the survey area, generally to the north of Cluster 1. Both clusters primarily represented mixtures of 2 and 3 year old krill but differed in the proportions of those age groups, sex ratios, and reproductive condition (Figures 4.4A and 4.4B). Cluster 1 krill lengths ranged from 26-54mm with a primary mode of 42-44mm and secondary mode of 36-38mm. Juveniles made up 5% and immature and mature stages equally contributed the rest. Females outnumbered males by 60%. Most of the males (76%) were in M2a and M2b; these are early stages of sexual development or the final stages of post-spawning sexual regression. Most of the mature females

(61%) were F3a; these animals were either becoming reproductive or were post-reproductive and had regressed back to their pre-reproductive sexual stage. Cluster 2 krill lengths ranged from 33-54mm with a primary mode of 44-45mm and secondary mode of 47-48mm. Males and females were equally represented. The majority of males were reproductively mature (M3b, 81%), while the majority of females had developing ovaries (F3c, 27%), were gravid (F3d, 42%), or spent (F3d, 14%).

(2) *Salpa thompsoni*

Abundance

Salpa thompsoni was present in all Survey A samples with overall mean and median abundance of 124.4 and 66.9 per 1000 m^3, respectively. Highest abundance and most uniform catch sizes occurred in the Elephant Island area where mean and median abundance were 197.5 and 159.1 per 1000 m^3, respectively (Table 4.1A; Figure 4.5A). These salps were least abundant in the South area (57.7 per 1000 m^3 mean; 37.6 per 1000 m^3 median).

Maturity Stages, Size and Age

The aggregate (sexual) stage dominated catches in all three areas and contributed 95% of all individuals. Aggregates ranged in size from 5 to 70mm with the majority (75%) between 15 and 45mm. These demonstrated a polymodal size distribution which was common to all three subareas (Figure 4.6A). Length modes occurred within 9-12mm, 18-30mm, 35-40mm, and 44-46mm size ranges; the primary mode was 24-28mm. Based on the aggregate size distribution and an estimated growth rate of 14mm per month (after birth at 5mm), budding probably was initiated in late August/early September with more or less continuous production starting in mid-September. Pulses of production leading to the four size modes probably occurred during late October, mid-November, early to mid-December, and early January. The relatively rare solitary salps ranged in size from 5 to 125mm. Half of these were <20mm in length and resulted from early seasonal spawning by the aggregate form.

Cluster analysis applied to salp length frequency distributions in samples with >100 individuals did not yield any distinct groupings or obvious distribution patterns. This is not surprising giving the similarity of size distribution characteristics in the three subareas (Figure 4.6A).

(3) Zooplankton and Micronekton Assemblage:

Distribution and Abundance Relations of Dominant Taxa

Six taxonomic categories numerically dominated the zooplankton/micronekton assemblage. These were copepods, *S. thompsoni*, postlarvae of the euphausiid *Thysanoessa macrura*, larvae of both krill and *T. macrura*, and chaetognaths. Together these six taxa constituted >95% of the zooplankton. Of these, copepods were by far the most abundant. They were present in all

Survey A samples, numerically dominated the catches in all three subareas, and contributed 54% of total mean zooplankton abundance (Table 4.3). Largest copepod concentrations (3500-7500 per 1000 m^3) occurred in offshore Drake Passage waters between King George and Elephant Islands (Figure 4.7A). Other large concentrations (2100-3200 per 1000 m^3) occurred northwest of Livingston Island. Although copepod abundance was highest in the Elephant Island area and lowest in the South area, these differences were not significant (ANOVA, $P > 0.05$).

Salpa thompsoni was the second most abundant taxon and contributed 12% of total mean zooplankton abundance (Table 4.3). As noted above, this salp was most abundant in the Elephant Island area where it also ranked second in abundance after copepods. Postlarval *T. macrura* was third in overall mean abundance; however, due to its uneven distribution pattern, this was the second most abundant taxon in the West and South areas but sixth in the Elephant Island area (Figure 4.8A).

Larval krill and larval *T. macrura* were, respectively, the fourth and fifth most abundant taxa. Krill larvae were most abundant in the Elephant Island area where they averaged 175 per 1000 m^3 and ranked 3 in abundance. The largest concentration (ca. 5100 larvae per 1000 m^3) was northeast of Elephant Island (Figure 4.7B). Other relatively large concentrations (ca. 200-700 per 1000 m^3) were in the northwest Elephant Island area. More than 99% of the krill larvae were calyptopis stage 1 and 2 and therefore about 4-6 weeks old (Quetin and Ross, 1984). Larval *T. macrura* were also most abundant in the Elephant Island area where they were the fourth most abundant taxon. As with larval krill, their largest concentrations (ca. 1500 larvae per 1000 m^3) were in the northwest Elephant Island area (Figure 4.8B). Relatively large concentrations of larval krill and *T. macrura* also co-occurred northwest of Livingston Island. Chaetognaths ranked 6 in overall mean abundance and either 4 or 5 in the subareas.

In contrast to the numerically dominant taxa, some of the less common zooplankton had significant areal abundance differences (Table 4.3). The euphausiid *Euphausia frigida* and amphipod *Vibilia antarctica* were more abundant in the Elephant Island area than in the West area (ANOVA, $P \leq 0.02$). *Ihlea racovitzai*, another Southern Ocean salp species, was most abundant in the South area ($P=0.000$). Almost all of these salps were aggregates (99%). Aggregate lengths ranged from 5-35mm, but 80% were 13-25mm with distinct 15mm and 20mm modes. The few solitary forms collected had internal lengths of 42-53mm. Because of its distribution pattern (Foxton, 1971), the occurrence of *I. racovitzai* in Bransfield Strait and east of Elephant Island is probably associated with input of Eastwind Drift water (Figure 4.9A). The siphonophore *Dimophyes antarcticus* and gastropod larvae were also most abundant in the South ($P<0.01$ in all cases). Larvae of the myctophid genus *Electrona* had greatest concentrations in the West area ($P<0.01$).

Diel Abundance Differences

Several of the zooplankton taxa exhibited significant diel abundance differences. Analysis of variance performed on day, twilight, and night abundance indicated significantly higher night vs.

day values for *S. thompsoni* (P<0.01) and *E. frigida* (P=0.000), and significantly higher night vs. day (P=0.000) and twilight (P<0.01) values for *Euphausia triacantha*. All three species perform extensive upward vertical migrations at night that greatly influence their abundance in the upper 200m.

Interspecific Relationships

Cluster analysis, performed on the 25 most abundant zooplankton taxa, resulted in two groupings (Table 4.4; Figure 4.10A). The two clusters were equally represented across the survey area and were similar in that *S. thompsoni* was represented in equal numbers and was the third most abundant taxon. With the exception of *S. thompsoni*, the two clusters differed greatly in the absolute and relative abundance of taxa; this is reflected by a low Percent Similarity Index (PSI) value of 48.8. Total mean abundance of Cluster 1 (553 per 1000 m^3) was about 25% that of Cluster 2 with copepods, postlarval *T. macrura*, and *S. thompsoni* each contributing ca. 30% of the zooplankton. Mean abundance of only three taxa (krill, *T. macrura* and *V. antarctica*) were substantially larger in Cluster 1 than in Cluster 2, but these differences were not significant (ANOVA, P>0.05). Copepods clearly dominated Cluster 2, contributing 60% of total mean abundance. Larval krill (rank 2) and larval *T. macrura* (rank 4), contributed 9.6% and 6.7%. Abundance of copepods and chaetognaths were an order of magnitude greater, and of larval *T. macrura* and larval krill two orders of magnitude greater, than in Cluster 1. These differences are significant (P<0.05) for all but larval krill. Mean abundance of *E. frigida*, *I. racovitzai*, ostracods, *Tomopteris* spp. and *E. triacantha* were also significantly larger than in Cluster 1 (Table 4.4). The distribution of the two clusters generally conforms to the eastward flow of water along the Shetland Island chain, with elevated zooplankton abundance (Cluster 2) occurring in areas of complex hydrography (e.g., gyres, eddies and fronts; see Section 1, Physical oceanography).

(4) Leg I, Between-Year Comparisons

Krill

Mean and median abundance of postlarval krill in the Elephant Island area were the lowest monitored by January surveys in the past eight years (Table 4.5). Krill biomass rivaled the record low values of February 1995 (Table 4.6). These minima continue a trend of decreasing krill abundance since 1996 and result from a succession of years of poor recruitment after the 1994/95 year class. The overall krill size/maturity composition during Survey A reflects this history (Figure 4.4; Table 4.7). Dwindling numbers of the 1994/95 year class, now represented by lengths ≥50mm, made up only 11% of the krill in the Elephant Island area; the remainder consisted of primarily 3 year old (1995/96 year class) and secondarily 2 year old (1996/97 year class) individuals (Figure 4.2B). The virtual absence of smaller, juvenile krill in the large-area survey (<1% of total krill in 1999 vs. 55% in 1996 and 15-18% in 1997 and 1998) is testament to failure of the 1997/98 year class.

The large proportion of females in advanced maturity stages (93% stages 3c-3e) is similar to proportions observed in January 1995 and 1996 (96-98%) and represents "normal" (i.e., December to March) spawning seasonality. This contrasts markedly with January 1993 and 1998 when <20% of mature females were in advanced stages (Table 4.7). The high mean abundance and frequent occurrence of larval krill are most similar to values in 1995 (Table 4.8) and, given optimal feeding and overwintering conditions, bode well for recruitment of the 1998/99 year class.

Salpa thompsoni

The mean and median abundance and biomass values of *S. thompsoni* were intermediate to extreme highs observed in January 1993, 1994, and 1998 and lows of January 1995 and 1996 (Tables 4.5 and 4.6). These values were most like those of January 1997, which marked a transition from 1995 and 1996 "copepod years" to the 1998 "salp year." Almost total dominance by the aggregate stage (>90%) was similar to all years except 1997 when small solitary stages made up 20%.

The salp size distribution, centered around 20-40mm lengths, was most like that during January 1994 and 1996 (Figure 4.11; Kolmogorov-Smirnov test D_{max} values 9.5-10.6). The major differences between these years were the relatively even representation of lengths between 12 and 45mm and greater proportions of 25-45mm sizes during 1999. These differences possibly result from two factors: (a) an earlier initiation of chain production (e.g., late August/early September 1998 vs. first half of October in 1993 and 1995); and (b) fairly uniform pulses of chain production at 3-4 week intervals from late October 1998 to early January 1999 vs. a November-December production peak in 1993 and 1995. The estimated initiation of chain production in August/September 1998 was the earliest over the past six year period and most likely related to the exceptionally low sea ice development that year.

The widespread distribution of all salp sizes across the survey area in January 1999 was also observed in 1994 and 1997 (both transition years) and most likely resulted from similar production periods and production rates in coastal and oceanic regions. These years differed from 1995, 1996 and 1998 when distinct patterns of salp size frequency distribution and/or abundance occurred within the area. In contrast to January 1998, there must have been an order of magnitude decrease in chain production rate, solitary stage "seed population" size, or a combination of these to result in a 10-fold reduction in salp abundance during 1999 (Figure 4.11).

Zooplankton/Micronekton Assemblage

Distribution and Abundance Relations of Dominant Taxa

Overall zooplankton diversity in the 75 Survey A samples (69 categories; Table 4.8) was similar to that represented by 90-105 samples in previous years. The numerically dominant taxa were

characteristic of the Antarctic Peninsula region during austral summer. Eight taxa typically make up >90% of mean zooplankton abundance in AMLR collections: copepods; *S. thompsoni*; postlarval and larval stages of *T. macrura*; krill; postlarval *E. frigida*; and chaetognaths. These taxa comprised 96% of the zooplankton collected in the large-area survey and 97% of that in the Elephant Island area during January 1999 (Tables 4.8 and 4.9).

Mean copepod abundance in the Elephant Island area (928 per 1000 m^3; Table 4.5) was similar to that during January 1995, 1996 and 1997 (656-898 per 1000 m^3); abundance values during those four years were an order of magnitude and significantly larger than during January 1993, 1994 and 1998 (32-74 per 1000 m^3; ANOVA, $P \leq 0.01$ in all cases). Similarly, mean salp abundance (198 per 1000 m^3) was comparable to that during January 1995, 1996 and 1997 (20-223 per 1000 m^3); values from those four years were significantly smaller than during January 1993, 1994 and 1998 (932-1213 per 1000 m^3; $P<0.05$). Relatively large numbers of chaetognaths and *E. frigida* occurred in January 1995 and 1999; chaetognath abundance during those two years was significantly greater than during the other five years considered ($P<0.05$). *E. frigida* abundance in 1995 and 1999 was significantly higher than in 1996 ($P<0.05$). Abundance of postlarval *T. macrura* in 1999 was significantly lower than in January 1998 ($P<0.05$); this is possibly due to the virtual absence of larvae the previous year. Although *T. macrura* larvae were quite abundant in 1999, their numbers, like those in 1995, 1997 and 1998, were significantly smaller than in 1996 ($P<0.05$).

Interannual abundance fluctuations of dominant zooplankton taxa cause dramatic shifts in their abundance relations. Proportions of copepods and *S. thompsoni* during January 1999 were similar to those in January 1997. Within the Elephant Island area, copepods made up 57-58% and salps 12-18% of mean zooplankton abundance in those years (Table 4.9). Equally large proportions of copepods (56-62%) also occurred in January 1995 and 1996 when salps were relatively uncommon (<2%, abundance rank 5-6). The relatively large contribution by larval krill in January 1999 was most like that in 1995 when this was the second most abundant taxon and made up 13% of the zooplankton. The percent contributions by larval *T. macrura* and chaetognaths in January 1999 were second only to values, respectively, in 1995 and 1996. As noted above, postlarval *T. macrura* were not abundant in 1999 and their contribution to the total zooplankton (3%, rank 6) was the lowest in the seven year January data set.

Of note is the low abundance of *I. racovitzai* in January 1999 (<0.2% of zooplankton; Table 4.9). This salp was relatively abundant in the Elephant Island area during January 1998 (>3%, rank 4). It was also reported to be abundant in the South Shetland Island region during February 1986 and December 1990-January 1991 (Esnal and Deponte; 1990; Nishikawa et al. 1995). As surmised last year, this species may undergo episodes of elevated abundance in the area due to variations in the East Wind Drift.

Interannual shifts in taxonomic abundance relations are summarized in Table 4.10 using PSI values. These values indicate that the overall zooplankton composition of 1999 Survey A samples was most similar to that during January 1997, a "transition year" (84.9), followed by

1995 (79.9) and 1996 (71.1), both "copepod years." Low PSIs were obtained from comparisons with 1994, another "transition year" (26.1), 1993 and 1998 "salp years" (22.1 and 30.6). Given the dominance by copepods and a salp:krill carbon biomass ratio >1, January 1999 conforms to the definition of a "transition year" (Table 4.6). This follows "salp year" 1998 when salps far outnumbered copepods and the salp:krill biomass ratio was 4:1. It most likely presages a "copepod year" in 2000 when copepods will be the numerically dominant taxon and krill carbon biomass will exceed that of salps.

(B) Leg II, Survey D, 10-26 February 1999

(1) Krill

Abundance

A total of 7314 krill were collected during Survey D. The vast majority of these were from the Elephant Island area where they occurred in 29 of 39 samples (Table 4.1B). Three samples alone contributed 79% of total krill; these were from west and northwest of Elephant Island (Figure 4.1B). One sample from the northeast shelf of King George Island yielded 823 of the 843 krill collected in the West area. Together the three South area tows netted 56 krill. Mean krill abundance in the Elephant Island area was ca. 3X that in the West area (35.5 vs. 9.6 per 1000 m^3), but the median values in both subareas were extremely small (0.8 and 0.0 per 1000 m^3, respectively) due to the general paucity of krill.

Size Distribution, Maturity Stage Composition and Distributional Attributes

Predominantly large krill were collected: lengths ranged from 35-58mm and centered around a 47mm mode; 60% were between 44 and 49mm (Figure 4.12). Lengths <40mm made up <5%, while sizes ≥50mm (1995/96 and 1994/95 year classes) represented 25% of the total.

Mature females constituted 64% of the catch (Table 4.2). Most of these (83%) were gravid or spent (stages 3d and 3e). However, relatively large proportions also exhibited developing ovaries (3c), suggesting that some previously spent individuals were undergoing batch spawning. The majority of males were reproductive (3b). Again, widespread occurrence of calyptopis 1 and 2 stage larvae indicated that spawning had occurred over the past month.

Cluster analysis applied to samples with ≥15 krill indicated two groups with somewhat different size distributions (Figure 4.13A). Cluster 1 krill ranged from 35-53mm, with a 44mm mode; 58% were 42-46mm in length. Cluster 2 krill were slightly larger, with lengths 37-58mm and a 48mm mode; 48% were 47-50mm. Females dominated both clusters (63-66%), but they differed greatly in their reproductive condition (Figure 4.13B). Cluster 1 was comprised of recently spent females (3e, >55%) and animals which were post-reproductive and had regressed back to their pre-reproductive sexual stage (stage 2, 6%). Similarly, most Cluster 1 males demonstrated post-reproductive maturity stage regression (2b and 2c, 24%). In contrast, Cluster 2 krill were actively

reproductive: 49% were gravid females (3d); 11% were females with ovarian development (3c); and 33% were sexually functional males (3b). Post-reproductive Cluster 1 krill occurred at five stations, all in shelf areas around Elephant and King George Islands. Reproductively active Cluster 2 krill occurred at 10 stations primarily located north of Cluster 1 (Figure 4.3B).

(2) *Salpa thompsoni*

Abundance, Size Distribution, Maturity Stage Composition and Distributional Attributes

Salpa thompsoni again was present in all samples and was relatively abundant (mean and median abundance, respectively, 247.2 and 149.8 per 1000 m^3). Their mean and median abundance values in the Elephant Island area were 2X those in the West area (Table 4.1B). As during January, the aggregate stage predominated (93%). Aggregates ranged from newly budded 5mm long individuals to 90mm (ca. 6 months old) forms that budded early in the seasonal production period. Solitary stages ranged in length from 5-123mm; most (80%) were >16mm. Together the low abundance and large size of solitaries indicate that production of the overwintering stock had not yet started. Large numbers of 9-11mm aggregates indicated that solitaries were still actively budding during the survey period (Figure 4.6B). The bulk of the salps were 28-46mm (45%) centered around a primary mode of 35-40mm. These lengths were prevalent in both the Elephant Island and West areas (Figure 4.6B). Greater proportions of small salps occurred in the Elephant Island area (e.g., individuals <30mm contributed 50% there vs. 20% in the West area), but the difference was not significant (Kolmogorov-Smirnov test, $P>0.05$). Cluster analysis applied to salp length frequency distributions at each station did not yield any interesting or significant patterns.

(3) Zooplankton and Micronekton Assemblage:

Distribution and Abundance Relations of Dominant Taxa

A total of 59 zooplankton taxa were identified in the 67 Survey D samples (Tables 4.11 and 4.12). Copepods again dominated the catch in all subareas and comprised 65% of the total zooplankton. Greatest concentrations (1100 to 11,000 per 1000 m^3) again occurred offshore in Drake Passage; relatively large numbers (1000-2500 per 1000 m^3) were also encountered at scattered locations around the islands (Figure 4.7C). *Salpa thompsoni* ranked second in overall abundance (11%), followed by chaetognaths, larval and postlarval *T. macrura*, and larval and postlarval krill. Postlarval *T. macrura* were most abundant in the southern portion of the survey area; *T. macrura* larvae were generally rare or absent here and had greatest concentrations offshore of King George Island (Figures 4.8C and 4.8D). Largest concentrations of larval krill, like those of copepods and larval *T. macrura*, occurred offshore of King George Island, presumably in association with a retention zone (e.g., front or gyral area) (Figure 4.7D). *Euphausia frigida,* ostracods, and *I. racovitzai,* respectively, ranked 8, 9, and 10 in abundance; *E. frigida* and *I. racovitzai* were most abundant in the Elephant Island area, while ostracods were most abundant in the South area. The distribution of *I. racovitzai* again can be attributed to an

East Wind Drift influence (Figure 4.9B). None of the dominant or common zooplankton taxa had significant abundance differences between the subareas (ANOVA, $P>0.50$ in all cases).

Diel Abundance Differences

Unlike Survey A, *S. thompsoni* did not exhibit a significant day-night catch size difference. Highest concentrations of *E. frigida* occurred at night vs. day (ANOVA, $P<0.05$) and of *E. triacantha* at night vs. day and twilight ($P<0.05$, both cases). *Thysanoessa macrura* postlarvae also exhibited significantly higher night vs. day abundance ($P<0.05$) in Survey D samples.

Interspecific Relationships

Cluster analysis applied to zooplankton abundance (Log N+1) resulted in four distinct station groupings; these had a somewhat disjunct distribution pattern across the survey area (Figure 4.10B). The two largest groups, Cluster 1 (27 stations) and Cluster 2 (17 stations), generally divided the area into southern and northern (i.e., Bransfield Strait and Drake Passage) sectors. Most Cluster 3 stations (13 of 15) were adjacent to island shelf areas. Six of the eight Cluster 4 stations were offshore in the presumed retention area. All clusters were dominated by copepods and shared most taxa, but they differed greatly in absolute and relative abundance of taxa (Table 4.14). Cluster 4 was characterized by dense concentrations of small zooplankters; significantly greater mean abundance of copepods, chaetognaths, larval krill, larval *T. macrura*, and *Spongiobranchaea australis* occurred here relative to the other clusters (ANOVA, $P<0.05$). Additionally, significantly larger concentrations of *Tomopteris* spp. and ostracods occurred in Cluster 4 than in two other clusters. Copepods comprised 72% of Cluster 4 zooplankton; *T. macrura* larvae were second in mean abundance (12%), followed by chaetognaths (8%) and salps (3%). Clusters 1 and 2 shared similar proportions of copepods (61-69%) and *S. thompsoni* (16-17%). However, significantly greater numbers of postlarval *T. macrura* and *E. frigida* occurred in Cluster 1. Greatest concentrations of postlarval krill, *E. triacantha, S. thompsoni*, and *I. racovitzai* also occurred in the southern sector inhabited by Cluster 1. Both Clusters 2 and 3 were characterized by relatively low numbers of most taxa. Copepods were least abundant and contributed only 42% of zooplankton in Cluster 3; consequently *S. thompsoni* and postlarval *T. macrura* comprised relatively larger proportions (29% and 19%, respectively) than in other clusters. Clusters 2 and 3, therefore, represent a zooplankton-poor band extending along the northern island shelves and adjacent areas, bounded by richer waters of Bransfield Strait and offshore retention zones.

(4) Survey A and D 1999 Comparisons

Krill

Although there was a four-fold increase in mean krill abundance between January and February surveys, the median abundance decreased by an equal amount (Table 4.12). Similarly, in the Elephant Island area the mean krill biomass value demonstrated an order of magnitude increase,

while the median biomass value was halved between the two surveys (Table 4.6). Standard deviations associated with abundance means also increased over an order of magnitude between

January and February. These shifts indicate a marked change in distributional attributes, with krill becoming more aggregated (i.e., patchy) with advancing season.

Krill size increased significantly between the two surveys (Kolmogorov-Smirnov test, $P<0.01$) due to fewer individuals <40mm and greater numbers of 47-58mm long krill (Figures 4.2A and 4.12A). Decreased abundance of juvenile and immature stages were associated with this size change (Table 4.2). These changes reflect seasonal southward migration of age/maturity classes (Siegel 1988) with the smaller, immature (i.e., 2 year old) krill moving into higher latitudes and larger mature krill (i.e., 3 years and older) entering the area from offshore. Increased patchiness with the advancing season may be associated with reproduction (Siegel and Kalinowski, 1994). Although the presence of krill larvae in January indicated that spawning was probably initiated in mid- to late-December, it is strange that there were not substantial increases in either larval abundance (Table 4.12) or development beyond the calyptopis stage 2 over the two month period. These observations suggest that there may have been low larval survivorship and/or retention within the survey area this summer, which dampen somewhat optimism about recruitment success of the 1998/99 year class.

Salpa thompsoni

Median salp abundance across the survey area increased by 50%, while that in the Elephant Island area remained constant between the two months (Tables 4.5 and 4.12). This relatively stable population size indicates that production of new aggregates was not much greater than loss due to mortality and advection out of the area. During both surveys the length-frequency distributions reflect an early initiation (late August/early September) and relatively long budding period with peak production in December (Figure 4.6). The increase of the primary length mode from 24-28mm in January to 35-40mm in February (11-12mm change over a 23 day period) is consistent with the 14mm per month summer growth rate estimated in 1997.

Overall Zooplankton Taxonomic Composition and Abundance

Greatest seasonal changes in the zooplankton assemblage during 1999 were largely due to increased abundance of dominant taxa (Table 4.12). Mean and median abundance of copepods, chaetognaths, *T. macrura* larvae, *E. frigida,* and ostracods essentially doubled between the January (Leg I) and February (Leg II) surveys; these abundance increases were significant for all but *T. macrura* larvae (ANOVA, $P<0.05$). Because of a substantial abundance decrease, postlarval *T. macrura* contributed less to the zooplankton in February than January (4 vs. 10%), and chaetognaths replaced them as the third ranked taxon. Aside from this shift abundance relations of dominant taxa remained fairly similar between the cruises, as indicated by a PSI value of 79.

(5) Leg II, Between Year Comparisons

Krill

While mean krill abundance in February 1999 was not particularly low, the median value in the Elephant Island area was among lowest in the past eight years (Table 4.5). As for January, the maturity stage composition clearly demonstrates that this low abundance resulted from poor recruitment since 1996 (Table 4.7). Although juvenile stages have been relatively scarce in the past (e.g., 1% of the total in February 1995), this is the first time they have been totally absent from the Elephant Island samples. Abundance of immature stages (1% of total) during February 1999 is also the lowest since 1991, additional evidence for poor recruitment success over the past three years.

The prevalence of gravid and spent females (82%) supports "normal" seasonal spawning activity during summer 1999 . This contrasts markedly with February 1998 when only 5% of mature females were in advanced maturity stages (Table 4.7). Marked seasonal increase in krill patchiness was associated with reproductive activity in 1996 and 1999. Increased seasonal patchiness also occurred in 1998, but given delayed or deferred spawning then, may have been associated with seasonal migratory behavior rather than reproduction (Table 4.5).

Males typically outnumber females in AMLR samples therefore female dominance (60%) during February 1999 is unusual (Table 4.7). As the majority of these females were gravid or spent, the paucity of males could have resulted from avoidance of spawning grounds. Reproductively active krill (i.e., Cluster 2) appeared to have a more southerly distribution in 1999 than other years (Figure 4.3). If so, then it is possible that typically offshore spawning grounds were displaced into the survey area this year.

Occurrence (81% of samples) and abundance of larval krill during February 1999 were the highest observed since 1995 (Tables 4.5 and 4.13). However, these values are the same order of magnitude as those in February 1996 and 1997 and one to two orders of magnitude lower than those in February 1995. These relatively modest mid-season abundance values again call for guarded optimism about recruitment success of the 1998/99 year class.

Salpa thompsoni

Summer 1999 was unusual in that there was no marked change in median salp abundance between January (Leg I) and February (Leg II) surveys (Table 4.5). In past summers median salp abundance has either increased or decreased substantially (generally by a factor of two or more) over the survey period. Seasonal population decreases of $\geq$50% occurred in 1994, 1995 and 1996, while increases of 60-250% occurred in 1993 and 1998; the six-fold increase in 1997 most likely is biased due to small sample size. Median salp abundance in February 1999 was most similar to that in 1994; these were intermediate to the high densities of 1993, 1997 and 1998 (>500 per 1000 m^3) and low densities of 1995 and 1996 (<6 per 1000 m^3). This has implications

for the overwintering "seed" population size. It is possible that the shift from salp to copepod years is in part due to low numbers of overwintering solitary stages produced the preceding year.

Overall Zooplankton/Micronekton

The 1-2 abundance ranking and proportions of copepods and salps in February 1999 were similar to the situation in 1994 (Table 4.9). Unfortunately incomplete analyses of the older zooplankton samples limit comparisons between these data sets. Among recent summers, the 1-2 copepod-salp abundance rankings also occurred during the 1997 "transition" period. However, a higher PSI value (81.1 vs. 64.5) results from comparison with 1996 due to more similar proportions of copepods and other dominant taxa. The salp and krill biomass values in February 1999 most resembled those during 1994 (Table 4.6). Like 1994, 1999 is expected mark a transition from salp to copepod periods.

(C) AMLR 99 Cruise Summary

During the past 11 summer field seasons, the AMLR Program has observed a multi-year cycle of physical and biological conditions in the Elephant Island area. The annual reproductive success of krill follows this cycle and results in variations in population demographics and abundance (Siegel and Loeb, 1995; Loeb et al. 1997; Siegel et al. 1997). The multi-year nature of these cycles offers the promise of predictive capability.

Within the context of this multi-year cycle, the 1998/1999 season marks a transition between a period of low sea-ice development when the pelagic community is dominated by salps and a period of above-average sea-ice when a more diverse copepod dominated zooplankton community prevails. This has profound implications for the reproductive success and potential growth of the krill population.

During the 1999 field season we observed:

- Krill abundance near the lowest level ever recorded during the AMLR surveys. This is the result of three successive years of poor reproductive and recruitment success.

- The remaining krill population was dominated by older age classes that had been actively spawning since mid- to late December. This contrasts with the last three years when spawning was reduced in intensity and occurred unfavorably late in the season.

- Reduction in the abundance of salps and a dramatic increase in the numbers of copepods, chaetognaths, *Thysanoessa macrura* larvae, *Euphausia frigida* and several other zooplankton taxa.

These results do not come as a total surprise. They confirm our predicted failure of the 1997/1998 krill year class. They also confirm our prediction that the 1998/99 austral summer

would be a transition period based on the cyclic trend of environmental conditions here over the past 11 years.

The question now is whether enough young krill were produced to rebuild the population. This depends on survival of the larval stages to and through the first winter and on how many more young can be produced during the following two to three years.

4.4 Disposition of Data and Samples: All of the krill, salp, other zooplankton, and fish data have been digitized and are available upon request from Valerie Loeb. These data have been submitted to Roger Hewitt and Wesley Armstrong (Southwest Fisheries Science Center). Alcohol preserved salp specimens were provided to Linda Holland (SIO). Frozen myctophids were provided to Mike Goebel and Dan Costa (UCSC) for chemical analyses.

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Table 4.1 AMLR 1999 Large-area survey IKMT station information.

A. SURVEY A

STATION #	DATE	TIME (Local) START	TIME (Local) END	DIEL	TOW DEPTH (m)	FLOW VOLUME (m3)	KRILL ABUNDANCE TOTAL	KRILL ABUNDANCE #/m2	KRILL ABUNDANCE #/1000m3	SALP ABUNDANCE TOTAL	SALP ABUNDANCE #/1000m3
A010	15/01/99	1438	1503	D	170	4694.1	102	3.7	21.7	515	109.7
A104	15/01/99	1831	1853	D	170	3262.0	10	0.5	3.1	84	25.8
A105	15/01/99	2216	2246	T	169	4605.8	0	0.0	0.0	2122	460.7
A186	16/01/99	0225	0253	N	171	4544.9	0	0.0	0.0	2660	585.3
A187	16/01/99	0644	0703	D	171	2674.1	0	0.0	0.0	2614	977.5
A110	16/01/99	1848	1909	D	171	2816.4	0	0.0	0.0	69	24.5
A016	16/01/99	2218	2248	T	172	4497.6	12	0.5	2.7	311	69.1
A013	17/01/99	0157	0231	N	170	4289.0	9	0.4	2.1	2	0.5
A014	17/01/99	0527	0545	D	143	2482.8	38	2.2	15.3	166	66.9
A116	17/01/99	0858	0920	D	170	2949.5	0	0.0	0.0	212	71.9
A123	17/01/99	1235	1258	D	170	3412.0	4	0.2	1.2	4	1.2
A124	17/01/99	1613	1636	D	172	3081.0	0	0.0	0.0	38	12.3
A125	17/01/99	1946	2012	D	171	3745.0	6	0.3	1.6	610	162.9
A138	17/01/99	2330	2358	N	169	3708.3	0	0.0	0.0	863	232.7
A137	18/01/99	0329	0355	T	171	3581.0	0	0.0	0.0	369	103.0
A136	18/01/99	0716	0739	D	170	3148.2	9	0.5	2.9	27	8.6
A135	18/01/99	1038	1105	D	170	3581.2	143	6.8	39.9	84	23.5
A150	19/01/99	0111	0128	N	110	2670.5	68	2.8	25.5	1146	429.1
A151	19/01/99	0503	0529	T	171	3954.9	0	0.0	0.0	102	25.8
A152	19/01/99	085	0925	D	171	4344.9	0	0.0	0.0	48	11.0
A153	19/01/99	1238	1302	D	171	3867.8	0	0.0	0.0	56	14.5
A164	19/01/99	2039	2109	D	165	3899.7	15	0.6	3.8	337	86.4
A165	20/01/99	0022	0049	N	173	3970.2	0	0.0	0.0	383	96.5
A166	20/01/99	0405	0441	T	172	6036.8	0	0.0	0.0	782	129.5
A174	20/01/99	1209	1237	D	170	3931.7	60	2.6	15.3	293	74.5
A175	20/01/99	1543	1607	D	170	3187.7	0	0.0	0.0	30	9.4
A176	20/01/99	1904	1930	D	170	3597.0	0	0.0	0.0	254	70.6
A133	21/01/99	1104	1129	D	170	3395.6	2	0.1	0.6	640	188.5
A134	21/01/99	1429	1458	D	170	3976.2	21	0.9	5.3	118	29.7
A001	21/01/99	1807	1831	D	170	3624.6	291	13.6	80.3	2	0.6
A121	22/01/99	0134	0205	N	170	4035.2	4	0.2	1.0	410	101.6
A005	22/01/99	0518	0543	D	167	3673.7	5	0.2	1.4	38	10.3
A003	22/01/99	0824	0851	D	170	5210.6	0	0.0	0.0	195	37.4
A109	22/01/99	1520	1555	D	170	5445.1	28	0.9	5.1	206	37.8
A007	22/01/99	1900	1925	D	170	3535.7	46	2.2	13.0	226	63.9
A017	22/01/99	2349	0014	N	173	3370.5	12	0.6	3.6	938	278.3
A018	23/01/99	0248	0313	T	171	3464.9	20	1.0	5.8	820	236.7
A019	23/01/99	0623	0654	D	168	4425.3	1	0.0	0.2	313	70.7
A020	23/01/99	0954	1021	D	170	3462.6	0	0.0	0.0	262	75.7
A021	23/01/99	1319	1349	D	170	5093.4	2	0.1	0.4	26	5.1
A022	23/01/99	1639	1704	D	170	3441.0	2	0.1	0.6	205	59.6
A023	23/01/99	1945	2009	D	170	3071.2	3	0.2	1.0	188	61.2
A024	23/01/99	2234	2257	N	171	2725.6	0	0.0	0.0	2309	847.1
A043	24/01/99	0329	0358	T	168	4433.6	2	0.1	0.5	1420	320.3
A042	24/01/99	0637	0705	D	169	3857.0	0	0.0	0.0	696	180.5
A041	24/01/99	0945	1009	D	171	3456.8	0	0.0	0.0	601	173.9
A040	24/01/99	1249	1316	D	170	3800.3	0	0.0	0.0	100	26.3
A039	24/01/99	1613	1642	D	170	3994.4	0	0.0	0.0	218	54.6

Table 4.1 AMLR 1999 Large-area survey IKMT station information (Contd.)

