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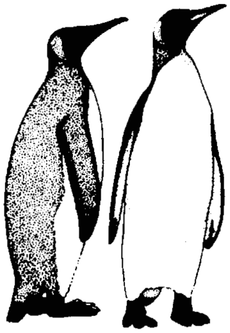

UNITED STATES AMLR ANTARCTIC MARINE LIVING RESOURCES PROGRAM

AMLR 1997/98 FIELD SEASON REPORT

Objectives, Accomplishments and Tentative Conclusions

Edited by
Jane Martin

October 1998

ADMINISTRATIVE REPORT LJ-98-07

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.

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BACKGROUND

The long-term objective of the U.S. AMLR field research program is to describe the functional relationships between krill, their predators, and key environmental variables. The field program is based on two working hypotheses: (1) krill predators respond to changes in the availability of their food source; and (2) the distribution of krill is affected by both physical and biological aspects of their habitat. To refine these hypotheses a study area was designated in the vicinity of Elephant, Clarence, and King George Islands, and a field camp was established at Seal Island, a small island off the northwest coast of Elephant Island. For eight consecutive austral summers, shipboard studies were conducted in the study area to describe variations within and between seasons in the distributions of nekton, zooplankton, phytoplankton, and water zones. Complementary reproductive and foraging studies on breeding pinnipeds and seabirds were also accomplished at Seal Island.

Beginning in the 1996/97 season, the AMLR study area was expanded to include a larger area around the South Shetland Islands, and a new field camp was established at Cape Shirreff, Livingston Island (Figure 1). Research at Seal Island was discontinued due to landslide hazards. The 1997/98 season continued with descriptive surveys of the pelagic ecosystem in the expanded AMLR study area, and studies on the reproductive success and feeding ecology of pinnipeds and seabirds at Cape Shirreff. In addition, a bottom trawl survey was conducted during Leg III to describe the abundance and distribution of bottom fish in the South Shetland Islands area. As in the past, research on the ecology of Adelie penguins was conducted at Palmer Station on Anvers Island during the austral spring and summer.

SUMMARY OF 1998 RESULTS

Shipboard surveys were conducted on three legs in the AMLR study area between early January and early April 1998. A large-area survey was conducted on Leg I and again on Leg II, while Leg III was dedicated to a bottom trawl survey. Two major water zones were observed during the surveys on Legs I and II: "Drake Passage water" dominated the area north of Livingston Island, which included new AMLR stations; "Bransfield Strait water" and transitional waters were identified on the South Shetland continental slope and shelf. A prevailing southwest to northeast flow was observed across the expanded AMLR study area, with an eddy-like feature northwest of Elephant Island. The flow was most intense northwest of Elephant Island during Leg I, but lost intensity during Leg II. Phytoplankton biomass at 5 meters depth, as indicated by chlorophyll-a concentrations, was low throughout the large-area survey grid on both legs; these low chlorophyll-a values are comparable to similarly low values recorded in 1992 and 1993, and are in contrast to data from all other years since sampling began in 1990.

Leg I's bioacoustic studies revealed high concentrations of krill along and immediately downstream of a bathymetric shoal northwest of Elephant Island. Other high density areas were found near the shelf-break north of Livingston Island, at the northeast end of King George Island, and south of Nelson's Passage in Bransfield Strait. On Leg II, the krill biomass estimate in the Elephant Island area was lower than that of Leg I by 43%. Highest krill densities were found in the northeast corner of the survey grid, surrounding Gibbs Island to the southwest of Elephant Island, in the southeast corner of the station grouping south of King George Island, and again along the shelf-break to the north of the archipelago. Krill density estimates have been derived in the Elephant Island area for the austral summers of 1992-1998, excluding 1993. This time series suggests a 6-year periodicity in the krill density circa Elephant Island and indicates rapid declines in the population (intra-1992 and 1998) compared to the more gradual increases (1994-1997); data from additional years will be required to corroborate the consistency of this cycle. The krill population reached a 7-year low in 1994 and a 7-year high in 1997.

The 1998 Isaacs-Kidd Midwater Trawl (IKMT) tows were dominated by sexually mature krill ≥40 millimeter (mm), which were 3 year old krill from the highly successful 1994/95 year class. Lower proportions of smaller, immature krill reflect comparatively poor recruitment success from subsequent years. The averaged contribution of juvenile krill in the Elephant Island area was only 11%, indicating low recruitment of the 1996/97 year class. This had been predicted, given potential competition due to elevated salp abundance and delayed krill spawning observed during the 1997 summer surveys. Unusually small juvenile krill collected during both 1998 surveys suggested that survival success was limited to late-spawned eggs and larvae in 1997. The prolonged summer season and formation of extensive sea ice cover in late winter could have provided enough development time and food resources for these late spawned larvae. Extremely small proportions of advanced female maturity stages during January-February 1998 do not bode well for recruitment success of the 1997/98 year class. Delayed spawning and low numbers of larval krill in 1998 were again associated with high salp abundance during both surveys; salp levels were similar to those observed during the 1993 "salp year."

The presence of large numbers of the high latitude salp species *Ihlea racovitzai* on both legs was unique to AMLR surveys and indicated faunal input from the northeast, possibly through deflection of the Weddell and/or East Wind drift. Presence/absence of this species delineated a strong frontal zone extending across the area during Leg II. This distribution pattern was shared by a group of zooplankton taxa with maximum abundance south of the front, while taxa of another group were generally more abundant to the north. Relatively homogenous distributions of krill and *S. thompsoni* length clusters and of zooplankton taxonomic clusters during Leg II compared to Leg I, suggested that a more homogeneous and/or stabilized advective regime was established later in the summer.

Comparisons of 1998 survey data with data from previous AMLR seasons yielded interesting information on interannual variations in zooplankton species abundance relationships. Recurring patterns allowed the definition of three ecological regimes: "copepod years," "salp years," and intermediate "transition periods." Since 1983 the 4-5 year periodicity of "salp years" in the study area coincided with that of the Antarctic Circumpolar Wave (ACW). It is possible that shifts between copepod and salp dominance, as well as winter sea ice development and krill recruitment success, are associated with changes in advective regimes propagated by the ACW. It appears that the transition period between these two ecological regimes is established within a brief time span (e.g., between January-February and February-March survey efforts in 1994 and 1997).

This was the first full season of seabird research at Cape Shirreff and thus comparisons with prior years are not possible. However, based on mean breeding success from Admiralty Bay, approximately 140 kilometers (km) northeast on King George Island, the chinstrap penguin population had average and the gentoo penguin population above average breeding success. Both chinstrap and gentoo penguins ate primarily krill 31-45mm in length, and fish were noted in about one-third of all chinstrap and nearly all gentoo penguin samples. Chinstrap foraging trip durations were bimodal with 8-10 hour trips alternating with 20-24 hour trips.

Pinniped studies at Cape Shirreff revealed that the total number of Antarctic fur seal pups born at the Cape and San Telmo Islands during the 1997/98 breeding season was 7,748, which is a 14.1% decrease in pup production from the 1996/97 count of 9,015. Studies on female fur seal attendance behavior revealed mean trip duration for the first six trips to sea ranged from 3.82 to 4.66 days, and mean visit duration ranged from 1.22 to 1.80 days. A total of 53 scat and enema samples were collected from fur seals for diet studies; 42 of these samples contained identifiable hard parts (fish bone, krill chitin, or squid beaks). Scats and enemas containing fish comprised 61.9%, krill 57.2%, and squid 14.3%. As an indicator of diet, 68 milk samples were collected from fur seals for fatty-acid signature analysis. Foraging trip length of lactating female fur seals averaged 4.6 days. The mean distance traveled was 98km (s.d.=24.9). Two fur seals tagged at other sites were observed this season at Cape Shirreff; both were females tagged at Seal Island.

A total of 10551.1 kilograms (kg) (34867 individuals) of 45 different fish species were caught and processed from 74 hauls collected during Leg III's bottom trawl survey. There were 7420.148kg (24917 individuals) of 35 species from the Elephant Island area, and 3130.943kg (9950 individuals) of 40 species from the lower South Shetland Islands. Species that were caught in substantial numbers included *Gobionotothen gibberifrons*, *Champsocephalus gunnari*, *Notothenia coriiceps*, *Chaenocephalus aceratus*, *Chionodraco rastrospinosus*, *Lepidonotothen squamifrons*, *Gymnoscopelus nicholsi*, *Lepidonotothen larseni*, *Lepidonotothen nudifrons*, and *Electrona antarctica*. The greatest catches of fish in both areas combined in terms of total weight was *G. gibberifrons* (5777kg), although yields of *N. coriiceps* (1250kg) were greater than *G. gibberifrons* (755kg) in the lower South Shetland Islands. In terms of total numbers for combined regions, *C. gunneri* was the most abundant fish, with a total of 16,686 individuals captured. However, for the lower South Shetland Island region, the most abundant fish in numbers was the myctophid *G. nicholsi* (3124) followed by *G. gibberifrons* (2288).

At Palmer Station, there were 4412 breeding pairs of Adelie penguins at 54 sample colonies during the peak egg-laying period (24-29 November 1997), which was essentially unchanged from the number of breeding pairs (4445) censused in November 1996. Adelie penguins exhibited a slightly increased breeding success in the 1997/98 season, creching 1.58 chicks per pair, or 0.11 chicks more than were creched per pair in the 1996/97 season. Of the 2359 broods censused in January 1998, 60.9% contained two chicks, a slight decrease from the 68.1% reported in January 1997. Chick production totaled 5722 chicks, a decrease of 7.3% from the 1996/97 season in which 6142 chicks were censused. Compared to February 1997, the average fledgling weight of 358 Adelie chicks sampled in February 1998 was unchanged (3.05 vs. 3.04kg). Diet studies revealed a mix of prey items, with krill as the dominant component. The krill in the diet samples were mainly comprised of size classes 36-40mm and 41-45mm.

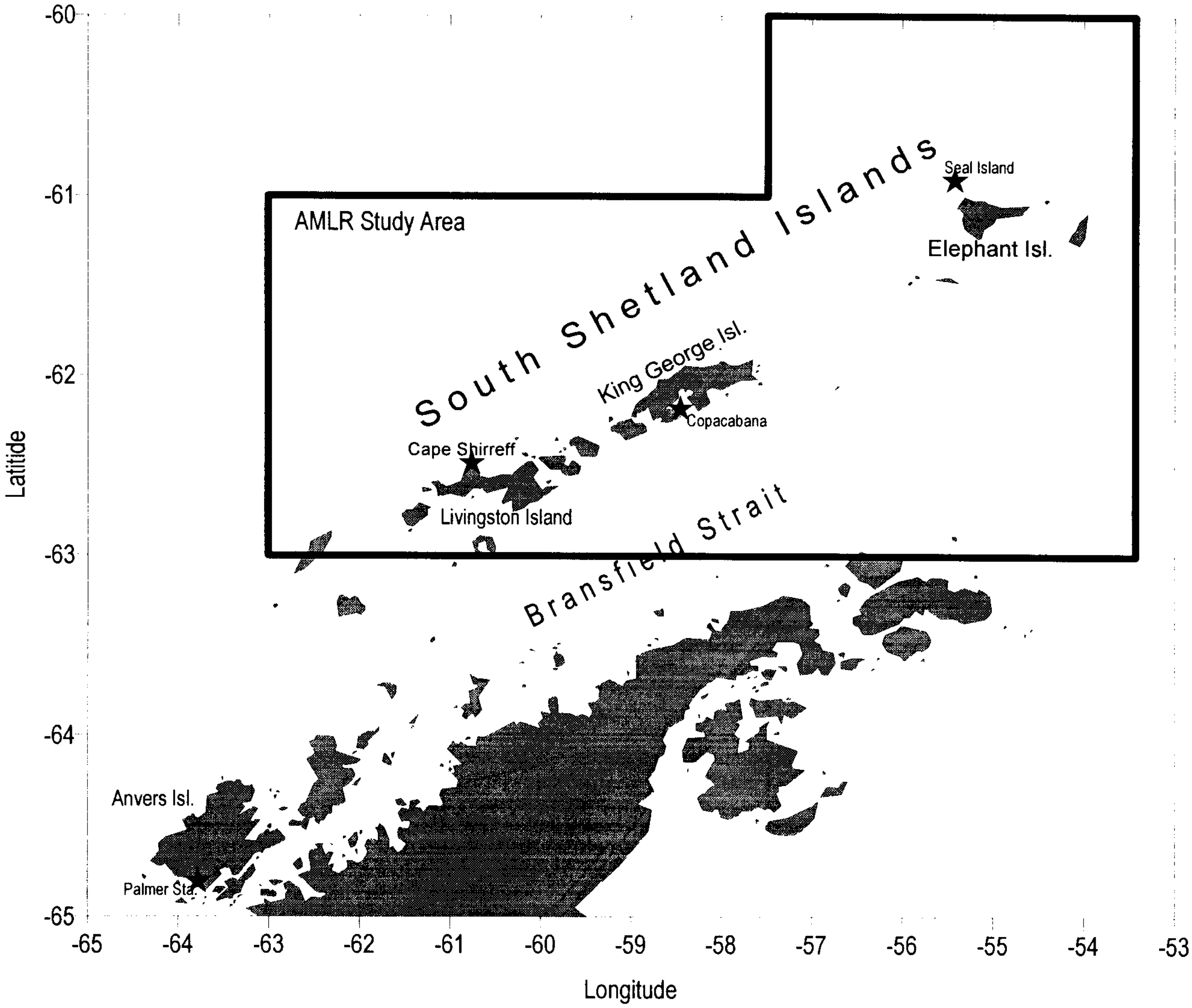


Figure 1. Locations of the U.S. AMLR field research program: AMLR study area, Cape Shirreff, Seal Island, and Palmer Station.

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. Conduct acoustic and net sampling surveys in Admiralty Bay, King George Island to describe krill demographic characteristics.
4. Conduct transects across the front between Elephant and King George Islands to describe water mass structure and collect acoustic data.
5. Conduct directed sampling to identify the composition of acoustic images of zooplankton layers and swarms.
6. Calibrate acoustic system at the beginning of Leg I and again after the large-area survey on Leg II.
7. 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.
8. Provide logistical support to three land-based field sites: Copacabana field camp (Admiralty Bay, King George Island); Cape Shirreff (Livingston Island); and Seal Island.
9. Conduct bottom trawls at selected sites in the area around the South Shetland Islands to provide baseline estimates of abundance, species size and composition, and demographic structure of fish species.

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. Conduct a weekly census of all pinniped species hauling out at Cape Shirreff.
9. Document Antarctic fur seal pup production for Cape Shirreff and the San Telmo Islands.
10. Monitor female Antarctic fur seal attendance behavior.
11. Assist Chilean researchers in collecting Antarctic fur seal pup length, girth, and mass for 100 pups every two weeks through the season.

12. Collect 20 Antarctic fur seal scat samples every two weeks for diet studies.
13. Collect a milk sample at each female Antarctic fur seal capture for fatty acid signature analysis and diet studies.
14. Measure at-sea foraging locations for female Antarctic fur seals using ARGOS satellite-linked transmitters.
15. Deploy time-depth recorders on female Antarctic fur seals for diving studies.
16. Measure at-sea metabolic rates and foraging energetics of lactating Antarctic fur seals using doubly labeled water.
17. Measure milk intake and energetics for 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 Antarctic fur seals and pups.
20. Deploy a weather station for continuous recording of wind speed, wind direction, ambient temperature, humidity, and barometric pressure.

Palmer Station

1. Determine Adelie penguin breeding population size.
2. Determine Adelie penguin breeding success.
3. Obtain information on Adelie penguin diet composition and meal size.
4. Determine Adelie penguin chick weights at fledging.
5. Determine adult Adelie penguin foraging trip durations.
6. Band 1000 Adelie penguin chicks for future demographic studies.
7. Determine Adelie penguin breeding chronology.

DESCRIPTION OF OPERATIONS

Shipboard Research:

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

Itinerary

Leg I:	Depart Punta Arenas	01 January 1998
	Deliver/Pick-up Equipment at Seal Island	04 January
	Drop off Personnel/Supplies at Cape Shirreff	05-06 January
	Supplies to Copacabana/Transducer Calibration	07-08 January
	Net Stations AB1, AB2, AB3, and AB4	08 January
	Large-area Survey (Survey A)	08-25 January
	Cross-front CTDs and Directed Sampling	26-27 January
	Transfer personnel, Cape Shirreff to Seal Island	28 January
	Arrive Punta Arenas	31 January
Leg II:	Depart Punta Arenas	03 February
	Transfer Personnel, Seal Island to Cape Shirreff	06-07 February
	Large-area Survey (Survey D)	08-25 February
	FishMASS, Neptun & MOCNESS Deployments/CTDs	26-28 February
	Close Cape Shirreff/Transducer Calibration	28 February
	Close Copacabana	01-02 March
	Cross-front CTDs	02-03 March
	Arrive Punta Arenas	05 March
Leg III:	Depart Punta Arenas	09 March
	Bottom Trawls/Neptun Deployment/CTDs	12 March - 01 April
	Arrive Punta Arenas	07 April

Leg I.

1. The R/V *Yuzhmorgeologiya* departed Punta Arenas, Chile via the eastern end of the Strait of Magellan. Landfall was made at Seal Island, and building materials from the closed field camp were retrograded. Provisions were put ashore for use later in the season; antennas were erected and radio communications were established.

2. Personnel and provisions were delivered to Cape Shirreff, and excess building materials were retrograded. A Chilean scientist was transported from Cape Shirreff to Frei Base on Maxwell Bay, King George Island.

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

4. Acoustic data and four net samples (Stations AB1, AB2, AB3, AB4) were collected in Admiralty Bay to describe krill demographic characteristics (Figure 2).

5. A large-area survey of 105 Conductivity-Temperature-Depth (CTD)/carousel and net sampling stations, separated by acoustic transects, was conducted in the vicinity of Elephant, Clarence, King George Island, and Livingston Islands (Survey A, Figure 3). 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." Two of the planned stations (A059 and A061) were canceled due to heavy weather and ice. 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 (PAR), 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.

6. A series of closely-spaced CTDs (Stations X002-X009) were conducted across the front between Elephant and King George Islands to describe water mass structure. Acoustic data were collected during the transits between the CTD stations. In addition, directed sampling experiments were accomplished using an IKMT net outfitted with a coarse mesh net (Stations X010-X013) and also a Multiple-Opening-Closing-Net-Environmental-Sampling-System (MOCNESS) (Stations X014-X015) (Figure 4).

7. Field team personnel were retrieved from Cape Shirreff, and several boat loads of trash were retrograded. Personnel were then transferred from Cape Shirreff to Seal Island.

8. Thirty-one 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 retrograded material were recovered. The ship then transited to Cape Shirreff to deliver personnel, equipment, and provisions to the field camp.

2. A large-area survey, similar to Survey A, was conducted in the vicinity of Elephant, Clarence, King George Island, and Livingston Islands (Survey D, Figure 3).

3. An experimental acoustic system (FishMASS) was opportunistically deployed at stations north of King George and Livingston Islands (Stations X10, X11, and X19). FishMASS is a prototype self-contained, broadband, split-beam system under development by RD Instruments, San Diego, California. The data will be analyzed for the purpose of advancing methods for *in-situ* target strength measurements and taxa delineation. An underwater camera system (Neptun) was also deployed several times to provide direct observations of acoustic targets and the benthic environment. MOCNESS tows were also accomplished in the area to identify major constituents of each class of acoustic image. See Figure 5 for these operations.

4. A cross-front transect of CTDs was conducted north of Livingston Island (Stations X13-X17) (Figure 5). The field camp at Cape Shirreff was then closed for the season, and the field team was embarked onto the ship. While at anchor at Cape Shirreff, the acoustic transducers were calibrated again using similar techniques as on Leg I.

5. The ship transited to Admiralty Bay to close the Copacabana field camp and take aboard personnel, garbage, and equipment. Another cross-front transect of CTDs was conducted between King George and Elephant Islands (Stations X23-X27) (Figure 5).

6. Similar to Leg I, thirty 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 first trawl station on the west shelf of Elephant Island.

2. A total of 75 bottom trawls were conducted at selected stations on the shelf surrounding the South Shetland Islands; 74 of these trawls were successfully retrieved. The trawl gear consisted of a two-warp bottom trawl and a third-wire linked net sonde.

3. Other scientific operations included continuous acoustic data collection, 29 days of continuous underway measurements of meteorological and sea surface conditions, 22 CTD casts at selected sites, and eight deployments of an underwater camera and video system (Neptun).

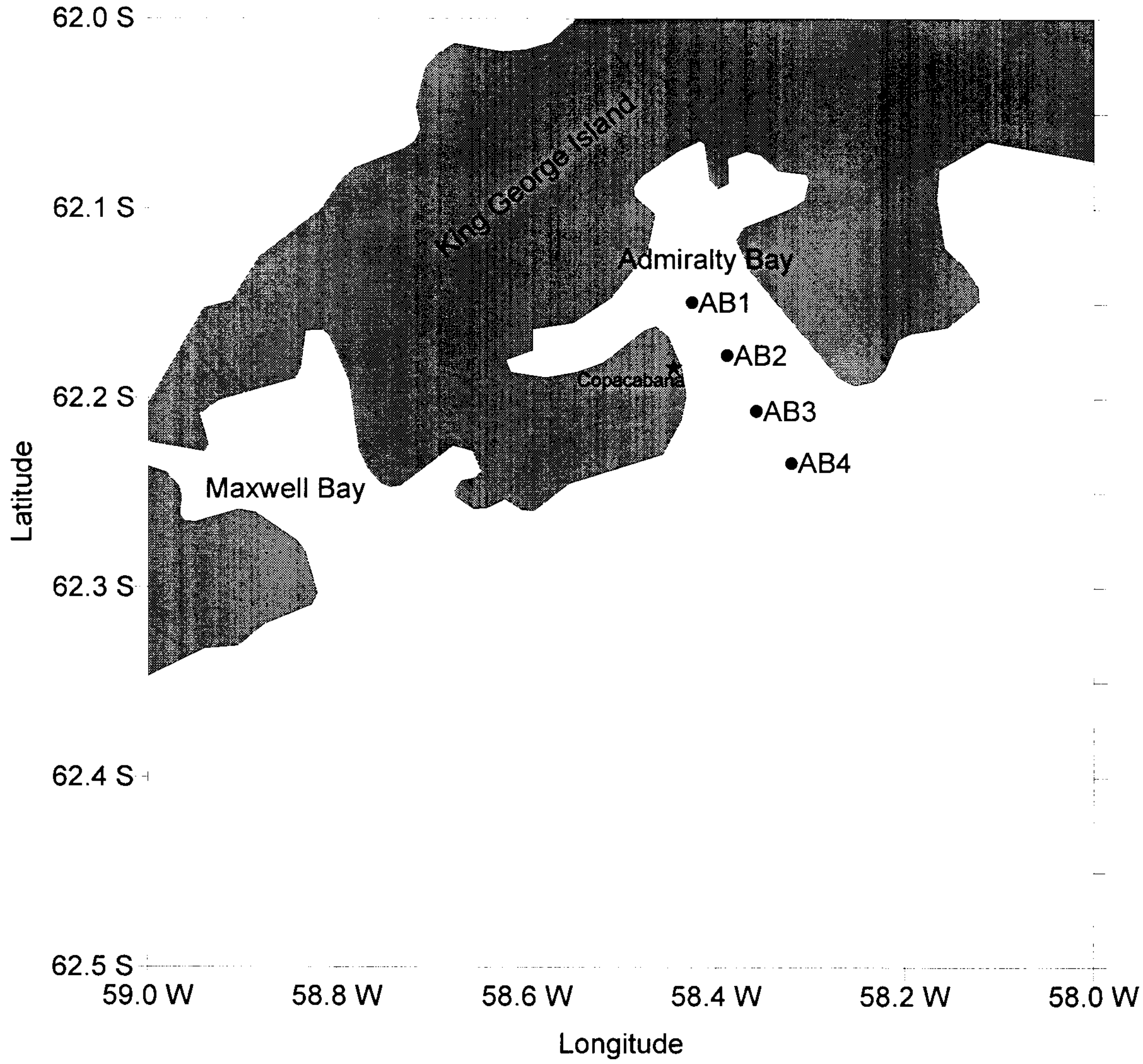


Figure 2. Admiralty Bay Stations: AB1, AB2, AB3, AB4.

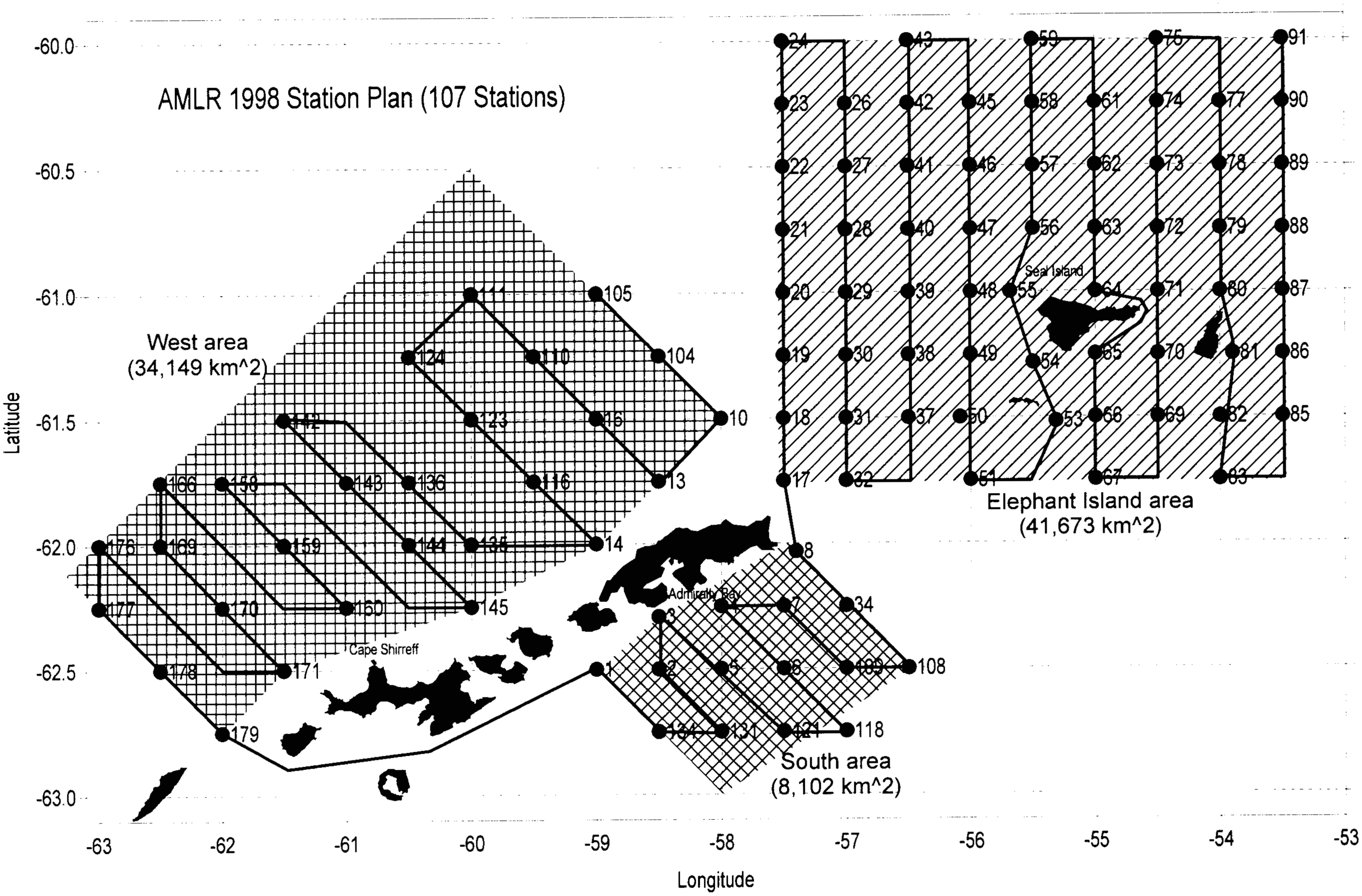


Figure 3. The large-area surveys for AMLR 98 (Surveys A and D) in the vicinity of Elephant, Clarence, King George, and Livingston Islands. Stations located to the west of Livingston and King George Islands are designated the "West area," those to the south of King George Island are designated the "South area," and those around Elephant Island are designated the "Elephant Island area."

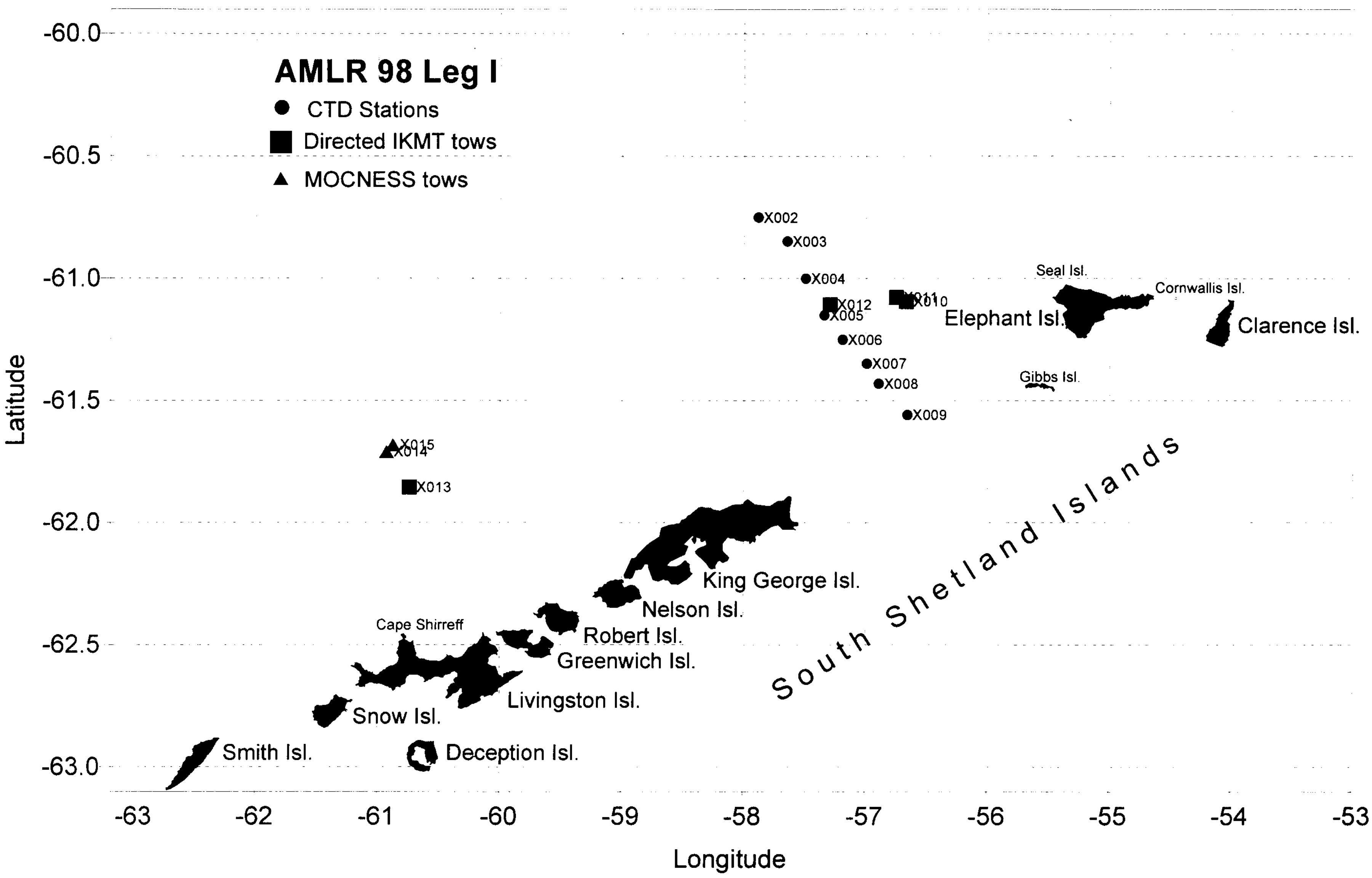


Figure 4. Cross-front CTDs (Stations X002-X009), directed IKMT tows with coarse mesh net (Stations X010-X013), and MOCNESS tows (Stations X014-X015) conducted on Leg I.

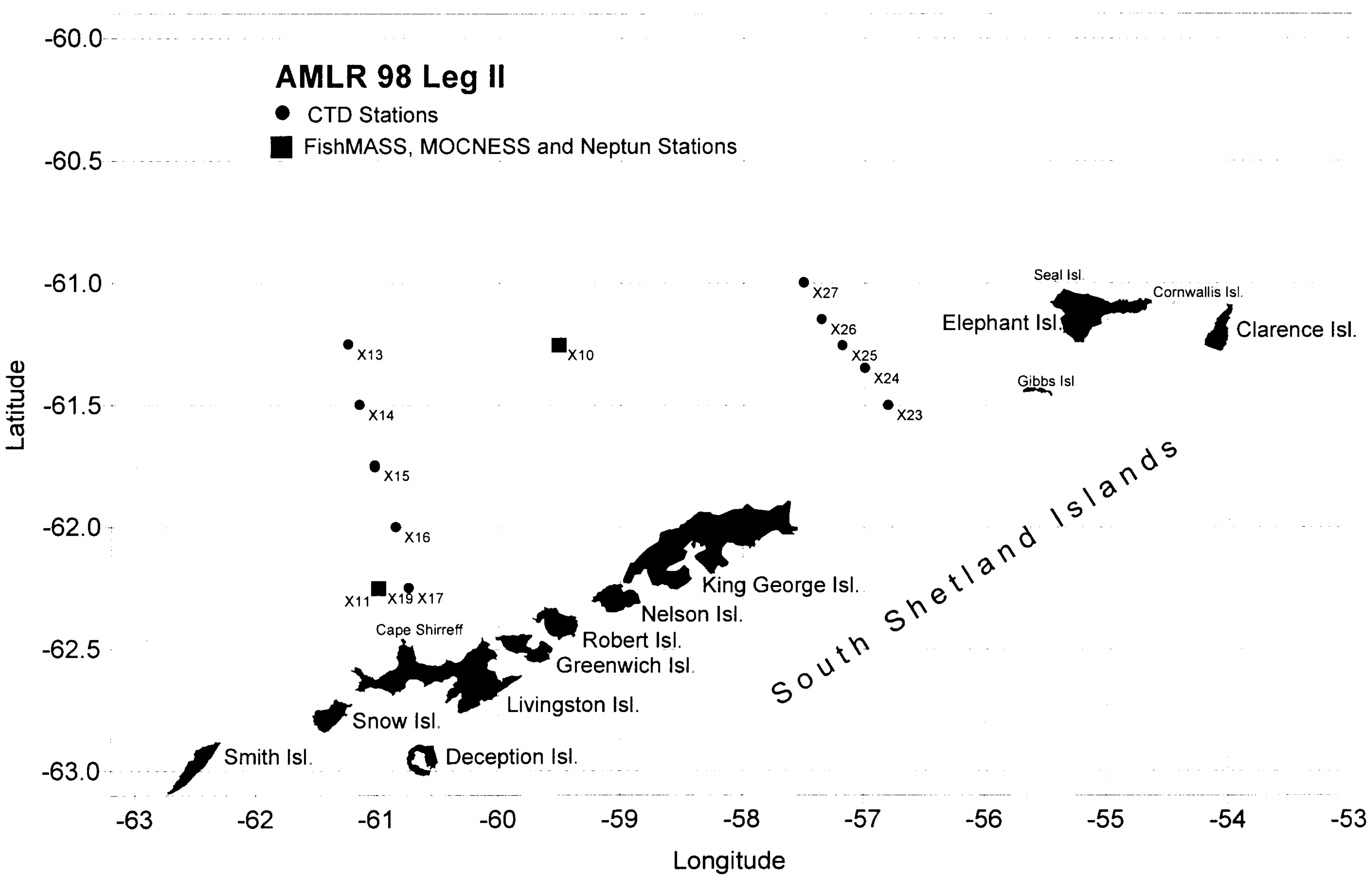


Figure 5. Cross-front CTD transects (Stations X13-X17 and X23-X27), and deployments of the FishMASS system, Neptun system, and MOCNESS on Leg II.

Land-based Research:

Cape Shirreff

1. A four-person field team (W. Cobb, W. Trivelpiece, J. Sterling, and T. Carten) arrived at Cape Shirreff, Livingston Island, on 28 November 1997 via the R/V *Abel J*. Ten Zodiac loads of supplies and equipment were transferred from the R/V *Abel J* to Cape Shirreff. A fifth person (P. Thorson) arrived via the R/V *Abel J* on 21 December.

2. A sixth person (R. Holt) and building materials, supplies, and equipment arrived at Cape Shirreff via the R/V *Yuzhmorgeologiya* on 5 January 1998.

3. Several major construction projects were completed at the Cape Shirreff camp, including the installation of a 6-panel solar array, rain gutters for collection of fresh water, a walkway between the main building and the generator shed, decks for the generator shed and laboratory buildings, an entryway shed for fresh food storage, and interior improvements to living quarters.

4. Chinstrap and gentoo penguin populations were censused on 3 December 1997. All colonies were counted, and the number of breeding pairs were determined. Reproductive success was studied by following a sample of 100 chinstrap penguin pairs and 50 gentoo penguin pairs from egg laying to creche formation.

5. The nests of 19 brown skua pairs were mapped and marked; 27 of 38 birds were banded. A survey for kelp gull nests was conducted, and nests were checked for eggs and chicks.

6. Radio transmitters were attached to 19 chinstrap penguins feeding 1-2 week old chicks on 8 January; the birds were followed during their foraging trips through mid-February.

7. Diet studies of chinstrap and gentoo penguins feeding chicks were initiated on 9 January and continued through 13 February. A total of 40 chinstrap and 20 gentoo adult penguins were captured upon returning from foraging trips, and their stomach contents were removed by lavaging.

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

9. A count of all chinstrap and gentoo penguin chicks was conducted on 5 February. Fledging weights of chinstrap penguin chicks were collected 18-26 February. Two hundred gentoo penguin chicks were also weighed on 18 February.

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

11. True seals were counted weekly at Cape Shirreff from 10 December to 29 January. Antarctic fur seals were censused every two days at two of the fur seal breeding sites on the east side of the Cape from 1 December to 7 January.

12. Antarctic fur seal pups were counted across the entire Cape once every week 1-30 December. Chilean and US researchers jointly conducted a census of Antarctic fur seal pups at the San Telmo Islands off Cape Shirreff on 6 January.

13. Attendance behavior of female Antarctic fur seals was measured using radio transmitters. Thirty perinatal female seals were instrumented 21-31 December, and their pups were captured, weighed, and measured.

14. US researchers assisted Chilean scientists in collecting data on Antarctic fur seal pup growth. Measurements were begun by the Chileans on 16 December and continued every two weeks until 26 February.

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. Nineteen female Antarctic fur seals were instrumented with TDRs during their perinatal period for diving behavior studies.

17. Eleven lactating Antarctic fur seals were instrumented with ARGOS satellite-linked transmitters for studies of foraging locations and energetics. Eight of the eleven fur seals also received doubly-labeled water for measurements of at-sea metabolic rate, condition, and water turnover.

18. Five hundred Antarctic fur seal pups were tagged at Cape Shirreff 14-26 February by US and Chilean researchers for demography studies. Studies of pup milk consumption and energetics were conducted on eight pups.

19. Total blood volume was determined for 22 Antarctic fur seals using the Evan's blue dye dilution method.

20. A weather data recorder was set up at Cape Shirreff from 1 December to 26 February for wind speed, wind direction, barometric pressure, temperature, humidity, and rainfall.

21. Three field team members (R. Holt, W. Cobb, and P. Thorson) were retrieved from Cape Shirreff via the R/V *Yuzhmorgeologiya* on 27 January. Cobb and Thorson returned home to the U.S., and Holt was transported to Seal Island.

22. On 7 February, three personnel (R. Holt, M. Goebel, and D. Costa), along with supplies and equipment, were deployed to Cape Shirreff via the R/V *Yuzhmorgeologiya.*

23. The Cape Shirreff field camp was closed for the season on 28 February; all personnel (R. Holt, M. Goebel, D. Costa, T. Carten, J. Sterling, and W. Trivelpiece), garbage, and equipment were retrieved by the R/V *Yuzhmorgeologiya.*

Seal Island

1. Four field team members (R. Holt, W. Armstrong, J. Popp, and A. Jenkins) arrived at Seal Island on 28 January via the R/V *Yuzhmorgeologiya.*

2. During their ten day stay, the team dismantled a storage building at the main campsite and an observation hut located on the back side of the island.

3. The four person team (R. Holt, W. Armstrong, J. Popp, and A. Jenkins) was recovered from Seal Island on 6 February. Building materials from the dismantled structures, along with additional supplies and equipment, were removed from the island.

Palmer Station

1. Field work at Palmer Station was initiated on 1 October 1997 and terminated on 4 April 1998.

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

3. Breeding population size was determined by censusing the number of breeding pairs of Adelie penguins at 54 sample colonies during the peak egg-laying period (24-29 November).

4. The proportion of one and two Adelie penguin chick broods was assessed at 54 sample colonies on 5 and 14 January. Chick production was determined by censusing Adelie penguin chicks between 29 January and 4 February at 54 sample colonies when approximately 2/3 of them had entered the creche stage.

5. Fledging weights of Adelie penguin chicks were obtained at beaches near the Humble Island rookery between 6 and 23 February.

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

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

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

SCIENTIFIC PERSONNEL

Cruise Leader:
Roger P. Hewitt, Southwest Fisheries Science Center (Legs I and III)
David A. Demer, Southwest Fisheries Science Center (Leg II)

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

Phytoplankton:
Osmund Holm-Hansen, Scripps Institution of Oceanography (Leg I)
Maximo Frangopulos, Instituto de Fomento Pesquero, Punta Arenas, Chile (Leg II)
Christopher D. Hewes, Scripps Institution of Oceanography (Legs I and II)
Jenny Maturana, Universidad Católica de Valparaiso (Leg I)
Milena Ruiz, Universidad de Magallanes, Punta Arenas, Chile (Leg II)

Bioacoustic Survey:
Adam Jenkins, Wayward Sailor Maritime (Legs I and II)
Jacqueline Popp, University of California at Santa Cruz (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 (Legs I and II)
Kimberly Dietrich (Leg II)
Michael Force (Legs I and II)
Rachel Johnson, California Academy of Sciences (Legs I and II)
Elizabeth Linen, University of Washington (Legs I and II)
Matthew M. Nelson, San Diego State University (Leg II)
Charles F. Phleger, San Diego State University (Leg I)
Volker Siegel, Sea Fisheries Research Institute (Leg I)

Bottom Trawl Survey:
Christopher D. Jones, Southwest Fisheries Science Center (Leg III)
Kimberly Dietrich (Leg III)
Peter Kappes, Biological Resource Division, USGS (Leg III)
Karl-Hermann Kock, Sea Fisheries Research Institute (Leg III)
Sunhild Wilhelms, Bundesamt fuer Seeschiffahrt und Hydrographie (Leg III)

Cape Shirreff Personnel:

William T. Cobb, Southwest Fisheries Science Center (11/28/97 to 1/27/98)
Terence Carten (11/28/97 to 2/28/98)
Daniel P. Costa, University of California at Santa Cruz (2/7/98 to 2/28/98)
Michael E. Goebel, University of California at Santa Cruz (2/7/98 to 2/28/98)
Rennie S. Holt, Southwest Fisheries Science Center (1/5/98 to 1/27/98; 2/7/98 to 2/28/98)
Jeremy T. Sterling, University of California at Santa Cruz (11/28/97 to 2/28/98)
Philip H. Thorson, SRS Technologies (12/21/97 to 1/27/98)
Wayne Z. Trivelpiece, Southwest Fisheries Science Center (11/28/97 to 2/28/98)

Seal Island Personnel:

Rennie S. Holt, Southwest Fisheries Science Center (1/28/98 to 2/6/98)
Wesley A. Armstrong, Southwest Fisheries Science Center (1/28/98 to 2/6/98)
Adam Jenkins, Wayward Sailor Maritime (1/28/98 to 2/6/98)
Jacqueline Popp, University of California at Santa Cruz (1/28/98 to 2/6/98)

Palmer Station Personnel:

William R. Fraser, Montana State University (12/15/97 to 4/4/98)
Donna L. Patterson, Montana State University (12/15/97 to 4/4/98)
Peter Duley, Montana State University (10/1/97 to 2/28/98)
Matt Irinaga, Montana State University (10/1/97 to 2/28/98)

Electronic Technician:

Frank Gomes, Pacific Marine Center (Legs I and II)

DETAILED REPORTS

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

1.1 Objectives: The physical oceanography component of the AMLR program provided the means to identify contributing water masses and environmental influences within the 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 98 is the ninth field season for the collaboration of physical measurements with biological studies.

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

CTD/Carousel Stations: One hundred fourteen CTD/carousel casts were made on Leg I, including the large-area survey stations (Survey A, Stations A001-A179), eight cross-front transect stations (Stations X002-X009), and one test CTD off Cape Shirreff. One hundred fourteen casts were made on Leg II, including the large-area survey stations (Survey D, Stations D001-D179) and 10 cross-front transect stations (Stations X13-X17, X23-X27). See Figures 3, 4, and 5 in the Introduction Section for station locations. Twenty-two casts were made on Leg III. Four hundred and fifty-six water samples were collected from the carousel bottles for analyses during Leg I (out of a total of 1254 water samples collected). Four hundred forty water samples were collected during Leg II (out of a total of 1254 water samples collected). The water samples were analyzed for micronutrient concentration, phytoplankton, chlorophyll-a, and dissolved oxygen by the phytoplankton group, and for salinity by the Russian scientific team. Salinity samples were analyzed aboard using a Guildline Autosal to verify the depth that each bottle tripped and to provide calibration data for the CTD conductivity sensor. The difference between the salinity measured by the Autosal and the CTD sensor was about 0.003, confirming the high accuracy of the CTD. Additional sensors on the CTD (fluorometer, transmissometer, and PAR sensor) functioned well, but problems were encountered with the dissolved oxygen sensor. Comparisons between dissolved oxygen data from the sensor and those from water samples (run aboard by the phytoplankton group with Winkler titration method) indicate that the sensor values were 18% lower than the water samples. This difference will be accounted for in the final analysis by applying a correction to the coefficients used in the calculation of dissolved oxygen from the raw oxygen current and temperature data provided by the sensor.

Underway Environmental Observations: Thirty-one, 30, and 29 days of continuously acquired weather, sea temperature, salinity, water clarity, chlorophyll, and solar radiation data were collected during Leg I, Leg II, and Leg III, 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 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 Bernoulli drive removable cartridges (two 150 Mbyte 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. For Leg III, the CTD was used with a dissolved oxygen sensor, transmissometer, and altimeter, but no fluorometer or PAR sensor. The carousel was removed and no water samples were collected.

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 SBE-21 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. 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 is based on the following characteristics: warm, low salinity surface water; strong sub-surface temperature minimum (called "Winter Water" at approximately -1 °C and a salinity 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. Water Zone IV has the following characteristics: bottom waters around -1 °C; and subsurface extrema that are far less prominent, although a slight "crook" in the curve is characteristic. In between, there are transition zones where adjacent water zones mix.

The composite T/S scatter diagram for all stations of Surveys A and D are shown in Figures 1.1a and 1.1b, respectively. During Survey A, it appeared that 1998 would be a "cold year," with surface temperatures below 3 °C. However, the sea surface warmed up during Survey D, with Water Zone I waters measuring above 3.5 °C. Note the split in the region between the Winter Water T-min and the CDW T-max, indicating the difference between upper and lower CDW (Figure 1.1a). This difference is less well-defined during Survey D (Figure 1.1b). In Figures 1.2a-1.2j, 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 insets show 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 is characterized by the evidence of isopycnal mixing of the CDW with shelf water.

The conditions during AMLR 98 were more variable than on previous AMLR cruises, and the zonation is less obvious. Water Zone III was difficult to classify and was almost absent in both large-area surveys (Figures 1.2c and 1.2h). Water Zone V, with Weddell Sea influence, was quite prominent with some stations in Survey D having profiles entirely below 0 °C. In Figures 1.3a and 1.3b, T/S curves have been plotted for each station in the AMLR study area for 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 dominates the area north of Livingston Island, which includes new AMLR stations, some occupied for the first time during AMLR 98. Some transition stations and Water Zone IV stations are seen on the South Shetland continental slope and shelf here. New stations added in the Bransfield Strait fall into Water Zone IV, except for the extreme southeast where some influence of modified CDW can be seen. These stations have been classified in the Water Zone V. Note the almost isothermal profiles of Stations D082, D085, and D086 southeast of Clarence Island (Figure 1.3b) in comparison to the same stations during Survey A (Figure 1.3a).

The dynamic topography of the region is shown in Figures 1.4a and 1.4b. The implied flow at the surface relative to 500dbar is illustrated by arrows pointing in the direction of flow. As usual, the major feature was the prevailing southwest to northeast flow across the entire AMLR study area. With the expansion of the large-area survey to include stations by Livingston Island, the dominance of this feature becomes readily apparent, as was the eddy-like feature northwest of Elephant Island. This dynamic topographic high is a quasi-permanent feature of the flow in the

AMLR study area and has been present on all AMLR cruises on both legs. A similar pattern was revealed by referencing the surface to 200m, so it is assumed that these patterns are reasonably representative of the mean flow in the upper water column. The flow was most intense to the northwest of Elephant Island during Survey A, but lost intensity by the time Survey D was carried out. The topographic high (centered around 60°30'S, 57°W) was prominent during both surveys, but significant recirculation to the northwest was only evident during Survey D. The flow was weaker along the South Shetland Islands shelf off Livingston and King George Islands during both surveys. Parallel flow was seen south of King George Island in the Bransfield Strait; this flow was stronger for Survey A than Survey D, while a minor topographic high was seen between Elephant and Clarence Islands. There was northward flow along the eastern margin of the large-area survey grid. With the exception of the eddies, flow throughout the region was exclusively in a northeasterly to northerly direction.

Sea surface temperature data are presented for both legs in Figure 1.5a, and salinity data for both legs are shown in Figure 1.5b. Data are from the underway environmental data system, rather than from the CTD, to increase the resolution. Temperatures measured by the Sea-Bird thermosalinograph have been adjusted using the CTD surface values to correct for warming which occurred in the pipe leading from the intake at the bottom of the ship's hull (Figure 1.5a). The mean difference was 0.6°C. During Survey A on Leg I, surface temperatures did not exceed 3°C; however, during Survey D on Leg II, temperatures reached 3.5°C. This is the normal trend between AMLR legs, unlike 1997, when much cooler surface temperatures were encountered during the shortened Leg II (carried out during the last several days of March). A third leg (Leg III) was conducted this year from early March to early April. The continuous underway data system was run throughout the leg. Although the cruise track was mainly in the shallow shelf waters, sea surface temperatures were consistently low, not exceeding 2°C. Salinity showed a typical trend for both legs (Figure 1.5b). The boundary of the Water Zone I oceanic water with the other zones approximately followed the 33.9 PSU isohaline, running from southwest to northeast.

For AMLR 98, we used new software to analyze CTD data. The software has been developed at the Alfred Wegener Institut by Dr. Reiner Schiller. Ocean Data View 40 (ODV40) allowed us to visualize oceanographic sections of the large-area survey in color in almost real-time and proved to be a powerful analytical tool. Two meridional sections from Surveys A and D have been reproduced in Figures 1.6a and 1.6b, respectively. The resolution is diminished as it is not possible to reproduce the ODV40 sections in color here. The sections are along the 57°W meridian from the Drake Passage into the Bransfield Strait, crossing the oceanic front at its most defined location. The sections include stations from the large-area surveys (Stations 026-034, 109 and 118) and also from cross-front transects completed after the large-area surveys. Station locations are shown by the vertical lines on each section in Figure 1.6 and on the inset map. T/S curves for each of the stations are shown in the panel on the lower right. During January (Leg I), the winter water minimum was well developed and nearly continuous with the cold interior waters of the Bransfield Strait (Figure 1.6a). CDW, characterized by its temperature and salinity maximum and oxygen minimum, was offshore. The surface expression of the front and the

CDW boundary coincided in January, but by February the CDW had advanced shoreward and was impinging on the continental shelf (Figure 1.6b). Winter water was more isolated and confined to the oceanic waters of the Drake Passage, but the surface expression of the front in temperature was farther offshore than in January (Figure 1.5a).

Underway Data: Data were recorded at 1-minute intervals covering over 14,500 nautical miles of cruise track. Only a few periods of data loss were experienced, mostly due to the underway program hanging up when communication from sensors was lost. Leg I was the calmest of all three legs. The mean wind below 60°S was 14.7 knots, which was windier than last year. Maximum wind was 45.3 knots. Mean wind on Leg II was 17.1 knots, with a maximum of 44.4 knots. The mean wind on Leg III was 16.1 knots, but the high wind was 68.4 knots. A remarkable meteorological event occurred on Leg III, while the ship was southeast of Clarence Island on 17-18 March. A low pressure area of "cyclonic" proportions passed over the area. A high wind gust of 77.7 knots from the northwest was recorded. Perhaps more remarkable was an air temperature of 15.4°C (60°F) at 1612 local time, 17 March. Several hours later, the temperature had dropped to 2.7°C (37°F). The high temperature readings were confirmed using a sling psychrometer. Air temperatures below freezing were recorded on all three legs with a low of -2.1°C on Leg I. Leg I was characterized by dense fog, persisting for lengthy periods. The combination of fog and numerous icebergs made navigation and station positioning difficult. Barometric pressure was unusually low throughout Leg I, reaching 1000mb for only one hour during the time the ship was south of 60°S.

1.5 Disposition of Data: The CTD/carousel, underway, and weather station data have been stored on 150 Mbyte Bernoulli disks and 100Mbyte "Zip" diskettes. The raw data were taken to the University of Texas Marine Science Institute in Port Aransas, Texas. 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 acoustics groups. CTD and underway data for Leg III are archived at UTMSI. Copies of the printed log sheets and plots were provided daily to the phytoplankton group. Special logs listing time, position and weather conditions for each scientific event were provided to the phytoplankton and zooplankton groups.

1.6 Acknowledgments: We were most impressed by Captain Igor Zhelyabovskiy and the improvements to the ship and crew attributable to his leadership. Fog and ice conditions made the day-to-day operation of the ship very difficult this year, but the Captain's and bridge crews' diligence inspired our confidence. Special mention must go to the Russian crew who prepared, launched, and recovered the CTD. The four-hour on, eight-hour off watches with three crews worked out well for the CTD operation. We are grateful to Chief of Expedition Dmitry Tugolesov, and especially 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 were very high, reflecting the care they took doing the measurements.

1.7 Problems and Suggestions: The Sea-Bird CTD operated well throughout the cruise. Occasional noise on the records was tracked down to water in the external connectors. A pin on the PAR sensor corroded and broke off near the end of Leg II. This is the second time the PAR sensor pin has broken on an AMLR cruise. The CTD pump pin was also badly corroded and will need to be replaced. The oxygen sensors continued to give us problems. On the very first station, a newly repaired and calibrated sensor gave erroneously high readings and was immediately replaced with a sensor that was used throughout Legs I and II. This sensor was also reading in error, but was consistently offset from the values obtained by Winkler oxygen determinations made by the phytoplankton group; corrections can be made to give reasonably good CTD oxygen values. It should be noted that the oxygen work done by Jenny Maturana was excellent.

The Sea-Bird Carousel water sampler worked well. However, we again had to use the frames supplied by the Pacific Marine Center (PMC) to hold the water sampling bottles, which prevented us from mounting the CTD in the preferred horizontal orientation. In the vertical orientation used this year, there is considerable entrainment of water by the great bulk of the carousel, water sampling bottles, and auxiliary sensors during the uptrace. While we use the downtrace CTD data as our primary data source, the bottles must be tripped on the uptrace. Output from the CTD and its auxiliary sensors is used to compare with the data from analyses of water samples collected in the bottles. Due to time-constants and the entrainment of water by the CTD, these values could be erroneous. On Leg I, we had a near-disaster in rough seas when the CTD/carousel crashed into the ship's stern on retrieval, shearing off the bottom of the PMC frame, breaking nine water sampling bottles, and leaving the altimeter hanging by its connecting cable. Fortunately, no damage was done to the CTD or any auxiliary sensors, including the altimeter. Several of the bottles were repaired by Chuck Rowe and were used again, but one bottle was smashed beyond repair.

The new Coastal Climate Weatherpak system, which measures wind conditions, air temperature, humidity and barometric pressure, worked well, with the exception of the humidity sensor which gave frequent readings above 100%. Communication with the manufacturer (Coastal Environmental Company) did little to resolve this problem, but on Legs II and III a sling psychrometer was used to calibrate the sensor at regular intervals. The underway system and its various components and software functioned well. We occasionally had the mysterious "Fluke error," which caused the underway recording to halt, but this was far less prevalent than it was during AMLR 97.

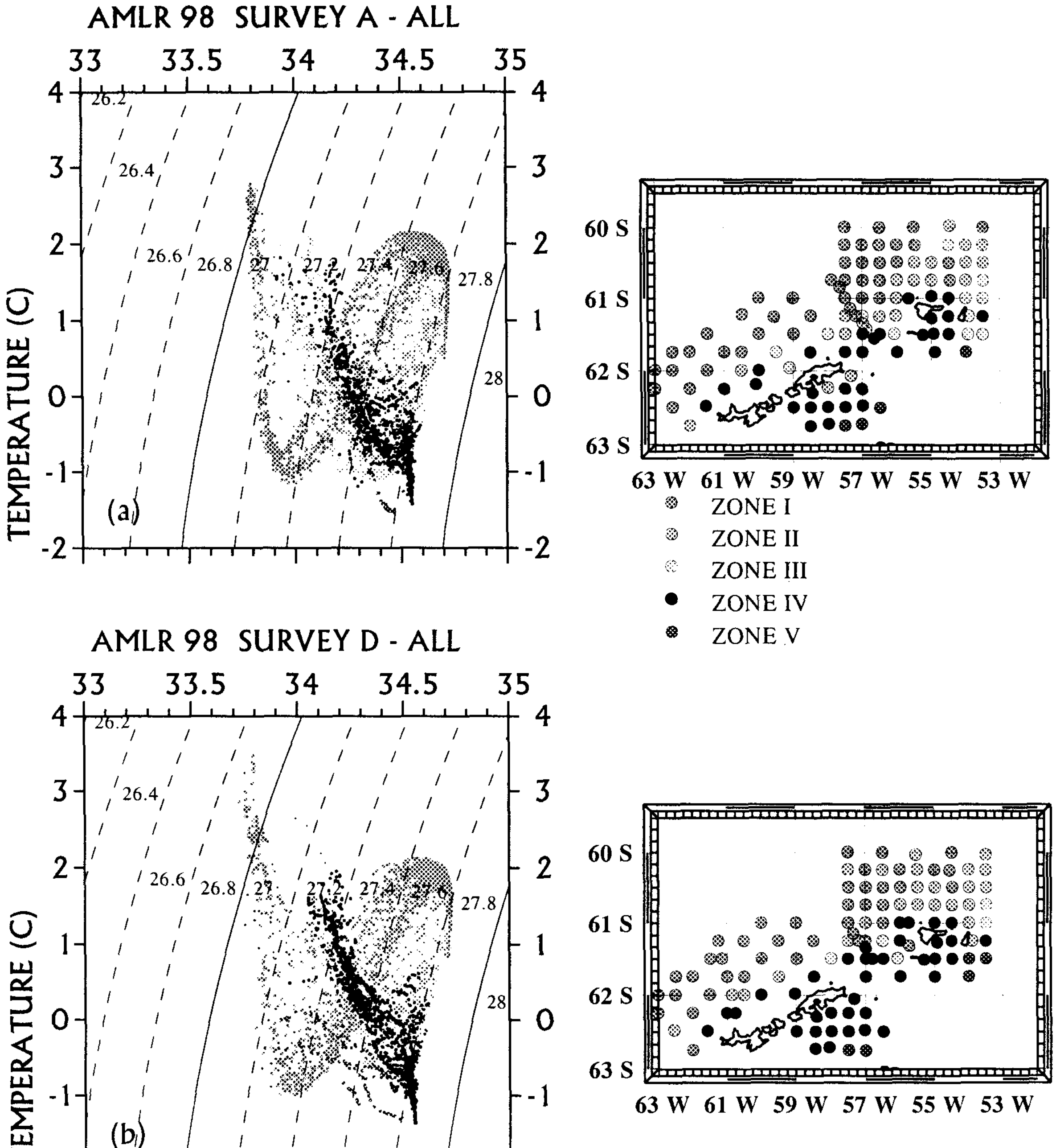


Figure 1.1 Composite Temperature/Salinity (T/S) diagram for all stations from the large-area surveys. (a) Survey A, Leg I; (b) Survey D, Leg II. Symbols on inset maps show station locations shaded by water zones of similar T/S characteristics.

