UNITED STATES
AMLR ANTARCTIC MARINE LIVING RESOURCES PROGRAM



# AMLR 1990/91 FIELD SEASON REPORT

## Objectives, Accomplishments and Tentative Conclusions

Edited by
Jane Rosenberg and Roger Hewitt

June 1991

ADMINISTRATIVE REPORT LJ-91-18

Southwest Fisheries Science Center
Antarctic Ecosystem Research Group

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

Inquiries should be addressed to:

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

Telephone Number: (619) 546-5600

UNITED STATES
AMLR ANTARCTIC MARINE LIVING RESOURCES PROGRAM

# AMLR 1990/91 FIELD SEASON REPORT

## Objectives, Accomplishments and Tentative Conclusions


Edited by
Jane Rosenberg and Roger Hewitt


**June 1991**


ADMINISTRATIVE REPORT LJ-91-18



**Antarctic Ecosystem Research Group**

U.S. Department of Commerce
National Oceanic & Atmospheric Administration
National Marine Fisheries Service
Southwest Fisheries Science Center
P.O. Box 271
La Jolla, CA 92038

## TABLE OF CONTENTS

## 1. Introduction

In support of its commitment to the Convention for the Conservation of Antarctic Marine Living Resources (CCAMLR), the U.S. Antarctic Marine Living Resources (AMLR) program conducted field research in the Antarctic Peninsula area during the 1990-91 austral summer. As in past seasons, the field research consisted of two components: (1) land-based studies at Seal Island, a small island at the tip of the peninsula, and at Palmer Station, a U.S. scientific station further south on the peninsula; and (2) a research cruise aboard the NOAA Ship *Surveyor* in the waters surrounding Elephant Island, also at the tip of the peninsula (Figure 1.1).

The AMLR program's field research is based on the working hypotheses that physical features in the pelagic ocean (such as water mass fronts, sea ice, and upper layer mixing) constrain primary production and the spatial distribution of krill (*Euphausia superba*); and that the spatial distribution of krill affects the life history parameters of land-based krill predator populations during the reproductive season.

To investigate these hypotheses, reproductive and foraging studies were conducted on krill predators (pinnipeds and seabirds) at Seal Island (see sections 2.3, 2.4, 2.5, and 2.6); and studies of the ecology of Adelie penguins were accomplished at Palmer Station (see section 2.7). Work aboard the NOAA Ship *Surveyor* included physical oceanography studies (see section 3.3), phytoplankton and primary production studies (see section 3.4), a hydroacoustic survey to map the spatial distribution of krill (see section 3.5), and direct sampling for krill with nets (see sections 3.6 and 3.7).

In addition, some ancillary projects were conducted during the *Surveyor* cruise: (1) a study on the Antarctic Euphausiid *Thysanoessa macrura* (see section 3.8); (2) a survey of some Antarctic fish species collected during net sampling (see section 3.9); and (3) a study on oil pollution hazard in the Elephant Island area, and the thermal structure and geostrophy of the Drake Passage (see section 3.10).

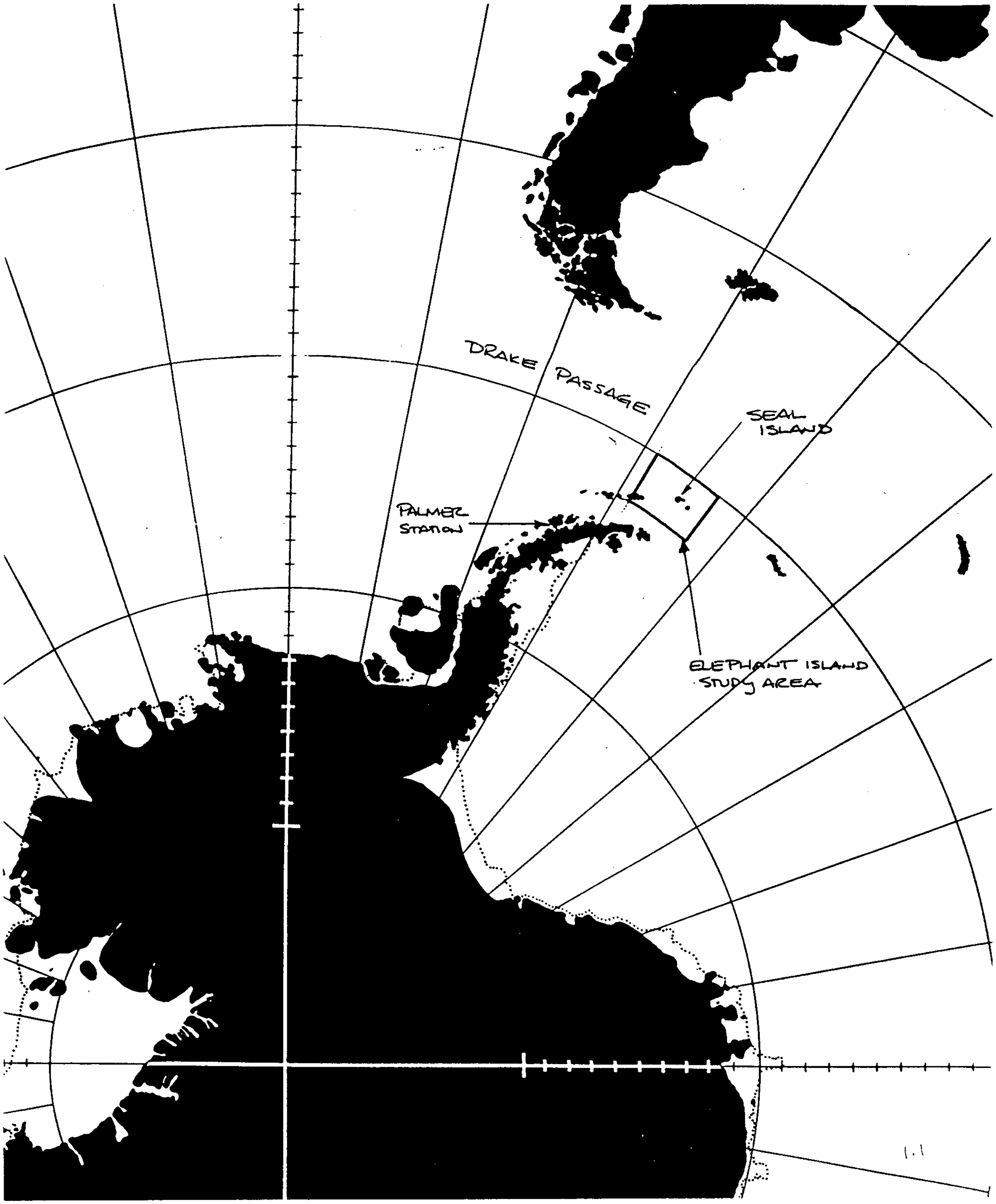


Figure 1.1 Antarctic Peninsula; locations of Elephant Island study area, Seal Island, and Palmer Station shown.

## 2. Land-based activities

### 2.1 Description of operations:

The AMLR program has established a field camp at Seal Island, South Shetland Islands, in support of land-based research on marine mammals (pinnipeds), birds (penguins and petrels), and their prey (mostly krill) during the Antarctic austral summer. The five person field team arrived at Seal Island on December 4, 1990 and remained until March 11, 1991.

Pinniped research at Seal Island included monitoring pup growth and condition, and adult female foraging trips of Antarctic furs seals, as well as directed research on fur seals and all other pinnipeds on the island. Seabird research this season consisted of intensive studies of the reproductive and foraging behaviors of chinstrap and macaroni penguins in accordance with CEMP protocols, as well as reproductive studies on cape petrels. In addition, a study on the potential effects of electronic instruments on penguin behavior was conducted. Shipboard predator tracking studies included cooperative field work aboard the Japanese research vessel *Kaiyo Maru* in early January 1991, and aboard the Chilean research vessel *Alcazar* in mid-February 1991.

A Japanese scientist, Yoshihisa Mori, joined the field team late in December to begin a 30-day study of foraging ecology and reproductive behavior in chinstrap penguins.

In addition, research on aspects of the ecology of Adelie penguins continued at Palmer Station; this work is jointly funded by NSF and the AMLR program. This year's field work at Palmer Station began on December 7, 1990 and ended on March 10, 1991.

### 2.2 Abstract of observations:

Although early in the season fur seal foraging trips were relatively long in duration (possibly indicating that food was more difficult to obtain), the average foraging trip duration obtained over the entire season and the pup growth rates were not very different from those observed in previous seasons. The number of chinstrap and macaroni penguins occupying nests was down 20% as compared to last year. However, the chick growth rate and reproductive success of birds that did nest were equal to or higher than previous years. Shipboard predator tracking studies indicated that both fur seals and penguins foraged further offshore early in the season and close to shore late in the season. Preliminary analyses of prey abundance data from acoustic and net sampling suggest a good correlation between prey abundance and the foraging patterns of predators.