STATION #	DATE	TIME START (Local)	TIME END (Local)	DIEL	TOW DEPTH (m)	FLOW VOLUME (m3)	KRILL ABUNDANCE TOTAL	KRILL ABUNDANCE #/m2	KRILL ABUNDANCE #/1000m3	SALP ABUNDANCE TOTAL	SALP ABUNDANCE #/1000m3
A038	24/01/99	1923	1954	D	170	4710.1	6	0.2	1.3	862	183.0
A037	24/01/99	2225	2250	T	170	3647.7	44	2.1	12.1	578	158.5
A036	25/01/99	0118	1045	N	169	3966.2	35	1.5	8.8	794	200.2
A052	25/01/99	0550	0617	D	173	4011.3	7	0.3	1.7	1122	279.7
A053	25/01/99	0845	0915	D	170	4568.9	0	0.0	0.0	228	49.9
A054	25/01/99	1117	1127	D	65	1606.9	0	0.0	0.0	1016	632.3
A055	25/01/99	1453	1511	D	135	2661.9	19	1.0	7.1	343	128.9
A056	25/01/99	1900	1925	D	170	3560.0	11	0.5	3.1	361	101.4
A057	25/01/99	2158	2225	T	175	3740.0	0	0.0	0.0	912	243.9
A058	26/01/99	0111	0140	N	170	4337.3	36	1.4	8.3	481	110.9
A059	26/01/99	0411	0436	T	170	3668.6	0	0.0	0.0	955	260.3
A075	26/01/99	0905	0931	D	170	3660.7	125	5.8	34.1	1223	334.1
A074	26/01/99	1214	1236	D	170	3114.1	0	0.0	0.0	112	36.0
A073	26/01/99	1530	1554	D	170	3482.9	15	0.7	4.3	145	41.6
A072	26/01/99	1841	1905	D	172	3360.7	24	1.2	7.1	560	166.6
A071	26/01/99	2135	2200	T	170	3011.4	0	0.0	0.0	481	159.7
A070	27/01/99	0035	0059	N	170	3950.0	40	1.7	10.1	578	146.3
A069	27/01/99	0348	0413	T	170	3555.8	65	3.1	18.3	1286	361.7
A068	27/01/99	0701	0728	D	169	4191.0	147	5.9	35.1	543	129.6
A084	27/01/99	1118	1140	D	170	3137.2	34	1.8	10.8	574	183.0
A085	27/01/99	1412	1435	D	170	3387.3	36	1.8	10.6	163	48.1
A086	27/01/99	1703	1728	D	170	3710.6	37	1.7	10.0	216	58.2
A087	27/01/99	2003	2026	D	169	2933.0	14	0.8	4.8	279	95.1
A088	27/01/99	2248	2311	N	177	3133.8	23	1.3	7.3	2737	873.4
A089	28/01/99	0211	0238	N	165	3765.2	6	0.3	1.6	805	213.8
A090	28/01/99	0519	0545	S	170	3926.1	18	0.8	4.6	505	128.6
A091	28/01/99	0829	0851	D	170	3988.8	0	0.0	0.0	739	185.3
SURVEY A AREA					No.	75	1657			42710	
					Mean			1.0	6.1		163.3
					SD			2.0	12.0		197.9
					Median			0.2	1.3		101.4
ELEPHANT ISLAND AREA					No.	40	784			26694	
					Mean			0.9	5.3		197.5
					SD			1.4	8.1		191.6
					Median			0.3	1.7		159.1
WEST AREA					No.	27	476			14181	
					Mean			0.8	5.0		143.8
					SD			1.5	9.7		219.4
					Median			0.0	0.0		70.6
SOUTH AREA					No.	8	397			1835	
					Mean			2.3	13.3		58.7
					SD			4.4	25.6		57.2
					Median			0.6	3.3		37.6

Table 4.1 AMLR 1999 Large-area survey IKMT station information.

B. SURVEY D

STATION #	DATE	TIME		DIEL	TOW DEPTH	FLOW VOLUME	KRILL ABUNDANCE			SALP ABUNDANCE	
		START (Local)	END		(m)	(m3)	TOTAL	#/m2	#/1000m3	TOTAL	#/1000m3
D174	10/02/99	1942	2008	D	168	3515.1	0	0.0	0.0	518	147.4
D175	10/02/99	2319	2343	N	170	3961.8	1	0.0	0.3	1163	293.6
D176	11/02/99	0303	0323	N	170	2388.1	1	0.1	0.4	1033	432.6
D164	11/02/99	1036	1100	D	170	3325.6	0	0.0	0.0	120	36.1
D165	11/02/99	1428	1459	D	173	4277.2	0	0.0	0.0	1273	297.6
D166	11/02/99	1823	1849	D	171	3487.0	0	0.0	0.0	1097	314.6
D150	12/02/99	0339	0353	N	100	2129.1	5	0.2	2.3	106	49.8
D153	12/02/99	1746	1811	D	173	3790.9	0	0.0	0.0	332	87.6
D138	12/02/99	2132	2156	N	170	3900.0	0	0.0	0.0	697	178.7
D137	13/02/99	0131	0159	N	176	3944.3	1	0.0	0.3	276	70.0
D136	13/02/99	0552	0622	N	170	3992.1	0	0.0	0.0	351	87.9
D135	13/02/99	0930	0954	D	170	4004.6	1	0.0	0.2	99	24.7
D014	13/02/99	1344	1409	D	149	4020.3	1	0.0	0.2	142	35.3
D116	13/02/99	1749	1814	D	170	3941.2	6	0.3	1.5	331	84.0
D125	14/02/99	0537	0602	N	170	4197.5	0	0.0	0.0	331	78.9
D188	14/02/99	0944	1006	D	170	4358.2	0	0.0	0.0	1794	411.6
D111	14/02/99	1331	1357	D	168	4323.5	0	0.0	0.0	376	87.0
D110	14/02/99	1724	1752	D	180	5075.3	0	0.0	0.0	366	72.1
D016	14/02/99	2115	2140	N	170	3860.0	0	0.0	0.0	700	181.3
D013	14/02/99	1257	0124	N	170	3530.9	823	39.6	233.1	311	88.1
D010	15/02/99	0457	0521	N	170	3820.8	4	0.2	1.0	628	164.4
D104	15/02/99	0832	0855	D	170	3746.3	0	0.0	0.0	461	123.1
D105	15/02/99	1218	1244	D	173	4503.3	0	0.0	0.0	90	20.0
D186	15/02/99	1609	1635	D	172	4328.7	0	0.0	0.0	1669	385.6
D187	15/02/99	1951	2018	D	168	3867.4	0	0.0	0.0	772	199.6
D024	16/02/99	0614	0639	N	169	3884.5	7	0.3	1.8	1107	285.0
D023	16/02/99	0913	0936	D	172	3680.6	0	0.0	0.0	918	249.4
D022	16/02/99	1214	1241	D	167	4942.9	0	0.0	0.0	347	70.2
D021	16/02/99	1521	1549	D	168	5084.6	0	0.0	0.0	679	133.5
D020	16/02/99	1829	1852	D	170	4475.0	0	0.0	0.0	916	204.7
D019	16/02/99	2125	2149	T	170	3753.8	0	0.0	0.0	915	243.8
D018	18/02/99	1033	1055	D	170	3810.8	3	0.1	0.8	569	149.3
D017	18/02/99	1328	1356	D	167	4721.3	1	0.0	0.2	379	80.3
D036	18/02/99	1750	1819	D	172	4599.4	3	0.1	0.7	141	30.7
D037	18/02/99	2046	2112	T	169	4081.9	26	1.1	6.4	5151	1261.9
D038	18/02/99	2331	2357	N	170	4842.4	769	27.0	158.8	355	73.3
D039	19/02/99	0238	0307	N	174	4715.1	4614	170.3	978.6	539	114.3
D040	19/02/99	0600	0628	N	170	3882.6	2	0.1	0.5	624	160.7
D041	19/02/99	0925	0947	D	172	3683.7	0	0.0	0.0	281	76.3
D043	19/02/99	2139	2210	N	170	3676.3	0	0.0	0.0	5699	1550.2
D059	19/02/99	0257	0323	N	177	4782.1	137	5.1	28.6	572	119.6
D058	20/02/99	0754	0820	D	170	4485.2	2	0.1	0.4	584	130.2
D057	20/02/99	1039	1102	D	168	4166.2	0	0.0	0.0	146	35.0
D056	20/02/99	1422	1451	D	170	5502.8	7	0.2	1.3	428	77.8
D055	20/02/99	1728	1749	D	139	3674.3	0	0.0	0.0	1822	495.9
D054	20/02/99	2100	2123	T	171	3855.8	3	0.1	0.8	190	49.3
D053	20/02/99	2328	2370	N	170	3772.6	164	7.4	43.5	794	210.5

Table 4.1 AMLR 1999 Large-area survey IKMT station information (Contd.)

STATION #	DATE	TIME START (Local)	TIME END (Local)	DIEL	TOW DEPTH (m)	FLOW VOLUME (m3)	KRILL ABUNDANCE TOTAL	KRILL ABUNDANCE #/m2	KRILL ABUNDANCE #/1000m3	SALP ABUNDANCE TOTAL	SALP ABUNDANCE #/1000m3
D052	21/02/99	0225	0250	N	170	4502.8	19	0.7	4.2	2037	452.4
D068	21/02/99	0649	0718	T	170	4698.9	3	0.1	0.6	791	168.3
D069	21/02/99	0944	1005	D	172	3187.8	1	0.1	0.3	350	109.8
D070	21/01/99	1229	1258	D	170	4654.1	153	5.6	32.9	616	132.4
D071	21/02/99	2400	0031	N	170	4676.4	15	0.5	3.2	6204	1326.7
D072	22/02/99	0338	0410	N	170	5033.5	32	1.1	6.4	818	162.5
D073	22/02/99	0655	0721	D	170	4007.6	10	0.4	2.5	1102	275.0
D074	22/02/99	1006	1029	D	170	3776.1	3	0.1	0.8	1480	391.9
D075	22/02/99	1321	1347	D	168	3770.9	0	0.0	0.0	645	171.0
D091	22/02/99	1810	1833	D	170	3894.3	2	0.1	0.5	2498	641.4
D090	22/02/99	2128	2152	N	170	3948.3	24	1.0	6.1	4888	1238.0
D089	23/02/99	0115	0145	N	170	4564.2	396	14.7	86.8	1506	330.0
D088	23/02/99	0505	0530	N	170	3778.1	3	0.1	0.8	502	132.9
D087	23/02/99	0853	0915	D	170	4000.0	39	1.7	9.8	230	57.5
D086	23/02/99	1231	1258	D	170	4010.6	18	0.8	4.5	601	149.9
D085	23/02/99	1617	1641	D	171	3262.9	3	0.2	0.9	625	191.6
D084	23/02/99	1947	2012	D	171	3427.1	1	0.0	0.3	923	269.3
D189	24/02/99	0524	0550	D	170	4103.2	7	0.3	1.7	1597	389.2
D007	24/02/99	0949	1013	D	172	3914.7	4	0.2	1.0	23	5.9
D001	25/02/99	2259	2323	N	168	4260.8	45	1.8	10.6	914	214.5
SURVEY D AREA					No.	66	7359			66544	
					Mean			4.2	24.4		247.2
					SD			21.3	122.7		306.6
					Median			0.1	0.4		149.9
ELEPHANT ISLAND AREA					No.	39	6460			48974	
					Mean			6.1	35.5		307.8
					SD			27.1	155.7		375.3
					Median			0.1	0.8		162.5
WEST AREA					No.	25	843			15036	
					Mean			1.6	9.6		158.1
					SD			7.8	45.6		123.8
					Median			0.0	0.0		88.1
SOUTH AREA					No.	3	56			2534	
					Mean			0.8	4.4		203.2
					SD			0.1	4.3		156.7
					Median			0.3	1.7		214.5

Table 4.2 Maturity stage composition of krill collected in large-area survey and three subareas during 1999. Advanced maturity stages are proportions of mature females that are 3c-3e in January and 3d-3e in February. February South area data are omitted due to small sample size.

	E. superba January 1999			
Area	Survey A	Elephant I.	West	South
Stage	%	%	%	%
Juveniles	3.1	0.4	0.3	7.5
Immature	30.1	11.7	20.1	56.5
Mature	66.8	87.9	79.6	37.0
Females:				
F2	10.4	1.6	8.7	20.5
F3a	12.7	1.7	35.6	11.2
F3b	3.0	1.8	5.0	3.2
F3c	8.5	14.7	5.8	3.7
F3d	12.8	23.9	0.5	9.3
F3e	3.9	9.2	0.2	0.9
Advanced Stages	61.5	93.2	13.9	49.1
Males:				
M2a	9.1	2.2	4.0	19.6
M2b	7.3	3.9	3.3	13.5
M2c	3.3	4.1	4.2	1.9
M3a	2.0	1.7	3.1	1.6
M3b	24.0	34.9	29.3	7.2
Male:Female	0.9	0.9	0.8	0.9
No. measured	1420	751	434	235

	February 1999			
Area	Survey D	Elephant I.	West	
Stage	%	%	%	
Juveniles	0.0	0.0	0.0	
Immature	5.2	1.3	28.1	
Mature	94.8	98.7	71.9	
Females:				
F2	0.7	0.0	4.9	
F3a	1.1	0.4	5.3	
F3b	0.2	0.0	1.3	
F3c	9.6	11.1	0.3	
F3d	40.6	47.3	1.4	
F3e	12.2	4.8	56.1	
Advanced Stages	82.9	81.8	89.3	
Males:				
M2a	0.0	0.0	0.0	
M2b	2.5	0.7	13.3	
M2c	1.9	0.6	9.9	
M3a	2.9	2.6	4.4	
M3b	28.2	32.4	3.1	
Male:Female	0.6	0.6	0.4	
No. measured	1369	1176	182	

Table 4.3 Abundance relations of dominant zooplankton taxa in the Survey A area and three subareas, January 1999. Only the 20 most abundant taxa overall are considered. F(%) is frequency of occurrence in N samples. Abundance ranks (R) are provided for the 10 most abundant taxa in each subarea. N(%) is proportion of total mean abundance provided by each taxon. (L) indicates larval form.

	SURVEY A AREA (N = 75)						ELEPHANT ISLAND AREA (N = 40)						WEST AREA (N = 27)						SOUTH AREA (N = 8)					
Taxon	F(%)	R	%	Mean	SD	Med.	F(%)	R	%	Mean	SD	Med.	F(%)	R	%	Mean	SD	Med.	F(%)	R	%	Mean	SD	Med.
Copepods	100.0	1	53.9	711.6	1266.8	286.8	100.0	1	58.0	928.2	1590.8	333.0	100.0	1	45.6	501.3	692.9	252.9	100.0	1	49.6	338.5	498.4	144.1
Salpa thompsoni	100.0	2	12.4	163.3	197.9	101.4	100.0	2	12.4	197.5	191.6	159.1	100.0	3	13.1	143.8	219.4	70.6	100.0	3	8.6	58.7	57.2	37.6
Thysanoessa macrura	93.3	3	10.2	135.1	587.1	36.9	90.0	6	2.9	46.7	54.1	23.2	96.3	2	24.5	269.7	959.3	41.8	100.0	2	18.0	123.0	105.2	104.0
Euphausia superba (L)	65.3	4	7.8	103.1	587.4	2.6	75.0	3	10.9	175.1	795.5	7.3	59.3	7	1.3	14.4	33.9	1.3	37.5	4	6.2	42.7	103.6	0.0
Thysanoessa macrura (L)	69.3	5	5.5	72.5	262.7	3.0	70.0	4	7.3	116.5	348.8	2.8	74.1	5	2.4	26.9	71.8	5.5	50.0	8	1.0	6.7	11.3	0.8
Chaetognaths	97.3	6	5.4	70.9	170.7	23.0	97.5	5	4.0	63.9	159.1	14.7	96.3	4	8.2	89.8	206.2	25.0	100.0	5	6.1	41.9	31.3	39.6
Euphausia frigida	34.7	7	0.7	9.0	22.6	0.0	50.0	7	1.0	15.9	29.1	0.1	18.5		0.1	1.4	3.6	0.0	12.5		0.0	0.1	0.3	0.0
Euphausia superba	60.0	8	0.5	6.1	12.0	1.3	65.0	8	0.3	5.3	8.1	1.7	44.4	8	0.5	5.0	9.7	0.0	87.5	7	2.0	13.3	25.6	3.3
Vibilia antarctica	94.7	9	0.3	3.8	4.5	1.7	100.0	9	0.3	5.1	5.3	3.1	85.2		0.2	2.1	2.5	1.1	100.0		0.4	2.9	3.0	1.0
Ihlea racovitzai	25.3	10	0.2	3.3	9.0	0.0	30.0		0.2	2.4	5.2	0.0	3.7		0.0	0.3	1.3	0.0	75.0	6	2.6	17.8	19.4	10.9
Ostracods	49.3	11	0.2	2.8	5.6	0.0	45.0		0.1	2.1	4.7	0.0	51.9	10	0.3	3.3	5.9	0.5	62.5	10	0.7	4.8	7.8	2.3
Primno macropa	69.3	12	0.2	2.5	3.4	1.3	65.0		0.1	2.1	2.5	0.8	70.4	9	0.3	3.3	4.4	1.3	87.5		0.3	2.1	2.1	1.6
Limacina helicina	61.3	13	0.2	2.4	4.2	0.5	45.0		0.1	1.2	3.4	0.0	77.8		0.3	3.0	3.3	2.1	87.5	9	0.9	6.4	6.9	3.9
Tomopteris spp.	56.0	14	0.2	2.0	4.7	0.3	47.5	10.5	0.2	2.5	6.0	0.0	66.7		0.1	1.4	2.3	0.3	62.5		0.3	2.0	3.4	0.8
Cyllopus magellanicus	78.7	15	0.2	2.0	2.4	1.0	87.5	10.5	0.2	2.5	2.4	1.6	77.8		0.1	1.6	2.3	0.7	37.5		0.1	1.0	2.0	0.0
Spongiobranchaea australis	72.0		0.1	1.5	2.4	0.6	70.0		0.1	1.5	2.1	0.3	81.5		0.2	1.8	2.9	0.6	50.0		0.1	0.6	0.9	0.2
Rhynchonereella bongraini	33.3		0.1	0.8	1.5	0.0	42.5		0.1	0.9	1.6	0.0	7.4		0.0	0.1	0.3	0.0	75.0		0.4	2.4	2.2	2.1
Hyperiella dilatata	52.0		0.0	0.5	0.9	0.2	47.5		0.0	0.5	1.1	0.0	55.6		0.0	0.4	0.6	0.3	62.5		0.1	0.8	0.9	0.4
Diphyes antarctica	34.7		0.0	0.5	1.1	0.0	40.0		0.0	0.5	1.2	0.0	18.5		0.0	0.3	0.8	0.0	62.5		0.1	1.0	1.0	0.7
Larvaceans	4.0		0.0	0.5	3.0	0.0	5.0		0.0	0.3	1.3	0.0	0.0		0.0	0.0	0.0	0.0	12.5		0.5	3.2	8.4	0.0
Gastropods	5.3		0.0	0.5	2.7	0.0	0.0		0.0	0.0	0.0	0.0	3.7		0.0	0.0	0.2	0.0	37.5		0.6	4.1	7.3	0.0
Euphausia triacantha	17.3		0.0	0.4	1.2	0.0	20.0		0.0	0.5	1.2	0.0	14.8		0.0	0.4	1.4	0.0	12.5		0.0	0.1	0.3	0.0
Electrona spp. (L)	24.0		0.0	0.2	0.6	0.0	15.0		0.0	0.1	0.2	0.0	44.4		0.0	0.5	0.9	0.0	0.0		0.0	0.0	0.0	0.0
Dimophyes arctica	6.7		0.0	0.1	0.4	0.0	2.5		0.0	0.0	0.0	0.0	7.4		0.0	0.1	0.4	0.0	25.0		0.1	0.6	1.0	0.0

Table 4.4 Relative abundance of zooplankton taxa in two groupings derived from cluster analysis of January 1999 Survey A data. Ranks of the 15 most abundant taxa based on mean abundance (No. per 1000 m3) within each station grouping. Asterisks denote significantly larger values based on analysis of variance: *** P<0.001; **P<0.01; * P<0.05.

	CLUSTER 1 (N = 38)				CLUSTER 2 (N = 37)				
Taxon	Rank		Mean	SD	%	Rank		Mean	SD	%
Thysanoessa macrura	1		175.8	826.4	31.8	6		95.5	110.9	4.6
Copepods	2		167.8	242.9	30.3	1	***	1241.1	1594.2	60.0
Salpa thompsoni	3		156.8	193.9	28.4	3		169.7	201.6	8.2
Chaetognaths	4		12.3	16.1	2.2	5	**	127.9	225.1	6.2
Euphausia superba	5		8.7	16.0	1.6	10		3.5	4.7	0.2
Thysanoessa macrura (L)	6		5.4	13.0	1.0	4	*	137.9	356.9	6.7
Euphausia superba (L)	7		4.7	11.1	0.8	2		198.9	813.8	9.6
Vibilia antarctica	8		4.6	5.4	0.8	14		2.9	3.1	0.1
Primno macropa	9		1.9	2.9	0.4	13		3.1	3.7	0.1
Cyllopus magellanicus	10.5		1.6	2.0	0.3	15		2.4	2.6	0.1
Limacina helicina	10.5		1.6	2.6	0.3	11.5		3.2	5.2	0.2
Ostracods	12		1.2	3.2	0.2	9	*	4.3	6.9	0.2
Spongiobranchaea australis	13		1.1	2.2	0.2			1.7	2.3	0.1
Ihlea racovitzai	14		1.0	3.5	0.2	8	*	5.6	11.7	0.3
Tomopteris spp.	15		0.9	1.8	0.2	11.5	*	3.2	6.2	0.2
Rhynchonereella bongraini			0.6	1.1	0.1			0.9	1.9	0.0
Euphausia frigida			0.5	2.7	0.1	7	***	17.0	29.5	0.8
Diphyes antarctica			0.5	1.1	0.1			0.5	1.0	0.0
Hyperiella dilatata			0.4	0.6	0.1			0.6	1.1	0.0
Themisto gaudichaudi			0.3	0.7	0.1			0.3	0.7	0.0
Hydromedusae			0.3	0.6	0.0			0.2	0.3	0.0
Electrona spp. (L)			0.1	0.5	0.0			0.3	0.7	0.0
Gastropods			0.0	0.1	0.0			0.9	3.8	0.0
Euphausia triacantha			0.0	0.0	0.0		**	0.8	1.6	0.0
TOTAL ZOOPLANKTON			553.1	932.7				2069.3	2237.7	

Table 4.5 Abundance of krill and other dominant zooplankton taxa collected in the Elephant Island area during January-February and February-March surveys, 1992-1999. Zooplankton data are not available (n.a.) for February-March 1992.

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

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

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

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

Table 4.5 (Contd)

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

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

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

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

Table 4.6 Salp and krill carbon biomass (mg C per m^2) in the Elephant Island area during 1994-1999 surveys. N is number of samples. Salp:Krill biomass ratio is based on median values.

	January-February											
	1994		1995		1996		1997		1998		1999	
Biomass	Salps	Krill	Salps	Krill	Salps	Krill	Salps	Krill	Salps	Krill	Salps	Krill
Mean	570.6	314.1	7.8	242.3	20.2	337.3	334.5	229.0	430.8	173.1	151.8	48.6
SD	563.2	856.4	16.1	201.1	30.9	756.1	1115.6	522.1	565.3	290.6	166.1	66.1
Median	400.5	25.6	1.3	43.5	10.0	72.2	108.9	45.1	187.0	46.7	93.2	14.5
Maximum	3276.8	4971.1	75.3	1545.2	134.2	4721.0	9434.6	3115.5	2699.0	1488.4	882.7	304.4
N	63	63	57	71	72	72	71	71	61	60	40	40
Salp:Krill	15.6		0.03		0.1		2.4		4.0		6.4	

	February-March											
	1994		1995		1996		1997		1998		1999	
Biomass	Salps	Krill	Salps	Krill	Salps	Krill	Salps	Krill	Salps	Krill	Salps	Krill
Mean	483.7	425.9	13.1	59.2	50.7	1702.3	1139.7	313.1	694.6	1555.8	321.9	451.0
SD	469.5	2351.4	47.3	149.1	146.5	12441.6	1269.8	655.2	1121.2	8218.7	335.1	2082.6
Median	285.6	2.8	0.7	13.1	4.6	40.7	504.8	50.0	379.4	31.6	193.5	6.9
Maximum	1843.6	19314	325.2	1107.1	954.0	106458.5	4645.4	2638.7	8543.0	62155.8	1698.1	13133.1
N	70	70	71	71	72	72	16	16	61	60	39	39
Salp:Krill	102.0		0.1		0.1		10.1		12.0		28.0	

Table 4.7 Maturity stage composition of krill collected in the Elephant Island area during 1999 compared to 1992-1998. Advanced maturity stages are proportions of mature females that are 3c-3e in January-February and 3d-3e in February-March.

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

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

Table 4.8 Zooplankton and nekton taxa present in the large-area survey samples during January 1999 compared to January 1993-1998 surveys. F(%) is the frequency of occurrence in (N) tows. Abundance is mean number per 1000 m^3. n.a. indicates taxon was not enumerated. (L) indicates larval stages; (J) indicated juvenile stages. *Sagitta gazellae* and *Eukhronia hamata* are enumerated separately from other chaetognaths.

	JANUARY -FEBRUARY													
	1999		1998		1997		1996		1995		1994		1993	
	F(%) (75)	Mean No.	F(%) (105)	Mean No.	F(%) (105)	Mean No.	F(%) (91)	Mean No.	F(%) (90)	Mean No.	F(%) (91)	Mean No.	F(%) (87)	Mean No.
Copepods	100.0	711.6	94.2	56.5	100.0	582.6	100.0	794.4	98.9	652.7	30.0	41.3	31.0	38.1
Salpa thompsoni	100.0	163.3	100.0	808.2	97.1	181.4	64.8	20.4	66.7	16.0	100.0	818.3	100.0	1001.5
Thysanoessa macrura	93.3	135.1	100.0	180.8	97.1	104.4	98.9	106.9	91.1	96.4	90.0	79.7	95.4	51.5
Euphausia superba (L)	65.3	103.1	11.5	1.0	55.2	15.2	22.0	2.7	22.2	135.8	n.a	n.a	n.a	n.a
Thysanoessa macrura (L)	69.3	72.5	1.9	0.0	44.8	17.0	90.1	308.5	36.7	15.9	n.a	n.a	n.a	n.a
Chaetognaths	49.3	47.8	42.3	8.9	74.3	22.9	68.1	12.5	98.9	79.7	n.a	n.a	56.3	9.2
Sagitta gazellae	57.3	23.0	27.9	1.9	31.4	0.3	23.1	0.3	48.9	3.4	20.0	0.4	n.a	n.a
Eukhronia hamata	5.3	0.1	13.5	0.5	21.9	0.2	20.9	0.1	10.0	0.1	21.3	0.2	n.a	n.a
Euphausia frigida	34.7	9.0	5.8	0.2	41.9	14.8	30.8	1.9	50.0	9.8	17.5	3.8	26.4	3.6
Euphausia superba	60.0	6.1	92.3	36.8	93.3	40.4	96.7	112.5	87.8	14.5	77.5	27.1	90.8	44.1
Euphausia spp. (L)	10.7	11.1	---	---	---	---	1.1	0.0	---	---	---	---	---	---
Vibilia antarctica	94.7	3.8	96.2	13.2	70.5	2.5	48.4	0.5	22.2	0.2	98.8	11.8	64.4	1.6
Ihlea racovitzai	25.3	3.3	5.8	41.5	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Ostracods	49.3	2.8	51.0	4.8	41.0	5.5	53.8	4.9	56.7	9.7	n.a	n.a	n.a	n.a
Primno macropa	69.3	2.5	26.0	0.7	63.8	4.3	20.9	0.1	20.0	0.1	6.3	0.5	3.4	0.0
Limacina helicina	61.3	2.4	73.1	8.1	47.6	2.9	74.7	33.7	43.3	1.9	6.3	0.3	---	---
Tomopteris spp.	56.0	2.0	31.7	1.3	54.3	1.9	60.4	0.9	84.4	4.2	37.5	2.5	33.3	0.5
Cyllopus magellanicus	78.7	2.0	64.4	1.9	76.2	3.8	41.8	1.6	24.4	0.2	82.5	6.3	18.4	0.5
Spongiobranchaea australis	69.3	1.4	45.2	0.9	67.6	2.2	47.3	1.8	64.4	0.5	11.3	0.1	40.2	0.6
Rhynchonereella bongraini	33.3	0.8	9.6	0.2	4.8	0.1	2.2	0.0	3.3	0.1	---	---	---	---
Polychaetes	20.0	0.6	28.8	1.5	1.0	0.0	1.1	0.0	---	---	---	---	---	---
Hyperiella dilatata	52.0	0.5	39.4	0.4	56.2	2.2	41.8	0.6	54.4	0.3	18.7	0.3	6.9	0.0
Diphyes antarctica	34.7	0.5	37.5	1.1	9.5	0.2	17.6	0.1	58.9	1.0	20.0	0.3	20.7	0.5
Larvaceans	4.0	0.5	---	---	---	---	---	---	---	---	---	---	---	---
Euphausia triacantha	17.3	0.4	7.7	0.3	18.1	1.4	15.4	0.5	33.3	1.5	7.5	1.2	25.3	1.0
Cyllopus sp.	28.0	0.4	1.0	0.0	1.0	0.0	---	---	---	---	---	---	---	---
Themisto gaudichaudii	32.0	0.3	31.7	0.3	92.4	3.6	92.3	4.9	76.7	4.9	83.8	10.6	50.6	0.8
Hydromedusae	37.3	0.2	---	---	20.0	0.1	4.4	0.0	6.7	0.1	---	---	---	---
Electrona spp. (L)	24.0	0.2	10.6	0.2	37.1	1.4	27.5	0.7	61.1	2.5	2.5	0.0	2.3	0.0
Lepidonotothen larseni (L)	20.0	0.2	23.1	0.5	27.6	1.8	22.0	0.2	40.0	1.1	6.3	0.7	16.1	0.2
Acanthepyra pelagica	17.3	0.2	3.8	0.0	9.5	0.1	---	---	22.2	0.1	---	---	---	---
Clio pyramidata	9.3	0.1	4.8	0.3	2.9	0.0	6.6	0.1	72.2	5.3	40.0	5.4	6.9	0.2
Clione limacina	17.3	0.1	38.5	0.9	21.9	0.3	56.0	2.1	41.1	0.5	13.8	0.3	4.6	0.1
Larval fish	9.3	0.1	8.7	0.1	---	---	1.1	0.0	---	---	---	---	---	---
Dimophyes arctica	6.7	0.1	2.9	0.1	19.0	0.3	15.4	0.1	25.6	0.8	7.5	0.0	3.4	0.0
Euphausia crystallorphorias	9.3	0.1	---	---	---	---	---	---	4.4	0.0	---	---	1.1	0.0
Pleuragramma antarcticum (J)	1.3	0.1	4.8	0.0	2.9	0.0	1.1	0.0	2.2	0.0	---	---	---	---
Vanadis antarctica	5.3	0.1	4.8	0.1	1.0	0.0	4.4	0.0	15.6	0.1	2.5	0.0	4.6	0.0
Sipunculids	10.7	0.0	11.5	0.1	10.5	0.1	7.7	0.0	24.4	0.1	---	---	n.a	n.a
Cyllopus lucasii	6.7	0.0	20.2	0.5	49.5	0.4	11.0	0.1	22.2	0.5	16.3	0.7	11.5	0.4
Notolepis coatsi (L)	5.3	0.0	3.8	0.0	6.7	0.0	8.8	0.0	27.8	0.1	---	---	---	---
Lepidonotothen kempi	6.7	0.0	13.5	0.3	32.4	0.6	30.8	0.3	20.0	0.1	6.3	0.3	5.7	0.1
Ctenophores	6.7	0.0	3.8	0.1	16.2	0.1	---	---	6.7	0.0	---	---	---	---
Notothenia coriiceps	1.3	0.0	---	---	---	---	---	---	1.1	0.0	1.3	0.0	---	---
Gammarids	2.7	0.0	1.0	0.0	---	---	1.1	0.0	---	---	---	---	---	---
Hyperiella macronyx	2.7	0.0	2.9	0.1	8.6	0.1	5.5	0.0	23.3	0.1	---	---	1.1	0.0
Orchomene rossi	4.0	0.0	---	---	8.6	0.0	---	---	5.6	0.0	---	---	---	---
Bolinopsis infundibulum	5.3	0.0	1.9	0.0	---	---	---	---	---	---	---	---	---	---
Hyperoche medusarum	5.3	0.0	1.0	0.0	1.0	0.0	3.3	0.0	18.9	0.0	---	---	---	---
Beroe cucumis	4.0	0.0	3.8	0.0	15.2	0.1	7.7	0.0	12.2	0.0	15.0	0.1	2.3	0.0
Patagononotothen guntheri (J)	1.3	0.0	---	---	---	---	---	---	---	---	---	---	---	---

Table 4.8 cont.