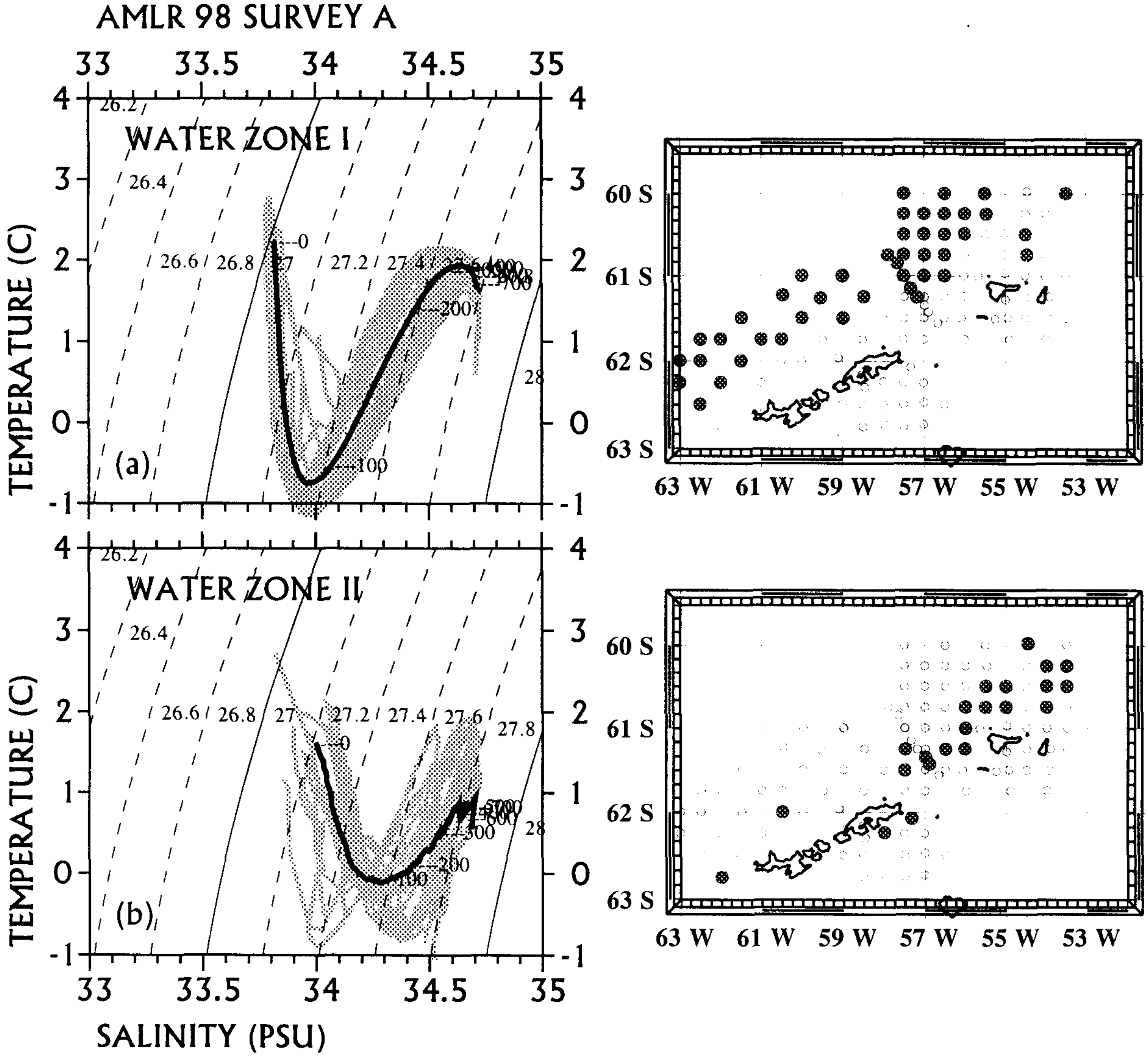


Figure 1.2 Temperature/Salinity (T/S) curves for various water zones in the AMLR study area. The gray area is the T/S envelope of all stations identified as having the water zone characteristics. The heavy black curve is the mean T/S curve for each water zone. Inset maps show the location and numbers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

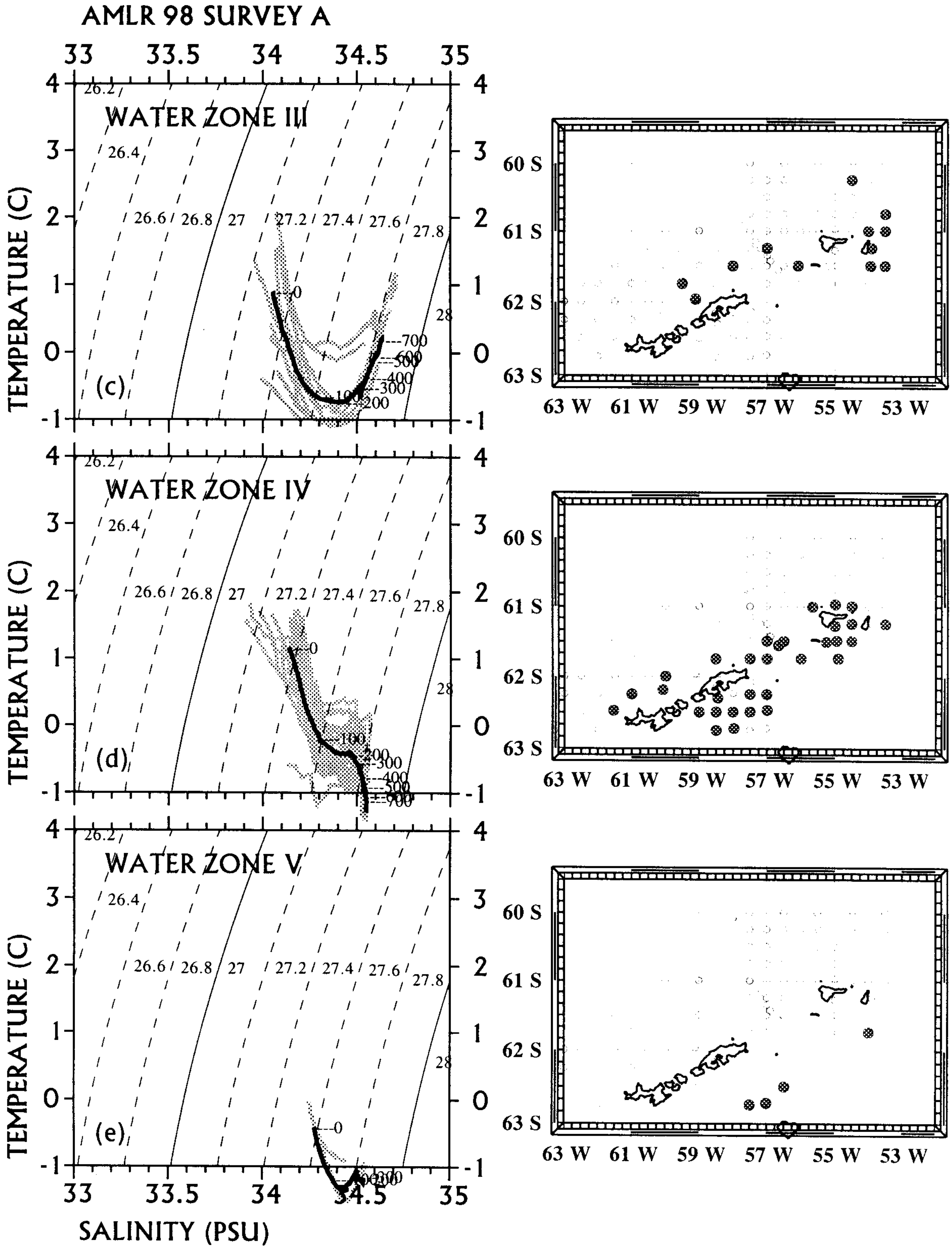


Figure 1.2 (cont.) (c) Survey A, Water Zone III; (d) Survey A, Water Zone IV; (e) Survey A, Water Zone V.

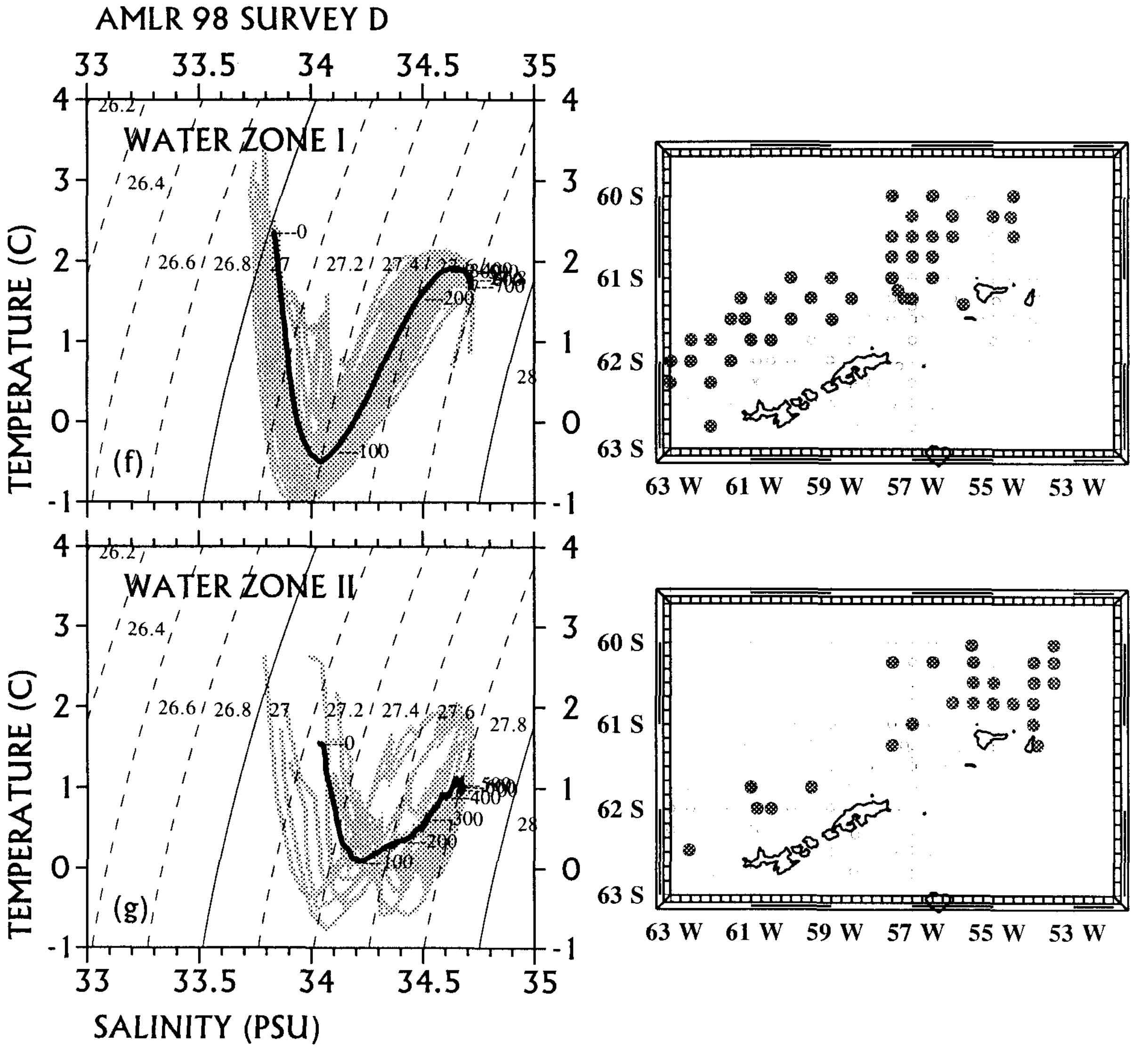


Figure 1.2 (cont.) (f) Survey D, Water Zone I; (g) Survey D, Water Zone II.

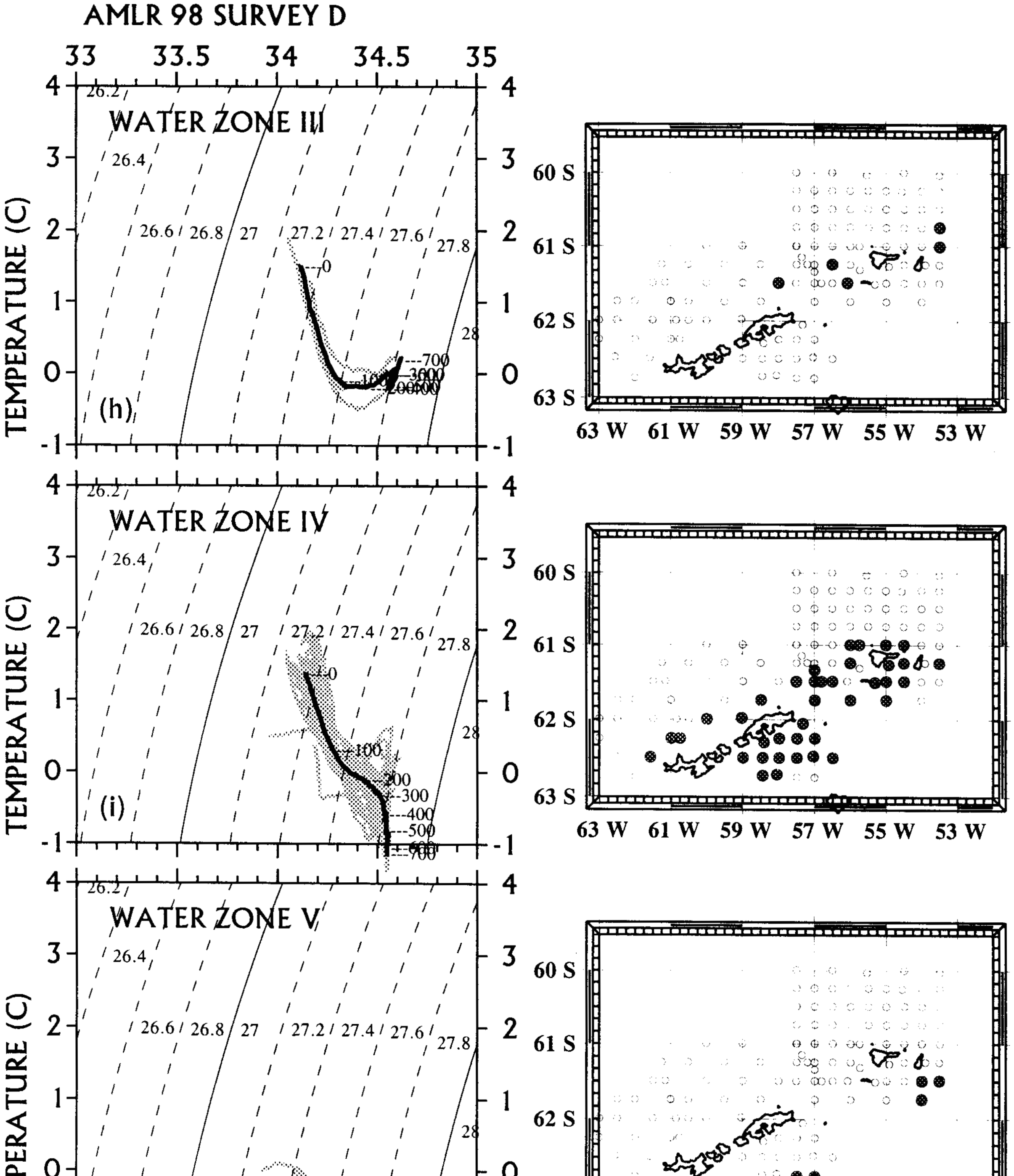


Figure 1.2 (cont.) (h) Survey D, Water Zone III; (i) Survey D, Water Zone IV; (j) Survey D, Water Zone V.

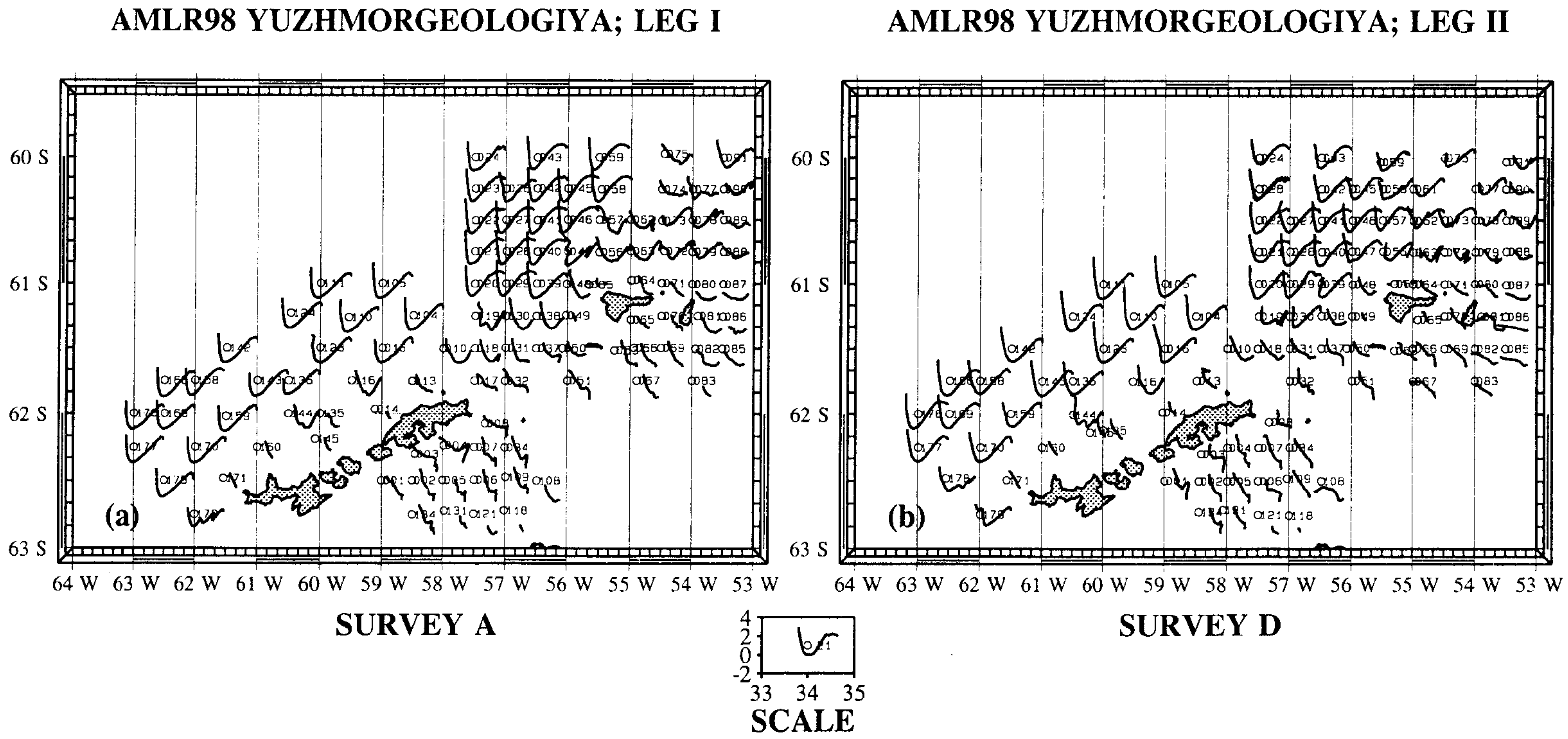
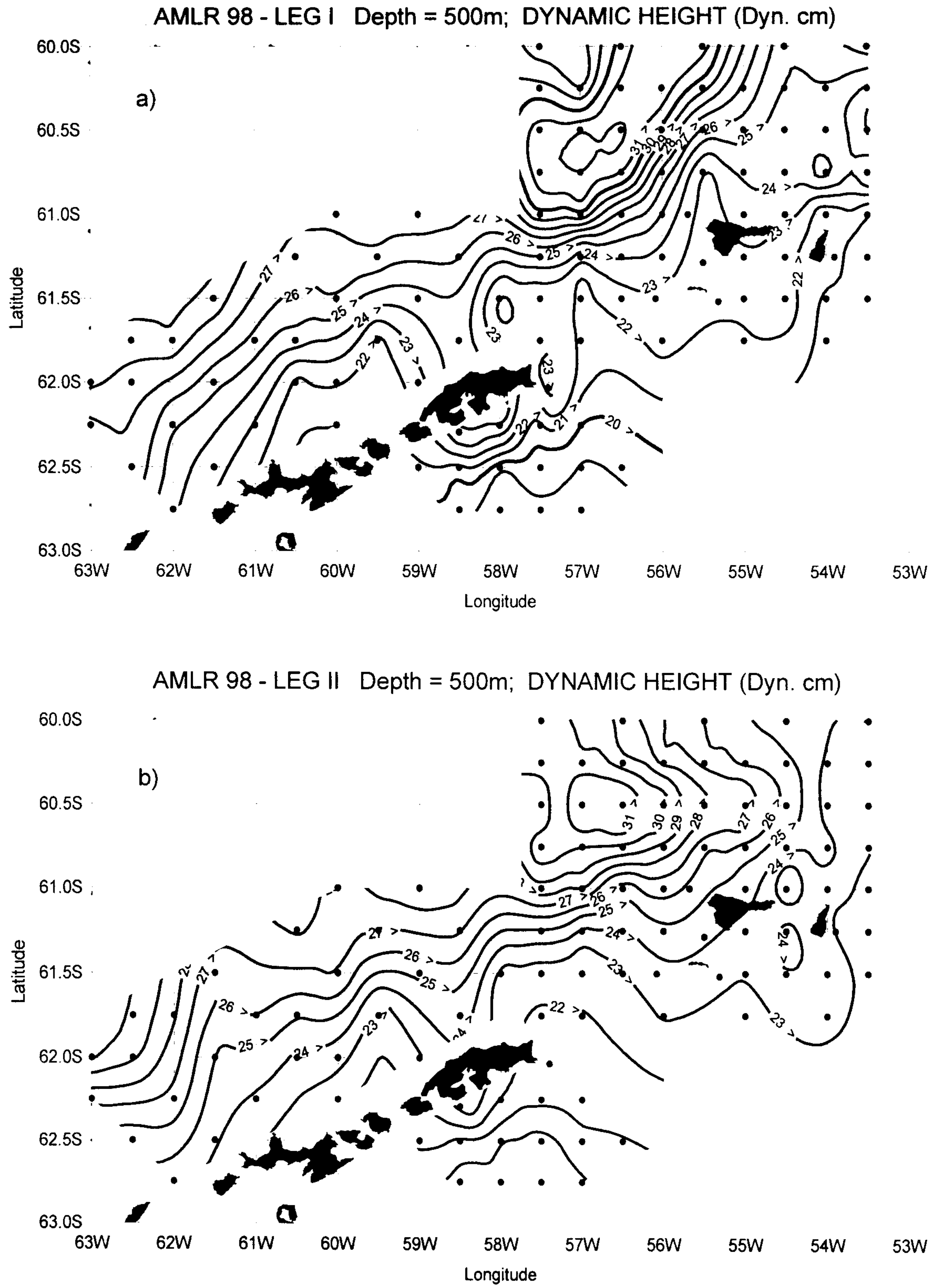


Figure 1.3 Temperature/Salinity curves for individual stations plotted at the station locations. The circle representing station location is plotted at S=34, T=+0.5 (see scale inset). (a) Survey A, Leg I; (b) Survey D, Leg II.



AMLR 98 - LEG I Depth = 500m; DYNAMIC HEIGHT (Dyn. cm)

AMLR 98 - LEG II Depth = 500m; DYNAMIC HEIGHT (Dyn. cm)

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

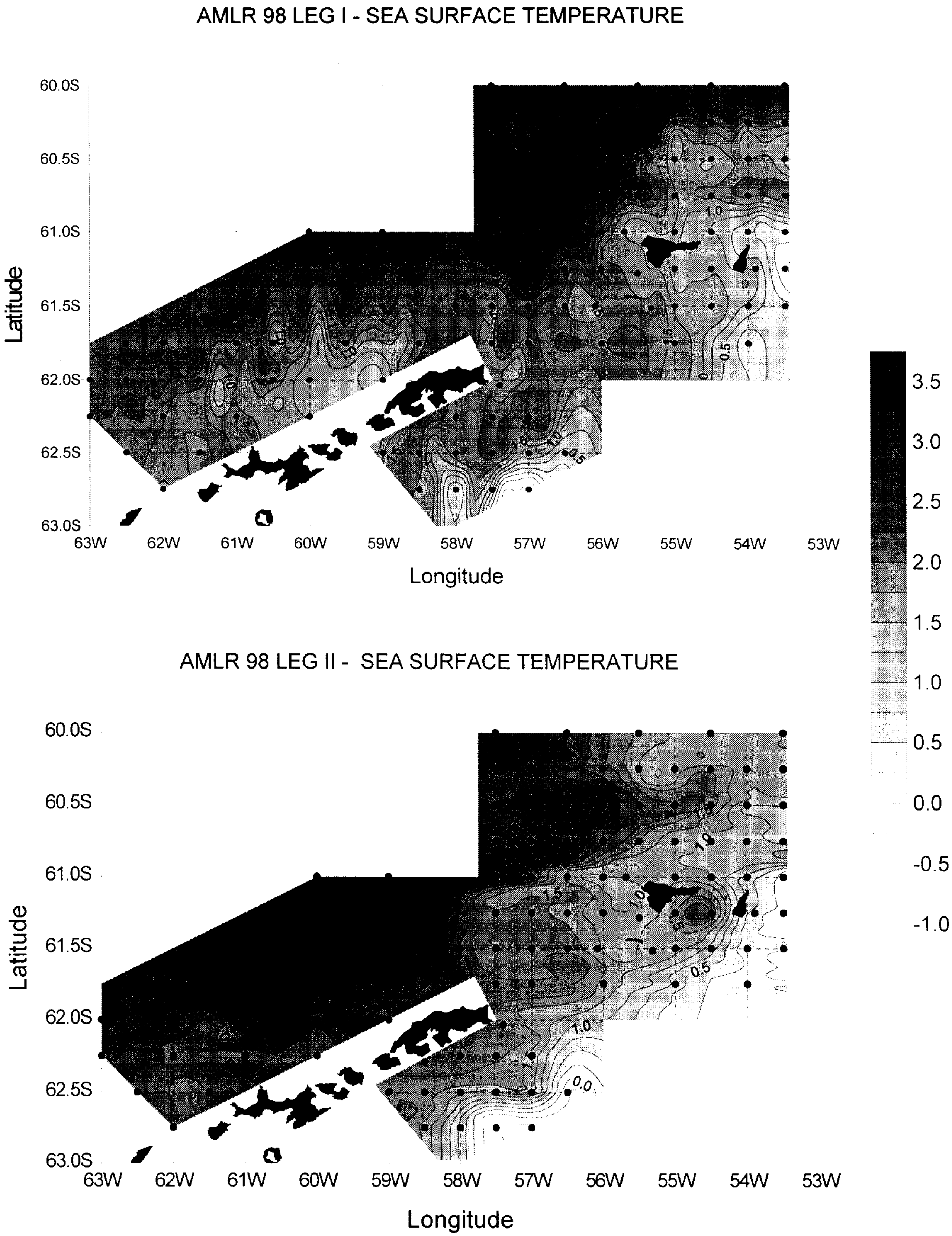


Figure 1.5a Horizontal maps of near surface oceanographic conditions (temperature) in the AMLR study area during Legs I and II. Data are from the continuously recorded underway environmental system.

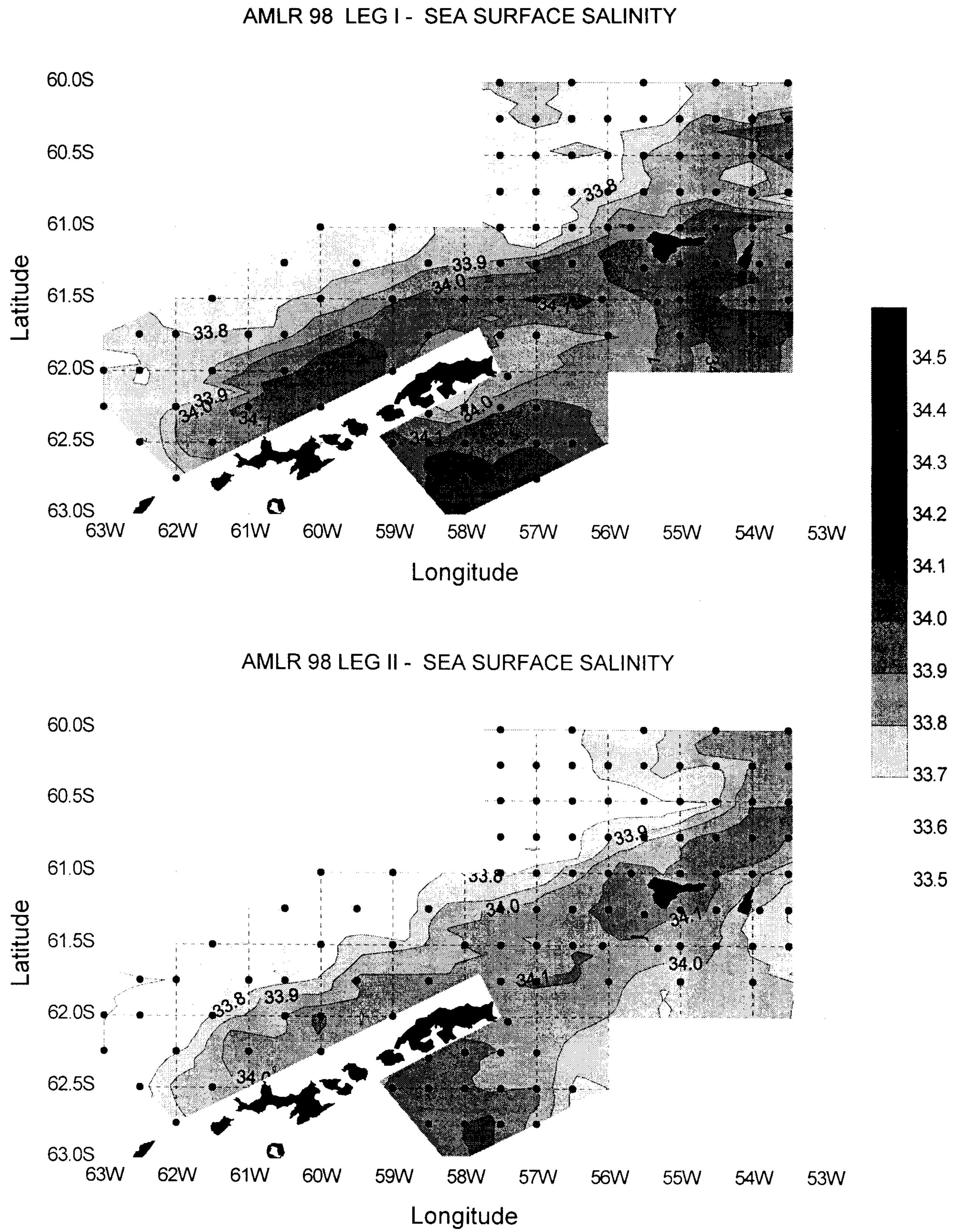


Figure 1.5b Horizontal maps of near surface oceanographic conditions (salinity) in the AMLR study area during Legs I and II. Data are from the continuously recorded underway environmental system.

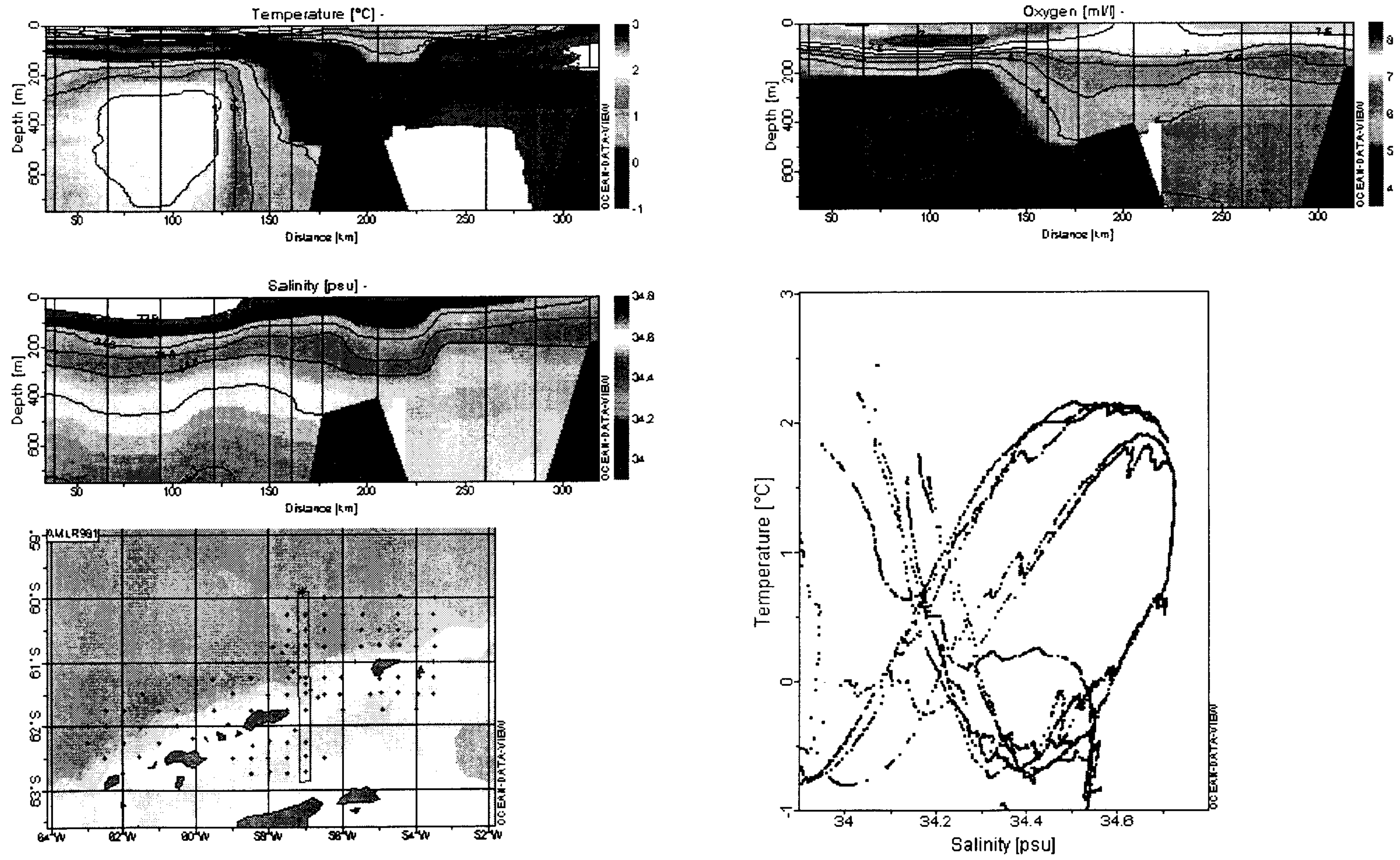


Figure 1.6a Temperature, salinity, and oxygen section along the 57°W meridian during Survey A (Leg I), plotted using the ODV40 software.

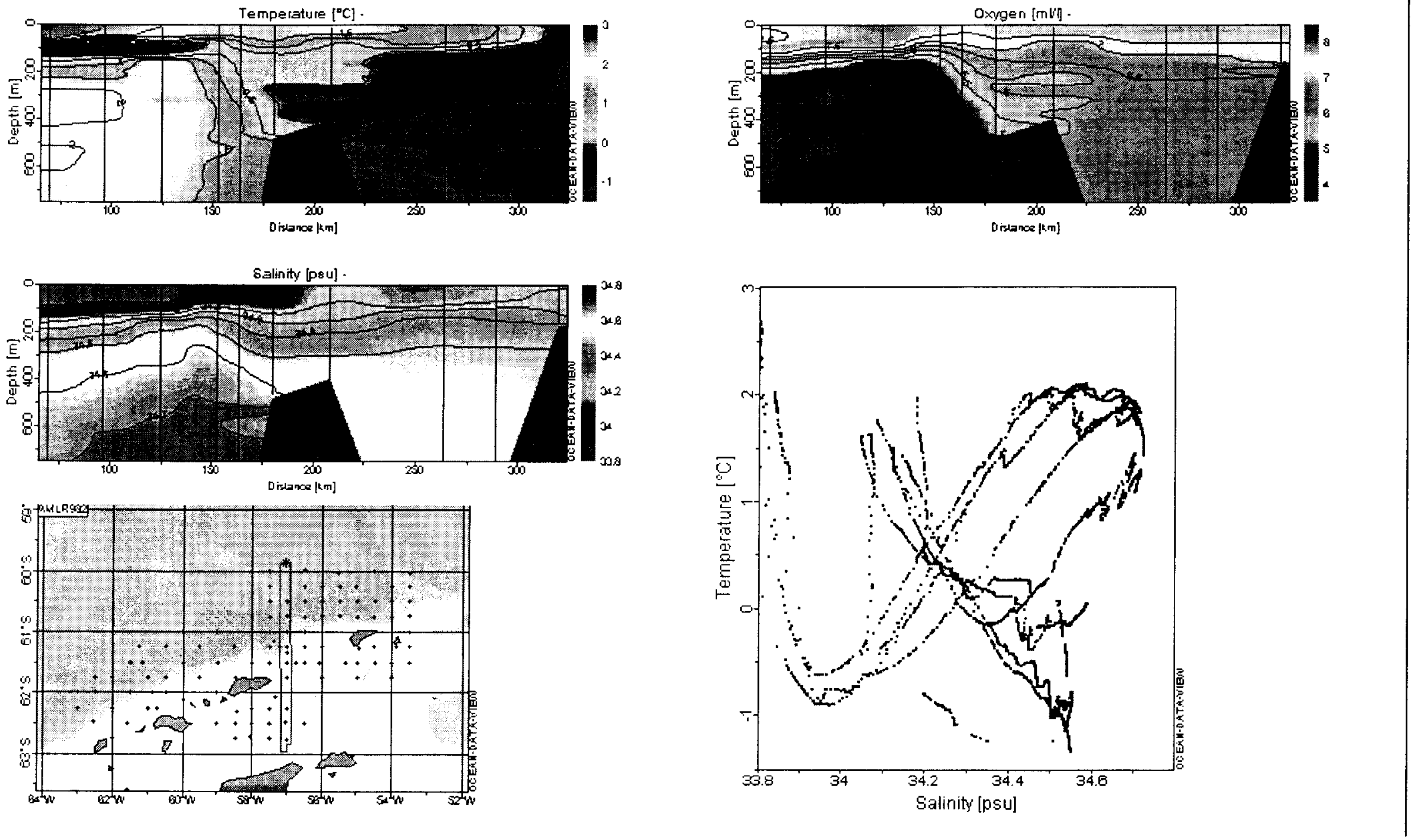


Figure 1.6b Temperature, salinity, and oxygen section along the 57°W meridian during Survey D (Leg II), plotted using the ODV40 software.

2. Phytoplankton; submitted by Osmund Holm-Hansen (Leg I), Christopher D. Hewes (Legs I and II), Jenny Maturana (Leg I), Milena Ruiz (Leg II), and Maximo Frangopulos (Leg II).

2.1 Objectives: The overall objective of this 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 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 composition of the phytoplankton, in addition to cell size and biomass expressed in cellular organic carbon; (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; and (5) to relate the profiles of oxygen throughout the euphotic zone to metabolic activity of both the autotrophic and heterotrophic assemblages of organisms.

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. Legs I and II each occupied 105 CTD/carousel 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 and also to obtain samples for extraction of chlorophyll-a (chl-a) at many of the 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 (ten depths from 5 to 200m) from the Niskin bottles at every CTD/carousel station are normally determined by measurement of chl-a fluorescence after extraction in an organic solvent. During Leg I, however, there was insufficient methanol to extract chl-a from all these samples. We therefore routinely extracted chl-a from the water samples obtained at 5, 10, 30, and 50m. At any station where the profile of *in situ* chl-a fluorescence looked interesting or unusual, we filtered water samples from additional depths. At the productivity stations, samples were taken for chl-a analysis at all eight

depths used for the CO_2 incorporation experiments. During Leg II, chl-a concentrations were measured at eleven sampling depths between 5m and the bottom. Sample volumes of 100 milliliters (ml) were filtered through glass fiber filters [Whatmann GF/F, 25 millimeter (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 fluorometer was verified daily by use of sealed coproporphyrin standards which fluoresce in the same spectral region as chl-a, as well as by use of a new sealed, solid fluorescence standard made available to us by Turner Designs, Inc. In order to calculate the integrated chl-a values per square meter (0 to 100m) for Leg I stations, it was necessary to apply an algorithm relating *in vivo* chl-a fluorescence (obtained from the fluorometer on the CTD/carousel unit) to chl-a concentrations. This algorithm was developed by comparison of the chl-a concentrations in extracted samples and the *in vivo* measurement of chl-a fluorescence when the Niskin bottles were closed during the upcasts of the CTD/carousel unit.

(2) Primary production: Rates of primary production were measured at the CTD/carousel station occupied close to 0700 each day during Leg I. Water samples from eight depths (from 5 to 75m) were poured into 50ml 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 glass fiber filters (GF/F, 25mm). The filters were placed in 7ml glass scintillation vials, and any inorganic ^{14}C was 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.

(3) 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 some of the productivity stations and also at Station X002, which sampled down to 2000m. Water samples (about 40ml) were poured into acid-cleaned 50ml polyethylene screw-cap bottles and maintained at -20 °C until time of analysis using an autoanalyzer at the Universidad Catolica de Valparaiso, Chile.

(4) Dissolved oxygen: Concentrations of dissolved oxygen were determined in water samples obtained from various depths from the Niskin bottles on the CTD/carousel unit. Four depths (10, 100, 200, and 750m) were sampled at the first station after midnight, and eight depths were sampled at the first station after 1200 on each day. All eight depths were sampled at Station X002 (See Figure 4 in the Introduction Section for location of Station X002). These oxygen determinations were made using a micro-Winkler titration unit and were used primarily to check the calibration of the oxygen sensor mounted on the CTD/carousel unit.

(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. During Leg I, the following operations were conducted: (a) net tows [20 micrometer (μm) mesh size] were taken at various stations to sample the larger micro-phytoplankton which usually are not well represented in the preserved water samples; and (b) Nuclepore filters (1.0, 5.0, 8.0, and 12μm pore size) were used to determine the percentage of chl-a in cells that passed through these various filters. During Leg II, water samples (100ml) from 5, 30, and 75m were passed through a 10μm nitex mesh for most stations in the large-area survey grid. Additionally, 10μm size fractions were made at bottle cast depths (5 through 100m) for a few selected stations. The filtrates from these fractionations were put through a glass fiber filter (GF/F), which supposedly retains all phytoplankton, including the picoplankton, and the chlorophyll concentration measured as described above. In separate tests with natural phytoplankton assemblages, glass fiber filters (GF/F) were found to retain as much chl-a as the Millipore GS filters (0.22μm pore size). Glass fiber filters (GF/F) were thus used in the routine fractionation studies because of their much faster rate of filtration.

(6) Biomass and organic carbon concentrations: Three methods were used to estimate phytoplankton biomass expressed as cellular organic carbon. (a) The data obtained from the microscopic observations (see above) were 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 were used to estimate phytoplankton biomass using published algorithms of carbon:chlorophyll ratios. (c) Data on beam coefficients (cp, as obtained with the transmissometer on the CTD/carousel unit and also the one on the pumped sea water line) were 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; and (b) attenuation of PAR in the water column was measured with 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) Data in Figures 2.1A and 2.1B show that phytoplankton biomass at 5m depth, as indicated by chl-a concentrations, was low throughout the large-area survey grid during both legs. Surface concentrations above 1.0 milligrams per cubic meter (mg m^{-3}) chl-a were found at only two stations during Leg I and at three stations during Leg II (105 stations each leg). The low and fairly uniform distribution of chl-a during both legs is comparable to similarly low values recorded in the 1992 and 1993 seasons, and in contrast to data from all other years since the first extensive sampling began in 1990.

(B) Due to the shortage of methanol on board ship during Leg I, which limited the number of samples that could be processed for chl-a analysis, values for chl-a per square meter in the upper 100m of the water column cannot be estimated for Leg I at this time. Such a map of integrated values will not be available until we generate the algorithm that permits us to calculate chl-a concentrations from *in vivo* chl-a fluorescence. Integrated chl-a values for the upper 200m of the water column during Leg II, however, are shown in Figure 2.2. The pattern of integrated chl-a values is fairly similar to the distribution of chl-a in surface waters (see Figure 2.1B), except for the high integrated values to the southeast of Elephant Island.

(C) The distribution of chl-a in the upper water column throughout the survey grid shows three general patterns as indicated by the data in Figure 2.3. Stations in Drake Passage waters (Water Zone I) show very low biomass near the surface, but a deep maximum at depths between 50 to 100m (Figures 2.3A and 2.3B). Stations strongly influenced by Weddell Sea waters (Water Zone V) show maximal but fairly low biomass near the surface, with concentrations decreasing slowly with depth. As there is relatively little vertical stability in the upper water column at such stations (Figures 2.3C and 2.3D), this distribution of chl-a in deep waters most likely reflects settling of cells out of the euphotic zone. Stations in Bransfield Strait waters, or at stations showing evidence of much mixing between water zones (Water Zone II), show relatively high biomass near the surface, with concentrations decreasing rapidly with depth (Figures 2.3E and 2.3F). These stations also have a better developed upper mixed layer.

(D) In addition to the low biomass of phytoplankton recorded during both Legs I and II, there were a few other differences of note as compared to data from previous years. First, the phytoplankton assemblages at the three most south-easterly stations in the Bransfield Strait, which are located in continental shelf waters of the Antarctic Peninsula, were large cells (microplankton in contrast to nanoplankton) and tended to form aggregates. The dominance of such aggregates caused the profiles for *in vivo* fluorescence to be very different (Figure 2.4A) as compared to all other stations (Figure 2.4B). This "clumpy" nature of the particulates was also evident in the trace from the transmissometer mounted on the CTD/carousel unit. It is of interest to note that the highest chl-a value recorded on Leg I [2.4 microgram per liter (µg/l)] occurred at 50m depth at the station shown in Figure 2.4A.

Second, the phytoplankton distribution at stations in the northwest corner of the Elephant Island grid (A024 and A026) showed maximal concentrations in surface waters (about 0.8μg/l), in addition to the usual deep sub-surface maximum (about 0.4μg/l) at 75-100 meter depth (Figure 2.5). In previous years the surface waters at these stations have been routinely low (<0.1μg/l), similar to the profile for chl-a shown in Figure 2.3A. Such a change in chl-a distribution with depth as compared to the same stations in other years was also noted for several stations in the northeast section of the survey grid and apparently reflects a change in the physical mixing regimes at these stations as compared to previous years. The frontal mixing zone north of Elephant Island was further north during Leg I as compared to past years (see Section 1, Physical oceanography). This change in oceanographic conditions affected the distribution of phytoplankton, as the stations showing the deep chl-a maximum (characteristic of Drake Passage waters) were displaced to the north during Leg I, resulting in fewer stations located in typical Drake Passage waters.

(E) During Leg I, there was much variation in daily incident solar radiation due to cloud cover as shown by the data in Figure 2.6. Although light is often cited as one of the factors limiting primary production in polar seas, at the time of the AMLR cruises it apparently does not limit the rate of primary production in the upper mixed layer (UML), which generally contains over 50% of the total chl-a in the upper water column. The mean daily irradiance in Antarctic waters during Leg I was 41.4 Einsteins per square meter per day, which calculates out to a mean irradiance of approximately 638 microEinsteins per square meter per second (μEinsteins m^{-2} s^{-1}) incident upon the sea surface from sunrise to sunset. As the mean depth of the UML is close to 35m, and the 1% light level is usually at approximately 80m, the mean irradiance that cells in the UML will be experiencing is about 400μEinsteins m^{-2} s^{-1}. This value is well above the irradiance required to permit maximal photosynthetic rates, which is approximately 100μEinsteins m^{-2} s^{-1}. During Leg II, the mean daily incident solar irradiation was approximately 50% that for Leg I. This was partially the result of a reduced day length (about 30%) and partially due to increased storm activity and cloudiness.

(F) *In vivo* fluorescence measurements appear to be a reliable method to use in estimating the concentration of chl-a in the upper water column. By comparing the values of *in vivo* fluorescence at the same depths from which the water samples were obtained for measurement of extracted chl-a on the upcast of the CTD/carousel unit, it is possible to determine how good the correlation is between *in vivo* fluorescence and absolute chl-a concentrations. Data in Figure 2.7 show this relationship for all samples (Figure 2.7A) and individually for samples from 5, 10, 30, 50, and 100m (Figure 2.7B-2.7F, respectively). The r^2 values range from 0.72 to 0.95, with the most scatter evident in the samples from 5m. The reason for this is that solar radiation in the upper water column causes photoinhibition of chl-a fluorescence, resulting in less fluorescence per unit chl-a during daylight hours as compared to samples at night. The magnitude of this photoinhibition of chl-a fluorescence by solar radiation is maximal at or close to the surface and decreases rapidly with depth, so that there is little or no detectable effect at 10m depth. A derived algorithm is required to correct fluorescence measurements in the upper 10m of the water column to compensate for this photoinhibition of chl-a fluorescence by sunlight.

(G) Size-fractionation experiments indicated that the phytoplankton crop in the AMLR study area this year was composed predominately of very small cells. The average values for the percent of the total chl-a that passed through filters with pore sizes of 12.0, 8.0, 5.0, and 1.0µm were 60, 46, 42, and 22 %, respectively. Thus, most of the chl-a was contained in phytoplankton cells that are considerably smaller than the optimum size for efficient grazing by krill.

2.4 Disposition of the Samples and Data: The nutrient samples will be processed at the Universidad Catolica de Valparaiso (Chile). The radiocarbon samples will be 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 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 and equipment needed on the ship to do our work satisfactorily. We would, however, like to make the following suggestions:

(1) Comparison of the down and upcasts of the CTD/carousel unit shows that quality of the data on the upcast is often compromised as a result of the physical arrangement of the various instruments and sensors on the CTD/carousel unit. This makes it difficult for us to compare the continuous data acquired on the downcast with the data acquired at the depth at which the Niskin bottles are closed on the upcast. It would enhance the quality and utility of the data used by our program if this "mismatch" in the down and upcasts could be minimized with a different physical arrangement of the sensors on the CTD/carousel unit. (2) We have also acquired evidence this year that considerable horizontal patchiness may occur on very small scales, and for which our current sample routine at stations may be overlooking. This may be assessed in the future by increasing the frequency of automated sample measurement times of the continuous flow fluorometer. (3) Considerable spatial and temporal variability in water properties and phytoplankton distributions probably occurs during the course of the 2+ week large-area survey on each leg. Incorporation of satellite (SeaWIFs) remote sensing could provide the synoptic measures of surface temperature and chlorophyll needed to assess the extent of this variability over the AMLR study area.

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 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 Oceanographic group who meshed some of our instruments and sensors with their data acquisition systems. Special thanks are also due Frank Gomes for solving many instrument and computer problems so efficiently.

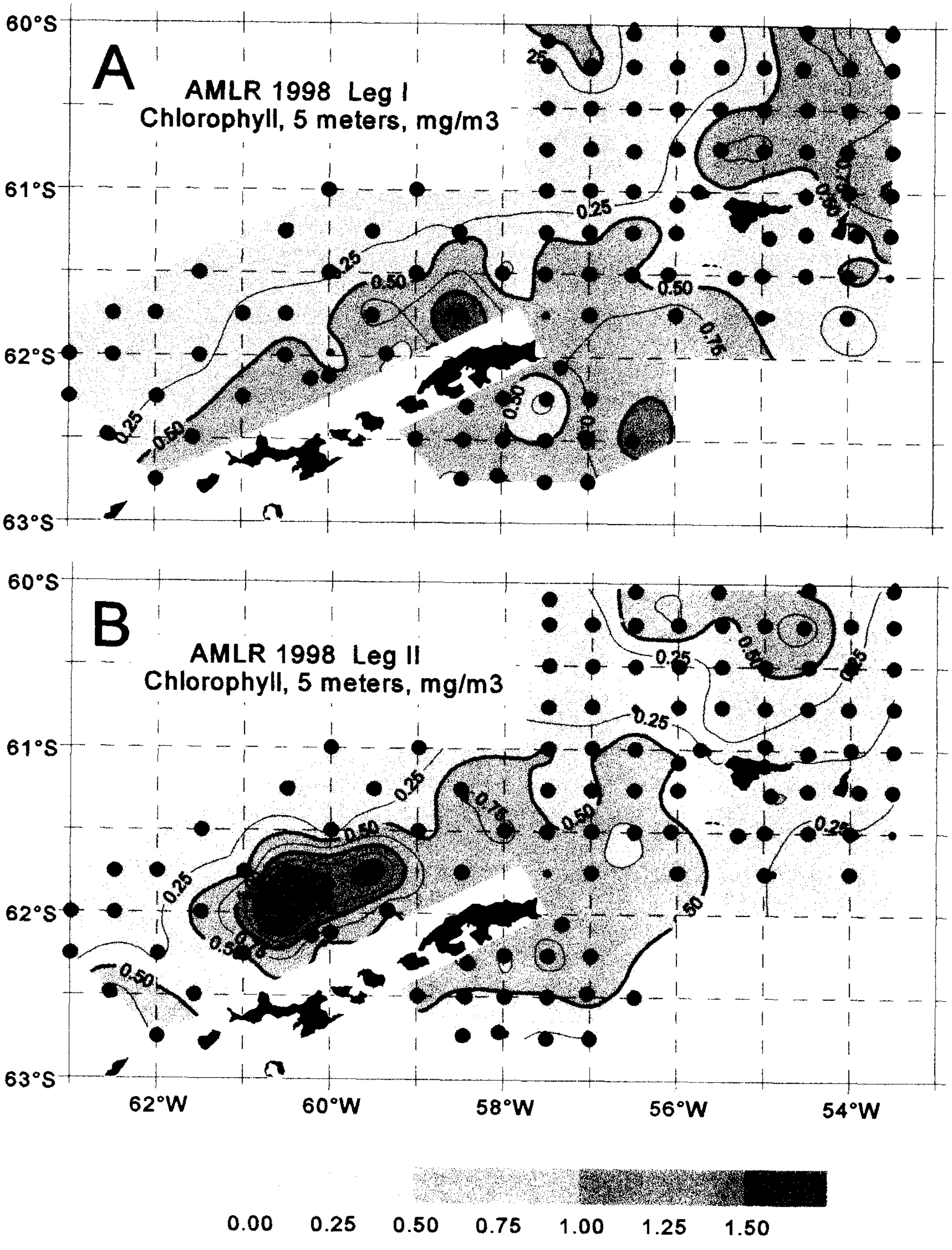


Figure 2.1 Concentration of chl-a at 5m depth throughout the large-area survey grid. (A) Survey A, Leg I; (B) Survey D, Leg II. The scale at the bottom refers to the chl-a concentrations in mg m^{-3}.

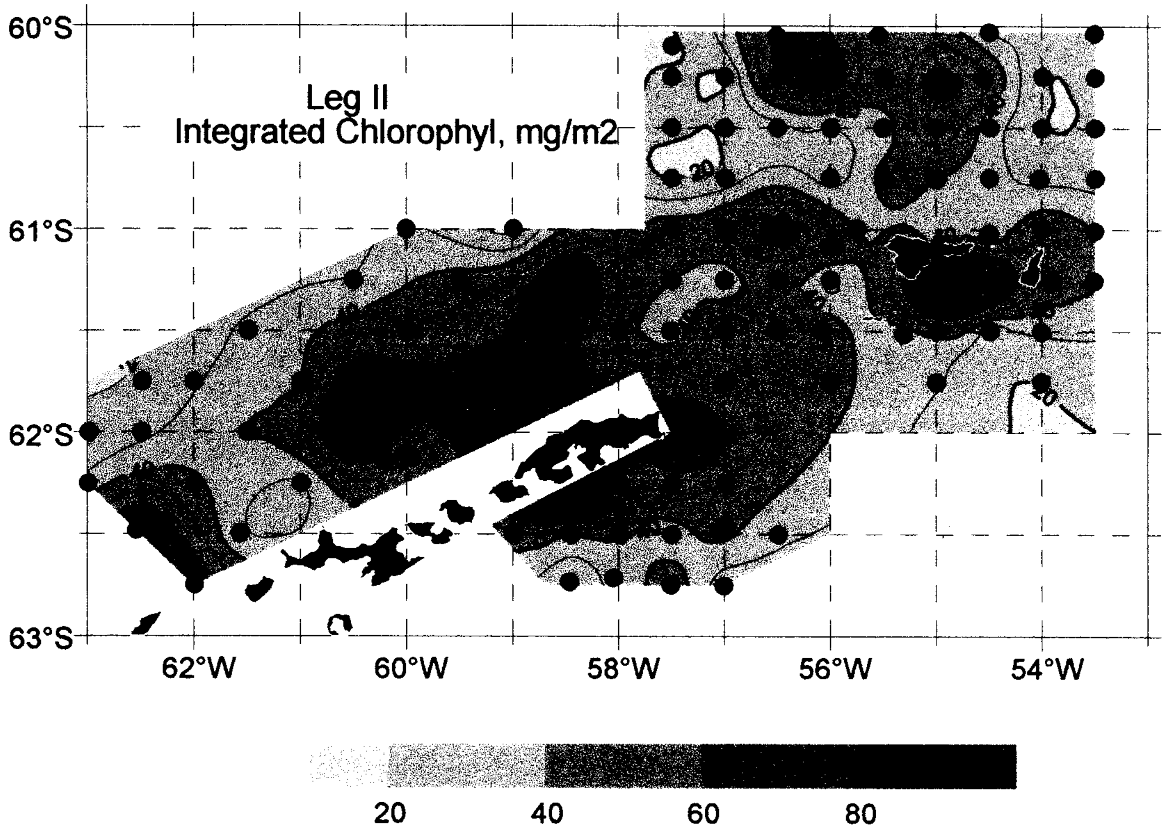


Figure 2.2 Integrated chl-a (mg m^{-2}, 0-200m) as contoured over the AMLR large-area survey grid during Leg II.

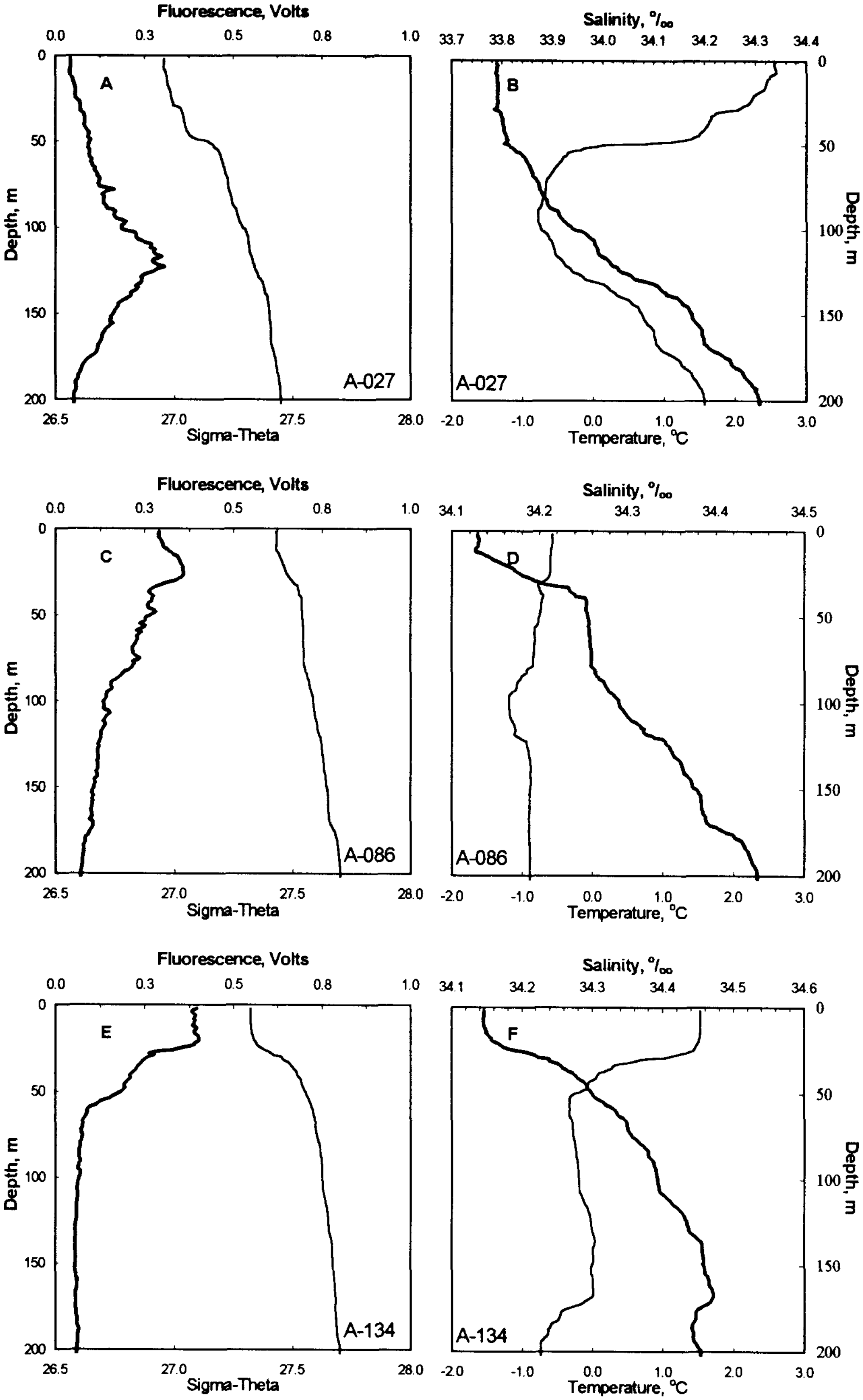
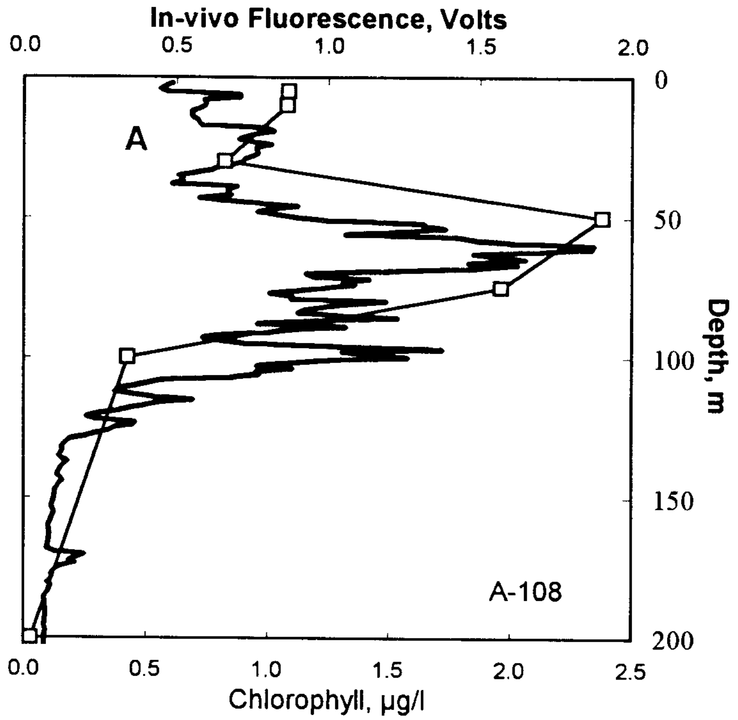


Figure 2.3 Data from three representative stations showing the differences in distribution of *in vivo* chl-a fluorescence and profiles of sigma-t in various regions of the large-area survey grid (Figures 2.3A, 2.3C, and 2.3E), and the profiles of temperature and salinity at these stations (Figures 2.3B, 2.3D, and 2.3F). Figures 2.3A and 2.3B are for Station A027; Figures 2.3C and 2.3D are for Station A086, and Figures 2.3E and 2.3F are for Station A134.



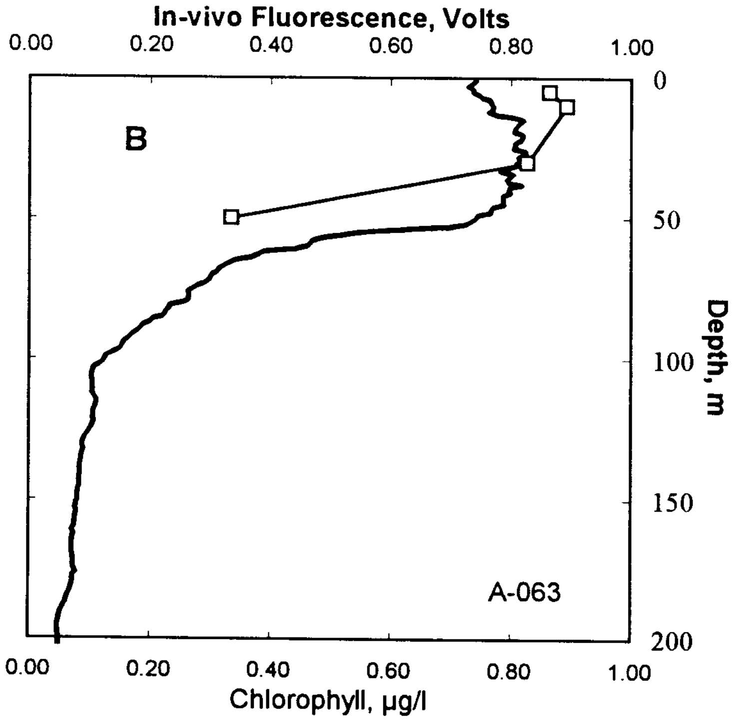


Figure 2.4 Contrasting depth profiles for *in vivo* chl-a fluorescence at two stations during Leg I. (A) Station A108; (B) Station A063.

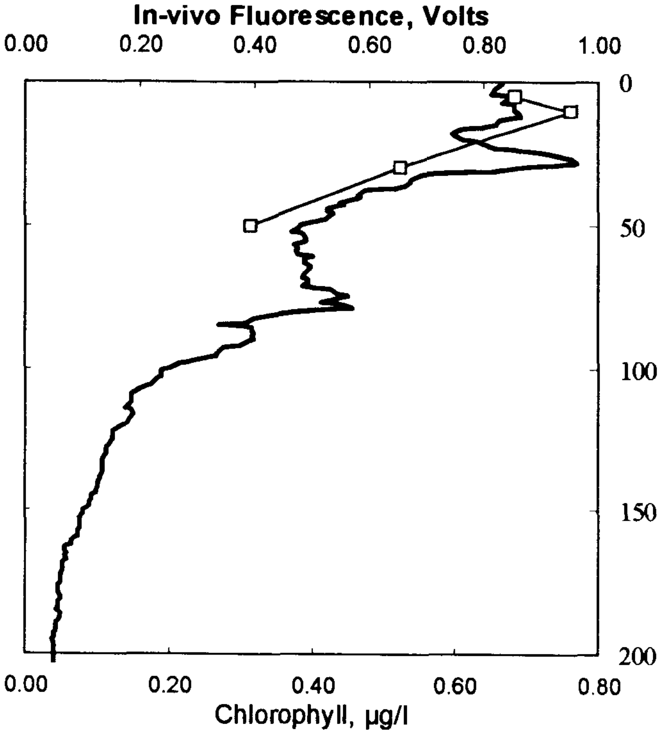


Figure 2.5 Profiles of *in vivo* chl-a fluorescence (thick line) and of extracted chl-a concentrations (thin line) at Station A024.