At Palmer Station, chick counts at designated AMLR colonies decreased by 17% as compared to last season. As in past seasons, Antarctic krill (*Euphausia superba*) were the main component of the Adelie diet; however, the predominant krill size class was significantly larger than last season.

**2.3 Seal Island logistics and operations during 1990/91; submitted by J.L. Bengtson, National Marine Mammal Laboratory.**

**2.3.1 Objectives:** The AMLR Program maintains a field camp at Seal Island, South Shetland Islands, Antarctica (60°59.5'S, 55°24.5'W), in support of land-based research on marine mammals and birds. The camp is occupied during the austral summer field season, which normally runs from December through February. The main logistics objectives of the 1990/91 season were:

1) To deploy the field team early in December aboard the M/V *Society Explorer* in order to arrive at Seal Island in time to monitor fur seal pupping and penguin chick hatching,

2) To resupply the field camp with its season's provisions, which were transported from the United States aboard the NOAA Ship *Surveyor*,

3) To perform a health and safety inspection of Seal Island operations,

4) To maintain effective communications systems on the island and to maintain daily radio contact with either Palmer Station or the NOAA Ship *Surveyor*,

5) To repair, maintain, and improve camp facilities at the Seal Island field camp,

6) To repair and maintain the National Weather Service automatic weather station, and

7) To retrograde trash and other cargo from the island and to transport the field team to Chile at the end of the season aboard the NOAA Ship *Surveyor*.

**2.3.2 Accomplishments**: The five person field team departed the U.S. on 16 November and embarked the tour ship M/V *Society Explorer* in Rio de Janeiro on 7 December. After its trip south via South Georgia, the South Orkney Islands, and the South Shetland Islands, the ship arrived at Seal Island and disembarked the field team on 4 December. Good weather resulted in an efficient landing at the camp beach with 2 Zodiac loads of cargo. Camp structures overwintered well except for the fiberglass "igloo" which was badly damaged by snow. Our early arrival date allowed us to start observations of fur seal pupping prior to the peak of pupping.

The NOAA Ship *Surveyor* arrived and offloaded cargo at Seal Island on 19 January. Cargo operations began at 0730 and finished at 2030, when high winds required that cargo operations be interrupted. Two Mark V Zodiacs were used to transport supplies ashore. Landing conditions were good at the sand beach near camp, and a total of 26 Zodiac loads was brought ashore without difficulty. The assistance of ship's personnel and members of the scientific party expedited cargo operations. In addition to the persons who came ashore to help unload and carry cargo up to camp, four divers in dry suits were stationed to steady the Zodiacs during unloading. The remaining cargo was brought ashore during the *Surveyor's* subsequent visits to Seal Island.

On 5 February 1991, Lt. A.M. Smith, U.S. Public Health Service (medical officer of the *Surveyor*), visited Seal Island to conduct the annual health and safety inspection. This inspection went well, with no problems noted.

Radio systems at Seal Island were inspected for efficient operations. The single side-band radio, and its associated antennas, worked with no problems. The 40 Watt VHF transceiver, situated on the top of the island, worked well, but the remote cable linking it with camp sustained some overwinter damage. After the cable was repaired, this system worked well for the remainder of the season. The ATS-3 satellite communications system developed some problems early in the season, caused by a faulty power amplifier. After replacing this amplifier, the system worked well in both voice and data modes for the remainder of the season.

Daily radio communications were maintained with Palmer Station from 4 December to 11 January prior to the arrival of the *Surveyor* in the operations area. Daily contact was maintained with the *Surveyor* from 10 January to 11 February and 21 February to 11 March, using single side-band or VHF radio when the ship was within radio range of the island, or INMARSAT telephone (through the ATS-3 satellite) during the ship's port call between cruise legs. Daily contact was maintained with the *Alcazar* from 12 February to 20 February. In addition to these regular schedules, radio contacts were made with biologists and other personnel at Palmer Station, Anvers Island (U.S.); Fildes Station, King George Island (Chile); Admiralty Bay camp, King George Island (U.S.); Bird Island, South Georgia (U.K.); Signy Station, Signy Island (U.K.); M/V *Society Explorer* (U.S.); R/V *Alcazar* (Chile); R/V *Polar Duke* (U.S.), and R/V *Maurice Ewing* (U.S.). Communications were also maintained with various offices in the U.S. via the ATS-3 satellite system.

Routine maintenance of camp facilities was undertaken as necessary. Obsolete and unneeded equipment was identified and removed from the island for shipment to the U.S. Wooden structures were painted and weatherproofed. The fiberglass "igloo", which had been damaged by snow overwinter, was replaced with a reinforced wooden shed. The remnants of the igloo were dismantled and transported to the *Surveyor* for disposal. The new shed will provide accommodation early and late in the season, laboratory work area, and storage space for medical supplies, food, and other equipment.

The NWS remote weather station at Seal Island was refurbished during the 1990/91 field season. In January, the damaged aluminum antenna tower was replaced with a new, 20 foot steel tower. Wind speed, wind direction, relative humidity, temperature, solar radiation, and barometric pressure sensors were installed on the tower. A refurbished data processing unit and transmitter, as well as a new GOES antenna, solar panel, and batteries were also installed. Weather station data collection and data transmission were activated in early February; however, problems arose with the barometric and solar radiation sensors. Therefore, the sensors, transmitter, and processing unit were dismantled and shipped to the U.S. for evaluation and repairs.

During the initial resupply of Seal Island on 19 January, trash from the early part of the season was transported to the NOAA Ship *Surveyor* for proper disposal. Additional trash and retrograde cargo was transported to the *Surveyor* each time that the ship called at Seal Island throughout the season to minimize the amount of cargo necessary to offload at the end of the season. All remaining trash and cargo was loaded onto the ship on 11 March, when the camp was closed and the field team embarked the ship for transport to Chile.

**2.3.3 Recommendations:** Once again, the excellent support provided by the NOAA Ship *Surveyor* made a significant contribution to the success of the field season at Seal Island. Cargo and small boating operations went very smoothly. The practice of providing 4 divers in dry suits to assist landings and launchings of Zodiacs has proven to be very successful, and should be continued in future seasons.

An arrival date of early December was ideal for initiating Antarctic fur seal studies prior to the peak of pupping. If possible, arrival of the field team should be planned for the first week of December in future seasons as well. Such an arrival date provides good access to perinatal female fur seals, as well as an opportunity to obtain data on female fur seals' early feeding trips before their pups fall prey to leopard seals.

Daily radio communications with Palmer Station and the *Surveyor* were successful throughout the season. This season we were able to contact the *Surveyor* easily, both during scheduled periods as well as during other times when the need arose. While in the operations area, the ship's constant monitoring of frequencies 4125 MHz, CH 9 and CH 16 was very helpful to operations ashore at Seal Island. Having a daily radio contact with the *Surveyor*, with the ship maintaining a log of such contacts, is a good arrangement that should be continued in future seasons.

## 2.4 Pinniped research at Seal Island during 1990/91; submitted by Peter Boveng, Michael E. Goebel, and J.L. Bengtson, National Marine Mammal Laboratory.

**2.4.1 Objectives:** During the 1990/91 field season, the objectives of the pinniped research at Seal Island were:

1) To monitor pup growth and condition and adult female foraging of Antarctic fur seals according to CCAMLR Ecosystem Monitoring Program (CEMP) protocols,

2) To conduct directed research on pup production, female foraging behavior, diet, and abundance, survival and recruitment of fur seals, and

3) To monitor the abundance of all other pinniped species ashore.

**2.4.2 Accomplishments:**

**Growth and condition:** Fur seal pups were weighed at approximately 14-day intervals between 31 December 1990 and 28 February 1991 (CEMP Standard Method C.1)(Table 2.4.1). Male pups grew at a mean rate of about 142 grams per day (standard error = 8.5). Females grew at a rate of about 113 grams per day (standard error = 6.0).

---

Table 2.4.1 Mean weights, standard deviations, and sample sizes of male and female fur seal pups weighed during 5 sampling intervals in 1990/91.

| | Sampling Dates | | | | |
|---|---|---|---|---|---|
| | 31 Dec-<br>2 Jan | 13 Jan-<br>14 Jan | 28 Jan-<br>30 Jan | 12 Feb-<br>14 Feb | 27 Feb-<br>28 Feb |
| MALES: | | | | | |
| mean wt.(kg) | 8.43 | 9.95 | 13.19 | 14.76 | 16.29 |
| std. dev. | 1.60 | 1.81 | 1.76 | 1.86 | 1.88 |
| n | 49 | 56 | 49 | 37 | 38 |
| FEMALES: | | | | | |
| mean wt.(kg) | 7.23 | 8.62 | 11.15 | 12.14 | 13.73 |
| std. dev. | 1.08 | 1.28 | 1.15 | 1.60 | 1.61 |
| n | 51 | 44 | 51 | 40 | 41 |

**Pup production:** Daily counts were made of fur seal pups at the North Cove and North Annex study sites. The maximum number of live pups observed at North Cove was 235 on 26 December. The maximum count at North Annex was 44 on 6 January. Prior to those dates, 5 dead pups were observed, suggesting that a minimum of 284 pups were born this season at the two sites. The total number of pups at the two sites declined to about 120 by 19 February 1991 and remained relatively constant thereafter. Predation by leopard seals, a major source of pup mortality, seemed to occur later in the season than in previous years, and the magnitude of the decline in pup numbers was slightly smaller than last year.