	JANUARY -FEBRUARY													
	1999		1998		1997		1996		1995		1994		1993	
	F(%) (75)	Mean No.	F(%) (105)	Mean No.	F(%) (105)	Mean No.	F(%) (91)	Mean No.	F(%) (90)	Mean No.	F(%) (91)	Mean No.	F(%) (87)	Mean No.
Beroe forskalii	2.7	0.0	1.0	0.0	----	----	1.1	0.0	----	----	----	----	1.1	0.0
Electrona carlsbergi	2.7	0.0	1.0	0.0	10.5	0.1	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a	n.a
Notolepis annulata (L)	2.7	0.0	----	----	1.0	0.0	----	----	13.3	0.0	----	----	----	----
Scyphomedusae	1.3	0.0	1.9	0.0	1.0	0.0	13.2	0.1	----	----	1.3	0.0	6.9	0.0
Calycopsis borchgrevinki	2.7	0.0	1.0	0.0	2.9	0.0	2.2	0.0	1.1	0.0	1.3	0.0	1.1	0.0
Electrona antarctica	1.3	0.0	3.8	0.1	9.5	0.0	13.2	0.0	13.3	0.1	2.5	0.0	10.3	0.0
Periphylla periphylla	1.3	0.0	----	----	----	----	1.1	0.0	1.1	0.0	----	----	4.6	0.0
Decapod larvae	1.3	0.0	2.9	0.0	----	----	2.2	0.2	----	----	----	----	1.1	0.0
Cephalopods	1.3	0.0	1.0	0.0	----	----	----	----	2.2	0.0	----	----	----	----
Fish Eggs	1.3	0.0	1.0	0.0	2.9	0.1	1.1	0.0	4.4	0.0	----	----	----	----
Eusirus perdentatus	1.3	0.0	----	----	----	----	1.1	0.0	22.2	0.1	----	----	----	----
Bylgides pelagica	1.3	0.0	----	----	2.9	0.1	----	----	5.6	0.0	----	----	----	----
Maupasia coeca	1.3	0.0	----	----	1.9	0.0	1.1	0.0	----	----	----	----	----	----
Chionodraco rastrospinosus (L)	1.3	0.0	1.9	0.0	1.0	0.0	----	----	----	----	----	----	2.3	0.0
Gobionotothen gibberifrons (L)	1.3	0.0	1.0	0.0	----	----	----	----	1.1	0.0	----	----	----	----
Vogtia serrata	1.3	0.0	----	----	3.8	0.1	----	----	----	----	----	----	----	----
Travisiopsis coniceps	----	----	----	----	1.0	0.0	----	----	----	----	----	----	----	----
Chaenodraco wilsoni (L)	----	----	----	----	----	----	----	----	----	----	----	----	1.1	0.0
Artededraco sp. B (L)	----	----	----	----	1.0	0.0	----	----	----	----	----	----	----	----
Oediceroides calmani	----	----	----	----	1.0	0.0	----	----	----	----	----	----	----	----
Scina spp.	----	----	----	----	4.8	0.1	----	----	----	----	----	----	----	----
Krefftichthys anderssoni	----	----	----	----	1.0	0.0	----	----	----	----	----	----	----	----
Krefftichthys anderssoni (L)	----	----	----	----	1.9	0.0	----	----	----	----	----	----	----	----
Cyphocaris richardi	----	----	----	----	1.9	0.0	----	----	4.4	0.0	----	----	1.1	0.0
Eusirus microps	----	----	----	----	----	----	----	----	4.4	0.0	----	----	2.3	0.0
Gosea brachyura	----	----	----	----	----	----	----	----	3.3	0.0	----	----	----	----
Euphysora gigantea	----	----	----	----	----	----	----	----	2.2	0.0	----	----	----	----
Artededraco mirus (L)	----	----	----	----	----	----	----	----	1.1	0.0	----	----	----	----
Pegantha martagon	----	----	----	----	----	----	----	----	1.1	0.0	----	----	----	----
Travisiopsis levinseni	----	----	----	----	----	----	----	----	1.1	0.0	----	----	2.3	0.0
Gymnodraco acuticeps (L)	----	----	----	----	----	----	----	----	1.1	0.0	----	----	----	----
Botrynema brucei	----	----	----	----	----	----	----	----	1.1	0.0	----	----	----	----
Hyperia antarctica	----	----	----	----	1.9	0.0	----	----	0.0	0.0	----	----	----	----
Thyphloscolex muelleri	----	----	----	----	1.0	0.0	4.4	0.0	----	----	----	----	----	----
Lepidonotothen nudifrons (L)	----	----	----	----	----	----	2.2	0.0	8.9	0.1	1.3	0.2	1.1	0.1
Hyperiella antarctica	----	----	----	----	----	----	2.2	0.0	2.2	0.0	----	----	2.3	0.0
Cumaceans	----	----	----	----	3.8	0.4	1.1	0.0	----	----	----	----	----	----
Arctapodema ampla	----	----	----	----	----	----	1.1	0.0	----	----	----	----	----	----
Gymnoscopelus opisthopteris	----	----	----	----	3.8	0.0	2.2	0.0	7.8	0.0	----	----	----	----
Phalacrophorus pictus	----	----	----	----	----	----	1.1	0.0	----	----	----	----	----	----
Pelagobia longicirrata	----	----	----	----	1.0	0.0	1.1	0.0	----	----	----	----	----	----
Chorismus antarcticus	----	----	----	----	----	----	1.1	0.0	----	----	----	----	----	----
Cryodraco antarctica (L)	----	----	----	----	----	----	1.1	0.0	----	----	----	----	----	----
Gymnoscopelus nicholsi	----	----	----	----	1.9	0.0	1.1	0.0	1.1	0.0	----	----	----	----
Atolla wyvillei	----	----	----	----	2.9	0.0	1.1	0.0	7.8	0.0	----	----	1.1	0.0
Harpagifer antarcticus (L)	----	----	----	----	----	----	1.1	0.0	----	----	----	----	----	----
Epimeriella macronyx	----	----	5.8	0.2	1.9	1.4	1.1	0.0	8.9	0.0	----	----	----	----
Hyperia macrocephala	----	----	1.0	0.1	1.0	0.0	----	----	3.3	0.0	1.3	0.0	1.1	0.4
Chaenocephalus aceratus (L)	----	----	3.8	0.0	----	----	----	----	----	----	----	----	----	----
Eusirus sp.	----	----	1.0	0.0	----	----	----	----	----	----	----	----	----	----
Bathylagus sp. (L)	----	----	1.0	0.0	1.0	0.0	2.2	0.0	8.9	0.0	----	----	----	----
Bolinopsis sp.	----	----	1.0	0.0	----	----	----	----	----	----	----	----	----	----
Notolepis spp. (L)	----	----	1.0	0.0	----	----	----	----	----	----	----	----	12.6	1.0
Eusirus antarcticus	----	----	1.0	0.0	----	----	1.1	0.0	----	----	----	----	----	----
Artededraco skottsbergi (L)	----	----	1.0	0.0	1.0	0.0	----	----	----	----	----	----	----	----
Orchomene plebs	----	----	1.0	0.0	2.9	0.0	1.1	0.0	4.4	0.0	1.3	0.0	3.4	0.1
TOTAL TAXA	68		65		72		69		70		33		43	

Table 4.9 Percent contribution and abundance rank of numerically dominant zooplankton and nekton taxa in the Elephant Island Area during January-March surveys, 1993-1999. Includes the 10 most abundant taxa each year. n.a. indicates taxon not enumerated. each year. Shaded columns are "salp years".

	January-February Elephant Island Area													
	1993		1994		1995		1996		1997		1998		1999	
Taxon	%	Rank	%	Rank	%	Rank	%	Rank	%	Rank	%	Rank	%	Rank
Copepods	3.30	4	4.08	3	61.54	1	56.18	1	57.16	1	4.80	3	58.05	1
Salpa thompsoni	86.63	1	80.83	1	1.51	5	1.45	6	17.79	2	68.76	1	12.35	2
Euphausia superba (L)	n.a.		n.a.		12.80	2	0.19	10	1.49	7	0.09		10.95	3
Thysanoessa macrura (L)	n.a.		n.a.		1.50	6	21.82	2	1.67	6	0.00		7.29	4
Chaetognaths	0.80	5	0.04		7.84	4	0.90	7	2.28	5	0.92	7	4.00	5
Thysanoessa macrura	4.45	2	7.87	2	9.09	3	7.56	4	10.24	3	15.38	2	2.92	6
Euphausia frigida	0.31	8	0.38	9	0.92	8	0.14		1.45	8	0.02		1.00	7
Euphausia superba	3.81	3	2.68	4	1.37	7	7.95	3	3.96	4	3.13	5	0.33	8
Vibilia antarctica	0.14	7	1.17	5	0.02		0.04		0.24		1.12	6	0.32	9
Tomopteris spp.	0.04		0.25	10	0.40		0.06		0.19		0.11		0.15	10
Cyllopus magellanicus	0.04		0.62	7	0.02		0.11		0.37		0.16	10	0.15	
Ihlea racovitzai	n.a.		n.a.		n.a.		n.a.		n.a.		3.53	4	0.15	
Ostracods	n.a.		n.a.		0.91	9	0.35	8	0.54	9	0.41	9	0.13	
Primno macropa	0.00		0.05		0.01		0.01		0.42	10	0.06		0.13	
Spongiobranchaea australis	0.05	10	0.01		0.05		0.13		0.22		0.07		0.09	
Limacina helicina	0.00		0.03		0.18		2.38	5	0.28		0.69	8	0.07	
Euphausia triacantha	0.09	8	0.12		0.14		0.04		0.14		0.02		0.03	
Themisto gaudichaudii	0.07	9	1.05	6	0.46		0.34	9	0.35		0.03		0.02	
Clio pyramidata	0.02		0.53	8	0.50	10	0.01		0.00		0.02		0.01	
TOTAL	99.75		99.69		99.26		99.64		98.79		99.32		98.15	

	February-March Elephant Island Area													
	1993		1994		1995		1996		1997		1998		1999	
Taxon	%	Rank	%	Rank	%	Rank	%	Rank	%	Rank	%	Rank	%	Rank
Copepoda	0.46	4	82.15	1	40.49	2	62.07	1	44.46	1	7.38	4	62.77	1
Salpa thompsoni	89.62	1	11.78	2	0.22	7	1.39	6	43.62	2	65.31	1	12.46	2
Thysanoessa macrura (L))	n.a.		n.a.		3.76	3	21.40	2	0.38	8	0.03		7.49	3
Chaetognaths	0.04		0.47	6	3.61	4	2.43	5	0.65	7	0.60	8	5.94	4
Thysanoessa macrura	7.29	2	1.83	3	0.87	5	4.86	4	6.36	3	9.40	3	3.84	5
Euphausia superba (L)	n.a.		n.a.		50.16	1	0.59	7	0.88	6	0.16		2.71	6
Euphausia superba	2.01	3	0.41	7	0.06	10	5.57	3	1.07	5	10.87	2	1.43	7
Euphausia frigida	0.06	9	0.69	5	0.21	8	0.40	8	1.57	4	0.60	7	1.00	8
Ostracods	n.a.		n.a.		0.43	6	0.38	9	0.17	10	0.35	10	0.65	9
Ihlea racovitzai	n.a.		n.a.		n.a.		n.a.		n.a.		2.77	5	0.34	10
Cyllopus magellanicus	0.05	10	0.12		0.01		0.10		0.12		0.55	9	0.17	
Vibilia antarctica	0.08	7	0.16	9	0.00		0.05		0.28	9	0.71	6	0.15	
Euphausia spp. larvae	n.a.		0.75	4	0.00		0.00		0.00		0.00		0.10	
Primno macropa	0.00		0.00		0.00		0.15	10	0.02		0.11		0.08	
Euphausia triacantha	0.07	8	0.03		0.02		0.03		0.03		0.04		0.06	
Themisto gaudichaudii	0.12	5	0.27	8	0.01		0.09		0.10		0.01		0.01	
Cyllopus lucasii	0.09	6	0.14	10	0.01		0.01		0.08		0.14		0.01	
Electrona antarctica (L)	0.01				0.07	9	0.04		0.01		0.01		0.01	
TOTAL	99.90		98.79		99.94		99.56		99.79		99.05		99.20	

Table 4.10 Percent Similarity Index (PSI) values from comparisons of overall zooplankton composition during each large area survey, 1993-1999. Light shading indicates "salp years" and "salp year" intercomparisons. Dark shading indicates "copepod years" and "copepod year" intercomparisons. Note that comparisons with February 1993 are biased by the lack of copepod and chaetognath data.

	January-February Survey PSI Values					
Year	**1993**	1994	**1995**	**1996**	1997	**1998**
1999	22.1	26.1	79.9	71.1	84.9	30.6
1998	**80.9**	85.2	19.0	19.4	38.6	***
1997	31.0	34.4	77.2	73.6	***	
1996	14.3	16.7	**70.5**	***		
1995	12.2	16.9	***			
1994	92.1	***				

	February-March Survey PSI Values					
Year	**1993**	1994	**1995**	**1996**	1997	**1998**
1999	17.0	81.9	54.3	81.1	64.5	29.8
1998	**66.8**	28.3	14.1	25.1	63.4	***
1997	51.5	63.0	46.1	55.8	***	
1996	10.2	68.8	**51.7**	***		
1995	2.6	44.1	***			
1994	17.8	***				

Table 4.11 Abundance relations of dominant zooplankton taxa in the Survey D area and three subareas, February 1999. Only the 20 most abundant taxa overall are considered. F(%) is frequency of occurrence in N samples. Abundance ranks (R) are provided for the 10 most abundant taxa in the Elephant Island and West areas and the 3 most abundant taxa in the South area. % is proportion of total mean abundance contributed by each taxon. (L) indicates larval form.

	SURVEY D AREA (N = 67)						ELEPHANT ISLAND AREA (N = 39)						WEST AREA (N = 25)						SOUTH AREA (N = 3)					
Taxon	F(%)	R	%	Mean	SD	Med	F(%)	R	%	Mean	SD	Med	F(%)	R	%	Mean	SD	Med	F(%)	R	%	Mean	SD	Med
Copepods	100.0	1	65.5	1445.1	2197.9	662.6	100.0	1	62.9	1557.9	621.6	621.6	100.0	1	72.0	1337.0	2072.2	735.3	100.0	1	55.4	879.4	691.1	651.1
Salpa thompsoni	100.0	2	11.2	248.1	307.2	149.9	100.0	2	12.5	309.2	162.5	162.5	100.0	2	8.5	158.1	123.8	88.1	100.0	3	12.8	203.2	156.7	214.5
Chaetognaths	98.5	3	6.4	140.2	257.8	52.6	97.4	4	6.0	147.4	48.7	48.7	100.0	3	7.7	142.2	264.1	72.8	100.0		1.8	28.8	29.5	12.2
Thysanoessa macrura (L)	74.6	4	6.2	137.4	428.4	10.0	76.9	3	7.5	185.9	10.3	10.0	72.0	4	4.2	77.7	186.6	10.9	66.7		0.3	5.2	5.3	3.2
Thysanoessa macrura	98.5	5	4.2	93.1	142.9	18.0	100.0	5	3.8	95.2	14.1	18.0	96.0	5	3.2	58.6	96.2	12.0	100.0	2	22.3	353.8	273.9	199.8
Euphausia superba (L)	80.6	6	2.3	49.8	119.3	9.0	89.7	6	2.7	67.2	12.3	12.3	64.0	6	1.3	24.7	60.5	3.6	100.0		2.1	33.8	29.6	17.6
Euphausia superba	61.2	7	1.1	24.4	122.7	0.4	74.4	7	1.4	35.5	155.7	0.8	36.0	8	0.5	9.6	45.6	0.0	100.0		0.2	3.6	3.2	1.7
Euphausia frigida	64.2	8	0.9	20.0	36.1	4.1	66.7	8	1.0	24.7	7.6	7.6	56.0	7	0.8	14.2	23.6	1.0	100.0		0.5	7.8	3.0	8.0
Ostracods	80.6	9	0.6	14.0	28.9	6.6	76.9	9	0.6	16.0	3.9	6.6	84.0	9	0.4	7.8	8.4	5.1	100.0		2.5	40.3	23.3	40.1
Ihlea racovitzai	26.9	10	0.2	5.1	18.4	0.0	33.3	10	0.3	8.5	0.0	0.0	8.0		0.0	0.2	0.6	0.0	100.0		0.2	2.5	1.3	3.2
Cyllopus magellanicus	95.5	11	0.2	4.8	5.3	3.4	94.9		0.2	4.3	3.6	3.4	96.0	10	0.3	5.9	6.6	4.2	100.0		0.1	2.0	1.5	1.0
Vibilia antarctica	98.5	12	0.2	3.6	3.2	2.5	100.0		0.2	3.8	3.4	3.4	96.0		0.2	3.3	3.5	2.1	100.0		0.2	3.6	3.7	1.2
Tomopteris spp.	55.2	13	0.1	2.8	4.5	0.8	51.3		0.1	2.7	0.4	0.2	64.0		0.1	2.6	3.1	1.5	33.3		0.4	5.8	8.2	0.0
Primno macropa	65.7	14	0.1	2.6	3.4	1.6	56.4		0.1	2.1	1.2	0.8	80.0		0.2	3.3	3.7	2.6	66.7		0.2	3.0	2.2	4.0
Rhynchonereella bongraini	31.3	15	0.1	2.3	12.2	0.0	30.8		0.1	3.2	0.0	0.0	28.0		0.0	0.8	2.5	0.0	66.7		0.1	2.3	1.7	2.8
Limacina helicina	26.9		0.1	1.9	13.3	0.0	20.5		0.0	0.1	0.0	0.0	36.0		0.2	4.5	21.5	0.0	33.3		0.2	2.5	3.5	0.0
Euphausia triacantha	22.4		0.1	1.8	5.5	0.0	25.6		0.1	1.4	0.0	0.0	20.0		0.1	2.6	6.7	0.0	0.0		0.0	0.0	0.0	0.0
Euphausia spp. (L)	13.4		0.1	1.5	6.8	0.0	17.9		0.1	2.4	0.0	0.0	4.0		0.0	0.1	0.4	0.0	33.3		0.1	0.9	1.2	0.0
Hyperiella dilatata	56.7		0.1	1.2	2.6	0.3	51.3		0.1	1.5	0.2	0.2	68.0		0.0	0.8	0.9	0.5	33.3		0.0	0.2	0.2	0.0
Spongiobranchaea australis	65.7		0.0	1.0	1.3	0.3	56.4		0.0	0.8	0.2	0.2	84.0		0.1	1.4	1.4	1.3	33.3		0.0	0.1	0.1	0.0

Table 4.12 Zooplankton collected in the large Survey A and Survey D areas, January and February 1999.
F(%) is frequency of occurrence in samples each survey. Ranks (R) provided for the 15 most abundant taxa.
% is proportion of total zooplankton abundance contributed by each taxon. (L) indicates larval form.

	LARGE SURVEY AREA A January 1999 (N = 75)						LARGE SURVEY AREA D February 1999 (N = 67)					
Taxon	F(%)	R	%	Mean	SD	Med	F(%)	R	%	Mean	SD	Med
Copepods	100.0	1	54.4	711.6	1266.8	286.8	100.0	1	65.5	1445.1	2197.9	662.6
Salpa thompsoni	100.0	2	12.5	163.3	197.9	101.4	100.0	2	11.2	248.1	307.2	149.9
Chaetognaths	97.3	6	5.4	70.9	170.7	23.0	98.5	3	6.4	140.2	257.8	52.6
Thysanoessa macrura (L)	69.3	5	5.5	72.5	262.7	3.0	74.6	4	6.2	137.4	428.4	10.0
Thysanoessa macrura	93.3	3	10.3	135.1	587.1	36.9	98.5	5	4.2	93.1	142.9	18.0
Euphausia superba (L)	65.3	4	7.9	103.1	587.4	2.6	80.6	6	2.3	49.8	119.3	9.0
Euphausia superba	60.0	9	0.5	6.1	12.0	1.3	61.2	7	1.1	24.4	122.7	0.4
Euphausia frigida	34.7	8	0.7	9.0	22.6	0.0	64.2	8	0.9	20.0	36.1	4.1
Ostracods	49.3	12	0.2	2.8	5.6	0.0	80.6	9	0.6	14.0	28.9	6.6
Ihlea racovitzai	25.3	11	0.3	3.3	9.0	0.0	26.9	10	0.2	5.1	18.4	0.0
Cyllopus magellanicus	78.7		0.2	2.0	2.4	1.0	95.5	11	0.2	4.8	5.3	3.4
Vibilia antarctica	94.7	10	0.3	3.8	4.5	1.7	98.5	12	0.2	3.6	3.2	2.5
Tomopteris spp.	56.0	15	0.2	2.0	4.7	0.3	55.2	13	0.1	2.8	4.5	0.8
Primno macropa	69.3	13	0.2	2.5	3.4	1.3	65.7	14	0.1	2.6	3.4	1.6
Rhynchonereella bongraini	33.3		0.1	0.8	1.5	0.0	31.3	15	0.1	2.3	12.2	0.0
Limacina helicina	61.3	14	0.2	2.4	4.2	0.5	26.9		0.1	1.9	13.3	0.0
Euphausia triacantha	17.3		0.0	0.4	1.2	0.0	22.4		0.1	1.8	5.5	0.0
Euphausia spp. (L)	10.7	7	0.8	11.1	64.7	0.0	13.4		0.1	1.5	6.8	0.0
Hyperiella dilatata	52.0		0.0	0.5	0.9	0.2	56.7		0.1	1.2	2.6	0.3
Spongiobranchaea australis	72.0		0.1	1.5	2.4	0.6	65.7		0.0	1.0	1.3	0.3
Larvaceans	4.0		0.0	0.5	3.0	0.0	4.5		0.0	0.8	5.2	0.0
Larval fish (unid.)	9.3		0.0	0.1	0.4	0.0	14.9		0.0	0.7	4.4	0.0
Gastropods	5.3		0.0	0.5	2.7	0.0	6.0		0.0	0.5	2.1	0.0
Calycopsis borchgrevinki	2.7		0.0	0.0	0.0	0.0	19.4		0.0	0.4	1.7	0.0
Polychaetes	20.0		0.0	0.6	1.8	0.0	7.5		0.0	0.3	2.2	0.0
Hydromedusae	37.3		0.0	0.2	0.5	0.0	40.3		0.0	0.3	0.5	0.0
Electrona spp.(L)	24.0		0.0	0.2	0.6	0.0	20.9		0.0	0.3	1.2	0.0
Diphyes antarctica	34.7		0.0	0.5	1.1	0.0	31.3		0.0	0.3	0.5	0.0
Themisto gaudichaudii	32.0		0.0	0.3	0.7	0.0	32.8		0.0	0.2	0.5	0.0
Cyllopus lucasii	6.7		0.0	0.0	0.2	0.0	29.9		0.0	0.2	0.4	0.0
Lepidonotothen kempi (L)	6.7		0.0	0.0	0.2	0.0	16.4		0.0	0.1	0.5	0.0
Hyperiella sp.	0.0		0.0	0.0	0.0	0.0	9.0		0.0	0.1	0.6	0.0
Gymnoscopelus braueri	0.0		0.0	0.0	0.0	0.0	7.5		0.0	0.1	0.3	0.0
Clio pyramidata	9.3		0.0	0.1	0.6	0.0	13.4		0.0	0.1	0.2	0.0
Euphausia crystallorphorias	9.3		0.0	0.1	0.5	0.0	4.5		0.0	0.0	0.3	0.0
Sipunculids	10.7		0.0	0.0	0.2	0.0	11.9		0.0	0.0	0.1	0.0
Electrona carlsbergi	2.7		0.0	0.0	0.0	0.0	4.5		0.0	0.0	0.2	0.0
Lepidonotothen larseni (L)	20.0		0.0	0.2	0.6	0.0	11.9		0.0	0.0	0.1	0.0
Beroe cucumis	4.0		0.0	0.0	0.1	0.0	9.0		0.0	0.0	0.1	0.0
Chorismus antarcticus	0.0		0.0	0.0	0.0	0.0	1.5		0.0	0.0	0.2	0.0
Electrona antarctica	1.3		0.0	0.0	0.1	0.0	6.0		0.0	0.0	0.1	0.0
Ctenophores	6.7		0.0	0.0	0.2	0.0	4.5		0.0	0.0	0.1	0.0

Table 4.12 (Contd.)

Taxon	LARGE SURVEY AREA A January 1999 F(%)	R	%	Mean	SD	Med	LARGE SURVEY AREA D February 1999 F(%)	R	%	Mean	SD	Med
Beroe forskalii	2.7		0.0	0.0	0.0	0.0	9.0		0.0	0.0	0.1	0.0
Notolepis spp. (L)	0.0		0.0	0.0	0.0	0.0	7.5		0.0	0.0	0.1	0.0
Hyperoche medusarum	5.3		0.0	0.0	0.1	0.0	4.5		0.0	0.0	0.1	0.0
Acanthephyra pelagica	17.3		0.0	0.2	0.5	0.0	3.0		0.0	0.0	0.1	0.0
Clione limacina	17.3		0.0	0.1	0.4	0.0	3.0		0.0	0.0	0.1	0.0
Fish eggs	1.3		0.0	0.0	0.0	0.0	1.5		0.0	0.0	0.1	0.0
Cephalopods	1.3		0.0	0.0	0.0	0.0	4.5		0.0	0.0	0.1	0.0
Bathylagus antarcticus	0.0		0.0	0.0	0.0	0.0	3.0		0.0	0.0	0.0	0.0
Hyperiella macronyx	2.7		0.0	0.0	0.2	0.0	1.5		0.0	0.0	0.1	0.0
Vanadis antarctica	5.3		0.0	0.1	0.4	0.0	1.5		0.0	0.0	0.1	0.0
Mysids	0.0		0.0	0.0	0.0	0.0	1.5		0.0	0.0	0.0	0.0
Scina spp.	0.0		0.0	0.0	0.0	0.0	1.5		0.0	0.0	0.0	0.0
Orchomene rossi	4.0		0.0	0.0	0.1	0.0	1.5		0.0	0.0	0.0	0.0
Periphylla periphylla	1.3		0.0	0.0	0.0	0.0	1.5		0.0	0.0	0.0	0.0
Eusirus antarcticus	0.0		0.0	0.0	0.0	0.0	1.5		0.0	0.0	0.0	0.0
Gymnoscopelus nicholsi	0.0		0.0	0.0	0.0	0.0	1.5		0.0	0.0	0.0	0.0
Cyphocaris richardi	0.0		0.0	0.0	0.0	0.0	1.5		0.0	0.0	0.0	0.0
Dimophyes arctica	6.7		0.0	0.1	0.4	0.0	0.0		0.0	0.0	0.0	0.0
Pleuragramma antarcticum (J)	1.3		0.0	0.1	0.6	0.0	0.0		0.0	0.0	0.0	0.0
Notolepis coatsi	5.3		0.0	0.0	0.3	0.0	0.0		0.0	0.0	0.0	0.0
Notothenia coriiceps (L)	1.3		0.0	0.0	0.2	0.0	0.0		0.0	0.0	0.0	0.0
Bolinopsis infundibulum	5.3		0.0	0.0	0.1	0.0	0.0		0.0	0.0	0.0	0.0
Patagonotothen guntheri	1.3		0.0	0.0	0.1	0.0	0.0		0.0	0.0	0.0	0.0
Notolepis annulata	2.7		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Scyphomedusae	1.3		0.0	0.0	0.1	0.0	0.0		0.0	0.0	0.0	0.0
Eusirus perdentatus	1.3		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Chionodraco rastrospinosus (L)	1.3		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Bylgides pelagica	1.3		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Maupasia coeca	1.3		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Gobionotothen gibberifrons (L)	1.3		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Vogtia serrata	1.3		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Total No. Taxa	63						59					

Table 4.13 Zooplankton taxa present in the large-area survey samples during February 1999 compared to February-March 1993-1998. F is the frequency of occurrence (%) in (N) tows. n.a. indicates taxon was not enumerated. (L) indicates larval stages; (J) indicates juvenile stages.

	February-March													
	1999		1998		1997		1996		1995		1994		1993	
Taxon	F(%) (67)	Mean No.	F(%) (104)	Mean No.	F(%) (16)	Mean No.	F(%) (91)	Mean No.	F(%) (89)	Mean No.	F(%) (89)	Mean No.	F(%) (80)	Mean No.
Copepods	100.0	1445.1	97.1	119.0	100.0	1267.8	98.9	1387.0	100.0	3189.1	89.9	3090.2	n.a.	n.a.
Salpa thompsoni	100.0	248.1	98.1	689.1	100.0	1245.5	62.6	28.2	59.6	16.5	98.9	523.5	100.0	1567.1
Chaetognaths	91.0	127.4	61.5	10.7	75.0	18.2	93.4	64.1	100.0	296.4	n.a.	n.a.	n.a.	n.a.
Sagitta gazellae	17.9	2.4	18.3	0.3	12.5	0.1	31.9	0.3	59.6	3.0	34.8	3.8	n.a.	n.a.
Eukronia hamata	4.5	0.0	4.8	0.5	—	—	19.8	0.1	33.7	0.8	3.4	0.1	n.a.	n.a.
Thysanoessa macrura (L)	74.6	137.4	13.5	2.6	50.0	10.8	87.9	414.4	79.8	276.9	n.a.	n.a.	—	—
Thysanoessa macrura	98.5	93.1	100.0	177.4	100.0	181.3	91.2	143.3	93.3	161.3	91.0	118.9	96.3	141.5
Euphausia superba (L)	80.6	49.8	12.5	1.6	37.5	25.0	62.6	13.9	93.3	3690.0	n.a.	n.a.	—	—
Euphausia superba	61.2	24.4	89.4	133.5	68.8	30.4	86.8	106.7	78.7	5.7	66.3	18.4	83.8	35.0
Euphausia frigida	64.2	20.0	29.8	9.3	68.8	44.8	54.9	9.0	60.7	16.7	61.8	25.9	7.5	1.0
Ostracods	80.6	14.0	43.3	5.4	56.3	4.8	47.3	10.1	75.3	43.4	n.a.	n.a.	n.a.	n.a.
Ihlea racovitzai	26.9	5.1	61.5	51.5	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Cyllopus magellanicus	95.5	4.8	81.7	5.6	93.8	3.3	46.2	2.1	25.8	0.7	79.8	4.4	32.5	0.9
Vibilia antarctica	98.5	3.6	96.2	8.0	81.3	8.1	48.4	1.0	23.6	0.2	85.4	6.4	47.5	1.6
Tomopteris spp.	55.2	2.8	8.7	0.0	31.3	0.5	38.5	0.9	57.3	1.3	24.7	0.6	12.5	0.2
Primno macropa	65.7	2.6	49.0	1.9	18.8	0.5	63.7	3.5	31.5	0.4	10.1	0.1	—	—
Rhynchonereella bongraini	31.3	2.3	1.0	0.0	—	—	5.5	0.1	20.2	0.1	—	—	—	—
Limacina helicina	26.9	1.9	37.5	0.8	—	—	24.2	1.9	4.5	0.0	—	—	—	—
Euphausia triacantha	22.4	1.8	11.5	0.6	43.8	0.9	22.0	0.8	28.1	1.6	11.2	1.0	21.3	1.0
Euphausia spp. larvae	13.4	1.5												
Hyperiella dilatata	56.7	1.2	34.6	0.4	25.0	0.2	52.7	0.8	24.7	0.1	36.0	0.6	1.3	0.0
Spongiobranchaea australis	65.7	1.0	38.5	0.8	43.8	2.8	68.1	1.4	60.7	0.4	14.6	0.1	20.0	0.3
Larvaceans	4.5	0.8	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Larval fish (unid.)	14.9	0.7	1.9	0.1	—	—	1.1	0.0	—	—	—	—	—	—
Gastropods	6.0	0.5	1.9	0.0	—	—	—	—	—	—	—	—	—	—
Calycopsis borchgrevinki	19.4	0.4	4.8	0.0	6.3	0.0	6.6	0.0	11.2	0.0	10.1	0.1	11.3	0.1
Polychaetes	7.5	0.3	13.5	0.3	—	—	3.3	0.1	2.2	0.0	—	—	—	—
Hydromedusae	40.3	0.3	12.5	0.2	12.5	0.2	3.3	0.1	5.6	0.0	—	—	—	—
Electrona spp. (L)	20.9	0.3	10.6	0.2	12.5	0.1	38.5	0.9	62.9	5.2	11.2	0.2	5.0	0.1
Diphyes antarctica	31.3	0.3	29.8	0.4	6.3	0.3	7.7	0.1	23.6	0.4	13.5	0.1	15.0	0.3
Themisto gaudichaudii	32.8	0.2	32.7	0.3	87.5	2.9	91.2	2.5	74.2	3.6	94.4	11.8	60.0	2.3
Cyllopus lucasii	29.9	0.2	57.7	1.6	93.8	2.4	34.1	0.2	23.6	0.5	89.9	6.1	37.5	1.5
Lepidonotothen kempi (L)	16.4	0.1	22.1	0.2	6.3	0.2	39.6	0.4	48.3	0.4	6.7	0.1	1.3	0.0
Hyperiella sp.	9.0	0.1	1.0	0.0	—	—	—	—	—	—	—	—	—	—
Gymnoscopelus braueri	7.5	0.1	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Clio pyramidata	13.4	0.1	—	—	—	—	3.3	0.0	12.4	0.0	9.0	0.2	1.3	0.0
Sipunculids	11.9	0.0	4.8	0.1	6.3	0.0	8.8	0.1	9.0	0.0	3.4	0.0	—	—
Electrona carlsbergi	4.5	0.0	1.9	0.0	—	—	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Lepidonothen larseni (L)	11.9	0.0	13.5	0.1	—	—	13.2	0.3	10.1	0.0	—	—	5.0	0.2
Beroe cucumis	9.0	0.0	4.8	0.0	—	—	11.0	0.1	4.5	0.0	2.2	0.0	1.3	0.0
Chorismus antarcticus	1.5	0.0	—	—	—	—	—	—	—	—	—	—	—	—
Electrona antarctica	6.0	0.0	8.7	0.0	31.3	0.2	20.9	0.2	15.7	0.1	13.5	0.1	3.8	0.0
Ctenophores	4.5	0.0	—	—	6.3	0.0	1.1	0.0	3.4	0.0	—	—	—	—
Beroe forskalii	9.0	0.0	2.9	0.0	—	—	—	—	1.1	0.0	3.4	0.1	—	—
Notolepis spp. (L)	7.5	0.0	—	—	—	—	—	—	2.2	0.0	5.6	0.0	3.8	0.1
Hyperoche medusarum	4.5	0.0	—	—	12.5	0.3	2.2	0.0	12.4	0.0	—	—	—	—
Acanthephyra pelagica (L)	3.0	0.0	1.0	0.0	—	—	—	—	5.6	0.0	—	—	—	—
Clione limacina	3.0	0.0	10.6	0.1	12.5	0.0	15.4	0.2	—	—	—	—	—	—
Fish eggs	1.5	0.0	1.0	0.0	—	—	—	—	1.1	0.0	7.9	0.1	—	—
Cephalopods	4.5	0.0	1.9	0.0	—	—	9.9	0.0	—	—	—	—	—	—
Bathylagus antarcticus	3.0	0.0	—	—	—	—	—	—	—	—	—	—	—	—
Hyperiella macronyx	1.5	0.0	—	—	6.3	0.0	6.6	0.1	13.5	0.0	—	—	—	—
Vanadis antarctica	1.5	0.0	3.8	0.1	—	—	1.1	0.0	6.7	0.0	7.9	0.1	—	—

Table 4.13 (Contd.)

	February-March													
	1999		1998		1997		1996		1995		1994		1993	
Taxon	F(%)	Mean	F(%)	Mean	F(%)	Mean	F(%)	Mean	F(%)	Mean	F(%)	Mean	F(%)	Mean
Mysids	1.5	0.0	—	—	—	—	—	—	—	—	—	—	—	—
Scina spp.	1.5	0.0	—	—	6.3	0.5	2.2	0.0	1.1	0.0	—	—	—	—
Orchomene rossi	1.5	0.0	1.0	0.0	—	—	5.5	0.5	6.7	0.0	—	—	—	—
Periphylla periphylla	1.5	0.0	—	—	—	—	1.1	0.0	1.1	0.0	3.4	0.0	—	—
Eusirus antarcticus	1.5	0.0	1.9	0.0	—	—	—	—	—	—	—	—	—	—
Cyphocaris richardi	1.5	0.0	—	—	—	—	1.1	0.0	3.4	0.1	—	—	—	—
Gymnoscopelus nicholsi	1.5	0.0	1.0	0.0	12.5	0.1	3.3	0.0	1.1	0.0	—	—	—	—
Atolla wyvillei	—	—	—	—	—	—	1.1	0.0	—	—	—	—	—	—
Eusirus microps	—	—	—	—	—	—	3.3	0.0	—	—	—	—	1.3	0.0
Gymnoscopelus opisthopterus	—	—	—	—	—	—	3.3	0.0	10.1	0.0	2.2	0.0	—	—
Epimeriella macronyx	—	—	—	—	—	—	1.1	0.0	5.6	0.6	—	—	—	—
Travisiopsis coniceps	—	—	—	—	—	—	1.1	0.0	1.1	0.0	—	—	—	—
Lepidonotothen nudifrons (L)	—	—	—	—	—	—	1.1	0.0	3.4	0.0	—	—	—	—
Harpagifer antarcticus (L)	—	—	—	—	—	—	1.1	0.0	—	—	—	—	—	—
Bathylagus sp. (L)	—	—	—	—	6.3	0.0	1.1	0.0	14.6	0.0	—	—	—	—
Dimophyes arctica	—	—	16.3	0.4	12.5	0.1	13.2	0.1	13.5	0.3	10.1	0.0	6.3	0.2
Orchomene plebs	—	—	1.9	0.0	—	—	2.2	0.0	3.4	0.0	2.2	0.1	—	—
Pleurogramma antarcticum (J)	—	—	2.9	0.0	—	—	1.1	0.0	2.2	0.0	—	—	—	—
Byglides pelagica	—	—	1.0	0.0	—	—	—	—	2.2	0.0	—	—	—	—
Scyphomedusae	—	—	1.9	0.0	12.5	0.0	19.8	0.1	13.5	0.1	—	—	1.3	0.0
Eusirus perdentatus	—	—	1.0	0.0	—	—	2.2	0.0	6.7	0.1	—	—	—	—
Chaenodraco wilsoni (L)	—	—	1.0	0.0	—	—	—	—	—	—	—	—	—	—
Krefftichthys anderssoni (L)	—	—	1.0	0.0	—	—	—	—	—	—	—	—	—	—
Champsocephalus gunnari (L)	—	—	—	—	—	—	—	—	1.1	0.0	—	—	—	—
Pagetopsis macropterus	—	—	—	—	—	—	—	—	1.1	0.0	—	—	—	—
Lepidonothen larseni (J)	—	—	—	—	—	—	—	—	1.1	0.0	—	—	—	—
Hyperia spp.	—	—	—	—	—	—	1.1	0.1	—	—	—	—	—	—
Cumaceans	—	—	—	—	—	—	1.1	0.0	—	—	—	—	—	—
Decapod larvae	—	—	—	—	—	—	1.1	0.0	—	—	—	—	—	—
Notolepis annulata (L)	—	—	—	—	6.3	0.0	5.5	0.0	3.4	0.0	—	—	—	—
Cyllopus sp.	—	—	24.0	0.7	24.0	0.7	—	—	—	—	—	—	—	—
Notolepis coatsi (L)	—	—	4.8	0.0	—	—	18.7	0.1	36.0	0.2	—	—	—	—
Gymnoscopelus sp.	—	—	1.9	0.0	—	—	—	—	—	—	—	—	—	—
Pagothenia brachysoma	—	—	1.9	0.0	—	—	—	—	—	—	—	—	—	—
Hyperia macrocephala	—	—	1.9	0.0	—	—	1.1	0.0	5.6	0.0	—	—	—	—
Rhynchonereella sp.	—	—	1.0	0.0	—	—	—	—	—	—	—	—	—	—
Artedidraco skottsbergi (L)	—	—	1.0	0.0	—	—	—	—	—	—	—	—	—	—
TOTAL TAXA	59		61		37		65		63		32		24	

Table 4.14 Relative abundance of zooplankton taxa in four groupings derived from cluster analysis of February 1999 Survey D data. Ranks of the 10 most abundant taxa based on mean abundance (No. per 1000 m3) within each station grouping. Asterisks denote significantly larger abundance values based on analysis of variance: *** P<0.001; **P<0.01; * P<0.05.