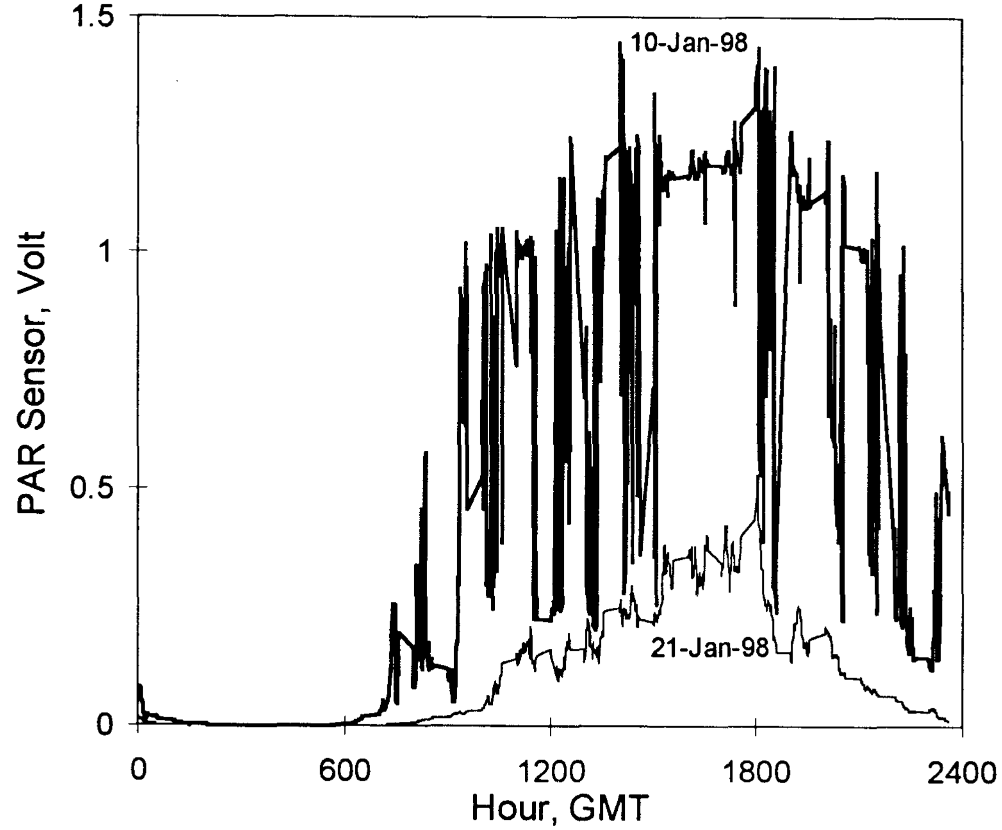


Figure 2.6 Daily pattern of incident solar radiation (400 to 700 nanometers) during Leg I, showing the irradiance for the sunniest day (10 January, 75 Einsteins per square meter from sunrise to sunset) and for the cloudiest day (21 January, 15.7 Einsteins per square meter from sunrise to sunset) . Much of the jaggedness of the curves is due to occasional shading of the light sensor by the ship's boom and superstructure.

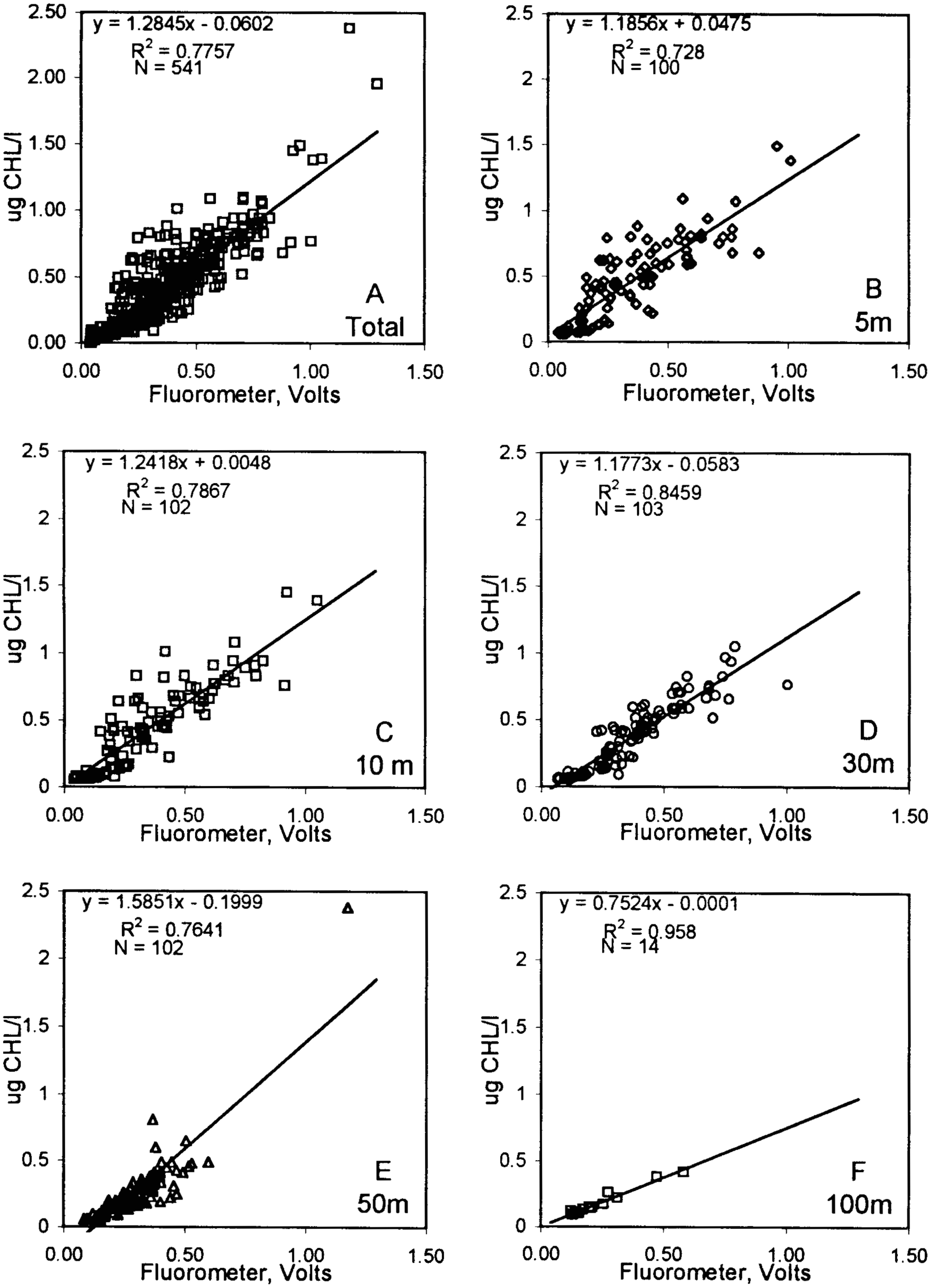


Figure 2.7 Relationship between *in vivo* chl-a fluorescence and extracted chl-a values for samples taken at various depths in the water column during the upcast of the CTD/carousel unit during Leg I. (A) All samples, 0 to 100m; (B) Samples from 5m; (C) Samples from 10m; (D) Samples from 30m; (E) Samples from 50m; (F) Samples from 100m.

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

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 scatters, qualitatively assess their distribution, and judge the type of bottom habitat (e.g. mud, sand, rock, etc.).

3.2 Methods and Accomplishments: Acoustic data were collected using a multi-frequency echo sounder (Simrad EK500) configured with downlooking 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 and off Cape Shirreff, Livingston Island, respectively. During the surveys, pulses were transmitted every 2 seconds at 1 kilowatt for 1 millisecond (ms) duration at 38kHz and 120kHz, and 0.6ms at 200kHz. Geographic positions were logged every 60 seconds. Ethernet communications were maintained between the EK500, a UNIX workstation, a Windows NT workstation, and two Windows 95 computers. The UNIX workstation (running Simrad BI500 software) was used for system control, data logging, and data post-processing, including interpretation of echograms, echo-integration, and target strength (TS) analyses. In parallel, acoustic data were also logged and processed on a Windows NT workstation running SonarData Echoview software. The latter system is under development and is intended to replace the UNIX based system for data logging and postprocessing in the future.

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. Processed data were passed to the Windows 95 computers for gridding and contouring of integrated volume backscattering strength. A 30x15 cell grid was imposed on the survey area and integrated volume backscattering values were interpolated at grid nodes using the method of triangular interpolation.

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

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

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

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

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

In-situ TS measurements were accurately recorded throughout the surveys using a new multiple-frequency method (Demer et al., submitted). The algorithm virtually eliminates measurements of unresolvable target multiples by rejecting echoes which are not mutually coherent at two or more echosounder frequencies. Differences in these three-frequency TS 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 (Demer and Martin, 1995).

Preliminary krill density estimates were calculated as the simple mean density from transects conducted in the Elephant Island area portion of the survey. This area is described in Figure 3 (see Introduction Section) as the "Elephant Island area" and is similar to areas used for estimating krill density during previous surveys.

Large-Area Surveys: Survey A (8-25 January, Figures 3.1a, 3.1b, and 3.1c) and Survey D (8-25 February, Figure 3.2a, 3.2b, and 3.2c) were conducted to map the meso-scale dispersion of krill in the vicinity of the South Shetland Islands, and to estimate the biomass of krill in a 41,673km^2 area centered on Elephant Island, a 34,149km^2 area to the west of the South Shetland archipelago (West area), and an 8,102km^2 area to the south of King George Island (South area). Each large-area survey consisted of approximately 4000km of acoustic transects conducted between 107 stations. Station work included a CTD/carousel cast and an IKMT plankton tow. Using the methods described in Jolly and Hampton (1990), mean krill density for the Elephant Island area was calculated from 9 north-south transects with 27.8km (15 n.mi.) spacing between lines. The mean krill densities for the West and South areas were calculated similarly, including each of the longer transects as an independent estimate of krill density.

Transects: During Leg I, additional acoustic transects were conducted while transiting in and out of Admiralty Bay (8 January), during a series of CTDs conducted across the frontal zone north of the South Shetland Islands (26 January), and while crossing Drake Passage (2 and 30 January). During Leg II, additional acoustic transects were conducted in the foraging areas of tagged female fur seals near Cape Shirreff (26-28 February) and during a repetition of the aforementioned CTD transect (2-3 March). During Leg III, acoustic data were collected continuously during the bottom trawling operations as well as during bottom recognizance transects (12 March to 3 April).

3.3 Tentative Conclusion:

Large-Area Surveys: Survey A mapped high concentrations of krill along and immediately downstream of a bathymetric shoal to the northwest of Elephant Island (Figure 3.1b). Additional high-density areas were found circa the shelf-break to the north of Livingston Island, to the northeast end of King George Island, and to the south of Nelson's Passage in Bransfield Strait. Higher levels of integrated volume backscattering strength at 38kHz (Figure 3.1a), compared to 120kHz (Figure 3.1b) and 200kHz (Figure 3.1c), were mapped along the shelf-break to the north of the South Shetland Islands and are thought to be associated with scattering from myctophid fish. Efforts to confirm this theory using directed net sampling (MOCNESS and IKMT) and underwater video observations (Neptun system) were inconclusive; the nets were ineffective at capturing fish and opportunistic deployment of the Neptun video system was precluded due to inclement weather conditions. Moreover, the development of an objective and robust algorithm for apportioning the integrated volume backscattering strengths to krill versus the other species resident in the area continues to be a challenge.

In the Elephant Island area, the krill biomass estimate from Survey D was lower than that of Survey A by 43% (Table 3.1). High krill densities were found in the northeast corner of the grid, surrounding Gibbs Island to the southwest of Elephant, and in the southeast corner of the South area. In the West area, high krill concentrations were again mapped along the shelf-break to the north of the archipelago. It is conceivable that the inter-survey distributional changes resulted from a transport of the zooplankton biomass to the northeast with the prevailing currents (compare Figure 3.1b and 3.2b). The relatively small distributional changes at 38kHz (Figures 3.1a and 3.2a) are consistent with this hypothesis and the aforementioned hypothesis that dominant scattering at 38kHz is from nekton.

Transects Across Front: The cross-front transect echogram from Leg I (Figure 3.3) was consistent with the prevailing pattern of dominant scattering in the Elephant Island area which follows a band, just north of the archipelago, extending from the southwest to the northeast (see Figure 3.1b). (See Figure 4 in the Introduction Section for locations of stations in the cross-front transect.) This feature is roughly coincident with both the shelf-break and with a persistent but variable frontal zone. Krill in the area tend to reside in the upper 50m, frequently near the thermocline and above water circa 0 °C. Myctophids may be associated with circumpolar deep water and their residence in the Elephant Island area may be influenced by the advance and retreat of the warm water dome.

Density Estimates: Estimates have been derived for krill density and biomass in the Elephant Island area for the austral summers of 1992 to 1998, excluding 1993 (Table 3.1). This time series suggests a 6-year periodicity in the krill density circa Elephant Island and indicates rapid declines in the population (intra-1992 and 1998) compared to the more gradual increases (1994-1997); data from additional years will be required to corroborate the consistency of this cycle (Figure 3.4). The population reached a 7-year low in 1994. Conversely, the 7-year high in 1997 was the result of recruitment from a strong 1995 year class.

3.4 Disposition of Data: Integrated volume backscattering data will be made available to other investigators in MS-DOS or UNIX (Sun-OS) format ASCII files. The analyzed echo-integration data, averaged over 0.1852km (0.1 n.mi.) intervals, consumes approximately 10 Mbyte. The data are available from David Demer, Southwest Fisheries Science Center, 8604 La Jolla Shores Drive, La Jolla, CA 92037; phone/fax - (619) 546-5603/546-5608; internet: ddemer@ucsd.edu.

3.5 References:

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Jolly, G.M. and I. Hampton. 1990. *Can. J. Fish Aquat. Sci.* 47:1282-1291.
Siegel, V. 1986. *Arch. FischWiss.* 37: 51-72.

Table 3.1 Mean krill biomass density for surveys conducted from 1992 to 1998. 1993 estimates were omitted due to system calibration uncertainties. 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.

Survey	**Mean Density (g/m^2)**	**Area (km^2)**	**Biomass (10^3 tons)**	**CV**
1992				
A (late Jan large-area)	61.20	36,271	2,220	15.8%
D (early Mar large-area)	29.63	36,271	1,075	9.2%
1994				
A (late Jan large-area)	9.63	41,673	401	10.7%
D (early Mar large-area)	7.74	41,673	323	22.2%
1995				
A (late Jan large-area)	27.84	41,673	1,160	12.0%
D (late Feb large-area)	35.52	41,673	1,480	24.2%
1996				
A (late Jan large-area)	80.82	41,673	3,368	11.4%
D (early Mar large-area)	70.10	41,673	2,921	22.7%
1997				
A (late Jan large-area)	100.47	41,673	4,187	21.8%
1998				
A (late Jan large-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 Feb large-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%

* See Figure 3 in the Introduction Section for descriptions of each survey area.

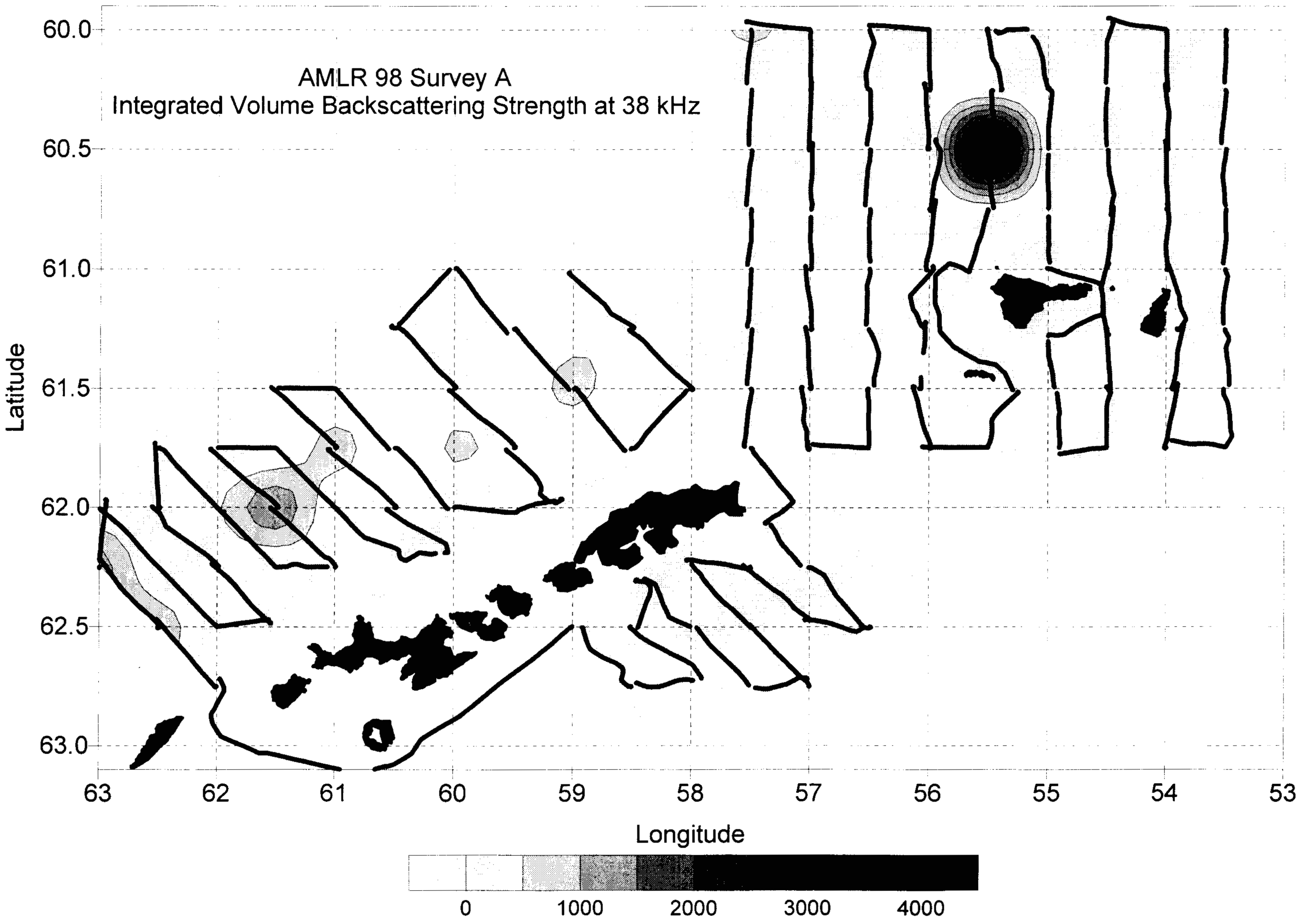

Figure 3.1a Integrated volume backscattering strength at 38kHz for Survey A (Leg I). Transect lines are indicated but not station positions.

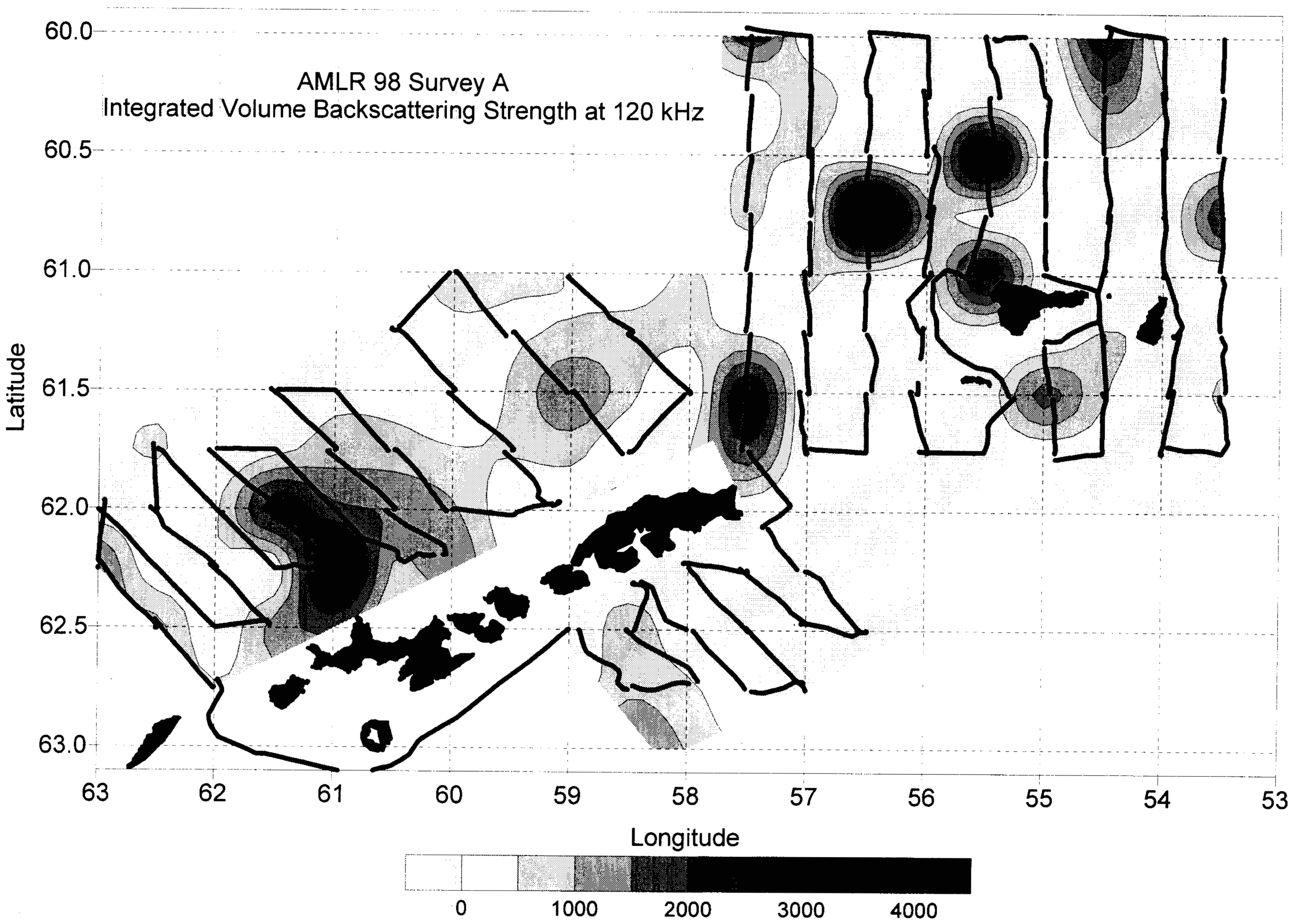

Figure 3.1b Integrated volume backscattering strength at 120kHz for Survey A (Leg I). Transect lines are indicated but not station positions.

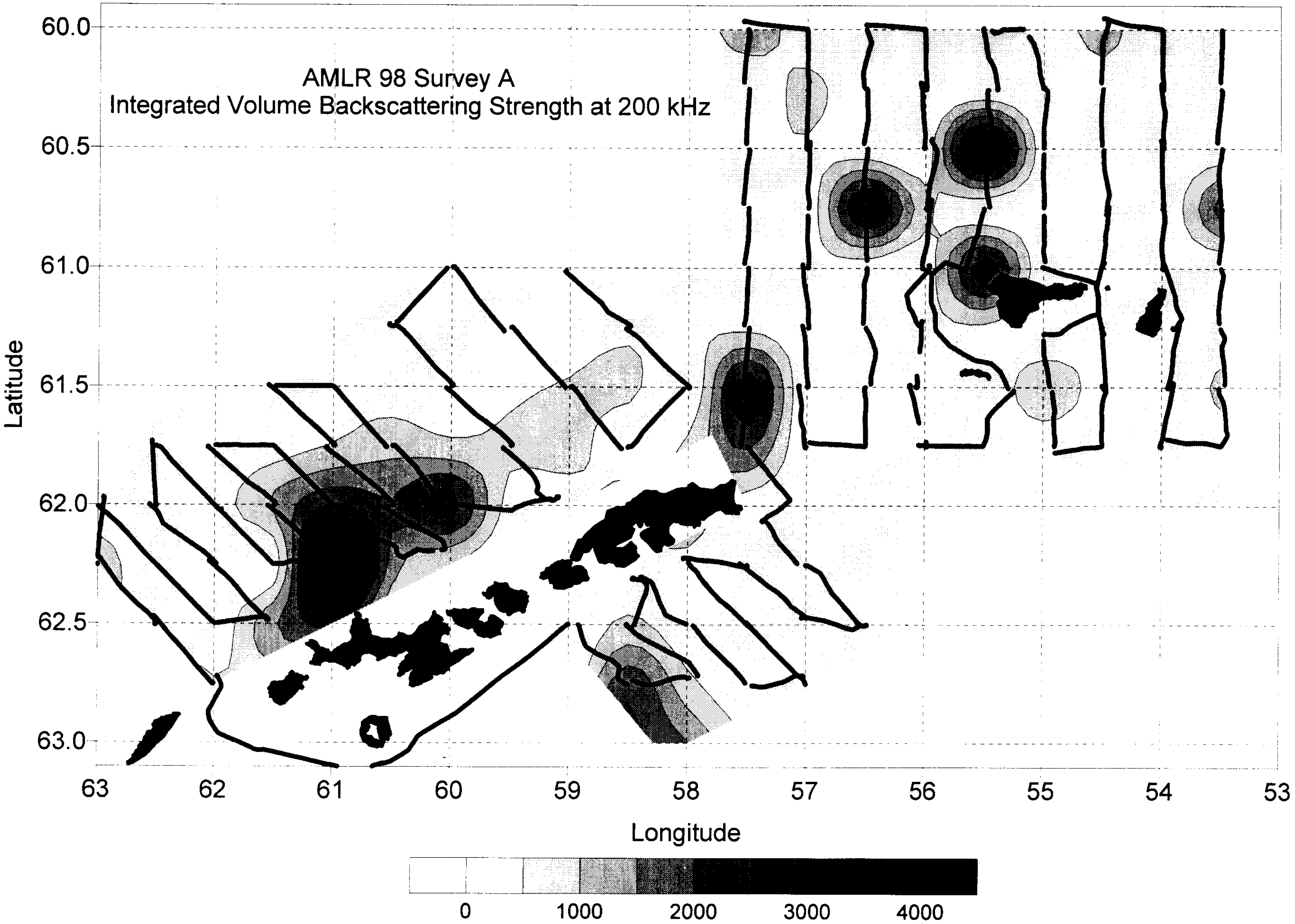

Figure 3.1c Integrated volume backscattering strength at 200kHz for Survey A (Leg I). Transect lines are indicated but not station positions.

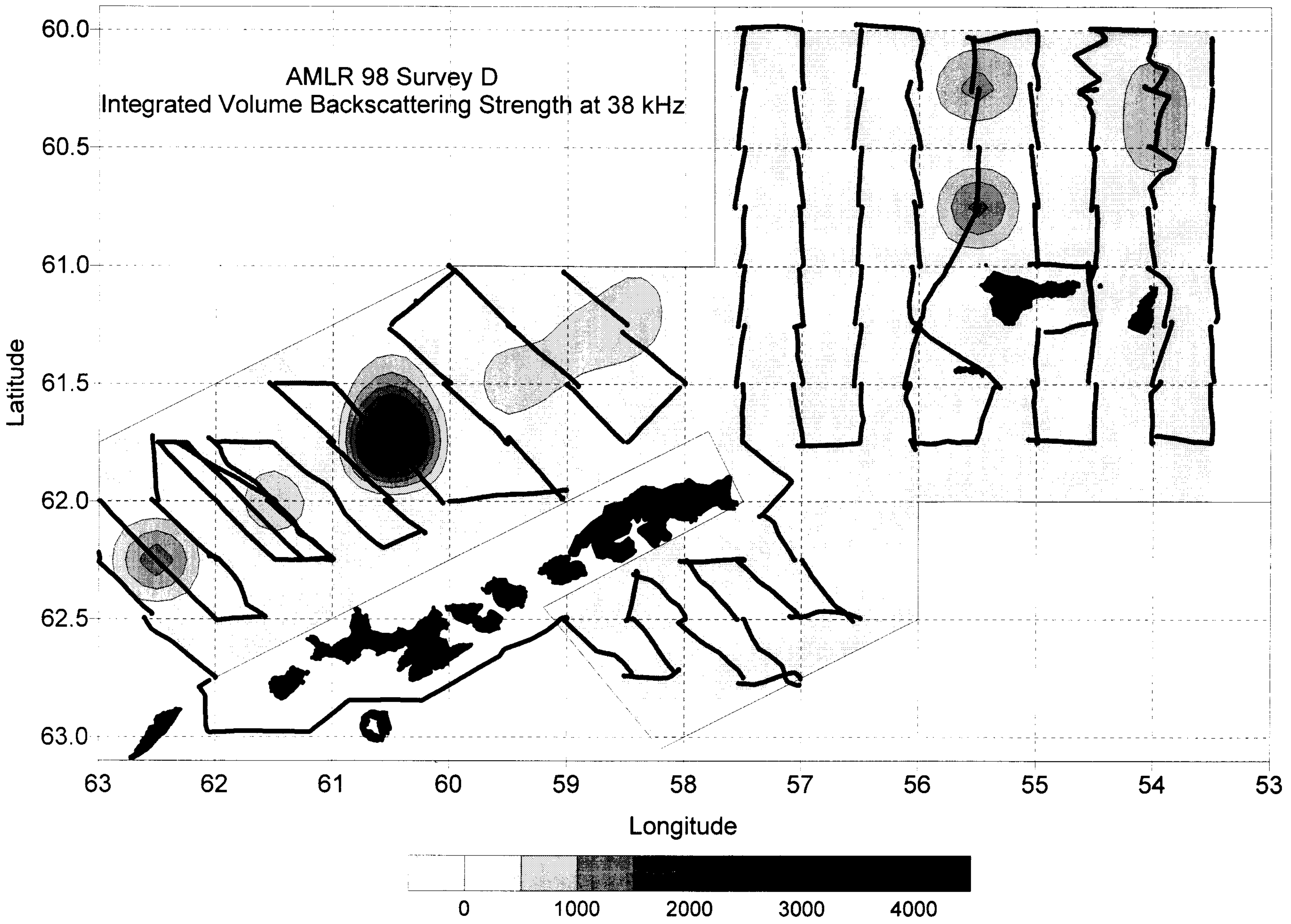

Figure 3.2a Integrated volume backscattering strength at 38kHz for Survey D (Leg II). Transect lines are indicated but not station positions.

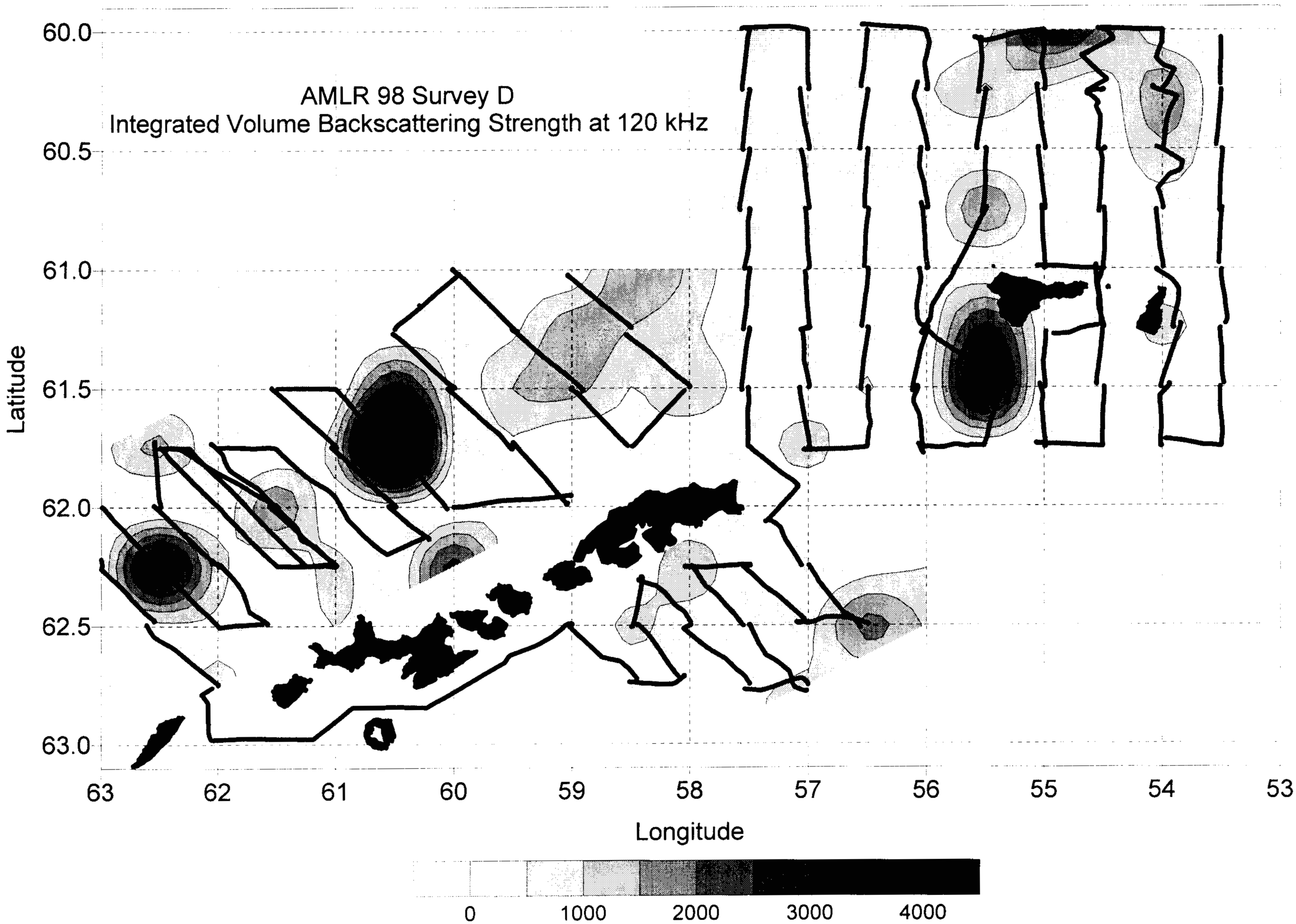

Figure 3.2b Integrated volume backscattering strength at 120kHz for Survey D (Leg II). Transect lines are indicated but not station positions.

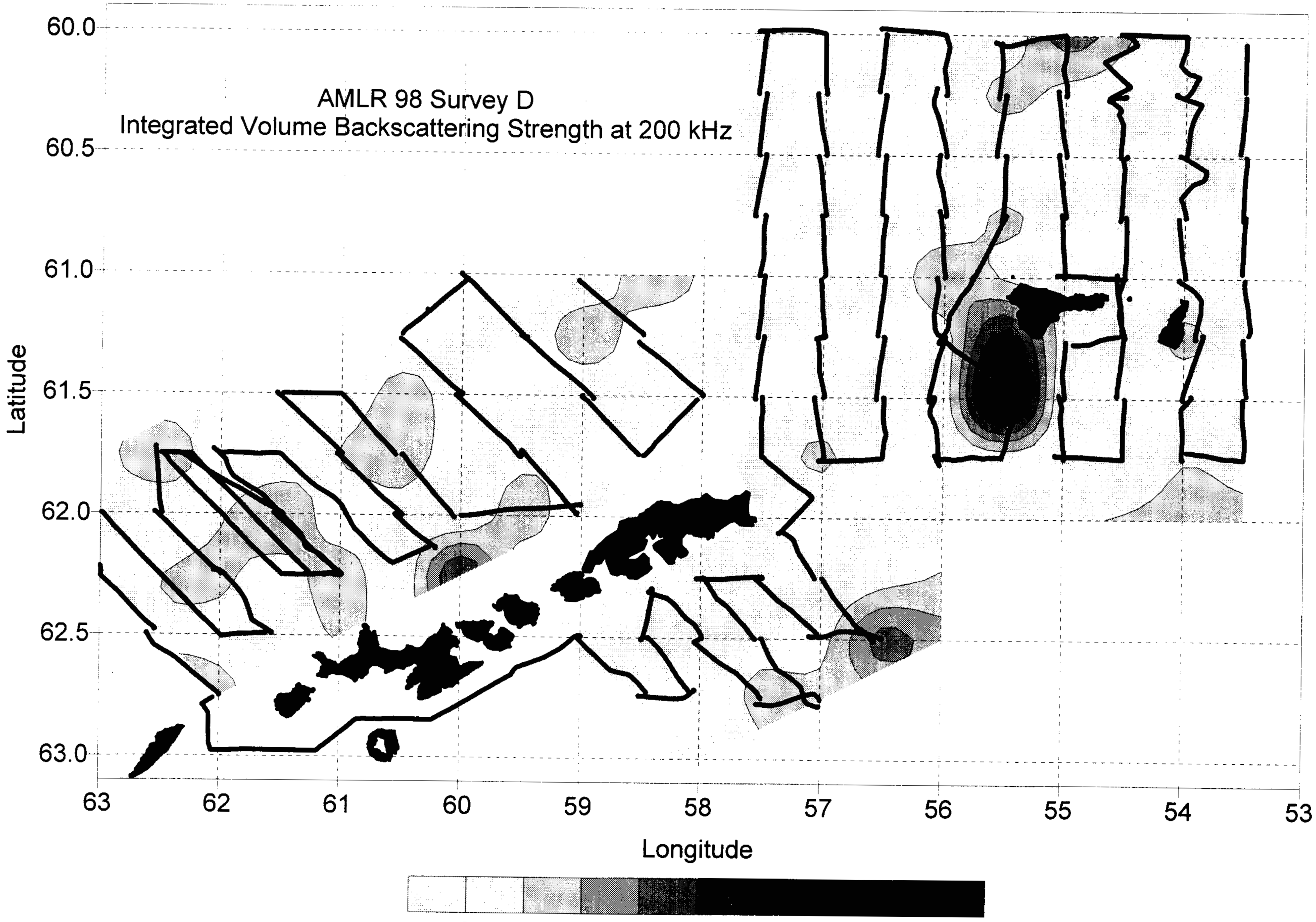

Figure 3.2c Integrated volume backscattering strength at 200kHz for Survey D (Leg II). Transect lines are indicated but not station positions.

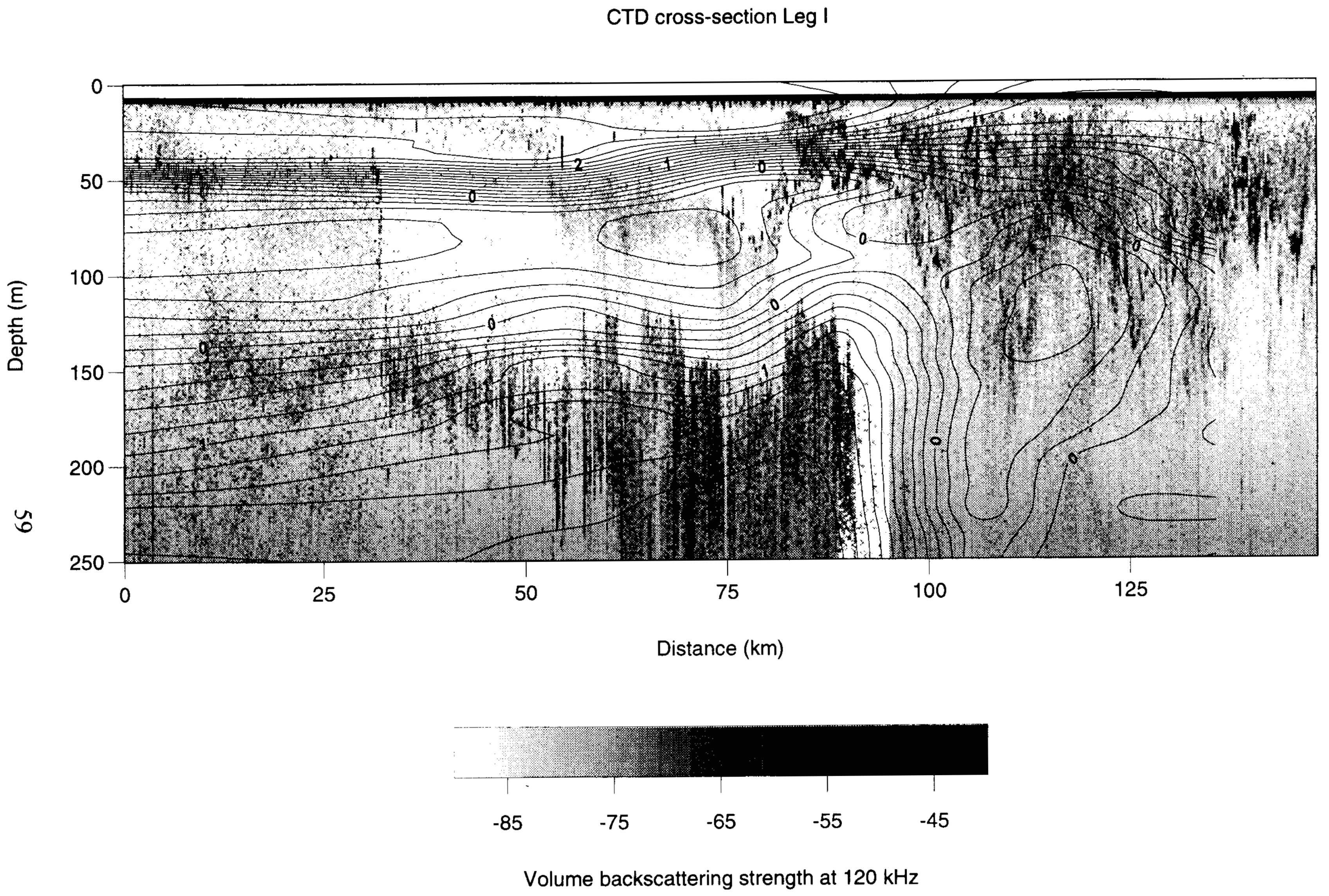

Figure 3.3 Acoustic cross-section during a series of CTDs conducted across the frontal zone north of the South Shetland Islands during Leg I (Stations X002-X009).

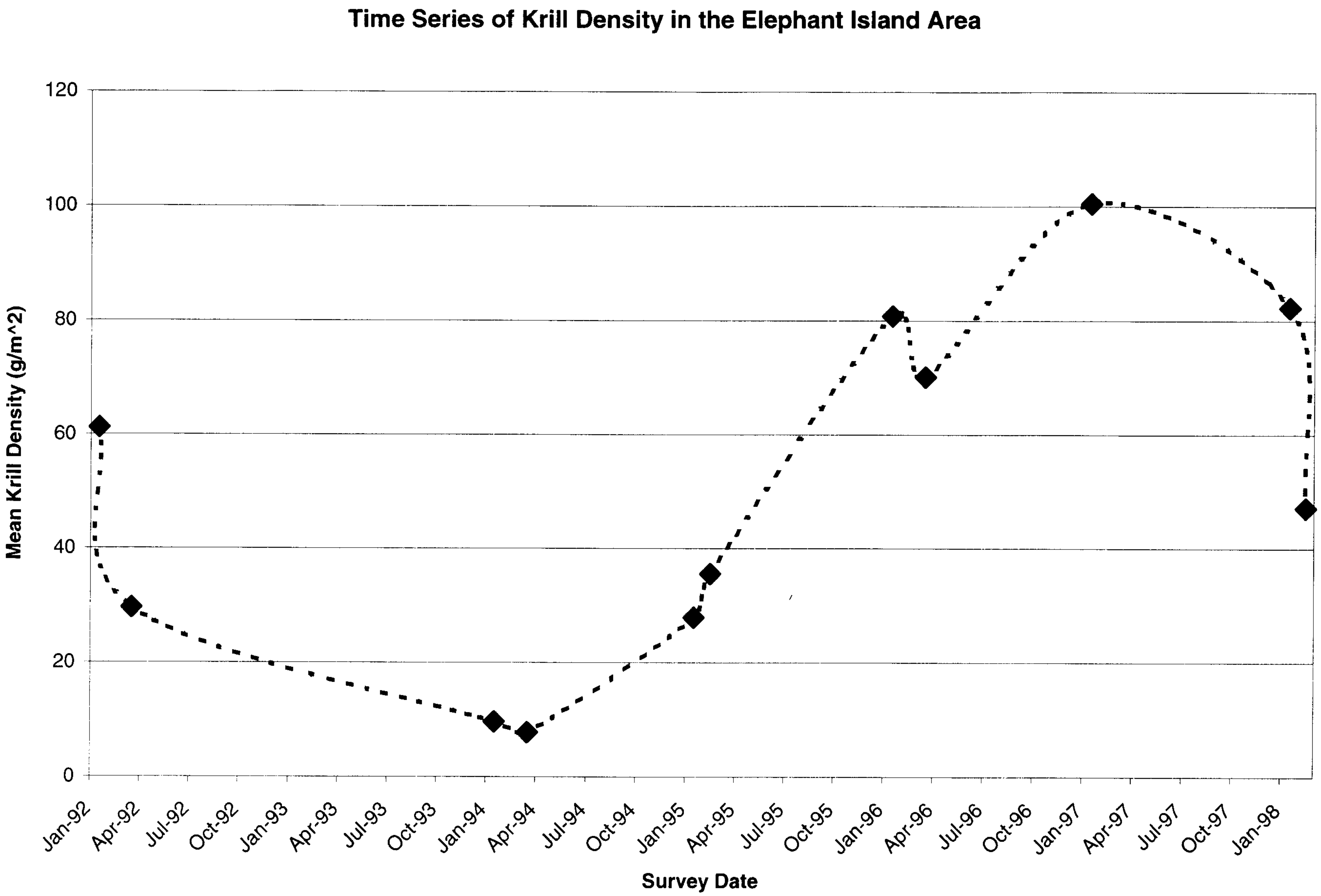

Figure 3.4 Time series of krill density in the Elephant Island area from austral summer 1991/92 to 1997/98. As a visual aid, the data were connected using a cubic spline interpolate. Data from 1993 were omitted due to uncertainty in the system calibration and other equipment parameters.

4. Direct krill and zooplankton sampling; submitted by Valerie Loeb (Legs I and II), Wesley A. Armstrong (Legs I and II), Rachel Johnson (Legs I and II), Elizabeth Linen (Legs I and II), Michael Force (Legs I and II), Charles F. Phleger (Leg I), Volker Siegel (Leg I), Kimberly Dietrich (Legs II and III), and Matthew M. Nelson (Leg II).

4.1 Objectives: The objective of this work was to provide information on the demographic structure of Antarctic krill (*Euphausia superba*) and the abundance and distribution of salps and other zooplankton components in the vicinity of Elephant, King George, and Livingston Islands. Essential demographic information for krill 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 (*Salpa thompsoni*) received special attention because of its hypothesized influence on the distribution, behavior, and recruitment success of krill. Results from the Elephant Island area are compared to those from previous AMLR surveys to assess between-year differences in krill demography and zooplankton composition and abundance over the 1992-1998 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. During Leg I, a modified nekton net with 2 millimeter (mm) stretch mesh was utilized at two stations (A065 and A066) while the plankton nets were being repaired; only krill and salp data were derived from those stations. 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 to a depth of 170 meters (m) or to ca. 10m above bottom in shallower waters. Tow depths were derived from a depth recorder mounted on the trawl bridle and monitored in the acoustics lab. Tow speeds were ca. 2 knots. Samples were collected at large-area survey stations during both cruise legs (see Figure 3, Introduction Section). Three regionally distinct groups of stations are considered here (see 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 represent the new AMLR survey area west of King George and Livingston Islands; these stations form a data base with which to examine the abundance and age/maturity/length composition of krill stocks available 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.

Directed Sampling.

During Leg II, sampling was done with a Multiple-Opening-Closing-Net-Environmental-

Sampling-System (MOCNESS) to determine the source of acoustically detected targets and to describe the vertical distribution patterns of salps within the upper 200m. Four opening/closing nets were fished within desired depth strata. The 1 m^2 nets were fitted with 505μm mesh. Because of electronic problems, flow volumes were not available for these tows. Tow speeds were ca. 2 knots. One night tow was made at acoustics targets in the vicinity of Station D116. The depths fished here were 284-275m, 185-175m, 185-168m, and 50-45m. One twilight and one day vertically stratified tow were made near Station D160 in shelf waters off Cape Shirreff. Depths fished were 190-140m, 140-90m, 90-40m, and 40-0m. No 140-90m sample was available from the day tow because of a lost cod-end.

Shipboard Analyses.

All net samples were processed on board using fresh material. Krill demographic analyses were made using fresh or freshly frozen specimens. The other zooplankton analyses were made 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 entire large-area survey.

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

(2) Salps: All salps were removed from samples of 2 liters or less and enumerated. For larger catches, the numbers of salps in 1-2 liter subsamples were used to estimate abundance. For samples with $\leq$100 individuals, the two salp life stages (aggregate/sexual and solitary/asexual) were enumerated and the internal body length was measured to the nearest millimeter (Foxton, 1966). Representative subsamples of >80 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 from the samples, the remaining zooplankton fraction was analyzed. If the catches were large, zooplankton in subsamples of 1-3 liters were quantified. All of the larger organisms (e.g., other euphausiids, amphipods, pteropods, polychaetes) were sorted, identified to species if possible, and enumerated. Following this, the smaller constituents (e.g., copepods, chaetognaths, euphausiid larvae) were enumerated using dissecting microscopes. This fraction typically represented 5-20% of the total sample which is comparable to small fraction aliquots examined during the 1995-97 surveys. 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:

(I) Leg I, Survey A

(1) Krill: Krill occurred in 92% of the samples from both the Survey A area and Elephant Island subarea (Table 4.1A). Largest catches (182-493 per 1000 m^3) were made in the West and South areas (Figure 4.1A). Within the Elephant Island area, three of the four densest krill concentrations (144-166 per 1000 m^3) occurred north of the island and one (175 per 1000 m^3) was to the southwest. Mean krill abundance in the Elephant Island area (27.1 per 1000 m^3) was lower than in the West and South areas (respectively, 56.0 and 40.7 per 1000 m^3). Median krill abundance in the Elephant Island area (10.2 per 1000 m^3) was intermediate to that in the West area (15.1 per 1000 m^3) and South area (3.6 per 1000 m^3) and approximated that of the entire survey area (10.7 per 1000 m^3). The similarity of median values in the three subareas reflects the rather even distribution of krill catches across much of the large-area survey.

Krill lengths ranged from 15 to 54mm (Figure 4.2A). Bimodal length distributions were represented in all three areas (Figures 4.2B-4.2D). Lengths centered around 22-25mm and 33-45mm size modes correspond to 1 year old (i.e., the 1996/97 year class) and a mix of 2 and 3 year old individuals (1995/96 and 1994/95 year classes). Older krill (4+ years) were virtually absent as indicated by few individuals larger than 50mm. The larger size mode numerically dominated in all cases, but the modal characteristics differed from area to area. Elephant Island area krill were predominantly 39-46mm in length (3 years old, 49%), with a minor contribution by 24-26mm sizes (7%). Smaller krill occurred in the West area where the modes were 35-39mm (2 years old, 34%) and 21-23mm (10%). The two length modes were closest together in the South area where 1-2 year old krill of 32-37mm (51%) and 23-26mm (11%) lengths predominated. Data from Wayne Trivelpiece indicate that the diets of krill predators at Cape Shirreff (25 stomach content samples of chinstrap penguins) show a fairly good correspondence with the length composition of krill in the West area (Figure 4.2C) (Trivelpiece, pers. comm.) Data from 75 samples (Adelie, gentoo, and chinstrap penguins) in Admiralty Bay indicate that they had fed upon a broader size range and larger krill than were characteristic of the adjacent South area (Trivelpiece, pers. comm.) (Figure 4.2D).

The majority of krill collected during Survey A represented immature (41%) and sexually mature (35%) stages; juveniles contributed 24% of the total (Table 4.2). Areal differences in maturity stage composition correspond to the different length frequency distributions (Figure 4.2B-4.2D). Greatest proportions of mature krill (50%) occurred in the Elephant Island area, while those of juvenile (36%) and immature stages (56%) occurred in the South area. Immature (44%) and juvenile (26%) stages predominated in the West area. Relatively few (22%) of the mature females collected during Survey A had mated. Only small proportions had spermatophore packets attached to the thelycum (stage 3b), ovarian development (3c), were gravid (3d), or spent (3e). Most of the reproductively active individuals were collected in the Elephant Island area (Table 4.2), but here only 6% of the mature females were in advanced maturity stages (3c-3e). Presence of calyptopis and furcilia larvae in occasional samples indicate that some spawning occurred during December and early January, but their mean abundance was relatively low (1 per 1000 m^3). These results suggest a late peak spawning period.

The between-area differences in krill length and maturity composition result from distributional differences of the different length-maturity stages (Siegel 1988). Cluster analysis performed on length frequency distributions of krill (≥ 17 individuals per sample) resulted in three clusters (Figures 4.3A and 4.3B). Cluster 1 was composed primarily of krill smaller than 40mm. These included juveniles (39%) with a 22-23mm length mode and 2 year old immature krill (48%) with a 35mm length mode. Cluster 3 was composed primarily of mature krill (79%) with a 45mm length mode (3 year old); juveniles comprised only 4 % of this cluster. Cluster 2, with lengths centered around a 39mm mode, represented a mixture of 2 year old krill (immature and mature stages) with krill from Clusters 1 and 3. Overall distributional patterns of the length-maturity stages (Figure 4.4A) is typical for the area (Siegel 1988). Small juvenile and immature Cluster 1 krill occurred to the south, primarily in Bransfield Strait and Drake Passage water adjacent to the Shetland Islands. Large mature Cluster 3 krill occurred in oceanic waters of Drake Passage. The mixed krill of Cluster 2 occurred between these two groups.

(2) Salps: *Salpa thompsoni* was present in every sample collected in the large-area survey. With mean and median abundances of 808.2 and 323.7 per 1000 m^3, respectively, this was the numerically dominant zooplankton taxon (Tables 4.1A and 4.3). These salps occurred in abundance throughout the entire survey area, although densities were greatest across the Elephant Island area where the median catch was 348.9 per 1000 m^3 compared to 190.1-194.4 per 1000 m^3 across the South and West areas. Highest densities (to 4800 per 1000 m^3) were primarily located north, east, and south of Elephant Island, although large catches (from 3500-9400 per 1000 m^3) were also made in the South and West areas (Figure 4.5A). Over 92% of the individuals collected were the chain forming aggregate stage. Production of this stage by overwintering solitary stage individuals may, under benign conditions, lead to massive salp population blooms during spring and summer months (Foxton 1966). Apparently conditions during 1997/98 were highly favorable for salp production.

While most of the solitary stage salps were large (e.g., 60-180mm internal body length), 99% of the aggregate individuals were $\leq$45mm and 66% were <35mm in length (Figure 4.6A). Cluster analysis on the salp length frequency distributions in each sample resulted in three distinct size-age groups (Figure 4.6B). Cluster 1 salps were small, with 90% between 4-13mm. These represent newly released aggregate chains probably less than 2-3 weeks in age, based on an estimated growth rate of 14mm per month (Loeb et al., submitted). Cluster 3 salps were relatively large, with 90% between 20-50mm in length and a peak centered around 28-33mm. These salps were probably released up to ca. 3 months ago (i.e., mid- to late October) with peak production in late November. Cluster 2 salps had an intermediate size range, with 80% between 10-33mm. These salps demonstrated length modes of 10-13mm, 20mm, and 25mm and probably result from pulses of production over the past 6 weeks (i.e., from mid-December on). Intermediate size Cluster 2 salps were distributed over much of the large-area survey, while the other two groups had more limited distributions (Figure 4.7A). Small, recently budded Cluster 1 salps occurred mostly in the West area, especially north of King George Island. The large Cluster 3 salps occurred in the western and eastern portions of the Elephant Island area.

(3) Zooplankton and Micronekton Assemblage: A total of 65 taxonomic categories were identified in the Survey A samples (Table 4.3). As stated above, *S. thompsoni* was by far the numerical dominant in the entire survey area and each subarea.

Postlarvae of the euphausiid *Thysanoessa macrura* also occurred in all samples and ranked second in overall abundance with a mean of 180.8 per 1000 m^3; the maximum concentration was 3900 per 1000 m^3. Greatest concentrations extended in a band north of the South Shetland Islands and west of Elephant Island (Figure 4.8A). Mean concentrations were highest in the West area (313 per 1000 m^3), followed by the Elephant Island (135 per 1000 m^3) and South areas (119 per 1000 m^3). Greatest frequency of occurrence and largest median value were in the Elephant Island area (Table 4.3). The overall abundance pattern was similar to that of *S. thompsoni* as indicated by a significant ($P = 0.003$) correlation of abundance (Kendall's Tau test). The *T. macrura* size distribution shows a modal length of 15mm. This mode is similar to that observed in 1995 (Figure 4.9); however, individuals smaller than 10mm (i.e., juvenile stages) were not collected in the 1998 Survey A samples. Because spawning occurs in August-September (late winter), all mature individuals were in the post-spawning resting stage. Furcilia stage *T. macrura* larvae are typically present in January. The paucity of these larvae during Survey A suggests delayed spawning and/or poor spawning success during 1997. The absence of very large specimens (e.g., ≥30mm) can be explained by the late winter spawning season and subsequent mortality of the oldest age group. Cluster analysis performed on the length frequency distributions at each station produced two distinct size clusters, but these did not demonstrate any coherent geographical distribution pattern.

Vibilia antarctica, an amphipod commensal with *S. thompsoni* (Madin and Harbison, 1977), occurred in all but four samples and, with mean abundance of 13.2 per 1000 m^3, ranked sixth overall (Table 4.3). As with *S. thompsoni*, *V. antarctica* was most frequent in the Elephant Island area where it occurred in all of the samples; the abundance there was significantly higher than in the South area (ANOVA, $P=0.04$). Copepods were relatively frequent in samples and ranked third in overall mean abundance (56.5 per 1000 m^3). Largest and smallest copepod concentrations occurred in the South and Elephant Island areas, respectively. Postlarval krill comprised the fifth most frequent and abundant taxon in the large-area survey.

While a second Southern Ocean salp species, *Ihlea racovitzai*, was noted only in six samples, its mean abundance was 41.5 per 1000 m^3 and so it ranked fourth in overall abundance (Table 4.3). This species was identified only after a large number of solitary and aggregate stage individuals were collected at Station A082 where they constituted 91% of the salp catch. The species was more abundant at Station A083 (3286 per 1000 m^3) but co-occurred with a large number of *S. thompsoni* and so constituted only 43% of the total salps. Thereafter, *I. racovitzai* was identified at four more stations in the eastern Elephant Island area (Stations A085, A086, A087 and A090). *Ihlea racovitzai* is a cold water circumpolar species confined to waters south of the Antarctic convergence (Foxton 1971). Although its distribution overlaps with that of *S. thompsoni*, maximum densities of *S. thompsoni* occur in the middle latitudes (45°-55°S), while those of *I. racovitzai* occur at higher latitudes. In the Atlantic sector *I. racovitzai* is distributed in both the West Wind and East Wind drift, while *S. thompsoni* is excluded from the East Wind drift. Foxton's (1971) distribution map of *I. racovitzai*, based on the Discovery Expedition material, indicates that while it was quite abundant north and east of the Weddell Sea it was rarely collected west of 45°W, and so was not a regular member of zooplankton assemblages in the Antarctic Peninsula region. Obviously the surface circulation pattern during summer 1998 resulted in the advection of this species, possibly through a southwestward deflection of the Weddell drift. The co-occurrence of *I. racovitzai* and Cluster 3 *S. thompsoni* at four of the six stations where *I. racovitzai* were identified suggests that the large-sized *S. thompsoni* were advected from the same source waters to the northeast.

It is possible that *I. racovitzai* has become a regular, but typically minor, component of salp catches in the Antarctic Peninsula region in years since the Discovery Expeditions. If so, those specimens in the AMLR collections have previously been misidentified as damaged *S. thompsoni* due to the extremely delicate nature of the gelatinous test (Foxton 1971). Also, because of their poor condition, probably few of these animals have been used for salp length measurements. The solitary form of *I. racovitzai* in our samples was represented by 49-52mm lengths, while the aggregate individuals were mostly 17-27mm.

Other relatively frequent taxa occurring in ≥33% of the samples were chaetognaths, the pteropods *Limacina helicina, Spongiobranchae australis*, and *Clione limacina*, amphipods *Cyllopus magellanicus* and *Hyperiella dilatata*, ostracods, and the siphonophore *Diphyes antarctica* (Table 4.3). Chaetognaths were significantly more abundant in the West area compared to both the Elephant Island and South areas (ANOVA, $P < 0.01$ in both cases). Like *S. thompsoni, V. antarctica* was most frequent in the Elephant Island area (64% of samples); this amphipod had significantly higher abundance in the Elephant Island vs. West area (ANOVA, $P < 0.01$). Ostracods and *Diphyes antarctica* both were significantly more abundant in the South vs.. other areas (ANOVAs, $P < 0.05$). Two typically frequent taxa in AMLR collections, the amphipod *Themisto gaudichaudii* and euphausiid *Euphausia frigida*, were relatively uncommon in the Survey A collections.

(4) Leg I, Interspecific Relationships: Cluster analysis applied to adjusted abundances [Log(n+1)] of the zooplankton taxa (excluding *I. racovitzai*) yielded four groupings which exhibited some degree of spatial coherence (Figure 4.10A). Clusters 1 and 2 were primarily represented at stations adjacent to, and south of, the strong frontal zone which extended across the survey area (see Section 1, Physical oceanography). Cluster 2 was present at 36 stations, most of which were close to the frontal zone. Cluster 1 was present at 21 stations, most of which were south of King George, Elephant and Clarence Islands. Cluster 3, represented at only 13 stations, occurred primarily in the West area north of the front. In contrast to the other groups, the 32 stations at which Cluster 4 occurred were more evenly distributed north and south of the frontal zone. These stations were mostly in the northwest and west portion of the Elephant Island area and around King George Island.

Taxonomic composition of the four zooplankton clusters was fairly similar, but overall zooplankton abundance, as well as absolute and relative abundance of dominant taxa, differed (Table 4.4). Clusters 1 and 2 had highest overall mean zooplankton abundance due to large numbers of *S. thompsoni* and *T. macrura*. Together these two species made up 92-95% of the total zooplankton compared to 50-65% in Clusters 3 and 4. Mean abundance of *S. thompsoni* at Cluster 1 and 2 stations was significantly greater than at Cluster 4 stations (ANOVAs, $P < 0.05$). Abundance of *T. macrura* was not significantly different among the four clusters. Clusters 1 and 2 primarily differed in krill abundance: krill was the third most abundant taxon in Cluster 2 but ranked 15 in Cluster 1. Mean krill abundance in Cluster 2 was significantly larger than in Clusters 1 and 4 (ANOVAs, $P \leq 0.01$). Excluding krill, the rank order of abundance of the nine most abundant taxa was the same for Clusters 1 and 2. Total mean zooplankton abundance of Clusters 3 and 4 was 3-4X less than the other two clusters. Copepods were a relatively abundant taxon in both of these clusters, ranking second to *S. thompsoni* in Cluster 3 and third, after *S. thompsoni* and *T. macrura,* in Cluster 4. Mean abundance of copepods in both clusters was significantly higher than in Clusters 1 and 2 (ANOVAs, $P \leq 0.02$). Cluster 3 was distinct in having significantly higher abundance of chaetognaths (P values all 0.000), *P. macropa* ($P \leq 0.01$), and larval krill ($P \leq 0.02$) than the other three groups; mean abundance of radiolarians in Cluster 3 was significantly higher than in Clusters 1 and 2 ($P \leq 0.02$). Cluster 4 was distinct in having relatively high krill abundance (second to, and not significantly different from, that in Cluster 2) and significantly higher abundance of *Sagitta gazallae* than the other clusters ($P \leq 0.02$). In accordance with these results, Percent Similarity Index (PSI) values were highest for Clusters 1 and 2 (88), intermediate for Clusters 3 and 4 (77), and lowest between these two cluster pairs (54-68).

Pairwise Kendall's Tau (*T*) comparisons between individual taxa indicate two groups within which the taxa share similar abundance patterns across the large-area survey based on P values ≤ 0.05. Significant positive relationships between *S. thompsoni, V. antarctica*, and *C. magellanicus* reflect the commensal relationships of these amphipods with salps (Madin and Harbison, 1977). As indicated above, similar abundance patterns of ubiquitous *S. thompsoni* and *T. macrura* also result in a significant positive correlation. Significant positive correlations between *L. helicina, C. limacina*, and *S. australis* and the amphipod *H. dilatata* result from similar distributional patterns of the three pteropod species in conjunction with the documented parasitic relationship between *H. dilatata* and *S. australis* (McClintock and Janssen, 1990). There is also a significant positive relationship between the abundance patterns of *Tomopteris* spp. and *L. helicina, H. dilatata,* and *S. australis*. Significant negative correlations between (a) *S. thompsoni* and *C. limacina-H. dilatata,* (b) *V. antarctica* and *C. limacina,* and (c) *T. macrura* and *Tomopteris* spp. suggest different distribution patterns of member species between the two groups (e.g., areas of greatest salp concentrations are areas where *C. limacina* is not likely to be found in abundance).