A census on 25 January of the fur seal rookery on a nearby island (Large Leap Island) revealed at least 228 pups were born there this year. In addition, 7 pups were born at a small rookery (Big Boote) on the northeast coast of Seal Island.

**Foraging behavior and attendance ashore:** Time-depth recorders (TDRs) were attached to 19 female fur seals between 10 and 17 December 1990. All of these females were perinatal (ashore with a newborn pup, before departing the first feeding trip) at the time of instrument attachment. A second sample of 9 female fur seals (not perinatal) was instrumented with TDRs and head-mounted radio transmitters between 1 and 6 February 1991, as part of the study of at-sea tracking to foraging areas conducted from the Chilean research vessel *Alcazar*. Twenty-seven of the 28 TDRs were recovered between 13 January and 1 March 1991. At least 23 of the 27 instruments recovered functioned properly, providing good dive records. The dive records will be analyzed at the National Marine Mammal Laboratory (NMML) to provide estimates of the foraging effort required by females raising pups.

Attendance of adult female fur seals was monitored by radio transmitters, following CEMP Standard Method C.2. The 28 female fur seals with TDRs, as well as an additional 21 females with pups, were instrumented with radio-transmitters, allowing continuous monitoring of presence and absence at the rookery. Of the 49 radio-transmittered females, 40 were perinatal. The CCAMLR Ecosystem Monitoring Program (CEMP) Standard Method for estimating foraging trip duration (C.2.) specifies that the first six feeding trips made by each female be used for estimation of the parameter. Of the 40 perinatal female fur seals instrumented with radio-transmitters for monitoring foraging trip duration, 30 were known to have completed 6 trips before losing their pups. The mean duration of the first 6 trips for those 30 females was 115 hours. Further analysis of foraging trip duration and of attendance behavior at the fur seal rookery will be completed at NMML.

**Diet:** Fur seal feces were collected at bi-weekly intervals. Each sample consisted of 10 scats from each sex. The scats were put in frozen storage aboard *Surveyor* for analysis of prey remains at NMML.

**Abundance, survival, and recruitment:** Pup counts form the best index of abundance for the fur seal population because the pup cohort is the only age class found ashore in its entirety during a particular census. As described above, the maximum number of pups counted at North Cove, 239, was a slight decrease from the 249 pups counted last year, whereas the North Annex colony had 45 pups, a slight increase from 41 last year.

Daily observations were made of fur seals tagged in this and previous years to assess survival and recruitment to the breeding population. Of 39 tagged, adult female fur seals that had pups last year, 31 were observed at least once this year (25 of which were observed with pups this year). Twenty-four fur seals tagged as pups since the 1986/87 season were observed this year. One fur seal tagged as a pup on Seal island in February, 1987, was observed with a pup this year.

Between 28 January and 28 February, 171 pups were tagged with metal flipper tags. The members of this and previously tagged cohorts that survive to breeding age will allow future estimation of parameters such as age at first reproduction and recruitment rates.

**Abundance of other pinnipeds:** Abundances of all pinniped species ashore on Seal Island were monitored by conducting (approximately) weekly censuses. During these censuses fur seals were tallied by sex and reproductive status (Table 2.4.2); other species were recorded as the total number present ashore (Table 2.4.3).

**2.4.3 Tentative conclusions:** Nearly all of the objectives for pinniped research at Seal Island this season were met. Anecdotal observations early in the season suggested that fur seals may have had more difficulty obtaining food than in previous years (fur seal feeding trips seemed relatively long, krill were largely absent from the acoustic record during tracking operations aboard the Japanese R/V *Kaiyo Maru*, and many chinstrap penguin nests were failing). However, in retrospect, the pup growth rates and the average foraging trip duration obtained over the entire season do not appear to be very different from those obtained in previous years. Subsequent detailed analyses will determine whether differences between the values obtained in 1990/91 and those in previous seasons are statistically significant.

**2.4.4 Recommendations:** Support by *Surveyor* of the pinniped research at Seal Island was very good again this year, contributing substantially to a successful season of research. This season the Seal Island field team was put ashore at the study site by the M/V *Society Explorer* on 4 December 1990. The early arrival allowed the team to capture the number of perinatal fur seal females specified in the CEMP Standard Method for monitoring foraging trip duration. The early arrival date may also allow the first estimate of median birth date for fur seal pups at Seal Island, an important parameter for timing of the CEMP Standard Methods. It is therefore recommended that in the future, the AMLR Program continue to investigate any possible means of transporting the team to Seal Island by 1 December.

Table 2.4.2 Weekly counts of Antarctic fur seals, by sex and reproductive status, at Seal Island, Antarctica, 1990/91.

| Date | Pups | Adult Females | Adult Males With Females | Adult Males Without Females | Subadult Males |
|---|---|---|---|---|---|
| 13 Dec | 184 | 156 | 32 | 58 | 1 |
| 20 Dec | 241 | 101 | 26 | 54 | 2 |
| 27 Dec | 262 | 88 | 24 | 34 | 6 |
| 3 Jan | 249 | 66 | 20 | 16 | 18 |
| 10 Jan | 240 | 105 | 16 | 9 | 26 |
| 21 Jan | 214 | 120 | 6 | 6 | 68 |
| 31 Jan | 194 | 145 | 16 | 8 | 113 |
| 9 Feb | 163 | 162 | 27 | 30 | 134 |
| 20 Feb | 138 | 189 | 43 | 35 | 157 |
| 26 Feb | 116 | 147 | 49 | 43 | 172 |

Table 2.4.3 Weekly counts of pinnipeds other than Antarctic fur seals at Seal Island, Antarctica, 1990/1991.

| Date | Leopard Seals | Weddell Seals | Elephant Seals |
|---|---|---|---|
| 13 Dec | 0 | 0 | 22 |
| 20 Dec | 0 | 2 | 26 |
| 27 Dec | 0 | 1 | 18 |
| 3 Jan | 0 | 2 | 38 |
| 10 Jan | 1 | 0 | 32 |
| 21 Jan | 0 | 2 | 20 |
| 31 Jan | 0 | 2 | 20 |
| 9 Feb | 0 | 5 | 11 |
| 20 Feb | 0 | 2 | 8 |
| 26 Feb | 0 | 5 | 7 |

**2.5 Seabird research at Seal Island, Antarctica during 1990/91; submitted by Donald A. Croll, John K. Jansen, and J.L. Bengtson, National Marine Mammal Laboratory.**

**2.5.1 Objectives:** Seabirds have been shown to serve as useful monitors of offshore prey resources. During the breeding season they are tied to one location ashore where they return repeatedly throughout a 4 to 5 month period. As flightless seabirds, penguins are particularly useful for monitoring purposes because they are limited in the distance they are able to forage from the breeding site. Therefore, aspects of their behavior and ecology reflect biotic and abiotic conditions adjacent to their land-based breeding areas.

Five species of seabirds breed on Seal Island: chinstrap penguins (*Pygocelis antarctica*), macaroni penguins (*Eudyptes chrysolophus*), cape petrels (*Daption capensis*), Wilson's storm petrels (*Oceanites oceanicus*), and kelp gulls (*Larus dominicanus*). Southern giant petrels (*Macronectes giganteus*) breed on adjacent islands. Of these seabirds, the Seal Island research focused on chinstrap and macaroni penguins, supplemented by surveys of cape petrels. The principal research objectives for the 1990/91 field season were:

1) To monitor the breeding success and chronology, foraging behavior, chick diet, abundance, survival, and recruitment, and fledgling size of chinstrap and macaroni penguins as part of the CCAMLR Ecosystem Monitoring Program (CEMP),

2) To conduct directed research on chick growth and condition, and seasonal patterns in the diving behavior of chinstrap penguins to assess changes in foraging patterns and effort throughout the season,

3) To evaluate the potential effects of electronic instruments on the behavior of penguins,

4) To measure the energetic cost of reproduction in chinstrap penguins during the incubation, guard, and creche stages of the reproductive cycle,

5) To assess the reproductive success, survival, and recruitment of cape petrels, and

6) To conduct cooperative research with a Japanese researcher on the relationship between foraging behavior and chick growth in chinstrap penguins.