	CLUSTER 1 (N = 27)				CLUSTER 2 (N = 17)				CLUSTER 3 (N = 15)				CLUSTER 4 (N = 8)			
Taxon	Rank	Mean	SD	%	Rank	Mean	SD	%	Rank	Mean	SD	%	Rank	Mean	SD	%
Copepods	1	1254.5	1072.8	61.2	1	655.0	307.6	69.1	1	246.1	210.3	41.5	1	6015.3	3355.5	71.8 ***
Salpa thompsoni	2	349.4	429.3	17.0	2	151.9	106.5	16.0	2	173.4	181.7	29.2	4	250.3	132.6	3.0
Thysanoessa macrura	3	145.2	178.5	7.1 **	6	7.1	10.8	0.8	3	114.9	119.1	19.4	6	59.1	99.5	0.7
Chaetognaths	4	77.2	63.9	3.8	3	74.9	52.9	7.9	4	25.6	37.8	4.3	3	705.7	408.9	8.4 ***
Euphausia superba	5	59.2	188.0	2.9		0.4	0.7	0.0		1.5	2.5	0.2		0.8	1.6	0.0
Euphausia superba (L)	6	47.7	109.6	2.3	5	10.8	9.7	1.1		0.7	0.9	0.1	5	232.2	193.6	2.8 ***
Euphausia frigida	7	40.2	44.3	2.0 **		0.5	0.8	0.1	5	13.7	30.6	2.3		5.5	9.7	0.1
Thysanoessa macrura (L)	8	26.6	42.1	1.3	4	19.9	12.6	2.1	10	2.0	3.2	0.3	2	1015.1	809.4	12.1 ***
Ostracods	9	18.1	24.3	0.9	8	5.2	4.6	0.5	9	2.1	2.8	0.4	7	41.5	61.0	0.5 *
Ihlea racovitzai	10	11.3	27.6	0.6		0.0	0.0	0.0	8	2.5	4.4	0.4		0.0	0.0	0.0
Euphausia triacantha		4.3	8.1	0.2		0.0	0.0	0.0		0.3	0.6	0.0		0.0	0.0	0.0
Vibilia antarctica		4.0	3.4	0.2		3.0	2.7	0.3	7	3.0	2.2	0.5		4.9	4.3	0.1
Cyllopus magellanicus		3.8	4.2	0.2	7	5.5	4.5	0.6	6	3.5	5.4	0.6	10	9.1	6.8	0.1
Tomopteris spp.		2.3	4.2	0.1	10	3.7	3.5	0.4		0.2	0.4	0.0		7.1	7.1	0.1 *
Primno macropa		2.1	3.3	0.1	9	4.9	4.4	0.5 *		1.5	1.3	0.2		1.3	1.1	0.0
Hyperiella dilatata		1.0	2.6	0.0		1.3	1.4	0.1		0.2	0.4	0.0		3.5	4.7	0.0
Rhynchonereella bongraini		0.8	1.9	0.0		1.0	3.0	0.1		0.4	0.6	0.1	9	13.7	32.8	0.2 *
Spongiobranchaea australis		0.5	1.1	0.0		1.1	1.0	0.1		0.7	1.0	0.1		2.7	1.8	0.0 **
Diphyes antarctica		0.5	0.8	0.0		0.0	0.1	0.0		0.2	0.4	0.0		0.1	0.1	0.0
Electrona spp. (L)		0.4	1.7	0.0		0.3	0.8	0.0		0.0	0.0	0.0		0.3	0.3	0.0
Limacina helicina		0.4	1.4	0.0		0.1	0.1	0.0		0.3	0.4	0.1	8	13.8	36.2	0.2
Hydromedusae		0.3	0.7	0.0		0.5	0.5	0.0		0.1	0.3	0.0		0.2	0.2	0.0
Cyllopus lucasii		0.3	0.5	0.0		0.0	0.1	0.0		0.3	0.4	0.0		0.0	0.1	0.0

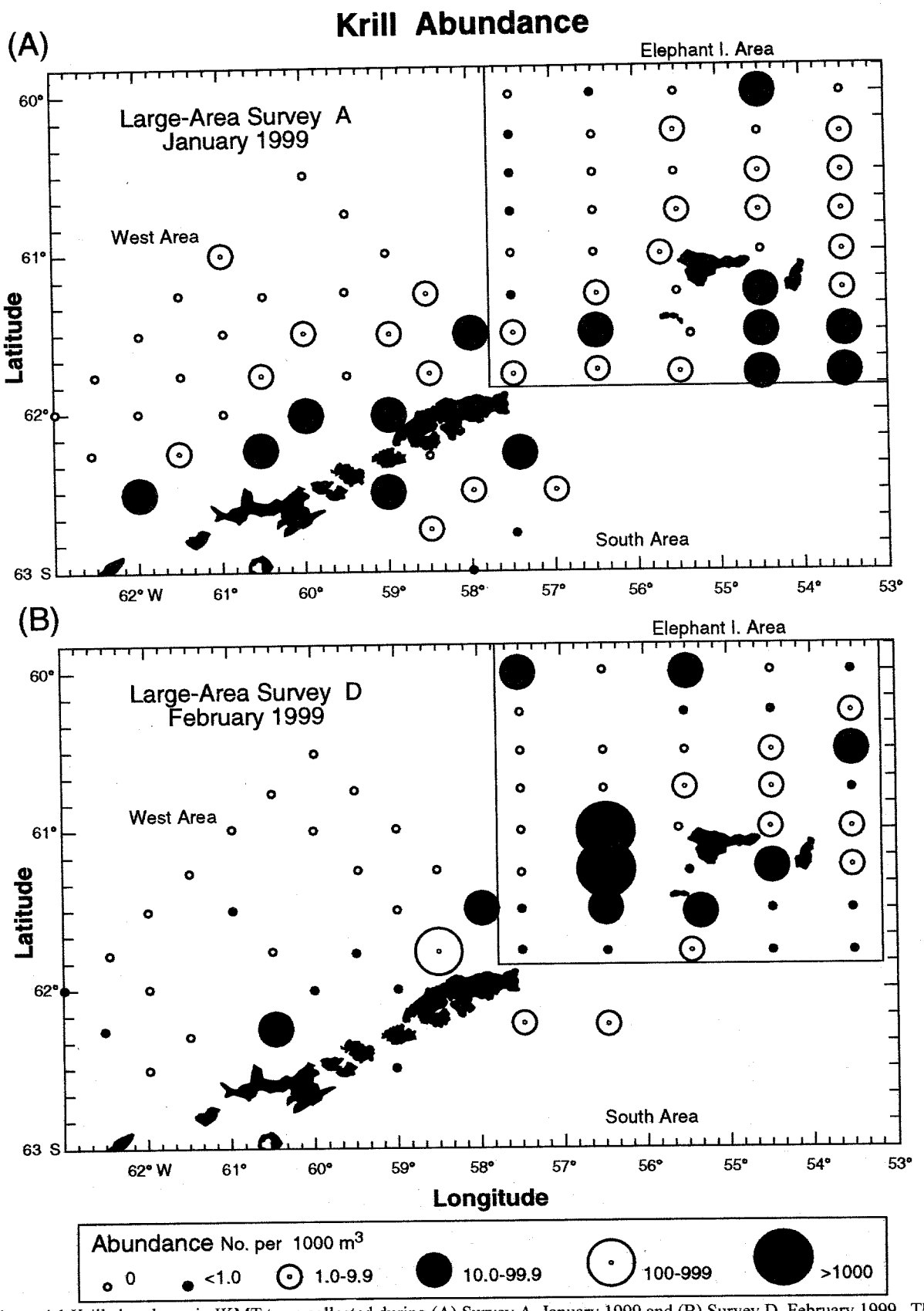

Figure 4.1 Krill abundance in IKMT tows collected during (A) Survey A, January 1999 and (B) Survey D, February 1999. The outlined stations are included in the "Elephant Island area" and used for between-year comparisons. "West" and "South" area stations are indicated.

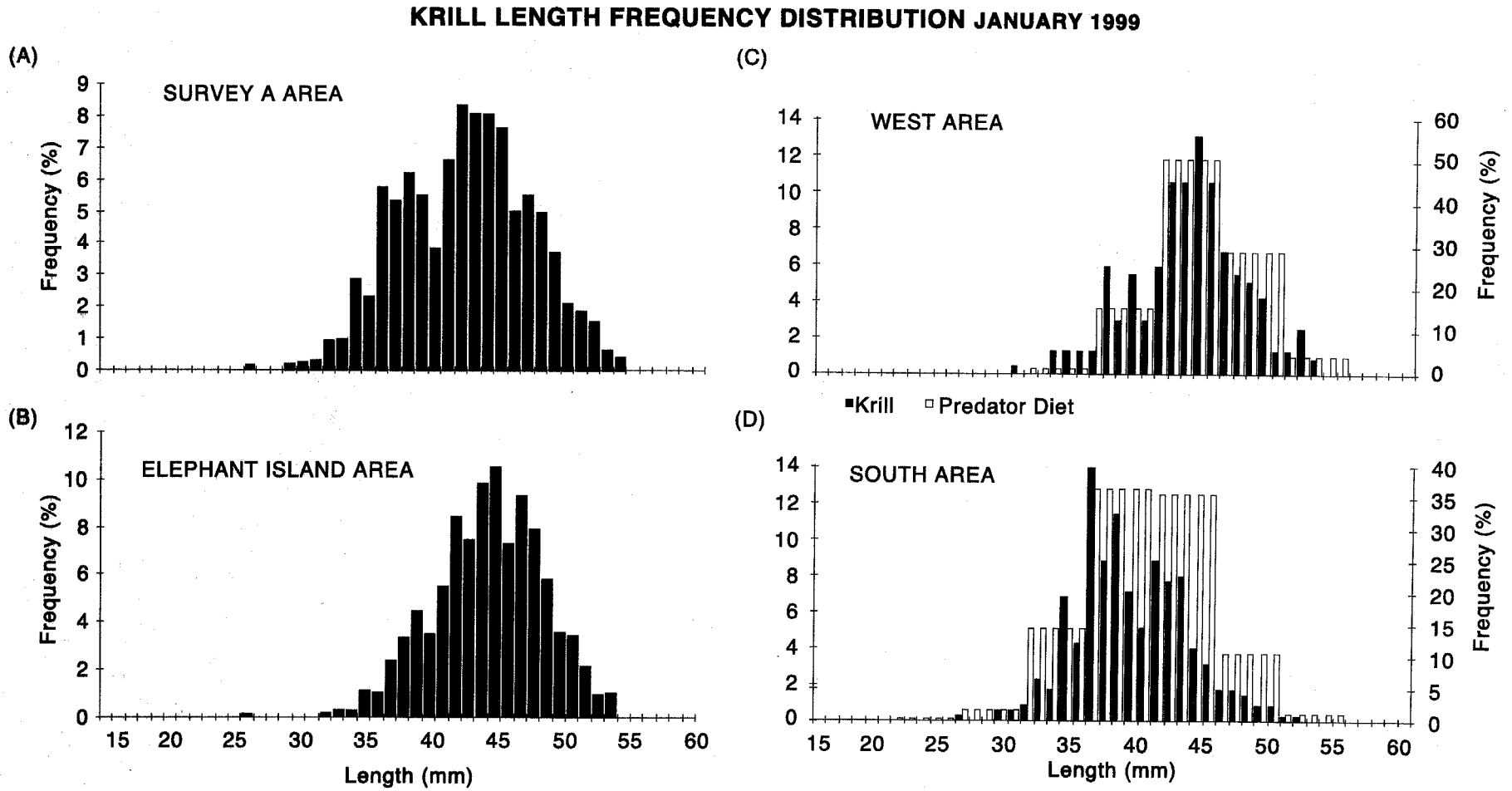

Figure 4.2 Overall length frequency distribution of krill collected during (A) Survey A, (B) Elephant Island area, (C) West area, and (D) South area, January 1999. Length frequency distributions provided for krill in predator diets at (C) Cape Shirreff and (D) Admiralty Bay.

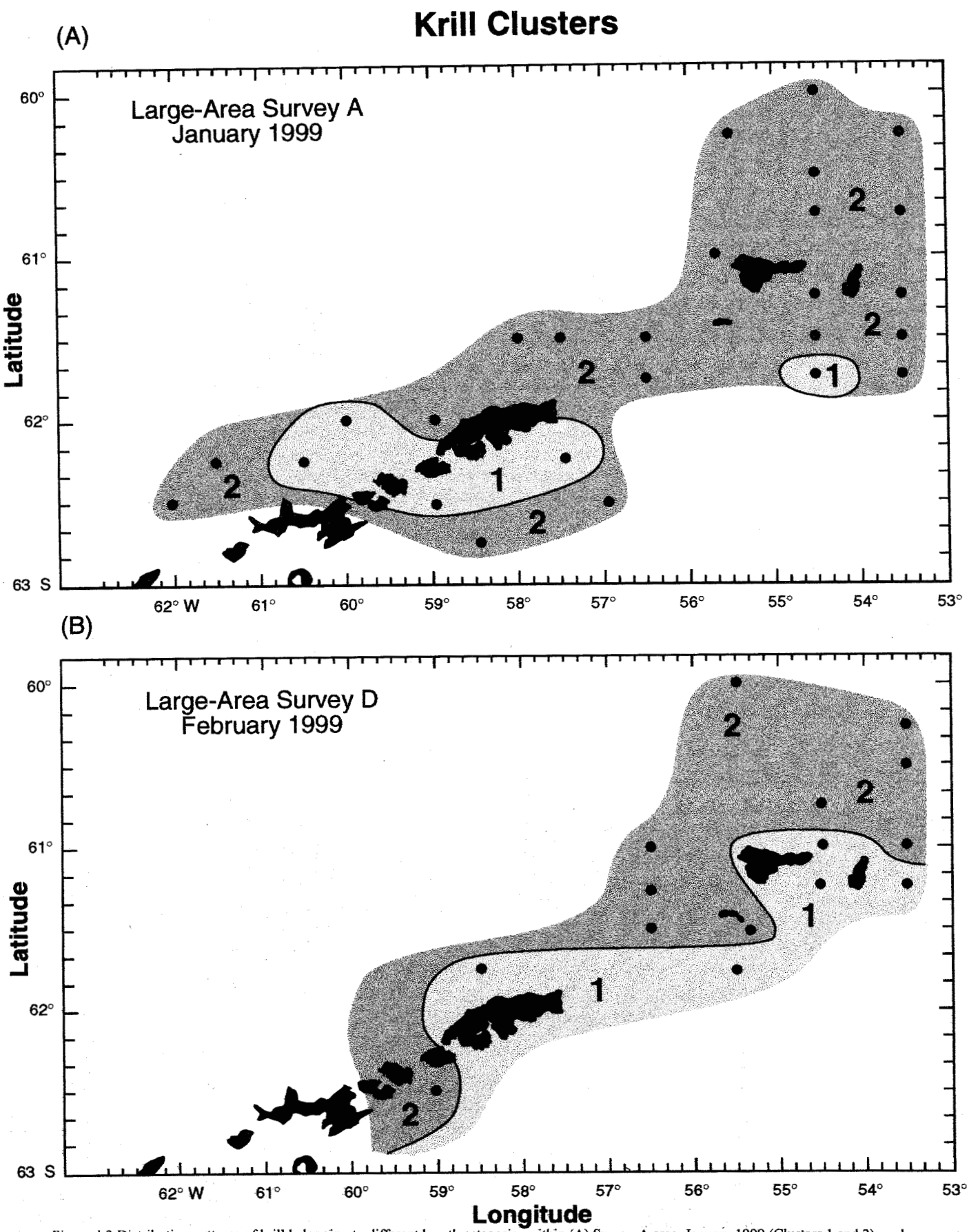

Figure 4.3 Distribution patterns of krill belonging to different length categories within (A) Survey A area, January 1999 (Clusters 1 and 2); and (B) Survey D area, February 1999 (Clusters 1 and 2).

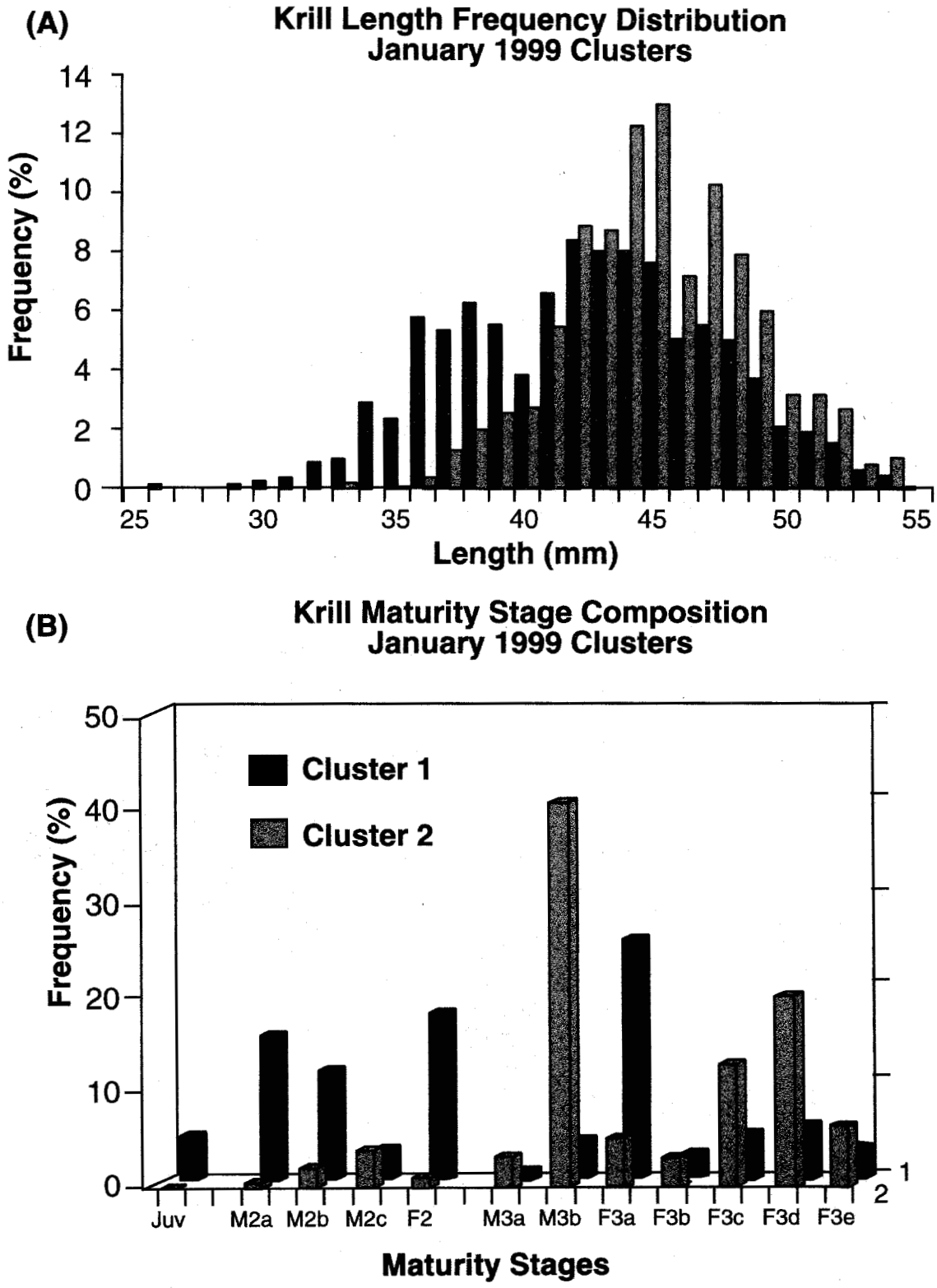

Figure 4.4 (A) Length frequency distribution and (B) maturity stage composition of krill belonging to two length categories (Clusters 1 and 2) in the Survey A area, January 1999.

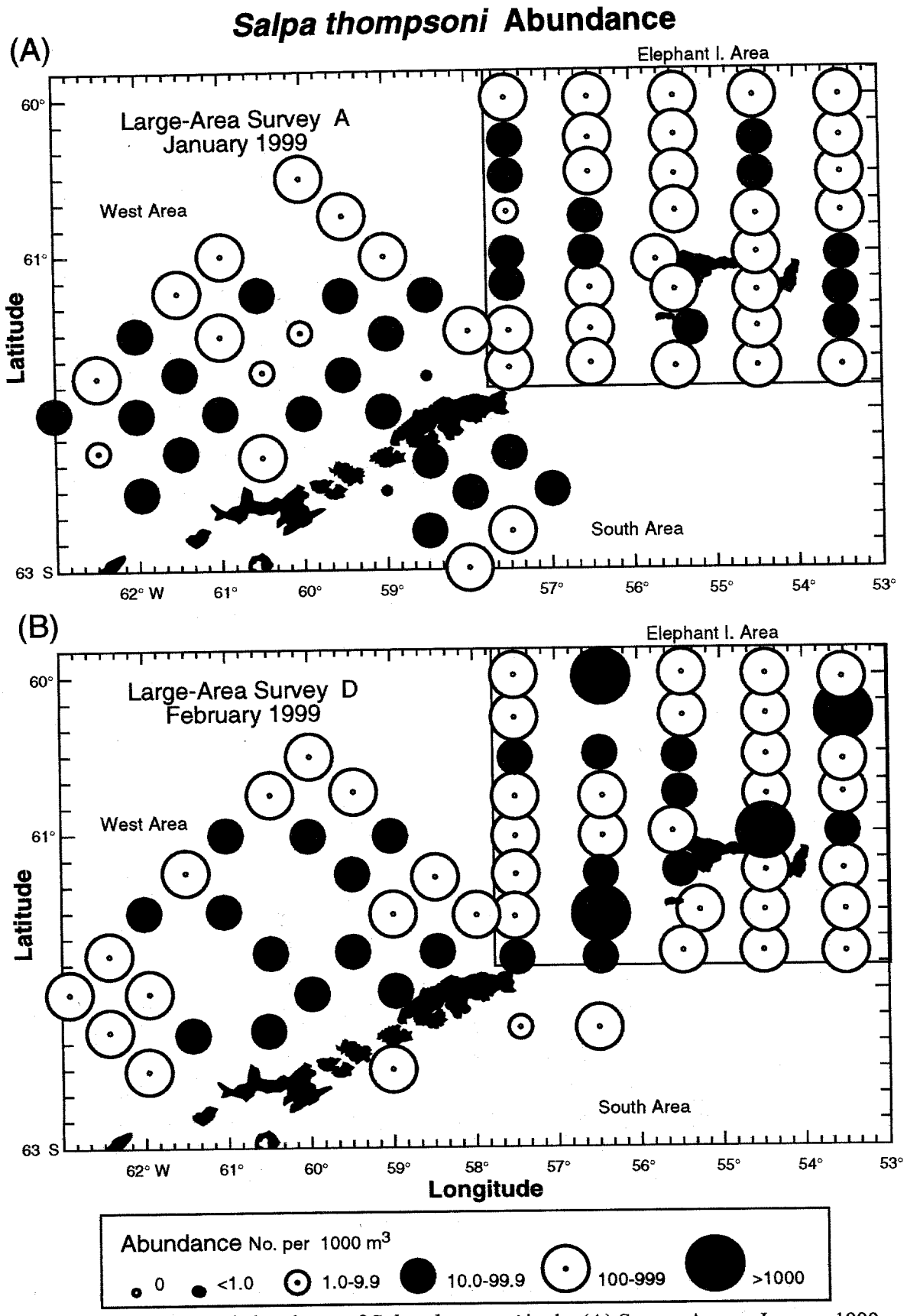

Figure 4.5 Distribution and abundance of *Salpa thompsoni* in the (A) Survey A area, January 1999; and (B) Survey D area, February 1999.

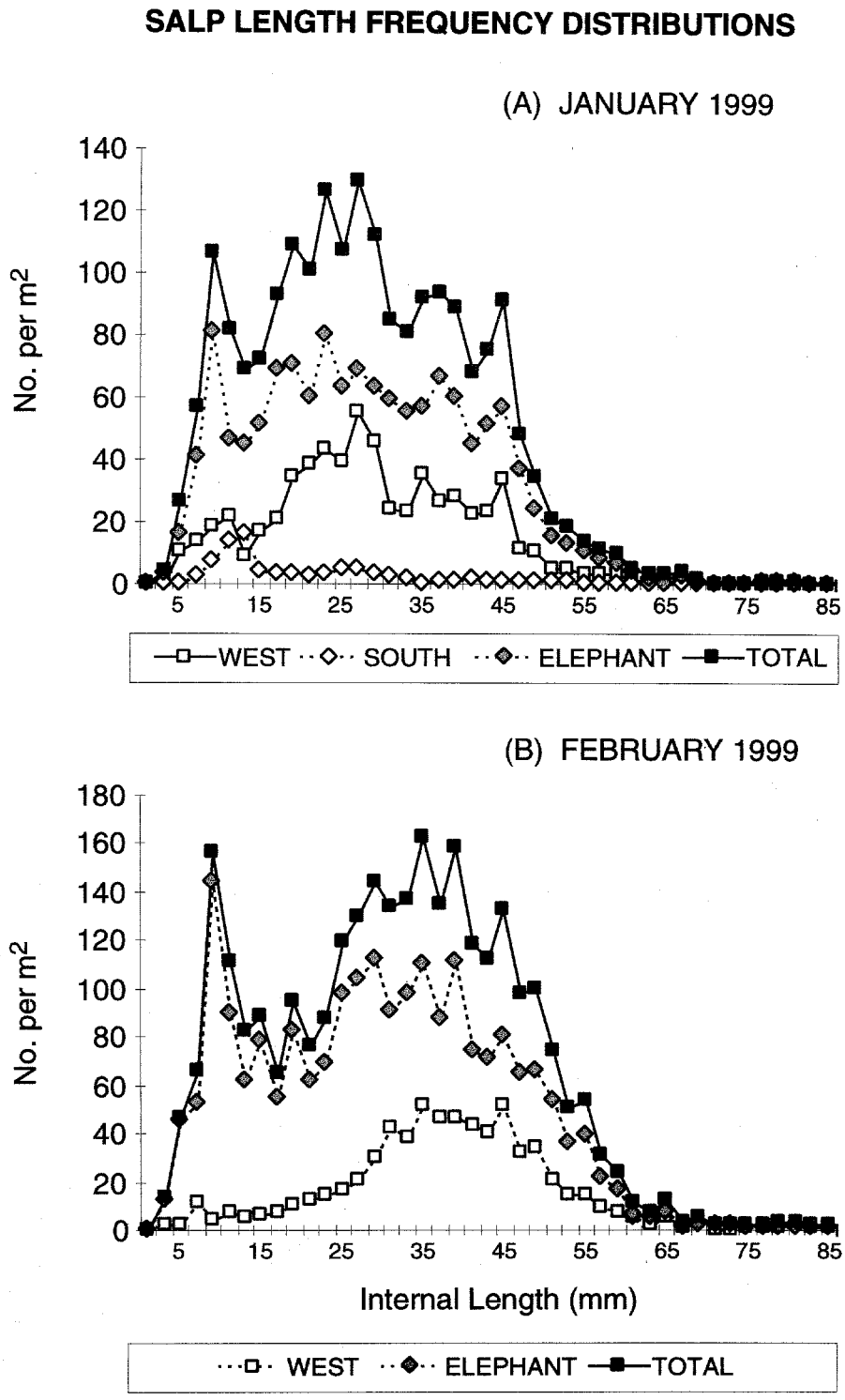

Figure 4.6 Length frequency distributions of *Salpa thompsoni* in the (A) Survey A area and three subareas, January 1999 and (B) Survey D area and two subareas, February 1999.

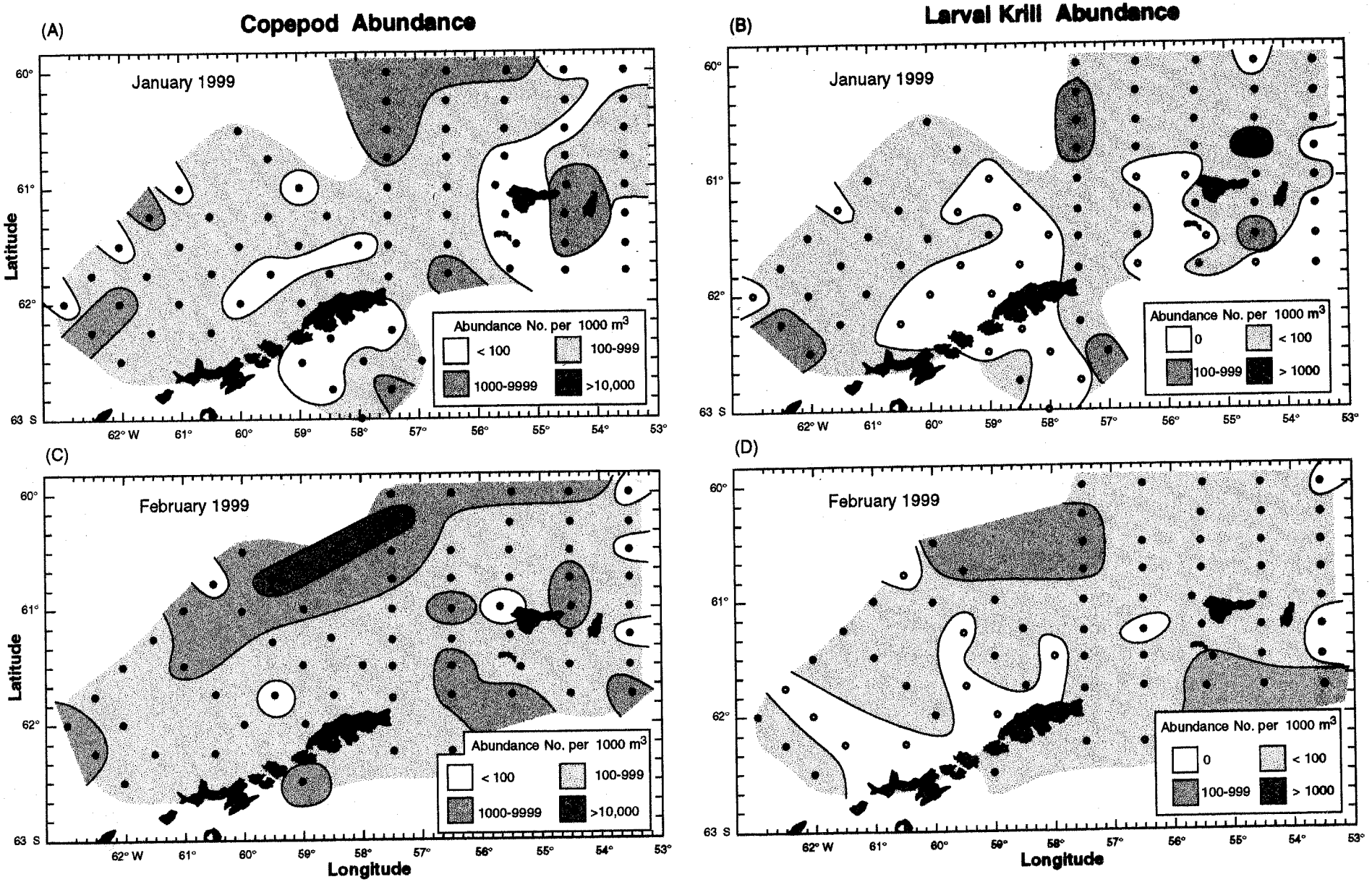

Figure 4.7 Distribution and abundance of copepods and larval krill in the (A,B) Survey A area, January 1999 and (C,D) Survey D area February 1999.

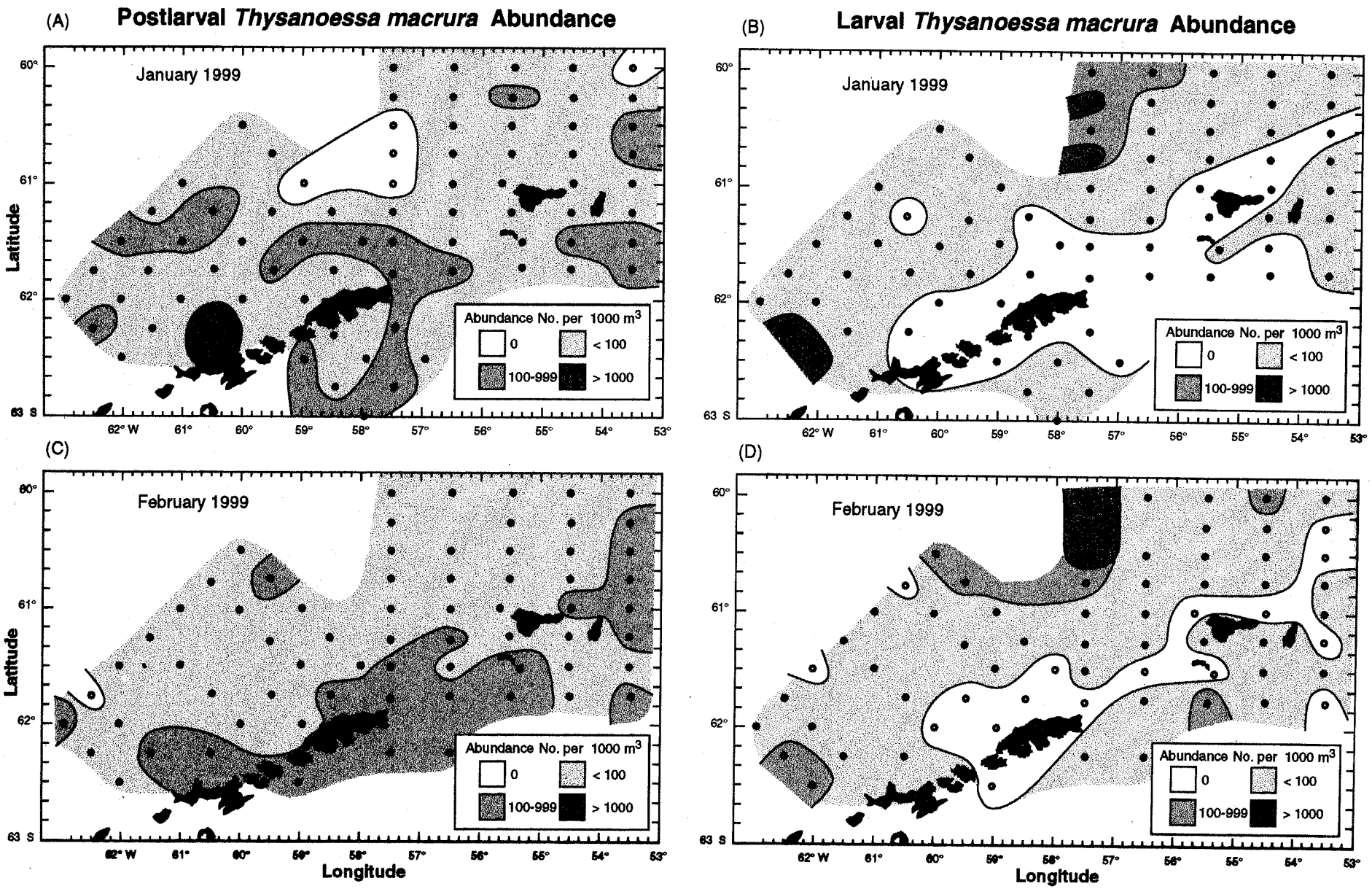

Figure 4.8 Distribution and abundance of postlarval and larval *Thysanoessa macrura* in the (A,B) Survey A area, January 1999 and (C,D) Survey D area, February 1999.