(5) Leg I, Between Year Comparisons:

(a) Krill: The mean abundance of postlarval krill in the Elephant Island area (27.1 per 1000 m^3)

was similar to that observed during January surveys in 1992, 1993 and 1997 (23.7-29.6 per 1000 m^3; Table 4.5) and is "typical" for the 1990's (Loeb et al. 1997). The median krill abundance value, however, is relatively high and similar to that in January 1996 (10.2 vs. 11.4 per 1000 m^3). High mean and median abundance in 1996 resulted from strong recruitment of the 1994/95 year class. In contrast, the high median abundance value in January 1998 resulted from relatively uniform distribution of moderate krill catches across the area. The maximum krill catch size is one of the smallest in the past seven years (Table 4.5).

Expressed as carbon, the median krill biomass in the Elephant Island area during January 1998 [46.7 milligrams of carbon per square meter (mg C per m^2)] was similar to that during 1995 and 1997, and intermediate between the 1994 low (25.6 mg C per m^2) and 1996 high (72.2 mg C per m^2) values (Table 4.6). The mean krill biomass value was the lowest in the 1994-1998 period.

Overall krill maturity stage composition in the Elephant Island area was most like that during January-February 1997, as indicated by a high PSI value of 96 (Table 4.7). As in 1997, moderate recruitment success of the preceding year class is suggested by the 18.4% juvenile contribution. However, this proportion may be inflated due to low representation by older krill (i.e., 4+ age class) in the January 1998 catches. The extremely low proportion of advanced reproductive stages among mature females is noteworthy as it indicates delayed seasonal maturation and spawning activity. Minimal spawning activity is also evidenced by the low numbers of krill larvae collected (Table 4.3). This is not a sampling artifact due to an earlier field season in 1998; the median sampling date within the Elephant Island area, 21 January, is similar to the median survey dates during previous years (generally 24-31 January). Low proportions of advanced reproductive stages in January 1998, as in 1993 and 1994, are associated with massive salp concentrations in the area and theoretically result from competition with salps for food resources (Siegel and Loeb 1995).

Of note is the relatively small size of the juvenile (1 year old) krill in the large-area survey and subareas (Figure 4.2A-D). Modal lengths were ≤26mm in the Elephant Island and South areas and only 21-23mm in the West area. During January AMLR surveys, modal lengths of 1 year old krill typically are 26-29mm. This size discrepancy may result from delayed spawning during the 1996/97 field season. Survival of late spawned eggs and larvae (e.g., those produced during late March and April) could have been promoted by the delayed (July), but extensive, formation of winter sea ice in 1997. This would have provided sufficient development time for the planktonic larvae followed by sufficient food supplies and refuge in the sea ice for the juveniles.

(b) Salps: Both median and mean abundance of *S. thompsoni* during January 1998 were 4X greater than those observed in January 1997 and similar to those of the 1993 and 1994 "salp years." Median salp carbon biomass (187.0 mg C per m^2) was 72% greater than during the previous January and exceeded that of krill biomass by 4X (Table 4.6). As speculated last year, elevated abundances in 1997 marked a transition to a "salp year." Here the previous definition of a "salp year" is revised and a tentative distinction is established between "transition periods" and "salp years." "Transition periods" are defined as those when the median salp:krill biomass ratio is >1:1, but copepods numerically dominate the zooplankton. "Salp years" have salp:krill biomass ratios >1:1 and salps far outnumber copepods (see "Overall Zooplankton/Micronekton Assemblage" discussion below) .

Almost total dominance by the aggregate stage (>90%) during January 1998 was similar to all other years except 1997 when small solitary stages made up 20%. The overall length frequency distributions of salps over the past five January sampling periods have differed greatly from one another (Figures 4.11A-4.11E). During 1994 and 1996, the populations were dominated (≥60%) by aggregate forms of 20-40mm length. Small aggregate forms (15-25mm) predominated in 1995. In January-February 1997, the aggregate form exhibited multiple abundance peaks within the 15-50mm size range. In January 1998, 50% of the aggregates were ≤20mm. The aggregate abundance peaks present in the length frequency curves suggest successive release of blocks of young (i.e., three or four chains of aggregates) by the parent solitary stages across spring months.

Overall salp length distribution each January-February sampling period varies greatly (Figures 4.11A-4.11E), suggesting large between-year variability in the timing and temporal extent of chain production by the overwintering solitary stages. Using these length frequency distributions and a 14mm per month growth rate after budding (5mm at birth; Foxton, 1966), one can estimate an approximate initiation date of chain production each spring. Based on aggregate individuals with internal lengths up to 63mm during January (Figure 4.11D), budding started earliest in the 1996/97 spring-summer period, perhaps around the last week in September 1996. Initiation of chain production was also relatively early in 1993/94 (Figure 4.11A; ca. the first week of October 1993) and 1995/96 (Figure 4.11C; ca. the second week of October 1995). The January 1998 length curve indicates that chain production started around the third week of October 1997 (Figure 4.11E). The small salp sizes encountered during January 1995 (<35mm; Figure 4.11B), indicate that production was greatly delayed with an initiation time around the first week of December 1994 if the 14mm per month growth rate is correct. Given the significant negative correlation between salp abundance and annual sea ice development, one would suspect that these variations in the timing of chain production within the Antarctic Peninsula region are related to sea ice extent during spring months. Theoretically those years with rapid retreat of the sea ice during early spring (e.g., August-September) will have an earlier and much longer period of local salp production than those when extensive sea ice cover persists into late spring (e.g., October-November). Although length data are not available, increased salp abundance from January to February 1993 (Table 4.5) suggests a later and/or prolonged production peak during 1992/93 spring and summer months. Also noteworthy is the fact that "salp years" are not necessarily due to early and prolonged chain production. The 1998 salp bloom probably started in mid- to late October which, within the existing data set, is not particularly early. The magnitude of this bloom is therefore possibly enhanced by a large overwintering solitary population (i.e., individuals that were produced in abundance in January-February 1997, and possibly again after the March 1997 aggregate bloom). This might also have been the case in 1992/93 which was followed by the 1993/94 "salp year."

Salp distributional patterns also show between-year variability which may reflect variations in local production and advection of older individuals from Drake Passage and Bransfield Strait. The widespread occurrence, high abundance, and broad size range of salps across the Elephant Island area during 1994 (Figures 4.11A and 4.12A) most likely resulted from rapid population growth in November and an extended production period both locally and offshore. The predominately small sized salps of 1995 were most abundant in Bransfield Strait waters south and east of Elephant Island (Figure 4.12B); these probably were produced locally, with small sizes resulting from the short December production period (Figure 4.11B). In contrast, salps sampled during January-February 1996 were most abundant in Drake Passage water and possibly advected into the Elephant Island area after a prolonged production period in the West Wind Drift (Figure 4.12C). A wide variety of salp sizes were broadly distributed in 1997 and probably resulted from prolonged production and growth periods across the entire area as well as adjacent Drake Passage and Bransfield Strait waters (Figure 4.12D). The complex salp distribution pattern in January 1998 indicates possible advection of recently budded young chains from the northwest and of older, mature aggregates from the northeast (Figure 4.7A). Mixtures of these two groups and intermediate aged salps, probably from Bransfield Strait, prevailed over most of the survey area. Because of their reported distribution pattern (Foxton 1971), the association between large numbers of *I. racovitzai* and the large *S. thompsoni* of Cluster 3 suggests that these may have been advected from the northeast. This is supported by the occurrence of atypical oceanic water in the eastern Elephant Island area during Survey A (see Section 1, Physical oceanography).

(c) Overall Zooplankton/Micronekton Assemblage: Overall diversity in the survey samples (65 taxonomic categories; Table 4.8) was similar to that observed during January 1995-1997 surveys and presumably is characteristic of the large-area survey during this time of the year. Previously, low diversity during 1993 and 1994 was suspected to be due to the dense salp concentrations occurring then. Relatively low numbers of taxa identified those years may have resulted from early, unrefined shipboard processing and identification techniques in conjunction with necessary subsampling which diminishes finds of rarer taxa. However, various dramatic changes in the zooplankton assemblages are associated with "salp years." These are demonstrated by PSI comparisons between the taxonomic composition of zooplankton samples collected over the past six years (Table 4.9). Highest PSI values in January-February (81-92) resulted from comparisons between the 1993, 1994 and 1998 "salp years," while lowest values (12-19) resulted between comparison of those years with 1995 and 1996. Although salps were quite abundant in January-February 1997, inter-comparisons between this and non-salp years 1995 and 1996 gave relatively high and similar values (70-77), while comparisons between 1997 and the three "salp years" gave relatively low values (31-39). These relationships reflect shifts in the relative proportions of dominant taxa (Table 4.10). During January-February of the three "salp years," *S. thompsoni* contributed 69-87% of total mean zooplankton abundance in the Elephant Island area and postlarval *T. macrura* ranked second in abundance (4-15%) there. Copepods ranked third or fourth and contributed only 3-5%; postlarval krill generally followed, comprising 3-4% of total mean zooplankton abundance. In contrast, copepods were by far the numerically dominant taxon in the Elephant Island area during January-February of the non-salp years, contributing 56-62% of total zooplankton each year. The dichotomy of "salp" and "copepod" (specifically *Metridia* *gerlachei*) years in the Antarctic Peninsula region has previously been described by Park and Wormuth (1993). The relative proportions and composition of other dominant taxa were variable during "copepod" years; the second most abundant taxon in January was larval krill in 1995 (13%), larval *T. macrura* in 1996 (22%) and *S. thompsoni* in 1997 (18%). During those years, postlarval *T. macrura* generally ranked third or fourth and contributed 8-10%; postlarval krill or chaetognaths usually followed these in abundance. Elevated larval abundances of both *T. macrura* and krill during "copepod" years suggest that lowered salp abundance then may favor larval production and/or survival, possibly through reduced predation on the egg and larval stages (e.g., krill eggs in summer, *T. macrura* eggs in early spring) and reduced competition for food.

(II) Leg II, Survey D

(1) Krill: Krill were present in 93 of 104 Survey D samples (89%) and 57 of 61 Elephant Island area samples (93%; Table 4.1B). Two of the three largest catches were in the Elephant Island area in offshore Drake Passage water (5667 per 1000 m^3) and over the eastern shelf of Elephant Island (2212 per 1000 m^3; Figure 4.1B). Moderately high krill densities (102-678 per 1000 m^3) also occurred to the north of Elephant Island and in Bransfield Strait southeast of the island. One large (1846 per 1000 m^3) and three moderately large (347-698 per 1000 m^3) catches were made in the South area. Mean and median krill densities were highest in the South area (328.3 and 223.4 per 1000 m^3) and lowest in the West area (22.3 and 2.7 per 1000 m^3). The substantially larger mean vs. median abundance estimate in the Elephant Island area (162.6 and 4.5 per 1000 m^3), and large associated standard deviation, reflect the patchy krill distribution there during Survey D (Figure 4.1B).

Krill lengths ranged from 19 to 53mm (Figure 4.13). While small krill (≤30mm, 25-27mm mode) were collected in each area, they formed a relatively abundant size category only in the South area (32%; Figures 4.13B-4.13D). These small individuals (i.e., 1996/97 year class) made up <4% of the krill collected in the West and Elephant Island areas and 10% of the Survey D total. Krill ≥40mm (45-46mm mode representing the 1994/95 year class) comprised the dominant size category in the Elephant Island area (75%) and total survey area (60%). The most abundant length category in the South area centered around a 37mm mode (36% of total). West area krill were dominated by >40mm (60%) and 35-40mm (30%) lengths. Predator diets (40 chinstrap and 20 gentoo penguins) at Cape Shirreff during the West area survey effort (Figure 4.13C) indicate that 30-40mm krill comprised a larger proportion of the diet than were represented by the net catches suggesting the importance of patchiness in prey availability (Trivelpiece, pers. comm.).

Krill maturity stage composition reflects differences in length composition between the three subareas (Table 4.2). The proportions of juveniles were essentially the same as those of the small size category in each area. These and immature stages made up >80% of krill collected in the South area. Mature stages comprised 71%, and immature stages 25%, of total krill collected in the Elephant Island area. More similar proportions of immature (41%) and mature (54%) stages were collected in the West area. Overall, mature stages made up 59%, immature stages

31%, and juveniles 10% of krill collected in the large-area survey. Greatest proportions of advanced female maturity stages occurred in the Elephant Island area, where 5% of mature females were either gravid (3d) or spent (3e). Increased proportions of mature females with attached spermatophore packets (3b) and developing ovaries (3c) in this area relative to the West area indicate that, although reproductive activity increased over the survey period, peak seasonal spawning had not occurred by late February. This is supported by low numbers of predominantly calyptopis larvae collected during Survey D (Table 4.11).

Two length-maturity groupings resulted from cluster analysis applied to the size frequency distributions of krill in samples with >15 individuals (Figure 4.14A). Cluster 1 exhibited a trimodal length frequency distribution with lengths centered around a juvenile mode of 25mm and 2-3 year old modes of 39mm and 42mm. Immature stages were most abundant (46%), followed by mature forms (35%), and juveniles (19%). Females outnumbered males by a ratio of 1.7 to 1. Few of the mature females were in advanced maturity stages (Figure 4.14B). Cluster 2 was primarily composed of krill >40mm with a size distribution centered around a 3 year old length mode of 45-46mm. Few juveniles were included in this cluster; 85% of the individuals were mature and 15% immature. Males outnumbered females by a ratio of 3.5 to 1. About 10% of mature females in this cluster were gravid or spent. Cluster 1 krill were the most widely spread, occurring around Elephant Island and to the south and west of King George Island (Figure 4.4B). Cluster 2 krill were distributed in Drake Passage water north of King George and Elephant Islands.

(2) Salps: *Salpa thompsoni* was present in 102 of 104 large-area survey samples and in all 61 Elephant Island area samples; it was the most abundant taxon collected overall and in the three subareas (Table 4.1B, Table 4.11). Sixteen of the 19 largest salp catches (>1000 per 1000 m^3) were made in the Elephant Island area, and mean and median abundance estimates from this area (977.3 and 553.8 salps per 1000 m^3, respectively) were 2-4 X larger than in the West and South areas (Figure 4.5B). The largest catch of *S. thompsoni* was 93 liters, collected at night at Station D069 southeast of Elephant Island. At this time large numbers of salp chains were observed near the surface and salps clogged the ship's engine intake filter. Strong disturbances in the CTD transmissometer records at this station indicated that densest concentrations were within the upper 25m. Salp density here was estimated at nearly 11,000 per 1000 m^3 water filtered and 1,800 salps per 1 m^2 sea surface area.

As during January, the vast majority of *S. thompsoni* collected (97%) were the aggregate stage. Aggregate stage individuals ranged from 4 to 61mm internal body length; solitary stage individuals ranged from 4 to 116mm. The overall length frequency distribution had a 32-37mm mode, with 75% of individuals between 20 and 45mm and 5% between 45 and 60mm (Figure 4.15A). Using a 14mm per month estimated growth rate, the majority of the salps were probably between 6 weeks and 3 months in age, which places their production between mid-November and mid-January, with most intense production during mid-December. The size distribution is consistent with the estimated initiation of budding during the third week of October based on the January length frequency distribution. Relatively low numbers of small solitary individuals during Survey D indicate that intense production of the overwintering form had not begun by mid-February.

Cluster analysis yielded two groups of *S. thompsoni* with different length and spatial distribution patterns (Figure 4.7B and Figure 4.15B). Each group was present at about half of the survey stations (48 vs. 52). Twenty six percent of Cluster 1 salps were ≤20mm (i.e., 2 weeks old and younger) and 50% were 21-35mm (<2 months old). Cluster 2 salp lengths centered around 32-37mm (ca. 2 months old), and 60% of individuals were 29-43mm. The overall length frequency distribution of Cluster 2 salps was significantly larger than that of Cluster 1 (Kolmogorov-Smirnov test, $P = 0.05$). Cluster 2 salps primarily occurred in north, west, and south portions of the Elephant Island area and around King George Island. These large, older salps were responsible for the surface swarms at Station D069. Cluster 1 salps primarily occurred in the east and central portions of the Elephant Island area and northwest of King George Island. As indicated by the minor abundance peak of Cluster 1 salps <10mm long, these were areas where chain production was occurring during the survey (Figure 4.15B).

(3) Zooplankton and Micronekton Assemblages: Sixty one taxa were collected in large-area Survey D samples, but five taxa numerically dominated (Table 4.11); these were *S. thompsoni*, postlarval *T. macrura,* copepods, postlarval krill, and *I. racovitzai. Thysanoessa macrura* postlarvae occurred in 100% of samples, and their mean and median abundance values ranked second to *S. thompsoni* in all but the Elephant Island area where mean krill abundance was higher. Largest densities of postlarval *T. macrura* (1640 and 2250 per 1000 m^3) were encountered east of King George Island; other relatively large catches (520-710 per 1000 m^3) primarily occurred north of Livingston Island, northeast of King George Island, and southeast of Clarence Island (Figure 4.8B). Mean *T. macrura* abundance was highest in the South area and lowest in the Elephant Island area, but abundance differences among subareas were not significant. Copepods generally ranked third or fourth in abundance in the large-area survey and three subareas. Copepod abundance was quite patchy with fairly similar mean and median values in the subareas. *Vibilia antarctica* was collected in moderate numbers by most tows (96%). This amphipod was most frequent and abundant in the Elephant Island area (10.7 and 7.6 per 1000 m^3 mean and median values, respectively) and ANOVAs indicate that abundance there was significantly higher than in the South ($P=0.05$) and West ($P=0.02$) areas.

Ihlea racovitzai was present in 61% of Survey D samples. It ranked fifth in overall mean abundance (51.5 per 1000 m^3) and third in median abundance (12.2 per 1000 m^3) across the large-area survey (Table 4.11). This salp occurred in all samples from the South area and was significantly more abundant there than in the Elephant Island and West areas (ANOVAs, $P=0.003$ in both cases). The distribution of this species was distinctive in that virtually all individuals were collected south of the frontal zone and its presence/absence was a strong biological indicator of this zone (Figure 4.16). Greatest concentrations were encountered just south of the frontal zone, south of King George Island, and south of Clarence Island. *I. racovitzai* was caught at 40-190m depths by the two vertically stratified MOCNESS hauls and was associated with cool, moderately saline water of 0.2-0.5 °C, 34.2-34.4 ppt. Almost all individuals were aggregate stage. These ranged in length from 3-32mm, with 60% between 20-30mm. The few solitary stages collected had 47-59mm internal lengths.

Other relatively frequent and abundant taxa during Survey D were chaetognaths and the amphipods *V. antarctica, C. magellanicus, C. lucasii* and *P. macropa* (Table 4.11). Chaetognaths were present in 61% of samples and ranked sixth in overall mean abundance with highest abundance in the West area. *Vibilia antarctica* was collected in 96% of samples; its mean abundance in the Elephant Island area was significantly greater than in the South (ANOVAs, $P = 0.05$) and West ($P=0.003$) areas. Although not so frequent, overall mean abundance values of *E. frigida* (9.3 per 1000 m^3) and ostracods (5.4 per 1000 m^3) were relatively high. *Euphausia frigida* was present in a third of the samples, and ranked seventh in mean abundance in both the Elephant Island and West areas but was absent from South area samples. Ostracods were most abundant in the South area where they ranked sixth in mean abundance.

(4) Leg II, Day-Night Catch Differences and Interspecific Relationships: Significance of diel catch differences of dominant taxa were tested by applying ANOVA and post hoc Tukey tests to their abundance estimates from 25 night, 11 twilight, and 68 day tows. In contrast to 1997 January-February Survey A, *S. thompsoni* did not show any significant diel catch difference. *Euphausia frigida, T. macrura,* copepods, and ostracods had significantly larger night vs. day and twilight mean abundance ($P << 0.01$ in all cases except for ostracod night vs. twilight catches where $P = 0.05$). Postlarval krill had significantly larger night vs. day catches ($P = 0.02$). *Primno macropa* had significantly larger day than night mean abundance ($P = 0.04$).

In contrast to Survey A, cluster analysis applied to zooplankton abundance data from Survey D samples [log (n+1)] yielded three groups with distinct spatial distribution patterns (Figure 4.10B). Distributional differences between Clusters 1 and 3, represented by 38 and 45 stations respectively, resemble the presence/absence distribution of *I. racovitzai* with their separation associated with the strong frontal feature. Cluster 2 was represented by only 16 stations; these occurred in five spatially cohesive locations south of the front and embedded in Cluster 1. Although *S. thompsoni* numerically dominated all three clusters (Table 4.12), its overall contribution to the total zooplankton ranged widely (34-75%) and abundance relations of the 15 most abundant taxa differed significantly between the three clusters (Kendall's Tau tests, $P < 0.001$ in all cases). PSI values were most similar between Cluster 3 and Clusters 1 (72) and 2 (74) and least similar between Clusters 1 and 2 (54), due primarily to proportions of *S. thompsoni*.

Cluster 2 had the largest mean total zooplankton abundance and largest mean abundance values for half (11 of 22) of the taxa considered. Among the dominant taxa, only *S. thompsoni* did not have maximum abundance in Cluster 2. Mean abundance values of *T. macrura*, copepods, *E. frigida,* ostracods, and *C. limacina* in Cluster 2 were significantly larger than in Clusters 1 and 3 (ANOVAs, $P \leq 0.02$). Mean abundance of postlarval krill and *S. australis* in Cluster 2 were significantly larger than in Cluster 1 ($P \leq 0.05$). In accordance with its overall distribution pattern, mean abundance of *I. racovitzai* in Clusters 1 and 2 was significantly larger than that in Cluster 3 (both $P = 0.000$). *Cyllopus lucasii* was significantly more abundant in Cluster 1 vs. Cluster 3 ($P=.0.001$). The location of Cluster 2 in proximity to the frontal zone and/or King George, Elephant, and Clarence Islands suggests that the elevated zooplankton abundance may result from retention in gyres and eddies associated with complex hydrography, especially near topographic features. Mean zooplankton abundance in Cluster 1 was roughly half that of Cluster 2, and was largely due to maximum abundance of *S. thompsoni* and relatively large numbers of *I. racovitzai*. Greatest concentrations of *V. antarctica* and *C. lucasii* also occurred in Cluster 1. Cluster 3 was distinguished by having relatively large proportions of postlarval krill, copepods, and chaetognaths (ranks 2, 3 and 5; respectively; together 29% of total zooplankton). Copepod abundance in Cluster 3 was significantly larger than in Cluster 1 (ANOVA, $P < 0.05$).

(5) Survey A and D Comparisons: While mean krill abundance increased by >3X from January to February, the associated standard deviation increased by 10X and median abundance decreased by ca. 3X, reflecting change from a relatively uniform to variable (i.e., patchy) pattern of krill catch size across the survey area (Figures 4.1A and 4.1B). There was also a substantial change in krill maturity composition, with marked reductions in proportions of juvenile and immature stages and dominance by mature stages with advancing season (Table 4.2). Changes in length-age-maturity stage composition and distribution of the krill clusters result from seasonal onshore migration of different age-classes (Siegel, 1988; Siegel et al. 1997) (Figures 4.4A and 4.4B). Although larger krill were collected during February than January, median krill carbon biomass in the Elephant Island area was reduced by 32% in association with lower median catch size (Tables 4.5 and 4.6).

Over the 31 days separating Survey A and D median dates, the modal length of 1 year old juveniles increased 3mm (from 22 to 25mm) and of 2 year old stages 4mm (from 34-35mm to 38-39mm), indicating growth rates of ca. 0.10mm per day and 0.14mm per day for the respective age classes. These values differ from reported summertime growth rates for juveniles (0.12mm per day) and 1 year olds (0.07mm per day; Siegel and Kalinowski, 1994) and growth rates reported from the AMLR 1996/97 field season (0.07mm per day for both age classes; Loeb et al., 1997). These differences could result from interannual variability in growth rates (Siegel, 1987). Alternatively, growth rates derived from modal lengths may be biased by seasonal onshore migrations. Seasonal replacement of small juvenile and immature stages by larger mature stages from offshore waters could alter modal lengths for the various age classes; between-year differences in timing and/or magnitude of onshore migration of different maturity stages could result in variable "growth rates" such as those presented here.

Salpa thompsoni abundance values were relatively similar between the two large-area surveys, as were proportions and numbers of aggregate and solitary stages (Table 4.13). The overall length distribution during February was significantly larger than during January (Figure 4.11E; K-S test, $P << 0.01$), reflecting growth with only minor production of new aggregate or solitary stages over the survey period. Median salp carbon biomass in the Elephant Island area was 2X greater than during Survey A; this was associated with increased salp size and a 60% increase in median abundance there. Maximum production of the overwintering solitary form typically occurs in

March and April (Foxton 1966), so few small, recently released individuals were collected during either survey. Length differences between dominant size modes in January (9-12mm and 20-25mm) and February (24-25mm and 33-37mm; Figure 4.11E) suggest growth rates of ca. 12-15mm over a 31 day period (0.39-0.48mm per day). These values are similar to those estimated in 1997 using the change in several length modes across a 45 day period (14mm per month, 0.44mm per day). Assuming a 14mm per month growth rate, the aggregate stage size distribution during both surveys is consistent with an initiation of budding during the third week of October and peak production during December. Comparisons of the salp clusters during each survey suggest (a) a mixture of January Cluster 1 and 2 salps plus new aggregate production, to form February Cluster 1 and (b) a mixture of January Cluster 2 and 3 salps plus loss of older individuals, to form February Cluster 2 (Figures 4.6B and 4.15B). The general distributional patterns of the two February clusters conform to these mixtures (Figures 4.7A and 4.7B).

Overall zooplankton taxonomic composition and abundance were fairly similar between Surveys A and D (Table 4.13). *Salpa thompsoni, T. macrura,* postlarval krill, copepods, and *I. racovitzai* numerically dominated during both surveys. The large mean January abundance estimate for *I. racovitzai* is most likely an underestimate as its calculation included zero values for the 95 Survey A stations sampled prior to its identification. Among other dominant taxa only copepods exhibited a significant seasonal abundance difference, with substantially larger catches in February (Z test, $P = 0.05$). Among less abundant taxa amphipods *C. magellanicus* and *C. lucasii* had significantly larger mean abundance in February, while pteropods *L. helicina* and *C. limacina* had significantly larger January mean abundance (Z tests, $P < 0.05$ in all cases).

During both surveys distribution patterns of the zooplankton clusters were associated with the strong frontal zone, although this association was much more distinct and distributions of each cluster more spatially homogeneous during February (Figures 4.10A and 4.10B). The complexity of January zooplankton clusters, as with January krill and salp clusters, suggests a great deal of hydrographic complexity during Survey A with a variety of water mass influences affecting each of the three subareas plus local, topographically related circulation patterns (Figures 4.4A, 4.7A). Based on the various distribution patterns, a more homogeneous advective regime appears to have been established during Survey D (Figures 4.4B, 4.7B and 4.10B).

The composition and abundance relations of zooplankton taxa comprising the clusters which occurred mostly north or south of the frontal zone during January were generally similar to those during February. Largest concentrations of *S. thompsoni, T. macrura, V. antarctica,* and *I. racovitzai* occurred south of the frontal zone in February; these taxa were most abundant in "south tending" Clusters 1 and 2 during January. Largest concentrations of copepods, chaetognaths, and *P. macropa* occurred north of the frontal zone in February (excluding Cluster 2) and in "north tending" Clusters 3 and 4 in January. This dichotomy relates to "oceanic" vs. "transitional" faunal zones in the Antarctic Peninsula region (Piatkowski, 1989; Siegel and Piatkowski, 1990), with the mixed faunal assemblage of the "transitional" zone associated with a hydrographic front and water mass mixing. An interesting discrepancy, however, is that *S. thompsoni* and *V. antarctica* are considered, respectively, a dominant and an indicator species of the "oceanic" community. Like *I. racovitzai*, their "transitional" distributions may be due to advection from the northeast, possibly through a southwestward deflection of the Weddell drift. As noted above, exceedingly large concentrations of both "oceanic" and "transition" taxa in February Cluster 2 may have resulted from gyral circulation and retention south of the frontal feature.

(6) Leg II, Between Year Comparisons:

(a) Krill: While median krill abundance in the Elephant Island area (4.1 per 1000 m^3) was similar to that monitored during February-March 1996 and 1997, the mean value (162.6 per 1000 m^3) was the largest in the past seven years (Table 4.5). Overall maturity stage composition was fairly similar to that observed during the limited sampling effort in March 1997 but with proportionately fewer juveniles and more immature stages (Table 4.7). The low contribution by juveniles (3.6%) is similar to that during February-March 1993 and 1994 surveys. The proportion of advanced female maturity stages (gravid and spent, 5.2%) is one of the lowest in the seven year record suggesting a greatly delayed spawning season in 1998. Extremely low larval krill abundance in the survey area relative to the past three years is further evidence of little spawning activity and/or poor egg and larval survival during the summer spawning season (Table 4.14). Juvenile krill lengths during February 1998 (25-27mm mode) were ca. 2-6mm smaller than observed in the large-area surveys during previous years, again suggesting relatively good survivorship of late spawned eggs and larvae during the 1996/97 season.

(b) Salps: Median and mean abundance values of *S. thompsoni* in the Elephant Island area were similar to those during the limited March 1997 survey (Table 4.5). Median abundance (553.8 per 1000 m^3) ranked second, and mean abundance third, to peak values encountered in February-March 1993. Like 1993 and 1997, abundance of the aggregate form did not show a seasonal decline from January levels. Unlike the previous three years, no major production of small overwintering solitary stages or aggregate chains occurred during the second large-area survey (Figures 4.11B-4.11E). The Survey D sampling period obviously was before the seasonal production peak of solitary stages and possibly before a final pulse of aggregate production. Late summer production of aggregates in conjunction with delayed onset of winter sea ice may permit production of a large overwintering seed population and a massive salp bloom the following spring. As suggested previously, this may have been the case during 1997 and 1993 to provide a high abundance of salps early the following summer despite relatively short production periods.

(c) Overall Zooplankton/Micronekton Assemblage: As for Survey A, the number of zooplankton taxa collected during February 1998 (61) was comparable to previous surveys, negating the idea that massive salp blooms affect species diversity (Table 4.14). Overall taxonomic abundance relations were most like those during February-March 1993 and March 1997 (PSI values 67 and 63, respectively) due to large late season abundance of aggregate stage *S. thompsoni* (Table 4.9). In contrast to the January surveys, extremely low PSI values resulted from comparisons of February-March 1994 vs. 1998 and 1993 surveys (PSIs 28 and 18, respectively); this is a direct result of the dramatic seasonal increase in copepod abundance and decline in salp abundance during summer 1994 (Table 4.10). Note that comparisons with February-March 1993 data are biased to an unknown extent by the lack of copepod and chaetognath abundance data from that survey. However, given the increased February 1993 salp abundance, copepods and chaetognaths probably contributed relatively low proportions to the total zooplankton (e.g., similar to January 1993 values). Assuming this, then abundance relations of the four dominant taxa are most like those of February-March 1993 with *S. thompsoni* and *T. macrura* ranked 1 and 2, respectively, followed by copepods and krill.

The February-March zooplankton data provide further insight into ecological changes associated with "copepod years," "salp years," and transition periods between these years (Table 4.10).

> (i) "Copepod years" (1995 and 1996): Copepods (presumably *Metridia gerlachei*) were dominant taxa during late-summer 1995 and 1996 (although they ranked second during February-March 1995 due to high mean larval krill abundance). Larval *T. macrura* ranked fourth and second in mean abundance, respectively, during February-March 1995 and 1996. Postlarval *T. macrura* and chaetognaths switched between ranks third and fifth during these years. In contrast, *S. thompsoni* ranked sixth and eighth and contributed <1.5% of total zooplankton.
>
> (ii) "Salp years" (1993 and 1998): *Salpa thompsoni* was the numerical dominant during February 1993 and 1998 and made up 56-89% of total zooplankton; post larval *T. macrura* was second most abundant (8-14%) followed by postlarval krill and copepods. Larval krill and *T. macrura* were both quite rare during February 1988.
>
> (iii) "Transition periods" (1994 and 1997): February-March 1994 and March 1997 appear to be transition periods between "copepod years" and "salp years." During these surveys, copepods were the numerical dominant, followed in order by *S. thompsoni*, post larval *T. macrura* and *E. frigida*. The relatively large abundance of *E. frigida* is interesting as this species ranked seventh to ninth during other late summer surveys. Copepod dominance in conjunction with a salp:krill biomass ratio >1.0 during the 1994 and 1997 late summer surveys conforms to the tentative definition of "transition periods."

The direction of salp and copepod seasonal abundance shifts during the late summer transition periods presaged conditions observed the following spring-summer season. These fairly abrupt changes in species structure suggest that some forcing factor other than, or associated with, winter sea-ice development and springtime competition among dominant herbivores is involved. Changes in current regimes, specifically advection from the northeast (e.g., a southwestward deflection of the Weddell drift and East Wind drift water), are a possibility. Distribution patterns of *S. thompsoni* during the two 1993 surveys suggest such a northeast influence and resemble the recurring biological patterns observed during 1998 (Figures 4.17A and 4.17B). A northeast influence is again suggested in the January 1994 salp distribution pattern, but the February-March survey indicated a stronger influence from the northwest (Figures 4.17C and 4.17D). The abrupt change in copepod and salp abundance relations between the two 1994 surveys is associated with the altered salp distribution pattern.

The coincidence of "salp years" and El Niño events in the north Pacific during recent years is thought provoking. Major salp blooms in the Elephant Island area during the 1970's and 1980's (1975/76, 1983/84, 1988/90; Loeb et al., 1997) followed tropical El Niño events by 1-2 years and were associated with developing or established La Niña periods (Allan et al., 1996). In contrast, the 1992/93 and 1993/94 salp blooms were associated with tropical warm water and an El Niño off the U.S. west coast, while transition to the 1998 "salp year" coincided with establishment of the strong El Niño event off South America in 1997. These inconsistencies suggest that salp-copepod dominance fluctuations are not directly associated with El Niño-Southern Oscillation events. There is, however, a close association between periods of salp dominance in the Antarctic Peninsula region and the 4-5 year period of the Antarctic Circumpolar Wave (ACW; White and Peterson, 1996). Over the past 15 years summer salp blooms have been encountered about every 4-5 years and the 1988/89 and 1989/90 blooms were associated with strong poleward anomalies in wind stress and sea ice extent which characterize one phase of the ACW as it moves eastward (White and Peterson, 1996). It is possible that shifts between copepod and salp dominance, as well as winter sea ice development, are associated with sea surface temperature anomalies and changes in wind stress wind direction (e.g., changes in advective regimes) propagated by the ACW.

(III) AMLR 98 Cruise Summary: The 1998 AMLR summer field season followed delayed winter sea-ice development in the Antarctic Peninsula region. Satellite derived images of sea ice cover indicated that although it was late in forming (around July), the sea ice was spatially extensive during late winter-early spring (e.g., 1.5 standard deviations above average in September; Hewitt pers. comm.). Between-year variations in sea ice development have marked effects on the Antarctic Peninsula pelagic ecosystem (Loeb et al., 1997). Results from the two 1998 surveys reflect the influence of the previous winter sea ice conditions plus environmental changes which occurred during summer 1997.

Overall krill length/maturity composition from the 1998 surveys was dominated by sexually mature individuals ≥40mm. These were 3 year old krill resulting from the highly successful 1994/95 year class. Lower proportions of smaller, immature krill reflect comparatively poor recruitment success from subsequent years. The averaged contribution of juvenile krill in the Elephant Island area was only 11%, indicating low recruitment of the 1996/97 year class. This had been predicted, given potential competition pressure due to elevated salp abundance and delayed krill spawning observed during the 1997 summer surveys. Anomalously small juvenile krill collected during both 1998 surveys suggested that survival success was limited to late-spawned eggs and larvae in 1997. The prolonged summer season and formation of extensive sea ice cover in late winter could have provided sufficient development time and food resources for these late spawned larvae. Extremely small proportions of advanced female maturity stages during January-February 1998 do not bode well for recruitment success of the 1997/98 year class. Delayed spawning and low numbers of larval krill in 1998 were once again associated with high salp abundance.

Salpa thompsoni abundance remained extremely high during both surveys and was similar to levels observed during the 1993 "salp year." The estimated initiation time of aggregate chain production was mid- to late October, which is not particularly early and precludes a long production period. Therefore, the magnitude of the salp bloom was possibly enhanced by a large overwintering "seed" population of solitary forms. This could have been related to extended summer/fall seasons in 1997, which permitted multiple production periods of both aggregate and solitary stages. This may be a regular factor promoting salp blooms in the Antarctic Peninsula region.

Presence of large numbers of the high latitude salp species *I. racovitzai* both cruise legs was unique to AMLR surveys and indicated faunal input from the northeast, possibly through deflection of the Weddell and/or East Wind drift. Presence/absence of this species delineated a strong frontal zone extending across the area during Survey D. This distribution pattern was shared by a group of zooplankton taxa with maximum abundance south of the front, while taxa of another group were generally more abundant to the north. Relatively homogenous distributions of krill and *S. thompsoni* length clusters and of zooplankton taxonomic clusters during Survey D compared to Survey A, suggested that a more homogeneous and/or stabilized advective regime was established later in the summer.

Comparisons of January and February 1998 survey data with data from previous AMLR field seasons yielded interesting information on interannual variations in zooplankton species abundance relationships. Recurring patterns allowed the definition of different ecological regimes defined as "copepod years," "salp years," and intermediate "transition periods." Since 1983 the 4-5 year periodicity of "salp years" in the study area coincided with that of the ACW. It is possible that shifts between copepod and salp dominance, as well as winter sea ice development and krill recruitment success, are associated with changes in advective regimes propagated by the ACW. It appears that the transition period between these two ecological regimes is established within a brief time span (e.g., between January-February and February-March survey efforts in 1994 and 1997).

4.4 Disposition of the Samples and Data: 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 Dave Demer (Southwest Fisheries Science Center). Liquid nitrogen frozen krill, salps, other zooplankton, and myctophid specimens were provided to Charles Phleger for use in lipid analyses. Alcohol preserved salp specimens were provided to Linda Holland (SIO) and Bill Baker (FIT). Alcohol preserved *Pleuragramma antarcticum* specimens were provided to Dawn Outram (MLML). Frozen myctophids were provided to Mike Goebel and Dan Costa (UCSC) for chemical analyses.

4.5 Problems and Suggestions: Because of the wealth of information that is coming together about ecological change in the Elephant Island area and possible forcing mechanisms, it is imperative that we continue the historical survey effort here. The 1998 sampling grid was adequate, but less would not be acceptable as we need this sort of spatial resolution given the hydrographic complexity. The usefulness of two Elephant Island survey efforts during January-

March has become obvious in this study, and it would be a pity to abandon one of these. Because of late summer/fall indications of ecological change, it is also desirable to obtain net samples from Leg III. However, this would require some shipboard modifications to accommodate IKMT and MOCNESS tows at least before and after the bottom trawl work.

The underwater video system used during Leg II provided a great deal of valuable ecological and behavioral information. This included the co-occurrence of large numbers of salps and krill in the upper water column; salp chain length, diameter, and number of aggregate individuals per chain; and salp orientation and swimming ability. I strongly recommend that this becomes a regular part of the targeted sampling effort during Legs I and II. I also strongly recommend the use of systematic vertically stratified MOCNESS tows during targeted sampling efforts to establish the overall vertical distribution and migration patterns of abundant taxa. This would provide useful information for both acoustics and krill/zooplankton studies.

4.6 References:

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Table 4.1 AMLR 1998 Large-area survey IKMT station information.

A. SURVEY A

STATION	DATE	TIME			TOW	FLOW	KRILL ABUNDANCE			SALP ABUNDANCE	
#		START	END	DIEL	DEPTH	VOLUME	TOTAL	#/m2	#/1000m3	TOTAL	#/1000m3
		(Local)			(m)	(m3)					
A105	08/01/98	1835	1857	D	170	3029.7	16	0.9	5.3	544	179.6
A104	08/01/98	2012	2040	D	183	3732.5	16	0.8	4.3	3019	808.8
A010	09/01/98	0212	0232	N	170	1698.7	369	36.9	217.2	15957	9393.7
A013	09/01/98	0538	0600	D	170	4714.0	5	0.2	1.1	3270	693.7
A016	09/01/98	0920	0947	D	174	4496.3	58	2.2	12.9	466	103.6
A110	09/01/98	1325	1351	D	174	3915.4	43	1.9	11.0	155	39.6
A111	09/01/98	1759	1826	D	170	3773.3	32	1.4	8.5	365	96.7
A124	09/01/98	2142	2210	D	170	3798.7	17	0.8	4.5	841	221.4
A123	10/01/98	0130	0155	N	170	3671.6	145	6.7	39.5	2449	667.0
A116	10/01/98	0504	0533	D	170	4176.1	144	5.9	34.5	5464	1308.4
A014	10/01/98	0819	0842	D	150	2346.7	167	10.7	71.2	794	338.3
A135	10/01/98	1159	1228	D	179	4124.6	275	11.9	66.7	1478	358.3
A136	10/01/98	1542	1613	D	170	4462.4	55	2.1	12.3	738	165.4
A142	10/01/98	2115	2142	D	170	3688.1	2	0.1	0.5	1572	426.2
A143	11/01/98	0100	0127	N	170	4250.3	283	11.3	66.6	665	156.5
A144	11/01/98	0439	0508	D	170	4721.0	145	5.2	30.7	1542	326.6
A145	11/01/98	0743	0816	D	168	5412.1	5	0.2	0.9	690	127.5
A158	11/01/98	1555	1627	D	169	5052.4	205	6.9	40.6	116	23.0
A159	11/01/98	1936	2006	D	171	4327.2	44	1.7	10.2	279	64.5
A160	11/01/98	2048	2118	T	170	4293.3	781	30.9	181.9	10274	2393.0
A166	12/01/98	0536	0618	D	170	4997.0	598	20.3	119.7	566	113.3
A169	12/01/98	0857	0929	D	168	4660.4	7	0.3	1.5	400	85.8
A170	12/01/98	1247	1317	D	172	4173.9	72	3.0	17.3	51	12.2
A171	12/01/98	1601	1617	D	135	2163.0	1066	66.5	492.8	1356	626.9
A176	12/01/98	2305	2338	N	168	4864.8	3	0.1	0.6	1018	209.3
A177	13/01/98	0233	0302	N	171	3238.5	93	4.9	28.7	2333	720.4
A178	13/01/98	0704	0734	D	176	4042.1	4	0.2	1.0	269	66.5
A179	13/01/98	1132	1202	D	172	4826.3	420	15.0	87.0	145	30.0
A001	14/01/98	0108	0135	N	170	4282.9	2	0.1	0.5	2940	686.4
A134	14/01/98	0449	0519	D	170	4087.3	174	7.2	42.6	504	123.3
A131	14/01/98	0809	0839	D	169	4512.2	93	3.5	20.6	1849	409.8
A002	14/01/98	1206	1230	D	172	3482.8	798	39.4	229.1	561	161.1
A003	14/01/98	1540	1605	D	170	3323.2	12	0.6	3.6	165	49.7
A005	14/01/98	1859	1924	D	170	3416.2	0	0.0	0.0	392	114.7
A121	14/01/98	2234	2305	T	170	5639.8	57	1.7	10.1	44	7.8
A118	15/01/98	0113	0145	N	170	4766.6	129	4.6	27.1	1446	303.4
A006	15/01/98	0512	0541	D	170	4271.7	0	0.0	0.0	14950	3499.8
A004	15/01/98	0902	0927	D	170	4344.2	6	0.2	1.4	477	109.8
A007	15/01/98	1156	1225	D	170	4110.1	12	0.5	2.9	1768	430.2
A109	15/01/98	1531	1557	D	170	3255.9	1	0.1	0.3	1438	441.7
A108	15/01/98	1820	1845	D	170	3647.9	884	41.2	242.3	373	102.3
A034	15/01/98	2154	2224	D	170	4297.6	0	0.0	0.0	817	190.1
A008	16/01/98	0043	0112	N	171	4562.4	136	5.1	29.8	1565	343.0
A017	16/01/98	0502	0527	D	170	3587.9	628	29.8	175.0	129	36.0
A018	16/01/98	0802	0827	D	170	3529.3	47	2.3	13.3	705	199.8
A019	16/01/98	1100	1129	D	172	5248.7	221	7.2	42.1	430	81.9
A020	16/01/98	1403	1433	D	170	4103.1	18	0.7	4.4	397	96.8
A021	16/01/98	1707	1736	D	170	4197.5	78	3.2	18.6	577	137.5
A022	16/01/98	2004	2032	D	171	3696.2	28	1.3	7.6	211	57.1
A023	16/01/98	2259	2329	N	170	3921.8	0	0.0	0.0	1375	350.6
A024	17/01/98	0210	0237	N	170	4164.4	0	0.0	0.0	1470	353.0
A026	17/01/98	0723	0752	D	170	4358.6	166	6.5	38.1	1495	343.0
A027	17/01/98	1058	1120	D	170	3120.3	22	1.2	7.1	181	58.0
A028	17/01/98	1401	1430	D	170	4198.3	139	5.6	33.1	401	95.5
A029	17/01/98	1650	1720	D	172	4316.0	40	1.6	9.3	1430	331.3
A030	17/01/98	2005	2032	D	170	4326.2	44	1.7	10.2	387	89.5
A031	17/01/98	2341	0010	N	170	3757.8	108	4.9	28.7	25591	6810.1
A032	18/01/98	0324	0354	D	170	4076.1	352	14.7	86.4	783	192.1
A037	18/01/98	0750	0819	D	169	3459.6	26	1.3	7.5	2470	714.0
A038	18/01/98	1115	1142	D	170	3262.3	136	7.1	41.7	2249	689.4
A039	18/01/98	1418	1448	D	170	4074.2	87	3.6	21.4	670	164.5
A040	18/01/98	1709	1735	D	170	3664.0	165	7.7	45.0	431	117.6
A041	18/01/98	2010	2038	D	170	3700.9	11	0.5	3.0	1124	303.7

Table 4.1 AMLR 1998 Large-area survey IKMT station information (Contd.)

A. SURVEY A

STATION	DATE	TIME			TOW	FLOW	KRILL ABUNDANCE			SALP ABUNDANCE	
#		START	END	DIEL	DEPTH	VOLUME	TOTAL	#/m2	#/1000m3	TOTAL	#/1000m3
		(Local)			(m)	(m3)					
A042	18/01/98	2323	2348	T	170	3458.4	576	28.3	166.6	6937	2005.9
A043	19/01/98	0238	0310	T	170	4335.1	28	1.1	6.5	2599	599.5
A045	19/01/98	0719	0749	D	170	4458.8	99	3.8	22.2	835	187.3
A046	19/01/98	1040	1107	D	170	3615.5	10	0.5	2.8	1079	298.4
A047	19/01/98	1452	1521	D	173	4603.7	74	2.8	16.1	1056	229.4
A048	19/01/98	1840	1907	D	170	3664.6	38	1.8	10.4	1212	330.7
A049	19/01/98	2220	2243	T	135	3551.1	29	1.1	8.2	592	166.7
A050	20/01/98	0128	0156	N	170	3638.3	1	0.0	0.3	3890	1069.2
A051	20/01/98	0446	0517	D	170	4766.3	0	0.0	0.0	2254	472.9
A053	20/01/98	0909	0935	D	170	3580.8	2	0.1	0.6	777	217.0
A055	20/01/98	1629	1638	D	38	1382.6	2	0.1	1.4	98	70.9
A056	20/01/98	1944	2010	D	169	3971.8	17	0.7	4.3	671	168.9
A057	20/01/98	2248	2313	N	168	3445.6	4	0.2	1.2	16586	4813.7
A058	21/01/98	0138	0207	N	172	3302.9	476	24.8	144.1	1307	395.7
A062	21/01/98	2057	2123	D	170	4160.8	4	0.2	1.0	793	190.6
A063	22/01/98	0018	0047	N	170	4000.3	15	0.6	3.7	6840	1709.9
A064	22/01/98	0313	0346	T	170	4592.9	1	0.0	0.2	8880	1933.4
A065	22/01/98	0855	0920	D	170	4373.3	0	0.0	0.0	315	72.0
A066	22/01/98	1132	1159	D	169	4398.4	64	2.5	14.6	1865	424.0
A067	22/01/98	1431	1459	D	169	3916.3	105	4.5	26.8	4560	1164.4
A069	22/01/98	1836	1902	D	170	3337.2	262	13.3	78.5	3150	943.9
A070	22/01/98	2140	2207	D	170	4006.0	3	0.1	0.7	17474	4362.0
A071	23/01/98	0142	0210	N	170	3873.8	609	26.7	157.2	31108	8030.4
A072	23/01/98	0453	0522	D	170	4026.4	60	2.5	14.9	4253	1056.3
A073	23/01/98	0805	0832	D	171	3637.3	84	3.9	23.1	4020	1105.2
A074	23/01/98	1056	1123	D	169	4156.2	388	15.8	93.4	1333	320.7
A075	23/01/98	1354	1423	D	170	4081.3	138	5.7	33.8	769	188.4
A077	23/01/98	1816	1840	D	169	3361.1	76	3.8	22.6	2317	689.3
A078	23/01/98	2118	2144	D	170	3733.0	3	0.1	0.8	2433	651.8
A079	24/01/98	0029	0054	N	170	2992.4	69	3.9	23.1	3510	1173.0
A080	24/01/98	0331	0359	T	170	4031.6	3	0.1	0.7	7452	1848.39
A081	24/01/98	0649	0718	D	170	3980.9	0	0.0	0.0	4236	1064.07
A082	24/01/98	0956	1021	D	172	3275.9	44	2.3	13.4	208	63.49
A083	24/01/98	1246	1315	D	170	3245.1	1	0.1	0.3	14343	4419.89
A085	24/01/98	1655	1726	D	180	4235.7	450	19.1	106.2	1478	348.94
A086	25/01/98	2025	2053	D	170	3467.2	22	1.1	6.3	2823	814.19
A087	25/01/98	0000	0025	N	170	3517.3	76	3.7	21.6	1929	548.43
A088	25/01/98	0313	0344	T	174	3842.4	1	0.0	0.3	4192	1090.98
A089	25/01/98	0607	0637	D	170	4247.9	23	0.9	5.4	908	213.75
A090	25/01/98	0857	0927	D	170	4311.4	72	2.8	16.7	916	212.46
A091	25/01/98	1159	1227	D	170	3676.1	30	1.4	8.2	1601	435.52
SURVEY A AREA					No.	104	13649			302207	
					Mean			6.1	36.8		808.2
					SD			10.7	68.9		1538.7
					Median			1.8	10.7		323.7
ELEPHANT ISLAND AREA					No.	61	6275			216102	
					Mean			4.6	27.1		939.7
					SD			7.2	42.3		1556.3
					Median			1.7	10.2		348.9
WEST AREA					No.	28	5070			56816	
					Mean			8.9	56.0		705.6
					SD			14.3	99.7		1742.4
					Median			2.6	15.1		194.4
SOUTH AREA					No.	15	2304			29289	
					Mean			6.9	40.7		464.9
					SD			13.3	77.6		830.7
					Median			0.6	3.6		190.1

Table 4.1 AMLR 1998 Large-area survey IKMT station information (Contd.)

B. SURVEY D

STATION	DATE	TIME			TOW	FLOW	KRILL ABUNDANCE			SALP ABUNDANCE	
#		START	END	DIEL	DEPTH	VOLUME	TOTAL	#/m2	#/1000m3	TOTAL	#/1000m3
		(Local)			(m)	(m3)					
D105	08/02/98	0702	0728	D	170	3800.8	0	0.00	0.00	1556	409.39
D104	08/02/98	1036	1107	D	170	4863.2	120	4.19	24.68	1434	294.87
D010	08/02/98	1413	1443	D	170	3831.9	91	4.04	23.75	527	137.53
D013	08/02/98	1731	1758	D	170	3669.8	17	0.79	4.63	1254	341.71
D016	08/02/98	2114	2144	T	170	4756.8	2	0.07	0.42	264	55.50
D110	09/02/98	0113	0140	N	169	3773.3	82	3.67	21.73	1320	349.83
D111	08/02/98	0505	0531	D	170	3989.4	5	0.21	1.25	4249	1065.08
D124	09/02/98	0908	0936	D	170	4201.6	4	0.16	0.95	676	160.89
D123	09/02/98	1241	1311	D	174	4332.1	0	0.00	0.00	430	99.26
D116	09/02/98	1618	1643	D	170	3831.9	66	2.93	17.22	1525	397.98
D014	09/02/98	1926	1957	D	159	4440.5	6	0.21	1.35	1245	280.37
D135	09/02/98	1132	1159	N	170	3636.7	359	16.78	98.71	3990	1097.13
D136	10/02/98	0305	0337	N	170	4555.9	5	0.19	1.10	374	82.09
D142	10/02/98	0812	0837	D	171	3453.0	1	0.05	0.29	89	25.77
D143	10/02/98	1139	1203	D	171	3114.1	118	6.48	37.89	15	4.82
D144	10/02/98	1511	1535	D	170	3942.8	120	5.17	30.44	806	204.42
D145	10/02/98	1738	1806	D	170	4150.9	1	0.04	0.24	2086	502.54
D158	11/02/98	0149	0222	N	174	4314.4	20	0.81	4.64	1528	354.16
D159	12/02/98	0014	0044	N	170	4218.4	474	19.10	112.36	2196	520.57
D160	12/02/98	0347	0416	N	170	3802.7	774	34.60	203.54	796	209.32
D166	12/02/98	1127	1154	D	167	4294.2	14	0.54	3.26	156	36.33
D169	12//02/98	1451	1519	D	171	3971.1	0	0.00	0.00	1	0.25
D170	12/02/98	1838	1909	D	175	4812.0	64	2.33	13.30	4	0.83
D171	12/02/98	2157	2225	N	164	4011.8	8	0.33	1.99	323	80.51
D176	13/02/98	0549	0617	D	174	4083.7	0	0.00	0.00	269	65.87
D177	13/02/98	0859	0926	D	171	4159.5	0	0.00	0.00	36	8.65
D178	13/02/98	1239	1308	D	173	4162.9	9	0.37	2.16	191	45.88
D179	13/02/98	1626	1653	D	170	4144.1	81	3.32	19.55	142	34.27
D001	14/02/98	0247	0312	N	175	3172.5	3	0.17	0.95	2358	743.27
D134	14/02/98	0617	0646	D	175	4194.1	1455	60.71	346.91	900	214.59
D131	14/02/98	0905	0928	D	173	3187.1	23	1.25	7.22	1025	321.61
D002	14/02/98	1203	1228	D	169	3411.7	19	0.94	5.57	1609	471.61
D003	14/02/98	1500	1526	D	169	3361.0	0	0.00	0.00	304	90.45
D005	14/02/98	1812	1843	D	169	4729.9	3	0.11	0.63	1393	294.51
D121	14/02/98	2129	2157	T	170	4201.4	2934	118.72	698.33	0	0.00
D118	15/02/98	0012	0037	N	145	3575.7	6600	267.64	1845.80	0	0.00
D006	15/02/98	0355	0421	N	170	3961.8	13	0.56	3.28	5709	1441.00
D004	15/02/98	0725	0754	D	170	4359.1	1	0.04	0.23	974	223.44
D007	15/02/98	1022	1048	D	169	3629.5	1	0.05	0.28	1821	501.73
D109	15/02/98	1342	1411	D	170	4031.5	0	0.00	0.00	148	36.71
D108	15/02/98	1641	1711	D	170	4837.0	2039	71.66	421.54	497	102.75
D034	15/02/98	2013	2039	T	170	3853.2	2	0.09	0.52	493	127.94
D008	15/02/98	2248	2318	N	170	4308.5	19	0.75	4.41	1529	354.88
D018	16/02/98	0529	0556	T	172	3961.7	18	0.78	4.54	811	204.71
D019	16/02/98	0837	0905	D	171	4541.1	28	1.05	6.17	2818	620.55
D020	16/02/98	1139	1205	D	176	3620.4	10	0.49	2.76	90	24.86
D021	16/02/98	1438	1508	D	171	4680.8	6	0.22	1.28	9656	2062.88
D022	16/02/98	1747	1813	D	171	4495.3	19	0.72	4.23	9476	2107.98
D023	16/02/98	2049	2119	T	171	4321.6	3	0.12	0.69	5412	1252.32
D024	17/02/98	2350	0016	N	170	3760.8	379	17.13	100.78	5501	1462.71
D026	17/02/98	0454	0522	N	171	4390.9	3	0.12	0.68	3864	880.01
D027	17/02/98	0811	0839	D	170	4319.3	17	0.67	3.94	1917	443.82
D028	17/02/98	1128	1152	D	170	3500.6	13	0.63	3.71	1350	385.64
D029	17/02/98	1452	1518	D	170	3723.2	24	1.10	6.45	57	15.31
D030	17/02/98	1801	1834	D	170	5933.4	89	2.55	15.00	2048	345.16
D031	17/02/98	2228	2258	D	170	4768.1	34	1.21	7.13	8034	1684.94
D032	18/02/98	0117	0145	N	170	4083.1	882	36.72	216.01	1223	299.53
D037	18/02/98	0546	0616	D	171	4729.3	155	5.60	32.77	243	51.38
D038	18/02/98	0836	0903	D	170	3929.9	2	0.09	0.51	249	63.36
D039	18/02/98	1126	1154	D	172	3648.2	24	1.13	6.58	409	112.11
D040	18/02/98	1423	1447	D	170	3196.3	7	0.37	2.19	2571	804.37
D041	18/02/98	1711	1743	D	171	3810	47	1.66	9.72	3233	668.78

Table 4.1 AMLR 1998 Large-area survey IKMT station information (Contd.).

B. SURVEY D

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
D042	18/02/98	2013	2038	T	170	3503.3	2	0.10	0.57	678	193.53
D043	18/02/98	2300	2329	N	175	4442.6	25176	991.72	5666.96	972	218.79
D045	19/02/98	0341	0412	N	170	4466.9	103	3.92	23.06	704	157.60
D046	19/02/98	0711	0739	D	172	4154.3	0	0.00	0.00	1763	424.37
D047	19/02/98	1030	1058	D	170	4761.1	1	0.04	0.21	2528	530.97
D048	19/02/98	1413	1442	D	170	4779.7	10	0.36	2.09	1569	328.26
D053	19/02/98	2057	2131	T	172	5188.6	37	1.23	7.13	1146	220.87
D051	20/02/98	1032	1103	D	171	4911.4	6	0.21	1.22	270	54.97
D050	20/02/98	1343	1408	D	171	3914.3	6	0.26	1.53	390	99.63
D049	20/02/98	1633	1700	D	157	4218.9	0	0.00	0.00	3145	745.46
D055	20/02/98	1933	2000	D	140	3966.2	4	0.14	1.01	1445	364.33
D056	20/02/98	2257	2327	N	170	4658.9	473	17.26	101.53	7946	1705.54
D057	21/02/98	0232	0304	N	172	4744.7	371	13.45	78.19	2319	488.76
D058	21/02/98	0545	0614	D	171	4338.9	69	2.72	15.90	3671	846.07
D059	21/02/98	0849	0916	D	170	3869.9	62	2.72	16.02	2557	660.73
D061	21/02/98	1341	1408	D	172	4083.5	30	1.26	7.35	3737	915.14
D062	21/02/98	1649	1717	D	172	4307.4	5	0.20	1.16	1834	425.78
D063	21/02/98	2010	2034	T	171	3604.2	0	0.00	0.00	2219	615.67
D064	21/02/98	2257	2328	N	170	4766.3	3230	115.20	677.67	11089	2326.53
D071	22/02/98	0327	0357	N	171	4516.3	9990	378.25	2211.99	2501	553.77
D070	22/02/98	0635	0707	D	171	5146.2	6	0.20	1.17	1037	201.51
D065	22/02'98	0903	0935	D	168	5295.9	1	0.03	0.19	4872	919.96
D066	22/02/98	1158	1224	D	169	4054.0	15	0.63	3.70	1031	254.31
D067	22/02/98	1514	1543	D	170	5192.1	7	0.23	1.35	3702	713.01
D069	22/02/98	2005	2031	T	170	3680.9	203	9.38	55.15	39433	10712.90
D072	23/02/98	0204	0233	N	170	4569.8	592	22.02	129.55	5918	1295.02
D073	23/02/98	0520	0551	T	172	4951.2	4	0.14	0.81	1599	322.95
D075	23/02/98	1508	1539	D	170	4654.9	1	0.04	0.21	5101	1095.84
D077	23/02/98	2049	2115	N	173	3927.3	30	1.32	7.64	1744	444.07
D078	24/02/98	0126	0155	N	170	4484.0	56	2.12	12.49	2200	490.64
D079	24/02/98	0546	0615	D	171	4443.4	46	1.77	10.35	6667	1500.42
D080	24/02/98	0844	0910	D	171	3634.3	31	1.46	8.53	3483	958.38
D081	24/02/98	1147	1211	D	171	3603.7	2	0.09	0.55	2339	649.06
D082	24/02/98	1451	1520	D	172	4640.4	481	17.83	103.66	5161	1112.20
D083	24/02/98	1755	1825	D	175	4491.6	137	5.34	30.50	18312	4076.92
D085	24/02/98	2207	2236	N	169	3913.1	714	30.84	182.46	7310	1868.08
D086	25/02/98	0136	0204	N	170	3706.6	442	20.27	119.25	2853	769.71
D087	25/02/98	0514	0545	T	173	4645.1	2	0.07	0.43	479	103.12
D088	25/02/98	0806	0830	D	175	3087.2	24	1.36	7.77	718	232.57
D089	25/02/98	1059	1129	D	173	4432.3	15	0.59	3.38	14519	3275.73
D090	25/02/98	1346	1415	D	169	4343.9	0	0.00	0.00	2070	476.53
D091	25/02/98	1633	1705	D	170	4579.0	3	0.11	0.66	12713	2776.37
SURVEY D AREA				No.		104	59700			300948	
				Mean				22.6	133.5		686.6
				SD				106.9	620.4		1214.0
				Median				0.7	4.1		354.5
ELEPHANT ISLAND AREA				No.		61	44147			254706	
				Mean				28.2	162.6		977.3
				SD				134.0	768.3		1496.5
				Median				0.8	4.5		553.8
WEST AREA				No.		28	2441			27482	
				Mean				3.8	22.3		245.2
				SD				7.5	44.2		280.3
				Median				0.5	2.7		149.2
SOUTH AREA				No.		15	13112			18760	
				Mean				34.8	222.4		328.3
				SD				71.3	479.7		359.2
				Median				0.6	3.3		223.4

Table 4.2 Maturity stage composition of krill collected in the large-area surveys and three subareas during 1998. Advanced maturity stages are proportions of mature females that are 3c-3e in January and 3d-3e in February.

	E. superba January 1998			
Area	Survey A	Elephant I.	West	South
Stage	%	%	%	%
Juveniles	24.1	18.4	25.6	35.6
Immature Stages	40.6	31.7	44.2	56.0
Mature Stages	35.3	49.9	30.3	8.4
Females:				
F2	13.4	9.1	16.1	18.9
F3a	19.4	21.4	23.0	5.5
F3b	4.3	9.0	0.8	0.0
F3c	0.6	1.0	0.2	0.4
F3d	0.4	0.3	0.0	1.5
F3e	0.3	0.7	0.0	0.0
Advanced Stages	5.1	6.2	0.7	26.0
Males:				
M2a	14.1	8.5	15.8	25.2
M2b	8.7	8.3	8.4	10.1
M2c	4.4	5.7	3.9	1.7
M3a	2.0	3.1	1.3	0.5
M3b	8.4	14.4	5.0	0.3
Male:Female	1.0	1.0	0.9	1.4
No. measured	6804	3600	2314	890

	February 1998			
Area	Survey D	Elephant I.	West	South
Stage	%	%	%	%
Juveniles	10.2	3.6	4.3	32.9
Immature Stages	31.3	25.4	41.3	48.4
Mature Stages	58.6	71.0	54.4	18.8
Females:				
F2	10.9	6.9	16.6	23.0
F3a	13.1	10.9	30.6	16.6
F3b	9.2	11.8	6.1	1.1
F3c	2.3	3.0	1.3	0.3
F3d	0.9	1.3	0.0	0.0
F3e	0.1	0.1	0.2	0.0
Advanced Stages	4.1	5.2	0.5	0.0
Males:				
M2a	4.1	1.9	5.6	10.9
M2b	8.3	6.6	12.0	13.2
M2c	8.0	10.0	7.0	1.4
M3a	13.1	17.5	5.2	0.0
M3b	19.9	26.2	11.0	0.8
Male:Female	1.5	1.9	0.7	0.6
No. measured	5123	3153	1227	743

Table 4.3 Zooplankton collected in the Survey A area and three subareas, January 1998. F(%) is frequency of occurrence in (N) samples. (L) are larval and (J) juvenile stages.