**2.5.2 Accomplishments:**

**Reproductive success and chronology:** Breeding success was estimated according to CEMP Standard Methods A.6.B (observations of 100 nest plots) and A.6.C (discrete counts of colonies). Method A.6.B. is designed to determine the number of chicks raised to the creche stage for a set of individual nests. Rectangular plots of individually-identified chinstrap nests each were marked by stakes in 2 colonies (124 and 113 nests in the North Cove and Parking Lot study plots, respectively). Thirty-five macaroni penguin nests at Mac Top were also identified and monitored. Nests were observed every other day using a spotting scope from an observation blind, thereby avoiding the need to enter the colony. At each nest check, the number of incubated eggs or brooded chicks was recorded. Overall, of the chinstrap nests active at the commencement of observations (14 December), a total of 1.23 chicks/active nest was raised to creching at the Parking Lot plot, while approximately 1.25 chicks/active nest reached the creche stage at North Cove. The total for the North Cove study plot is approximate due to a large storm which swept through the plot on 4 February, before creching had completed. The number of macaroni chick/active nest raised to creching at the Mac Top colony was 0.84, while 100% of these chicks survived to fledging, giving a fledging success rate of 0.84 fledglings/active nest.

These plots were also used to determine the chronology of penguin reproductive events (CEMP Standard Method A.9) at Seal Island through creching (Table 2.5.1). At the North Cove and Parking Lot study plots, respectively, chinstrap hatching began on 29 December and 23 December; the rate of hatching peaked on 2 January and 26 December, and was completed by 20 January and 18 January. Hatching of macaroni chicks began on 24 December; hatching rate peaked around 26 December, and was completed by 10 January. Macaroni creching began on 16 January and was completed by 24 January. Fledging began on 18 February and was completed on 25 February.

Table 2.5.1 Nesting chronology of chinstrap penguins on Seal Island, 1989/90 and 1990/91.

| Event | 1989/90 | 1990/91 |
|---|---|---|
| Peak Hatching | 23 December | 26 December |
| Start Creching | 20 January | 22 January |
| Start Fledging | 5 February | 16 February |

Upon completion of chinstrap creche formation, the number of creched chicks were counted every other day in colony 66 (an isolated, discrete colony of about 300 nests) to provide an estimate of mean date of fledging. Chinstrap fledging began on 16 February; the fledging rate peaked around 24 February, and was completed by 10 March.

**Foraging behavior:** The duration of foraging trips was monitored to determine the amount of time at sea required by breeding adults to meet their own energetic needs and procure food for chicks, serving as an indicator of foraging effort and prey availability (CEMP Standard Method A.5). A total of forty adult chinstrap penguins was equipped with radio transmitters (10 nests with both members of the nesting pair equipped, and an additional 20 nests with only one member equipped) to monitor their presence ashore. An automatic scanning radio receiver and data logger recorded the attendance of radio-tagged birds every 15 minutes. These nests were checked regularly for survival of chicks.

To provide detailed information on chinstrap penguins' diving behavior at sea, and how that behavior may change with the progression of the breeding season, a total of 33 chinstrap penguins was equipped with time-depth recorders (TDRs), which recorded dive profiles and time ashore: 7 during incubation, 8 during the early guard stage, 8 during the late guard stage, and 10 during the creche stage. Of these deployments, twenty-nine records were obtained.

**Chick diet:** Between 28 December and 16 February 1991, a total of 44 stomach content samples was collected from breeding chinstrap penguins (CEMP Standard Method A.8). The sampling schedule was divided into 10 5-day collection periods. Adult birds were captured immediately upon returning to the colony after feeding trips to sea and weighed, measured (bill length, bill depth, and wing length), and banded prior to sampling. Stomach samples were obtained by lavaging with warm water. Prior to being released after lavaging, the birds were dyed with a yellow picric dye (to ensure that the bird was not handled again during the season).

Lavage samples were sorted to remove otoliths and other prey hard parts in preparation for preservation until subsequent detailed analysis. As in past seasons, preliminary analyses have indicated Antarctic krill as the major prey species.

**Abundance, survival, and recruitment:** The number of breeding pairs of all penguin colonies on the island was counted. The census was made after the completion of egg laying. All birds lying down in some sort of nest structure were assumed to be occupying a nest site, and were thus considered breeding. Large colonies (colony numbers 3,4,14,25, and 26) were counted from photographs. The total number of chinstrap pairs nesting at Seal Island in 1990/91 was estimated at 16,000, which is approximately 20% lower than the number of birds counted the previous year. A total of 292 pairs of macaroni penguins attempted to breed on Seal Island in 1990/91; 17% fewer nests than the previous year.

According to CEMP Standard Method A.6.C, three censuses were made of 10 geographically discrete chinstrap colonies undisturbed by other activities. The number of nests with incubated eggs was counted near our arrival date, some time after laying was complete. When hatching was complete, the number of nests with chicks and the number of chicks in each nest was counted. When creching was complete, the total number of chicks in each colony was counted. Three replicate counts were made of each colony on the same day. If one of the three counts differed by more than 10% of any other count, a fourth count was made. The mean and standard deviation of the three (or four) counts were computed as an estimate of the parameter (Table 2.5.2). Each of the four macaroni penguin colonies was also censused (Table 2.5.3).

To estimate annual survivorship and recruitment into the breeding population, 2,000 chinstrap and 81 macaroni penguin chicks were banded (CEMP Standard Method A.4). By resighting banded birds in subsequent years, an estimate of age specific annual survival and recruitment can be calculated. Both systematic and opportunistic surveys to resight birds banded in previous seasons were conducted throughout the season.

**Chick growth and fledging size:** The growth rates of chinstrap penguin chicks were monitored by measuring the weight, culmen length, culmen depth, wing length, and noting the status of juvenile plumage molt every 5 days between 5 January and 15 February at colony 4. Prior to creching, at least 50 chicks in at least 30 nests were measured during 5 sampling periods. After creching, a total of 75 chicks was measured per sampling period. After handling, chicks were marked with picric dye to avoid sampling them more than once during the season. Mean chinstrap chick weight peaked at 3.3 kg on 8 February (Figure 2.5.1).

Following the initiation of chinstrap penguin fledging on 16 February, daily samples of fledglings present on Beaker Bay were weighed (CEMP Standard Method A.7.A) until the completion of fledging, about March 6. A total of 254 fledglings was weighed and measured. Average (±sd) fledgling measurements were: weight 2.9 kg (±0.3); culmen length 42.7 mm (±2.7); culmen depth 14.3 mm (±0.8); wing length 107.7 mm (±4.2).

Macaroni chick weight, culmen length, culmen depth, and wing length were measured, and the status of juvenile plumage molt was noted when banding chicks just prior to fledging. Mean (±sd) weights at this time were 3.1 kg (±0.3), culmen length and depth were 45.9 mm (±4.0) and 16.8 mm (±1.2), respectively, while mean wing length was 108 mm (±4).

**Effects of instruments:** In order to assess the possible effects of electronic instruments on the behavior of chinstrap penguins, the attendance patterns of nesting birds with and without instruments were compared during 3 periods during the chick guard stage (late December, mid-January, and late January). Thirty-six birds equipped with radio transmitters (9 nests with both members equipped with transmitters and 18 nests with one member equipped) and 6 birds equipped with dive recorders were compared with a control group of 60 birds without instruments but marked with dye. The attendance of each of these birds at their nests in North Cove was continually monitored by visually observing their nests for 48 hours.

Table 2.5.2 Summary of breeding success censuses of chinstrap penguins, Seal Island, 1990/91.

Completion of egg laying (number of nests with eggs)

| Date | Colony | Mean | SD | N |
|---|---|---|---|---|
| 19 Dec | 9 | 311.7 | 8.3 | 3.0 |
| 20 Dec | 21 | 57.0 | 2.2 | 3.0 |
| 20 Dec | 24 | 34.7 | 0.5 | 3.0 |
| 17 Dec | 31 | 286.0 | 12.9 | 4.0 |
| 19 Dec | 32 | 61.0 | 1.6 | 3.0 |
| 17 Dec | 33 | 97.7 | 1.2 | 3.0 |
| 17 Dec | 42 | 163.8 | 7.2 | 4.0 |
| 17 Dec | 51 | 36.7 | 0.5 | 3.0 |
| 17 Dec | 54 | 151.3 | 8.4 | 4.0 |
| 21 Dec | 66 | 224.3 | 5.2 | 3.0 |

Post hatching (number of chicks)

| Date | Colony | Mean | SD | N |
|---|---|---|---|---|
| 11 Jan | 9 | 256.0 | 9.3 | 3.0 |
| 12 Jan | 21 | 46.7 | 0.5 | 3.0 |
| 16 Jan | 24 | 6.0 | 0.0 | 3.0 |
| 12 Jan | 31 | 228.7 | 14.1 | 3.0 |
| 11 Jan | 32 | 59.7 | 0.5 | 3.0 |
| 12 Jan | 33 | 100.7 | 2.5 | 3.0 |
| 12 Jan | 42 | 135.7 | 6.2 | 3.0 |
| 13 Jan | 51 | 24.0 | 0.0 | 3.0 |
| 12 Jan | 54 | 61.7 | 5.3 | 3.0 |
| 11 Jan | 66 | 186.3 | 7.1 | 3.0 |

Completion of creching (total number of chicks)

| Date | Colony | Mean | SD | N |
|---|---|---|---|---|
| 7 Feb | 9 | 236.3 | 1.7 | 3.0 |
| 7 Feb | 21 | 37.0 | 0.0 | 3.0 |
| 7 Feb | 24 | 0.0 | 0.0 | 3.0 |
| 7 Feb | 31 | 227.7 | 4.6 | 3.0 |
| 7 Feb | 32 | 51.7 | 0.9 | 3.0 |
| 7 Feb | 33 | 67.7 | 0.9 | 3.0 |
| 7 Feb | 42 | 139.7 | 2.1 | 3.0 |
| 7 Feb | 51 | 21.7 | 0.5 | 3.0 |
| 7 Feb | 54 | 19.0 | 0.0 | 3.0 |
| 7 Feb | 66 | 205.3 | 2.9 | 3.0 |

Table 2.5.3 Census results for macaroni penguins at the conclusion of egg laying, completior hatching, and completion of creching at Seal Island, 1990/91.