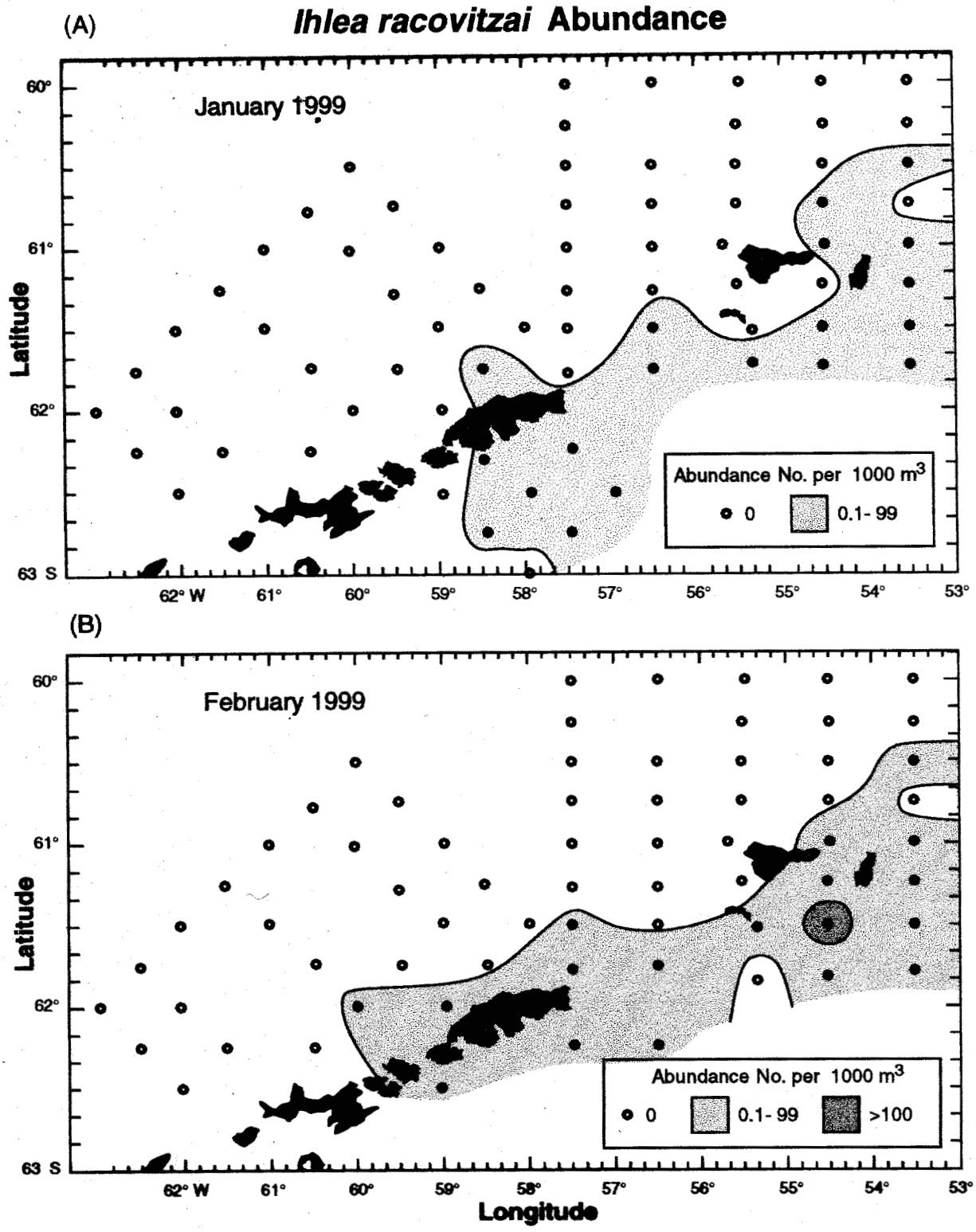

Figure 4.9 Distribution and abundance of *Ihlea racovitzai* during (A) Survey A, January 1999 and (B) Survey D, February 1999.

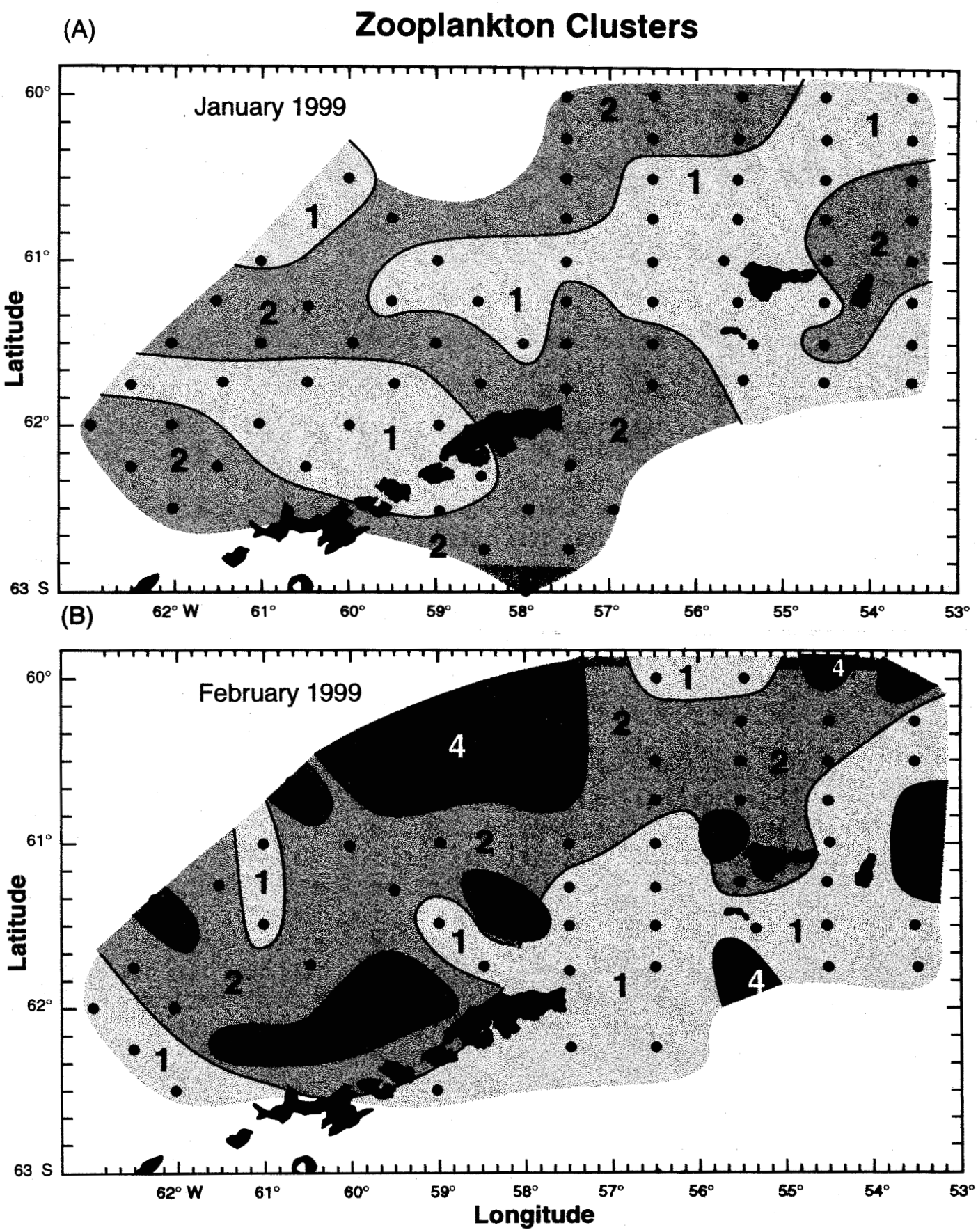

Figure 4.10 Distribution patterns of zooplankton taxa belonging to different station groupings in the (A) Survey A area, January 1999 (Clusters 1 and 2); and (B) Survey D area, February 1999 (Clusters1-4).

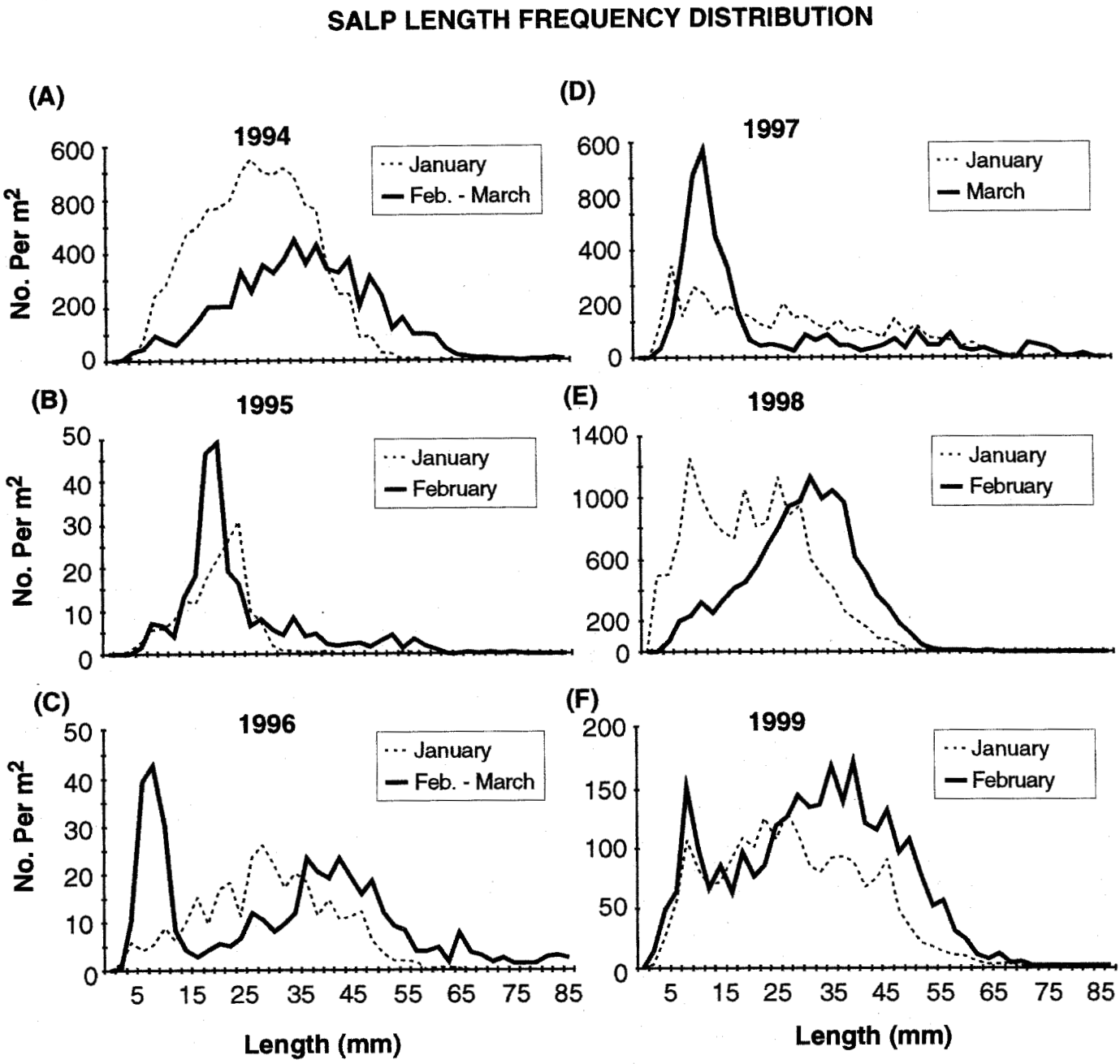

Figure 4.11 Length distribution of *Salpa thompsoni* during January-February and February-March large-area surveys 1994-1999.

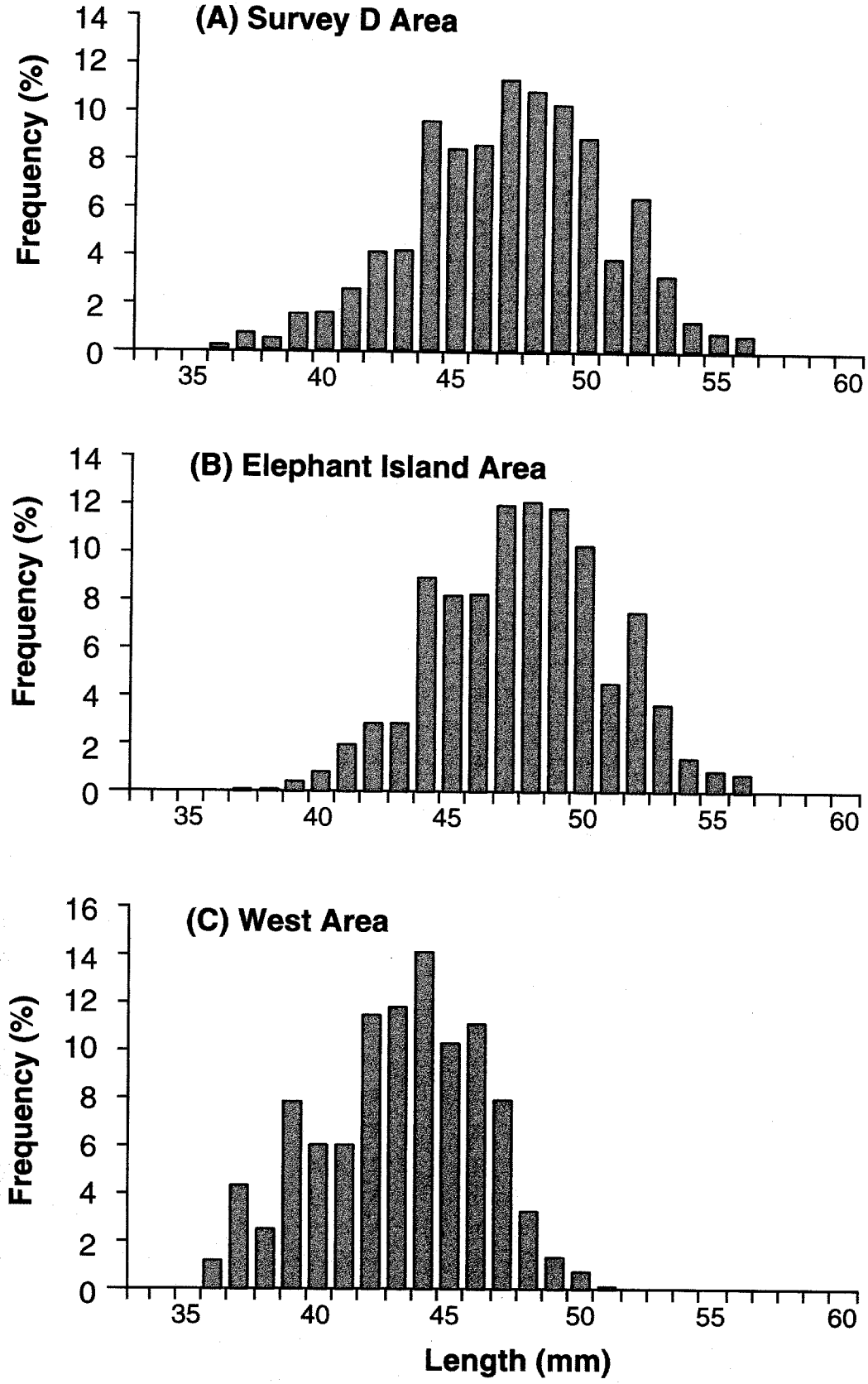

Figure 4.12 Overall length frequency distribution of krill collected during (A) Survey D, (B) Elephant Island area, and (C) West area, February 1999. South area data omitted due to small sample size.

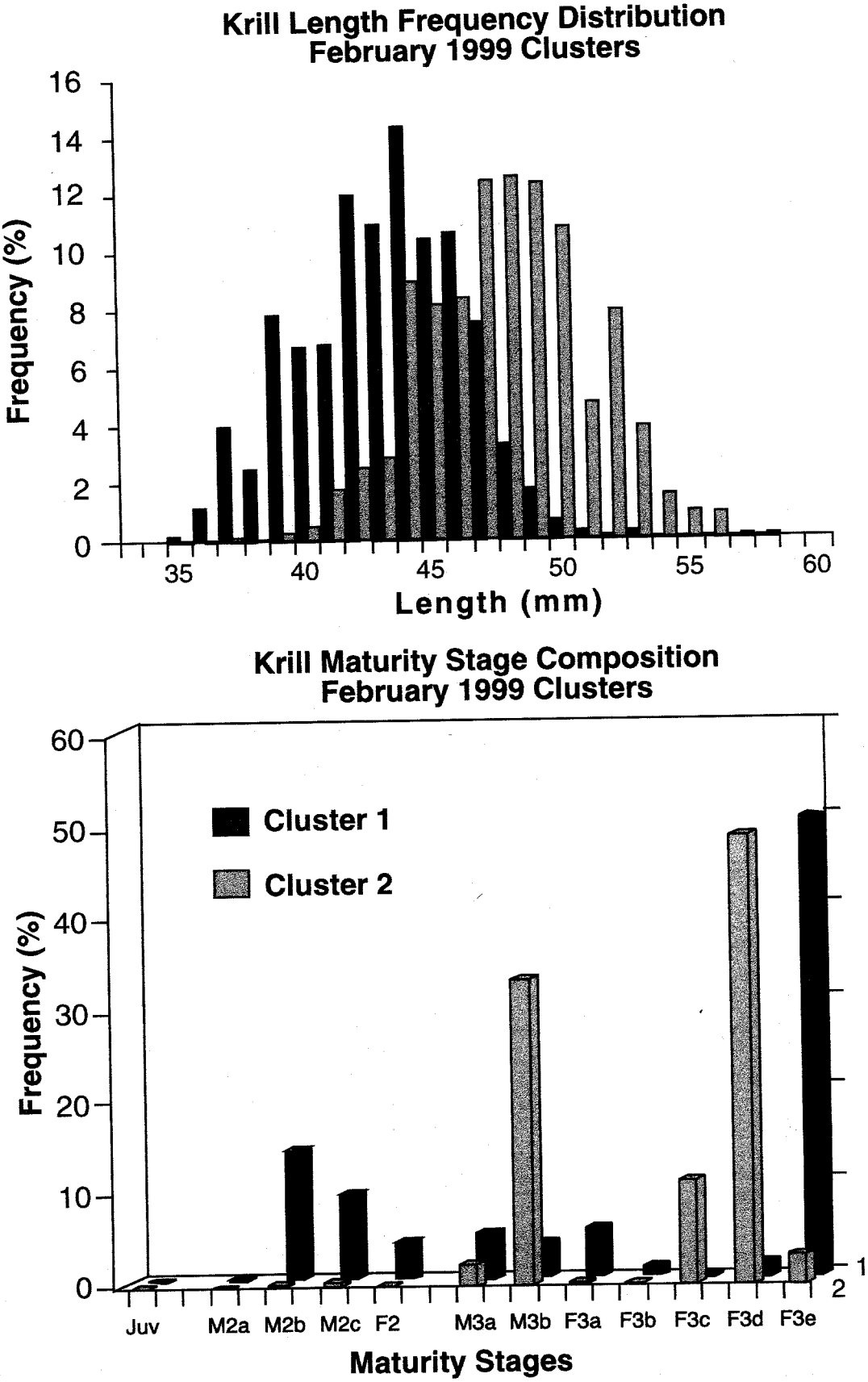

Figure 4.13 (A) Length frequency distributions and (B) maturity stage composition of krill belonging to different length categories (Clusters 1 and 2) in the Survey D area, February 1999.

5. Abundance and distribution patterns of copepod species during January-February 1999; submitted by Darci Lombard (Legs I, II, and III), Valerie Loeb (Legs I and II), Wesley A. Armstrong (Legs I and II), Kim Dietrich (Legs I, II, and III), and Nancy Gong (Legs I and II).

5.1 Objectives: Copepods constitute a substantial proportion of Southern Ocean zooplankton abundance (Pakhomov, E.A., et. al, 1997; Hopkins and Torres, 1989; Boysen-Ennen et al., 1991). Copepod species composition and distribution patterns reflect the water masses with which they are associated and therefore show mesoscale variability in areas of complex hydrography. Numerical and relative abundance of copepod species in surface waters [i.e., upper 200 meters (m)] within a given area also vary due to differing seasonal and diel vertical migrations (Atkinson, 1991; Schnack-Schiel and Hagen, 1995). Within the AMLR survey area total copepod abundance and individual species abundance exhibit extreme interannual variability; these are evidenced by fluctuations between "copepod" and "salp" dominated periods (Park and Wormuth, 1993; Section 4, Net sampling).

The objective of this work is to describe the abundance relations and distribution patterns of the biomass dominant copepod species in the AMLR survey area during the 1999 field season. Through the initiation of this study we established information and protocol necessary for the routine inclusion of copepod species identification during onboard zooplankton sample analysis. The resulting AMLR data base will hopefully provide valuable insight into intra- and interannual variations in species abundance and distribution within this important zooplankton component.

5.2 Accomplishments:

Shipboard Analyses.

Species identifications were made for copepods in subsamples of the small zooplankton fraction (see Section 4, Net sampling, for sampling and processing specifics). Generally, three or four aliquots of each sample were examined using dissecting microscopes. All copepods were enumerated and the four biomass dominant species were identified. These were *Metridia gerlachei, Calanus propinquus, Calanoides acutus* and *Rhincalanus gigas*. The unidentified individuals were grouped as "other" copepods. No designations were made with respect to the sex or maturity stage. Due to initial unfamiliarlarity with the species, copepods were pooled until identifications could be made with certainty. Therefore, species frequency of occurrence and abundance estimates were based on fewer than the total 75 Survey A stations: 68 stations for *M. gerlachei, R. gigas;* 65 stations for *C. acutus*; and 62 stations for *C. propinquus*. Copepod species abundance was determined for all 67 Survey D zooplankton samples. Abundance is expressed as numbers per 1000 m^3 water filtered.

5.3 Results and Preliminary Conclusions:

(A) Seasonal Changes in Species Abundance and Abundance Relations

During Survey A, *Calanoides acutus* and *C. propinquus* occurred in >98% of samples while *M. gerlachei* was in ca. 90%. *Rhincalanus gigas* was comparatively infrequent, occurring in only 73% of samples. *Calanoides acutus* had the greatest mean abundance (275.5 per 1000 m^3) and comprised 35.5% of total mean copepod abundance (Table 5.1). *Metridia gerlachei* mean abundance was fairly similar to this (249.6 per 1000 m^3; 32.1%). Mean values of *C. propinquus* (115.2 per 1000 m^3; 14.8 %) and the pooled "other" species (101.1 per 1000 m^3; 13.0%) were <50% of these. *Rhincalanus gigas* was least abundant (35.7 per 1000 m^3) and comprised only 4.6% of mean copepod abundance.

Differences in the distributional attributes of these species (i.e., patchiness, reflected by standard deviations) result in somewhat different abundance relations when based on median values (Table 5.1). *Calanus propinquus* had the largest median value (53.2 per 1000 m^3), followed closely by *M. gerlachei* (50.1 per 1000 m^3). Because of less even distribution across the large-area survey, *C. acutus* had the third largest median abundance (37.3 per 1000 m^3). During Survey A, median abundance of *R. gigas* (4.1 per 1000 m^3) was an order of magnitude smaller than the other species.

Total copepod abundance values in the Elephant Island area were 20-80% higher than those of the broader survey area (Table 5.1). Here *M. gerlachei* was the overall dominant species. Both mean and median abundance values of *C. propinquus* and "other" copepods were similar to those in Survey A. Because of more extreme patchiness here relative to the large-area survey, *C. acutus* was fourth in median abundance. As with the entire survey area, *R. gigas* was least abundant.

The four copepod species were represented in virtually all Survey D samples (Table 5.1). Mean and median copepod abundance was, respectively, ca. 2X and 4X that of Survey A, and reflected seasonal abundance increases of the four species. Each species exhibited doubled mean abundance over the January survey. Median abundance of *C. acutus, C. propinquus* and "other" copepods was also about doubled, while that of *M. gerlachei* and *R. gigas* increased by 4X and 9X, respectively. Analysis of variance indicates that the increases of *M. gerlachei*, *R. gigas*, and total copepod numbers were significant ($P<0.05$).

As during January, *C. acutus* had the largest mean abundance followed closely by *M. gerlachei* (495.5 and 441.1 per 1000 m^3, respectively); together these two species contributed 65.2% of the total. *Calanus propinquus* (241.5 per 1000 m^3) and *R. gigas* (169.2 per 1000 m^3) ranked third and fourth in mean abundance. While proportions *C. acutus, M. gerlachei* and *C. propinquus* were similar to those during January, *R. gigas* showed a large increase in relative abundance (11.8% vs. 4.6% of total). The decrease of "other" copepod mean abundance between the two surveys is probably an artifact due to improved identification abilities.

Species abundance relations again changed somewhat when based on median values. *Metridia gerlachei* was by far the most abundant species across the Survey D and Elephant Island areas with median values (206.9 and 216.9 per 1000 m^3) more than twice those of the other species.

This was followed by C. acutus, C. propinquus, "other" copepods and, lastly, *R. gigas*. In contrast to Survey A, median abundance values and abundance relations within the Elephant Island area were fairly similar to those of the large-area survey. The notable exception is substantially lower median abundance of *C. acutus* in the Elephant Island area which makes it slightly less abundant than *C. propinquus*.

In accordance with its high median abundance during January, *C. propinquus* had the lowest summed station rank of any species, indicating that it was most often the dominant species in Survey A samples. This was followed by *C. acutus*, *M. gerlachei*, "other" copepods, and *R. gigas*. *Metridia gerlachei* was most commonly the dominant species in Survey D samples, followed by *C. acutus*, *C. propinquus*, "other" copepods and, again in last place, *R. gigas*. Seasonal changes in species dominance relations are associated with changes in their median abundance.

(B) Diel Abundance Variations

Analysis of variance indicated that, among the four species, only *M. gerlachei* exhibited significant diel abundance differences. In January its night time mean abundance (609.1 per 1000 m^3) was significantly larger than that during day (80.6 per 1000 m^3; P=0.00) and twilight (418.8 per 1000 m^3; P=0.02). In February the mean catch size at night (824.4 per 1000 m^3) was significantly larger than during day (207.0 per 1000 m^3; P=0.00). As with the euphausiids *Euphausia frigida* and *E. triacantha* these abundance differences result from substantial migrations into the upper 170m at night during the survey periods (see Section 4, Net sampling).

(C) Distribution Patterns

Kendalls tau tests to identify similar abundance patterns across the large-area survey indicated that catch sizes of the copepod species were intercorrelated each month (Γ values >0.29; P<0.001). Station abundance ranks of these copepods were also highly correlated with those of larval krill and larval *Thysanoessa macrura* (P<0.005 in all cases), indicating that these small zooplankters shared areas of high and low abundance.

Copepod species abundance conforms to the distribution patterns of other zooplankton taxa during each survey. Applying cluster analysis to abundance of total copepods and other zooplankton taxa at each station yielded two groups for Survey A and four groups for Survey D (see Section 4, Net sampling).

During Survey A, the abundances of all four species plus "other" copepods were significantly higher at Cluster 2 than Cluster 1 stations (ANOVA, P<0.01 for the four species, P<0.05 for "others"; Table 5.2). Elevated abundance of these copepod species and other small zooplankton taxa, delimited by Cluster 2 (Figure 4.10A, Section 4), were associated with eastward flow along the South Shetland Islands and areas of complex hydrography (e.g., gyres, eddies and fronts).

During Survey D, significantly higher abundance of *C. acutus, C. propinquus, R. gigas* and "other" copepods (P = 0.000 in all cases) occurred at the eight stations of Cluster 4 than at the other grouped station (Figure 4.10B, Section 4). Similar to Survey A, this cluster was characterized by dense concentrations of small zooplankters, including larval krill and larval *T. macrura,* and most likely occurred in offshore retention areas. *Metridia gerlachei* differed in that its abundance at Cluster 1 stations was significantly higher than at those of Clusters 2 and 3 (P = 0.001 and P = 0.000, respectively), while intermediate values occurred at Cluster 4 stations. Cluster 1 generally occurred in the Bransfield Strait area and the distribution of *M. gerlachei*, a coastal species, is associated with flow of the Bransfield Current (Huntley and Escritor, 1992). Highest concentrations of the other copepod species in primarily offshore waters conforms to their more oceanic and lower latitude habitats (Atkinson, 1991). Lowest concentrations of all copepod species occurred at Cluster 2 and 3 stations which represent a zooplankton-poor band extending along the northern island shelves and adjacent areas (see Section 4, Net sampling).

5.4 References:

Atkinson, A. 1991. Life cycles of *Calanoides acutus, Calanus simillimus* and *Rhincalanus gigas* (Copepoda: Calanoida) within the Scotia Sea. *Mar. Bio.*, 109: 79-91.

Boysen-Ennen, E., W. Hagen, G. Hubold, and U. Piatkowski. 1991. Zooplankton biomass in the ice-covered Weddell Sea, Antarctica. *Mar. Bio.*, 111: 227-235.

Hopkins, T.L. and J.J. Torres. 1989. Midwater food web in the vicinity of a marginal ice zone in the western Weddell Sea. *Deep-Sea Res.*, 36: 543-560.

Huntley, M. and F. Escritor. 1992. Ecology of *Metridia gerlachei* Giesbrecht in the western Bransfield Strait, Antarctica. *Deep-Sea Res.*, 39: 1027-1055

Pakhomov, E.A.; H.M. Verheye, A. Atkinson, R.K. Laubscher; and J. Taunton-Clark. 1997. Structure and grazing impact of the mesozooplankton community during late summer 1994 near South Georgia, Antarctica. *Polar Biol.* 18(3): 180-192

Park, C. and J.H. Wormuth. 1993. Distribution of Antarctic zooplankton around Elephant Island during the austral summers of 1988, 1989, and 1990. *Polar Biol.* 13(4): 215-225.

Schnack-Schiel, S. B., and W. Hagen. 1995. Life-cycle strategies of *Calanoides acutus, Calanus propinquus* and *Metridia gerlachei* (Copepoda: Calanoida) in the eastern Weddell Sea, Antarctica. *J. Mar. Sci.* 52(3-4): 541-548.

Table 5.1 Copepod species abundance relations in the large-area survey and Elephant Island area during January and February 1999. F(%) is frequency of occurrence. Ranks provided for both mean and median abundance. *Survey A species frequency of occurrence and abundance based on between 62 and 68 of the 75 stations; Survey A proportions (%) based on summed mean total. Significantly higher Survey D abundance is indicated for various taxa: **P<0.05; ***P<0.01.

	JANUARY												
	SURVEY A (N = 75*)							ELEPHANT ISLAND AREA (N = 40)					
Taxa	F(%)	Rank	Mean	SD	%	Rank	Med	Rank	Mean	SD	%	Rank	Med
Calanoides acutus	98.5	1	275.5	829.0	35.5	3	37.3	2	335.4	1009.5	36.2	4	28.9
Metridia gerlachei	89.7	2	249.6	444.1	32.1	2	50.1	1	340.5	512.7	36.7	1	66.0
Calanus propinquus	98.4	3	115.2	215.8	14.8	1	53.2	3	109.1	161.9	11.8	2	52.0
Other	95.6	4	101.1	165.6	13.0	4	36.1	4	88.4	167.3	9.5	3	33.8
Rhincalanus gigas	73.5	5	35.7	101.3	4.6	5	4.1	5	53.6	127.3	5.8	5	4.0
TOTAL			777.1	1275.2			180.9		927.0	1590.8			332.9

	FEBRUARY												
	SURVEY D (N = 67)							ELEPHANT ISLAND AREA (N = 39)					
Taxa	F(%)	Rank	Mean	SD	%	Rank	Med	Rank	Mean	SD	%	Rank	Med
Calanoides acutus	98.5	1	495.5	1336.2	34.5	2	89.4	2	511.8	1395.6	32.8	3	70.7
*Metridia gerlachei***	98.5	2	441.1	614.9	30.7	1	206.9	1	521.1	699.0	33.5	1	216.9
Calanus propinquus	100	3	241.5	506.4	16.8	3	79.7	3	300.9	630.6	19.3	2	70.8
*Rhincalanus gigas****	98.5	4	169.2	323.2	11.8	5	37.4	4	144.6	291.7	9.3	5	36.9
Other	100	5	90.3	134.6	6.3	4	52.8	5	79.6	77.3	5.1	4	55.2
TOTAL**			1437.8	2186.7			662.6		1557.9	2337.8			621.6

Table 5.2 Abundance of copepod taxa at survey stations associated with zooplankton clusters, January and February 1999. (See Section 4, Net sampling.) N is number of stations represented by each zooplankton cluster.

	SURVEY A January					
	Cluster 1 (N = 38)			Cluster 2 (N = 37)		
Taxa	Mean	SD	Med	Mean	SD	Med
Calanoides acutus	44.0	66.8	23.1	790.0	1344.1	80.3
Metridia gerlachei	92.1	271.8	11.2	627.8	530.0	498.6
Calanus propinquus	44.1	57.5	30.9	251.3	327.8	135.6
Other copepods	71.2	116.9	26.3	172.9	227.6	93.7
Rhincalanus gigas	8.9	15.3	3.3	100.1	167.2	13.6

	SURVEY D February											
	Cluster 1 (N = 27)			Cluster 2 (N = 17)			Cluster 3 (N = 15)			Cluster 4 (N = 8)		
Taxa	Mean	SD	Med	Mean	SD	Med	Mean	SD	Med	Mean	SD	Med
Metridia gerlachei	825.3	778.5	526.7	165.9	120.3	157.2	72.1	29.3	70.4	421.4	346.4	260.3
Calanoides acutus	179.8	309.7	100.3	133.8	120.3	89.4	71.1	28.9	49.8	3125.8	2546.6	1844.9
Calanus propinquus	111.8	124.8	70.8	100.1	48.0	91.9	64.6	26.3	37.2	1311.5	863.1	1032.4
Other copepods	86.2	75.0	60.3	52.3	37.8	43.5	12.9	5.2	11.2	330.2	235.1	227.7
Rhincalanus gigas	51.5	55.1	32.4	202.8	284.6	46.9	25.1	10.2	6.3	765.7	482.9	861.9

6. Operations and logistics at Cape Shirreff, Livingston Island; Seal Island; and Copacabana, King George Island, Antarctica, 1998/99; submitted by Jane Martin and Rennie S. Holt.

6.1 Objectives: During the 1998/99 field season, the AMLR program occupied a field camp at Cape Shirreff, Livingston Island, Antarctica (62°28'07"S, 60°46'10"W) to support land-based research on seabirds and pinnipeds. The camp was occupied continuously from 25 November 1998 through 26 February 1999. Beginning in the 1986/87 austral summer, the AMLR program maintained a field camp at Seal Island, Antarctica (60°59'14"S, 55°23'04"W) in support of land-based research on pinnipeds and seabirds. However, due to safety concerns related to the geological instability of the cliffs surrounding the campsite, research at the Seal Island site was discontinued. The Seal Island camp was occupied from 30 January through 9 February 1999 during which all remaining camp structures were disassembled for removal from the island. The AMLR program provided logistical support to the Copacabana field camp on King George Island (62°10'S, 58°30'W), which is the site of seabird research funded by the National Science Foundation. The main logistical objectives of the 1998/99 season were:

1. To deploy a four-person field team and provisions in late November 1998 from the M/V *Explorer* to Cape Shirreff to initiate research activities pertaining to seabirds and pinnipeds;

2. To deploy two additional personnel, along with supplies and equipment, in mid-January 1999 from the R/V *Yuzhmorgeologiya* to Cape Shirreff;

3. To deploy two personnel and provisions in mid-January 1999 to the Copacabana field camp at Admiralty Bay, King George Island;

4. To retrieve one person from Copacabana field camp in late January 1999 for transfer to Cape Shirreff; and also to deliver another person from the R/V *Yuzhmorgeologiya* to Cape Shirreff.