	LARGE SURVEY AREA A				ELEPHANT ISLAND AREA				WEST AREA				SOUTH AREA			
	F(%)	Mean	SD	Med	F(%)	Mean	SD	Med	F(%)	Mean	SD	Med	F(%)	Mean	SD	Med
Taxon		(104)				(61)				(28)				(15)		
Salpa thompsoni	100.0	808.2	1538.7	323.7	100.0	939.7	1556.3	348.9	45.9	705.6	1742.4	194.4	24.6	464.9	830.7	190.1
Thysanoessa macrura	100.0	180.8	411.6	79.8	100.0	135.3	150.8	98.0	45.9	313.1	741.8	56.9	24.6	118.7	98.6	87.2
Vibilia antarctica	96.2	13.2	17.1	7.8	100.0	16.3	20.8	10.5	44.3	11.1	8.5	8.0	19.7	4.5	2.8	5.4
Copepods	94.2	56.5	80.3	25.8	95.1	41.2	55.1	21.5	41.0	73.5	107.5	24.9	24.6	86.9	91.7	56.3
Euphausia superba	92.3	36.8	68.9	10.7	91.8	27.1	42.3	10.2	45.9	56.0	99.7	15.1	19.7	40.7	77.6	3.6
Limacina helicina	73.1	8.1	12.9	3.4	63.9	9.1	15.0	3.1	37.7	8.4	10.3	4.2	23.0	3.2	2.8	2.4
Cyllopus magellanicus	64.4	1.9	3.1	0.5	78.7	2.6	3.3	1.2	26.2	0.7	1.2	0.2	4.9	1.1	3.7	0.0
Ostracods	51.0	4.8	11.7	0.4	47.5	3.4	7.4	0.0	24.6	3.9	7.0	0.5	14.8	12.2	24.0	1.0
Spongiobranchaea australis	45.2	0.9	1.7	0.0	42.6	0.9	1.8	0.0	31.1	1.2	1.7	0.4	3.3	0.1	0.2	0.0
Chaetognaths	42.3	8.9	31.9	0.0	31.1	1.6	3.7	0.0	32.8	27.5	57.1	7.0	8.2	3.8	7.2	0.0
Hyperiella dilatata	39.4	0.4	0.9	0.0	32.8	0.5	1.0	0.0	27.9	0.4	0.6	0.2	6.6	0.3	0.9	0.0
Clione limacina	38.5	0.9	2.3	0.0	37.7	1.3	2.9	0.0	13.1	0.3	0.8	0.0	14.8	0.3	0.3	0.3
Diphyes antarctica	37.5	1.1	2.6	0.0	32.8	0.6	1.3	0.0	13.1	1.4	3.5	0.0	18.0	2.6	3.5	2.0
Tomopteris spp.	31.7	1.3	9.1	0.0	29.5	0.5	1.2	0.0	24.6	3.8	17.2	0.3	—	—	—	—
Themisto gaudichaudii	31.7	0.3	0.9	0.0	23.0	0.2	0.7	0.0	26.2	0.7	1.2	0.2	4.9	0.1	0.1	0.0
Polychaetes	28.8	1.5	8.5	0.0	18.0	1.8	11.0	0.0	16.4	1.1	1.8	0.0	14.8	1.2	1.4	0.9
Sagitta gazellae	27.9	1.9	6.0	0.0	27.9	1.6	4.3	0.0	4.9	0.1	0.1	0.0	14.8	6.7	12.0	1.5
Radiolarians	27.9	0.7	1.5	0.0	24.6	0.5	1.1	0.0	18.0	1.2	2.2	0.0	4.9	0.2	0.5	0.0
Primno macropa	26.0	0.7	1.9	0.0	27.9	0.6	1.1	0.0	9.8	1.1	3.2	0.0	6.6	0.7	1.5	0.0
Lepidonotothen larseni (L)	23.1	0.5	1.5	0.0	26.2	0.5	1.2	0.0	3.3	0.2	1.1	0.0	9.8	1.4	2.7	0.0
Cyllopus lucasii	20.2	0.5	1.8	0.0	27.9	0.7	2.2	0.0	6.6	0.2	0.7	0.0	—	—	—	—
Eukrohnia hamata	13.5	0.5	2.1	0.0	13.1	0.4	1.4	0.0	6.6	0.4	1.2	0.0	3.3	1.2	4.4	0.0
Lepidonotothen kempi (L)	13.5	0.3	1.4	0.0	13.1	0.1	0.4	0.0	6.6	0.7	2.6	0.0	3.3	0.0	0.1	0.0
E. superba (L)	11.5	1.0	4.5	0.0	11.5	0.4	1.6	0.0	8.2	3.0	8.1	0.0	—	—	—	—
Sipunculids	11.5	0.1	0.5	0.0	8.2	0.2	0.6	0.0	4.9	0.1	0.2	0.0	6.6	0.1	0.2	0.0
Electrona antarctica (L)	10.6	0.2	1.4	0.0	4.9	0.0	0.2	0.0	11.5	0.7	2.7	0.0	1.6	0.0	0.1	0.0
Rhynchonereella bongraini	9.6	0.2	0.7	0.0	14.8	0.3	0.9	0.0	1.6	0.0	0.0	0.0	—	—	—	—
Hydromedusae	9.6	0.1	0.4	0.0	8.2	0.1	0.5	0.0	6.6	0.1	0.2	0.0	1.6	0.0	0.1	0.0
Euphausia triacantha	7.7	0.3	1.5	0.0	11.5	0.5	1.9	0.0	1.6	0.0	0.0	0.0	—	—	—	—
Ihlea racovitzai	5.8	41.5	326.6	0.0	9.8	70.7	424.0	0.0	—	—	—	—	—	—	—	—
Epimeriella macronyx	5.8	0.2	1.2	0.0	6.6	0.3	1.5	0.0	—	—	—	—	3.3	0.0	0.1	0.0
Euphausia frigida	5.8	0.2	1.0	0.0	9.8	0.3	1.4	0.0	—	—	—	—	—	—	—	—
Clio pyramidata	4.8	0.3	1.6	0.0	6.6	0.4	2.0	0.0	1.6	0.2	0.9	0.0	—	—	—	—
Vanadis antarctica	4.8	0.1	0.4	0.0	1.6	0.0	0.0	0.0	6.6	0.2	0.7	0.0	—	—	—	—
Pleuragramma antarcticum (J)	4.8	0.0	0.2	0.0	3.3	0.0	0.2	0.0	1.6	0.0	0.1	0.0	3.3	0.0	0.1	0.0
Electrona antarctica	3.8	0.1	0.8	0.0	4.9	0.1	1.0	0.0	—	—	—	—	1.6	0.0	0.1	0.0
Ctenophores	3.8	0.1	0.6	0.0	1.6	0.0	0.1	0.0	1.6	0.2	1.1	0.0	3.3	0.0	0.1	0.0
Acanthepyra pelagica	3.8	0.0	0.2	0.0	3.3	0.0	0.2	0.0	1.6	0.0	0.0	0.0	1.6	0.1	0.3	0.0
Notolepis coatsi (L)	3.8	0.0	0.2	0.0	4.9	0.0	0.2	0.0	—	—	—	—	1.6	0.1	0.2	0.0
Beroe cucumis	3.8	0.0	0.1	0.0	4.9	0.0	0.1	0.0	1.6	0.0	0.0	0.0	—	—	—	—
Chaenocephalus aceratus (L)	3.8	0.0	0.1	0.0	—	—	—	—	3.3	0.0	0.1	0.0	3.3	0.0	0.1	0.0
Dimophyes arctica	2.9	0.1	0.6	0.0	3.3	0.1	0.8	0.0	1.6	0.0	0.1	0.0	—	—	—	—
Hyperiella macronyx	2.9	0.1	0.6	0.0	1.6	0.0	0.0	0.0	—	—	—	—	3.3	0.5	1.5	0.0
Decapod Larvae	2.9	0.0	0.3	0.0	3.3	0.1	0.3	0.0	—	—	—	—	1.6	0.1	0.2	0.0
Siphonophores	2.9	0.0	0.3	0.0	1.6	0.0	0.0	0.0	—	—	—	—	3.3	0.3	0.7	0.0
Thysanoessa macrura (L)	1.9	0.0	0.2	0.0	—	—	—	—	3.3	0.1	0.4	0.0	—	—	—	—
Scyphomedusae	1.9	0.0	0.0	0.0	—	—	—	—	3.3	0.0	0.1	0.0	—	—	—	—
Bolinopsis infundibulum	1.9	0.0	0.0	0.0	3.3	0.0	0.0	0.0	—	—	—	—	—	—	—	—
Chionodraco rastrospinosus (L)	1.9	0.0	0.0	0.0	—	—	—	—	—	—	—	—	3.3	0.0	0.1	0.0
Hyperia macrocephala	1.0	0.1	0.6	0.0	—	—	—	—	—	—	—	—	1.6	0.4	1.5	0.0
Cyllopus sp.	1.0	0.0	0.2	0.0	—	—	—	—	1.6	0.1	0.4	0.0	—	—	—	—
Calycopsis borchgrevinki	1.0	0.0	0.1	0.0	1.6	0.0	0.2	0.0	—	—	—	—	—	—	—	—
Fish eggs	1.0	0.0	0.1	0.0	1.6	0.0	0.1	0.0	—	—	—	—	—	—	—	—
Eusirus sp.	1.0	0.0	0.1	0.0	1.6	0.0	0.1	0.0	—	—	—	—	—	—	—	—
Beroe forskalii	1.0	0.0	0.1	0.0	1.6	0.0	0.1	0.0	—	—	—	—	—	—	—	—
Bathylagus sp. (L)	1.0	0.0	0.1	0.0	1.6	0.0	0.1	0.0	—	—	—	—	—	—	—	—
Hyperoche medusarum	1.0	0.0	0.1	0.0	1.6	0.0	0.1	0.0	—	—	—	—	—	—	—	—
Bolinopsis sp.	1.0	0.0	0.0	0.0	—	—	—	—	—	—	—	—	1.6	0.0	0.1	0.0
Notolepis spp. (L)	1.0	0.0	0.0	0.0	1.6	0.0	0.0	0.0	—	—	—	—	—	—	—	—
Eusirus antarcticus	1.0	0.0	0.0	0.0	1.6	0.0	0.0	0.0	—	—	—	—	—	—	—	—
Gobionotothen gibberifrons (L)	1.0	0.0	0.0	0.0	—	—	—	—	—	—	—	—	1.6	0.0	0.1	0.0
Electrona carlsbergi	1.0	0.0	0.0	0.0	1.6	0.0	0.0	0.0	—	—	—	—	—	—	—	—
Artedidraco skottsbergi (L)	1.0	0.0	0.0	0.0	—	—	—	—	—	—	—	—	1.6	0.0	0.1	0.0
Orchomene plebs	1.0	0.0	0.0	0.0	1.6	0.0	0.0	0.0	—	—	—	—	—	—	—	—
Cephalopods	1.0	0.0	0.0	0.0	1.6	0.0	0.0	0.0	—	—	—	—	—	—	—	—
TOTAL TAXA	65				56				40				39			
TAXA/TOW	0.6				0.9				1.4				2.6			

Table 4.4 Relative abundance of zooplankton taxa in four groupings derived from cluster analysis of January 1998 Survey A data. Rank is based on mean abundance (No. per 1000m3) within each station grouping. The 15 most abundant taxa in each cluster are included. Ihlea racovitzai is excluded from consideration.

	CLUSTER 1				CLUSTER 2				CLUSTER 3				CLUSTER 4			
	(N = 21)				(N = 36)				(N = 13)				(N = 32)			
Taxon	Rank	Mean	SD	%	Rank	Mean	SD	%	Rank	Mean	SD	%	Rank	Mean	SD	%
Salpa thompsoni	1	1328.7	1530.5	85.1	1	1291.2	2135.1	74.5	1	179.4	208.3	42.5	1	204.0	169.6	42.7
Thysanoessa macrura	2	161.6	215.0	10.3	2	307.4	651.6	17.7	4	32.5	42.8	7.7	2	104.5	87.6	21.9
Euphausia superba	15	0.6	0.8	0.0	3	70.8	95.7	4.1	8	5.6	5.1	1.3	4	34.3	49.7	7.2
Copepods	3	22.5	18.5	1.4	4	27.6	41.3	1.6	2	112.8	120.2	26.7	3	82.4	86.2	17.2
Vibilia antarctica	4	19.1	31.0	1.2	5	17.2	12.4	1.0	7	7.5	3.7	1.8	6	7.3	7.2	1.5
Ostracods	5	7.7	18.8	0.5	6	3.7	8.0	0.2	13	1.7	4.7	0.4	9	5.0	11.1	1.0
Limacina helicina	6	7.2	13.8	0.5	7	3.3	5.6	0.2	5	11.2	11.5	2.7	5	12.2	16.3	2.5
Cyllopus magellanicus	7	2.3	3.5	0.1	8	2.3	2.7	0.1	21.5	0.4	0.4	0.1	11	1.7	3.6	0.4
Chaetognaths	8	1.4	3.3	0.1	9	1.7	4.5	0.1	3	44.1	75.9	10.4	7	6.5	17.2	1.4
Diphyes antarctica	15	0.6	1.5	0.0	10	1.2	2.4	0.1	11	2.0	4.0	0.5	15.5	0.9	2.6	0.2
Spongiobranchaea australis	20.5	0.4	0.8	0.0	11.5	0.8	1.3	0.0	17.5	1.0	1.9	0.2	13	1.2	2.3	0.3
Eukrohnia hamata	20.5	0.4	1.0	0.0	11.5	0.8	3.0	0.0	—	—	—	--	21.5	0.5	1.8	0.1
Lepidonotothen larseni (L)	20.5	0.4	1.1	0.0	13.5	0.5	1.2	0.0	15	1.5	3.1	0.4	23.5	0.4	0.9	0.1
Cyllopus lucasii	11	0.8	3.1	0.0	13.5	0.5	1.0	0.0	—	—	—	--	19.5	0.6	1.6	0.1
Primno macropa	17.5	0.5	1.1	0.0	15.5	0.4	1.1	0.0	10	2.6	4.3	0.6	15.5	0.9	2.7	0.2
Tomopteris spp.	20.5	0.4	1.4	0.0	15.5	0.4	1.0	0.0	6	7.6	24.7	1.8	23.5	0.4	0.8	0.1
Euphausia superba (L)	32	0.1	0.6	0.0	18	0.3	1.9	0.0	9	4.0	10.1	1.0	26	0.2	0.8	0.0
Clione limacina	10	1.0	2.2	0.1	18	0.3	0.9	0.0	19	0.7	1.0	0.2	12	1.6	3.5	0.3
Sagitta gazellae	12.5	0.7	1.4	0.0	23	0.2	0.9	0.0	—	—	—	--	8	5.5	9.8	1.2
Hyperiella dilatata	15	0.6	1.3	0.0	23	0.2	0.5	0.0	21.5	0.4	0.6	0.1	17	0.7	1.0	0.1
Polychaetes	25.5	0.3	0.6	0.0	23	0.2	0.9	0.0	14	1.6	2.2	0.4	10	3.7	15.0	0.8
Radiolarians	17.5	0.5	1.2	0.0	23	0.2	0.6	0.0	12	1.9	2.8	0.5	14	1.0	1.7	0.2
Epimeriella macronyx	12.5	0.7	2.3	0.0	23	0.2	0.8	0.0	—	—	—	--	—	—	—	—
Clio pyramidata	9	1.2	3.3	0.1	—	—	—	—	—	—	—	--	29.5	0.1	0.7	0.0
TOTAL ZOOPLANKTON		1561.8	1689.0			1732.5	2646.9			422.1	309.5			478.2	212.4	

Table 4.5 Abundance of krill and dominant zooplankton species collected in the Elephant Island area during (a) January-February and (b) March 1998 compared to similar sampling periods in 1992-1997. Zooplankton data are not available for February-March 1992.

	January-February Elephant Island Area																				
	Euphausia superba Abundance (No. per 1000 m3)							*Thysanoessa macrura* Abundance (No. per 1000 m3)							*Salpa thompsoni* Abundance (No. per 1000 m3)						
	1998	1997	1996	1995	1994	1993	1992	1998	1997	1996	1995	1994	1993	1992	1998	1997	1996	1995	1994	1993	1992
No. Tows	61	71	72	71	63	70	63	61	71	72	71	63	70	63	61	71	72	71	63	70	63
Median	10.2	5.6	11.4	3.6	3.1	8.2	5.7	98.0	52.8	52.3	36.1	25.4	27.5	22.5	348.9	87.1	10.5	1.6	582.3	245.8	14.0
Mean	27.1	29.6	82.1	9.5	34.5	28.8	23.7	135.3	101.0	103.4	104.1	74.6	48.6	48.1	939.7	223.2	25.5	20.2	931.9	1213.4	94.3
SD	42.3	80.5	245.1	20.6	94.2	64.4	78.0	150.8	127.2	118.1	231.9	144.3	60.1	57.0	1556.3	336.4	36.3	46.5	950.2	2536.7	192.3
Minimum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.0	0.0	0.0	0.0	0.0	0.0	36.0	0.0	0.0	0.0	9.5	6.9	0.0
Maximum	175.0	483.2	1500.6	146.1	495.9	438.9	594.1	992.3	616.2	500.1	239.9	901.6	307.1	233.7	8030.4	2006.3	161.6	239.9	4781.7	16078.8	1231.1

	February-March Elephant Island Area																				
	Euphausia superba Abundance (No. per 1000 m3)							*Thysanoessa macrura* Abundance (No. per 1000 m3) (* Includes larval stages)							*Salpa thompsoni* Abundance (No. per 1000 m3)						
	1998	1997	1996	1995	1994	1993	1992	1998	1997	1996	1995	1994*	1993*	1992	1998	1997	1996	1995	1994	1993	1992
No. Tows	61	16	72	71	70	67	67	61	16	72	71	70	67		61	16	72	71	70	67	
Median	4.5	4.6	4.1	1.2	0.4	3.0	7.1	70.0	122.6	53.6	22.2	23.8	22.1	n.a.	553.8	521.0	5.6	0.7	242.6	605.9	n.a.
Mean	162.6	30.4	133.2	5.2	17.1	35.0	38.0	140.6	181.3	116.1	79.7	77.1	128.9	n.a.	977.3	1245.5	33.2	20.6	495.1	1585.9	n.a.
SD	768.3	56.4	867.7	12.0	63.5	89.7	77.4	232.3	168.0	147.4	138.5	132.6	235.1	n.a.	1496.5	1224.6	85.7	66.5	579.4	2725.5	n.a.
Minimum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.1	12.0	0.0	0.0	0.0	0.0	n.a.	15.3	239.4	0.0	0.0	5.3	2.2	n.a.
Maximum	5667.0	204.2	7385.4	90.0	371.1	542.0	389.9	1638.5	538.9	679.4	664.9	815.9	1141.5	n.a.	10712.9	4348.3	659.4	391.9	2377.5	16662.5	n.a.

Table 4.6 Salp and krill carbon biomass (mg C per m^2) in the Elephant Island area during 1994-1998 surveys. N is number of of samples. Salp:Krill ratio is based on median values.

	January-February									
	1998		1997		1996		1995		1994	
Biomass (mg C m^-2)	Salps	Krill	Salps	Krill	Salps	Krill	Salps	Krill	Salps	Krill
Mean	430.8	173.1	334.5	229.0	20.2	337.3	7.8	242.3	570.6	314.1
SD	565.3	290.6	1115.6	522.1	30.9	756.1	16.1	201.1	563.2	856.4
Median	187.0	46.7	108.9	45.1	10.0	72.2	1.3	43.5	400.5	25.6
Maximum	2699.0	1488.4	9434.6	3115.5	134.2	4721.0	75.3	1545.2	3276.8	4971.1
N	61	60	71	71	72	72	57	71	63	63
Salp:Krill Ratio	4.0		2.4		0.1		0.03		15.6	

	February-March									
	1998		1997		1996		1995		1994	
Biomass (mg C m^-2)	Salps	Krill	Salps	Krill	Salps	Krill	Salps	Krill	Salps	Krill
Mean	694.6	1555.8	1139.7	313.1	50.7	1702.3	13.1	59.2	483.7	425.9
SD	1121.2	8218.7	1269.8	655.2	146.5	12441.6	47.3	149.1	469.5	2351.4
Median	379.4	31.6	504.8	50.0	4.6	40.7	0.7	13.1	285.6	2.8
Maximum	8543.0	62155.8	4645.4	2638.7	954.0	106458.5	325.2	1107.1	1843.6	19313.8
N	61	60	16	16	72	72	71	71	70	70
Salp:Krill Ratio	12.0		10.1		0.1		0.1		102.0	

Table 4.7 Maturity stage composition of krill collected in the Elephant Island area during 1998 compared to 1992-1997. 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	1998 %	1997 %	1996 %	1995 %	1994 %	1993 %	1992 %
Juveniles	18.4	15.2	55.0	4.6	4.0	7.2	37.1
Immature stages	31.7	30.6	18.3	4.0	18.8	30.7	19.1
Mature stages	49.9	54.2	26.7	91.4	77.2	62.2	43.9
Females:							
F2	9.1	6.3	1.1	0.1	2.3	7.8	0.8
F3a	21.4	3.5	0.0	0.2	18.0	11.7	0.6
F3b	9.0	0.6	0.2	1.2	19.3	14.3	12.3
F3c	1.0	6.9	1.9	15.3	20.1	5.1	9.2
F3d	0.3	6.1	0.7	17.7	2.3	1.2	0.4
F3e	0.7	7.4	11.6	3.7	0.0	0.0	0.0
Advanced Stages	6.2	83.2	98.3	96.3	37.5	19.5	42.7
Males:							
M2a	8.5	14.6	14.6	0.9	0.3	6.8	8.7
M2b	8.4	8.2	2.1	1.5	9.4	11.9	7.3
M2c	5.7	1.5	0.5	1.5	6.8	4.2	2.3
M3a	3.1	1.5	1.4	4.4	4.3	3.7	2.8
M3b	14.4	28.1	10.9	48.9	13.2	26.2	18.7
Male:Female ratio	1.0:1	1.8:1	1.9:1	1.5:1	0.5:1	1.3:1	1.7:1
No. measured	3600	3209	4296	2294	2078	4283	2472

	February-March						
Stage	1998 %	1997 %	1996 %	1995 %	1994 %	1993 %	1992 %
Juveniles	3.6	8.0	20.8	1.1	3.7	3.5	33.6
Immature stages	25.4	19.7	9.9	2.5	6.2	51.4	27.1
Mature stages	71.0	72.3	69.3	96.4	90.1	45.1	39.2
Females:							
F2	6.9	1.1	0.6	0.3	0.7	21.8	0.8
F3a	10.9	0.1	0.0	0.0	3.5	12.4	10.3
F3b	11.8	0.0	0.0	0.0	7.8	6.2	10.2
F3c	3.0	1.8	5.0	2.0	4.3	3.7	4.3
F3d	1.3	29.1	10.9	21.8	4.6	1.1	1.2
F3e	0.1	7.3	4.9	20.4	0.9	1.2	<0.01
Advanced Stages	5.2	95.0	76.0	95.5	26.1	9.3	4.6
Males:							
M2a	1.9	8.6	6.5	0.7	0.2	6.9	4.3
M2b	6.6	8.8	1.2	0.4	1.2	19.1	19.8
M2c	10.0	1.2	1.6	1.1	4.2	3.6	2.2
M3a	17.5	3.7	5.3	4.4	24.1	2.1	2.5
M3b	26.2	30.3	43.2	47.8	44.7	18.4	10.7
Male:Female ratio	1.9	1.3:1	2.7:1	1.2:1	3.4:1	1.1:1	1.5:1
No. measured	3153	560	2984	1271	1155	3669	3646

Table 4.8 Zooplankton and nekton taxa present in the large-area survey samples during January 1998 compared to January 1993-1997 surveys. F(%) is frequency of occurrence in (N) tows. n.a. indicates taxon was not enumerated. (L) indicates larval stages; (J) indicates juvenile stages.

	SURVEY A Jan. 1998		SURVEY A Jan.-Feb. 1997		SURVEY A Jan. 1996		SURVEY A Jan. 1995		SURVEY A Jan. 1994		SURVEY A Jan. 1993	
Taxon	F(%) (105)	Mean No./ 1000m3	F(%) (105)	Mean No./ 1000m3	F(%) (91)	Mean No./ 1000m3	F(%) (90)	Mean No./ 1000m3	F(%) (91)	Mean No./ 1000m3	F(%) (87)	Mean No./ 1000m3
Salpa thompsoni	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	100.0	180.8	97.1	104.4	98.9	106.9	91.1	96.4	90.0	79.7	95.4	51.5
Vibilia antarctica	96.2	13.2	70.5	2.5	48.4	0.5	22.2	0.2	98.8	11.8	64.4	1.6
Copepods	94.2	56.5	100.0	582.6	100.0	794.4	98.9	652.7	30.0	41.3	31.0	38.1
Euphausia superba	92.3	36.8	93.3	40.4	96.7	112.5	87.8	14.5	77.5	27.1	90.8	44.1
Limacina helicina	73.1	8.1	47.6	2.9	74.7	33.7	43.3	1.9	6.3	0.3	—	—
Cyllopus magellanicus	64.4	1.9	76.2	3.8	41.8	1.6	24.4	0.2	82.5	6.3	18.4	0.5
Ostracods	51.0	4.8	41.0	5.5	53.8	4.9	56.7	9.7	n.a	n.a	n.a	n.a
Spongiobranchaea australis	45.2	0.9	67.6	2.2	47.3	1.8	64.4	0.5	11.3	0.1	40.2	0.6
Chaetognaths	42.3	8.9	74.3	22.9	68.1	12.5	98.9	79.7	n.a	n.a	56.3	9.2
Hyperiella dilatata	39.4	0.4	56.2	2.2	41.8	0.6	54.4	0.3	18.7	0.3	6.9	0.0
Clione limacina	38.5	0.9	21.9	0.3	56.0	2.1	41.1	0.5	13.8	0.3	4.6	0.1
Diphyes antarctica	37.5	1.1	9.5	0.2	17.6	0.1	58.9	1.0	20.0	0.3	20.7	0.5
Tomopteris spp.	31.7	1.3	54.3	1.9	60.4	0.9	84.4	4.2	37.5	2.5	33.3	0.5
Themisto gaudichaudii	31.7	0.3	92.4	3.6	92.3	4.9	76.7	4.9	83.8	10.6	50.6	0.8
Polychaetes	28.8	1.5	1.0	0.0	1.1	0.0	—	—	—	—	—	—
Sagitta gazellae	27.9	1.9	31.4	0.3	23.1	0.3	48.9	3.4	20.0	0.4	n.a	n.a
Radiolaria	27.9	0.7	41.0	1.8	12.1	0.1	—	—	n.a	n.a	n.a	n.a
Primno macropa	26.0	0.7	63.8	4.3	20.9	0.1	20.0	0.1	6.3	0.5	3.4	0.0
Lepidonotothen larseni (L)	23.1	0.5	27.6	1.8	22.0	0.2	40.0	1.1	6.3	0.7	16.1	0.2
Cyllopus lucasii	20.2	0.5	49.5	0.4	11.0	0.1	22.2	0.5	16.3	0.7	11.5	0.4
Eukrohnia hamata	13.5	0.5	21.9	0.2	20.9	0.1	10.0	0.1	21.3	0.2	n.a	n.a
Lepidonotothen kempi	13.5	0.3	32.4	0.6	30.8	0.3	20.0	0.1	6.3	0.3	5.7	0.1
Euphausia superba (L)	11.5	1.0	55.2	15.2	22.0	2.7	22.2	135.8	n.a	n.a	n.a	n.a
Sipunculids	11.5	0.1	10.5	0.1	7.7	0.0	24.4	0.1	—	—	n.a	n.a
Electrona spp. (L)	10.6	0.2	37.1	1.4	27.5	0.7	61.1	2.5	2.5	0.0	2.3	0.0
Rhynchonereella bongraini	9.6	0.2	4.8	0.1	2.2	0.0	3.3	0.1	—	—	—	—
Larval fish	8.7	0.1	—	—	1.1	0.0	—	—	—	—	—	—
Euphausia triacantha	7.7	0.3	18.1	1.4	15.4	0.5	33.3	1.5	7.5	1.2	25.3	1.0
Ihlea racovitzai	5.8	41.5	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Epimeriella macronyx	5.8	0.2	1.9	1.4	1.1	0.0	8.9	0.0	—	—	—	—
Euphausia frigida	5.8	0.2	41.9	14.8	30.8	1.9	50.0	9.8	17.5	3.8	26.4	3.6
Clio pyramidata	4.8	0.3	2.9	0.0	6.6	0.1	72.2	5.3	40.0	5.4	6.9	0.2
Vanadis antarctica	4.8	0.1	1.0	0.0	4.4	0.0	15.6	0.1	2.5	0.0	4.6	0.0
Pleuragramma antarcticum (J)	4.8	0.0	2.9	0.0	1.1	0.0	2.2	0.0	—	—	—	—
Electrona antarctica	3.8	0.1	9.5	0.0	13.2	0.0	13.3	0.1	2.5	0.0	10.3	0.0
Ctenophores	3.8	0.1	16.2	0.1	—	—	6.7	0.0	—	—	—	—
Acanthepyra pelagica	3.8	0.0	9.5	0.1	—	—	22.2	0.1	—	—	—	—
Notolepis coatsi (L)	3.8	0.0	6.7	0.0	8.8	0.0	27.8	0.1	—	—	—	—
Beroe cucumis	3.8	0.0	15.2	0.1	7.7	0.0	12.2	0.0	15.0	0.1	2.3	0.0
Chaenocephalus aceratus (L)	3.8	0.0	—	—	—	—	—	—	—	—	—	—
Dimophyes arctica	2.9	0.1	19.0	0.3	15.4	0.1	25.6	0.8	7.5	0.0	3.4	0.0
Hyperiella macronyx	2.9	0.1	8.6	0.1	5.5	0.0	23.3	0.1	—	—	1.1	0.0
Decapod larvae	2.9	0.0	—	—	2.2	0.2	—	—	—	—	1.1	0.0
Thysanoessa macrura (L)	1.9	0.0	44.8	17.0	90.1	308.5	36.7	15.9	n.a	n.a	n.a	n.a
Scyphomedusae	1.9	0.0	1.0	0.0	13.2	0.1	—	—	1.3	0.0	6.9	0.0
Bolinopsis infundibulum	1.9	0.0	—	—	—	—	—	—	—	—	—	—
Chionodraco rastrospinosus (	1.9	0.0	1.0	0.0	—	—	—	—	—	—	2.3	0.0
Gammarids	1.0	0.0	—	—	1.1	0.0	—	—	—	—	—	—
Hyperia macrocephala	1.0	0.1	1.0	0.0	—	—	3.3	0.0	1.3	0.0	1.1	0.4
Cyllopus sp.	1.0	0.0	1.0	0.0	—	—	—	—	—	—	—	—
Calycopsis borchgrevinki	1.0	0.0	2.9	0.0	2.2	0.0	1.1	0.0	1.3	0.0	1.1	0.0
Fish Eggs	1.0	0.0	2.9	0.1	1.1	0.0	4.4	0.0	—	—	—	—
Eusirus sp.	1.0	0.0	—	—	—	—	—	—	—	—	—	—
Beroe forskalii	1.0	0.0	—	—	1.1	0.0	—	—	—	—	1.1	0.0
Bathylagus sp. (L)	1.0	0.0	1.0	0.0	2.2	0.0	8.9	0.0	—	—	—	—
Hyperoche medusarum	1.0	0.0	1.0	0.0	3.3	0.0	18.9	0.0	—	—	—	—

Table 4.8 (Contd.)

	SURVEY A Jan. 1998		SURVEY A Jan.-Feb. 1997		SURVEY A Jan. 1996		SURVEY A Jan. 1995		SURVEY A Jan. 1994		SURVEY A Jan. 1993	
Taxon	F(%) (105)	Mean No./ 1000m3	F(%) (105)	Mean No./ 1000m3	F(%) (91)	Mean No./ 1000m3	F(%) (90)	Mean No./ 1000m3	F(%) (91)	Mean No./ 1000m3	F(%) (87)	Mean No./ 1000m3
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	—	—	—	—	—	—
Gobionotothen gibberifrons (L	1.0	0.0	—	—	—	—	1.1	0.0	—	—	—	—
Electrona carlsbergi	1.0	0.0	10.5	0.1	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a	n.a
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
Cephalopods	1.0	0.0	—	—	—	—	2.2	0.0	—	—	—	—
Notothenia coriiceps	—	—	—	—	—	—	1.1	0.0	1.3	0.0	—	—
Periphylla periphylla	—	—	—	—	1.1	0.0	1.1	0.0	—	—	4.6	0.0
Lepidonotothen nudifrons (L)	—	—	—	—	2.2	0.0	8.9	0.1	1.3	0.2	1.1	0.1
Eusirus microps	—	—	—	—	—	—	4.4	0.0	—	—	2.3	0.0
Euphausia spp. (L)	—	—	—	—	1.1	0.0	—	—	—	—	—	—
Travisiopsis levinseni	—	—	—	—	—	—	1.1	0.0	—	—	2.3	0.0
Eusirus perdentatus	—	—	—	—	1.1	0.0	22.2	0.1	—	—	—	—
Chorismus antarcticus	—	—	—	—	1.1	0.0	—	—	—	—	—	—
Botrynema brucei	—	—	—	—	—	—	1.1	0.0	—	—	—	—
Euphausia crystallorphorias	—	—	—	—	—	—	4.4	0.0	—	—	1.1	0.0
Cryodraco antarctica (L)	—	—	—	—	1.1	0.0	—	—	—	—	—	—
Hyperiella antarctica	—	—	—	—	2.2	0.0	2.2	0.0	—	—	2.3	0.0
Hydromedusae	—	—	20.0	0.1	4.4	0.0	6.7	0.1	—	—	—	—
Orchomene rossi	—	—	8.6	0.0	—	—	5.6	0.0	—	—	—	—
Scina spp.	—	—	4.8	0.1	—	—	—	—	—	—	—	—
Cumaceans	—	—	3.8	0.4	1.1	0.0	—	—	—	—	—	—
Gymnoscopelus opisthopteris	—	—	3.8	0.0	2.2	0.0	7.8	0.0	—	—	—	—
Bylgides pelagica	—	—	2.9	0.1	—	—	5.6	0.0	—	—	—	—
Atolla wyvillei	—	—	2.9	0.0	1.1	0.0	7.8	0.0	—	—	1.1	0.0
Hyperia antarctica	—	—	1.9	0.0	—	—	0.0	0.0	—	—	—	—
Cyphocaris richardi	—	—	1.9	0.0	—	—	4.4	0.0	—	—	1.1	0.0
Gymnoscopelus nicholsi	—	—	1.9	0.0	1.1	0.0	1.1	0.0	—	—	—	—
Maupasia coeca	—	—	1.9	0.0	1.1	0.0	—	—	—	—	—	—
Pelagobia longicirrata	—	—	1.0	0.0	1.1	0.0	—	—	—	—	—	—
Travisiopsis coniceps	—	—	1.0	0.0	—	—	—	—	—	—	—	—
Krefftichthys anderssoni	—	—	1.0	0.0	—	—	—	—	—	—	—	—
Thyphloscolex muelleri	—	—	1.0	0.0	4.4	0.0	—	—	—	—	—	—
Notolepis annulata (L)	—	—	1.0	0.0	—	—	13.3	0.0	—	—	—	—
Chaenodraco wilsoni (L)	—	—	—	—	—	—	—	—	—	—	1.1	0.0
Harpagifer antarcticus (L)	—	—	—	—	1.1	0.0	—	—	—	—	—	—
Euphysora gigantea	—	—	—	—	—	—	2.2	0.0	—	—	—	—
Gosea brachyura	—	—	—	—	—	—	3.3	0.0	—	—	—	—
Arctapodema ampla	—	—	—	—	1.1	0.0	—	—	—	—	—	—
Artededraco mirus (L)	—	—	—	—	—	—	1.1	0.0	—	—	—	—
Gymnodraco acuticeps (L)	—	—	—	—	—	—	1.1	0.0	—	—	—	—
Phalacrophorus pictus	—	—	—	—	1.1	0.0	—	—	—	—	—	—
Pegantha martagon	—	—	—	—	—	—	1.1	0.0	—	—	—	—
Vogtia serrata	—	—	3.8	0.1	—	—	—	—	—	—	—	—
Krefftichthys anderssoni (L)	—	—	1.9	0.0	—	—	—	—	—	—	—	—
Oediceroides calmani	—	—	1.0	0.0	—	—	—	—	—	—	—	—
Artededraco sp. B (L)	—	—	1.0	0.0	—	—	—	—	—	—	—	—
TOTAL TAXA	65		72		69		70		33		43	

Table 4.9 Percent Similarity Index (PSI) values from comparisons of overall zooplankton composition during each large area survey, 1993-1998. Shaded years are "salp years" and shaded values are from "salp year" intercomparisons. The designation "salp year" used here is based on January data. Note that comparisons with February 1993 are biased by the absence of copepods and chaetognath abundance data from that survey.

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

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

Table 4.10 Percent contribution and abundance rank of numerically dominant zooplankton and nekton taxa in the Elephant Island Area during large-area surveys, 1993-1998. Includes the 10 most abundant taxa each survey. Ranks are based on the 30 most abundant taxa each year. Shaded columns are "salp years" based on January survey data.

	January-February Elephant Island Area											
	1998		1997		1996		1995		1994		1993	
Taxon	%	Rank	%	Rank	%	Rank	%	Rank	%	Rank	%	Rank
Salpa thompsoni	68.76	1	17.79	2	1.45	6	1.51	5	80.83	1	86.63	1
Thysanoessa macrura	15.38	2	10.24	3	7.56	4	9.09	3	7.87	2	4.45	2
Copepods	4.80	3	57.16	1	56.18	1	61.54	1	4.08	3	3.30	4
Ihlea racovitzai	3.53	4	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Euphausia superba	3.13	5	3.96	4	7.95	3	1.37	7	2.68	4	3.81	3
Vibilia antarctica	1.12	6	0.24	14	0.04	18	0.02	24.5	1.17	5	0.14	7
Chaetognaths	0.76	7	2.25	5	0.88	7	7.51	4	—	—	0.80	5
Limacina helicina	0.69	8	0.28	13	2.38	5	0.18	15	0.03	18	—	—
Ostracods	0.41	9	0.54	9	0.35	8	0.91	9	—	—	—	—
Sagitta gazellae	0.17	10	0.03	26	0.02	20	0.32	13	0.04	15	—	—
Cyllopus magellanicus	0.16	11	0.37	11	0.11	14	0.02	24.5	0.62	7	0.04	12
Tomopteris spp.	0.11	12	0.19	17	0.06	15	0.40	12	0.25	10	0.04	12
Euphausia superba (L)	0.09	13.5	1.49	7	0.19	10	12.80	2	—	—	—	—
Spongiobranchaea australis	0.07	15.5	0.22	15	0.13	13	0.05	21	0.01	22.5	0.05	10
Primno macropa	0.06	17.5	0.42	10	0.01	25	0.01	31.5	0.05	14	—	—
Themisto gaudichaudii	0.03	23	0.35	12	0.34	9	0.46	11	1.05	6	0.07	9
Clio pyramidata	0.02	26.5	—	—	0.01	25	0.50	10	0.53	8	0.02	15.5
Euphausia triacantha	0.02	26.5	0.14	20.5	0.04	18	0.14	16	0.12	11	0.09	8
Euphausia frigida	0.02	26.5	1.45	8.0	0.14	12	0.92	8	0.38	9	0.31	6
Thysanoessa macrura (L)	—	—	1.67	6.0	21.82	2	1.50	6	—	—	—	—
TOTAL	99.32		98.79		99.64		99.26		99.69		99.75	

	February-March Elephant Island Area											
	1998		1997		1996		1995		1994		1993	
Taxon	%	Rank	%	Rank	%	Rank	%	Rank	%	Rank	%	Rank
Salpa thompsoni	56.29	1	43.65	2	1.28	6	0.21	8	13.73	2	89.37	1
Thysanoessa macrura	14.49	2	6.35	3	6.52	3	2.09	5	3.12	3	8.07	2
Euphausia superba	10.90	3	1.07	5	4.86	4	0.07	9	0.48	5	2.00	3
Copepods	9.72	4	44.43	1	63.16	1	41.33	2	81.04	1	n.a.	n.a.
Ihlea racovitzai	4.21	5	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Chaetognaths	0.87	6	0.64	7	2.92	5	3.84	3	n.a.	n.a.	n.a.	n.a.
Euphausia frigida	0.76	7	1.57	4	0.41	9	0.22	7	0.68	4	0.06	7.5
Vibilia antarctica	0.65	8	0.28	9	0.05	15	0.00	25	0.17	7	0.09	5.5
Cyllopus magellanicus	0.46	9	0.12	11	0.10	12	0.01	16	0.11	9	0.05	9
Ostracods	0.44	10	0.17	10	0.46	8	0.56	6	n.a.	n.a.	n.a.	n.a.
Thysanoessa macrura (L)	0.21	11	0.38	8	18.87	2	3.59	4	n.a.	n.a.	n.a.	n.a.
Primno macropa	0.16	12	0.02	18	0.16	10	0.01	20.5	0.00	21	—	—
Euphausia superba (L)	0.13	13.5	0.88	6	0.63	7	47.82	1	n.a.	n.a.	n.a.	n.a.
Cyllopus lucasii	0.13	13.5	0.08	14	0.01	25	0.01	18	0.16	8	0.09	5.5
Spongiobranchaea australis	0.06	15	0.10	13	0.07	14	0.01	20.5	0.00	21	0.02	10.5
Euphausia triacantha	0.05	18	0.03	15	0.04	18.5	0.02	13	0.03	11	0.06	7.5
Diphyes antarctica	0.03	21	0.01	20.5	0.00	32.5	0.01	20.5	0.00	21	0.02	10.5
Sagitta gazellae	0.03	24	0.01	27	0.02	22.5	0.04	12	0.10	10	n.a.	n.a.
Themisto gaudichaudii	0.02	24	0.10	27.5	0.11	11	0.05	11	0.31	6	0.13	4
Electrona spp. (L)	0.02	27	0.00	28	0.04	16.5	0.07	10	0.00	14.5	0.01	16
TOTAL	99.64		99.89		99.71		99.94		99.94		99.95	

Table 4.11 Zooplankton collected in the Survey D area and three subareas, February 1998. F(%) is frequency of occurrence in (N) samples. (L) are larval and (J) juvenile stages.

Taxon	LARGE SURVEY AREA D				ELEPHANT ISLAND AREA				WEST AREA				SOUTH AREA			
	F(%) (104)	Mean	SD	Med	F(%) (61)	Mean	SD	Med	F(%) (28)	Mean	SD	Med	F(%) (15)	Mean	SD	Med
Thysanoessa macrura	100.0	177.4	292.5	93.0	100.0	140.6	232.3	70.0	100.0	187.4	194.7	116.8	100.0	308.6	529.4	134.0
Salpa thompsoni	98.1	689.1	1214.6	354.5	100.0	977.3	1496.5	553.8	100.0	254.7	303.2	149.2	86.7	328.3	359.2	223.4
Copepods	97.1	119.0	179.6	49.2	98.4	110.4	170.3	50.9	100.0	142.0	191.1	53.8	86.7	111.2	190.6	30.6
Vibilia antarctica	96.2	8.0	10.5	4.4	98.4	10.7	12.7	7.6	92.9	4.3	3.8	3.4	93.3	3.7	2.3	3.9
Euphausia superba	89.4	133.5	620.5	4.1	93.4	162.6	768.3	4.5	82.1	22.3	44.2	2.7	86.7	222.5	480.0	3.3
Cyllopus magellanicus	81.7	5.6	11.6	1.4	83.6	8.2	14.3	2.4	89.3	2.6	3.8	1.2	60.0	0.7	1.0	0.2
Ihlea racovitzai	61.5	51.5	99.4	12.2	59.0	41.5	96.0	7.3	46.4	29.4	81.5	0.0	100.0	133.5	102.7	115.3
Chaetognaths	61.5	10.7	26.3	1.6	52.5	8.8	23.1	0.6	71.4	16.3	36.3	2.7	80.0	8.0	10.5	2.5
Cyllopus lucasii	57.7	1.6	2.9	0.3	59.0	2.1	3.6	0.6	46.4	0.6	1.4	0.0	73.3	1.2	1.4	0.7
Primno macropa	49.0	1.9	3.5	0.0	44.3	1.7	2.9	0.0	67.9	3.3	5.0	0.9	33.3	0.4	0.5	0.0
Ostracods	43.3	5.4	16.8	0.0	41.0	5.3	16.6	0.0	46.4	2.7	4.4	0.0	46.7	11.1	27.7	0.0
Spongiobranchaea australis	38.5	0.8	2.8	0.0	26.2	0.8	3.6	0.0	57.1	0.8	1.1	0.3	53.3	0.5	0.9	0.2
Limacina helicina	37.5	0.8	1.8	0.0	21.3	0.4	0.9	0.0	57.1	1.6	2.9	0.5	66.7	0.9	1.2	0.5
Hyperiella dilatata	34.6	0.4	0.8	0.0	32.8	0.4	0.7	0.0	42.9	0.5	0.7	0.0	26.7	0.4	1.0	0.0
Themisto gaudichaudii	32.7	0.3	0.6	0.0	21.3	0.2	0.5	0.0	60.7	0.5	0.8	0.2	26.7	0.3	0.5	0.0
Euphausia frigida	29.8	9.3	34.2	0.0	34.4	9.0	26.0	0.0	35.7	14.9	52.7	0.0	—	—	—	—
Diphyes antarctica	29.8	0.4	1.0	0.0	26.2	0.3	0.8	0.0	17.9	0.1	0.2	0.0	66.7	1.4	1.5	1.3
Radiolaria	28.8	0.9	2.3	0.0	19.7	0.8	2.3	0.0	46.4	1.7	2.9	0.0	33.3	0.2	0.3	0.0
Cyllopus sp.	24.0	0.7	1.9	0.0	34.4	1.1	2.4	0.0	7.1	0.1	0.2	0.0	13.3	0.1	0.2	0.0
Lepidonotothen kempi (L)	22.1	0.2	0.7	0.0	19.7	0.2	0.6	0.0	32.1	0.3	0.9	0.0	13.3	0.2	0.5	0.0
Sagitta gazellae	18.3	0.3	1.0	0.0	14.8	0.2	0.5	0.0	14.3	0.6	1.7	0.0	40.0	0.5	0.6	0.0
Dimophyes arctica	16.3	0.4	2.6	0.0	13.1	0.5	3.3	0.0	17.9	0.2	0.5	0.0	26.7	0.5	1.2	0.0
Thysanoessa macrura (L)	13.5	2.6	16.3	0.0	8.2	0.5	2.0	0.0	32.1	8.6	30.5	0.0	—	—	—	—
Lepidonotothen larseni (L)	13.5	0.1	0.6	0.0	3.3	0.0	0.1	0.0	39.3	0.5	1.1	0.0	6.7	0.0	0.1	0.0
Hydromedusae	12.5	0.2	0.8	0.0	9.8	0.1	0.4	0.0	21.4	0.2	0.4	0.0	6.7	0.5	1.9	0.0
Euphausia superba (L)	12.5	1.6	14.1	0.0	4.9	2.5	18.3	0.0	32.1	0.7	1.4	0.0	6.7	0.0	0.2	0.0
Euphausia triacantha	11.5	0.6	2.2	0.0	11.5	0.6	2.5	0.0	14.3	0.7	1.7	0.0	6.7	0.3	1.0	0.0
Electrona spp (L)	10.6	0.2	0.9	0.0	6.6	0.2	1.0	0.0	25.0	0.4	0.8	0.0	—	—	—	—
Clione limacina	10.6	0.1	0.4	0.0	6.6	0.0	0.1	0.0	10.7	0.2	0.6	0.0	26.7	0.2	0.4	0.0
Electrona antarctica	8.7	0.0	0.2	0.0	9.8	0.1	0.2	0.0	10.7	0.0	0.1	0.0	—	—	—	—
Tomopteris spp.	8.7	0.0	0.0	0.0	8.2	0.0	0.0	0.0	14.3	0.0	0.0	0.0	—	—	—	—
Calycopsis borchgrevinki	4.8	0.0	0.1	0.0	6.6	0.0	0.2	0.0	3.6	0.0	0.1	0.0	—	—	—	—
Beroe cucumis	4.8	0.0	0.1	0.0	6.6	0.0	0.1	0.0	—	—	—	—	6.7	0.0	0.1	0.0
Sipunculids	4.8	0.1	0.3	0.0	6.6	0.1	0.4	0.0	—	—	—	—	6.7	0.0	0.1	0.0
Eukrohnia hamata	4.8	0.5	4.6	0.0	3.3	0.1	0.4	0.0	7.1	1.8	8.7	0.0	6.7	0.0	0.2	0.0
Notolepis coatsi (L)	4.8	0.0	0.3	0.0	—	—	—	—	14.3	0.1	0.5	0.0	6.7	0.1	0.2	0.0
Vanadis antarctica	3.8	0.1	0.4	0.0	4.9	0.1	0.5	0.0	3.6	0.1	0.5	0.0	—	—	—	—
Beroe forskalii	2.9	0.0	0.1	0.0	4.9	0.0	0.1	0.0	—	—	—	—	—	—	—	—
Pleuragramma antarcticum (J)	2.9	0.0	0.1	0.0	1.6	0.0	0.0	0.0	—	—	—	—	13.3	0.1	0.2	0.0
Unid. Gastropod	1.9	0.0	0.3	0.0	3.3	0.1	0.4	0.0	—	—	—	—	—	—	—	—
Larval fish	1.9	0.1	0.5	0.0	3.3	0.1	0.7	0.0	—	—	—	—	—	—	—	—
Electrona carlsbergi	1.9	0.0	0.1	0.0	1.6	0.0	0.1	0.0	3.6	0.0	0.2	0.0	—	—	—	—
Cephalopods	1.9	0.0	0.0	0.0	1.6	0.0	0.0	0.0	3.6	0.0	0.0	0.0	—	—	—	—
Gymnoscopelus sp.	1.9	0.0	0.1	0.0	1.6	0.0	0.1	0.0	3.6	0.0	0.1	0.0	—	—	—	—
Orchomene plebs	1.9	0.0	0.2	0.0	1.6	0.0	0.3	0.0	3.6	0.0	0.0	0.0	—	—	—	—
Eusirus antarcticus	1.9	0.0	0.2	0.0	1.6	0.0	0.3	0.0	—	—	—	—	6.7	0.0	0.2	0.0
Pagothenia brachysoma	1.9	0.0	0.1	0.0	1.6	0.0	0.1	0.0	—	—	—	—	6.7	0.0	0.1	0.0
Scyphomedusae	1.9	0.0	0.1	0.0	—	—	—	—	7.1	0.0	0.1	0.0	—	—	—	—
Hyperia macrocephala	1.9	0.0	0.0	0.0	—	—	—	—	3.6	0.0	0.0	0.0	6.7	0.0	0.1	0.0
Acanthepyra pelagica	1.0	0.0	0.0	0.0	1.6	0.0	0.0	0.0	—	—	—	—	—	—	—	—
Hyperiella sp.	1.0	0.0	0.1	0.0	1.6	0.0	0.1	0.0	—	—	—	—	—	—	—	—
Fish eggs	1.0	0.0	0.1	0.0	1.6	0.0	0.2	0.0	—	—	—	—	—	—	—	—
Orchomene rossi	1.0	0.0	0.2	0.0	1.6	0.0	0.3	0.0	—	—	—	—	—	—	—	—
Gymnoscopelus nicholsi	1.0	0.0	0.1	0.0	1.6	0.0	0.1	0.0	—	—	—	—	—	—	—	—
Eusirus perdentatus	1.0	0.0	0.1	0.0	1.6	0.0	0.1	0.0	—	—	—	—	—	—	—	—
Bylgides pelagica	1.0	0.0	0.1	0.0	1.6	0.0	0.1	0.0	—	—	—	—	—	—	—	—
Krefftichthys anderssoni (L)	1.0	0.0	0.0	0.0	—	—	—	—	3.6	0.0	0.0	0.0	—	—	—	—
Rhynchonereella bongraini	1.0	0.0	0.2	0.0	—	—	—	—	3.6	0.1	0.4	0.0	—	—	—	—
Rhynchonereella sp.	1.0	0.0	0.0	0.0	—	—	—	—	—	—	—	—	6.7	0.0	0.1	0.0
Chaenodraco wilsoni (L)	1.0	0.0	0.0	0.0	—	—	—	—	—	—	—	—	6.7	0.0	0.1	0.0
Artedidraco skottsbergi (L)	1.0	0.0	0.0	0.0	—	—	—	—	—	—	—	—	6.7	0.0	0.1	0.0
TOTAL TAXA	61				53				43				37			
TAXA/TOW	0.6				0.9				1.5				2.5			

Table 4.12 Relative abundance of zooplankton taxa in three groupings derived from cluster analysis of February 1998 Survey D data. Rank is based on mean abundance (No. per 1000m3) within each station grouping. The 15 most abundant taxa in each cluster are included.

	CLUSTER 1				CLUSTER 2				CLUSTER 3			
	(N = 38)				(N = 16)				(N = 45)			
Taxon	Rank	Mean	SD	%	Rank	Mean	SD	%	Rank	Mean	SD	%
Salpa thompsoni	1	884.0	1806.9	75.2	1	735.8	716.5	33.5	1	549.4	619.6	55.9
Thysanoessa macrura	2	123.1	90.6	10.5	2	501.8	587.5	22.8	4	106.4	133.7	10.8
Ihlea racovitzai	3	91.4	123.0	7.8	5	113.0	113.2	5.1	17	0.5	1.9	0.1
Copepods	4	38.4	34.2	3.3	4	282.4	304.2	12.9	3	131.1	159.1	13.3
Vibilia antarctica	5	10.3	13.5	0.9	10	5.6	5.1	0.3	7	7.4	9.0	0.8
Euphausia superba	6	9.1	19.1	0.8	3	449.9	636.2	20.5	2	140.3	833.6	14.3
Chaetognaths	7	5.0	9.4	0.4	8	15.3	25.5	0.7	5	14.8	35.2	1.5
Cyllopus magellanicus	8	3.7	9.5	0.3	12	2.1	2.5	0.1	6	8.7	14.6	0.9
Cyllopus lucasii	9	2.8	3.6	0.2	13	2.0	3.3	0.1	17	0.5	1.4	0.1
Ostracods	10	2.0	4.7	0.2	7	24.1	36.1	1.1	11	2.1	5.0	0.2
Limacina helicina	11	1.0	1.5	0.1	15.5	1.0	1.9	0.0	17	0.5	1.9	0.1
Dimophyes arctica	12	0.9	4.1	0.1	19.5	0.5	1.1	0.0	28.5	0.1	0.2	0.0
Primno macropa	13	0.6	1.5	0.0	17	0.8	1.6	0.0	10	3.3	4.7	0.3
Diphyes antarctica	14	0.5	1.1	0.0	15.5	1.0	1.5	0.0	24.5	0.2	0.5	0.0
Spongiobranchaea australis	15	0.3	0.7	0.0	11	2.4	6.7	0.1	14.5	0.6	1.1	0.1
Radiolarians	22.5	0.1	0.7	0.0	26	0.2	0.3	0.0	12	1.8	3.1	0.2
Euphausia frigida	22.5	0.1	0.4	0.0	6	45.9	75.7	2.1	9	4.9	9.1	0.5
Euphausia superba (L)	22.5	0.1	0.7	0.0	9	9.0	34.9	0.4	20	0.4	1.2	0.0
Hyperiella dilatata	22.5	0.1	0.3	0.0	18	0.6	1.1	0.0	14.5	0.6	0.8	0.1
Clione limacina	22.5	0.1	0.2	0.0	21.5	0.4	0.7	0.0	—	—	—	—
Thysanoessa macrura (L)	—	—	—	—	—	—	—	—	8	5.8	24.4	0.6
Euphausia triacantha	—	—	—	—	19.5	0.5	1.2	0.0	13	1.1	3.1	0.1
TOTAL ZOOPLANKTON		1174.8	1825.4			2196.8	1091.1			982.5	1020.9	

Table 4.13 Zooplankton collected in the Survey A and Survey D areas, January and February 1998. F(%) is frequency of occurrence in 104 samples each survey. Rank is based on mean abundance during each survey; mean values <0.1 per 1000 m^3 are not ranked. **Ihlea racovitzai* was first identified at the end of Survey A so values presented here are not representative of the full Survey A area.

	LARGE SURVEY AREA A JANUARY 1998					LARGE SURVEY AREA D FEBRUARY 1998				
Taxon	**Rank**	**F(%)**	**Mean**	**SD**	**Median**	**Rank**	**F(%)**	**Mean**	**SD**	**Median**
Salpa thompsoni	1	100.0	808.2	1538.7	323.7	1	98.1	689.1	1214.6	354.5
Thysanoessa macrura	2	100.0	180.8	411.6	79.8	2	100.0	177.4	292.5	93.0
Euphausia superba	5	92.3	36.8	68.9	10.7	3	89.4	133.5	620.5	4.1
Copepods	3	94.2	56.5	80.3	25.8	4	97.1	119.0	179.6	49.2
*Ihlea racovitzai**	(4	5.8	41.5	326.6	0.0)	5	61.5	51.5	99.4	12.2
Chaetognaths	7	42.3	8.9	31.9	0.0	6	61.5	10.7	26.3	1.6
Euphausia frigida	29.5	5.8	0.2	1.0	0.0	7	29.8	9.3	34.2	0.0
Vibilia antarctica	6	96.2	13.2	17.1	7.8	8	96.2	8.0	10.5	4.4
Cyllopus magellanicus	10.5	64.4	1.9	3.1	0.5	9	81.7	5.6	11.6	1.4
Ostracods	9	51.0	4.8	11.7	0.4	10	43.3	5.4	16.8	0.0
Thysanoessa macrura (L)	—	1.9	0.0	0.2	0.0	11	13.5	2.6	16.3	0.0
Primno macropa	18.5	26.0	0.7	1.9	0.0	12	49.0	1.9	3.5	0.0
E. superba (L)	15	11.5	1.0	4.5	0.0	13.5	12.5	1.6	14.1	0.0
Cyllopus lucasii	21	20.2	0.5	1.8	0.0	13.5	57.7	1.6	2.9	0.3
Radiolarians	18.5	27.9	0.7	1.5	0.0	15	28.8	0.9	2.3	0.0
Limacina helicina	8	73.1	8.1	12.9	3.4	16.5	37.5	0.8	1.8	0.0
Spongiobranchaea australis	16.5	45.2	0.9	1.7	0.0	16.5	38.5	0.8	2.8	0.0
Cyllopus sp.	—	1.0	0.0	0.2	0.0	18	24.0	0.7	1.9	0.0
Euphausia triacantha	25.5	7.7	0.3	1.5	0.0	19	11.5	0.6	2.2	0.0
Eukrohnia hamata	21	13.5	0.5	2.1	0.0	20	4.8	0.5	4.6	0.0
Dimophyes arctica	35.5	2.9	0.1	0.6	0.0	22	16.3	0.4	2.6	0.0
Diphyes antarctica	14	37.5	1.1	2.6	0.0	22	29.8	0.4	1.0	0.0
Hyperiella dilatata	23	39.4	0.4	0.9	0.0	22	34.6	0.4	0.8	0.0
Sagitta gazellae	10.5	27.9	1.9	6.0	0.0	25	18.3	0.3	1.0	0.0
Themisto gaudichaudii	25.5	31.7	0.3	0.9	0.0	25	32.7	0.3	0.6	0.0
Polychaetes	12	28.8	1.5	8.5	0.0	25	13.5	0.3	1.2	0.0
Lepidonotothen kempi (L)	25.5	13.5	0.3	1.4	0.0	28	22.1	0.2	0.7	0.0
Electrona antarctica (L)	29.5	10.6	0.2	1.4	0.0	28	10.6	0.2	0.9	0.0
Hydromedusae	35.5	9.6	0.1	0.4	0.0	28	12.5	0.2	0.8	0.0
Lepidonotothen larseni (L)	21	23.1	0.5	1.5	0.0	31.5	13.5	0.1	0.6	0.0
Clione limacina	16.5	38.5	0.9	2.3	0.0	31.5	10.6	0.1	0.4	0.0
Vanadis antarctica	35.5	4.8	0.1	0.4	0.0	31.5	3.8	0.1	0.4	0.0
Sipunculids	35.5	11.5	0.1	0.5	0.0	31.5	4.8	0.1	0.3	0.0
Electrona antarctica	35.5	3.8	0.1	0.8	0.0	—	8.7	0.0	0.2	0.0
Tomopteris spp.	13	31.7	1.3	9.1	0.0	—	8.7	0.0	0.0	0.0
Notolepis coatsi (L)	—	3.8	0.0	0.2	0.0	—	4.8	0.0	0.3	0.0
Calycopsis borchgrevinki	—	1.0	0.0	0.1	0.0	—	4.8	0.0	0.1	0.0
Beroe cucumis	—	3.8	0.0	0.1	0.0	—	4.8	0.0	0.1	0.0
Siphonophores	—	2.9	0.0	0.3	0.0	—	2.9	0.0	0.0	0.0
Beroe forskalii	—	1.0	0.0	0.1	0.0	—	2.9	0.0	0.1	0.0
Pleuragramma antarcticum (J)	—	4.8	0.0	0.2	0.0	—	2.9	0.0	0.1	0.0
Unid. Gastropod	—	—	—	—	—	—	1.9	0.0	0.3	0.0
Eusirus antarcticus	—	1.0	0.0	0.0	0.0	—	1.9	0.0	0.2	0.0
Orchomene plebs	—	1.0	0.0	0.0	0.0	—	1.9	0.0	0.2	0.0
Electrona carlsbergi	—	1.0	0.0	0.0	0.0	—	1.9	0.0	0.1	0.0
Gymnoscopelus sp.	—	—	—	—	—	—	1.9	0.0	0.1	0.0
Scyphomedusae	—	1.9	0.0	0.0	0.0	—	1.9	0.0	0.1	0.0
Pagothenia brachysoma	—	—	—	—	—	—	1.9	0.0	0.1	0.0
Cephalopods	—	1.0	0.0	0.0	0.0	—	1.9	0.0	0.0	0.0
Hyperia macrocephala	35.5	1.0	0.1	0.6	0.0	—	1.9	0.0	0.0	0.0
Orchomene rossi	—	—	—	—	—	—	1.0	0.0	0.2	0.0
Rhynchonereella bongraini	29.5	9.6	0.2	0.7	0.0	—	1.0	0.0	0.2	0.0
Fish eggs	—	1.0	0.0	0.1	0.0	—	1.0	0.0	0.1	0.0
Hyperiella macronyx	35.5	2.9	0.1	0.6	0.0	—	1.0	0.0	0.1	0.0
Bylgides pelagica	—	—	—	—	—	—	1.0	0.0	0.1	0.0
Eusirus perdentatus	—	—	—	—	—	—	1.0	0.0	0.1	0.0
Gymnoscopelus nicholsi	—	—	—	—	—	—	1.0	0.0	0.1	0.0
Rhynchonereella sp.	—	—	—	—	—	—	1.0	0.0	0.0	0.0
Chaenodraco wilsoni (L)	—	—	—	—	—	—	1.0	0.0	0.0	0.0
Krefftichthys anderssoni (L)	—	—	—	—	—	—	1.0	0.0	0.0	0.0
Acanthepyra pelagica	—	3.8	0.0	0.2	0.0	—	1.0	0.0	0.0	0.0
Artedidraco skottsbergi (L)	—	1.0	0.0	0.0	0.0	—	1.0	0.0	0.0	0.0
Clio pyramidata	25.5	4.8	0.3	1.6	0.0	—	—	—	—	—
Epimeriella macronyx	29.5	5.8	0.2	1.2	0.0	—	—	—	—	—
Ctenophores	35.5	3.8	0.1	0.6	0.0	—	—	—	—	—
Decapod Larvae	—	2.9	0.0	0.3	0.0	—	—	—	—	—
Chaenocephalus aceratus (L)	—	3.8	0.0	0.1	0.0	—	—	—	—	—
Eusirus sp.	—	1.0	0.0	0.1	0.0	—	—	—	—	—
Bathylagus sp. (L)	—	1.0	0.0	0.1	0.0	—	—	—	—	—
Hyperoche medusarum	—	1.0	0.0	0.1	0.0	—	—	—	—	—
Bolinopsis infundibulum	—	1.9	0.0	0.0	0.0	—	—	—	—	—
Chionodraco rastrospinosus (L	—	1.9	0.0	0.0	0.0	—	—	—	—	—
Bolinopsis sp.	—	1.0	0.0	0.0	0.0	—	—	—	—	—
Notolepis spp. (L)	—	1.0	0.0	0.0	0.0	—	—	—	—	—
Gobionotothen gibberifrons (L)	—	1.0	0.0	0.0	0.0	—	—	—	—	—
TOTAL TAXA		65					62			
TAXA/TOW		0.6					0.6			

Table 4.14 Zooplankton taxa present in large-area survey samples during February 1998 compared to February-March 1994-1997. F(%) is frequency of occurrence in (N) tows. n.a. indicates taxon was not enumerated. (L) indicates larval stages; (J) indicates juvenile stages.