Completion of egg laying (number of nests with eggs)

| Date | Colony | Colony name | 1 egg | 1 chick |
|---|---|---|---|---|
| 19 Dec | 4 | Mac Top | 32 | 0 |
| 17 Dec | 31 | Mac Peak | 54 | 0 |
| 17 Dec | 71 | Macaroon | 64 | 0 |
| 24 Dec | 74 | Macadamia | 136 | 0 |
| 24 Dec | 61 | | 5 | 1 |
| | | Total | 291 | 1 |

Completion of hatching (number of chicks)

| Date | Colony | Colony name | 1 egg | 1 chick |
|---|---|---|---|---|
| 12 Jan | 4 | Mac Top | 2 | 29 |
| 12 Jan | 31 | Mac Peak | 5 | 46 |
| 12 Jan | 71 | Macaroon | 4 | 53 |
| 11 Jan | 74 | Macadamia | 1 | 79 |
| 11 Jan | 61 | | 0 | 3 |
| | | Total | 12 | 210 |

Completion of creching (total number of chicks)

| Date | Colony | Colony name | 1 egg | 1 chick |
|---|---|---|---|---|
| 1 Feb | 4 | Mac Top | 0 | 27 |
| 1 Feb | 31 | Mac Peak | 0 | 43 |
| 1 Feb | 71 | Macaroon | 0 | 49 |
| 1 Feb | 74 | Macadamia | 0 | 62 |
| 3 Feb | 61 | | 0 | 3 |
| | | Total | 0 | 184 |

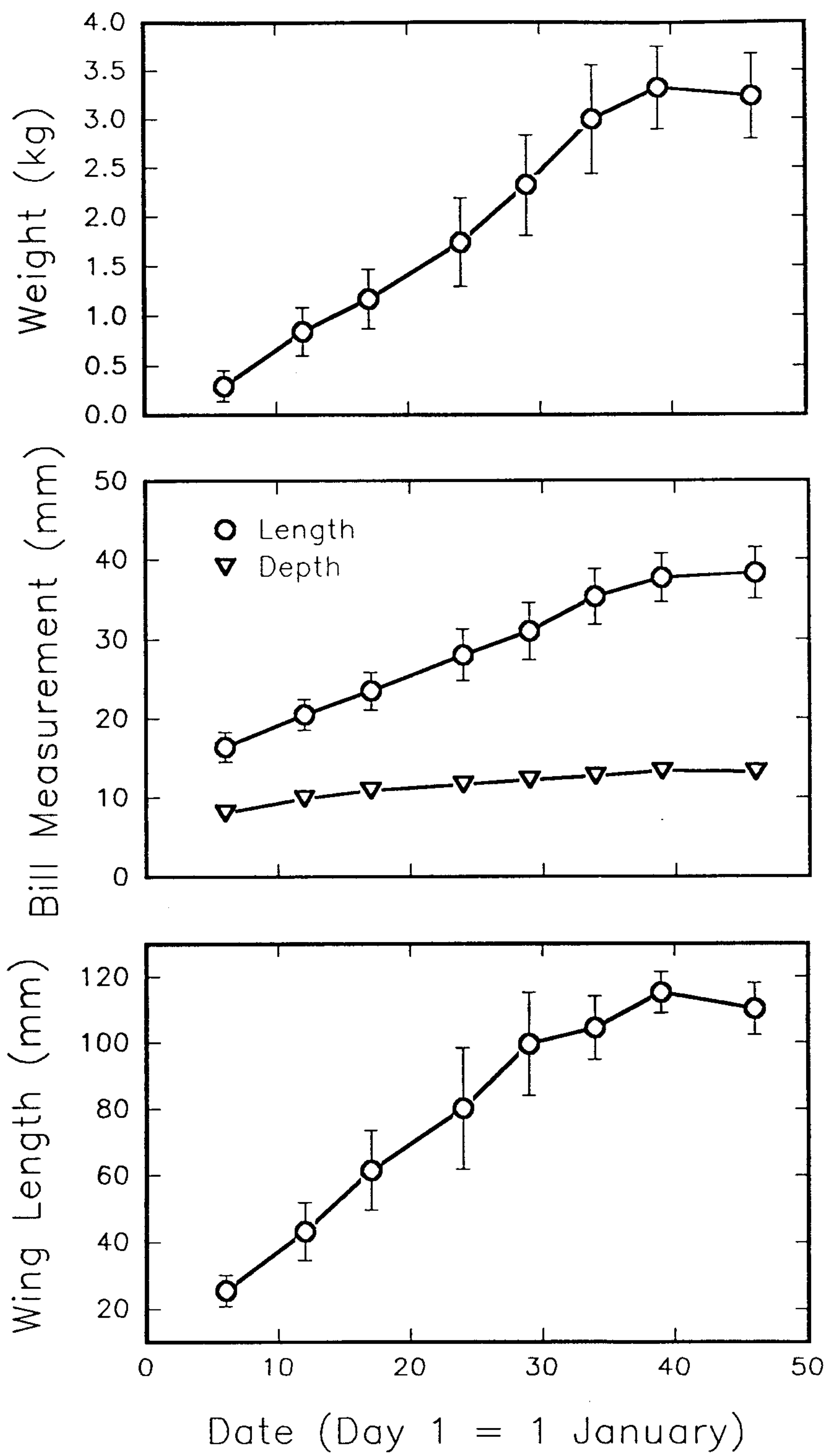


Figure 2.5.1 Growth of chinstap penguin chicks at Parking Lot study site on Seal Island, 1990/91.

**Chinstrap reproductive energetics:** The energetic cost of reproduction for adult chinstrap penguins was measured during three stages of the reproductive cycle in order to obtain an estimate of adult penguin krill requirements during reproduction. A doubly labeled water technique was used to directly measure carbon dioxide production in birds performing normal daily activities. Assuming a respiratory quotient for metabolism of krill, carbon dioxide production may be converted into krill required to meet energetic demand. The energetic output of 21 adults was measured. Seven adults each were measured during the incubation, chick guard, and creche stages of reproduction. The nests of the birds were watched continuously throughout the measurement period in order to obtain attendance records, and two of the birds monitored during each period were equipped with dive recorders as a measure of foraging effort. In addition, the two birds equipped with dive recorders during the chick guard stage were also equipped with radio transmitters and tracked at sea as part of a cooperative research program with the Japanese research vessel *Kaiyo Maru*. A sample of the stomach contents of these two birds was also obtained at the end of the experimental period. The results of these studies await analysis of blood samples obtained from the penguins.

**Cape petrels:** The breeding success of 60 accessible cape petrel nests was estimated by surveying nests 5 times during the season. The status of nests was recorded (occupied but empty, unoccupied and empty, incubated egg, attended chick, or unattended chick). Nesting success was estimated at .62 chicks/active nest on 18 February when 37 chicks were banded, weighed, and measured (mean weight (±sd) 0.63 kg (±0.06), culmen length 29.8 mm (±1.6), wing length 191 mm (±14)). Material regurgitated by chicks during banding indicated that most chicks were being fed krill and squid.

**Cooperative research with Japan:** The studies undertaken cooperatively with the Japanese scientist visiting Seal Island were quite successful. A total of 15 TDRs was deployed on chinstrap penguin adults to evaluate their at-sea foraging effort during a period when the Japanese research vessel *Kaiyo Maru* was conducting surveys of offshore prey resources and identifying penguin foraging areas. Samples of chick diet were obtained, and observations were made to assess adult attendance patterns ashore and chick feeding frequencies.

**2.5.3 Preliminary conclusions:** The number of penguins (both chinstrap and macaroni) occupying nests on Seal Island in 1990/91 was fewer than that observed in the previous year (down approximately 20% in both species). This may have reflected a decline in prey availability prior to breeding (resulting in fewer birds attempting to breed), a decline in prey availability during breeding (resulting in a higher nest failure rate during the incubation period prior to the field team's arrival), both factors, or other factors such as weather or ice conditions.