5. To recover two field team members from Cape Shirreff in late January 1999 aboard the R/V *Yuzhmorgeologiya*;

6. To deploy a four-person field team to Seal Island from the R/V *Yuzhmorgeologiya* in late January 1999;

7. To dismantle and retrograde all remaining building structures and equipment from Seal Island;

8. To recover the Seal Island field team, retrograded building materials, and equipment in early February 1999 aboard the R/V *Yuzhmorgeologiya*; and to transfer one person back to Cape Shirreff, and retrieve another person from Cape Shirreff.

9. To recover from the Copacabana field camp in late February 1999 aboard the R/V *Yuzhmorgeologiya* a three-person field team and to retrograde equipment and trash at the end of the season;

10. To recover from Cape Shirreff in late February 1999 aboard the R/V *Yuzhmorgeologiya* the six-person AMLR field team and to retrograde equipment and trash at the end of the field season;

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

6.2 Accomplishments: A four-person field team (M. Goebel, J. Sterling, T. Carten, and R. Capitan) arrived at Cape Shirreff aboard M/V *Explorer* on 25 November 1998. Supplies and equipment were also off-loaded. Scientific activities were quickly initiated. Maintenance of the campsite also was begun.

Two additional personnel (R. Holt and D. Costa) arrived at the Cape Shirreff campsite aboard the R/V *Yuzhmorgeologiya* on 13 January 1999. Building materials, supplies, and equipment were offloaded from the ship, but bad weather forced offloading operations to be suspended prior to completion.

Two field team members (W. Trivelpiece and K. Salwicka) and provisions were deployed from the R/V *Yuzhmorgeologiya* to the Copacabana field camp at Admiralty Bay, King George Island on 14 January 1999.

The R/V *Yuzmorgeologiya* returned to Cape Shirreff on 18 January 1999 to complete the transfer of cargo needed for the construction of an emergency shelter/bird observation blind at the northern end of the Cape. The materials were offloaded with the assistance of the Russian crew and packed to the building site by island and ship personnel.

On 29 January 1999, the R/V *Yuzhmorgeologiya* returned to Copacabana to retrieve one person (W. Trivelpiece). Trivelpiece, along with another person (M. Rutishauser), were then delivered to the Cape Shirreff field camp. During this same visit, two personnel (R. Holt and J. Sterling) were recovered from Cape Shirreff. Holt, along with three other personnel (W. Armstrong, A. Jenkins, and K. Dietrich), were transported to Seal Island on 30 January 1999. Sterling returned home to the U.S.

During their stay, the Seal Island team dismantled all remaining structures and retrograded materials for the last phase of the field camp deconstruction. The R/V *Yuzhmorgeologiya* returned to Seal Island on 8 February 1999 to recover three members of the field team personnel (W. Armstrong, A. Jenkins, and K. Dietrich), along with retrograded materials, supplies, and equipment. Due to very bad weather, the initial recovery effort extended through the next day, 9

February 1999, when the final team member (R. Holt) was picked up. The ship made two final visits to Seal Island on 17 and 21 February 1999 to complete the removal of all materials.

On 10 February 1999 the R/V *Yuzhmorgeologiya* returned to Cape Shirreff to deliver one person (R. Holt) and supplies. Another person (R. Capitan) left Cape Shirreff and embarked the R/V *Yuzhmorgeologiya* for the remainder of Leg II. The field team at Cape Shirreff continued to work on the construction of the emergency shelter/bird observation blind and completed the structure towards the end of February.

Three field team members (L. Shill, A. Breton, and K. Salwicka) were retrieved from the Copacabana field station by the R/V *Yuzhmorgeologiya* on 24 February 1999; the station was closed for the season and retrograded equipment and trash were removed.

On 26 February 1999, the field camp at Cape Shirreff was closed for the season. All personnel (R. Holt, M. Goebel, D. Costa, T. Carten, W. Trivelpiece, and M. Rutishauser), along with garbage and equipment requiring maintenance or protection from the winter cold, were removed to the R/V *Yuzhmorgeologiya.*

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

6.3 Recommendations: Support provided by the R/V *Yuzhmorgeologiya* and the AMLR scientific complement made a significant contribution to the success of the field season at Cape Shirreff and Seal Island. Use of the Chilean ATV and trailer were vital for transporting materials and supplies from the boat landing to the Cape Shirreff campsite. As in past seasons, the practice of using four swimmers in dry-suits to assist with Zodiac beach operations was invaluable.

7. Seabird research at Cape Shirreff, Livingston Island, Antarctica, 1998/99; submitted by Terence Carten, Wayne Z. Trivelpiece and Rennie S. Holt.

7.1 Objectives: The second season of land-based seabird studies was conducted by the U.S. AMLR program at its field camp on Cape Shirreff, Livingston Island, Antarctica (62°28'07"S, 60°46'10"W) during the 1998/99 austral summer. Cape Shirreff is the third site on the Antarctic Peninsula where long-term monitoring of predator populations is being undertaken in support of U.S. participation in the Convention for the Conservation of Antarctic Marine Living Resources (CCAMLR). The objectives of the seabird research for the 1998/99 season were to collect the following predator monitoring data:

1. To estimate chinstrap and gentoo penguin breeding population size (Standard Method A3);

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

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

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

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

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

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

7.2 Accomplishments: Four scientists were put ashore by the expedition cruise ship M/V *Explorer* on 25 November 1998, and research continued until camp closure on 26 February 1999. Logistical support and transit back to Punta Arenas, Chile at the end of the season was provided by the R/V *Yuzhmorgeologiya.*

Breeding Biology Studies.

The Cape Shirreff penguin rookery consists of 30 breeding colonies of penguins: 19 chinstrap penguin (*Pygoscelis antarctica)* colonies, 6 gentoo penguin (*Pygoscelis papua)* colonies, and 5 colonies with both species. Chinstrap and gentoo penguin breeding populations were censused on 30 November 1998, approximately one week following the peak of clutch initiation in both species. All colonies were counted in their entirety according to CCAMLR Standard Methods. The breeding populations in the 1998/99 season were determined to be 7581 chinstrap penguin pairs and 830 gentoo penguin pairs. This represents a slight change from the 1997/98 season when there were 7617 chinstrap penguin and 810 gentoo penguin breeding pairs.

Reproductive success was determined by following a sample of 100 banded chinstrap penguin pairs and 60 gentoo penguin pairs from egg laying to crèche formation. Chinstrap penguins hatched 1.54 and fledged 1.27 chicks/pair and had 82% of all hatched chicks survive to fledging. Gentoo penguins had slightly lower reproductive success, hatching 1.52 and fledging 1.15 chicks/pair, while 76% of all hatched chicks survived to fledging. Reproductive success of chinstrap penguins was higher and gentoo penguins lower in the 1998/99 season than in 1997/98, which was the first year that data were collected at Cape Shirreff.

Counts of all chicks on 8 February produced a total of 8774 chinstrap penguin chicks and 1013 gentoo penguin chicks. This is an increase over the 7936 chinstrap penguin chicks and 910 gentoo penguin chicks counted during the 1997/98 season.

We banded a sample of 1000 chinstrap and 200 gentoo chicks for future demographic studies. Birds that survive and return to the rookery will be followed throughout their reproductive lives during future seasons.

Chinstrap chick fledging weights were collected between 17 February and 24 February according to Standard Method 7c. The mean fledging weight of 217 chicks captured on the rookery beaches as they were about to depart to sea was 3200 grams (g), compared with mean fledging weights of 3180g for the 1997/98 cohort and 3270g in 1996/97. "Fledging" weights were also collected for gentoo chicks. Gentoo chicks do not fledge in the classic sense, returning after their first trips to sea to be supplementally fed by their parents. Weights were collected at a set date during the breeding chronology at 85 days past mean clutch initiation for inter-annual comparisons. Assuming a 36-day incubation backdated from the first chick hatching, the gentoo chicks were approximately seven weeks old at the time of weighing, the age at which other *Pygoscelid* penguins fledge. Two hundred chicks were captured and weighed on 14 February with a mean weight of 4450g, an increase of 250g from the 1997/98 season.

Reproductive studies of brown skuas (*Catharacta lonnbergi*) were conducted throughout the field season. Skua adults and chicks were banded, and measurements of the culmen length and depth, and tarsus length and weight were collected. A cape-wide survey of kelp gull (*Larus dominicanus*) nests was conducted in mid-December 1998.

Foraging Ecology Studies.

Diet studies of chinstrap and gentoo penguins during the chick rearing phase were initiated on 4 January and continued through 11 February 1999. This study was conducted concurrently with the large-area surveys of the AMLR ship in January-February 1999. Forty adult chinstrap and 20 adult gentoo penguins returning from foraging trips to sea were captured at their nest sites and their stomach contents were removed by lavaging prior to feeding their chicks. We noted the sex of the returning adult, the number of chicks present at the nest, and their approximate ages. Krill (*Euphausia superba*) was present as a prey species in 100% of the samples from both species, while evidence of fish was noted in 18% of chinstrap and 70% of gentoo samples. Most of the fish observed in the chinstrap penguin diets was from otolith evidence, as little fresh fish was found in the stomach contents. Gentoo penguins frequently had fresh fish in their stomachs,

and we also found semi-digested octopii, squid and crustaceans (unid. crab sp.) in the samples. As in the 1997/98 season, the length frequency distribution of krill in the penguins' diets during 1998/99 was predominated by three CCAMLR size classes which accounted for 95% of all krill in the samples. The strong 3-4 year age class of krill represented in 1997/98 by size classes of 31-35, 36-40 and 41-45 millimeters (mm) was predominant again in the 1998/99 season with the majority of krill shifting up into the 36-40, 41-45 and 46-50mm CCAMLR categories.

Time-depth recorders (TDRs) were deployed twice during the season. Four TDRs were placed on chinstrap penguins and four on gentoo penguins on 3 January. A second deployment of TDRs occurred in late January; instruments were deployed on 5 chinstrap penguins and 5 gentoo penguins. The TDRs remained on the penguins for 7-10 days of foraging before being removed and downloaded.

We attached 24 radio transmitters to adult chinstrap penguins feeding 2-3 week old chicks on 11 and 12 January. We started following their foraging trips on 15 January after the arrival of our remote receiver and data logger from the R/V *Yuzhmorgeologiya*. Data on foraging trip length and frequency were collected through mid-February. As in the 1997/98 season, foraging trips exhibited a bimodal distribution. The two main peaks for trip duration, however, were shorter during the 1998/99 season with a major peak around 8 hours and a second peak near 14 hours in duration. Generally, the shorter trips began between dawn and noon, while the longer trips began in the late afternoon and evening. The majority of the longer foraging trips (>13 hours) included the overnight period. Otolith evidence in the chinstrap diets follows our suggestion from the 1997/98 season that fish presence may be from the nocturnal foragers and is an important component of adult chinstrap penguin diets. In addition to the radio transmitters, seven satellite-linked transmitters (PTTs) were deployed on chinstrap penguin adults during the chick rearing phase to determine foraging location. Instruments were epoxied on the penguins, remained on for 7-10 days, and then retrieved for redeployment on other adults. Preliminary analysis from 10 deployments revealed that most chinstrap penguin adults are foraging over the continental shelf adjacent to Cape Shirreff.

7.3 Preliminary Conclusions: Being the second full season of research at Cape Shirreff, only limited inter-annual comparisons are possible. Future research plans include continuing the annual CCAMLR predator monitoring protocols and at sea foraging behavior studies with TDRs and PTTs. These methods in addition to the annual large-area surveys will enable us to investigate the seasonal and inter-annual variability of the land-based predators at Cape Shirreff and the adjacent marine ecosystem.

7.4 Acknowledgments: Thanks to the cruise ship M/V *Explorer* for getting us to our study site safe and sound. The AMLR research scientists and crew of the R/V *Yuzhmorgeologiya* were instrumental in resupplying camp and other logistical endeavors. Also, we thank R. Capitan, D. Costa, M. Goebel, M. Rutishauser, and J. Sterling for help in the collection of field data.

8. Pinniped research at Cape Shirreff, Livingston Island, Antarctica, 1998/99; submitted by Michael E. Goebel, Daniel P. Costa, Jeremy T. Sterling, Matthew R. Rutishauser, Rennie S. Holt, and Wesley A. Armstrong.

8.1 Objectives: Pinniped research was conducted by the U.S. AMLR Program at Cape Shirreff, Livingston Island, Antarctica (62°28'07"S, 60°46'10"W) during the 1998/99 season. No research was conducted at Seal Island. The field team arrived at Cape Shirreff via the M/V *Explorer* on 25 November 1998. Research activities were initiated soon after and continued until closure of the camp on 26 February 1999. Our research objectives for the 1998/99 field season were as follows:

1. Monitor Antarctic fur seal (*Arctocephalus gazella*) female attendance behavior (the time at sea foraging and time ashore attending a pup).

2. Assist Chilean researchers in collecting pup length, girth, and mass for 100 Antarctic fur seal pups every two weeks through the season.

3. Document Antarctic fur seal pup production at U.S. AMLR study rookeries on Cape Shirreff and assist Chilean colleagues in censuses of fur seal pups for the entire Cape and the San Telmo Islands.

4. Collect 20 Antarctic fur seal scats (10 from each sex) every two weeks for diet studies.

5. Collect a milk sample at each female Antarctic fur seal capture for fatty acid signature analysis and diet studies.

6. Deploy time-depth recorders (TDRs) on female Antarctic fur seals for diving studies.

7. Record at-sea foraging locations for female Antarctic fur seals using ARGOS satellite-linked transmitters (PTTs).

8. Measure at-sea metabolic rates and foraging energetics of 20 lactating female Antarctic fur seals using doubly-labeled water. Deployments were to coincide with the AMLR large-area surveys (10 during Leg I, 10 during Leg II).

9. Measure milk intake using deuterated water (HDO) on the pups of foraging energetics study female Antarctic fur seals.

10. Measure milk intake and energetics for 20 Antarctic fur seal pups using doubly-labeled water.

11. Tag 500 Antarctic fur seal pups for future demographic studies.

12. Measure total blood volume for adult female and juvenile Antarctic fur seals.

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

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

8.2 Accomplishments:

Attendance Behavior: Measuring changes in attendance patterns (especially duration of trips to sea) of lactating Antarctic fur seals is one of the standard indicators of a change in the foraging environment. We instrumented 33 lactating females from 5-15 December 1998. The study was conducted according to Convention for the Conservation of Antarctic Marine Living Resources (CCAMLR) protocol (CCAMLR Standard Method C1.2 Procedure A) using VHF radio transmitters (Advanced Telemetry Systems, Inc., Model 7PN with a pulse rate of 40ppm). Presence or absence on shore was monitored for each female every 30 minutes for 30 seconds. Females were instrumented 1-2 days post-partum and were left undisturbed for at least their first six trips to sea. Pups were captured along with their mothers and weighed, measured, and marked with an identifying bleach mark. The health and condition of the pups were monitored through the study by making daily visual observations. Two of the 33 transmitters failed and we report results for 31.

The first female in our study of attendance patterns began her foraging cycles on 10 December 1998. The last female completed six trips to sea on 3 February 1999. The mean trip duration for the combined first six trips to sea this year was greater than last year (ANOVA, df1, 364, p=0.02; 1998/99: Mean=4.65 ±1.82, N=186; 1997/98: Mean=4.19 ±1.35, N=180). The difference, however, was due to the first two trips to sea being particularly longer this year than last year (Figure 8.1). This may not have been due to a difference in the foraging environment during the early breeding season at Cape Shirreff in 1998/99. It may instead have been the result of a difference in arrival condition at the start of the breeding season. Females of similar length had a lower mass in 1998/99 compared to those in 1997/98 (Figure 8.2). Due to a late arrival of one of the field personnel in 1997/98, females in that year were sampled later in the season and were on average smaller, probably younger animals than in 1998/99.

Antarctic Fur Seal Pup Growth: The U.S. research team assisted Chilean researchers collecting data on Antarctic fur seal pup growth. Chilean researchers began collecting data on pup weights and measurements on 16 December 1998. Data were collected as directed in CCAMLR fur seal pup growth protocol (CCAMLR Standard Method C2.2 Procedure B). Measurements were taken every two weeks until 14 February. An additional 51 weights were collected during tagging operations on 20 February 1999.

Antarctic Fur Seal Pup Production: Antarctic 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 30 November 1998 through 6 January 1999. The maximum number counted at these four sites in 1998/99 was 1,983 on 27 December 1998 (Figure 8.3). This is a 10.4% increase over the maximum count for the same sites in 1997/98 (1,777 on 26 December 1997). The median date of pup births was 10 December (no change from 1997/98).

A census of the entire Cape by Chilean researchers resulted in a similar increase in pup production (Hucke-Gaete, pers. com.). However, pup production in 1997/98 for Cape Shirreff and the San Telmo Islets was 14.1% less than the previous year (1996/97). Pup production in 1998/99 for Cape Shirreff was therefore, back up to the pre-1997/98 level. Unfortunately, due to constraints imposed by ship schedules and weather, the San Telmo Islets were not censused this season.

Diet Studies: Information on Antarctic fur seal diet was collected using three different sampling methods: collection of scats, enemas, or from fatty acid signature analysis of milk. Scats were collected from around suckling sites of females, near sub-adult male haul out areas, or from captured animals that defecate while captive. All females that were captured to remove a TDR or PTT received enemas. Twenty scats (10 female and 10 male) were collected every two weeks beginning 22 December. We collected and processed 98 scats and 30 enemas in 1998/99. Otoliths were identified to species, the number of squid beaks and presence of krill chitin recorded. Results indicate an increase in the percent occurrence of fish and squid in fur seal diet in February (Figure 8.4).

In addition to scats and enemas, we collected 104 milk samples from 49 female fur seals. Each time a female was captured (either to instrument or to remove instruments), a 2-30 milliliter (ml) sample of milk was collected by manual expression following an intra-muscular injection of oxytocin (0.25ml, 10 UI/ml). The milk sample was returned within several hours to the lab where two 0.25ml aliquots were collected and each stored in a solvent-rinsed glass tube with 2ml of Chloroform (w/ 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, 31 were collected from perinatal females and 49 were collected from females that had dive data for the foraging trip prior to milk collection.

Diving Studies: Fifteen of the 31 female Antarctic fur seals instrumented with transmitters for attendance studies also received a TDR [Wildlife Computers Inc., Mark 7, 8.6 x 1.9 x 1.1 centimeters, 27 grams (g)] on their first visit to shore. All females carried their TDR for at least the first six trips to sea. In addition, all other females captured for studies of foraging locations and energetics also received a TDR. The total number of females with diving data for 1998/99 was 32. The total number of trips recorded on TDRs from 10 December 1998 to 20 February 1999 was 181.

Adult female Foraging Locations and Energetics: We instrumented 33 female Antarctic fur seals with ARGOS-linked PTTs from 23 December 1998 to 12 February 1999. Nineteen carried a PTT for a single trip to sea, 12 others for two trips to sea, and two females carried their PTT for three trips. In total, we recorded 3,131 locations at sea for 49 trips (174.6 days). Each PTT had a unique ID code and a transmission repetition rate of 34 seconds while the seal was at the surface. ARGOS provides a Location Quality (LQ) code for each location fix that depends primarily on the number of up-links received. They range from 0-3 with an ARGOS predicted accuracy of <150 meters (m) to 1 kilometer+. Two other LQ codes, "A" and "B", are assigned to poorer quality fixes. Of the 3,131 at-sea locations, 59.7 % (n=1,870) had LQ codes of 0-3. We used only 0-3 LQ codes for plotting and further analysis. We filtered remaining location fixes to eliminate any positions that required an animal to travel at speeds >4m/second. Once filtered, there were 1,459 at-sea locations, or on average, 8.4 locations/female/day.

We observed a change in foraging range from January (Figure 8.5) to February (Figure 8.6). In January females foraged greater distances from Cape Shirreff than in February. The mean total distance traveled in January was 441 kilometers (km) (±244, n=19) and for February it was 238km (±75, n=9; ANOVA, df1,26, P=0.02). Females in February spent most of their time in the shelf-break region (Figure 8.6).

Twenty (10 in January, 10 in February) of the 33 females we instrumented with PTTs also received an intra-peritoneal (IP) injection of doubly-labeled water (DLW). Each female was captured on her second day on shore, administered DLW, and recaptured as soon as possible on the next visit to shore. Measuring the relative decline of isotopes (oxygen-18 and tritium) in the DLW injected over a foraging trip results in measures of metabolic rate, water flux, and ultimately energy expended.

Antarctic Fur Seal Pup Milk Intake and Energetics: We also conducted energetic measurements on 20 Antarctic fur seal pups (10 female, 10 male). Each pup was captured 2-3 days post-absorptive (i.e. 2-3 days after its mother had gone to sea to insure that the pup was fasting) and given an IP injection of DLW. The pup was recaptured 2-3 days into its next fasting cycle. All injections and subsequent recaptures took place from 23 December 1998 to 3 February 1999.

Demography and Tagging: Together Chilean and U.S. researchers tagged 500 (244 females, 256 males) Antarctic fur seal pups from 20 January to 23 February 1999. 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, and the series used was 1000-1500 (one tag, 1098, was damaged and not deployed). All pups were tagged on the east side of the Cape from Playa Daniel beach to Chungungo beach. Eighty-nine percent were tagged from 14-23 February.

In addition to the 500 pups tagged, we also tagged 52 adult females with pups. Tags were of the same type used on pups and with numbers from 036 through 087. All tags were placed on females with parturition sites on Copihue, Maderas, and Cachorros beaches. Females 036-069 were tagged during their perinatal visits from 5-15 December; the rest were non-perinatal and

were tagged from 23 December to 24 January. One female (076) had been previously tagged with N342 orange Allflex.

Last year 36 adult females with pups were tagged at Cape Shirreff, and we report a return of 83.3% for 1998/99. Ninety percent were observed with a pup. Of the ones that had a pup, all but one gave birth on the same four study beaches (Copihue, Maderas, Cachorros, and Chungungo) used in last year's studies. Interestingly, of the females observed, the one female that moved to a new parturition site was one of only two females that lost a pup in 1997/98. She moved from Cachorros to La Caverna, which is a distance of approximately 2km by land.

We also observed 22 yearlings (12 females, 10 males) tagged as pups in 1997/98 that returned to Cape Shirreff in 1998/99. The first observation of a tagged yearling was 8 December, and first-time tag resights occurred up until our departure in late-February.

Three female fur seals tagged at Seal Island, Antarctica (60°59'S, 55°23'W) were observed with pups at Cape Shirreff in 1998/99. Females with orange Allflex tags N342 and N395 gave birth and suckled their pups at Maderas beach, and female U-00491 (Monel tag) gave birth and suckled her pup at Chungungo beach. Females N342 and N395 were tagged as adult females at Seal Island. Female U-00491 was tagged as a pup at Seal Island.

Antarctic Fur Seal Total Blood Volume Studies: Total blood volume (TBV) is an important measure for calculating oxygen stores of diving animals. Accurate measures of oxygen stores allow calculation of aerobic dive limits and an understanding of the physiological constraints imposed upon foraging behavior. We used the Evan's blue dye dilution method for calculation of TBV in eight yearlings (known-age from tags) and 11 adult female fur seals.

Weather at Cape Shirreff: Two weather data recorders (Davis Weather Monitor II) were set up at Cape Shirreff. The first was set up at the AMLR field camp from 4 December 1998 to 24 February 1999. The second station was deployed at Maderas beach from 7 January to 23 February. Maderas is one of the sites used for studies of Antarctic fur seals. Both stations recorded wind speed and direction, barometric pressure, temperature, humidity, and rainfall; rainfall, however, at the field camp station was only recorded from 22 December to 24 February. The archive interval was set at 15 minutes. The sample rate for wind speed, temperature, and humidity was every 8 seconds and 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 1 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.

8.3 Preliminary Conclusions: Antarctic fur seal pup production at Cape Shirreff increased in 1998/99 over last year. Return rates for adult females and yearling pups appeared to indicate good over-winter survival. However, this is only the second year of studies at the Cape Shirreff site and comparisons can only be made with survival and fecundity from other sites. Adult

female trip duration for the first six trips to sea was significantly greater in 1998/99, possibly indicating reduced prey resources early in the season over the 1997/98 field season. The difference, however, was confined to the first two trips to sea and may have been a result of a difference in arrival condition. Females of the same length had a greater mass at one day postpartum in 1997/98 than in 1998/99. The mean parturition date for females in 1997/98 was also later than in 1998/99, and subsequently foraging cycles in 1998/99 were started earlier than in 1997/98. Any differences in females (or arrival condition) between the two years did not appear to affect later foraging trips as there were no differences between years in trips 3-6. Foraging locations and trip duration change from January to February. Females foraged much closer to Cape Shirreff in February than in January. Trip duration was also shorter in February than in January. At the same time fur seals shifted prey species from primarily krill to a diet with a higher percentage of fish and squid. Fur seals in 1997/98 showed a similar shift in diet and reduction in trip duration in February. However, we have no foraging location data for January 1998 so comparison of this year's foraging location data is limited to February only. We suspect that the intra-seasonal changes in fur seal trip duration, diet, and foraging location are characteristic of most years and are related to physical and biological characteristics of the off-shore environment of Cape Shirreff. To what extent this is the case, however, will depend upon extending our annual database and comparisons.

8.4 Acknowledgments: We are most grateful to our Chilean colleagues, Daniel Torres, Veronica Vallejos, Olivia Blank, Rogrigo Hucke-Gaete, Jorge Acevedo, Juan Bravo, and Juan Carlos Quezada for their assistance in the field, good humor and for sharing with us, their considerable knowledge and experience of Cape Shirreff. We are also grateful to Wayne Trivelpiece and Terence Carten for their considerable help on pinniped studies. Rich Capitan also assisted in collecting pup weights, tagging, and censuses. We are particularly grateful to the Explorer Corporation, the *Explorer* Captain, Uli Demel, crew, and passengers who shared their *Explorer* experience and provided transport of the Cape Shirreff opening team. Without their help we would not have been able to start our studies on time. We are, likewise, grateful to the AMLR personnel and the Russian crew of the R/V *Yuzhmorgeologiya* for their invaluable support and assistance to the land-based AMLR personnel. Last but by no means least, we thank Jane Martin and Stephanie Sexton whose support and hard work keep field operations and communications at Cape Shirreff running efficiently.

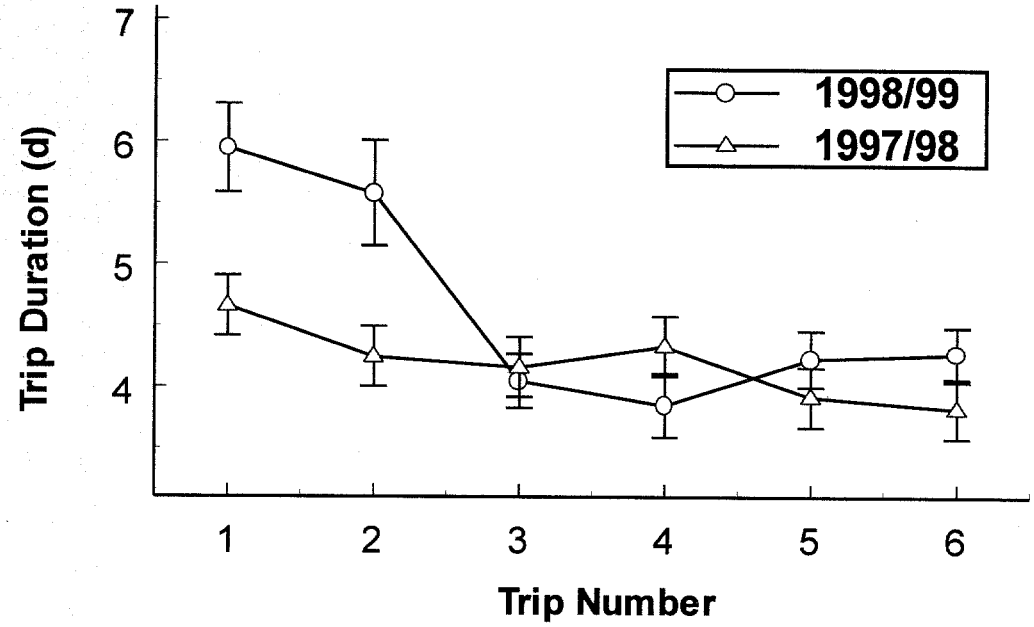

Figure 8.1 Antarctic fur seal trip durations for females rearing pups. Data plotted are for the first six trips to sea following parturition for 1997/98 (N Females=30, N Trips=180) and 1998/99 (N Females=31, N Trips=186).

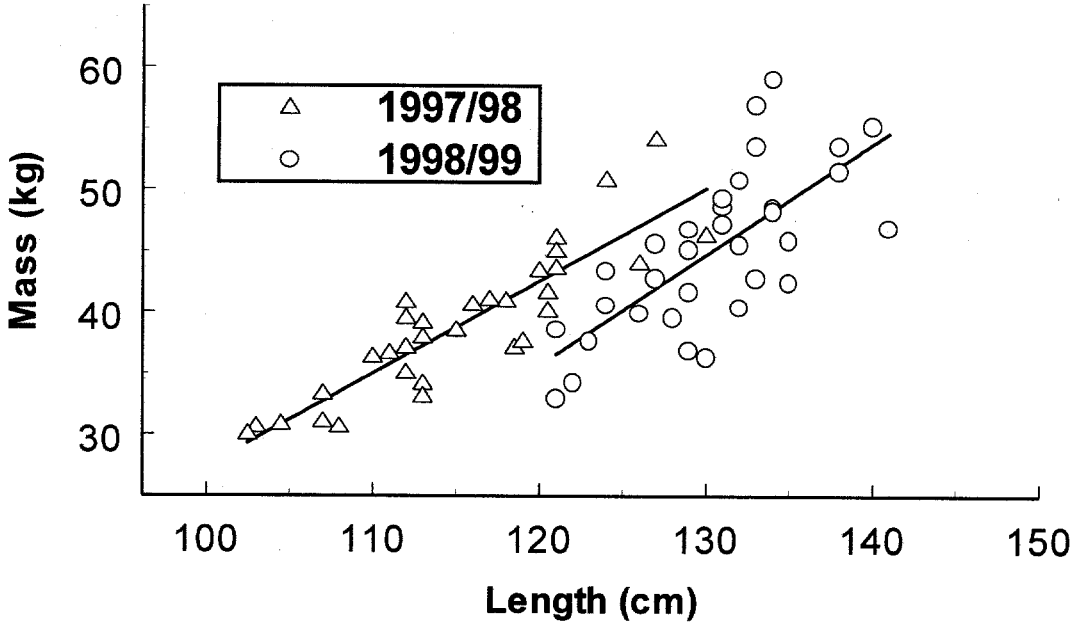

Figure 8.2 Female Antarctic fur seal mass to length relationships in two years of study at Cape Shirreff, Livingston Island. All females were 1-5 days post-partum and all values were mass adjusted to one day post-partum using a daily mass loss of 1.13 kilograms/day.

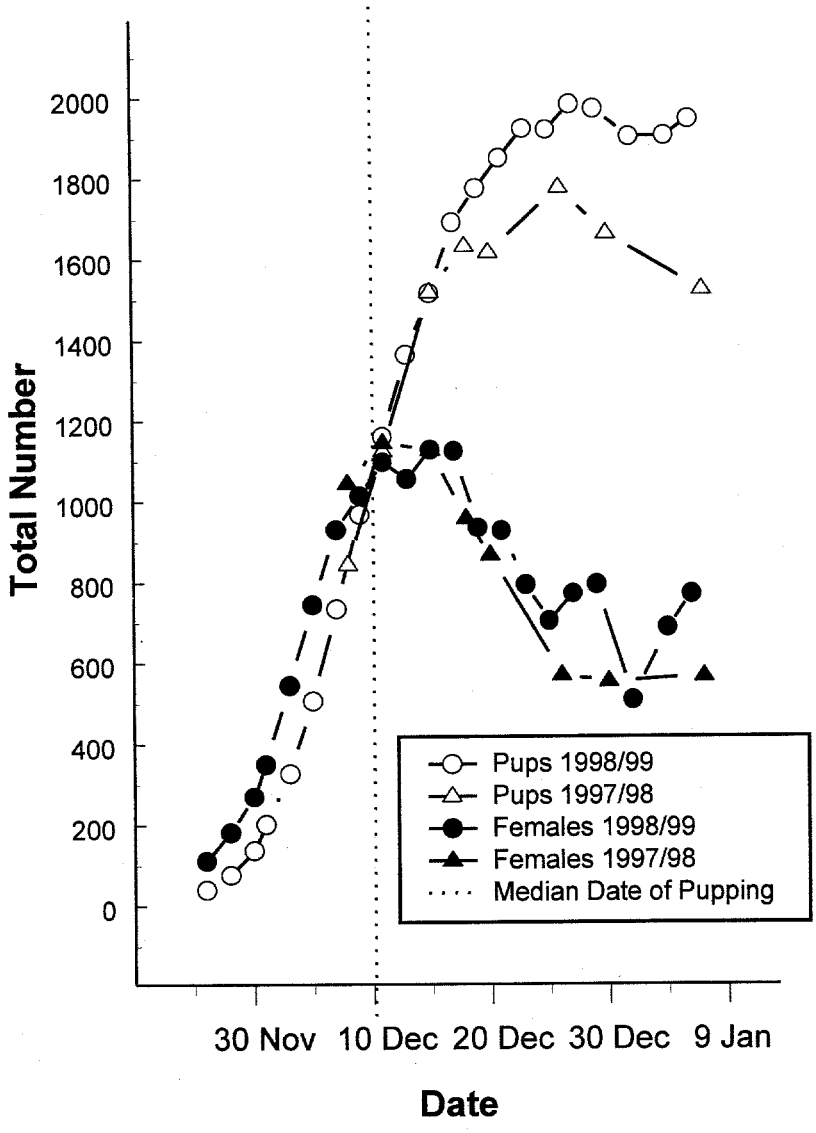

Figure 8.3 Antarctic fur seal pup production and adult female counts at U.S. AMLR study sites (Copihue, Maderas, Cachorros, and Chungungo beaches).

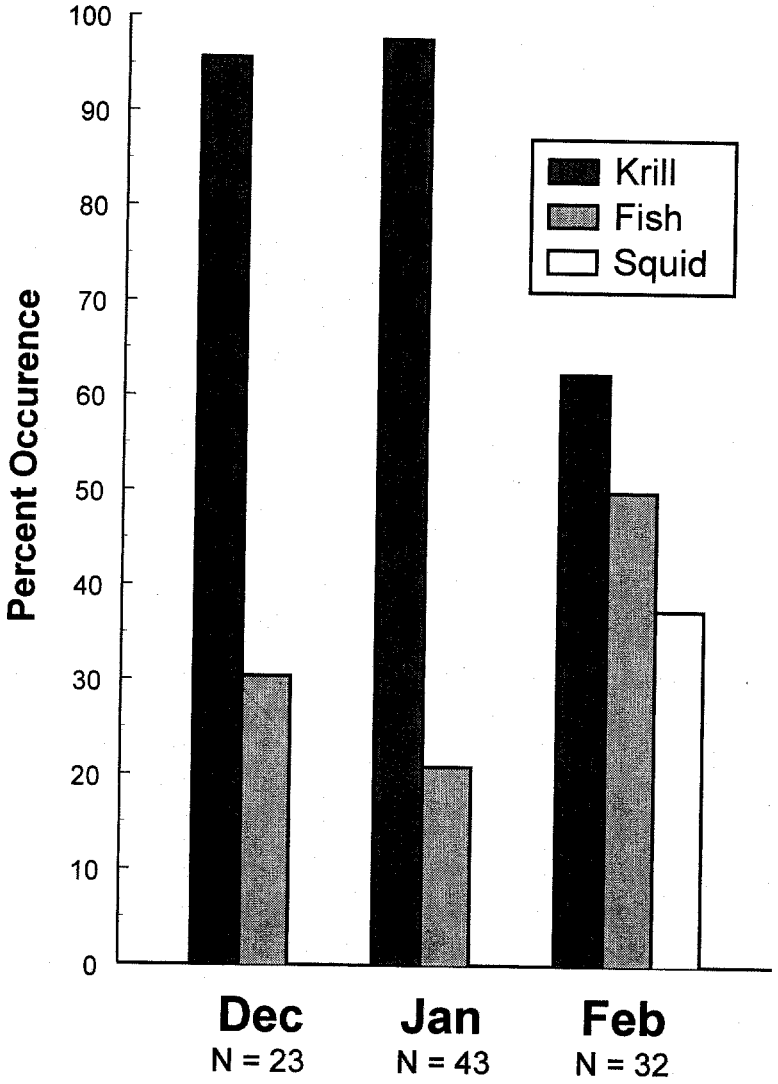

Figure 8.4 Antarctic fur seal diet results from scats collected on beaches at Cape Shirreff, Livingston Island. The percent occurrence of primary prey types: krill, fish, and squid from December through February.