	SURVEY D		SURVEY D		SURVEY D		SURVEY D		SURVEY D		SURVEY E	
	Feb. 1998		Mar. 1997		Feb.-Mar. 1996		Feb. 1995		Feb.-Mar. 1994		Feb.-Mar. 1993	
Taxon	F(%) (104)	Mean No/ 1000m3	F(%) (16)	Mean No/ 1000m3	F(%) (91)	Mean No/ 1000m3	F(%) (89)	Mean No/ 1000m3	F(%) (89)	Mean No/ 1000m3	F(%) (80)	Mean No/ 1000m3
Salpa thompsoni	98.1	689.1	100.0	1245.5	62.6	28.2	59.6	16.5	98.9	523.5	100.0	1567.1
Thysanoessa macrura	100.0	177.4	100.0	181.3	91.2	143.3	93.3	161.3	91.0	118.9	96.3	141.5
Copepods	97.1	119.0	100.0	1267.8	98.9	1387.0	100.0	3189.1	89.9	3090.2	n.a.	n.a.
Vibilia antarctica	96.2	8.0	81.3	8.1	48.4	1.0	23.6	0.2	85.4	6.4	47.5	1.6
Euphausia superba	89.4	133.5	68.8	30.4	86.8	106.7	78.7	5.7	66.3	18.4	83.8	35.0
Cyllopus magellanicus	81.7	5.6	93.8	3.3	46.2	2.1	25.8	0.7	79.8	4.4	32.5	0.9
Ihlea racovitzai	61.5	51.5	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Chaetognaths	61.5	10.7	75.0	18.2	93.4	64.1	100.0	296.4	n.a.	n.a.	n.a.	n.a.
Cyllopus lucasii	57.7	1.6	93.8	2.4	34.1	0.2	23.6	0.5	89.9	6.1	37.5	1.5
Primno macropa	49.0	1.9	18.8	0.5	63.7	3.5	31.5	0.4	10.1	0.1	—	—
Ostracods	43.3	5.4	56.3	4.8	47.3	10.1	75.3	43.4	n.a.	n.a.	n.a.	n.a.
Spongiobranchaea australis	38.5	0.8	43.8	2.8	68.1	1.4	60.7	0.4	14.6	0.1	20.0	0.3
Limacina helicina	37.5	0.8	—	—	24.2	1.9	4.5	0.0	—	—	—	—
Hyperiella dilatata	34.6	0.4	25.0	0.2	52.7	0.8	24.7	0.1	36.0	0.6	1.3	0.0
Themisto gaudichaudii	32.7	0.3	87.5	2.9	91.2	2.5	74.2	3.6	94.4	11.8	60.0	2.3
Euphausia frigida	29.8	9.3	68.8	44.8	54.9	9.0	60.7	16.7	61.8	25.9	7.5	1.0
Diphyes antarctica	29.8	0.4	6.3	0.3	7.7	0.1	23.6	0.4	13.5	0.1	15.0	0.3
Cyllopus sp.	24.0	0.7	24.0	0.7	—	—	—	—	—	—	—	—
Lepidonotothen kempi (L)	22.1	0.2	6.3	0.2	39.6	0.4	48.3	0.4	6.7	0.1	1.3	0.0
Sagitta gazellae	18.3	0.3	12.5	0.1	31.9	0.3	59.6	3.0	34.8	3.8	n.a.	n.a.
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
Polychaetes	13.5	0.3	—	—	3.3	0.1	2.2	0.0	—	—	—	—
Thysanoessa macrura (L)	13.5	2.6	50.0	10.8	87.9	414.4	79.8	276.9	n.a.	n.a.	—	—
Lepidonothen larseni (L)	13.5	0.1	—	—	13.2	0.3	10.1	0.0	—	—	5.0	0.2
Euphausia superba (L)	12.5	1.6	37.5	25.0	62.6	13.9	93.3	3690.0	n.a.	n.a.	—	—
Hydromedusae	12.5	0.2	12.5	0.2	3.3	0.1	5.6	0.0	—	—	—	—
Euphausia triacantha	11.5	0.6	43.8	0.9	22.0	0.8	28.1	1.6	11.2	1.0	21.3	1.0
Electrona spp. (L)	10.6	0.2	12.5	0.1	38.5	0.9	62.9	5.2	11.2	0.2	5.0	0.1
Clione limacina	10.6	0.1	12.5	0.0	15.4	0.2	—	—	—	—	—	—
Electrona antarctica	8.7	0.0	31.3	0.2	20.9	0.2	15.7	0.1	13.5	0.1	3.8	0.0
Tomopteris spp.	8.7	0.0	31.3	0.5	38.5	0.9	57.3	1.3	24.7	0.6	12.5	0.2
Eukronia hamata	4.8	0.5	—	—	19.8	0.1	33.7	0.8	3.4	0.1	n.a.	n.a.
Sipunculids	4.8	0.1	6.3	0.0	8.8	0.1	9.0	0.0	3.4	0.0	—	—
Notolepis coatsi (L)	4.8	0.0	—	—	18.7	0.1	36.0	0.2	—	—	—	—
Calycopsis borchgrevinki	4.8	0.0	6.3	0.0	6.6	0.0	11.2	0.0	10.1	0.1	11.3	0.1
Beroe cucumis	4.8	0.0	—	—	11.0	0.1	4.5	0.0	2.2	0.0	1.3	0.0
Vanadis antarctica	3.8	0.1	—	—	1.1	0.0	6.7	0.0	7.9	0.1	—	—
Beroe forskalii	2.9	0.0	—	—	—	—	1.1	0.0	3.4	0.1	—	—
Pleurogramma antarcticum (J)	2.9	0.0	—	—	1.1	0.0	2.2	0.0	—	—	—	—
Unid. larval fish	1.9	0.1	—	—	1.1	0.0	—	—	—	—	—	—
Unid. Gastropod	1.9	0.0	—	—	—	—	—	—	—	—	—	—
Eusirus antarcticus	1.9	0.0	—	—	—	—	—	—	—	—	—	—
Orchomene plebs	1.9	0.0	—	—	2.2	0.0	3.4	0.0	2.2	0.1	—	—
Electrona carlsbergi	1.9	0.0	—	—	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Gymnoscopelus sp.	1.9	0.0	—	—	—	—	—	—	—	—	—	—
Scyphomedusae	1.9	0.0	12.5	0.0	19.8	0.1	13.5	0.1	—	—	1.3	0.0
Pagothenia brachysoma	1.9	0.0	—	—	—	—	—	—	—	—	—	—
Cephalopods	1.9	0.0	—	—	9.9	0.0	—	—	—	—	—	—
Hyperia macrocephala	1.9	0.0	—	—	1.1	0.0	5.6	0.0	—	—	—	—
Orchomene rossi	1.0	0.0	—	—	5.5	0.5	6.7	0.0	—	—	—	—
Rhynchonereella bongraini	1.0	0.0	—	—	5.5	0.1	20.2	0.1	—	—	—	—
Fish eggs	1.0	0.0	—	—	—	—	1.1	0.0	7.9	0.1	—	—
Hyperiella sp.	1.0	0.0	—	—	—	—	—	—	—	—	—	—
Byglides pelagica	1.0	0.0	—	—	—	—	2.2	0.0	—	—	—	—
Eusirus perdentatus	1.0	0.0	—	—	2.2	0.0	6.7	0.1	—	—	—	—
Gymnoscopelus nicholsi	1.0	0.0	12.5	0.1	3.3	0.0	1.1	0.0	—	—	—	—
Chaenodraco wilsoni (L)	1.0	0.0	—	—	—	—	—	—	—	—	—	—

Table 4.14 (Contd.)

	SURVEY D Feb. 1998		SURVEY D Mar. 1997		SURVEY D Feb.-Mar. 1996		SURVEY D Feb. 1995		SURVEY D Feb.-Mar. 1994		SURVEY E Feb.-Mar. 1993	
Taxon	F(%) (104)	Mean No/ 1000m3	F(%) (16)	Mean No/ 1000m3	F(%) (91)	Mean No/ 1000m3	F(%) (89)	Mean No/ 1000m3	F(%) (89)	Mean No/ 1000m3	F(%) (80)	Mean No/ 1000m3
Rhynchonereella sp.	1.0	0.0	—	—	—	—	—	—	—	—	—	—
Krefftichthys anderssoni (L)	1.0	0.0	—	—	—	—	—	—	—	—	—	—
Acanthephyra pelagica (L)	1.0	0.0	—	—	—	—	5.6	0.0	—	—	—	—
Artedidraco skottsbergi (L)	1.0	0.0	—	—	—	—	—	—	—	—	—	—
Hyperoche medusarum	—	—	12.5	0.3	2.2	0.0	12.4	0.0	—	—	—	—
Scina spp.	—	—	6.3	0.5	2.2	0.0	1.1	0.0	—	—	—	—
Hyperiella macronyx	—	—	6.3	0.0	6.6	0.1	13.5	0.0	—	—	—	—
Bathylagus sp. (L)	—	—	6.3	0.0	1.1	0.0	14.6	0.0	—	—	—	—
Ctenophores	—	—	6.3	0.0	1.1	0.0	3.4	0.0	—	—	—	—
Notolepis annulata (L)	—	—	6.3	0.0	5.5	0.0	3.4	0.0	—	—	—	—
Epimeriella macronyx	—	—	—	—	1.1	0.0	5.6	0.6	—	—	—	—
Hyperia spp.	—	—	—	—	1.1	0.1	—	—	—	—	—	—
Lepidonothen larseni (J)	—	—	—	—	—	—	1.1	0.0	—	—	—	—
Hyperiids	—	—	—	—	1.1	0.0	—	—	—	—	—	—
Travisiopsis coniceps	—	—	—	—	1.1	0.0	1.1	0.0	—	—	—	—
Gymnoscopelus opisthopterus	—	—	—	—	3.3	0.0	10.1	0.0	2.2	0.0	—	—
Eusirus microps	—	—	—	—	3.3	0.0	—	—	—	—	1.3	0.0
Harpagifer antarcticus (L)	—	—	—	—	1.1	0.0	—	—	—	—	—	—
Atolla wyvillei	—	—	—	—	1.1	0.0	—	—	—	—	—	—
Lepidonotothen nudifrons (L)	—	—	—	—	1.1	0.0	3.4	0.0	—	—	—	—
Cyphocaris richardi	—	—	—	—	1.1	0.0	3.4	0.1	—	—	—	—
Notolepis spp. (L)	—	—	—	—	—	—	2.2	0.0	5.6	0.0	3.8	0.1
Cumaceans	—	—	—	—	1.1	0.0	—	—	—	—	—	—
Pagetopsis macropterus	—	—	—	—	—	—	1.1	0.0	—	—	—	—
Periphylla periphylla	—	—	—	—	1.1	0.0	1.1	0.0	3.4	0.0	—	—
Decapod larvae	—	—	—	—	1.1	0.0	—	—	—	—	—	—
Clio pyramidata	—	—	—	—	3.3	0.0	12.4	0.0	9.0	0.2	1.3	0.0
Champsocephalus gunnari (L)	—	—	—	—	—	—	1.1	0.0	—	—	—	—
TOTAL TAXA	61		37		65		63		32		24	

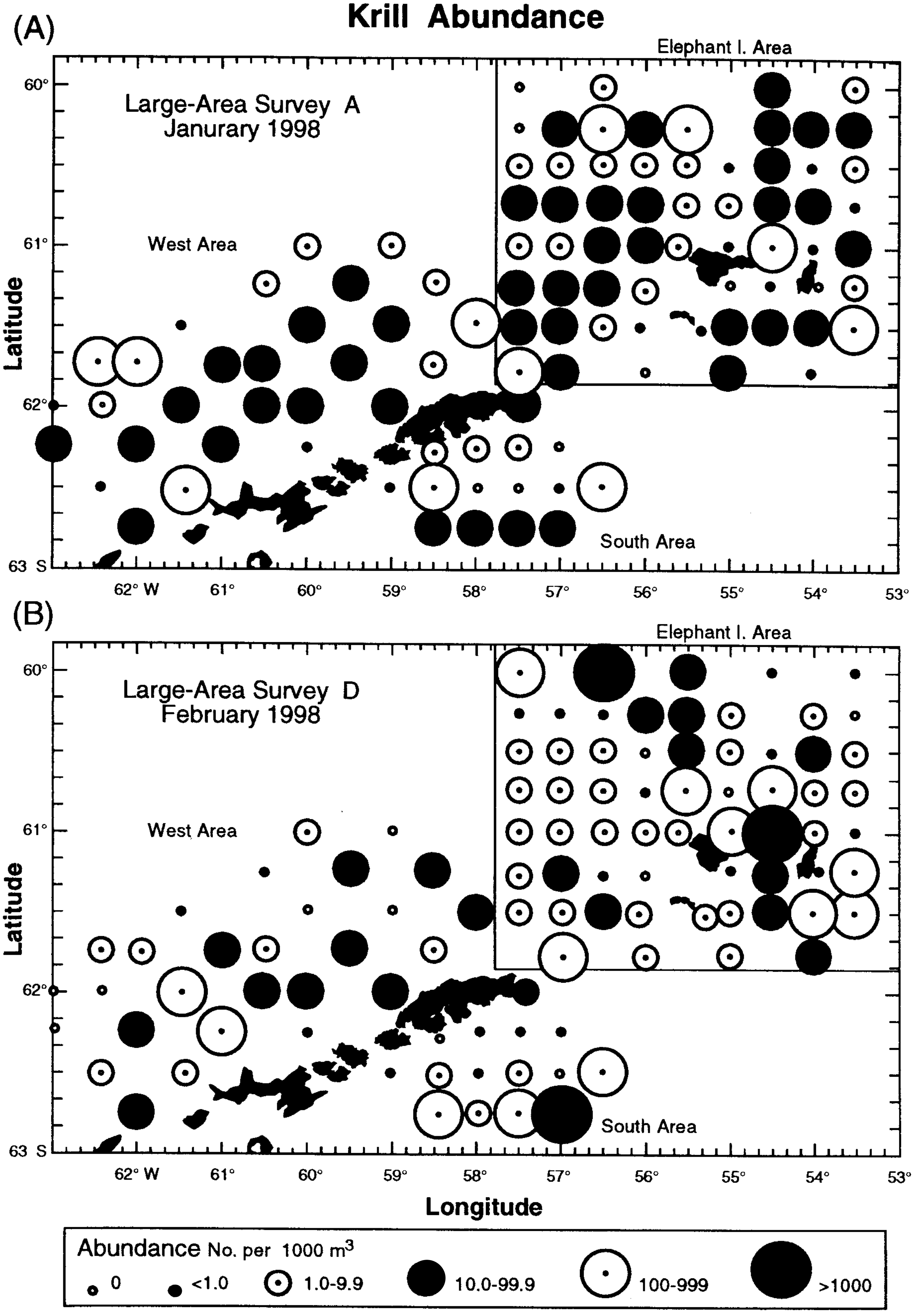


Figure 4.1 Distribution and abundance of krill in IKMT tows collected during the large-area surveys. (A) Survey A, Leg I (January 1998); and (B) Survey D, Leg II (February 1998). The outlined stations are included in the "Elephant Island area," which is used for between-year comparisons. The "West" and "South" area stations are also indicated.

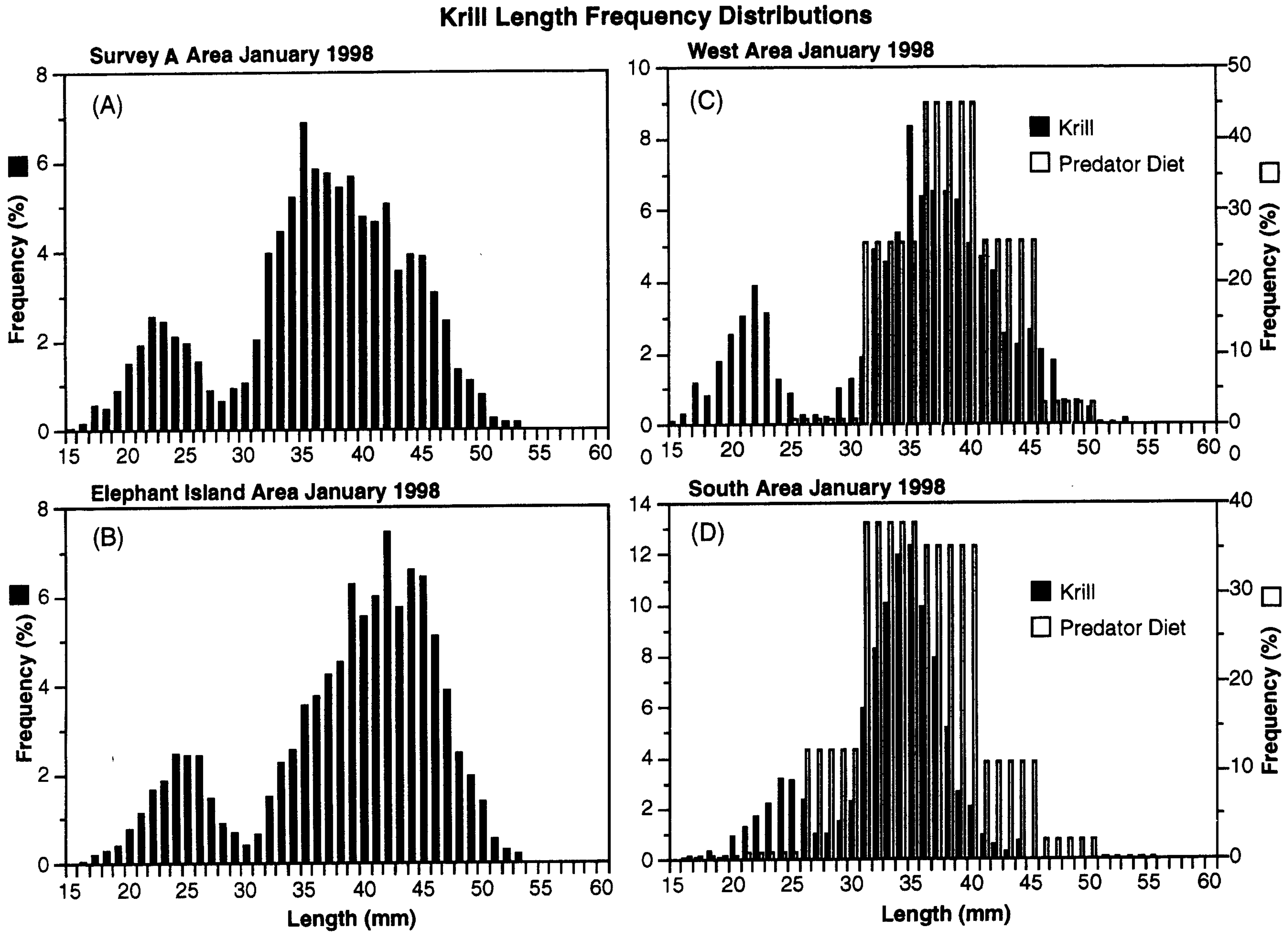
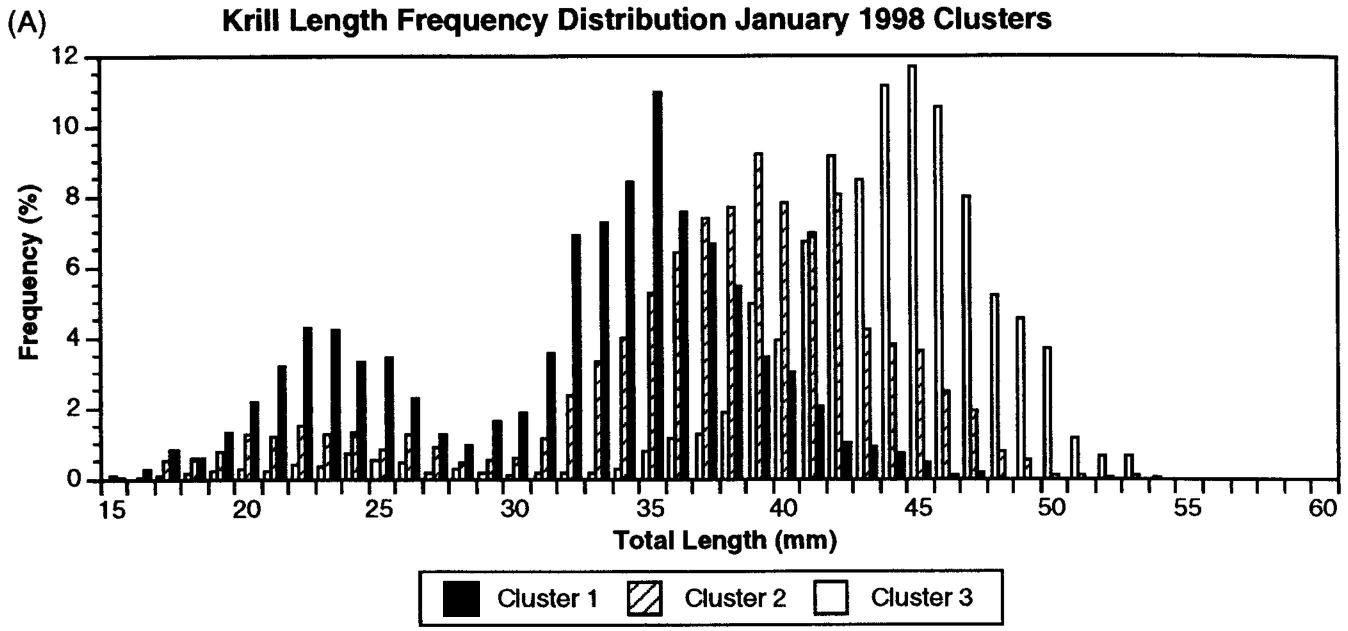


Figure 4.2 Overall length frequency distribution of krill collected (A) during Survey A, (B) in the Elephant Island area, (C) in the West area, and (D) in the South area, January 1998. Panel (C) has length frequency distributions for krill in predator diets at Cape Shirreff, and Panel (D) has those for Admiralty Bay.



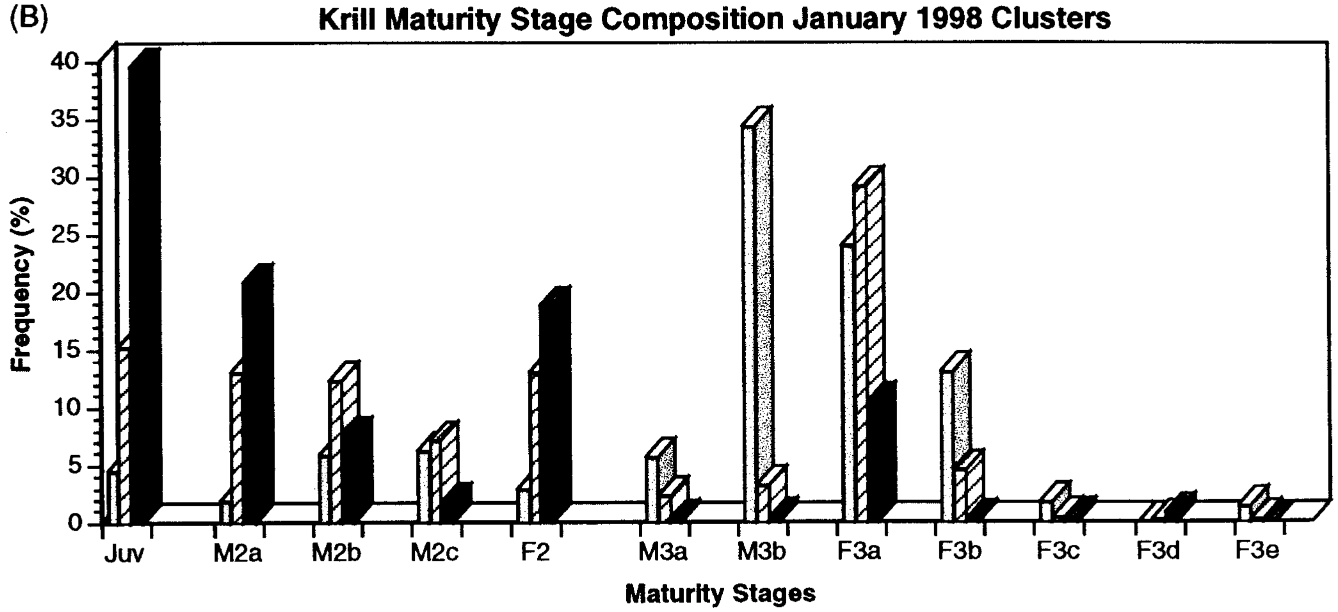


Figure 4.3 (A) Length frequency distribution and (B) maturity stage composition of krill belonging to three different length categories (Clusters 1, 2 and 3) in the Survey A area, January 1998.

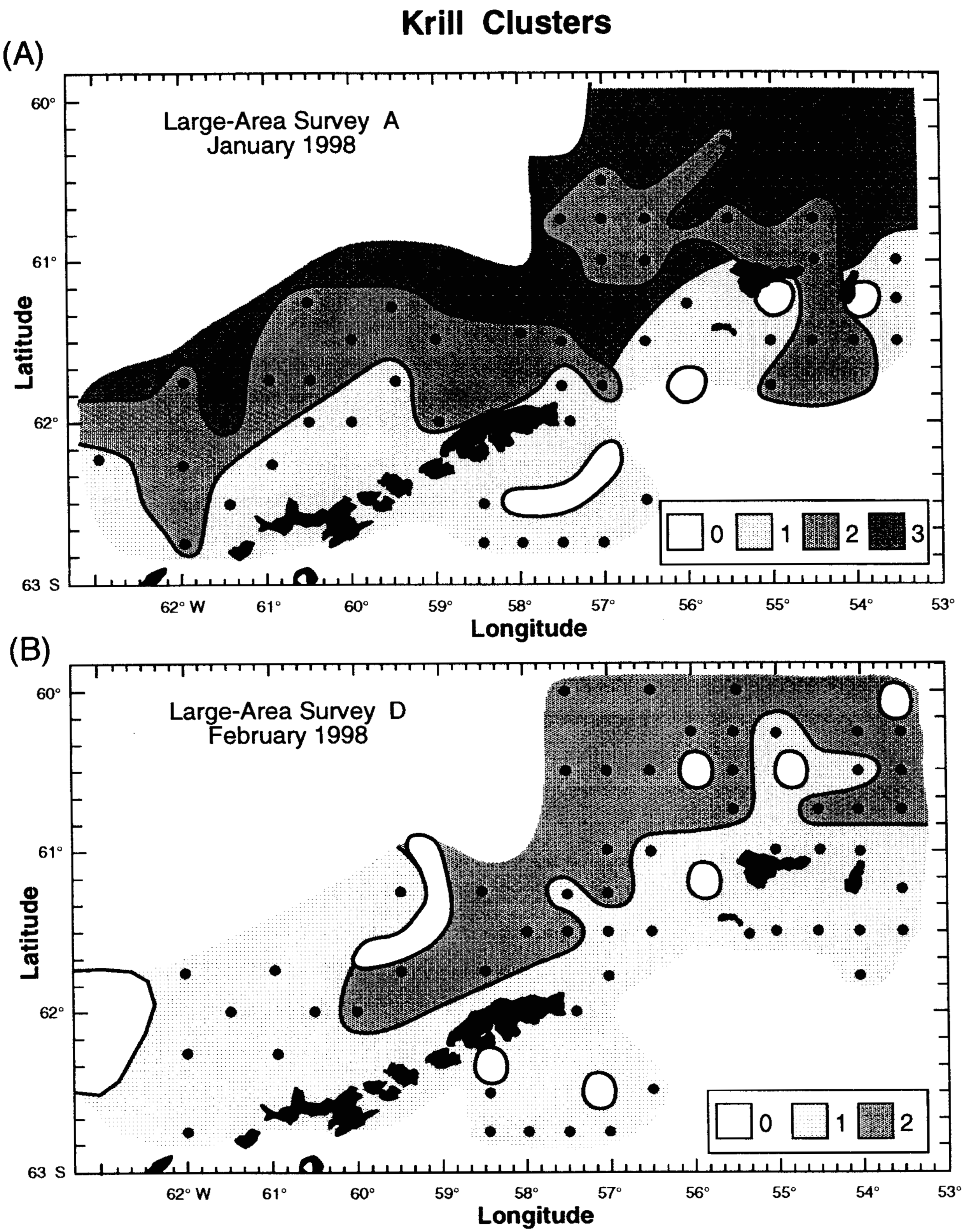


Figure 4.4 Distribution patterns of krill belonging to different length categories within (A) the Survey A area, January 1998 (Clusters 1,2 and 3); and (B) the Survey D area, February 1998 (Clusters 1 and 2).

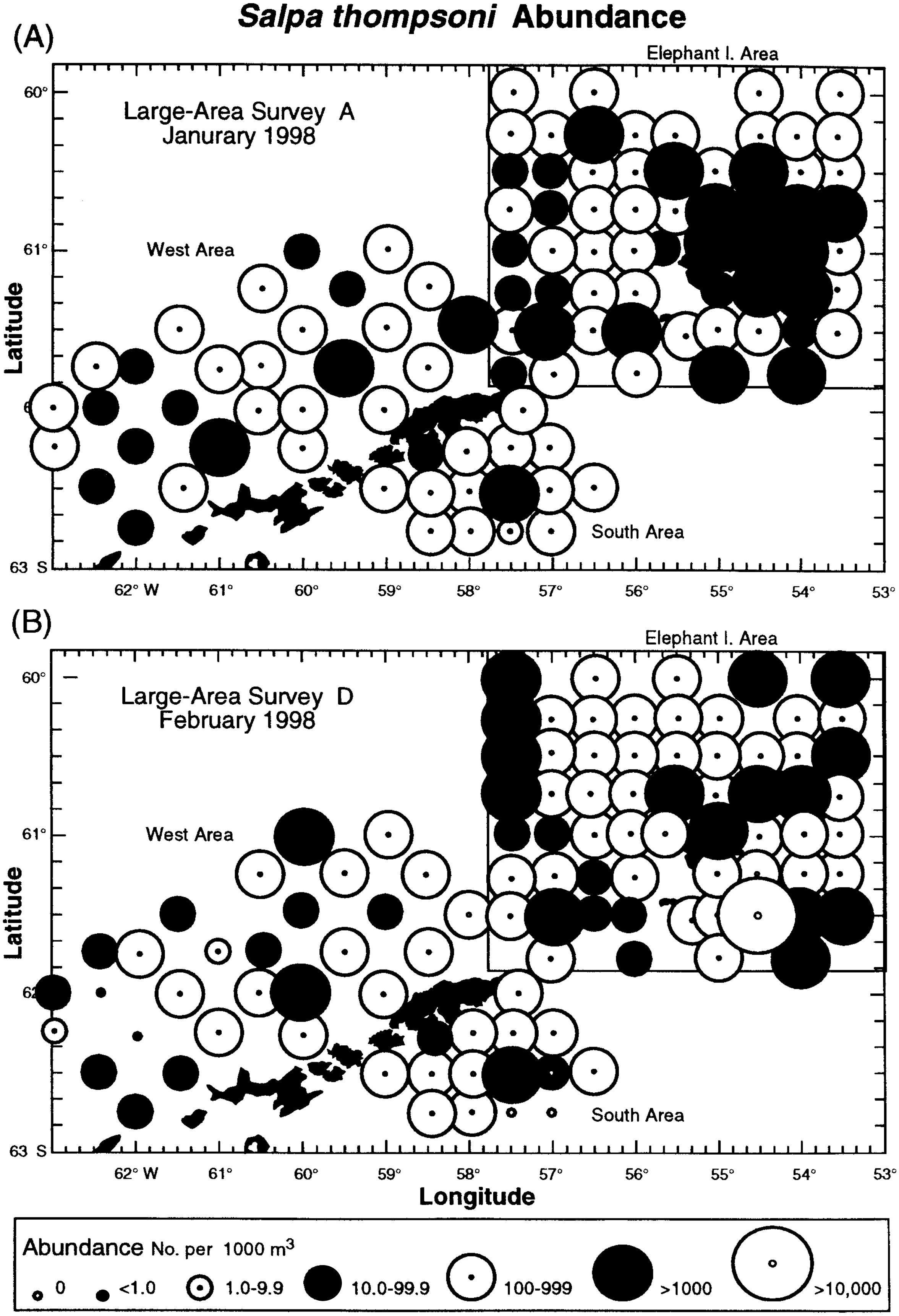


Figure 4.5 Distribution and abundance of *Salpa thompsoni* in (A) the Survey A area, January 1998 and (B) the Survey D area, February 1998.

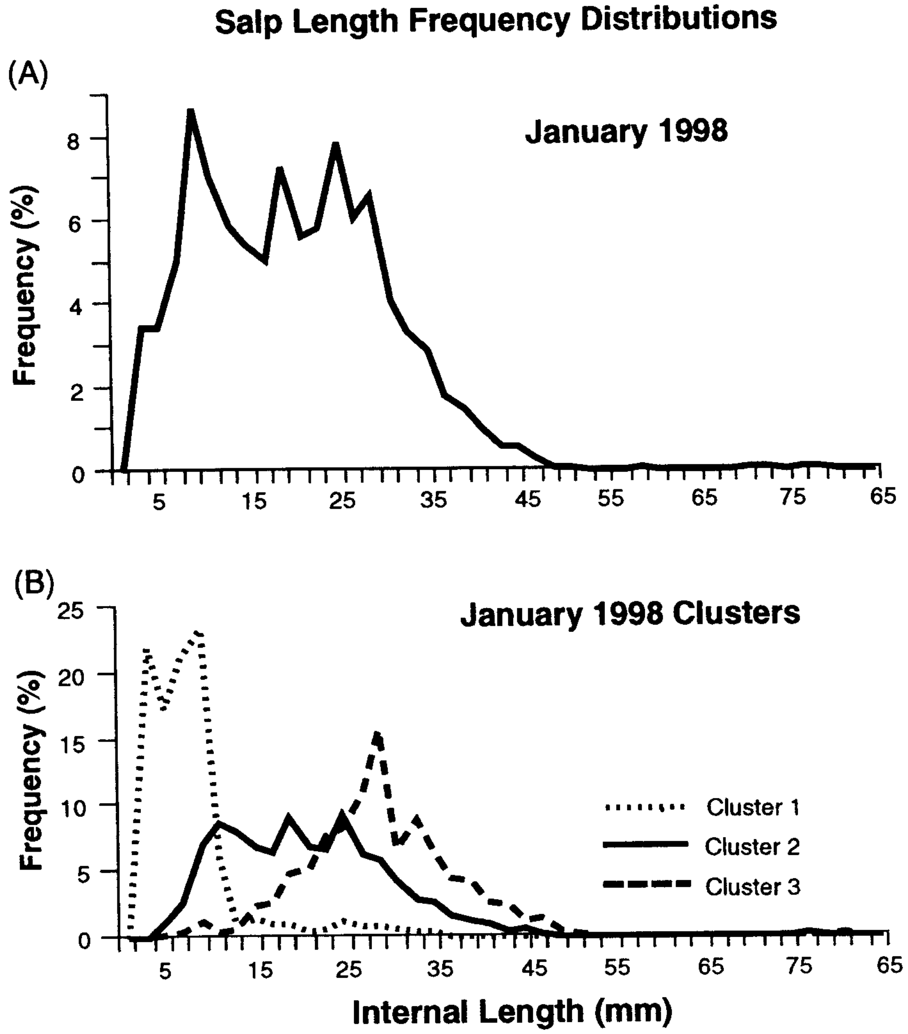


Figure 4.6 Length frequency distributions of *Salpa thompsoni* in (A) the Survey A area and (B) three different length categories (Clusters 1, 2 and 3), January 1998.

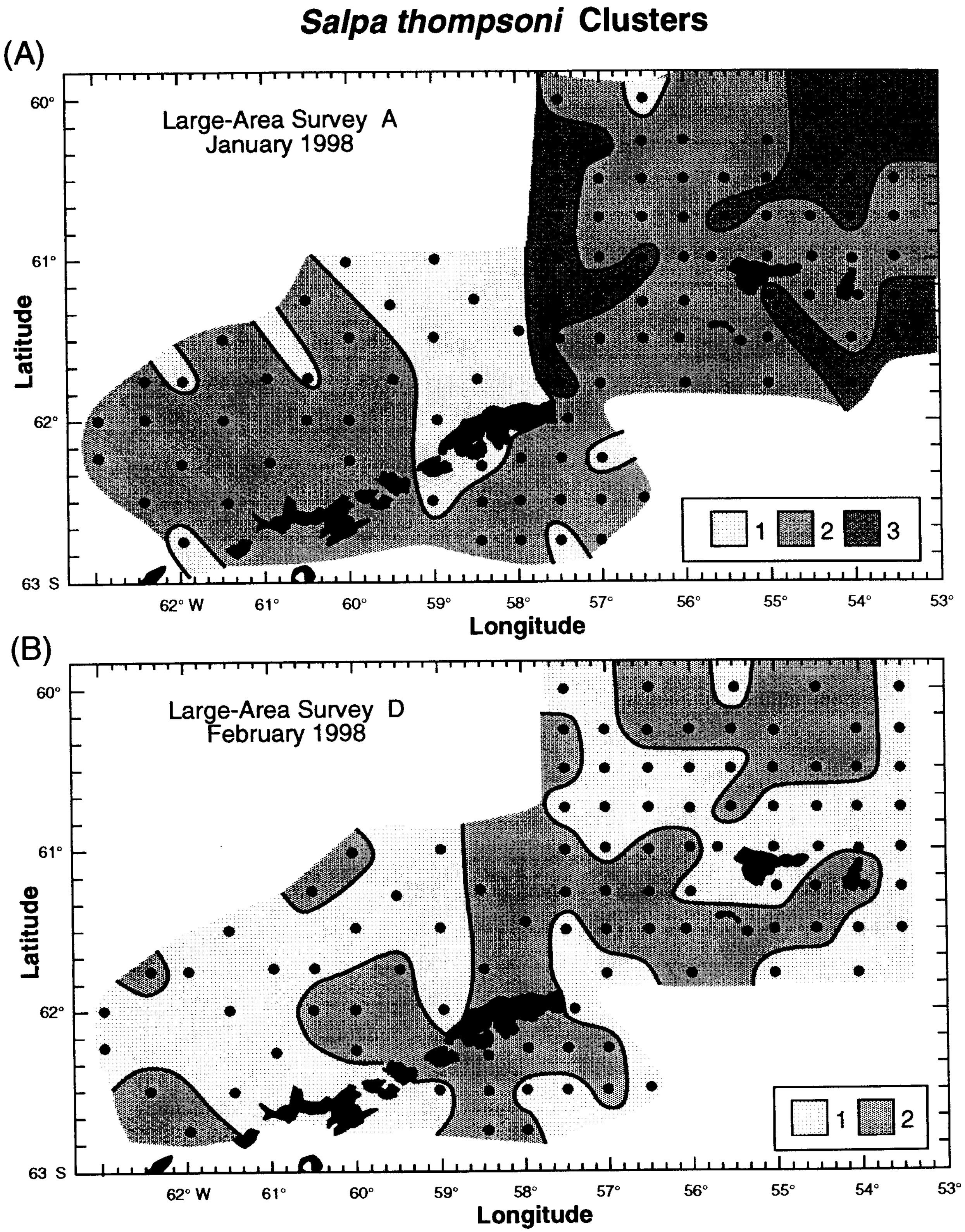


Figure 4.7 Distribution patterns of *Salpa thompsoni* belonging to different length categories in (A) the Survey A area, January 1998 (Clusters 1, 2 and 3) and (B) the Survey D area, February 1998 (Clusters 1 and 2).

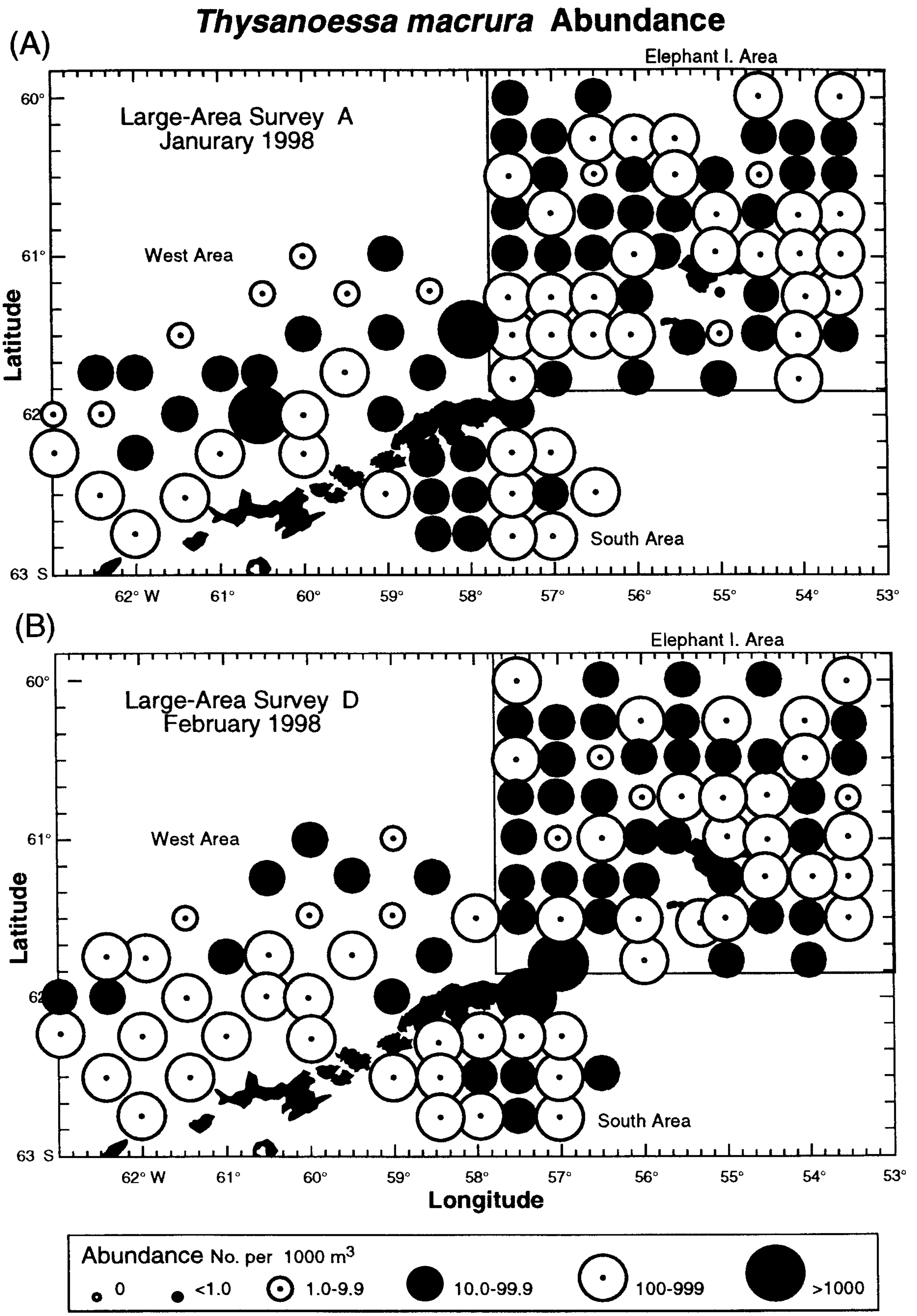


Figure 4.8 Distribution and abundance of *Thysanoessa macrura* postlarvae in (A) the Survey A area, January 1998 and (B) the Survey D area, February 1998.

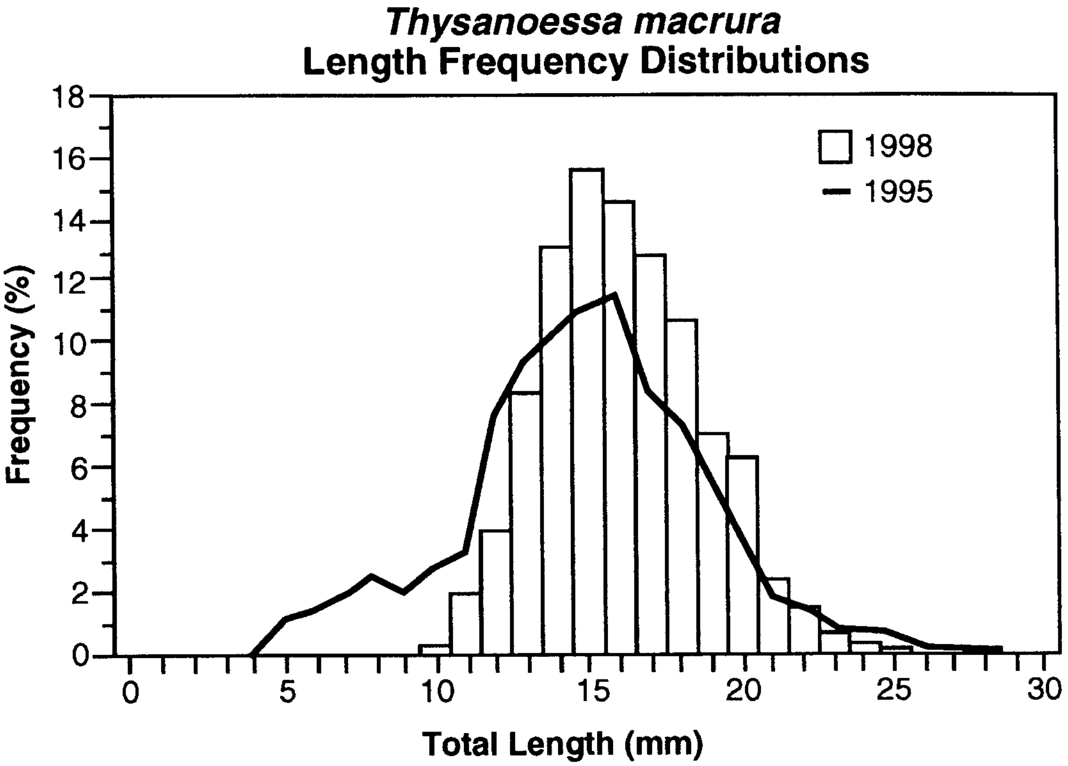


Figure 4.9 Length frequency distribution of *Thysanoessa macrura* in the Survey A area, January 1998, compared to that during January 1995.

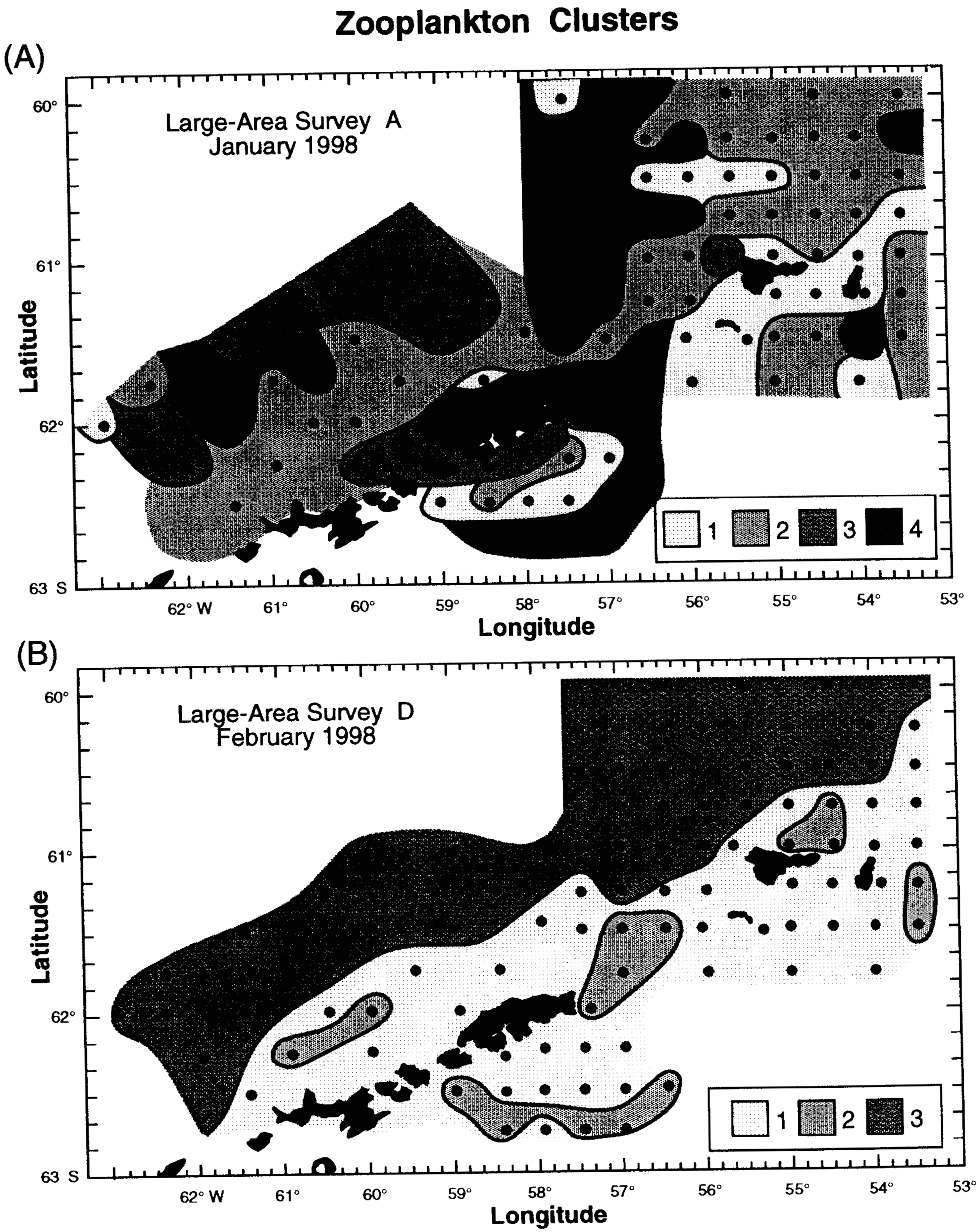


Figure 4.10 Distribution patterns of zooplankton belonging to different taxonomic groupings in (A) the Survey A area, January 1998 (Clusters 1, 2, 3 and 4) and (B) the Survey D area, February 1998 (Clusters 1, 2 and 3).

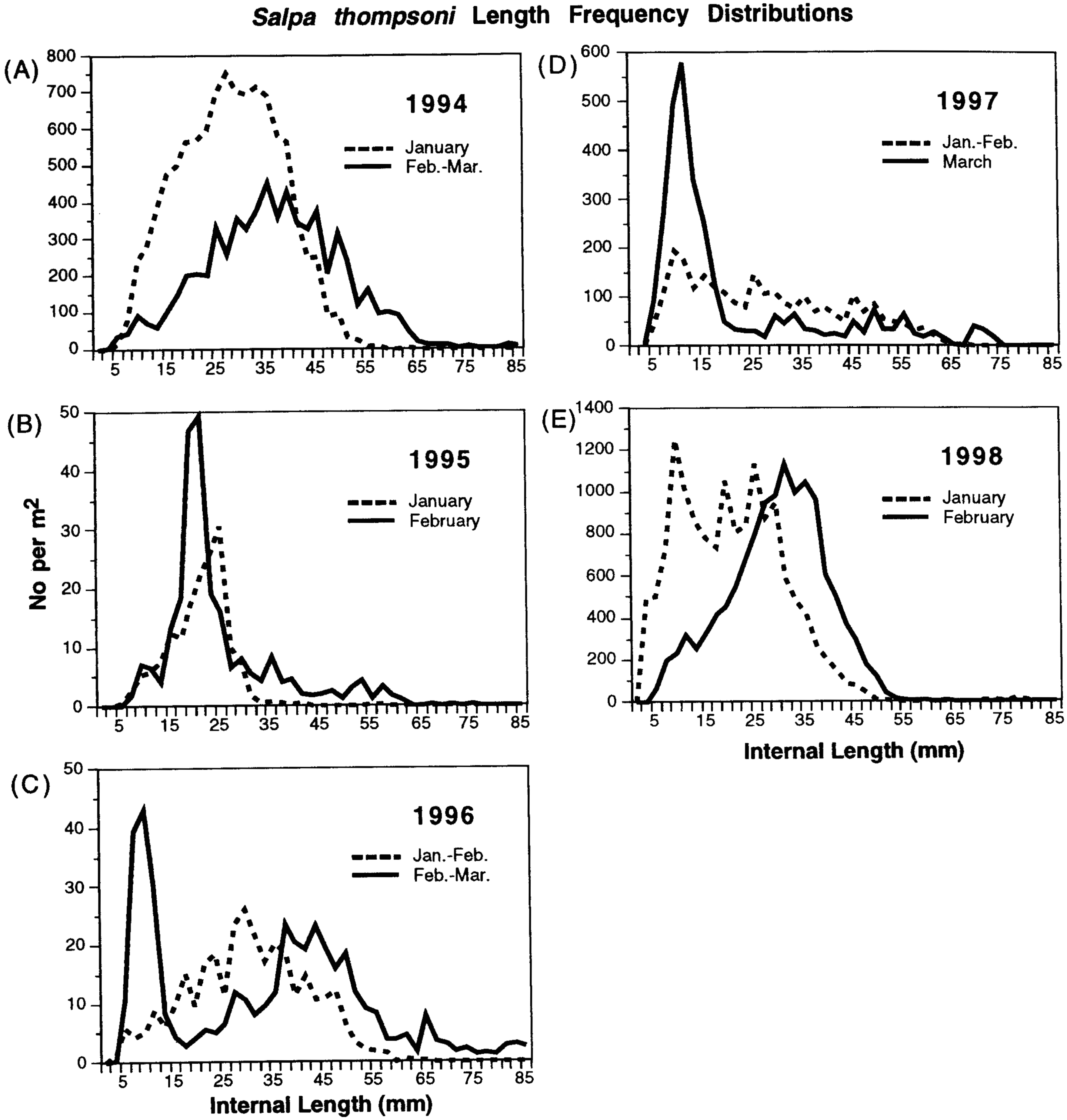


Figure 4.11A-E Length distribution of *Salpa thompsoni* during January-February and February-March large-area surveys 1994-1998. Distributions are for total salps except for (D) 1997 where only aggregate stages are depicted because of relatively large proportions of solitary stages in the total salp catch.

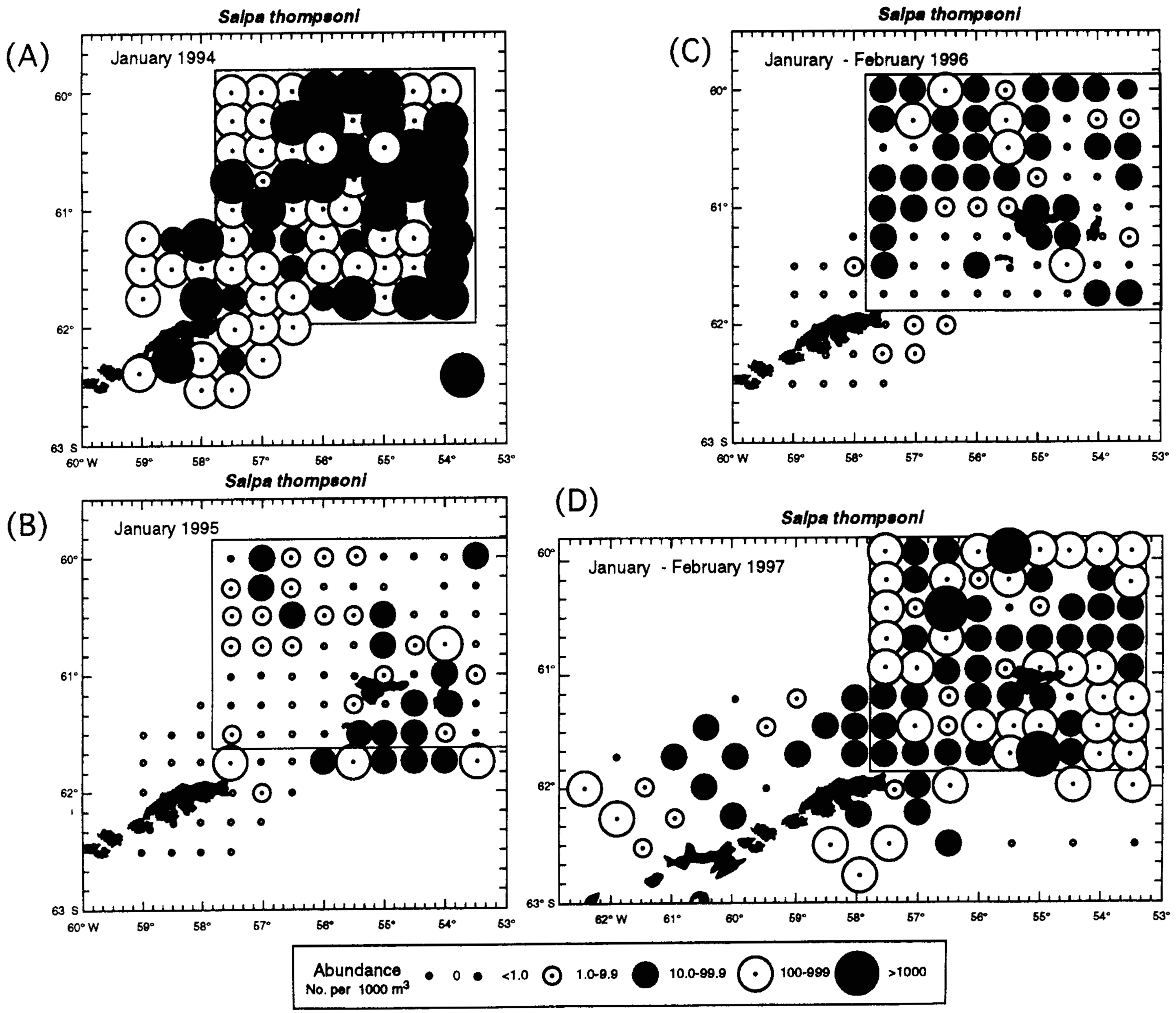


Figure 4.12A-D Distribution and abundance of *Salpa thompsoni* during January-February large-area surveys, 1994-1997.

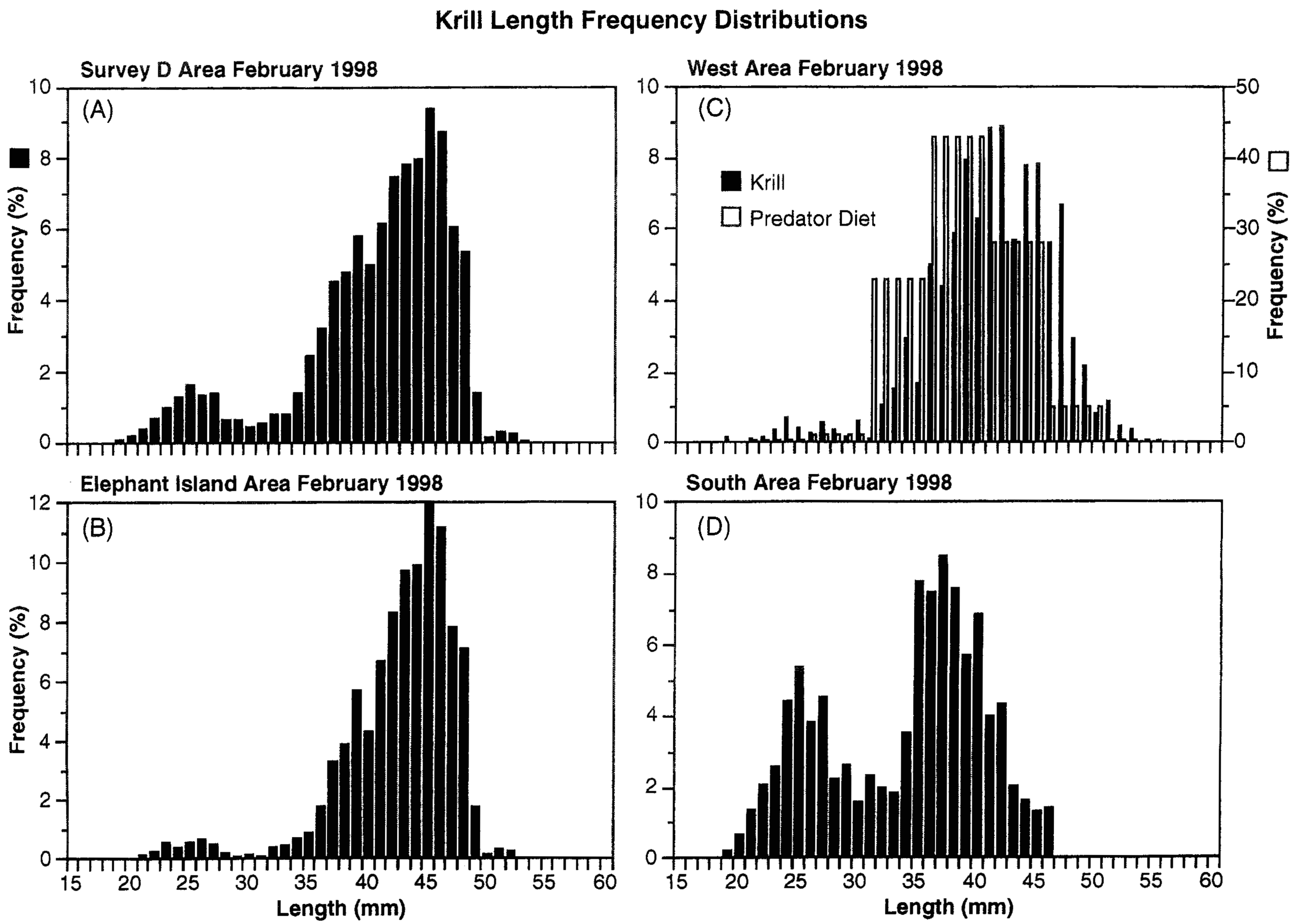


Figure 4.13 Overall length frequency distribution of krill collected (A) during Survey D, (B) in the Elephant Island area, (C) in the West area, and (D) in the South area, February, 1998. Panel (C) has length frequency distributions for krill in predator diets at Cape Shirreff.

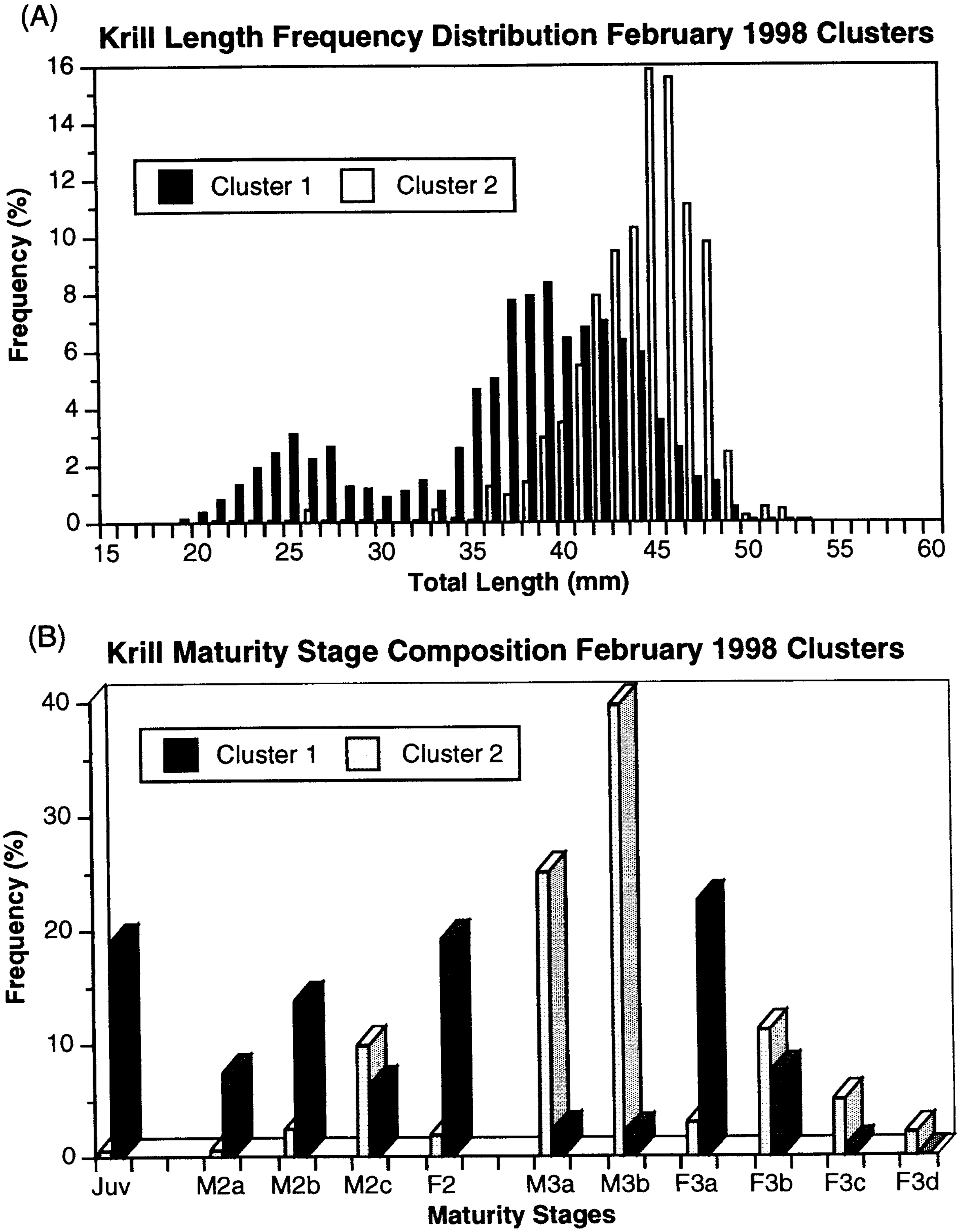


Figure 4.14 (A) Length frequency distributions and (B) maturity stage composition of krill belonging to different length categories (Clusters 1 and 2) in the Survey D area, February 1998.