Growth rates of chinstrap chicks were similar to those observed in previous years, while peak chick weight was slightly less than that observed in previous years. However, the reproductive success of those chinstrap penguins that did nest was higher than that observed the previous year (1.25 and 1.23 chicks creched/active nest in 1990/91 vs. 1.1 and 0.8 chicks creched/active nest in 1989/90 for the Parking Lot and N. Cove study plots, respectively). The reproductive success of macaroni penguins at Mac Top was 0.8, similar to that observed the previous year, while macaroni chick size at Macaroon at banding was similar to that observed the previous year. The timing of reproduction was also delayed in comparison with 1989/90. Peak hatching and the timing of creching in both penguin species was somewhat later than that observed the previous year. Finally, reproductive success and size of cape petrel chicks was similar to that observed in 1989/90.

It appears, therefore, that conditions for reproduction were less optimal either prior to egg laying or during the initial stages of incubation. This may have been due to lower prey availability or adverse weather or ice conditions. However, after this initial period, penguins breeding on Seal Island were able to find food in sufficient quantities to result in chick growth rates and reproductive success similar to or exceeding those observed in preceding years.

**2.5.4 Recommendations:** Given the potential differences in prey availability and thus foraging effort from one year to the next, we recommend that energetic work be conducted for a second year during the chick guard and creche stage to serve as a comparison with data obtained this year.

**2.6 Fur seal and penguin foraging areas near Seal Island during 1990/91; submitted by J.L. Bengtson, P. Boveng and J.K. Jansen, National Marine Mammal Laboratory; T. Ichii, Far Seas Fisheries Research Laboratory; A. Mujica, and J. Alvarado, Universidad Católica del Norte.**

**2.6.1 Objectives:** Knowledge of the foraging areas of predators such as Antarctic fur seals and chinstrap penguins allows identifying the specific areas over which changes in prey availability or environmental conditions may influence predators' reproductive success, growth and condition, feeding ecology, and behavior. Linking the results of pelagic studies on prey and environmental features with data obtained from land-based monitoring of predators is a vital step in elucidating the potential effects of natural and human-caused perturbations on various components of the Antarctic marine ecosystem.

The purpose of this research was to identify and describe the ecological characteristics of the foraging areas of Antarctic fur seals and penguins breeding at Seal Island, Elephant Island (60°59.5'S, 55°24.5'W). There were three principal objectives of the 1990/91 field work:

1) To follow Antarctic fur seals and chinstrap penguins during their feeding trips to sea in order to accurately locate important foraging areas,

2) To use hydroacoustic and net sampling in these areas to evaluate the distribution and abundance of prey species such as Antarctic krill, and

3) To compare predator foraging areas utilized early and late in the reproductive season to determine the extent to which these areas change within a season.

**2.6.2 Accomplishments:** Field work was carried out in two phases: in early January (aboard the Japanese research vessel *Kaiyo Maru*) and in mid-February (aboard the Chilean research vessel *Alcazar*). In preparation for tracking operations, radio transmitters and time-depth recorders (TDRs) were attached to Antarctic fur seals, chinstrap penguins, and macaroni penguins. The TDRs were programmed to sample the depth in the water column every 10 seconds, providing a record of the times and depths of fur seal or penguin feeding dives. A radio direction-finding system was installed aboard the research vessels to track the movements of the instrumented fur seals and penguins at sea. This system worked well, with a working radio reception range of approximately 5 km (penguins) to 15 km (fur seals) from the vessels.

Tracking operations were conducted aboard the R/V *Kaiyo Maru* from 1-8 January 1991. Tracks to foraging areas were completed for 4 chinstrap penguins (6 trips), 1 macaroni penguin, and 1 fur seal (Table 2.6.1). Most penguins were followed for the majority of an entire feeding trip to sea; however, the one fur seal followed was only monitored on its outbound journey until it appeared to have reached the outer limit of its foraging range. During tracking operations, a series of midwater trawls, ORI net samples (oblique tows), WP2 net samples (vertical tows), and XBT samples were taken.

Table 2.6.1 Summary of Antarctic fur seals, macaroni penguins, and chinstrap penguins tracked to foraging areas near Seal Island, Antarctica, from 1-8 January 1991. Maximum distance away from Seal Island is indicated. Bearing from Seal Island to the last position observed is also noted.

| I.D. no. | Tracking times start track | end track | Elapsed time | Maximum distance | Bearing |
|---|---|---|---|---|---|
| <u>Fur seal</u> | | | | | |
| 900[a] | 4 Jan: 2030 | 7 Jan: 2000 | 71.5 h | 240 km | 047 |
| <u>Macaroni penguin</u> | | | | | |
| 350[b] | 3 Jan: 0800 | 3 Jan: 1842 | 18.2 h | 15 km | 332 |
| <u>Chinstrap penguins</u> | | | | | |
| 762[c] | 1 Jan: 1725 | 2 Jan: 0825 | 14.0 h | 23 km | 027 |
| 660[b] | 2 Jan: 0834 | 2 Jan: 1424 | 5.8 h | 6 km | 040 |
| 820[b] | 3 Jan: 0327 | 3 Jan: 1005 | 6.6 h | 7 km | 345 |
| 372[b] | 3 Jan: 2015 | 4 Jan: 0250 | 6.6 h | 25 km | 030 |
| 762[c] | 4 Jan: 0240 | 4 Jan: 1353 | 11.2 h | 11 km | 044 |
| 660[b] | 4 Jan: 1539 | 4 Jan: 2030 | 4.9 h | 18 km | 019 |

NOTE: [a] partial track of feeding trip (outbound portion only)
[b] partial track of feeding trip
[c] complete track of feeding trip

From 13-22 February, the R/V *Alcazar* conducted a tracking and sampling program in the vicinity of Seal Island. Although the initial plan for tracking predators had included both penguins and fur seals, several practical considerations required that actual tracking operations be limited to fur seals alone. The main reason for this change in plans was due to unavoidable delays in starting the study, and thus penguin chicks of both macaroni and chinstrap penguins had already started to fledge. As chicks leave the colonies, the adults' daily foraging patterns and attendance ashore become increasingly unpredictable, and these birds were not reliable to track at sea. A total of 8 tracks of female fur seals during offshore feeding trips was obtained. A mast and hydroacoustic transducer was mounted to the ship's railing to collect acoustic data on prey abundance. A Seabird CTD was deployed by winch to depths up to 260 meters at a series of stations corresponding to locations where bongo tows were conducted. A summary of tracking results is provided in Table 2.6.2.

Table 2.6.2 Summary of Antarctic fur seals tracked to foraging areas near Seal Island, Antarctica, from 14-22 February 1991. Maximum distance away from Seal Island is indicated. Bearing from Seal Island to the last position observed is also noted.

| I.D. no. | Tracking times start track | end track | Elapsed time | Maximum distance | Bearing |
|---|---|---|---|---|---|
| 790[a] | 14 Feb: 1849 | 15 Feb: 0730 | 12.7 h | 23 km | 340 |
| 849[b] | 15 Feb: 2015 | 17 Feb: 0428 | 32.2 h | 49 km | 036 |
| 810[a] | 17 Feb: 2057 | 19 Feb: 0725 | 34.5 h | 41 km | 330 |
| 750[b] | 19 Feb: 0002 | 19 Feb: 0719 | 7.3 h | 14 km | 011 |
| 830[b] | 19 Feb: 0417 | 19 Feb: 1338 | 9.3 h | 14 km | 086 |
| 790[a] | 19 Feb: 2000 | 20 Feb: 1223 | 16.4 h | 36 km | 319 |
| 957[a] | 20 Feb: 2226 | 21 Feb: 0850 | 10.4 h | 18 km | 341 |
| 770[b] | 21 Feb: 2052 | 22 Feb: 0600 | 9.9 h | 35 km | 030 |

NOTE: [a] complete track of feeding trip
[b] partial track of feeding trip

**2.6.3 Preliminary conclusions:** The foraging locations identified during this study suggest that these locations can change within a breeding season as well as between years. Of course, the only direct comparison that can be made within this season is for fur seals. Although only one fur seal was tracked during January, it was quite different from the feeding areas used later in the season (or observed in previous years of tracking)--over four times farther out to sea than the farthest ranging fur seal in February. Moreover, the chinstrap penguin records from January indicated that penguins were feeding up to twice as far offshore as observed in previous seasons.

The results of the tracking correspond to the preliminary analyses of acoustic and net sampling for prey. In January, very little krill or other prey species were detected during sampling operations; during this period, feeding locations were well offshore and fur seals were making rather long (5-9 days) trips to sea. In February, acoustic and net sampling from the *Alcazar* and *Surveyor* revealed that patches of krill were present throughout the area; feeding trips of fur seals during this period were shorter (1-3 days) than in January. Therefore, preliminary analyses suggest a good correlation between prey abundance and the foraging patterns of predators.

**2.6.4 Recommendations:** The tracking operations went very well, with both the *Kaiyo Maru* and the *Alcazar* serving well as research platforms for this type of work. The portable hydroacoustic equipment used aboard the *Alcazar* did not operate entirely satisfactorily. The mast holding the transducer in the water was not quite strong enough to operate efficiently, causing problems with noise on the system as well as other mechanical trouble. Obtaining hydroacoustic information on the density and abundance of prey in the vicinity of foraging predators is an important element of understanding their feeding ecology. If such studies are undertaken in the future, it might be advantageous to mount the hydroacoustic transducer in the hull of the ship instead of holding in the water by a fixed mast.