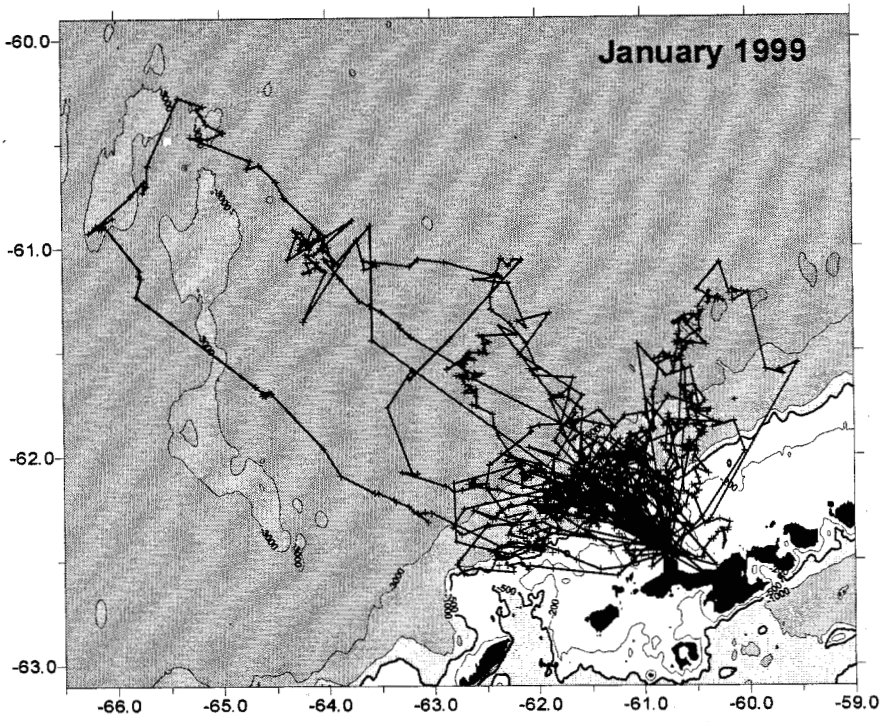

Figure 8.5 Female Antarctic fur seal foraging tracklines during the month of January 1999. Each line is for a single trip to sea. Tracklines are based on 1097 ARGOS locations with quality codes 0-3 (see text) filtered to eliminate locations requiring travelling speeds of >4m/second for 20 females making 25 trips to sea. Islands are black, the continental shelf is white, and deep water (>500m) is shaded.

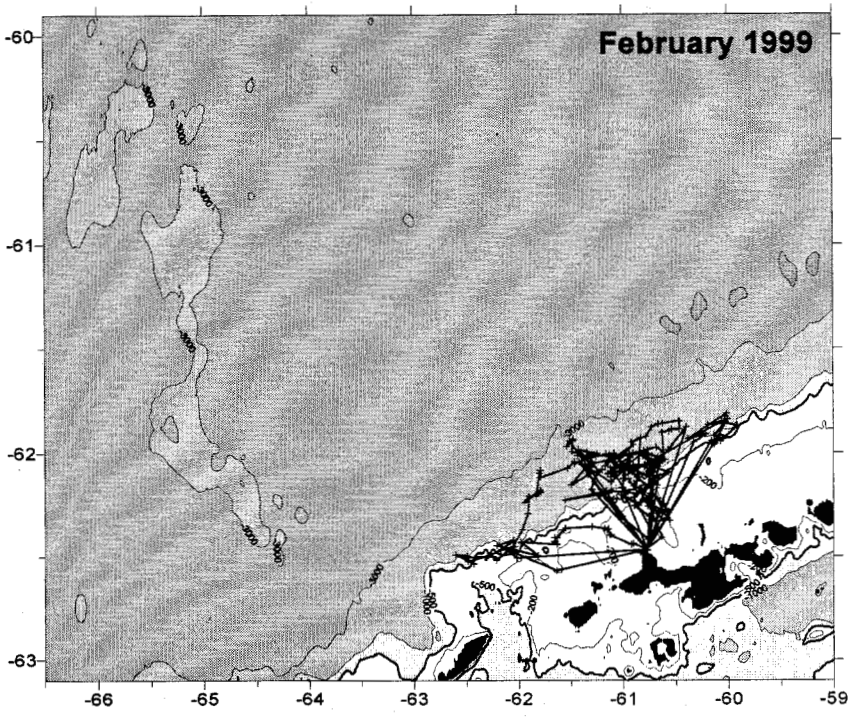

Figure 8.6 Female Antarctic fur seal foraging tracklines from 7-20 February 1999. Each line is for a single trip to sea. Tracklines are based on 218 ARGOS locations with quality codes 0-3 (see text) filtered to eliminate locations requiring travelling speeds of >4m/second for 9 females making 10 trips to sea. Islands are black, the continental shelf is white, and deep water is (>500m) shaded.

9. Bottom trawl survey of the South Orkney Islands; submitted by Christopher D. Jones (Leg III), Karl-Hermann Kock (Leg III), Sunhild Wilhelms (Leg III), Jacqueline Popp (Legs I, II, and III), David Ramm (Leg III), Kim Dietrich (Legs I, II, and III), Peter Kappes (Legs II and III), and Darci Lombard (Legs I, II, and III).

9.1 Objectives: The bottom trawl survey was designed to provide baseline estimates of abundance, species composition, size composition, and demographic structure of fish species within the 500 meter (m) isobath of the South Orkney Islands. Prior to this survey, there has been no information as to the levels of biomass of finfish in the South Orkney Islands since 1991. Although there is currently a moratorium on taking finfish from the South Orkney Islands, there has been a renewed interest in opening these areas to fishing. This survey, as well as future investigations, will provide the best possible baseline information on the health of bottom fish stocks in the South Orkney Islands.

9.2 Methods and Accomplishments:

Bottom Trawling.

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

Trawling operations were conducted aboard the R/V *Yuzhmorgeologiya* 9-25 March 1999. The sampling strategy was based on random stratified survey design. Sampling sites were stratified by depth and were positioned to account for a wide geographic range. There were three designated depth strata: 50-150m, 150-250m, and 250-500m. There was a total of 64 hauls conducted around the South Orkney Islands (Figure 9.1). The numbers of hauls within each of the three depth strata were 7, 24, and 33, respectively. Allocation of hauls within depth strata was initially based on the 1991 Spanish survey "ANTARTIDA 9101" (Balguerias, 1991), where the number of hauls taken within a strata was proportional to the known areas of seabed and previous estimates of abundance in each stratum from the 1989 Spanish survey "ANTARTIDA 8611" (Balguerias, 1989). The initial survey design called for 12 hauls within the 50-150m depth range. However, due to heavy ice concentrations and time restrictions, only seven hauls were conducted within this depth range. Although this survey was conducted with three levels of depth strata, the bounds of this stratification are heuristic, and fish captured are likely to follow species specific depth preferences. In many cases, species specific post stratification of yield prior to modelling biomass or other analysis may be justified.

The haul locations for the survey design were initially based on station coordinates from the 1991 Spanish survey "ANTARTIDA 9101" (Balguerias, 1991). However, the realized locations varied considerably from the initial planned coordinates due to sea, wind, bottom, and ice

conditions (Table 9.1). In all initially positioned stations within the 50-150m stratum, hauls were abandoned due to heavy sea ice or seabed and new stations were positioned within the stratum at other locations. In all cases, a haul was taken only after initial acoustic reconnaissance verified that bottom conditions were suitable for trawling.

All hauls were conducted during daylight hours. The target time for a trawl was 30 minutes. Any haul less than 20 minutes was considered invalid and was discarded. Trawling started as soon as the footrope made contact with the bottom. Once contact with the bottom was made, position, time, ship speed, bearing, headrope depth, bottom depth, and net mensuration were recorded (Table 9.1). Recordings were made every five minutes thereafter, for a total of seven observations for each haul. Supplementary data collected for each haul included ship course, air temperature, wind direction and speed, weather, cloud conditions, sea state, light, and ice conditions. All haul and cruise specific information is stored in hardcopy format and in a computer database maintained by the U.S. AMLR program.

Haul Processing.

After a successful haul, the contents of the trawl were emptied onto the deck and transferred to a sorting table. When catches were very large, a subsample of the catch was taken. Remaining fish were placed into fish baskets and the baskets counted. Once the catch was placed onto the sorting table, all fish were separated into species and placed into individual species baskets. Organisms other than fish (benthos and other by-catch) were removed and placed in separate baskets. Baskets were weighed to obtain total catch weights by species, with the by-catch sorted and weighed separately. In some cases, large yields of finfish that were subsampled were released live after counting and weighing.

From the sorted catch of each haul, length [nearest centimeter (cm) below], sex, and gonad maturity stage was collected from all specimens. Length types were collected as total length (length from tip of snout to end of caudal fin) for all species except myctophids, where length was measured as standard length (length from tip of snout to end of caudal peduncle). Maturity was classified on a scale of one to five (immature, maturing virgin or resting, developing, gravid, spent) according to the method of Kock and Kellermann (1991). For dominant species, a subsample of individual weights [grams (g)] was collected. Weights were measured as total fresh weight to nearest gram. In less frequently encountered species, lengths and weights were collected from all specimens. Gonad weights were recorded from a subsample of sexually mature/prespawning individuals for certain species. Catch processing included infrequent measurements of other individual characteristics, including eviscerated weight (weight after removal of intestines and gonads), gonad weight (weight of ovary or testis, to nearest 0.1g below), and oocyte size. Catch data were documented on hardcopy datasheets and entered into a computer database following each haul. The U.S. AMLR program maintains these hardcopies and computer databases.

Stomach contents and diet composition were analyzed for the channichthyid *Champsocephalus*

gunnari. Information collected from *C. gunnari* included length, weight, sex, maturity, eviscerated weight, gonad weight, whole stomach weight, stomach contents weight, stomach wall weight, filling degree, degree of digestion, and species present if identifiable.

Otoliths were collected from 2187 specimens of 32 species for age and growth studies. The best coverage by 1cm size class was obtained from *Gobionotothen gibberifrons*, where size classes between 11 - 42cm were completed for both sexes. Good coverage was also obtained for *Lepidonotothen squamifrons* (size classes 23-43cm complete), and *Chaenocephalus aceratus* (28-46cm complete). However, *Champsocephalus gunnari* could only be sampled sufficiently within the lengths from 39-48cm.

Rare or unusual specimens/biological materials were preserved in buffered formalin and packaged for transport to home laboratories. Preserved specimens included 99 fish of the genus *Pogonophryne*. Also, specimens collected more infrequently were oocytes, residual eggs of spent females, tissue samples for DNA analysis, and whole ovaries.

9.3 Results and Tentative Conclusions:

Catches.

A total of 16167.5 kilograms (kg) (38,356 individuals) of 42 different fish species were processed from all hauls from the South Orkney Islands (Table 9.2). Species that were caught in substantial numbers, defined as >500kg or >500 individuals, included *Gobionotothen gibberifrons, Lepidonotothen squamifrons, Chionodraco rastrospinosus, Chaenocephalus aceratus, Pseudochaenichthys georgianus, Electrona antarctica, Gymnoscopelus nicholsi, Champsocephalus gunnari, and Lepidonotothen larseni*. The greatest yields of fish in terms of both numbers and total weight were for the nototheniids *G. gibberifrons* (5062kg, 18,745 individuals), followed by *L. squamifrons* (5023kg, 6875 individuals).

Catches of fish by species are dependent on the depth strata at which the haul was taken and geographic location relative to the island chain (Table 9.2). Yields in Table 9.2 are sums, and can be somewhat misleading since the Orkney Island survey used an unequal allocation of hauls among strata. If average yield per haul is considered, the greatest yields in weight were found in the 150-250m depth strata; the lowest average yields in the 50-150m strata. Variability of catch was highest in the 250-500m strata and lowest in the 50-150m strata.

There was substantial variation in catches between stations. In general, highest yields were to the west and north of the island chain (Figure 9.2). This region is also generally more patchy than the southern or eastern sectors of the South Orkney Islands. The average yield for a single haul was 253kg (σ=483), and 599 individual fish (σ=664). The greatest yield in weight for a single haul was 2498kg (3617 individuals) at Station T1 west-northwest of the Inaccessible Islands. This haul was dominated in weight by *Lepidonotothen squamifrons* (63%) and *Gobionotothen gibberifrons* (22%). Other substantial yields were encountered southwest of the Inaccessible

Islands at Station T65 (2064kg, 2235 individuals), in which 99% were *Lepidonotothen squamifrons*, and north of Coronation Island at Station T11 (2001kg, 1797 individuals), 80% of which was comprised of *Pseudochaenichthys georgianus*.

Although there were a total of 42 different species encountered (with representatives within the genus *Pogonophryne* considered one species), the number of species present in each haul ranged from 6 to 16, with an average of 10 species per haul (Figure 9.3). Figure 9.3 demonstrates generally greater variability in species richness per haul in the near shore sectors and more stable and diverse species assembleges in the offshore regions to the south and east of the island chain. The most frequently encountered species was *C. rastrospinosus* which was found within catches at all 64 stations. Other species encountered frequently were *G. gibberifrons* (97%), *C. aceratus* (94%), *L. larseni* (89%), *C. gunnari* (69%), *L. squamifrons* (67%), *P. georgianus* (67%), and *T. eulepidotus* (67%). All other species occurred in less than 50% of hauls.

Species with Significant Yields.

Gobionotothen gibberifrons: This species was the most abundant in both weight and numbers and among the most encountered species in the South Orkney Island chain (5061kg, 18,745 individuals). Fish were encountered in all regions with concentrations in the western and northern sectors of the island chain. Catches throughout the rest of the island chain and offshore were relatively consistent. Figure 9.4A shows the abundance of fish standardized to a square nautical mile at each station location. Fish were captured at all depth strata sampled, with greatest average weight and numbers per haul in the 50-150m strata (Table 9.2). Stations with remarkably high catches included Station T9 (807.5kg, 1675 fish); Station T1 (561kg, 1317 fish); and Station T3 (508.6kg, 1600 fish). All other stations yielded less than 500kg. Most fish were maturity were stage 1 (62%), with 25% and 12% stage 3 and stage 2, respectively (n=18,550). There was only one stage 5 fish captured. Of all fish, 42% were females, 38% were males, and 20% possessed gonads that were too immature to distinguish sex. The mean size of the 18,550 measured fish was 28.8cm, with two distinctive modes in length frequency at 25cm and 33cm (Figure 9.5A).

Lepidonotothen squamifrons: This species was the second most abundant in terms of catch (5023.29kg, 6875 individuals), though it displayed the most patchy distribution. When standardized to one square nautical mile, this species demonstrated the highest localized densities. This was mainly the result of encountering dense spawning or pre-spawning aggregations during hauls in the western sectors of the island chain, particularly at Stations T1, T65, and T68 (Figure 9.4B). Regions in the south yielded relatively small and less variable catches. Fish were encountered only within the 150-250 and 250-500m depth strata, with the highest average yields per haul in the 250-500m strata. The average length was 35cm, with at least two distinctive length frequency modes at 32 and 39cm (Figure 9.5B). There were fish distributed across all stages of maturity. Most fish in this area (40%) were maturity stage 1, though there were with 30%, 20%, 0.2%, and 10% at stage 2, 3, 4, 5, respectively (n=5760).

This represents the highest proportion of spent females of any observed species collected. About 55% of these fish were females.

Chionodraco rastrospinosus: This was the third highest caught species (923.92kg, 3453 individuals), and the only species that was encountered at every station. There were relatively consistent yields across most stations, though most fish were captured in deeper waters in the 250-500m depth strata and offshore (Figure 9.4C). The average size was 31cm, with distinct modes at 23 and 30cm (Figure 9.5C). Most fish (77%) were maturity stage 1, with 12%, 11%, and 0.1% for stages 2, 3, and 5, respectively. Of these, about 44% were females.

Chaenocephalus aceratus: The specimens of *C. aceratus* captured (1454.16kg, 2592 individuals) were encountered at all depth strata, with the highest average concentrations per haul in the 50-150m strata and fewer catches offshore (Figure 9.4D). This fish displayed the highest range of lengths for any species, ranging from 15 to 70cm total length. The average size of all fish was 40cm, with at least three distinctive modes at 21, 36 and 57cm (Figure 9.5D). Most fish (57%) were maturity stage 1, with 28%, 15%, and 0.2% for stages 2, 3, and 5, respectively (n=2275). About 50% of these fish were females, 38% were males, and 12% were not sexed. The mean size of female fish was 44cm, significantly larger ($p<.001$, heteroscedastic t-test) than male fish (37cm).

Pseudochaenichthys georgianus: Of the 2583kg (1917 fish) captured throughout the survey, most (63%) were caught at Station T11 north of Coronation Island (Figure 9.4E). Large catches were also taken at other stations in the northern and eastern sectors, mostly as a result of encountering dense prespawning aggregations. As a result, the distribution of *P. georgianus* was the second most patchy (after *L. squamifrons*), based on the variability of catch on a haul by haul basis. Most offshore yields were relatively small. The highest average yields were encountered in the 150-250m strata. The average size was 47cm, with distinct length frequency modes occurring at 29, 40 and 48cm (Figure 9.5E). Most of these fish (78%) were maturity stage 3, with 10%, 12% and 0.1% stage 1, 2 and 5, respectively. Sexes were equally represented in the catch.

Champsocephalus gunnari: A surprisingly low number of *C. gunnari* were encountered in the South Orkney Islands (502kg, 761 individuals) relative to other species encountered. Most fish were found to the north and east of the island chain, with few caught offshore (Figure 9.4F). Most fish were captured in the 150-250m depth strata. Most fish (79%) were found at maturity stage 3, with 8%, and 13% observed at stages 1 and 2, respectively (n=812). About 44% of the *C. gunnari* catch were female. The average size was 42cm., with a strong mode at 43cm and a well defined mode at 23cm (Figure 9.5F). Preliminary estimates of biomass within the 500m isobath for this species suggest a very low population, substantially smaller than the most recent estimate in 1991 (Balguerias, 1991).

A total of 462 stomachs from *C. gunnari* were analyzed for diet composition. Of these stomachs, 17% were empty. Of the fish with full or partially full stomachs, 86% of stomach contents consisted solely of krill (*Euphausia superba*). Other contents included other species of *Euphausia*, amphipods, and myctophid fish.

Lepidonotothen larseni: Fish were encountered at all depths and regions across the islands, with highest average yields per haul in the 50-150m depth strata (Figure 9.4G). The average length was 17cm, with a strong mode at 18cm (Figure 9.5G). Most *L. larseni* were at maturity stage 3 (44%), with 27% and 30% at stages 1 and 2, respectively (n=730). About 64% of these were females, 27% males, and 8% were not positively sexed.

Notothenia rossii: A total of 273.3kg (152 individuals) of *N. rossi* were captured, mostly from Stations T1 (155kg) and T20 (73kg) in the eastern and western sectors, respectively (Figure 9.4H). Both of these stations were in the 250-500m strata. The average length was 47cm, with modes at 43 and 49cm (Figure 9.5H). Most fish captured were maturity stage 3 (52%), with 23%, 24%, and 1% stage 1, 2, and 4, respectively. These fish were 43% female and 57% male. There was no significant difference in length by sex.

Gymnoscopelus nicholsi: Almost all fish (99.7%) were encountered in deeper hauls (250-500m). Because this myctophid species is known to primarily occur in the mid-water pelagic zone, it is likely that yields were entrained in the net prior to or after the actual bottom trawling operation. Mean length was 14cm, with a corresponding mode at 14cm (Figure 9.5I). Only 123 fish were positively staged for maturity, of these 61% were stage 1, and 39% stage 2. A total of 175 fish were positively sexed. Of these, 57% were females and 43% were males.

Electrona antarctica: Like the other myctophid species captured in large numbers (*G. nicholsi*), *E. antarctica* was captured almost exclusively (99.5%) in deeper hauls (250-500m). Similarly, these fish were likely entrained in the net prior to or after the actual bottom trawling operation. Mean length was 9cm, with a corresponding mode at 9cm (Figure 9.5J). Only 30 fish were positively staged for maturity. Of these 23% were stage 1, 30% stage 2, and 37% stage 3. A total of 143 fish were successfully sexed: 86% were females and 14% males.

Cryodraco antarcticus: This channichythid was captured exclusively in the deeper hauls (250-500m strata), and most were immature. About 99% of fish were immature, stage 1. The average length of all fish was 27cm, with a strong mode at 26cm (Figure 9.5K). Of these, 44% were female, 36% were male, and 20% were not sexed.

Trematomus eulepidotus: A remarkable number of *T. eulepidotus* were captured (58.4kg, 214 individuals). *T. eulepidotus* is generally considered a high Antarctic species found mostly in the Weddell Sea. Most fish (77%) were captured in the 250-500m strata. The average length was 26cm, with two distinct modes at 19 and 26cm (Figure 9.5L). Sexes were equally represented, and females (μ=28 cm) were significantly larger than males (μ=25 cm). Most fish (66%) were maturity stage 3, with 31% and 3% stage 1 and 2, respectively.

Other Species.

Several other high Antarctic species, which are found mostly in the Weddell Sea and rarely in the S. Orkney Islands, were captured. Of these, most were within the genus *Trematomus*, including

Trematomus newnesi, *T. nicholai*, and *T. pinelli*. Other unusual or rare species encountered included *Magnisudis prionosa*, and *Bathydraco marri*. In addition, an unusually large number of fish (99) in the genus *Pogonophyne* were caught. Fish within this genus are extremely difficult to identify to species and have been preserved for further study. Several species of squid were also preserved for identification.

A species that was captured in considerably less abundance, yet are of particular importance and interest is the Antarctic toothfish, *Dissostichus mawsoni*. A total of only three *D. mawsoni* were captured; all fish were female maturity stage 1.

By-catch.

We considered all organisms other than finfish as by-catch. By-catch was weighed from all stations and composition was examined in more detail from 63 stations. By-catch, primarily benthic invertebrates, was sorted into 45 groups ranging in specificity from phylum to species (Table 9.3). Concentrations of benthic invertebrates were found mostly within the 250m isobath in the southern and eastern sectors of the S. Orkney islands. Over 6.3 metric tons of benthos of more than 75 spp. were been encountered, with sponge species dominating by weight, followed by holothuroideans. There was no significant relationship of by-catch weight per haul to yield of fish or fish species richness per haul (GLM analysis, $P<.99$).

Egg Diameter.

Egg diameter was determined in 124 specimens of 14 nototheniids and channichthyids. Egg diameter was measured in 30 fresh ooccytes per individual and species under a dissecting microscope at a magnification of seven. Results are presented in Table 9.4.

We estimated spawning time based on gonado-somatic indices and egg diameter. Spawning time in *C. gunnari* and *P. georgianus* is apparently 2-3 months later than at South Georgia and about 1 month later than at Elephant Island. Spawning in *N. rossii*, *C. rastrospinosus* and *C. aceratus* occurs about 1 month later. Spawning in *G. gibberifrons*, *L. larseni* , *L. squamifrons, N. coriiceps* and *T. eulepidotus* likely takes place at approximately the same time in all three areas. Spawning of *T. newnesi* appears to take place June-July. These results should be considered as tentative until the much larger material on gonado-somatic indices from the cruise have been analyzed.

The range of egg diameters measured (from limited material so far) appeared to be low in most species. This may suggest that spawning of most females in the stock appear over a limited time period of 4–6 weeks. Observations around Elephant Island by German researchers in May-June 1986 indicated that more than 80% of the population of *N. coriiceps* spawned within the four weeks between mid-May and mid-June.

Egg diameter at spawning was about 2.8-3.0 millimeters (mm) in *T. eulepidotus* both at Elephant Island and the South Orkney Islands. This appears to be remarkably different to *T. eulepidotus* from the Weddell Sea, where egg diameter in a batch of eggs collected from a bottom trawl haul assumed to be *T. eulepidotus* was 4.4mm. Surfaces compared in eggs from both areas were found to be remarkably similar in structure indicating that the batch of eggs collected in the Weddell Sea likely stem from *T. eulepidotus*. Further studies on the fecundity of *T. eulepidotus* will follow. Fecundity in the Weddell Sea is likely to be much less given the much larger size of eggs at spawning.

9.4 Problems and Suggestions: Due to an iceberg line positioned approximately at the 200m isobath, and extending the entire length of the western, southern, and eastern Orkney Islands, most planned shallow water stations had to be abandoned and repositioned in other sectors. Heavy concentrations of icebergs were also situated off Laurie Island, extending to the Saddle Islands in the northeastern South Orkney Islands. The search for alternate shallow seabeds (50-150m) required substantial time for bottom reconnaissance. These delays in trawling operations were unavoidable.

In future surveys of the South Orkney Islands, the existing survey design should be modified to accommodate an adjusted optimal allocation of hauls within a particular stratum. Allocation of hauls can now be optimized by weighting for updated estimates of biomass, using this survey as a source of prior information. In addition, areas of seabed should be used as a weighting factor now that these data have been refined.

A suggestion from the 1998 AMLR survey of the South Shetland Islands to take detailed photos of gender and gonad development by species was adopted during the 1999 South Orkney survey. These photos will be incorporated into a maturity staging field guide that can be used during future surveys to aid inexperienced researchers.

9.5 References:

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Table 9.1. Haul-specific information for the 1999 AMLR South Orkney Islands bottom trawl survey.

Station	Date	Starting Latitude	Starting Longitude	Ending Latitude	Ending Longitude	Distance Trawled (n.mi.)	Mean Fishing Depth (m)	Mean Horizontal Opening (m)	Mean Vertical Opening (m)	Haul Time (min)	Mean Tow-speed (knot)
T1	09-Mar-99	60°28.77S	47°04.42W	60°28.48S	47°01.89W	1.28	267	17.3	9.1	30	2.4
T3	23-Mar-99	60°25.80S	46°22.59W	60°25.72S	46°25.09W	1.24	143	18.9	9.6	30	2.5
T4	23-Mar-99	60°25.78S	46°25.88W	60°25.77S	46°28.56W	1.32	136	20.3	9.0	31	2.6
T9	23-Mar-99	60°25.51S	45°54.01W	60°24.99S	45°56.32W	1.25	203	21.4	10.2	29	2.6
T10	22-Mar-99	60°26.73S	45°37.73W	60°26.49S	45°40.07W	1.18	237	21.0	9.0	30	2.4
T11	22-Mar-99	60°30.59S	45°18.56W	60°30.18S	45°21.18W	1.35	232	20.3	10.2	30	2.4
T13	22-Mar-99	60°31.13S	45°14.43W	60°30.81S	45°16.62W	1.12	249	21.0	9.2	30	2.4
T14	23-Mar-99	60°25.40S	45°52.60W	60°25.23S	45°54.96W	1.20	224	20.2	10.0	30	2.3
T15	21-Mar-99	60°32.88S	44°41.83W	60°31.71S	44°42.64W	1.24	311	20.8	9.5	30	2.3
T16	18-Mar-99	60°51.82S	44°34.47W	60°51.80S	44°36.73W	1.10	181	19.7	9.7	29	2.4
T19	21-Mar-99	60°36.64S	44°17.56W	60°35.41S	44°17.92W	1.24	226	20.2	9.9	29	2.6
T20	20-Mar-99	60°45.61S	43°24.55W	60°45.44S	43°27.06W	1.24	316	19.7	9.2	29	2.6
T21	19-Mar-99	61°02.97S	42°55.84W	61°02.94S	42°58.14W	1.11	423	21.5	9.2	29	2.4
T22	20-Mar-99	60°59.04S	43°01.55W	60°58.97S	43°04.16W	1.27	389	20.0	9.3	31	2.4
T23	20-Mar-99	60°59.01S	43°19.97W	60°58.99S	43°22.26W	1.11	375	21.0	10.1	30	2.2
T24	19-Mar-99	61°02.97S	43°04.86W	61°03.02S	43°07.32W	1.19	415	21.3	9.7	28	2.6
T25	19-Mar-99	61°03.06S	43°15.62W	61°03.03S	43°18.03W	1.17	402	21.0	9.6	29	2.3
T26	19-Mar-99	61°03.02S	43°26.34W	61°03.06S	43°28.84W	1.21	364	19.6	10.5	31	2.3
T27	19-Mar-99	61°02.98S	43°38.14W	61°03.01S	43°40.85W	1.31	387	20.9	9.3	31	2.5
T28	20-Mar-99	60°44.57S	43°36.89W	60°44.38S	43°39.55W	1.31	271	20.8	8.8	31	2.4
T29	18-Mar-99	60°59.70S	44°36.22W	60°56.43S	44°38.47W	1.13	228	18.9	8.3	32	2.2
T30	18-Mar-99	60°55.78S	44°46.07W	60°55.54S	44°48.32W	1.12	240	20.5	9.4	28	2.6
T31	17-Mar-99	61°03.19S	44°42.08W	61°02.76S	44°44.27W	1.14	238	21.8	9.5	30	2.5
T32	17-Mar-99	61°05.17S	44°30.58W	61°04.76S	44°32.75W	1.13	258	20.5	9.8	30	2.2
T33	17-Mar-99	61°08.02S	44°13.93W	61°07.64S	44°16.21W	1.16	326	21.1	9.6	29	2.4
T34	17-Mar-99	61°11.07S	43°55.99W	61°10.73S	43°58.24W	1.14	416	20.1	9.5	31	2.3
T35	16-Mar-99	61°30.71S	45°06.42W	61°29.88S	45°08.26W	1.21	304	20.3	8.8	32	2.5
T36	16-Mar-99	61°30.97S	44°58.66W	61°31.04S	45°01.09W	1.16	315	20.2	8.0	30	2.5
T37	16-Mar-99	61°31.03S	44°38.97W	61°31.03S	44°41.46W	1.19	367	21.9	9.5	30	2.4
T38	16-Mar-99	61°30.09S	44°29.07W	61°30.61S	44°31.29W	1.18	374	20.4	9.8	28	2.4
T39	16-Mar-99	61°30.88S	44°21.07W	61°30.25S	44°23.28W	1.23	406	21.0	9.4	31	2.4
T40	17-Mar-99	61°01.46S	44°52.59W	61°01.01S	44°54.78W	1.15	252	19.8	9.0	29	2.4
T41	14-Mar-99	61°21.25S	45°37.41W	61°20.76S	45°39.72W	1.21	346	20.5	9.2	30	2.5
T42	15-Mar-99	61°40.90S	46°07.19W	61°40.70S	46°09.83W	1.27	318	21.2	8.5	31	2.5
T43	15-Mar-99	61°42.67S	45°44.06W	61°42.50S	45°46.67W	1.25	378	21.3	8.7	29	2.5
T44	15-Mar-99	61°43.50S	45°33.84W	61°43.32S	45°36.29W	1.17	367	21.1	9.3	28	2.5
T45	14-Mar-99	61°19.56S	46°14.99W	61°19.43S	46°17.57W	1.24	282	19.1	8.7	30	2.7
T46	14-Mar-99	61°21.64S	45°52.68W	61°21.65S	45°55.11W	1.16	357	20.8	9.0	29	2.2

Table 9.1 (cont.)

T47	18-Mar-99	60°51.81S	44°39.60W	60°52.20S	44°41.93W	1.20	205	20.3	9.4	31	2.3
T48	13-Mar-99	60°54.05S	45°20.28W	60°53.03S	45°22.30W	1.42	244	20.0	8.8	30	3.1
T50	13-Mar-99	60°52.74S	45°24.11W	60°51.92S	45°26.02W	1.24	222	20.4	9.5	30	2.3
T51	13-Mar-99	60°52.81S	45°39.49W	60°52.10S	45°41.43W	1.31	305	21.3	9.1	31	2.6
T54	13-Mar-99	60°55.29S	45°47.13W	60°55.33S	45°49.78W	1.29	216	21.5	9.0	30	2.6
T55	13-Mar-99	60°55.43S	45°57.75W	60°54.00S	45°58.30W	1.48	183	22.2	8.4	30	2.9
T56	12-Mar-99	60°46.05S	46°06.10W	60°46.48S	46°08.14W	1.09	178	20.1	9.1	29	2.4
T57	12-Mar-99	60°47.19S	46°17.13W	60°47.20S	46°20.09W	1.44	166	19.5	8.7	30	3.1
T58	12-Mar-99	60°58.76S	46°26.95W	60°57.48S	46°28.20W	1.42	234	19.8	8.9	30	2.9
T59	12-Mar-99	60°52.12S	46°35.54W	60°52.41S	46°38.52W	1.48	204	19.5	8.9	29	3.2
T60	12-Mar-99	60°43.93S	46°22.06W	60°42.93S	46°24.48W	1.55	134	18.6	9.4	30	3.0
T61	11-Mar-99	60°55.83S	46°50.09W	60°54.81S	46°51.58W	1.25	331	20.0	9.6	27	2.8
T62	11-Mar-99	60°46.98S	46°52.63W	60°45.67S	46°53.88W	1.49	230	19.8	8.6	30	3.2
T63	11-Mar-99	60°43.06S	46°33.97W	60°42.73S	46°36.42W	1.24	138	18.8	9.1	30	2.5
T64	10-Mar-99	60°39.78S	46°42.77W	60°38.98S	46°45.14W	1.41	149	18.9	8.6	28	2.9
T65	11-Mar-99	60°51.53S	47°02.44W	60°52.72S	47°01.01W	1.38	387	20.0	10.1	28	3.1
T66	11-Mar-99	60°46.91S	47°01.15W	60°48.36S	47°01.21W	1.45	277	21.3	8.7	34	2.5
T67	10-Mar-99	60°39.44S	47°04.40W	60°39.79S	47°01.85W	1.3	295	20.5	9.8	27	3.0
T68	10-Mar-99	60°36.67S	47°08.79W	60°37.86S	47°08.08W	1.24	366	19.8	8.8	30	2.6
T69	10-Mar-99	60°33.61S	46°59.96W	60°31.86S	47°00.24W	1.76	227	21.8	8.0	30	3.3
T70	24-Mar-99	60°31.84S	46°59.23W	60°32.90S	46°58.75W	1.09	213	20.3	10.4	29	2.2
T73	15-Mar-99	61°44.31S	45°23.73W	61°44.03S	45°26.75W	1.46	364	20.2	7.9	30	2.9
T74	24-Mar-99	60°42.85S	46°33.64W	60°42.44S	46°36.02W	1.23	135	18.8	10.1	30	2.6
T75	24-Mar-99	60°41.95S	46°29.91W	60°43.18S	46°29.99W	1.23	138	19.6	9.2	29	2.4
T76	25-Mar-99	60°47.99S	46°35.14W	60°48.02S	46°37.56W	1.18	183	20.4	8.6	31	2.4
T77	25-Mar-99	60°48.03S	46°22.68W	60°48.01S	46°25.21W	1.23	171	19.4	9.9	29	2.6

Table 9.2. Total numbers and weight (kg) of species caught within the 500m isobath of the South Orkney Islands.