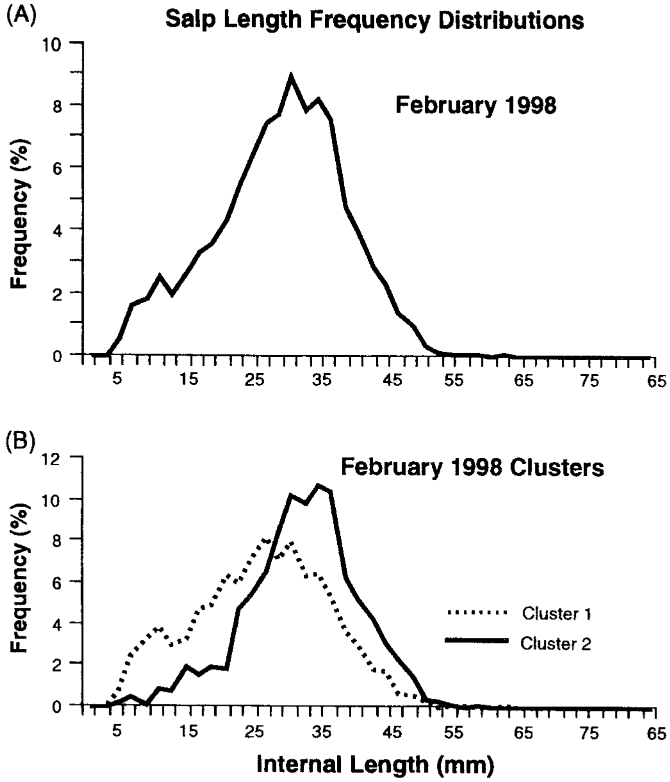


Figure 4.15 Length frequency distributions of *Salpa thompsoni* in (A) the Survey D area and (B) different length categories (Clusters 1 and 2), February 1998.

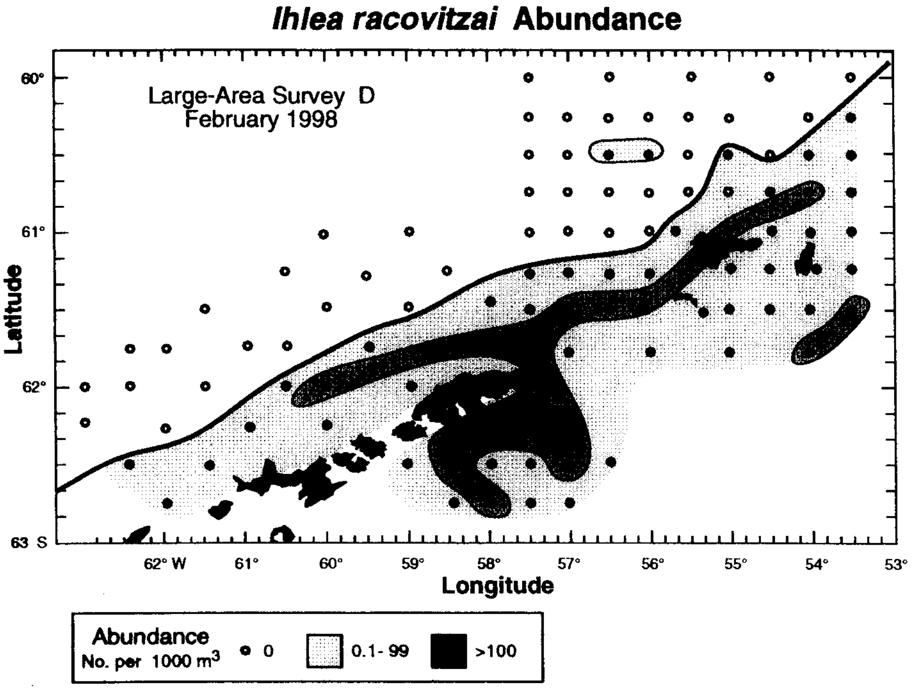


Figure 4.16 Distribution and abundance of *Ihlea racovitzai* in the Survey D area, February 1998.

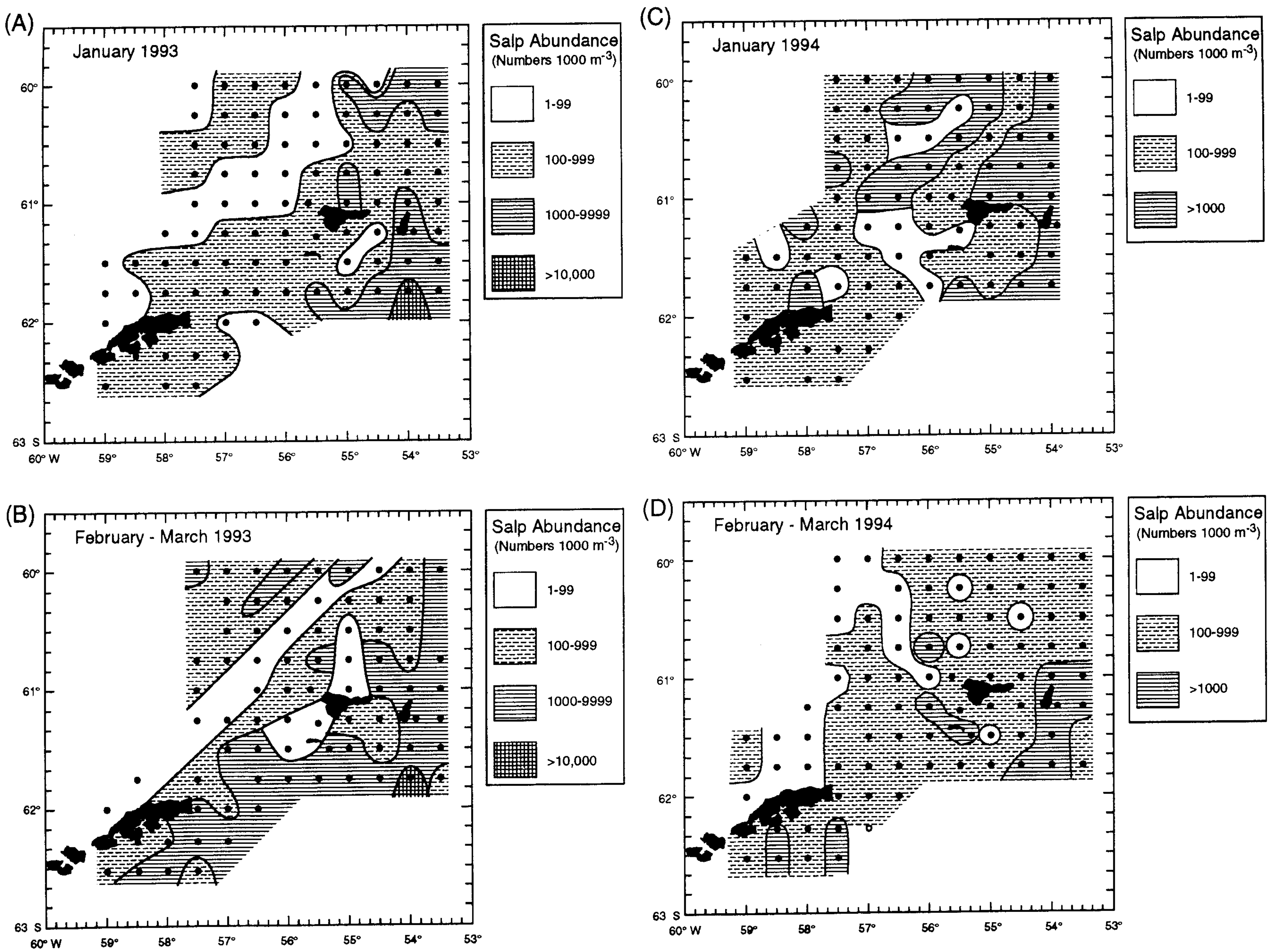


Figure 4.17A-D Distribution and abundance of *Salpa thompsoni* during January and February-March large-area surveys, 1993 and 1994.

5. Lipids and trophodynamics of the Antarctic zooplankton and micronekton ecosystem; submitted by Charles F. Phleger (Leg I) and Matthew M. Nelson (Leg II).

5.1 Objectives: The objectives of this study were to clarify and further understand Antarctic marine zooplankton trophodynamics and seasonal variability by examining lipid classes, particularly fatty acids and sterols, as key biochemical variables and biomarkers. Lipids are important energy reserve molecules and are necessary for cell membrane structure and function. Of special interest are the omega-3 polyunsaturated fatty acids, which are required for reproduction and growth (Pond et al., 1995). Sterols are key biomarker compounds and can be used to diagnose recent feeding activity. The different densities of lipids may also be important in hydroacoustics. Since acoustic impedance is a product of sound speed and density, it may be possible to delineate between various lipid classes and identify organisms beneath the surface.

Krill, salps, and copepods are the major components of the IKMT tows in the AMLR study area. This year, it was our objective to analyze collected krill and salps for lipid biomarkers. Krill have an estimated standing stock biomass of between 200-400 million metric tons, and their importance in the Southern Ocean is well studied. A second objective was to analyze lipid biomarkers in lantern fish (Myctophidae). The biomass of all mesopelagic myctophids south of 40°S has been estimated at 70-396 million metric tons (Sabourenkov, 1991; Lubimova et al., 1983). *Electrona antarctica*, one of the most abundant of Antarctic myctophids (Sabourenkov, 1991), has an established lipid profile (Phleger et al., 1997b), with a diet consisting of 40% amphipods, 30% copepods, and 20% *Thysanoessa macrura* (Hoddell, 1996). Considering the abundance of myctophids, further studies on these fish and their zooplankton prey are essential, and utilizing lipid analyses is a powerful tool.

Selected zooplankton taxa were collected near Elephant and Livingston Islands in the AMLR study area from IKMT tows. Samples were analyzed in the laboratory of Peter D. Nichols at CSIRO, Division of Marine Research, Hobart, Tasmania, Australia. Lipids were extracted by modified Bligh-Dyer (chloroform-methanol) extraction and their classes determined on an Iatroscan MK III THIO TLC-FID analyzer on silica gel chromarods. After saponification, transmethylation, and derivitization, fatty acids and sterols were analyzed on a Hewlett-Packard gas chromatograph mass spectrometer, allowing for exact identification. By identifying important lipid components, including omega-3 fatty acids and certain sterols, a better understanding of food web energy transfer in the Antarctic marine ecosystem can be obtained. Trophodynamic implications of lipids, especially fatty acid and sterol data, include an ability to distinguish herbivorous and carnivorous diets, and to determine survival and reproductive strategies (Virtue et al., 1993).

5.2 Accomplishments: Zooplankton samples from IKMT tows during Leg I and II were identified, sorted into phylogenetic groups, and immediately frozen in liquid nitrogen for analysis (Table 5.1). This year's availability and use of liquid nitrogen markedly improved analytical results by preventing endolytic degeneration, which is particularly significant in krill. A number of new species were obtained this year, including the siphonophore *Dimophyes* *arctica*, the ctenophore *Balinopsis infundibulum*, the polychaete *Tomopteris septentnonalis*, the hyperiid amphipods *Hyperia macrocephala* and *Primno macropa*, the gammarid amphipods *Eusirus perdentatus* and *Orchomene rossi*, sipunculans, the urochordate *Ihlea racovitzai*, and the teleosts *Artediodraco skottsbergii*, *Chaenocephalus aceratus*, *Chaniodraco rastrospinosus*, and *Pagothenia brachysoma*. In addition, amphipod-pteropod combinations (*H. dilatata* and *S. australis*) were successfully obtained.

5.3 Results: Results of the 1998 studies will be compared with those from 1997. In the 1997 studies, a wide range of sterols was observed in many of the Antarctic zooplankton species. Elevated levels of oleic acid [18:1(n-9)c] were also observed for herbivores and omnivores. An interesting finding was high (>30%) glyceryl ethers in the gymnosome pteropod, *Clione limacina*. These values are higher than previously reported (<30%; Phleger et al., 1997a). Glyceryl ethers could vary seasonally in this species and possibly reflect environmental conditions. The midwater myctophid *Krefftichthys anderssoni* had high levels of wax esters, which is a long-term energy reserve lipid, and are present to some extent in animals feeding on copepods. These wax esters were comparable in amount to another Antarctic myctophid fish, *Electrona antarctica*, with 82-91% wax esters, as percent total lipid (Phleger et al., 1997b). *Electrona carlsbergii*, collected in the same trawls as *E. antarctica*, had only trace amounts of wax ester, and its lipid spectrum is dominated by triacylglycerols, a short-term energy reserve lipid. This difference in lipid profiles indicates that winter survival strategies of these two species of *Electrona* may differ.

5.4 Acknowledgments: We are grateful to Valerie Loeb, Volker Siegel, Wes Armstrong, Rachel Johnson, Ellie Linen, Kim Dietrich, Mike Force, Dave Demer, and Jackie Popp for help with collecting, sorting, and identification of specimens. We thank Roger Hewitt and Rennie Holt for making our participation in the AMLR cruises possible and for providing liquid nitrogen. Our appreciation is extended to the Captain and crew of the R/V *Yuzhmorgeologiya* for their enthusiasm and hard work.

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Table 5.1 Zooplankton and micronekton from IKMT tows conducted during Legs I and II.

Taxon	Survey Station
Cnidaria	
Atolla wyvillei (Scyphomedusae)	X011*, D030A**
Calycopsis borchgrevinki (Hydromedusae)	A049, D026, D073
Dimophyes arctica (Siphonophora)	A007, A109
Diphyes antarctica (Siphonophora)	A121
Ctenophora	
Beroe cucumis	A029, A083, A085, A118, D024, D085, D118
Beroe forskalii	A048, A083, A118, D042
Balinopsis infundibulum	A029, A109
Chaetognatha	
Sagitta gazellae	A005, A049, A134
Polychaeta	
Tomopteris carpenteri	A080, D053, D072, D085
Tomopteris septentnonalis	A047
Vanadis antarctica	D086
Pteropoda	
Clione limacina	A045, D037, D055
Clio pyramidata	A080, A086
Limacina helicina	D176
Spongiobranchaea australis	A018, A045, A123, A143, D030A, D136, D158, D176
Euphausiacea	
Euphausia frigida	D085
Euphausia superba	A007, A010, A057, D118, D160
Euphausia triacantha	A008, A023, A176, D045, D136, D158
Thysanoessa macrura	A030, A086, D077
Hyperiidea	
Cyllopus lucasii	A030, A056, A062, A080, A144, D031, D037, D055
Cyllopus magellanicus	A142, A144, D030A, D031, D037, D046, D056, D069
Hyperia macrocephala	A006, X011*, D159
Hyperiella dilatata	A018, A123, A142, A160, A166, D045, D055, D073, D083, D085, D087
Hyperiella dilatata (with *S. australis*)	A018, A027, A040, A046, A143, A158, A166, D057, D158

Table 5.1 (cont.)

Taxon	Survey Station
Primno macropa	D070, D073
Themisto gaudichaudi	A177, D030A**, D042, D045, D053, D079
Vibilia antarctica	A070, D030A**, D160, D171
Gammaridea	
Eusirus perdentatus	D032, D064
Orchomene rossi	D032
Sipuncula	
sipunculans	D087
Urochordata	
Ihlea racovitzai, aggregates	A085, A086, D034
Salpa thompsoni, aggregates	A078, A104, D077
Salpa thompsoni, solitary	A056, D085
Teleostei	
Artediodraco skottsbergii, larva	A007
Chaenocephlaus aceratus, larva	A145
Chaniodraco restrospinosus, larva	A007
Gymnoscopelus nicholsi	D055, D159
Krefftichthys anderssoni	D110
Pagothenia brachysoma	D055

*Station X011 was a directed IKMT tow using a coarse mesh net.

**Station D30A was a directed IKMT tow conducted at Station D30 after the first IKMT tow.

6. Operations and logistics at Cape Shirreff, Livingston Island, and Seal Island, Antarctica, 1997/98; submitted by William T. Cobb, Jeremy T. Sterling, Wayne Z. Trivelpiece, and Rennie S. Holt.

6.1 Objectives: During the 1997/98 field season, the AMLR program conducted researched at 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 28 November 1997 through 28 February 1998. Since the 1986/87 austral summer, the AMLR program has 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, the Seal Island camp is being closed because of safety concerns related to the geological instability of the cliffs surrounding the campsite. The Seal Island camp was occupied from 28 January through 6 February 1998 during which camp structures were disassembled and then removed from the island. The main logistics objectives of the 1997/98 season were:

1. To deploy a four-person field team in late November 1997 from the National Science Foundation (NSF) R/V *Abel J* to Cape Shirreff to initiate research activities pertaining to seabirds and pinnipeds;

2. To deploy a senior seal biologist in mid-December from the NSF R/V *Abel J* to Cape Shirreff to conduct pinniped research;

3. To retrograde from Seal Island to the R/V *Yuzhmorgeologiya* in early January 1998 garbage, lumber, supplies, and equipment which had overwintered at the island because adverse weather prevented its removal the previous season;

4. To transport food, supplies, building materials, and equipment to Cape Shirreff in early January from the R/V *Yuzhmorgeologiya* for constructing additional camp structures, for camp maintenance, and for camp personnel living requirements; and to deploy a sixth person to the campsite;

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

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

7. To dismantle and retrograde one bird observation blind, one camp structure, and the partial remains of a fiberglass pod from Seal Island;

8. To recover the Seal Island field team, retrograded building materials, and equipment in early February aboard the R/V *Yuzhmorgeologiya*; and to resupply the Cape Shirreff camp with additional building materials and provisions.

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

10. To recover from the NSF Copacabana camp in early March aboard the R/V *Yuzhmorgeologiya* a three-person field team and to retrograde equipment and trash at the end of the season; and

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 arrived at Cape Shirreff aboard NSF R/V *Abel J* on 28 November 1997. Ten zodiac loads of supplies and equipment were off-loaded. Scientific activities were quickly initiated. Maintenance of the campsite also was begun. Construction of walkways connecting buildings and additional electrical wiring of the campsite were completed. A fifth person arrived at the campsite aboard the R/V *Abel J* on 21 December 1997.

The R/V *Yuzhmorgeologiya* arrived at Cape Shirreff, Livingston Island on 5 January 1998. A substantial amount of building materials, supplies, and equipment was offloaded from the ship. A sixth biologist joined the island team.

Several major construction projects were completed. These included the installation of a 6-panel solar panel array, rain gutters for collection of fresh water, an additional walkway from the main building to the generator shed, decks for the generator shed and laboratory buildings, an arctic entryway shed for fresh food storage, and interior improvements to living quarters.

Three members of the field team embarked the R/V *Yuzhmorgeologiya* from Cape Shirreff on 27 January. Several Zodiac loads of refuse were transported to the ship for disposal in Punta Arenas, Chile. All operations went quickly without incident in ideal weather conditions. Two of the three field team members returned home, while one was transported to Seal Island.

A four-person field team (one from Seal Island and three ship-board biologists) disembarked the R/V *Yuzhmorgeologiya* to Seal Island on 28 January after a 15 hour transit from Cape Shirreff. One MK V Zodiac was kept on the island for this stay.

Dismantling of a storage building and one observation hut were completed at Seal Island. The storage building had been used to store hazardous materials, hardware, generators, and general supplies. The hut was located on the backside of the island and all materials had to be transported by back-pack along ledges back to the main campsite.

On 6 February the four-person team was recovered from Seal Island aboard the R/V *Yuzhmorgeologiya.* All building material along with non-essential supplies and hardware were retrograded to the ship.

On 7 February the R/V *Yuzhmorgeologiya* returned to Cape Shirreff to off-load materials purchased in Chile and equipment recovered from Seal Island, while removing trash and retrograded cargo. Three personnel (one from Seal Island and two newly arrived biologists) were deployed to the camp.

On 28 February, the field camp at Cape Shirreff was closed for the season. All personnel and garbage, along with equipment requiring maintenance or protection from the winter cold, were removed to the R/V *Yuzhmorgeologiya.*

On 1 March, the field camp at Copacabana was closed for the season. All personnel and garbage, along with 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 campsite. Assistance of the AMLR electronic technician aided in establishing radio communications at Seal Island. 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, 1997/98; submitted by Wayne Z. Trivelpiece, Terence Carten, William T. Cobb, Daniel P. Costa, Michael E. Goebel, Rennie S. Holt, Jeremy T. Sterling, and Philip H. Thorson.

7.1 Objectives: Seabird research was initiated by the AMLR program at Cape Shirreff, Livingston Island, Antarctica (62°28'07"S, 60°46'10"W) during the 1997/98 austral summer. Cape Shirreff is the third site on the Antarctic Peninsula where long-term monitoring of seabird populations is being undertaken in support of US participation in the Convention for the Conservation of Antarctic Marine Living Resources (CCAMLR). The objectives for the 1997/98 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 demographic 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:

Field work at Cape Shirreff began on 28 November 1997 when four scientists were put ashore by the NSF R/V *Abel J* and continued until camp closing on 28 February 1998 assisted by the R/V *Yuzhmorgeologiya*. This was the first full season of predator studies at the new AMLR program field camp at Cape Shirreff.

Breeding Biology Studies.

The Cape Shirreff penguin rookery consists of 30 breeding colonies of penguins: 19 chinstrap penguin (*Pygoscelis antarctica*) colonies, six gentoo penguin (*Pygoscelis papua*) colonies, and five colonies with both species. Chinstrap and gentoo penguin populations were censused for the first time at this site on 3 December, approximately one week following the peak of clutch initiation in both species. All colonies were counted in their entirety according to CCAMLR Standard Methods, and the breeding populations were determined to be 7617 chinstrap penguin pairs and 810 gentoo penguin pairs.

Reproductive success was determined by following a sample of 100 banded chinstrap penguin pairs and 50 gentoo penguin pairs from egg laying to crèche formation. Chinstrap penguins hatched 1.35 and fledged 0.97 chicks/pair and had 72% of all hatched chicks survive to fledging. Gentoo penguins had better reproductive success, hatching 1.56 and fledging 1.34 chicks/pair, while 86% of all hatched chicks survived to fledging.

Counts of all chicks on 5 February produced a total of 7936 chinstrap chicks and 910 gentoo chicks. This represented a 9.3% decline in the total number of chinstrap chicks in the rookery compared to the 1996/97 counts, but a 10.3% increase in gentoo penguin chicks over the 1996/97 totals.

Chinstrap chick fledging weights were collected between 18 February and 26 February according to Standard Method 7c. The average fledging weight of 225 chicks captured on the rookery beaches as they were about to depart to sea was 3180 grams (g), a 90g decrease from the mean fledging weight of the 1996/97 cohort. Gentoo chicks were also weighed at "fledging" for the first time this season. Gentoo chicks do not depart the rookery beaches in a highly synchronized, mass exodus as do their congeners; however, we collected data on chick weights at a set date in their breeding chronology that can be repeated each season to give us a population mean weight for interannual comparisons. This season we captured 200 chicks on 18 February, 85 days following the gentoo penguins' mean clutch initiation date. Assuming a 36-day incubation period between the first egg and first chick, the gentoo penguin chicks were approximately 7 weeks old at the time of weighing, the age at which Adelie and chinstrap penguin chicks fledge. The mean weight of the gentoo penguin chicks captured on 18 February was 4200g.

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.

The nests of 19 brown skua (*Catharacta lonnbergi*) nesting pairs were located, mapped, and marked. Twenty-seven of the 38 birds were banded. In addition, a survey for kelp gulls (*Larus dominicanus*) was conducted across the Cape, and nests were checked for the presence of eggs and chicks.

Foraging Ecology Studies.

Diet studies of chinstrap and gentoo penguins feeding chicks were initiated on 9 January and continued through 13 February. A total of 40 chinstrap and 20 gentoo adults returning from foraging trips to sea were captured at their nest sites prior to feeding their chicks, and their stomach contents were removed by lavaging. We noted the sex of the returning adult, the number of chicks at the nest, and their approximate ages. Krill (*Euphausia superba*) was present as a food item in 100% of the samples from both species, while evidence of fish was noted in 38% of chinstrap and 90% of gentoo samples. However, most of the fish noted in the chinstrap diets was from otolith evidence, as little fresh fish was found in the stomach contents. Gentoo penguins frequently had fresh fish in their stomachs, as well as octopii, squid, and tunicates. The length frequency distribution of krill in the diet samples was predominated by three CCAMLR size classes; 31-35, 36-40 and 41-45 millimeters (mm), which together accounted for more than 93% of all krill in the samples (Table 7.1).

Time-depth recorders (TDRs) were deployed on five chinstrap and five gentoo adult penguins to study diving behavior. The TDRs remained on the penguins for 7-10 days of foraging before being removed, downloaded, and redeployed on ten new individuals.

We epoxied 19 radio transmitters to adult chinstrap penguins feeding 1-2 week old chicks on 8 January and followed their foraging trips through mid-February using a remote receiver and data logger set up in the rookery. Foraging trips over the season averaged 13.3 hours during brood and 12.5 hours during crèche periods, respectively (Table 7.2). However, the mean trip lengths are misleading, as the foraging trips exhibited a bimodal distribution with a major peak around 10 hours and a second peak at 22 hours duration (Figure 7.1). Further comparisons between trip length and time of departure to sea revealed that trips which began between dawn and noon were generally of the shorter duration, while trips that began in the afternoon were overnight trips that averaged 20-24 hours (Figure 7.2).

7.3 Preliminary Conclusions: This was the first full season of research at Cape Shirreff and thus comparisons with prior years are not possible. However, based on mean breeding success from Admiralty Bay, approximately 140 kilometers northeast on King George Island, the chinstrap penguin population had average and the gentoo penguin population above average breeding success. Both chinstrap and gentoo penguins ate primarily krill 31-45mm in length and fish were noted in about one-third of all chinstrap and nearly all gentoo penguin samples. Chinstrap foraging trip durations were bimodal with 8-10 hour trips alternating with 20-24 hour trips. We suggest that the short trips are to gather food only for the chicks, while the longer trips represent trips where the adult first acquires and digests food for itself then gathers additional food for the chicks. The longer trips all began in the afternoon and included a nocturnal component. We suggest that the presence of otoliths in the chinstrap diet samples may be from nocturnal foragers and that fish may be an important component of adult chinstrap penguin diets, but is of little importance in provisioning chicks.

Table 7.1 Krill length frequency distribution by CCAMLR 5mm size classes from diet samples of gentoo and chinstrap penguins at Cape Shirreff, 1997/98.

Krill Size Class (mm)	**Percent Occurrence**
<16	0.00
16-20	0.00
21-25	0.04
26-30	0.89
31-35	23.11
36-40	42.64
41-45	27.75
46-50	5.19
51-55	0.38
>55	0.00

Table 7.2 Foraging trip durations of chinstrap penguins at Cape Shirreff, 1997/98.

Foraging Trip Duration						
start date of 5 day periods	**5 day periods mean (h)**	**period**	**mean (h)**	**sd**	**n events**	**n 5 day periods**
9 Jan	14.0					
14 Jan	15.3					
19 Jan	11.2	brood	13.3	5.9	140	3
24 Jan	12.9					
29 Jan	12.0					
3 Feb	11.0					
8 Feb	14.1	creche	12.5	7.6	191	4

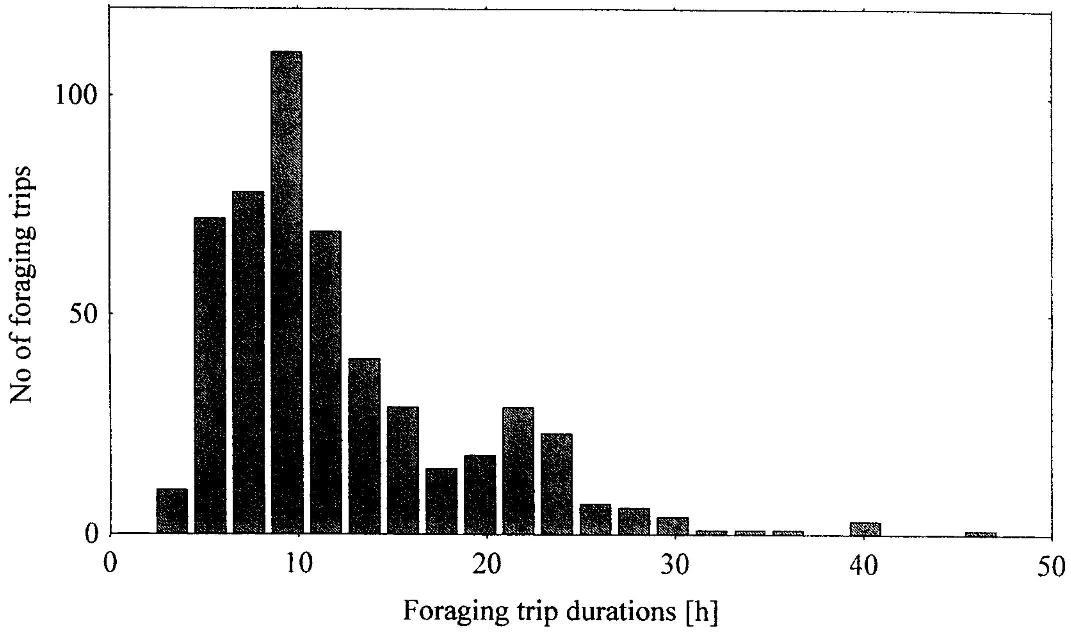

Figure 7.1 Chinstrap penguin foraging trip durations during chick rearing period at Cape Shirreff, Livingston Island, Antarctica, 1997/98.

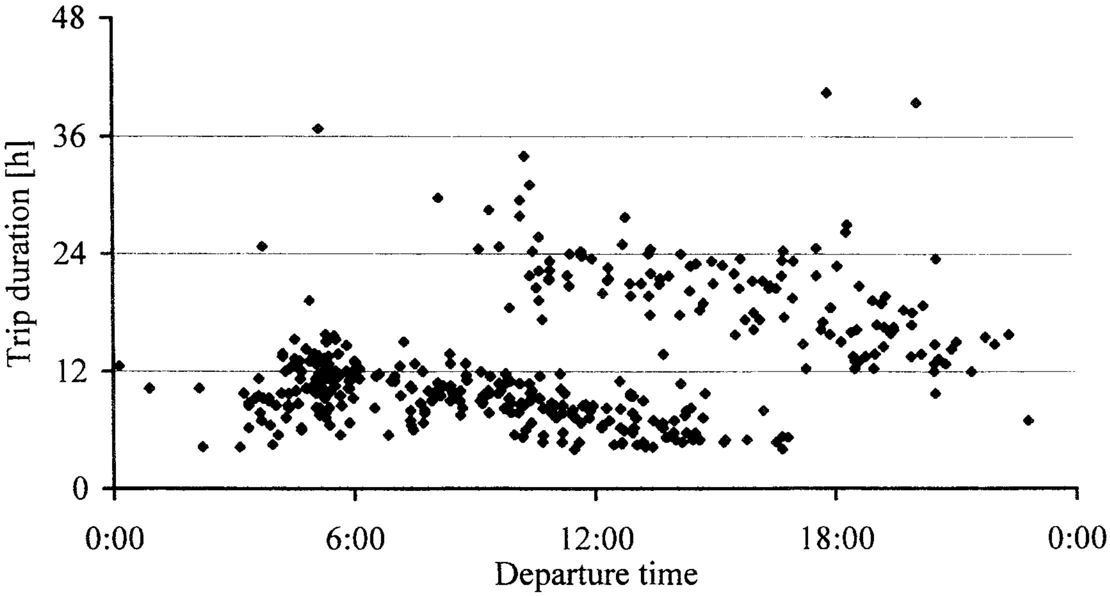

Figure 7.2 Diel pattern of chinstrap penguin foraging trip durations at Cape Shirreff, Livingston Island, Antarctica, 1997/98.

8. Pinniped research at Cape Shirreff, Livingston Island, Antarctica, 1997/98; submitted by Michael E. Goebel, Jeremy T. Sterling, Daniel P. Costa, William T. Cobb, Philip H. Thorson, Terence Carten, Wayne Z. Trivelpiece, and Rennie S. Holt.

8.1 Objectives: Pinniped research was conducted by the U.S. AMLR program at Cape Shirreff, Livingston Island, Antarctica (62°28'07"S, 60°46'10"W) during the 1997/98 season. U.S. presence at Cape Shirreff began last season with initial construction of a camp near the Chilean field camp. All research activities in 1997/98 were coordinated with continued construction of the base camp. The field team arrived at Cape Shirreff on 28 November 1997 and began pinniped studies on 30 November. Research activities continued until the close of camp on 28 February 1998. The primary research objectives for the 1997/98 season were as follows:

1. Conduct a weekly census of all pinniped species (*Arctocephalus gazella, Mirounga leonina, Leptonychotes weddelli, Lobodon carcinophagus,* and *Hydrurga leptonyx*) hauling out at Cape Shirreff.

2. Document Antarctic fur seal (*Arctocephalus gazella*) pup production at Cape Shirreff and the San Telmo Islands.

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

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

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

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

7. Measure at-sea foraging locations for female fur seals using ARGOS satellite-linked transmitters.

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

9. Measure at-sea metabolic rates and foraging energetics of lactating female fur seals using doubly labeled water.

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

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

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

13. Deploy a weather station for continuous recording of wind speed, wind direction, ambient temperature, humidity, and barometric pressure.

8.2 Accomplishments:

Pinniped Census: Pinniped censuses were divided into Phocid and Antarctic fur seal counts. Phocid surveys of Cape Shirreff began on 10 December and were conducted weekly until 29 January. For each Phocid species, we recorded age class (adult, juvenile, or pup) and sex when possible; otherwise counts were recorded as unknown. We report only total counts here (Table 8.1).

Antarctic fur seals were censused every two days at two of the fur seal breeding sites (Cachorros and Chungungo) on the east side of Cape Shirreff. Counts were made in the following categories: pups, females, sub-adult males, adult male non-territorial, adult male territorial with females, and adult male territorial without females (Figure 8.1). These counts were made to characterize arrivals of different age/sex classes of animals and were done only at these sites because the Cape is too large to count all fur seals with any frequency less than every week. Our counts of Cachorros and Chungungo were conducted from 1 December to 7 January. The median date of birth at these two sites was 8 December. Researchers did not arrive early enough to record the date of first birth. The last observed birth at Cape Shirreff was 2 January.

Fur Seal Pup Production: Antarctic fur seal pups were counted for the entire Cape once every week from 1 to 30 December. Both live and dead pups were counted. Chilean and US researchers jointly conducted a census of fur seal pups at the San Telmo Islands off Cape Shirreff on 6 January. The total number of fur seal pups born at Cape Shirreff and the San Telmo Islands in 1997/98 was 7,748 (Table 8.2). This count is a 14.1% decrease in pup production from 1996/97 count of 9,015 (Hucke-Gaete et al. 1997).

Attendance Behavior: Female fur seal attendance behavior was measured according to CCAMLR protocol (CCAMLR Standard Method C1.2 Procedure A) using VHF radio transmitters (ATS Model 7PN; pulse rate 40ppm). Thirty perinatal females were instrumented from 21 to 31 December. Their pups (13 males, 17 females) were captured at the same time. Each pup was weighed, measured, and bleached with a unique identifiable mark. Mother and pup were released at the same time, and further work did not commence until both had settled and were at each other's side. Transmitters were monitored using an Advanced Telemetry Systems, Inc. data collection computer programmed to log presence or absence for each of the 30 frequencies every 30 minutes for 30 seconds. Females were monitored for at least the first 6 trips to sea.

Mean trip duration for the first 6 trips to sea ranged from 3.82-4.66 days (d) (Figure 8.2). Maximum trip duration was 9.08d and the minimum was 0.50d. There was no difference in mean trip duration for the first 6 trips (ANOVA, p=0.19). Mean visit (shore) duration ranged from 1.22-1.80d (Figure 8.2). Maximum visit duration was 2.68d and the minimum was 0.46d. There was a difference in the mean visit duration for the first 6 visits following the perinatal visit (ANOVA, p<0.001). A Tukey's multiple comparisons test of visit duration indicated the difference was for visit 2 (mean = 1.8d, st.dev. = 0.49), which was longer than visits 3-7. No difference was found for visits 3-7.

Female fur seals at Cape Shirreff have a pronounced peak in departures several hours preceding sunset, whereas arrivals occur with similar frequency throughout the day light hours (Figure 8.3). By mid-February this trend is more pronounced and shortly before dusk most females have left the beaches.

Fur Seal Pup Growth: The US research team assisted Chilean researchers collecting data on Antarctic fur seal pup growth. Chilean researchers began collecting data on pup weights on 16 December 1997. 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 26 February. US researchers collected pup growth data for the last two measurements of the season (14 and 26 February).

Diet Studies: Information on fur seal diet was collected using three different sampling methods: scat collection from captured animals and from beaches, enemas of captured animals, or from fatty-acid signature analyses of milk. A total of 53 scats and enemas were collected throughout the season. Forty-two samples contained identifiable hard parts (fish bone, krill chitin, or squid beaks). Scats and enemas containing fish comprised 61.9%, krill 57.2% and squid 14.3% (Figure 8.4). Sixty-eight milk samples (31 perinatal, 37 non-perinatal) were collected for fatty-acid signature analysis. Fatty acids have recently been shown to be important indicators of diet in pinniped species (Iverson et al. 1997a). The method has already been used to examine diet in Antarctic fur seals using milk (Iverson et al. 1997b).

Diving Studies: Fifteen Antarctic fur seal females were instrumented with TDRs (Wildlife Computers Inc. Mark 7) during their perinatal period. An additional 4 TDRs (Wildlife Computers Inc. 3 Mark 5, 1 Mark 7) were deployed on lactating females for a single trip to sea from 9 to 24 February. All of the initial 15 females carried TDRs for at least 6 trips to sea. TDRs logged all dives >2 meters (m).

Fur Seal Foraging Locations and Energetics: During Leg II of the AMLR cruise we instrumented 11 lactating female fur seals with ARGOS satellite-linked transmitters (PTTs) for a single trip to sea. Foraging trip length averaged 4.6d (range: 3.2-6.8). After satellite location data were filtered to eliminate positions that required females to travel >4m/sec, we had 605 successful at-sea locations (average: 12/day/female; Figure 8.5). The mean distance traveled was 98 kilometers (km) (s.d.=24.9). Maximum distance traveled was 142km and only one female exceeded the bounds of the AMLR large-area survey grid.

Eight of the 11 females instrumented with satellite-linked transmitters also received doubly-labeled water (DLW) for measurements of at-sea metabolic rate, condition, and water turnover. An additional six females without PTTs were also given DLW. Five of these had isotopes for a single trip to sea; the remaining female had isotopes for four days but did not leave the beach.

Demography and Tagging: A total of 500 fur seal pups were tagged at Cape Shirreff from 14 to 26 February. Four hundred eighty fur seal pups (246 males, 231 females, and 3 unknown) were tagged by US researchers. An additional 20 pups (2 males, 1 female, 17 unknown) were tagged by Chilean researchers. All tags placed at Cape Shirreff were Dalton Jumbo Roto tags white (female upper) and orange (male lower). All pups were tagged on the east side of the Cape (most around Copihue or on Maderas Beach). During the last pup weighing on 26 February, some pups were tagged in the flats above Cachorros and Maderas. By mid-February fur seal pups are very mobile and travel considerable distances, and any pup from any breeding site on the Cape or the San Telmo Islands has a likelihood of being tagged.

Thirty-six adult female fur seals with pups were tagged. Thirty-two of these were tagged during their perinatal visit and four were tagged in mid-February. All females were tagged at Copihue (9), Maderas (11), Chungungo (9), Cachorros (6), and Playa Daniel (1).

Two fur seals tagged at other sites were observed in 1997/98 at Cape Shirreff. Both were females tagged at Seal Island, Antarctica with orange Allflex sheep ear tags (N342 and N395). Both were observed on several occasions, but only N395 was observed suckling a pup.

Fur Seal Total Blood Volume Studies: Total blood volume (TBV) is an important measure for calculating oxygen stores of diving animals. We used the Evan's blue dye dilution method for calculating TBV in 22 fur seals (20 adult females and 2 pups).

Weather at Cape Shirreff: A weather data recorder (Davis Weather Monitor II) was set up at Cape Shirreff from 1 December to 26 February. The station recorded wind speed, wind direction, barometric pressure, temperature, humidity, and rainfall. The archive interval was set at 15 minutes. The sample rate for wind speed, temperature, and humidity was every 8 seconds, thus the average measure for the 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 weather station recorded the direction in one of sixteen bins corresponding to the 16 compass points; at the end of the archive interval, it stored the most dominant wind direction. Maximum speed was measured continuously during the 15 minute interval and stored.

8.3 Tentative Conclusions: Cape Shirreff is an ideal location for conducting studies of fur seal foraging ecology and energetics. The size and density of the various fur seal colonies allows for capture and handling with minimal impact to the population at large. Fur seal diet at the Cape, at least through the 1997/98 season, is variable consisting of fish, krill and cephalopods. It is therefore an ideal location for examining variable diets, energetics, prey distribution, and their effects on maternal provisioning of offspring and reproductive success.

Overall fur seal pup production at the Cape and San Telmo islands was down this year by 14%. The San Telmo Islands off Cape Shirreff are difficult to get to and many parts of the islands are inaccessible. Usually only one census visit is made annually around the end of pup births. Part of the San Telmo numbers for 1996/97 were estimated from 1995/96 counts because researchers in that year were unable to get to a portion of the islands. Nonetheless, using the more accurate censuses on the Cape itself, pup production was down by 13%.

8.4 Acknowledgments: We are grateful to our Chilean colleagues, Daniel Torres, Rodrigo Hucke-Gaete, Veronica Vallejos, Sergio Zarate, and Jorge Acevedo for assistance in the field, good humor, and for sharing with us their considerable knowledge and experience of Cape Shirreff. A special thanks to Daniel Torres for helping us around the corner. We are also particularly grateful to Wayne Trivelpiece and Terry Carten for all their assistance (especially with collecting fur seal pup weights), their boundless good humor, and meticulous attention to the importance of a penguin biologist's personal hygiene. Special thanks to Dave Demer, Wes Armstrong, Roger Hewitt and the rest of the AMLR personnel and to the Russian crew of the R/V *Yuzhmorgeologiya* for their assistance in getting on and off Cape Shirreff. Stephanie Sexton of the AMLR program provided invaluable assistance on several permits required for Cape Shirreff pinniped research.

8.5 References:

Hucke-Gaete, R., D. Torres, V. Vallejos, and A. Aguayo. 1997. Population size and distribution of *Arctocephalus gazella* at SSSI No. 32, Livingston Island, Antarctica (1996/97 Season). CCAMLR WG-EMM.97/63.

Iverson, S.J., K.J. Frost, and L.F. Lowry. 1997. Fatty Acid signatures reveal fine scale structure of foraging distribution of harbor seals and their prey in Prince William Sound, Alaska. *Marine Ecology Progress Series*. 151:255-271.

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Table 8.1 Results of the weekly census of Phocids at Cape Shirreff, Livingston Island, Antarctica (62°28'07"S, 60°46'10"W) during the 1997/98 season.

	Date:							
Species	10 Dec	18 Dec	24 Dec	01 Jan	08 Jan	16 Jan	22 Jan	29 Jan
Mirounga leonina	250	283	277	272	257	296	311	305
Leptonychotes weddelli	36	13	18	21	21	30	21	6
Lobodon carcinophagus	0	1	0	0	1	1	0	0
Hydrurga leptonyx	0	0	0	0	1	0	1	0

Table 8.2 Total fur seal pup production at the San Telmo Islands and Cape Shirreff, Livingston Island, Antarctica (62°28'07"S, 60°46'10"W) during the 1997/98 season. Values for 1997/98 are for live pups with the dead pup count in parentheses. Values for 1996/97 are total counts combining dead and live pups.

Season	Cape Shirreff	San Telmo Islands	Total
1996/97	5,689	3,326	9,015
1997/98	4,921 (19)	2,781 (27)	7,748

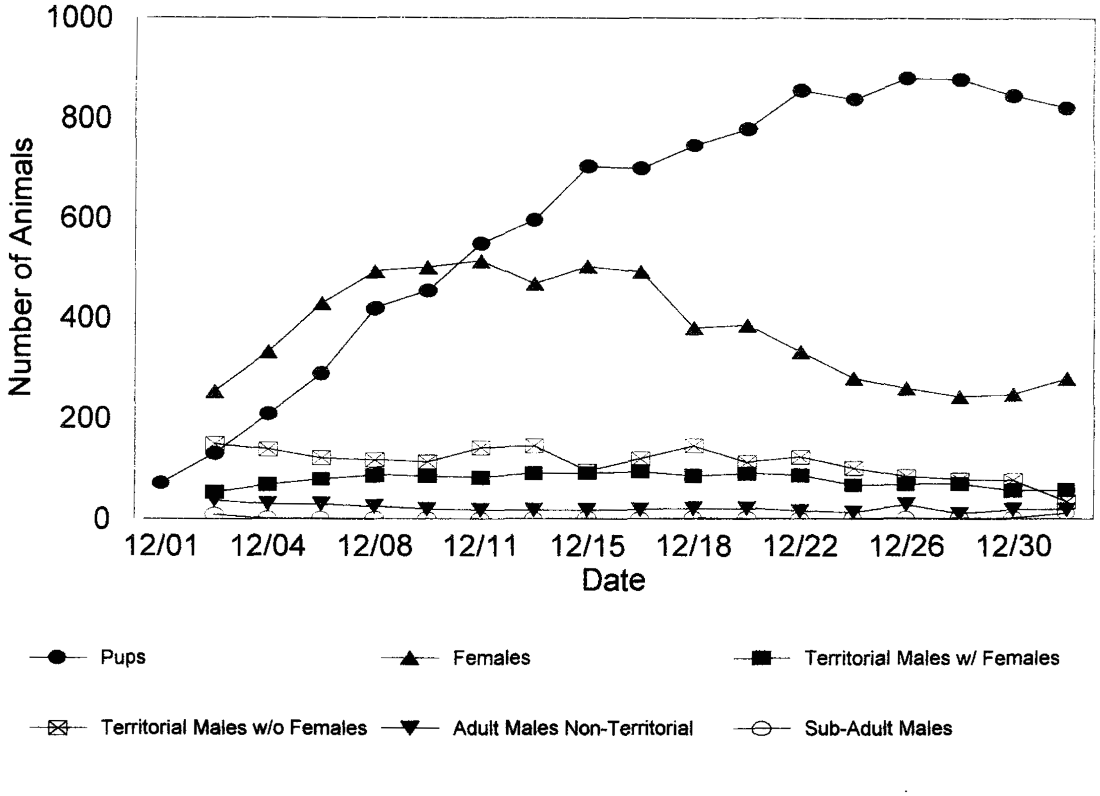

Figure 8.1 Antarctic fur seal census at two of the fur seal breeding sites (Cachorros and Chungungo) on the east-side of Cape Shirreff.

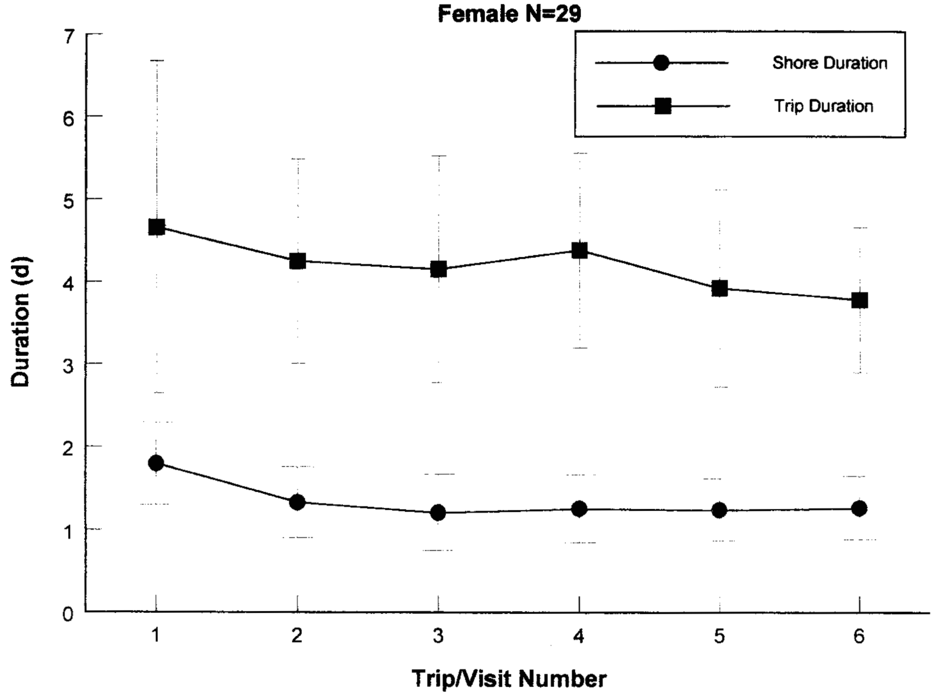

Figure 8.2 Attendance behavior of female Antarctic fur seals: mean trip durations and mean visit (shore) duration.

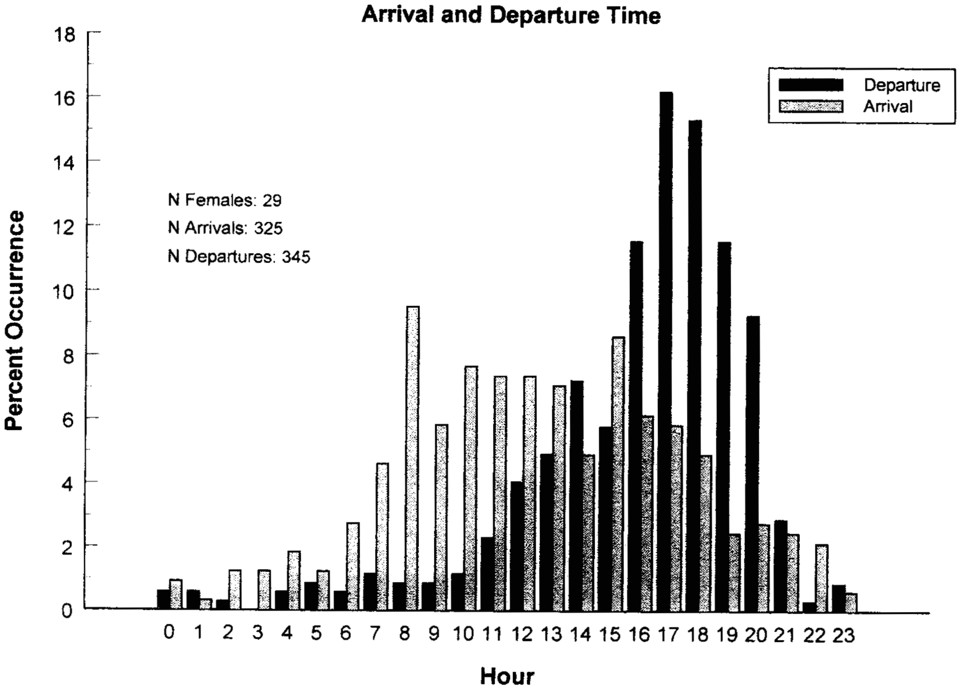

Figure 8.3 Attendance behavior of female Antarctic fur seals: arrival and departure times.

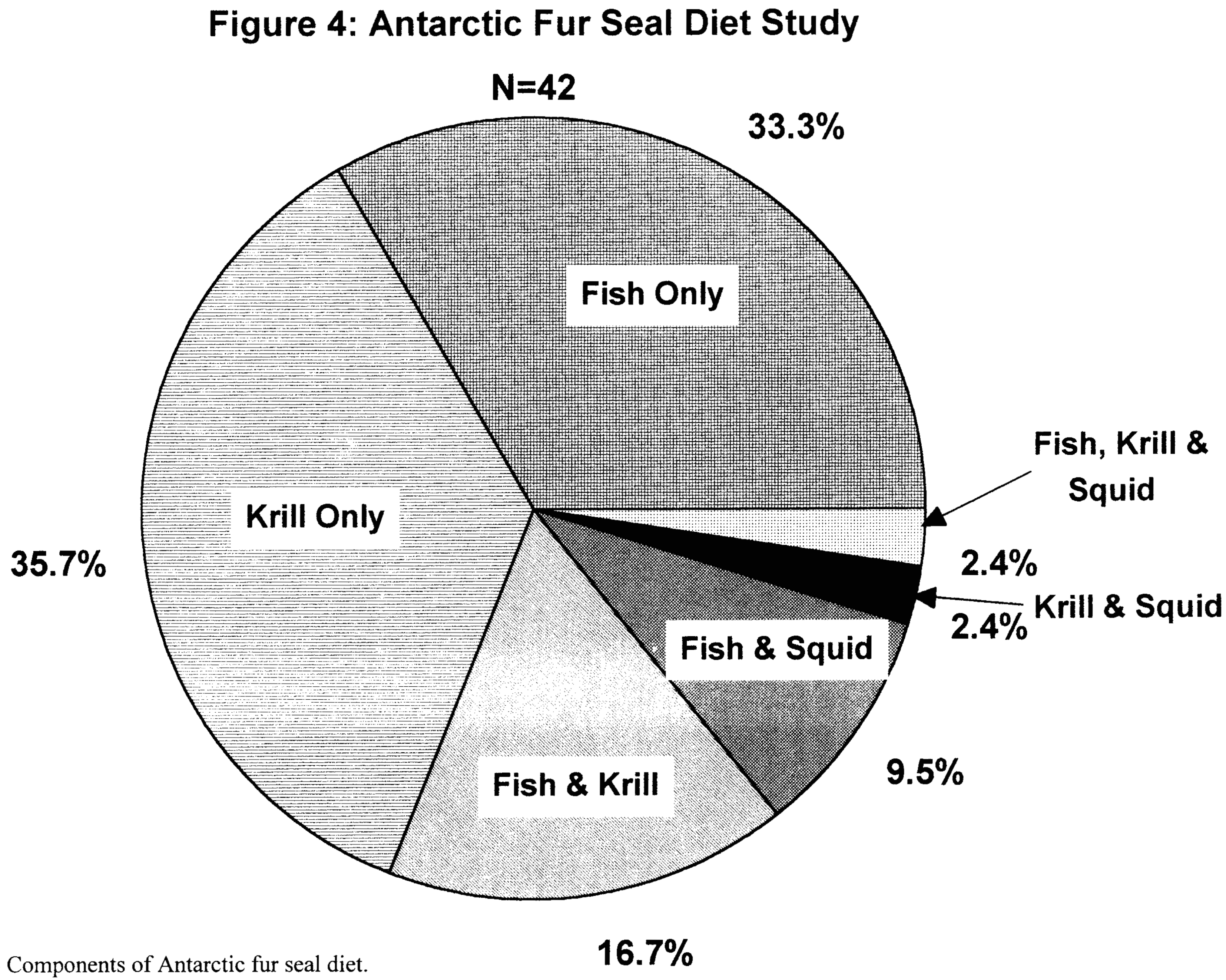

Figure 8.4 Components of Antarctic fur seal diet.

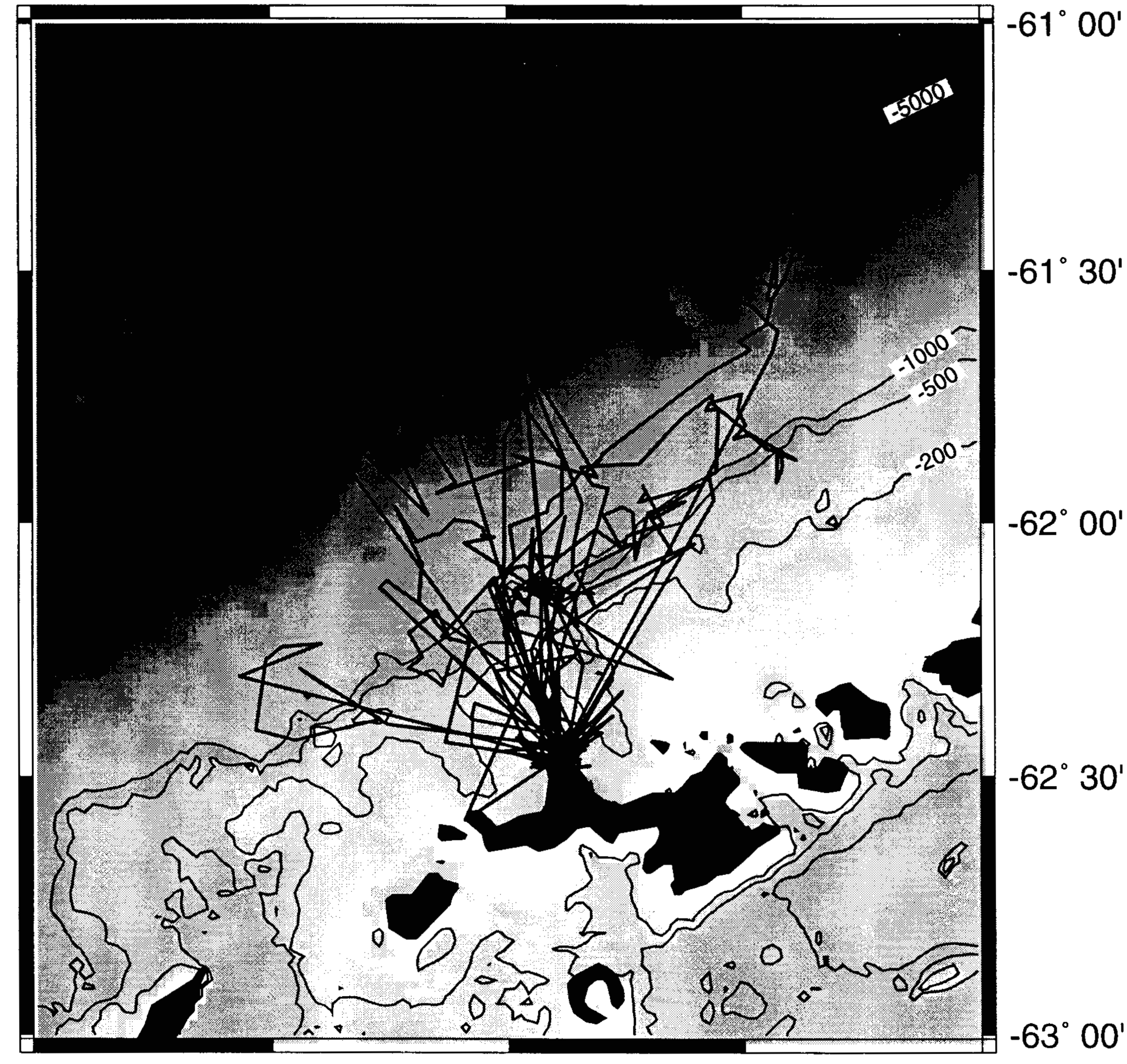

Figure 8.5 Foraging locations of female Antarctic fur seals instrumented with ARGOS satellite-linked transmitters.

9. Bottom trawl survey of the South Shetland Islands; submitted by Christopher D. Jones (Leg III), Karl-Hermann Kock (Leg III), Sunhild Wilhelms (Leg III), Kimberly Dietrich (Legs II and III), Peter Kappes (Leg III), Roger P. Hewitt (Legs I and III), Jacqueline Popp (Legs I, II, and III), and Charles Rowe (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 in two major regions of the South Shetland Islands: (1) Elephant Island, and (2) the north coast of the lower South Shetland Islands chain from King George to Livingston Island. This survey follows an AMLR pilot study conducted in 1997 and is intended to launch a series of future bottom trawl surveys in the South Shetland Islands, and possibly extend a previous survey conducted in 1996 around Elephant Island. Although there is currently a moratorium on taking finfish from the South Shetland 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 as to the health of bottom fish stocks in the South Shetland 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). In addition, we used a "Netsweep 325" net sonar system (Ocean Systems Inc.) to record the net mensuration (height and width of the trawl mouth), as well as the trawl interaction with the bottom. A detailed description of the net rigging and fishing gear hardware can be found in Watters et al. (1997). Complete 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* from 12 March through 1 April 1998. Separate trawl surveys were designed for the Elephant Island and lower South Shetland Islands chain. Both sampling strategies were based on random stratified survey designs. Sampling sites were stratified by depth and were positioned to account for a wide geographic range. There were five designated depth strata: 0-100 meters (m), 101-200m, 201-300m, 301-400m, and 401-500m. For the Elephant Island survey, there were 39 hauls conducted (Figure 9.1). The numbers of hauls within each of the five depth strata were 5, 13, 10, 7, and 4, respectively. This allocation of hauls was based on the 1996 R/V *Polarstern* bottom trawl survey, where the number of hauls taken within a strata was proportional to the known areas of seabed, and weighted by the abundance in each stratum from the previous R/V *Polarstern* surveys. For the lower South Shetland Island chain, there were 35 hauls conducted (Figure 9.2). Because there has been no prior information established on the areas of seabed within the 500m isobath, and no bottom trawl-based estimates of abundance for species within the depth strata examined, we allocated an equal number (7) of hauls per strata. Although this survey was conducted with five 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 modeling biomass may be justified.

The haul locations for the survey design were initially based on station coordinates from the 1996 R/V *Polarstern* survey for Elephant Island, and a Spanish semipelagic trawl survey conducted in 1987 for the lower South Shetland Islands. However, the realized locations varied considerably from the initial planned coordinates due to sea, wind, bottom, and ice conditions. In many cases, planned stations were abandoned and new stations were positioned within a stratum. In all cases, a haul was taken only after initial acoustic reconnaissance verified that bottom conditions were suitable for trawling. Table 9.1 is a list of the station specific information for the Elephant Island survey, and Table 9.2 for the lower South Shetland Islands survey.

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 abandoned. 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 (Tables 9.1 and 9.2). 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, sea surface temperature and salinity, bottom temperature and salinity, air temperature, wind direction and speed, weather, cloud conditions, sea state, light, and ice conditions.

On 26 March, while sampling Station T50 off King George Island, the trawl struck an undetected mound of unknown composition (Table 9.2). The weight of the material entrained in the trawl cod end was greater than the net reel's capacity for retrieval. In an attempt to mitigate this problem, the trawl was dragged in the water column behind the ship for approximately 10 hours. This procedure was performed with the expectation that fine-grade materials would wash out of the cod-end. After this was deemed ineffective, the trawl was lowered to the seafloor and dragged along coarse bottom. This procedure was to have the effect of abrading the cod-end mesh and releasing the contents. During the course of this procedure, the steel cables between the trawl doors and the bridles were severed. This resulted in the loss of the trawl, rigging, and net sonar. An identical backup system was rigged and trawling operations continued.

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 weighed separately as a group.

From the sorted catch of each haul, length [nearest centimeter (cm) below], sex, and gonad maturity stage (when possible) data were collected from 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 1 to 5 (immature, maturing virgin or resting, developing, gravid, spent) according to the method of Kock and Kellermann (1991). For dominant species, a subsample of weights [grams (g)] was recorded. Weights were measured as total fresh weight to nearest gram below for fish >50g, to nearest 0.1g below for fish <50g. In less frequently encountered species, length and weight were collected from all specimens. Gonad weights were recorded from a subsample of sexually mature/prespawning individuals for certain species. In addition, otoliths were removed from a sample of fish from most hauls. 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.