Given the importance of investigating the foraging areas of predators, consideration should be given to arranging for such data to be collected annually throughout the breeding season. Because of the expense and tight schedules of ships, it is unlikely that opportunities will routinely be available to obtain such information from aboard research vessels. Therefore, it may be useful to develop some type of automatic tracking system that could be implemented from shore stations. It may also be possible to deploy instruments to monitor the location of foraging areas on seals, but it is unlikely that suitable instruments will become available for penguins in the foreseeable future. A monitoring system that could provide data on the locations (or relative locations) for both seals and seabirds would be most desirable.

**2.7 Seabird research undertaken as part of the NMFS/AMLR ecosystem monitoring program at Palmer Station, 1990-1991; submitted by W. R. Fraser, Old Dominion University, and D. G. Ainley, Point Reyes Bird Observatory.**

**2.7.1 Objectives:** Palmer Station is one of two sites on the Antarctic Peninsula where long term monitoring of seabird populations is being undertaken in support of U.S. participation in the Commission and Scientific Committee of the Convention for the Conservation of Antarctic Marine Living Resources (CCAMLR). Research at Palmer Station focuses on aspects of the ecology of Adelie Penguins that are complementary to the scope of research outlined by CCAMLR, and as such follows CCAMLR recommended field protocols designed to insure that data collection is comparable year to year both between and within research sites. Our objectives during 1990-1991, the fourth season of field work at Palmer Station, therefore, were to: 1) establish indices of Adelie breeding success, 2) gather information on Adelie diet composition and meal size, 3) determine Adelie chick weights at fledging, 4) determine the amount of time breeding adult Adelie Penguins need to procure food for their chicks, 5) band a representative sample (1000 chicks) of the Adelie chick population, and 6) determine adult breeding chronology.

**2.7.2 Accomplishments and field schedules:** Field work at Palmer Station was initiated on 7 December 1990 and terminated on 10 March 1991. Field work schedules and activities related to the above cited objectives were as follows:

**Adelie breeding success:** As in past seasons, two indices of breeding success were determined. On 5 January, the proportion of 1 and 2 chick broods was determined at 39 colonies in 5 different rookeries; on 22 January these same colonies were censused to assess chick production.

**Diet composition:** Diet studies were initiated on 9 January and terminated on 15 February. During each of the 8 sampling periods, 5 adult Adelies 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=40) were subsequently released unharmed. The resulting diet samples were processed at Palmer Station.

**Chick fledging weights:** Data on Adelie chick fledging weights were obtained between 4-24 February at beaches near the Humble Island rookery. During this interval, 337 chicks were weighed and released.

**Length of foraging bouts:** Radio receivers and automatic data loggers were deployed on a bluff overlooking the Humble Island rookery between 18 January and 17 February to monitor presence/absence data on 25 breeding Adelies carrying small radio transmitters. These transmitters were deployed on adult penguins feeding 10-14 day old chicks. An additional 15 transmitters available to us were not deployed due primarily to problems with the performance of both radio receivers (see Problems and Recommendations).

**Chick banding:** One-thousand Adelie chicks were banded as part of long-term demographic studies at AMLR colonies on Humble Island on 3 February. This effort was accomplished in 2.5 hours with the help of 13 Palmer Station and 2 National Science Foundation personnel. The presence of birds banded in previous seasons was also monitored during the entire field season on Humble Island as part of these demographic studies.

**Adult breeding chronology:** As last season, a 100-nest plot was established on Humble Island to assess the chronology of breeding events. Pertinent data were subsequently obtained every 1-3 days as weather permitted from 7 December to 25 February.

**2.7.3 Preliminary results:** This season's production of 2-chick broods (56% of the breeding pairs sampled) exhibited no significant change relative to last season (59% of sampled pairs). When compared to last season, however, chick counts at designated AMLR colonies decreased by approximately 750 chicks or 17%. Whether this decrease is due to post-hatching chick mortality or a change in the number of breeding pairs must await further analysis of our data. As last year, the predominant component in the diets of Adelie penguins was the krill *Euphausia superba*, with fish, in particular *Pleuragramma antarcticum*, exhibiting some dietary significance in late January. Krill size classes evident in the diet this season emphasized larger specimens (41-50mm) relative to last season (31-40mm), and were thus more similar to those encountered in the diets of Adelie Penguins during the 88-89 season. We currently cannot provide any information on the relative availability of krill between seasons based on telemetry data used to estimate the length of foraging intervals; analysis of these data is currently beyond the scope of this report due to the large size of the pertinent databases.

Mean Adelie chick fledging weights did not differ significantly from those evident last season (3.10 vs. 2.97 kg.). Indeed, as last year, the fledging period again encompassed a 3-week interval (4-24 February), with peak fledging occurring on 16 February (vs. 15 February during 89-90). The chronology of breeding events was likewise quite similar between these two seasons.

**2.7.4 Disposition of the 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 Ecosystems Research Group coincident with the final report on this season's activities due 1 June.

**2.7.5 Problems, suggestions and recommendations:** Despite unusually severe weather during the field season and a relatively heavy schedule of visits by tour boats, virtually all AMLR related research was accomplished on a schedule complementary both to past seasons and CEMP/CCAMLR directives. The exception involved work associated with the telemetry phase of the study, specifically, the failure of both receivers to function off the external battery source. Each of these receivers had been refurbished by Advanced

Telemetry Systems in November 1990 and apparently incorrectly wired by their technicians. We know this to be the case because another receiver similarly refurbished for Dr. Wayne Trivelpiece for independent use on King George Island also exhibited the same problems as those in use at Palmer Station. With the help of Mr. Al Oxton, manager of Palmer's radio and communication systems, we eventually diagnosed and repaired the deficiency in the receivers. However, because this could only be accomplished by systematically rewiring and field testing each receiver on a trial and error basis, it was impossible to anticipate when and if the receivers would be repaired. By mid-January, therefore, coincident with a field test that suggested the receivers were working properly, the decision was made to deploy 25 transmitters rather than the full complement of 40. This was done to take advantage of an adequate sample of remaining adults feeding chicks of a suitable age within our study colony, yet at the same time minimize the loss and waste of transmitters that would result if the receivers continued to work improperly after deployment. By 20 January we were confident the receivers were operating properly, but elected not to deploy more transmitters as too many chicks at nest sites selected for this aspect of the research in our study colony had creched.

## 3. Shipboard activities

### 3.1 Description of operations:

**Leg I:** The NOAA Ship *Surveyor* departed Punta Arenas, Chile on 16 January, 1991. A series of XBT's was conducted while in transit across Drake Passage at the request of Chile's Servicio Hidrográfico y Oceanográfico de la Armada (SHOA). Provisions, supplies, and scientific equipment were transferred to the field camp at Seal Island; Dr. Rennie Holt also remained onshore for a 1-week stay. Samples were collected at Seal Island by a SHOA scientist for hydrocarbon content analysis. The *Surveyor* then proceeded to King George Island where the acoustic sensors were calibrated in Ezcurra Inlet off Admiralty Bay. On 21 January a survey (Survey A, Figure 3.1.1) of the physical oceanography, biomass and productivity of phytoplankton, and distribution and condition of krill in the waters around Elephant Island, Clarence Island and the eastern end of King George Island was initiated. The survey consisted of 1100 miles of acoustic transects between 50 CTD/rosette and net sampling stations. Survey operations were interrupted on 25 January to return to Seal Island, pick up Holt and transfer him to the Japanese research vessel *Kaiyo Maru* midway across Bransfield Strait. The survey was completed north of Elephant Island and finer-scale acoustic mapping was conducted in an area of higher krill densities along the shelf/slope break. Two sites were selected for intensive MOCNESS sampling (X Stations 1-4, Figure 3.1.4). A second survey (Survey B, Figure 3.1.2) was then conducted, focusing on the area north of Elephant Island. Higher krill densities were again encountered along the shelf/slope break, apparently associated with an oceanic front, and two CTD transects were conducted to delineate the hydrography of this feature in detail (X Stations 5-17, Figure 3.1.4). The last of the cargo was transferred to Seal Island on 6 February and three additional MOCNESS tows were conducted. The *Surveyor* departed the Elephant Island area on 8 February, conducted a series of CTD casts across Drake Passage at the request of SHOA, and arrived in Punta Arenas on 11 February.