Species	Number Caught by Stratum				Weight Caught by Stratum			
	50-150	150-250	250-500	Tot Num.	50-150	150-250	250-500	Tot. Wgt.
Artedidraco skottsbergi		1		1		0.01		0.01
Bathydraco marri			1	1			0.05	0.05
Bathyraja eatonii			2	2			6.74	6.74
Bathyraja maccaini	2	7	4	13	5.59	45.86	13.35	64.80
Bathyraja species		1	10	11		1.13	6.79	7.92
Chaenocephalus aceratus	656	1466	470	2592	353.83	896.46	203.87	1454.16
Chaenodraco wilsoni	2		1	3	0.43		0.15	0.58
Champsocephalus gunnari	151	491	119	761	76.92	341.39	84.11	502.42
Chionodraco rastrospinosus	33	157	3263	3453	23.43	85.57	814.92	923.92
Cryodraco antarcticus			373	373			27.89	27.89
Dissostichus mawsoni		2	1	3		1.00	0.90	1.90
Electrona antarctica		6	1315	1321		0.08	12.41	12.49
Electrona species			1	1			0.01	0.01
Gobionotothen gibberifrons	4417	8731	5597	18745	1084.10	2438.06	1539.41	5061.57
Gymnodraco acuticeps			11	11			1.23	1.23
Gymnoscopelus braueri			72	72			1.04	1.04
Gymnoscopelus nicholsi		2	783	785		0.05	28.44	28.49
Gymnoscopelus species			1	1			0.14	0.14
Krefftichthys anderssoni		2		2		0.01		0.01
Lepidonotothen larseni	124	370	265	759	6.71	15.55	10.89	33.15
Lepidonotothen nudifrons	8	10		18	0.28	0.42		0.70
Lepidonotothen squamifrons		126	6749	6875		65.45	4957.84	5023.29
Magnisudis prionosa			1	1			0.46	0.46
Muraenolepis microps		4	3	7		1.58	1.70	3.28
Neopagetopsis ionah		1	3	4		0.60	1.92	2.52
Notothenia coriiceps	18	12	2	32	25.20	16.64	2.51	44.35
Notothenia rossii	4	11	137	152	8.17	14.01	251.12	273.30
Pagothenia borchgrevinki		1		1		0.04		0.04
Parachaenichthys charcoti		2	1	3		0.30	0.12	0.42
Paradiplospinus gracilis			7	7			0.68	0.68
Pleuragramma antarcticum			12	12			1.19	1.19
Pogonophryne species	1	4	95	100	0.24	1.27	14.03	15.54
Pseudochaenichthys georgianus	24	1732	161	1917	26.65	2397.43	159.32	2583.40

Table 9.2 (cont.)

Racovitzia glacialis			1	1			0.03	0.03
Scopelosaurus hamiltoni			1	1			0.05	0.05
Trematomus bernacchii	3	15	2	20	1.90	3.92	0.53	6.35
Trematomus eulepidotus	4	45	165	214	0.70	9.05	48.68	58.42
Trematomus hansoni	1	11	39	51	1.27	4.16	16.42	21.85
Trematomus newnesi	14	8	2	24	1.54	0.63	0.33	2.50
Trematomus nicolai			1	1			0.05	0.05
Trematomus pennellii		1		1		0.19		0.19
Trematomus tokarevi			4	4			0.41	0.41
Total	**5462**	**13219**	**19675**	**38356**	**1616.96**	**6340.84**	**8209.71**	**16167.51**

Table 9.3 Summary of benthic invertebrates captured during trawling operations in the South Orkney Islands during the 1999 AMLR bottom trawl survey.

TAXON	Total Weight	Total Number	TAXON	Total Weight	Total Number
Acanthopyra pelagica (decapod)	0.13	31	Gastropoda: snail	0.32	13
Algae	6.78	19	Holothuroidean (sea cucumber)	1104.79	235
Anthozoa - Sea Whip	22.82	73	Hydromedusa-Calycopsis borchgrevinki	0.01	1
Anthozoa -anemone	138.66	299	Hydrozoa	7.18	409
Anthozoa--sea fan	1.23	29	Isopoda	0.06	9
Anthozoa-coral	1.75	41	Miscellaneous Organism Parts	124.32	
Asteroidean (sea star)	219.36	294	Ophiuroidean (brittle star)	0.55	150
Bivalvia	0.04	4	Polychaete	1.28	102
Brachiopod	0.26	35	Polyplacophora (chiton)	0.26	12
Bryozoan	3.90	8	Pycnogonid	0.69	130
Cephlopoda: octopus	74.766	101	Scyphozoa (pelagic jellies)	115.49	29
Cephlopoda: squid	2.55	12	Sipunculid worm	0.03	2
Cnidarian, various unidentified	0.96	10	Skate/shark egg case	0.07	7
Crinoidean	10.11	312	Sponge Hexactinellida	732.15	
Ctenophores (pelagic)	0.01	1	Sponge mixed	3604.17	
Echinoidean (sea urchin)	63.69	354	Tunicate	78.62	159
Gammarid amphipod	0.03	2	Unidentified Species	30.97	70
Gastropoda: Nudibranchia	4.24	92	Unidentified Worm	0.50	24

Table 9.4 Egg diameter (fresh), gonado-somatic index and estimated time of spawning in 14 species of Antarctic nototheniids and channichtyids at the South Orkney Islands

Species	Length range (cm)	Nos. invest.	Gonado-somatic index*	Egg diameter (mm)	Estimated Egg diameter at spawn. (mm)	Estimated Spawning time
G. gibberifrons	35 - 46	11	5.4 - 9.0	0.88 - 1.15	1.8 - 2.0	August-Sept.
L. larseni	17 - 20	5	5.1 - 9.4	0.76 - 1.10	1.8 - 2.2	August-Sept.
L. nudifrons	14 - 19	9	12.3 - 17.0	1.61 - 1.87	2.5	May-June
L. squamifrons	37 - 42	4	8.2	0.83	1.2 - 1.4	Feb. - April
N. coriiceps	39 - 48	4	7.9 - 13.1	1.77 - 2.13	4.4 - 4.7	May-June
N. rossii	51 - 65	10	11.3 - 14.0	2.31 - 2.98	4.8 - 5.2	May-June
T. bernacchii	37	1	8.6	1.23	4.4 - 4.6	October
T. eulepidotus	27 - 34	13	(10.6) 17.0 - 23.6	(1.66) 1.89 - 2.10	2.8 - 3.0**	April-May
T. hansoni	45	2	21.0 - 24.8	2.77 - 2.85	2.7 - 2.9	Feb. -March
T. newnesi	16 - 21	6	9.1 - 13.5	1.20 - 1.54	?	June - July
C. gunnari	40 - 52	10	5.5 - 9.5	1.71 - 2.29	3.5 - 3.8	July-August
C. aceratus	52 - 70	24	3.2 - 25.4	1.60 - 4.51	4.6 - 4.9	April-June
P. georgianus	45 - 51	10	5.4 - 10.6	1.92 - 2.98	4.4 - 4.9	June-July
C. rastrospinosus	32 - 48	15	16.9 - 23.7	3.82 - 4.53	4.7 - 5.0	April-May

* only from individuals collected for egg diameter measurements (we have more data from measurements of gonado-somatic indices)

** measured from a few residual eggs

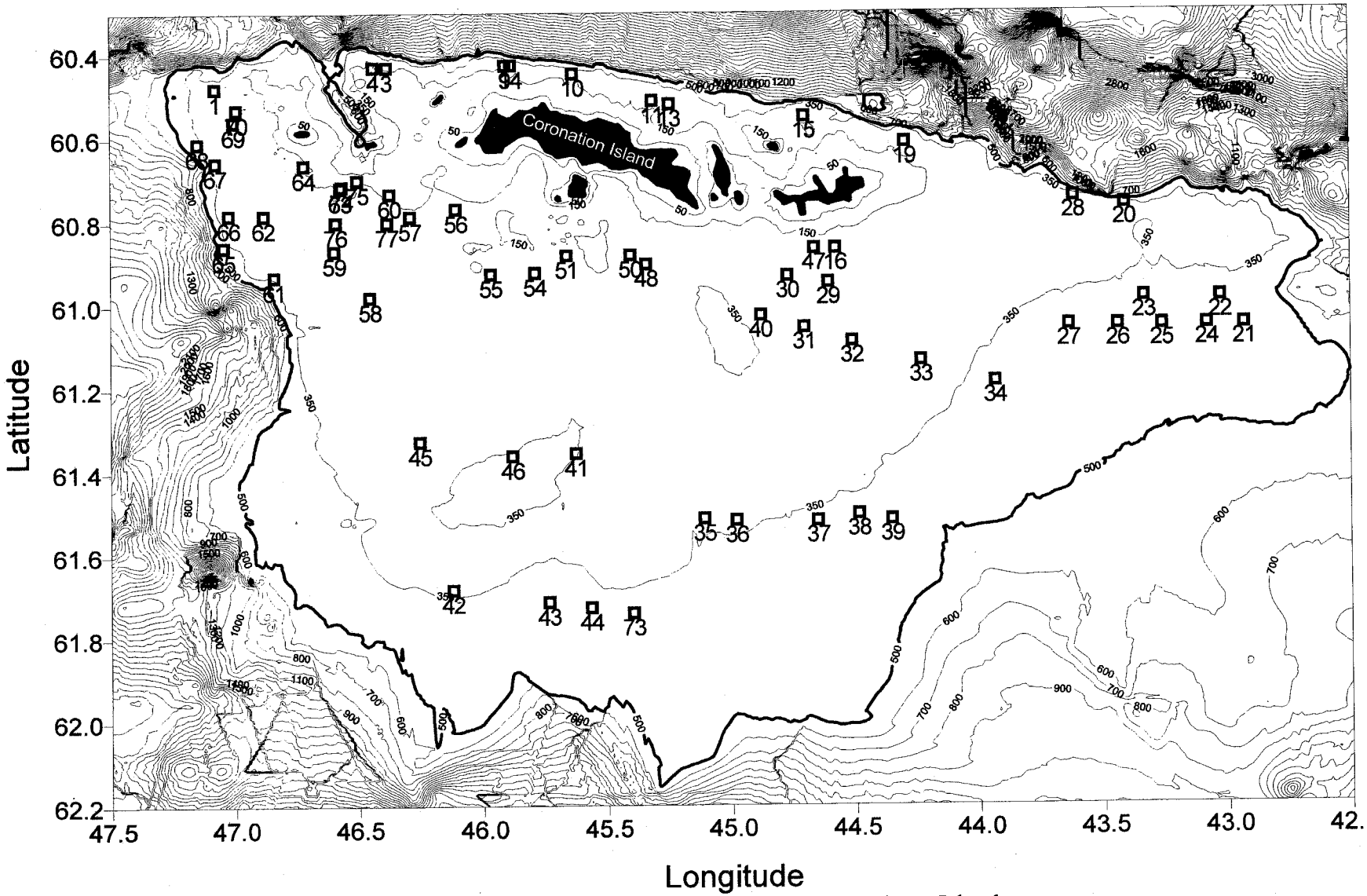

Figure 9.1 Station locations for the 1999 AMLR bottom trawl survey of the South Orkney Islands.

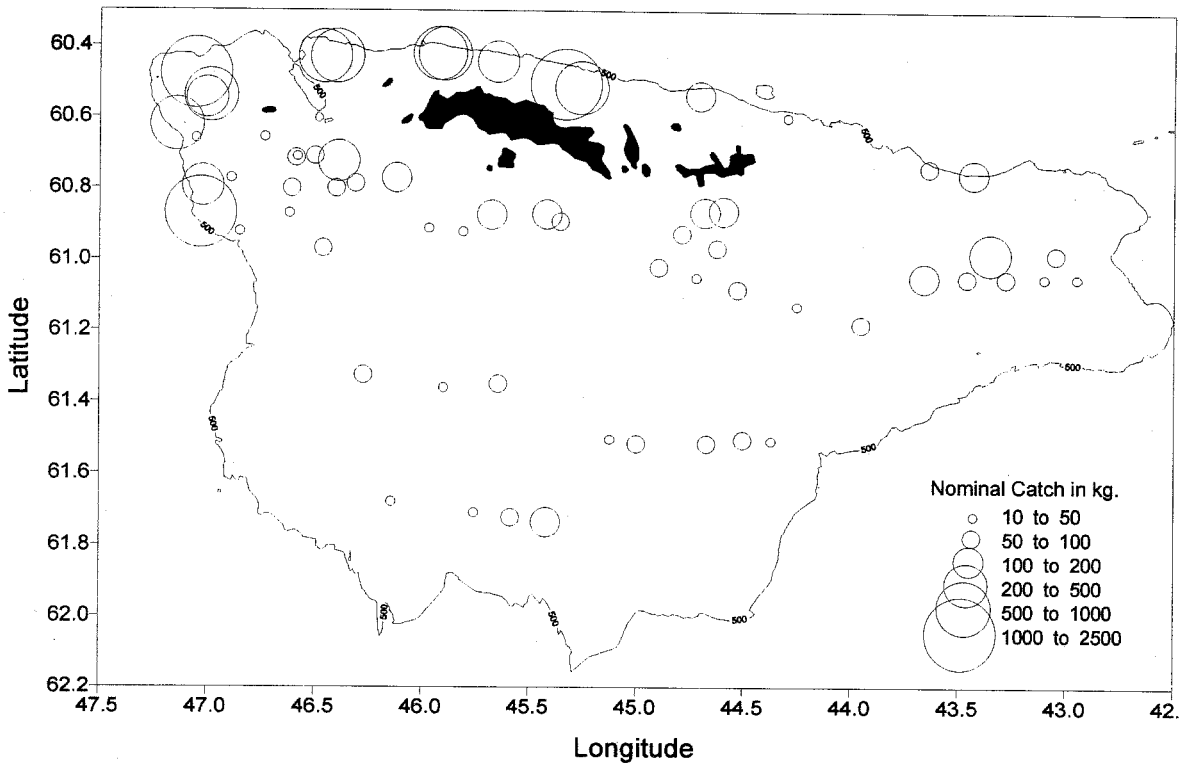

Figure 9.2 Map of nominal catches for all species combined from the 1999 AMLR survey of the South Orkney Islands.

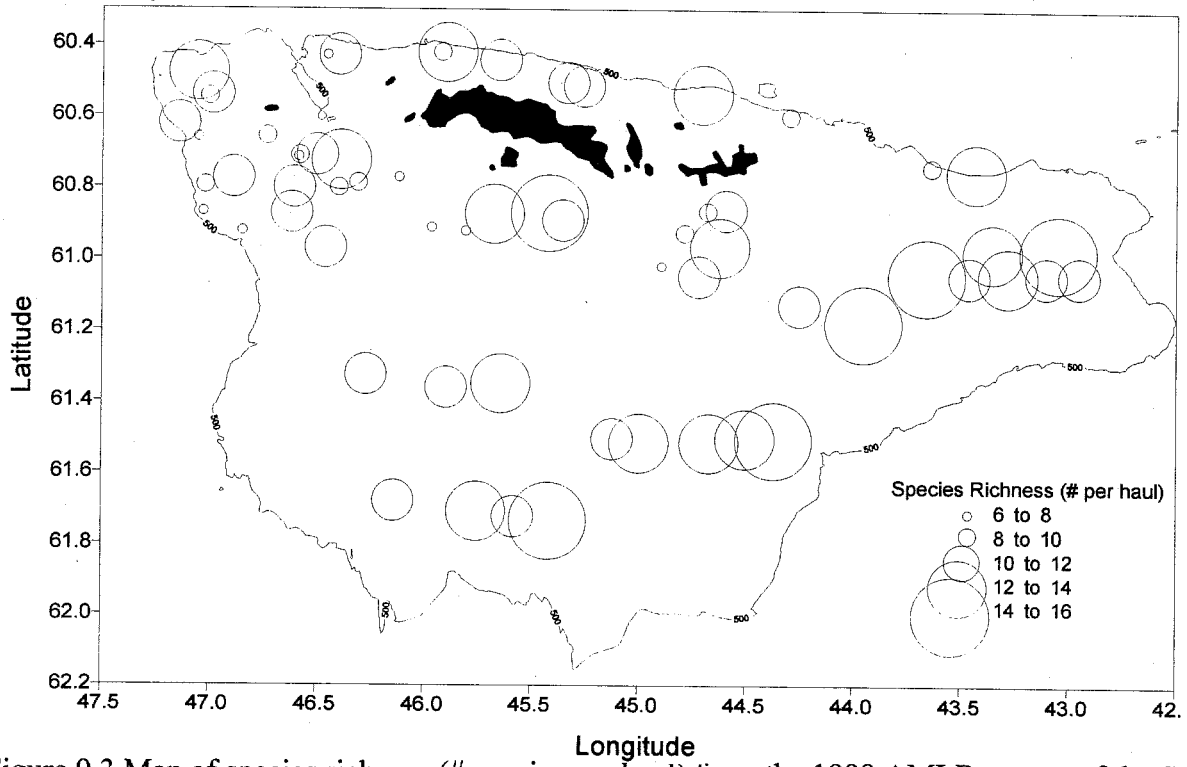

Figure 9.3 Map of species richness (# species per haul) from the 1999 AMLR survey of the South Orkney Islands.

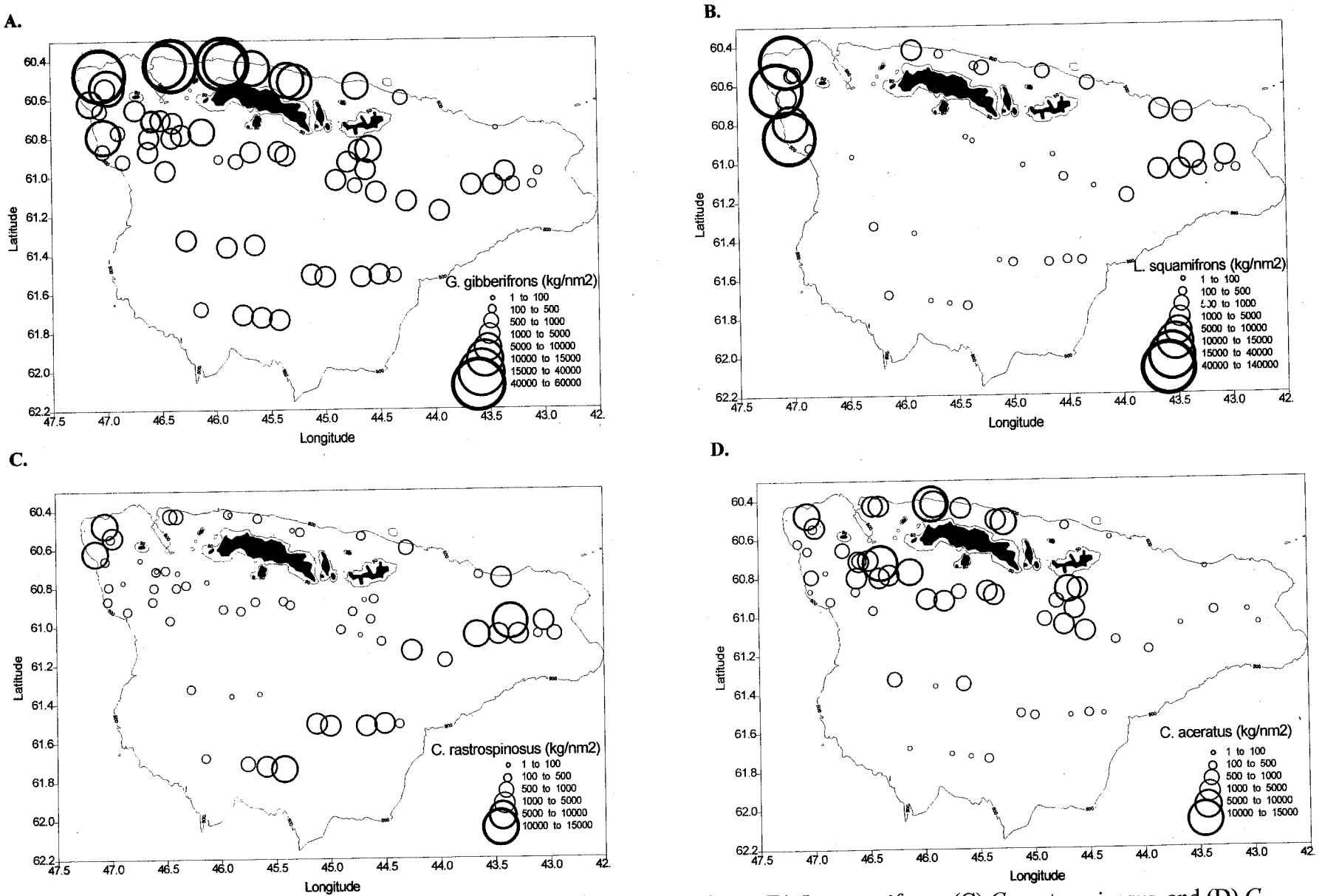

Figure 9.4 Map of catches (standardized to 1 n.mi.^{2}) for (A) *G. gibberifrons*, (B) *L. squamifrons*, (C) *C. rastrospinosus*, and (D) *C. aceratus* from the 1999 AMLR survey of the South Orkney Islands.

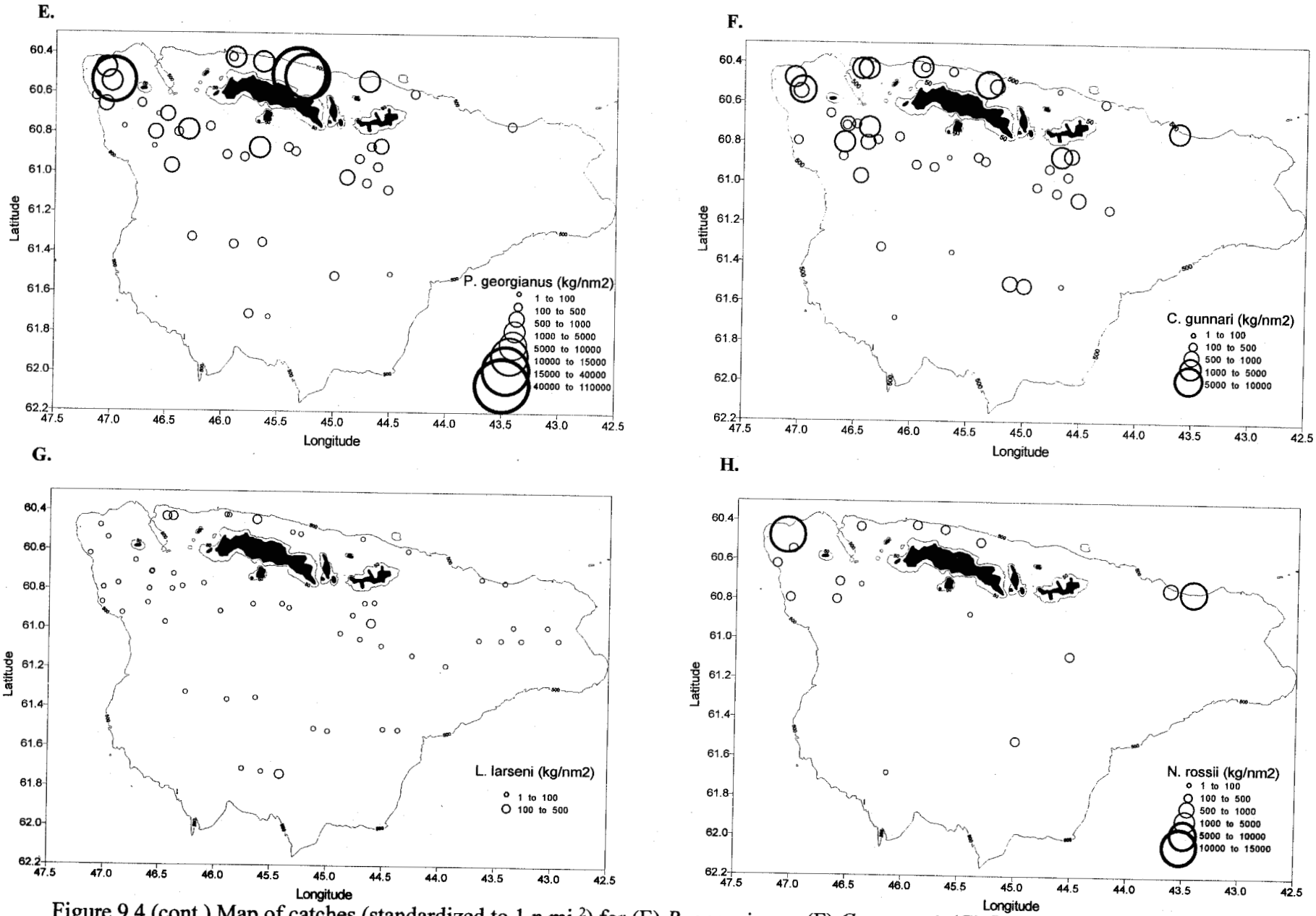

Figure 9.4 (cont.) Map of catches (standardized to 1 n.mi.^{2}) for (E) *P. georgianus*, (F) *C. gunnari*, (G) *L. larseni*, and (H) *N. rossii* from the 1999 AMLR survey of the South Orkney Islands.

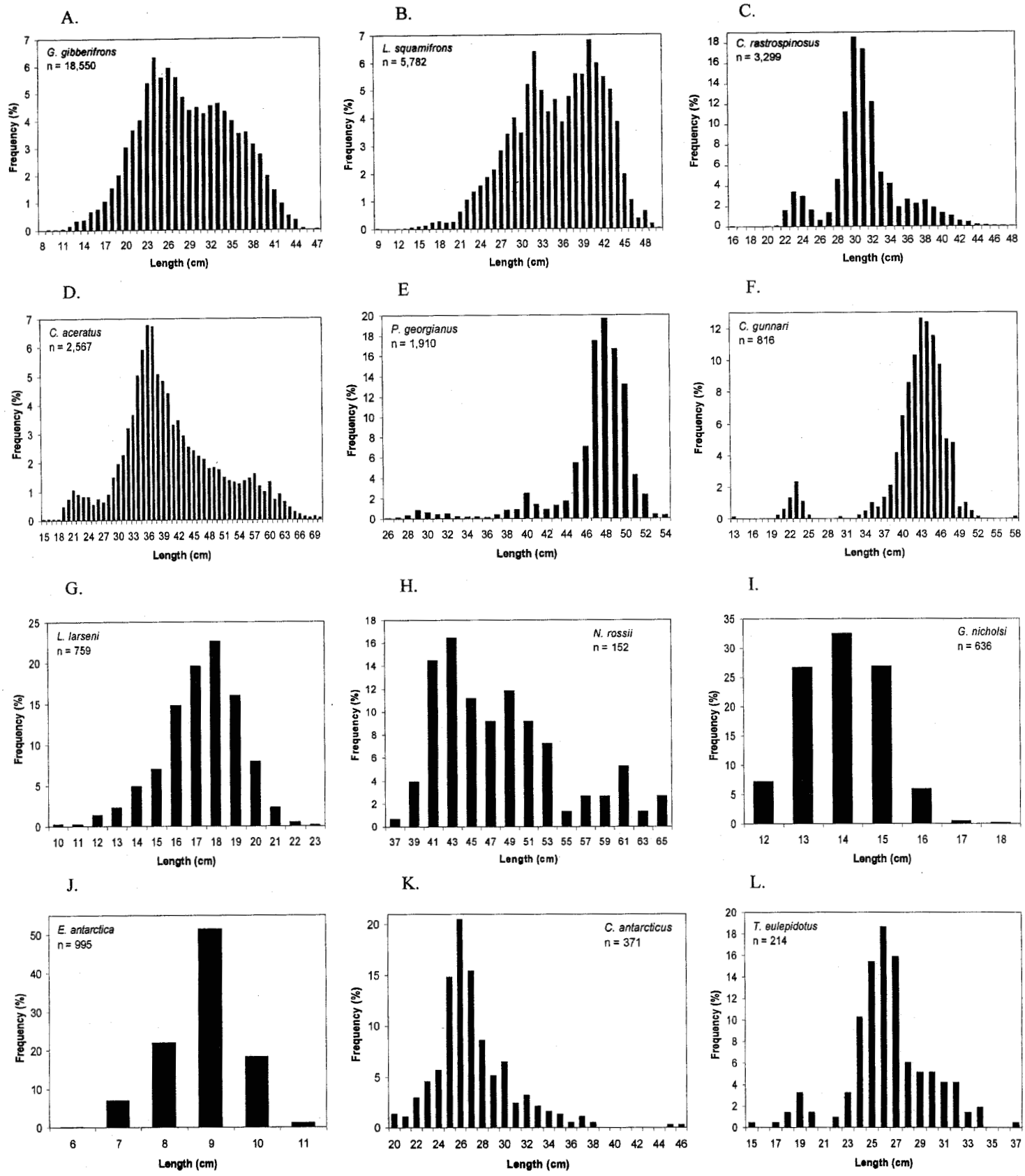

Figure 9.5 Length frequency distributions for species with significant yields. (A) *G. gibberifrons*, (B) *L. squamifrons*, (C) *C. rastrospinosus*, (D) *C. aceratus*, (E) *P. georgianus*, (F) *C. gunnari*, (G) *L. larseni*, (H) *N. rossii*, (I) *G. nicholsi*, (J) *E. antarctica*, (K) *C. antarcticus*, (L) *T. eulepidotus*.

10. Seabird research undertaken as part of the NMFS/AMLR ecosystem monitoring program at Palmer Station, 1998/99; submitted by William R. Fraser, Donna L. Patterson, Peter Duley and Matt Irinaga.

10.1 Objectives: Palmer Station is one of two sites on the Antarctic Peninsula where long-term monitoring of seabird populations is undertaken in support of U.S. participation in the CCAMLR Ecosystem Monitoring Program (CEMP). Our objectives during 1998/99, the twelfth season of field work at Palmer Station on Adélie penguins (*Pygoscelis adeliae*), were:

1. To determine Adélie penguin breeding population size,

2. To determine Adélie penguin breeding success,

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

4. To determine Adélie penguin chick weights at fledging,

5. To determine adult Adélie penguin foraging trip durations,

6. To band 500 Adélie penguin chicks for future demographic studies, and

7. To determine Adélie penguin breeding chronology.

10.2 Accomplishments: Field work at Palmer Station was initiated on 29 September 1998 and terminated on 6 April 1999. The early start date was aided by joint funding from the National Science Foundation's (NSF) Office of Polar Programs. In 1990, NSF selected Palmer Station as a Long Term Ecological Research (LTER) site, and has committed long-term funding and logistics support to an ecosystem study in which Adélie penguins represent one of two key upper trophic level predators selected for research. As a result of this cooperative effort between the National Marine Fisheries Service (NMFS) and NSF, field season duration at Palmer Station now covers the entire 5-month Adélie penguin breeding season.

Breeding Biology and Demography.

Adélie penguin breeding population size was determined by censusing the number of breeding pairs at 54 sample colonies. Due to heavy spring sea ice conditions, however, censuses had to be delayed past the peak egg-laying period, or until 10 December 1998. These colonies contained 3762 breeding pairs, representing a 14.7% decrease in the population relative to the 4412 pairs censused in November 1997.

Breeding success was determined by following a 100-nest sample on Humble Island from clutch initiation to crèche. Adélie penguin breeding success in 1998/99 decreased, with 1.49 chicks crèched per pair as opposed to 1.58 during 1997/98. As in past seasons, two other indices of

breeding success were also evaluated. The proportion of one and two chick broods was assessed at 54 sample colonies on 6 and 10 January 1999. Of the 2082 broods censused, 61.9% (n=1288) contained two chicks, no change from the 60.9% reported in January 1998. Chick production was determined by censusing chicks on 23 and 24 January 1999 at 54 sample colonies when approximately 2/3 had entered the crèche stage. Production at these colonies totaled 5469 chicks, a 4.4% decrease relative to the 5722 chicks reported from these colonies in 1998.

Chick fledging weights were obtained between 1 and 16 February 1999 at beaches near the Humble Island rookery. Peak fledging occurred on 10 February, three days earlier than in February 1998. Chick fledgling weights in 1999 averaged 3.01 kilograms as opposed to 3.05 kilograms in 1998. Data specific to the chronology of other breeding events are still under analysis and will be submitted at a later date.

As part of continued demographic studies, 500 Adélie penguin chicks were banded on 1 February 1999 at selected AMLR colonies on Humble Island. The presence of birds banded during previous seasons was also monitored throughout the entire field season on Humble Island as part of these studies.

Foraging Ecology.

Diet studies were initiated on 6 January and terminated on 16 February 1999. During each of the sampling periods, five adult Adélie penguins were captured and lavaged (stomach pumping using a water off-loading method) as they approached their colonies to feed chicks on Torgersen Island. All birds (N=50) were released unharmed. The resulting diet samples were processed at Palmer Station. The samples collected contained a mix of prey items, but the euphausiid *Euphausia superba* was the dominant component of the diet. The abundance of samples containing fish in 1999 was unchanged relative to 1998 (6% vs. 6%), and 9% of the diet samples contained *Thysanoesa macrura*, similar to the 1997/98 season. Amphipods were evident in 5% of the diet samples versus 12% during the 1997/98 season. Diet samples this season were mainly comprised of krill in the size classes 40-45 millimeters (mm), in general larger than the size frequencies observed in the 1997/98 diet samples.

Radio receivers and automatic data loggers were deployed at the Humble Island rookery between 5 January and 18 February 1999 to monitor presence-absence data on 35 breeding Adélie penguins carrying small radio transmitters. These transmitters were glued to adult penguins feeding 10-14 day old chicks. A preliminary analysis of the data obtained during the brood period suggests the mean foraging trip duration was 14.54 ± 4.46 h.

10.3 Tentative Conclusions: The 1998/99 season was characterized by heavy spring sea ice conditions but much lighter winter sea ice conditions than were present during the 1997/98 season. The nearly 15% decrease in the number of Adélie penguin breeding pairs agrees with the effects that a light ice year is expected to have on the overwinter survival of this species (Fraser

et al. 1992). That other measures of reproductive performance showed no significant departures between 1998 and 1999 may suggest that foraging conditions between seasons were comparable.

As in past seasons, the predominant component in the diets of Adélie penguins was *E. superba*. Other components of the diet were for all practical purposes inconsequential in the diets of this species during 1998/99. That krill size classes represented primarily include individuals in the 40-45mm size class agrees with expectations (cf. Fraser and Trivelpiece 1995a, b) given that the last strong krill year class occurred in 1994.

10.4 Disposition of the Data: No diet samples were returned to the U.S. for analysis because all work was completed at Palmer Station. All other data relevant to this season's research are currently in our possession and will be made available to the Antarctic Ecosystem Research Group.

10.5 Problems, Suggestions and Recommendations: Both population trend data and breeding success continue to suggest that environmental variables such as snow deposition, among others, may be key determinants of at least some aspects of the annual variability inherent in some of the monitored parameters (Fraser and Trivelpiece 1996, Fraser and Patterson 1997, Kaiser 1997). However, at the moment, there is no formal requirement in effect by which to standardize the collection and reporting of these data. Where these effects are becoming especially clear, is in the information conveyed by measures of reproductive success based on per-pair productivity. For example, the former can vary by up to 100% within the same colony based strictly on nest location, meaning this parameter is probably not "measuring" variability in the marine foraging environment as we assume. It is our opinion that the development of standards to measure snow deposition would greatly aid our interpretive potential within and between CEMP monitoring sites.

It is also important to note that during 1998/99 we only banded 500 Adélie penguin chicks as opposed to 1000 in past seasons. It is now clear that some colonies on the Humble Island rookery can no longer sustain a banding effort comparable to past years. This has resulted primarily from a continued decrease in the number of breeding pairs at these colonies and the concomitant reduction in the number of chicks being produced. What is causing this rapid decrease in Adélie penguins on Humble Island is open to debate, but certainly it would appear prudent to begin evaluating some of the CEMP protocols themselves, and particularly the possible effects that flipper banding may be having on demography (Fraser and Trivelpiece 1994, Culik et al. 1993, Froget et al. In Press).

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