Rare or unusual specimens/biological materials were preserved in buffered formalin and packaged for transport to home laboratories. These included oocytes, residual eggs of spent females, tissue samples for DNA analysis, ovaries, and entire individuals of rare species.

9.3 Results and Tentative Conclusions:

Catches.

A total of 10551.1 kilograms (kg) (34867 individuals) of 45 different fish species were processed from all hauls. There were 7420.148kg (24917 individuals) of 35 species from the Elephant Island area (Table 9.3), and 3130.943kg (9950 individuals) of 40 species from the lower South Shetland Islands (Table 9.4). Species that were caught in substantial numbers, defined as >100kg or >100 individuals for both areas combined, included *Gobionotothen gibberifrons*, *Champsocephalus gunnari*, *Notothenia coriiceps*, *Chaenocephalus aceratus*, *Chionodraco rastrospinosus*, *Lepidonotothen squamifrons*, *Gymnoscopelus nicholsi*, *Lepidonotothen larseni*, *Lepidonotothen nudifrons*, and *Electrona antarctica*. The greatest catches of fish in both areas combined in the terms of total weight was *G. gibberifrons* (5777kg), although yields of *N. coriiceps* (1250kg) were greater than *G. gibberifrons* (755kg) in the lower South Shetlands. In terms of total numbers for combined regions, *C. gunnari* was the most abundant fish, with a total of 16686 individuals captured. However, for the lower South Shetland Island region, the most abundant fish in numbers was the myctophid *G. nicholsi* (3124) followed by *G. gibberifrons* (2288).

Catches of fish by species are highly dependent on depth strata at which the haul was taken (Table 9.3 and 9.4). Yields in Table 9.3 are sums and can be somewhat misleading since the Elephant Island survey used an unequal allocation of hauls among strata. Because there were equal numbers of hauls per stratum in the lower South Shetland Islands, Table 9.4 is more useful for direct comparison of yields per stratum. If average yield per haul is considered, the greatest yields in the Elephant Island area were found in the 100-200m depth strata; the lowest yields were in the 0-100m strata. Variability of catch was highest in the 100-200m strata. In the South Shetland Islands, the highest average yield in terms of weight and numbers was found in the 200-300m depth strata. The highest sum yield in terms of numbers, however, was found in the 100-200m strata. Because of the apparent patchiness of fish dispersal, these two strata were also the most variable in terms of catch weight and numbers, respectively.

There was substantial variation in catches between stations. The average yield for a single haul in the Elephant Island area was 190.3kg (σ=547.4), and 639 individual fish (σ=1818). The greatest yield in weight for a single haul was 3145kg (3704 individuals) at Station T5. This haul was almost exclusively *G. gibberifrons* (97% total weight). The greatest yield in numbers in the Elephant Island area for a single haul was 9140 individuals at Station T11 (Table 9.5). This haul was also dominated (88%) by a single species, *C. gunnari*. The yield per haul in the lower South Shetland Islands area was lower and less variable, with an average of 89.5kg (σ=205.7) and 284 (σ=276) individual fish caught. The greatest yield for a single haul in the lower South Shetland Islands was 1231kg (748 individuals) at Station T47 (Table 9.5). This haul consisted of mostly *N. coriiceps* (90%). The greatest yield in numbers for a single haul in this region was 1125 individuals at Station T60. This haul was dominated (91%) by *G. nicholsi*.

Species Composition and Richness.

Along with general patchiness of yields, variation was also found in the number of species represented in each haul (Table 9.5.). Although a total of 35 species were caught in the 39 hauls at Elephant Island, the average number of species per haul was 7.8 (σ=2.7), and the number most often encountered was 6 (Figure 9.3). The most frequently encountered species was *G. gibberifrons* (85% of hauls), followed by *L. larseni*, *C. gunnari*, and *C. aceratus* (79%). All other species occurred in less than 50% of hauls. In the lower South Shetland Islands, there was a total of 40 different species captured, with an average of 10.4 (σ=3.1) species per haul and 10 most frequently encountered (Figure 9.3). The most commonly encountered species here was also *G. gibberifrons* (94%), followed by *C. aceratus* (71%), *C. rastrospinosus* (69%), *L. larseni* (66%), *C. gunnari* (57%), *N. coriiceps*, and *P. georgianus* (51%). All other species occurred in less than 50% of hauls.

Comparing Elephant Island and the lower South Shetland Islands, there was no significant difference of variance in species richness (defined here as the number of different species within a haul) between the two regions (*F*-test, $P<.184$). However, there was a significant difference in the mean species richness between the two regions (*t*-test, $P<.0001$), with the lower South Shetland Islands having a larger average number of species per haul. The explanation for this difference may be related to targeted depth strata. Firstly, there is some evidence from this survey that species richness increases as a function of the average depth of the station. This is particularly evident in the Elephant Island region (Figure 9.4A), where a general linear model (GLM) analysis (SAS, 1991) demonstrates a statistically significant increase ($P<.0001$) in species richness as a function of depth. The relationship is not as apparent in the lower South Shetland Islands (Figure 9.4B), though there exists a weak statistical significance ($P<.0362$). The effect of this increasing species richness with depth, combined with the different survey designs between the two areas (Elephant Island contained greater numbers of 100-200m stations), may account to some degree for the significantly greater average species richness in the lower South Shetland Islands.

Species with Significant Yields.

Champsocephalus gunnari: Yields of *C. gunnari* in the Elephant Island region were the most variable in terms of numbers of fish per haul and second most in terms of weight. This variability was driven mostly as result of unusually large yields at Station T11 (738kg, 8009 fish) and Station T16 (420kg, 5522 fish). Fish were caught in depths to 400m, with a concentration in the 101-200m strata. Most fish at Elephant Island (75%) were found at maturity stage 2, with 21%, 2%, and 2% observed at stages 1, 3 and 5, respectively (n=1638). Sexes were equally represented. The average size for the 15045 captured fish at Elephant Island was 25cm, with a distinct mode at 24cm and a somewhat less distinct mode at 35cm (Figure 9.5A).

In the lower South Shetland Islands, there were substantially fewer *C. gunnari* per haul, with less variability. Fish were encountered here in depths up to 300m, with a concentration in the 100-200m strata. Most fish (71%) were immature stage 1, with 16% and 13% at stage 2 and 3, respectively (n=1548). The average size of the 1639 measured fish was 30cm; significantly higher than at Elephant Island (heteroscedastic *t*-test, P<.0001). Like fish captured in the Elephant Island region, there were two distinct modes of size frequency. However, the first mode appears to be out of phase between the two regions (Figure 9.5A), thus explaining differences in mean size. The apparent contradiction in size/maturity stage between Elephant Island and the lower South Shetlands (Elephant Island appears to have smaller yet more mature fish) is due to the fact that the majority of fish caught at Elephant Island (89%) were immature and not possible to sex. Because in most cases maturity was assigned only to fish that could be successfully sexed, most of these stage 1 fish are not included. If these fish are assigned a stage 1 without sexing, the vast majority of *C. gunnari* at Elephant Island are stage 1. Of fish that were successfully sexed, exactly 50% were female.

Gobionotothen gibberifrons: This species was the most encountered, most abundant (in terms of weight), and most variable by haul, in the Elephant Island region. Fish were encountered at all depth strata sampled, with greatest numbers in the 100-200m strata. Like *C. gunnari*, there were a few stations that yielded remarkably high catches: Station T5 (3052.8kg, 3456 fish); Station T11 (562.898kg, 1093 fish) and Station T16 (485.15kg, 979 fish). All other stations yielded less than 200kg. Most fish at Elephant Island (51%) were stage 3, with 26% and 23% for stage 2 and stage 1, respectively (n=7347). Of these, 40% were females. The mean size of the 7361 measured fish was 38cm, with two very distinctive modes in length frequency at 36cm and 45cm (Figure 9.5B).

Averages catches by haul of *G. gibberifrons* in the lower South Shetland Islands were about 15% of those at Elephant Island. Nevertheless, this was the second most abundant species (in terms of weight), and the most encountered species, in this area. Fish here were caught in similar depth strata as Elephant Island. There were no significantly outstanding hauls; all were below 200kg. Most fish in the lower South Shetland Islands (55%) were maturity stage 1, with 25% and 20% at stage 2 and stage 3, respectively (n=1457). These percentages are almost the opposite of what was observed in the Elephant Island region. Of these fish, 49% were males. The mean length of the 2289 fish measured was 31cm. Compared to Elephant Island, there was significantly lower variability in length distribution (*F*-test, P<.0001) and significantly smaller fish (heteroscedastic *t*-test, P<.0001) in the lower South Shetlands. The first and most distinctive length frequency mode for the lower South Shetlands is clearly out of phase with the Elephant Island length frequencies (Figure 9.5B).

Chaenocephalus aceratus: The specimens of *C. aceratus* at Elephant Island were encountered at all depth strata, with a concentration in the 100-200m strata. This fish displayed some of the highest diversity in terms of length distribution for any species, ranging from 17 to 70cm total length. The average size of the 305 fish measured at Elephant Island was 46cm, with at least three distinctive modes at 19, 27 and 50cm (Figure 9.5C). Fish were found at all stages of maturity, with 31%, 30%, 35%, 1%, and 3% for stages 1 through 5, respectively (n=280). About 61% of these fish were females. Fish in the South Shetland Island region were encountered in all but the 400-500m depth strata, with greatest numbers in the 100-200m depths. The average size of the 404 measured *C. aceratus* in this region was 40cm, with distinctive modes at 18, 26, and 48cm (Figure 9.5C). The variance in length distribution between the two survey areas was not significantly different (*F*-test, P<.40). The mean size, nonetheless, was significantly smaller in the lower South Shetland Islands (*t*-test, P<.0001), likely due to a much larger length mode at around 26cm. Specimens in the lower South Shetland region appear to be less mature than fish captured at Elephant Island, with most fish (50%) at a maturity stage 1, and 40%, 13%, and 2% at stages 2, 3, and 5, respectively (n=395). About 49% of these fish were females.

Notothenia coriiceps: Of the 1373kg (791 fish) captured throughout the survey, only 9% were from the Elephant Island region. *N. coriiceps* were encountered in the more shallow depths to 300m, mostly in the 100-200m strata for Elephant Island and the 200-300m strata for the lower South Shetland Islands. The average size of the 86 measured fish in the Elephant Island region was 42cm with almost all of these fish (96%) at a maturity stage 3. Of these fish, 35% were females. Catches remained relatively consistent throughout the survey in both regions, with the exception of Station T47 in the lower South Shetland Islands. Here, an unusually high yield of 1109kg (597 fish) was captured in the 200-300m depth strata. Most fish captured in this region (93%) were stage 3, with 7% at stage 2. About 42% of these fish were females. The average size for the 706 measured fish from the lower South Shetland Islands was 45cm (Figure 9.5D). There was no difference in variability between the two regions, though the lower South Shetlands had a significantly lower mean size of captured fish (*t*-test, P<.0001). However, this lower mean size was driven primarily as a result of the haul at Station T47. If observations from this haul are discounted, there is no significant difference is length distributions between the two regions.

Chionodraco rastrospinosus: There were relatively consistent yields across most stations for both regions. These fish were captured mostly in the deeper depth strata, with most encountered in the 400-500m strata for the Elephant Island region, and 300-400m for the lower South Shetlands. In the Elephant Island area, the average size for the 243 measured fish was 39cm, with distinct modes at 37 and 43cm (Figure 9.5E). There were fish distributed across all stages of maturity, with 22%, 31%, 35%, 2%, and 10% for stages 1, 2, 3, 4 and 5, respectively. Of these, 73% were females. In the lower South Shetland Islands, the mean size of the 388 measured fish was 38cm, with only one distinctive length frequency mode (Figure 9.5E). Like the Elephant Island region, there were representatives from all stages of maturity in the catch, with 19%, 21%, 35%, 20%, and 4% from stages 1, 2, 3, 4, and 5, respectively. About 47% of these fish were females. There was no significant difference in variability in length frequencies for the two areas, and fish from the lower South Shetland Islands had a significantly lower mean size (*t*-test, P<.0003).

Lepidonotothen squamifrons: There were roughly equal overall numbers of *L. squamifrons* captured in both areas, with similar average abundance and variability per haul. In both areas, fish were encountered during deeper hauls, with most fish caught in the 400-500m strata for Elephant Island and the 300-400m strata in the lower South Shetlands. In the Elephant Island area, the average length of the 488 measured fish was 31cm, with two distinctive length frequency modes (Figure 9.5F). Most fish in this area (53%) were maturity stage 1, with 29%, 13%, and 5% at stage 2, 3, and 5, respectively (n=411). About 45% of these fish were females. The average length for the 492 measured fish in the lower South Shetlands was 27cm, with only one major length frequency mode at 30cm (Figure 9.5F). As with fish from Elephant Island, most fish (66%) were stage 1 maturity, with 20%, 10%, 3% at stage 2, 3, and 5, respectively (n=460). About 55% of these fish were females. There was significantly less variability in lengths (*F*-test , P<.0001), and a smaller mean length (heteroscedastic *t*-test, P<.0001) from fish in the lower South Shetlands compared to Elephant Island.

Lepidonotothen larseni: Fish were encountered at all depths for Elephant Island and all but the shallowest for the lower South Shetland Islands, with greatest yields in the 201-300m depth strata for both areas. The average length for the 325 measured fish in the Elephant Island region was 18cm, with a strong mode at 19cm. Most *L. larseni* were at maturity stage 3 (51%), with 41% and 8% at stages 2 and 1, respectively (n=71). About 73% of these were females. In the lower South Shetland Islands, the mean length of the 263 measured fish was 17cm, with a strong mode at 18cm (Figure 9.5G). Most of the fish that were positively sexed were stage 2 maturity (50%), with 38% and 12% at stage 3 and stage 1, respectively. However, these percentages are based on only 24 of the 263 fish captured in the lower South Shetlands that could be positively sexed (42% of these being female). There was no significant difference in length variability between the two regions, and fish in the lower South Shetland Islands were significantly smaller than those at Elephant Island (*t*-test, P<.0001).

Gymnoscopelus nicholsi: This fish was encountered in the deeper hauls (200-500m) for both areas, with most caught in the 301-400m depth strata for Elephant Island and the 401-500m strata for the lower South Shetland Islands. Because this species is known to often occur in the mid-water pelagic zone, it is unclear as to whether yields were entrained in the net prior to or after the actual bottom trawling operation. Nevertheless, yields were relatively high, particularly in the lower South Shetland Islands area. Mean lengths from both areas were 15cm, with no statistically significant difference in variability or size between survey areas (Figure 9.5H). No sex or maturity information was collected for this species.

Lepidonotothen nudifrons: Most *L. nudifrons* were encountered at 101-300m depths in both areas. Catches were about twice as much in the Elephant Island area, likely due to increased sampling at these depths for this region. The mean size for the 87 fish measured at Elephant Island was 14.5cm (Figure 9.5I), with most fish (76%) at maturity stage 3. Of these, 62% were females. In the lower South Shetland region the mean size for the 44 fish measured was 14.3cm (Figure 9.5I), with 88% of fish at stage 3 maturity and 53% being female. There were no statistically significant differences between variability or mean lengths between the two regions.

Other Species of Special Interest.

Species that were captured in considerably less abundance, yet are of particular importance and interest, included *Notothenia rossii*, and *Dissostichus mawsoni*. A total of 41.9kg (48 fish) of *N. rossii* were captured from both areas combined, with an average and modal size of 39cm (Figure 9.5J). Of these fish, 75% were stage 1 maturity, with 19%, 2%, and 4% at stage 2, 3, and 4, respectively. Sexes were equally represented within the catch. The few catches of *D. mawsoni* (total 28.7kg, 32 fish) exhibited great diversity of lengths: ranging from 13.5cm to 97.5cm. The average length was 35cm, with no clear mode (Figure 9.5K). All fish were at maturity stage 1, with sexes equally represented.

By-catch.

We considered all organisms other than fish as by-catch. Benthic by-catch found in high numbers included sponges, bryozoans, polychaetes, holothurians, asterioids, ophiuriods, and pycnogonids. Other by-catch included pelagic organisms such as jellyfish, mulluscs, etc. A total of 7764kg of by-catch was caught across all hauls for both regions. This figure includes an estimated 5000kg of mud and bryozoans that was retrieved at Station T35. There was an average by-catch per haul of 50kg in the Elephant Island region (not including the 5000kg haul), and 23kg in the lower South Shetland Island region. There was no significant relationship of by-catch per haul to yield of fish or fish species richness per haul (GLM analysis, $P<.99$). Composition of by-catch species was not considered during this survey.

9.4 Disposition of Data: All haul and cruise specific information is stored in hard copy format and in a computer data base. Catch data were also documented on hard copy data sheets and entered into a computer data base following each haul. The U.S. AMLR program maintains these hard copies and computer data bases.

9.5 Problems and Suggestions: The most significant problem of the fish survey was the loss of a trawl. Fortunately, a complete backup system was available and the survey proceeded with a minimum of down time. Although this loss was not preventable during the 1998 survey, there are some steps that can be taken to minimize potential future losses of this magnitude. If feasible, the net reel should be equipped with a more powerful motor to accommodate heavier loads. Otherwise, a system of hauling the trawl onto the deck by other means should be devised. In the event that another trawl is lost, a protocol for retrieving the trawl off of the seafloor must be established. This will certainly involve fitting the ship with the necessary hardware to accomplish this task. Because there are relatively accurate coordinates of the lost trawl, this gear would also be useful to retrieve or salvage the trawl and net sonar lost during this survey.

For future surveys in the lower South Shetland Islands, the existing survey design should be modified to accommodate an optimal allocation of hauls within a particular stratum. Allocation of hauls can now be optimized by weighting for biomass, using this survey as a source of prior information. In addition, areas of seabed should be used as a weighting factor once these data are available. In this regard, it is important that there be refinement of bathymetry throughout the entire South Shetland Island chain.

Processing of catch would be improved with a field guide that includes detailed photos of gender and gonad development by species. During future cruises, a collection of color photos of gender and maturity by species can be acquired for assemblage of this field guide.

9.6 References:

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Table 9.1 Haul-specific information for the Elephant Island bottom trawl survey.

Station	Date	Starting Latitude	Starting Longitude	Ending Latitude	Ending Longitude	Distance Trawled (nm)	Mean Fishing Depth (m)	Mean Horizontal Opening (m)	Mean Vertical Opening (m)	Haul Time (min)	Mean Tow-speed (kn)
T1	12-Mar-98	61 18.83 S	55 42.78 W	61 19.80 S	55 45.70 W	1.39	217	14.7	9.0	32	3.4
T2	13-Mar-98	61 18.60 S	55 45.70 W	61 17.52 S	55 48.08 W	1.57	227	14.0	7.2	31	3.1
T3	13-Mar-98	61 15.32 S	55 36.93 W	61 16.99 S	55 36.85 W	1.62	99	14.1	7.4	31	3.6
T4	14-Mar-98	61 13.45 S	55 41.65 W	61 11.60 S	55 41.42 W	1.85	92	16.4	6.5	31	3.6
T5	14-Mar-98	61 14.91 S	55 53.95 W	61 13.93 S	55 57.35 W	1.91	146	16.5	5.6	32	3.5
T6	14-Mar-98	61 17.95 S	56 00.86 W	61 17.55 S	56 04.00 W	1.55	288	15.9	7.1	30	3.2
T7	14-Mar-98	61 23.65 S	56 04.71 W	61 22.78 S	56 07.09 W	1.04	312	13.0	9.0	29	2.3
T8	15-Mar-98	61 18.26 S	56 31.20 W	61 17.63 S	56 33.66 W	1.34	428	15.0	6.9	24	3.0
T9	22-Mar-98	61 16.37 S	56 25.31 W	61 17.86 S	56 25.45 W	1.49	408	16.0	7.5	30	2.7
T10	22-Mar-98	61 09.96 S	56 10.71 W	61 08.43 S	56 10.68 W	1.53	341	16.1	7.3	31	3.0
T11	22-Mar-98	61 09.47 S	56 01.85 W	61 09.03 S	56 04.81 W	1.49	145	15.8	7.4	31	2.8
T12	22-Mar-98	61 10.88 S	55 51.57 W	61 10.40 S	55 54.55 W	1.51	106	14.5	7.7	30	3.0
T13	22-Mar-98	61 05.87 S	56 02.27 W	61 04.66 S	56 00.93 W	1.37	201	15.4	8.4	30	2.8
T14	21-Mar-98	61 04.76 S	55 55.57 W	61 03.55 S	55 54.02 W	1.42	162	15.9	7.2	30	2.7
T15	21-Mar-98	61 03.16 S	55 43.93 W	61 04.58 S	55 44.87 W	1.49	89	14.7	7.5	31	2.9
T16	21-Mar-98	61 04.81 S	55 52.93 W	61 03.38 S	55 52.35 W	1.46	128	15.5	6.5	31	2.9
T17	21-Mar-98	61 01.00 S	55 58.50 W	61 02.40 S	56 00.26 W	1.64	310	16.3	8.2	34	3.1
T18	21-Mar-98	60 56.88 S	55 51.85 W	60 58.31 S	55 54.25 W	1.84	192	16.1	7.0	37	3.1
T19	21-Mar-98	60 58.46 S	55 39.97 W	60 59.96 S	55 41.04 W	1.59	58	13.8	7.2	31	3.0
T20	20-Mar-98	60 53.64 S	55 37.65 W	60 54.55 S	55 40.28 W	1.57	138	15.7	7.7	30	2.9
T21	20-Mar-98	60 53.42 S	55 43.02 W	60 52.74 S	55 40.14 W	1.56	161	15.7	6.3	29	3.3
T22	20-Mar-98	60 51.27 S	55 44.88 W	60 50.42 S	55 42.20 W	1.56	268	15.1	8.0	28	2.8
T23	20-Mar-98	60 49.60 S	55 38.82 W	60 50.25 S	55 35.98 W	1.53	421	16.0	7.0	38	2.4
T25	19-Mar-98	60 51.41 S	55 31.78 W	60 52.07 S	55 27.45 W	2.21	285	15.0	7.3	36	2.9
T26	19-Mar-98	60 53.40 S	55 25.98 W	60 52.70 S	55 28.87 W	1.57	234	15.4	7.9	29	3.1
T27	19-Mar-98	60 55.37 S	55 25.37 W	60 56.17 S	55 28.56 W	1.74	114	14.6	6.3	30	3.0
T28	19-Mar-98	60 53.74 S	55 19.02 W	60 53.58 S	55 22.50 W	1.58	302	15.0	7.2	30	3.1
T30	18-Mar-98	60 57.94 S	55 07.21 W	60 57.73 S	55 10.44 W	1.58	277	15.3	7.7	29	3.1
T32	18-Mar-98	61 00.75 S	55 04.45 W	61 00.41 S	55 07.71 W	1.62	147	14.9	6.7	29	3.2
T33	18-Mar-98	61 02.28 S	54 44.51 W	61 02.71 S	54 48.06 W	1.77	518	14.4	7.5	30	3.2
T34	18-Mar-98	61 03.46 S	54 41.71 W	61 03.10 S	54 46.75 W	2.47	394	14.4	6.4	41	3.1
T35	16-Mar-98	61 12.19 S	54 40.25 W	61 11.74 S	54 43.31 W	1.54	244	16.0	6.6	28	3.2
T36	16-Mar-98	61 15.91 S	54 51.23 W	61 16.02 S	54 54.69 W	1.67	155	15.3	7.5	30	3.4
T71	16-Mar-98	61 12.01 S	54 49.21 W	61 12.01 S	54 52.52 W	1.59	86	15.4	7.6	30	3.1
T73	17-Mar-98	61 07.28 S	54 34.40 W	61 08.76 S	54 35.99 W	1.67	220	14.5	6.4	28	3.1
T76	22-Mar-98	61 17.92 S	56 10.73 W	61 16.16 S	56 10.72 W	1.76	312	17.0	6.7	36	3.0
T77	23-Mar-98	61 26.08 S	56 07.25 W	61 27.05 S	56 04.85 W	1.50	309	15.9	6.1	34	2.7
T78	23-Mar-98	61 11.64 S	55 53.17 W	61 10.76 S	55 55.63 W	1.48	115	14.1	6.9	30	2.7
T79	23-Mar-98	61 13.92 S	55 46.11 W	61 12.79 S	55 48.32 W	1.55	107	14.8	6.5	32	2.6

Table 9.2 Haul-specific information for the lower South Shetland Islands bottom trawl survey.

Station	Date	Starting Latitude	Starting Longitude	Ending Latitude	Ending Longitude	Distance Trawled (nm)	Mean Fishing Depth (m)	Mean Horizontal Opening (m)	Mean Vertical Opening (m)	Haul Time (min)	Mean Tow-speed (kn)
T37	24-Mar-98	61 57.49 S	56 58.61 W	61 57.95 S	57 01.27 W	1.33	439	15.2	7.1	28	3.0
T38	24-Mar-98	61 50.86 S	57 19.30 W	61 50.25 S	57 22.32 W	1.55	252	15.8	7.1	33	3.0
T39	24-Mar-98	61 39.64 S	57 02.89 W	61 39.33 S	57 05.93 W	1.48	447	15.2	7.8	30	3.1
T41	25-Mar-98	61 44.87 S	58 01.70 W	61 44.32 S	58 04.70 W	1.52	239	16.4	7.2	30	2.8
T42	25-Mar-98	61 39.07 S	57 44.13 W	61 39.11 S	57 47.10 W	1.41	349	16.7	7.1	29	3.0
T43	25-Mar-98	61 39.08 S	57 50.05 W	61 39.09 S	57 53.26 W	1.52	318	17.0	7.4	31	2.8
T44	26-Mar-98	61 36.66 S	58 36.26 W	61 35.97 S	58 33.17 W	1.62	349	15.7	8.1	31	3.2
T46	27-Mar-98	61 49.20 S	58 34.08 W	61 48.54 S	58 31.08 W	1.56	183	15.8	7.4	30	3.2
T47	26-Mar-98	61 45.70 S	58 33.37 W	61 46.44 S	58 36.05 W	1.47	262	15.3	7.9	30	2.9
T48	26-Mar-98	61 48.30 S	58 42.60 W	61 49.06 S	58 45.20 W	1.44	246	14.8	7.5	30	2.8
T49	26-Mar-98	61 40.40 S	58 52.14 W	61 39.74 S	58 49.57 W	1.39	355	15.9	8.1	29	2.9
T50*	26-Mar-98	61 51.77 S	58 54.60 W	61 52.58 S	58 57.43 W	1.56	219	15.4	5.9	31	3.1
T51	28-Mar-98	61 59.99 S	59 13.23 W	61 59.99 S	59 10.60 W	1.23	132	16.6	8.9	29	2.6
T52	28-Mar-98	61 59.97 S	59 32.54 W	61 59.99 S	59 30.74 W	0.85	177	16.0	7.3	23	2.7
T53	28-Mar-98	62 00.00 S	59 42.32 W	61 59.98 S	59 39.61 W	1.27	178	18.3	8.0	28	2.9
T54	29-Mar-98	61 57.24 S	59 34.39 W	61 57.36 S	59 37.54 W	1.49	231	18.0	8.9	29	3.1
T55	29-Mar-98	61 57.80 S	59 48.08 W	61 57.91 S	59 51.06 W	1.41	283	18.3	8.5	30	2.9
T56	29-Mar-98	62 06.09 S	59 32.09 W	62 06.69 S	59 34.59 W	1.31	88	16.3	9.1	30	2.7
T57	29-Mar-98	62 07.21 S	59 36.74 W	62 07.76 S	59 39.10 W	1.23	86	16.4	9.4	29	2.7
T58	29-Mar-98	62 08.55 S	59 42.59 W	62 09.16 S	59 45.14 W	1.34	89	16.0	9.2	30	2.7
T59	29-Mar-98	62 10.84 S	59 51.39 W	62 11.79 S	59 53.21 W	1.27	84	16.5	9.3	28	2.6
T60	30-Mar-98	62 00.23 S	60 19.57 W	62 01.07 S	60 21.78 W	1.33	382	18.2	9.0	25	3.4
T63	30-Mar-98	62 13.27 S	60 27.32 W	62 14.59 S	60 27.19 W	1.32	126	17.6	7.8	30	2.6
T64	31-Mar-98	62 06.07 S	60 34.20 W	62 06.85 S	60 36.95 W	1.50	373	18.4	8.3	31	3.1
T65	31-Mar-98	62 09.95 S	60 49.32 W	62 10.63 S	60 51.95 W	1.40	425	18.8	9.1	30	3.0
T67	01-Apr-98	62 42.62 S	61 58.85 W	62 41.43 S	61 56.85 W	1.50	480	18.7	10.7	30	3.2
T68	01-Apr-98	62 29.29 S	61 59.13 W	62 29.88 S	62 01.43 W	1.22	258	19.1	8.4	27	2.8
T69	01-Apr-98	62 32.56 S	62 16.24 W	62 32.94 S	62 19.14 W	1.39	363	18.8	9.7	30	2.7
T70	01-Apr-98	62 32.25 S	62 24.47 W	62 33.09 S	62 26.73 W	1.34	435	18.8	10.5	29	2.7
T80	25-Mar-98	61 36.74 S	57 11.26 W	61 36.38 S	57 14.27 W	1.48	434	16.6	7.8	28	3.0
T81	25-Mar-98	61 37.26 S	57 28.51 W	61 36.75 S	57 31.08 W	1.32	400	16.7	7.6	27	3.0
T82	30-Mar-98	62 09.83 S	60 27.77 W	62 11.17 S	60 27.54 W	1.34	174	16.7	9.7	29	2.8
T83	30-Mar-98	62 26.06 S	61 06.34 W	62 25.45 S	61 03.60 W	1.41	123	16.3	9.8	29	3.0
T84	30-Mar-98	62 24.18 S	60 57.66 W	62 23.54 S	60 55.26 W	1.28	91	16.6	8.4	29	2.7
T85	31-Mar-98	62 22.13 S	60 49.05 W	62 22.67 S	60 51.47 W	1.25	88	16.5	9.5	29	2.7
T86	31-Mar-98	62 24.12 S	60 46.57 W	62 23.74 S	60 49.06 W	1.24	78	15.8	9.4	30	2.6

*Trawl not recovered

Table 9.3 Total numbers and weight (kilograms, in parenthesis) of species caught around Elephant Island by depth stratum.

Species	Total	0-100 m	101-200 m	201-300 m	301-400 m	401-500 m
Anotopterus pharao	3 (1.383)					3 (1.383)
Bathylagus antarcticus	18 (0.600)					18 (0.600)
Bathyraja eatonii	4 (7.113)				4 (7.113)	
Bathyraja maccaini	14 (38.697)	7 (5.551)	1 (0.122)	1 (9.460)	3 (18.339)	2 (5.225)
Bathyraja species	6 (1.964)				3 (0.867)	3 (1.097)
Benthalbella elongata	1 (0.081)					1 (0.081)
Chaenocephalus aceratus	307 (273.408)	10 (11.033)	212 (199.657)	41 (23.285)	19 (9.881)	25 (29.552)
Champsocephalus gunnari	15047 (1447.747)	39 (8.367)	14483 (1319.279)	338 (65.500)	187 (54.601)	
Chionodraco rastrospinosus	243 (144.599)		3 (3.307)	25 (14.098)	96 (48.785)	119 (78.409)
Cryodraco antarcticus	24 (18.640)		1 (1.171)	1 (1.016)		22 (16.453)
Dissostichus mawsoni	12 (19.334)		5 (1.758)		5 (5.337)	2 (12.239)
Electrona antarctica	210 (2.263)			8 (0.095)	98 (1.068)	104 (1.100)
Electrona species	2 (0.011)				2 (0.011)	
Gobionotothen gibberifrons	7359 (5022.271)	5 (3.479)	6461 (4559.865)	594 (322.667)	279 (125.440)	20 (10.820)
Gymnodraco acuticeps	1 (0.129)		1 (0.129)			
Gymnoscopelus braueri	5 (0.041)					5 (0.041)
Gymnoscopelus nicholsi	494 (15.400)			40 (1.253)	51 (1.704)	403 (12.443)
Gymnoscopelus opisthopterus	9 (0.331)					9 (0.331)
Lampris immaculatus	1 (29.800)			1 (29.800)		
Lepidonotothen larseni	353 (18.515)	2 (0.062)	36 (1.671)	149 (7.282)	94 (4.631)	72 (4.869)
Lepidonotothen nudifrons	87 (3.658)	38 (1.719)	23 (1.089)	24 (0.803)	2 (0.047)	
Lepidonotothen squamifrons	488 (198.398)			42 (8.583)	133 (33.239)	313 (156.576)
Muraenolepis microps	7 (2.450)		1 (0.087)	2 (0.513)	3 (1.033)	1 (0.817)
Neopagetopsis ionah	3 (1.332)				1 (0.945)	2 (0.387)
Notolepis coatsi	1 (0.007)				1 (0.007)	
Notothenia coriiceps	86 (122.762)	27 (34.229)	58 (85.509)	1 (3.024)		
Notothenia rossii	29 (23.582)	10 (5.574)	13 (12.396)	6 (5.612)		
Ophthalmolycus amberensis	1 (0.055)				1 (0.055)	
Pachycara brachycephalum	2 (0.153)				2 (0.153)	
Parachaenichthys charcoti	13 (1.826)	10 (1.016)	1 (0.070)	1 (0.354)	1 (0.386)	
Paradiplospinus gracilis	11 (0.591)				5 (0.189)	6 (0.402)
Pleuragramma antarcticum	1 (0.041)					1 (0.041)
Pseudochaenichthys georgianus	14 (8.235)	2 (2.015)	3 (4.610)	8 (0.448)	1 (1.162)	
Trematomus eulepidotus	60 (14.614)		1 (0.035)	13 (1.578)	20 (3.545)	26 (9.456)
Trematomus hansoni	1 (0.117)				1 (0.117)	
Total	24917 (7420.148)	150 (73.045)	21303 (6190.760)	1295 (495.371)	1012 (318.655)	1157 (342.322)

Table 9.4 Total numbers and weight (kilograms, in parenthesis) of species caught in the lower South Shetland Islands (King George to Livingston Island) by depth stratum.

Species	**Total**	**0-100 m**	**101-200 m**	**201-300 m**	**301-400 m**	**401-500 m**
Bathyraja eatonii	7 (19.465)		2 (1.105)	1 (3.900)		4 (14.460)
Bathyraja maccaini	8 (17.492)	2 (0.891)	2 (3.250)	2 (1.308)	2 (12.043)	
Bathyraja species	22 (11.436)		1 (0.990)	15 (8.009)	1 (0.171)	5 (2.266)
Chaenocephalus aceratus	404 (232.217)	108 (69.726)	225 (118.431)	58 (32.451)	13 (11.609)	
Chaenodraco wilsoni	1 (0.150)				1 (0.150)	
Champsocephalus gunnari	1639 (283.645)	576 (82.276)	1033 (191.339)	30 (10.030)		
Chionobathyscus dewitti	2 (0.506)				1 (0.249)	1 (0.257)
Chionodraco rastrospinosus	388 (200.881)		37 (22.423)	138 (72.694)	141 (69.717)	72 (36.047)
Cryodraco antarcticus	50 (21.142)	1 (0.045)		3 (2.613)	26 (9.328)	20 (9.156)
Dissostichus mawsoni	20 (9.412)	3 (0.064)	8 (0.824)	7 (6.074)	1 (2.074)	1 (0.376)
Dolloidraco longedorsalis	1 (0.018)	1 (0.018)				
Electrona antarctica	233 (2.240)	1 (0.013)		22 (0.218)	99 (0.801)	111 (1.208)
Electrona carlsbergi	1 (0.003)				1 (0.003)	
Electrona species	2 (0.009)				2 (0.009)	
Gerlachea australis	1 (0.036)			1 (0.036)		
Gobionotothen gibberifrons	2288 (754.859)	16 (5.587)	1086 (315.199)	1033 (384.130)	87 (25.279)	66 (24.664)
Gymnodraco acuticeps	23 (2.086)	6 (0.532)	9 (0.739)	3 (0.263)	2 (0.320)	3 (0.232)
Gymnoscopelus braueri	5 (0.066)					5 (0.066)
Gymnoscopelus nicholsi	3124 (108.259)			116 (4.615)	1661 (55.480)	1347 (48.164)
Gymnoscopelus opisthopterus	2 (0.035)				1 (0.022)	1 (0.013)
Krefftichthys anderssoni	1 (0.006)	1 (0.006)				
Lepidonotothen larseni	263 (11.477)		92 (3.114)	91 (4.395)	39 (2.131)	41 (1.837)
Lepidonotothen nudifrons	44 (1.617)	5 (0.183)	29 (1.086)	10 (0.348)		
Lepidonotothen squamifrons	493 (109.690)			38 (10.023)	304 (61.635)	151 (38.032)
Muraenolepis microps	5 (1.004)			1 (0.113)	3 (0.306)	1 (0.585)
Neopagetopsis ionah	8 (7.627)		1 (1.303)	3 (2.980)	1 (1.071)	3 (2.273)
Notothenia coriiceps	705 (1249.925)	38 (43.377)	22 (26.491)	642 (1176.337)		3 (3.72)
Notothenia rossii	19 (18.306)		5 (3.720)	12 (10.514)	2 (4.072)	
Ophthalmolycus amberensis	13 (1.121)		3 (0.272)	3 (0.242)	7 (0.607)	
Pachycara brachycephalum	9 (1.096)	1 (0.106)		2 (0.365)	3 (0.311)	3 (0.314)
Parachaenichthys charcoti	41 (2.862)	35 (1.748)	3 (0.514)	3 (0.600)		
Paradiplospinus gracilis	3 (0.183)				2 (0.119)	1 (0.064)
Pleuragramma antarcticum	22 (1.103)				1 (0.059)	21 (1.044)
Pogonophryne species	4 (0.950)				4 (0.950)	
Protomyctophum bolini	1 (0.002)	1 (0.002)				
Pseudochaenichthys georgianus	65 (53.358)	10 (6.561)	41 (32.569)	13 (12.845)	1 (1.383)	
Racovitzia glacialis	1 (0.103)				1 (0.103)	
Trematomus eulepidotus	25 (4.334)			8 (1.466)	7 (1.009)	10 (1.859)
Trematomus hansoni	3 (1.740)		1 (0.984)	2 (0.756)		
Trematomus tokarevi	4 (0.482)			2 (0.071)	1 (0.380)	1 (0.031)
Total	9950 (3130.943)	805 (211.135)	2600 (724.353)	2259 (1747.395)	2415 (261.390)	1871 (186.668)

Table 9.5 Number of fish species, catch in weight and numbers by station for Elephant Island and the lower South Shetland Islands.

Elephant Island				Lower South Shetland Islands			
Station	Number of Species	Total Weight of Catch	Total Number of Fish	Station	Number of Species	Total Weight Of Catch	Total Number Of Fish
T1	5	13.717	43	T37	15	43.636	149
T2	5	79.516	227	T38	8	133.703	272
T3	7	33.827	48	T39	10	29.094	93
T4	6	9.719	23	T41	10	108.547	178
T5	7	3144.743	3704	T42	10	25.481	99
T6	9	82.428	132	T43	9	22.997	57
T7	8	12.704	42	T44	12	15.912	95
T8	8	216.876	436	T46	11	118.641	307
T9	16	56.173	155	T47	11	1231.113	748
T10	9	44.677	140	T48	15	42.482	109
T11	6	1341.843	9140	T49	12	55.828	219
T12	6	19.257	51	T51	11	43.920	160
T13	5	93.175	323	T52	14	196.844	654
T14	6	133.951	297	T53	9	262.833	983
T15	6	13.594	30	T54	11	45.665	179
T16	6	941.400	6536	T55	17	94.916	336
T17	11	44.380	82	T56	8	32.476	80
T18	7	217.255	455	T57	7	20.439	105
T19	4	12.270	15	T58	7	44.054	189
T20	7	189.000	276	T59	7	36.958	173
T21	8	46.817	87	T60	14	54.127	1225
T22	7	12.009	46	T63	5	27.181	154
T23	11	58.915	437	T64	18	33.048	205
T25	9	56.964	149	T65	13	33.416	500
T26	6	102.674	157	T67	7	26.009	674
T27	6	10.847	22	T68	15	90.970	437
T28	13	50.337	193	T69	9	53.998	515
T30	6	4.971	27	T70	7	20.921	114
T32	10	24.046	67	T80	10	13.614	78
T33	10	10.358	129	T81	9	19.978	263
T34	10	12.524	97	T82	10	53.032	231
T35	9	39.324	83	T83	9	21.902	111
T36	4	0.876	7	T84	8	27.570	125
T71	5	3.635	34	T85	9	32.430	47
T73	9	10.593	108	T86	8	17.208	86
T76	11	75.787	203				
T77	13	78.246	255				
T78	6	84.042	457				
T79	7	36.678	204				

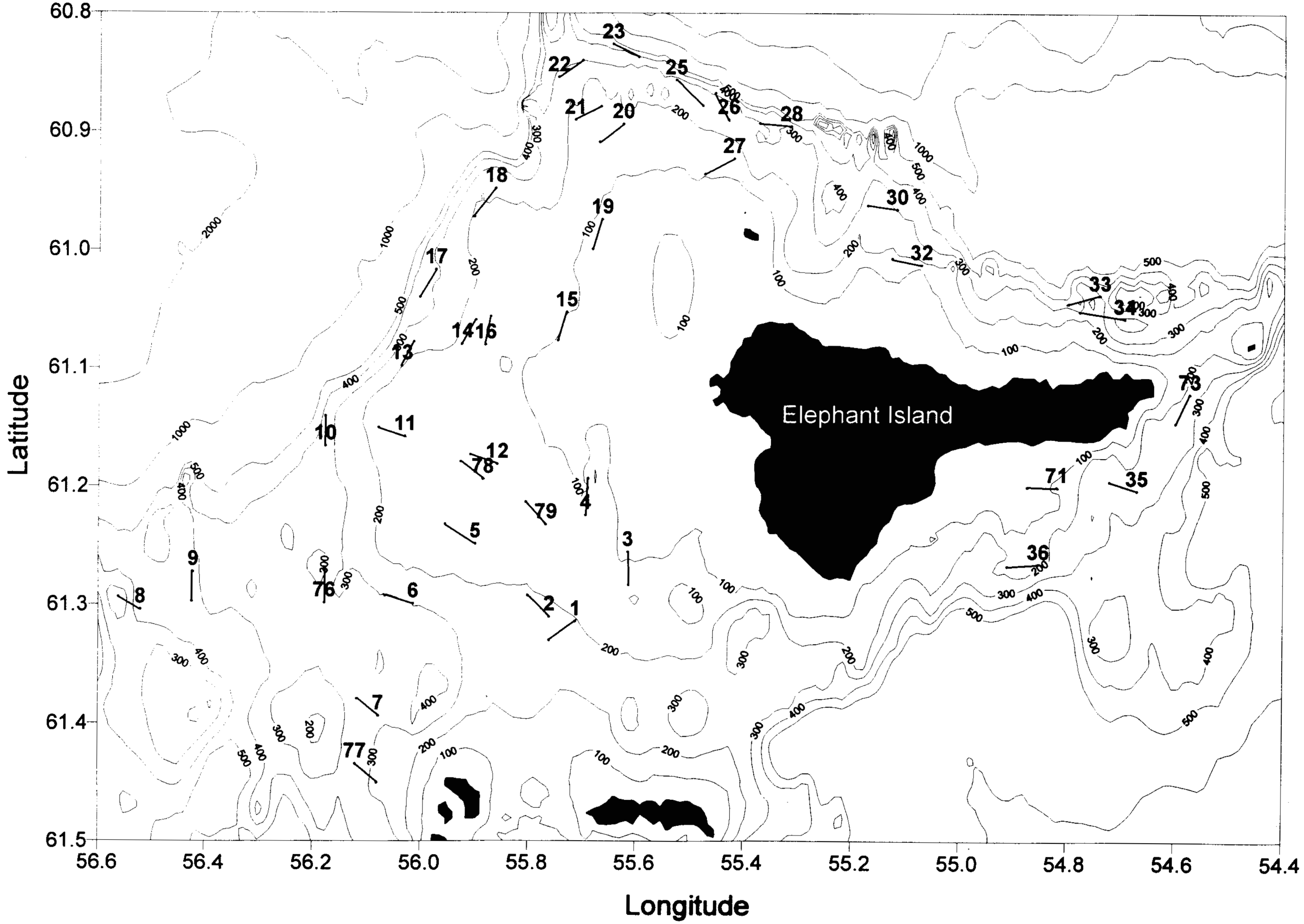

Figure 9.1 Station locations and trawl track lines for the Elephant Island bottom trawl survey.

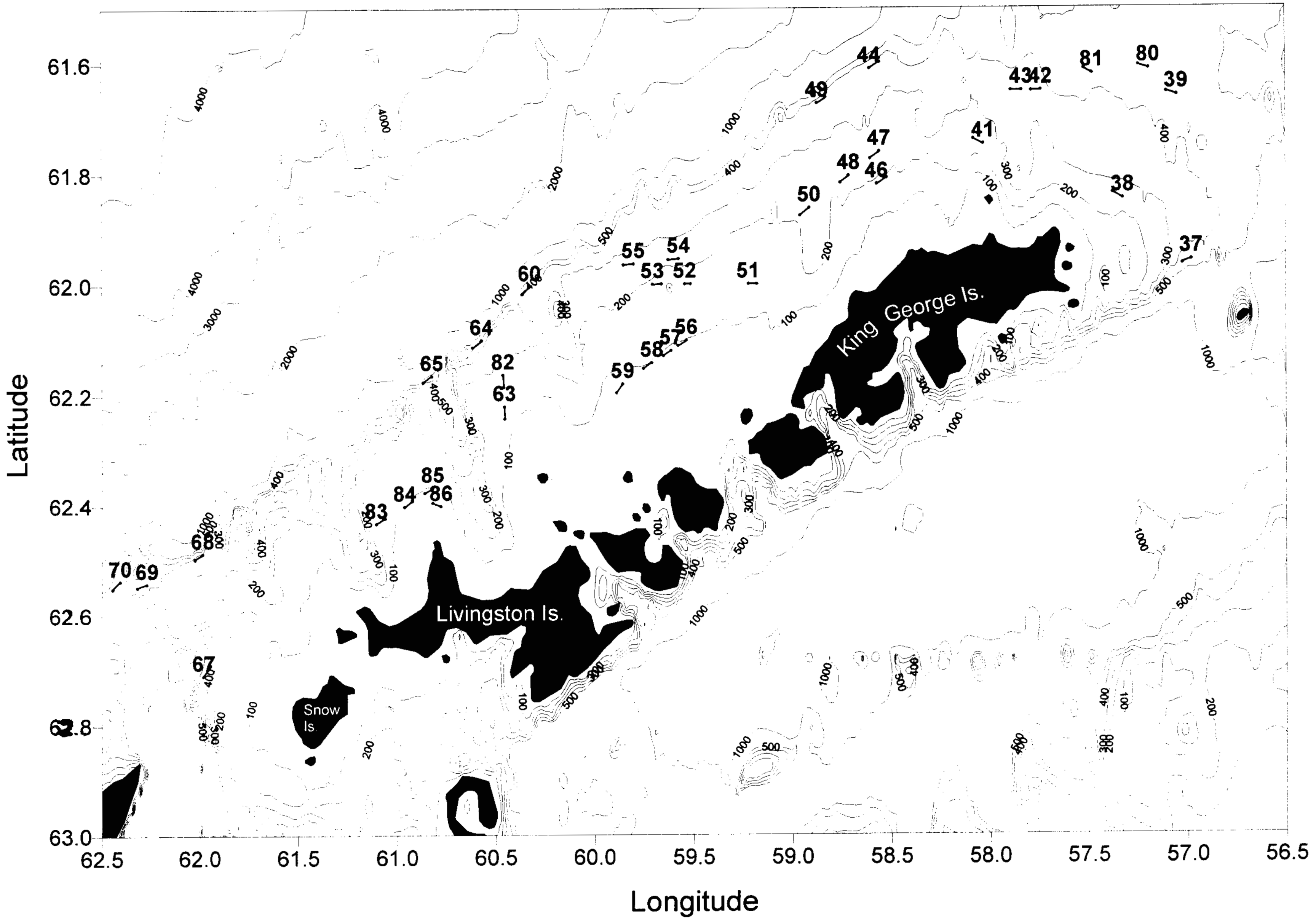

Figure 9.2 Station locations and trawl track lines for the lower South Shetland Islands bottom trawl survey.

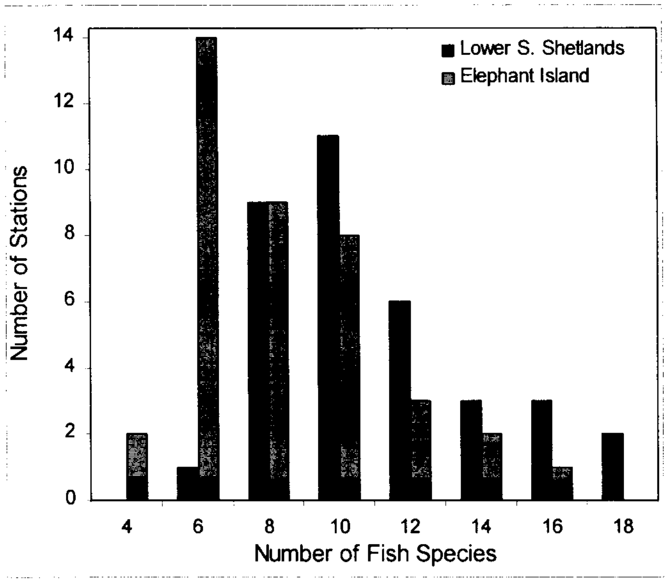

Figure 9.3 Frequency of fish species encountered for all stations at Elephant Island and the lower South Shetland Islands.

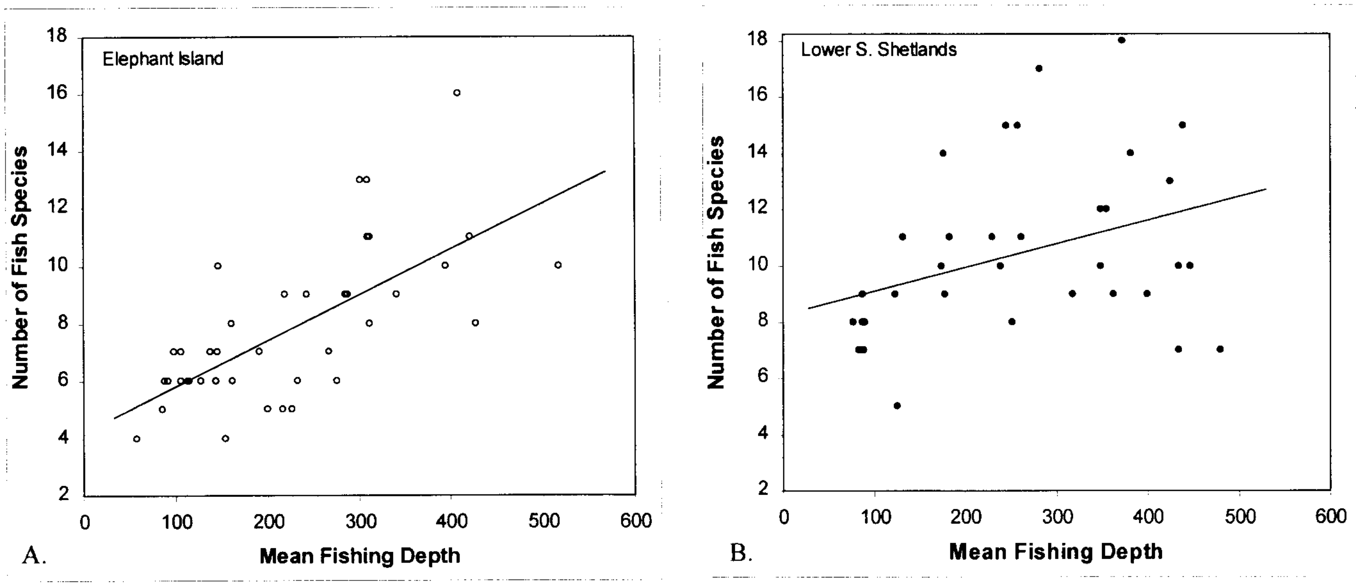

Figure 9.4 Relationship between mean depth of haul and number of fish species encountered for Elephant Island (A) and the lower South Shetland Islands (B).

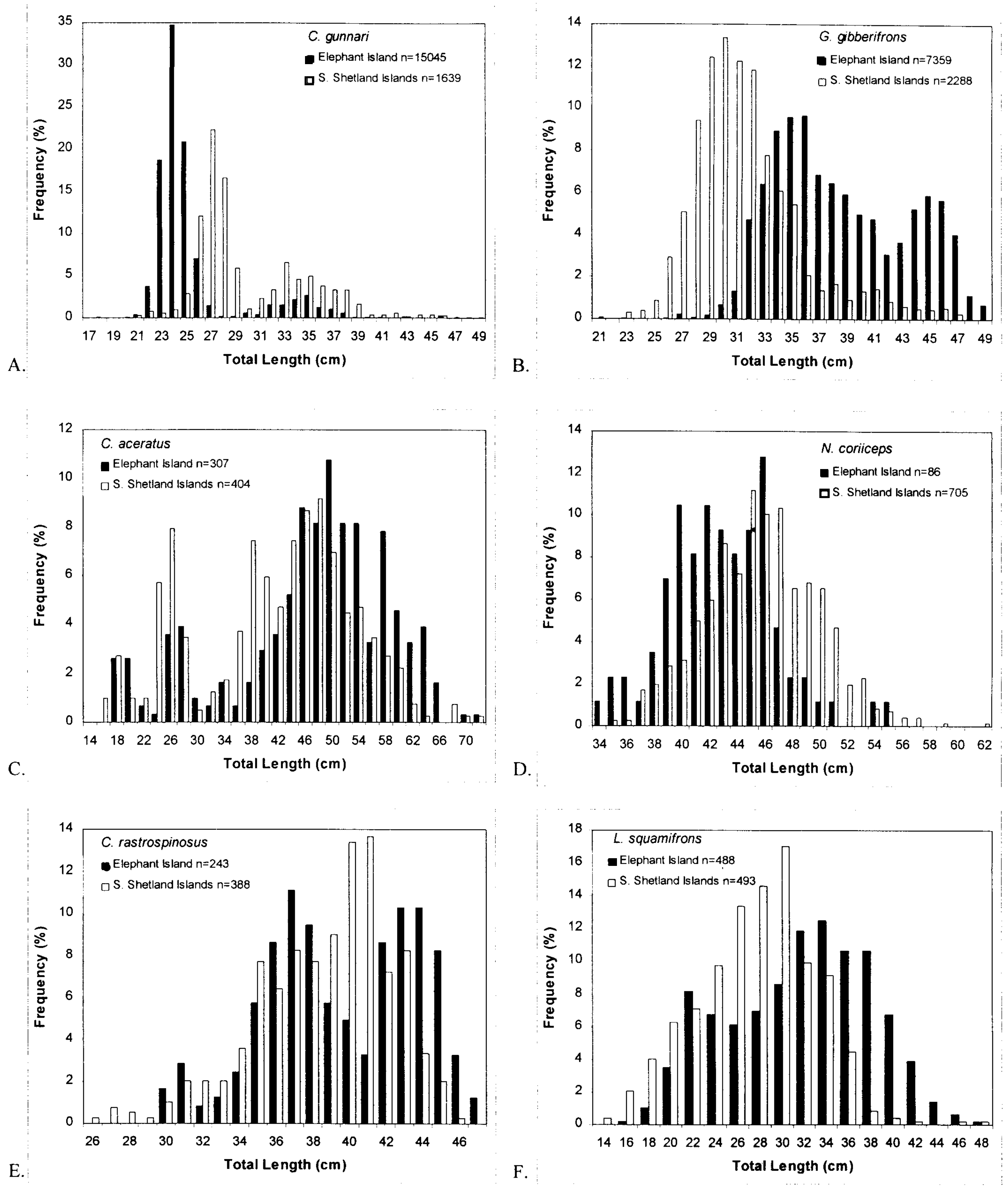

Figure 9.5 Length frequency distributions for species with significant yields: (A) *C. gunnari*, (B) *G. gibberifrons*, (C) *C. aceratus*, (D) *N. coriiceps*, (E) *C. rastrospinosus*, and (F) *L. squamifrons*.

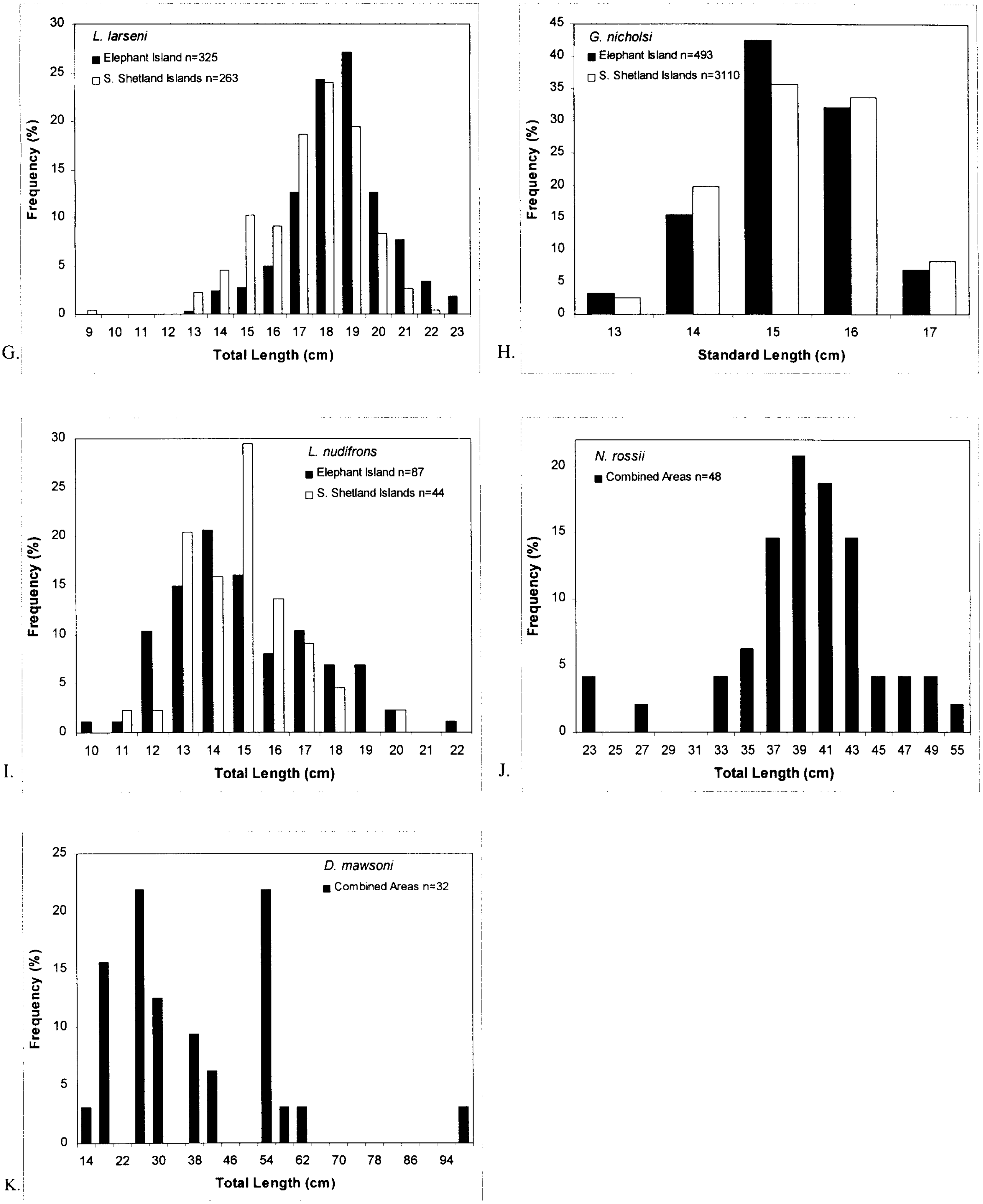

Figure 9.5 (continued) Length frequency distributions for species with significant yields: (G) *L. larseni*, (H) *G. nicholsi*, (I) *L. nudifrons*, (J) *N. rossii*, and (K) *D. mawsoni*.

10. Seabird research undertaken as part of the NMFS/AMLR ecosystem monitoring program at Palmer Station, 1997/98; 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 1997/98, the eleventh season of field work at Palmer Station on Adelie penguins (*Pygoscelis adeliae*), were:

1. To determine Adelie penguin breeding population size,
2. To determine Adelie penguin breeding success,
3. To obtain information on Adelie penguin diet composition and meal size,
4. To determine Adelie penguin chick weights at fledging,
5. To determine adult Adelie penguin foraging trip durations,
6. To band 1000 Adelie penguin chicks for future demographic studies, and
7. To determine Adelie penguin breeding chronology.

10.2 Accomplishments: Field work at Palmer Station was initiated on 1 October 1997 and terminated on 4 April 1998. The early start date was aided by joint funding from the National Science Foundation's (NSF) Office of Polar Programs. In 1990, NSF selected Palmer Station as a Long Term Ecological Research (LTER) site, and has committed long-term funding and logistics support to an ecosystem study in which Adelie penguins represent one of two key upper trophic level predators selected for research. As a result of this cooperative effort between the National Marine Fisheries Service (NMFS) and NSF, field season duration at Palmer Station now covers the entire 5-month Adelie penguin breeding season.

Breeding Biology and Demography.

Adelie penguin breeding population size was determined by censusing the number of breeding pairs at 54 sample colonies during the peak egg-laying period (24 - 29 November 1997). These colonies contained 4412 pairs, which was essentially unchanged relative to the 4445 breeding pairs censused 14 - 15 November 1996.

Breeding success was determined by following a 100-nest sample on Humble Island from clutch initiation to creche. Adelie penguins exhibited a slightly increased breeding success in the 1997/98 season, creching 1.58 chicks per pair, or 0.11 chicks more than were creched per pair in the 1996/97 season. 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 5 and 14 January 1998. Of the 2359 broods censused, 60.9% (N=1438) contained two chicks, a slight decrease from the 68.1% reported in January 1997.

Chick production was determined by censusing chicks between 29 January and 4 February 1998 at 54 sample colonies when approximately 2/3 had entered the creche stage. Production at these colonies totaled 5722 chicks, a decrease of 7.3% from the 1996/97 season in which 6142 chicks were censused.

Chick fledging weights were obtained between 6 to 23 February 1998 at beaches near the Humble Island rookery. Peak fledging occurred on 13 February, one day later than in February 1997. Compared to February 1997, the average fledgling weight of the 358 Adelie penguin chicks sampled this season was essentially unchanged (3.05 vs. 3.04 kilograms). Data specific to the chronology of other breeding events are still under analysis and will be reported later.

As part of continued demographic studies, 1000 Adelie penguin chicks were banded on 6 February 1998 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 20 February 1998. During each of the 10 sampling periods, 5 adult Adelie 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 subsequently 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. The abundance of samples containing fish was slightly lower than during the 1996/97 season (6% vs. 9%), and approximately 10% of the diet samples contained *Thysanoesa macrura*, similar to the 1996/97 season. Amphipods were evident in 12% of the diet samples versus only 4% during the 1996/97 season. Diet samples this season were mainly comprised of krill in the size classes 36-40 millimeters (mm) and 41-45mm, in general larger than the size frequencies observed in the 1996/97 diet samples.

Radio receivers and automatic data loggers were deployed at the Humble Island rookery between 4 January and 24 February 1998 to monitor presence-absence data on 35 breeding Adelie penguins carrying small radio transmitters. These transmitters were glued to adult penguins feeding 10-14 day old chicks. Analysis of the data has not yet been accomplished due to the volume of data obtained.

10.3 Tentative Conclusions: The 1997/98 season was characterized by heavy sea ice conditions well into the start of egg laying and frequent, heavy snows during much of the early Adelie penguin breeding season. The fact that the number of breeding pairs was relatively unchanged compared to last season agrees with the effects that a heavier ice year is expected to have on overwinter survival. The increase in breeding success of 0.11 chicks per pair may in part reflect enhanced foraging conditions, as krill were abundant during much of the season. For the second consecutive season, a heavy infestation of ticks was noted during the egg-laying period, but the infestation did not appear as widely distributed as the previous season. However, we have obtained preliminary evidence that tick infestations in smaller colonies may force the entire colony to abandon reproductive efforts.

The predominant component in the diets of Adelie penguins was once again krill (*E. superba*). Other components, significant in previous seasons' diet samples, were present in lesser amounts (e.g., *T. macrura*, amphipods, fish). That krill size classes represented primarily individuals in the 36-40mm size class agrees with expectations based on a strong recruitment year in 1994.

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