**Leg II:** The NOAA Ship *Surveyor* departed Punta Arenas, Chile on 16 February, 1991. A series of XBT's was conducted while in transit across Drake Passage at the request of SHOA. Fresh provisions and mail were transferred to the field camp at Seal Island. A third survey (Survey C, Figure 3.1.3) was conducted north of Elephant Island; both bongo and IKMT nets were used at each station. In an effort to collect krill eggs and larvae, MOCNESS sampling was conducted over deep water to the northeast of Elephant Island. Field operations were suspended on 24 February, when the ship proceeded to Teniente Marsh Base on King George Island to drop off a crew member for emergency leave to the States and to wait out a storm. Work resumed on 26 February with the beginning of Survey D (similar in scale to Survey A, Figure 3.1.1) around Elephant, Clarence and the eastern end of King George Islands. The survey was completed off Admiralty Bay on 7 March and the acoustic sensors were again calibrated in Ezcurra Inlet. Additional acoustic transects and stations (X Stations 24-29, Figure 3.1.4) were conducted in Bransfield Strait and a second acoustic calibration was performed at Deception Island. The *Surveyor* returned to the north side of Elephant Island where MOCNESS sampling was directed at the persistent area of high krill intensity along the shelf/slope break east of Seal Island (X Station 30, Figure 3.1.4). The Seal Island field team was recovered on 11 March and two CTD transects (X Stations 31-45, Figure 3.1.4) were conducted across the shelf/slope break north of Elephant Island. IKMT tows, conducted during the second CTD transect, caught reproductively active krill. A very fine-scale survey grid (1 mile by 1 mile with 0.2 mile transect spacing) was occupied at the inshore end of the transect; high resolution observations of the distribution of krill and foraging behavior of birds were obtained. The *Surveyor* departed the Elephant Island area on March 14 and arrived in Punta Arenas on 17 March. Adverse weather conditions precluded all but one of the planned CTD stations across Drake Passage.

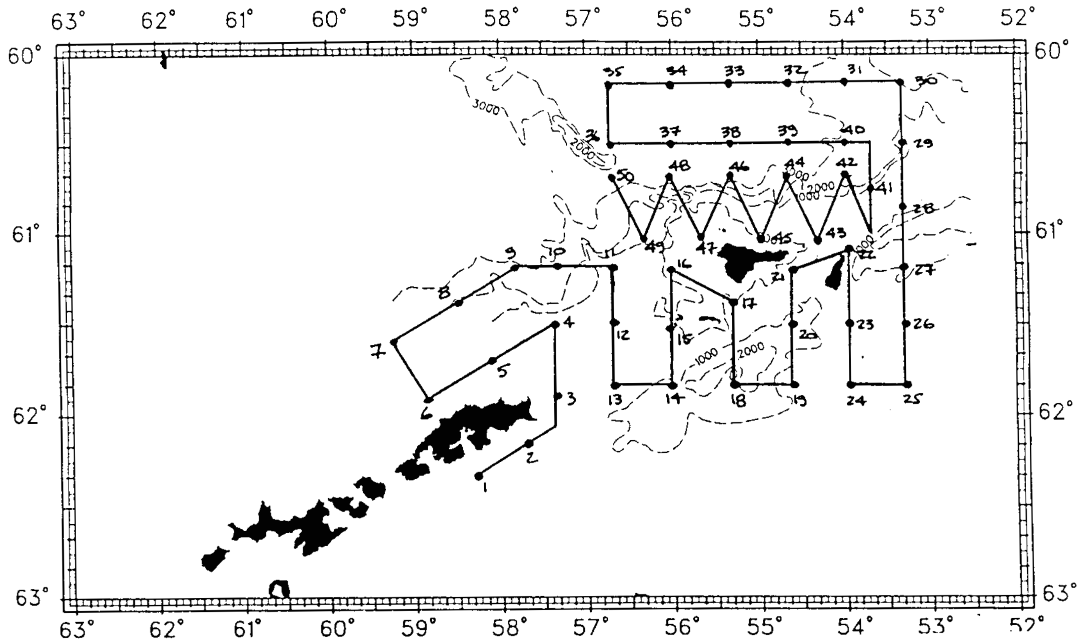


Figure 3.1.1 Large-area survey grid (Surveys A and D) around Elephant, Clarence and the eastern end of King George Islands. The grid included 50 stations and approximately 1100 n.mi. of transects, and was occupied during the first half of Leg I and the second half of Leg II. Approximately 10 days were required to complete the grid.

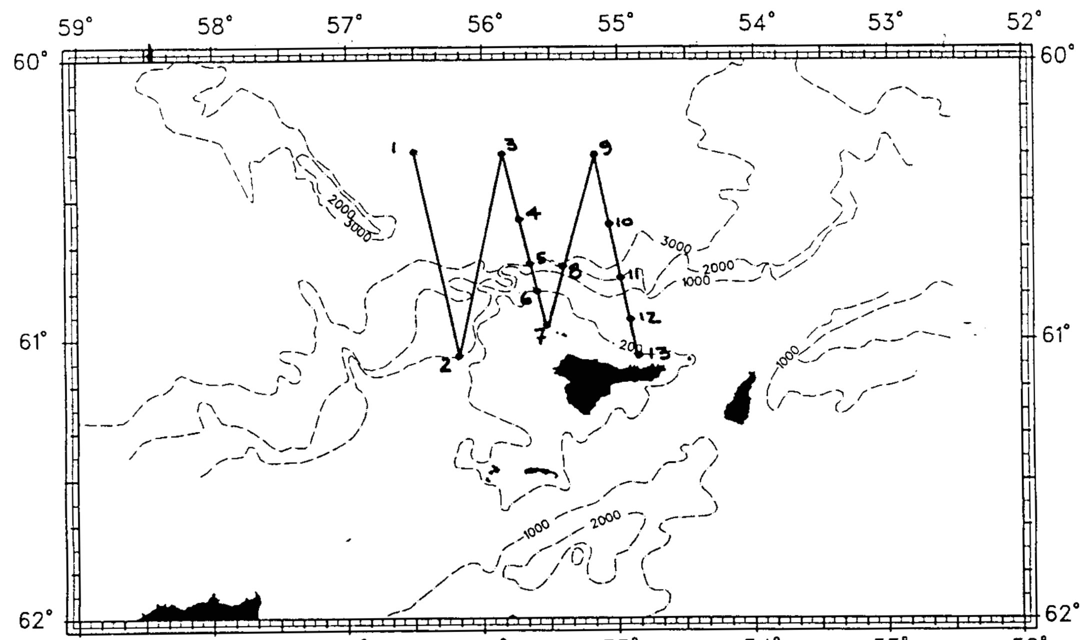


Figure 3.1.2 Small-area survey grid (Survey B) on the north side of Elephant Island. The grid included 13 stations and approximately 215 n.mi. of transects, and was occupied during the second half of Leg I. Due to time limitations-some of the stations and transects were ommitted.

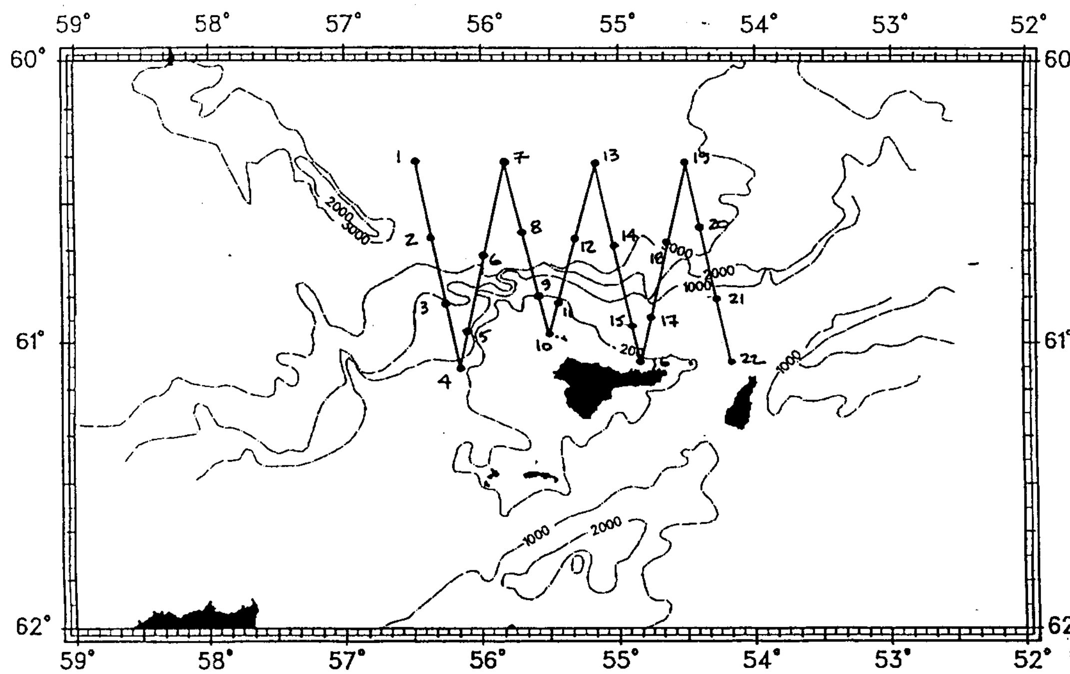


Figure 3.1.3 Small-area survey grid (Survey C) on the north side of Elephant Island. The grid included 22 stations and approximately 310 n.mi. of transects, and was occupied during the first half of Leg II. Approximetly 5 days were required to complete the grid.

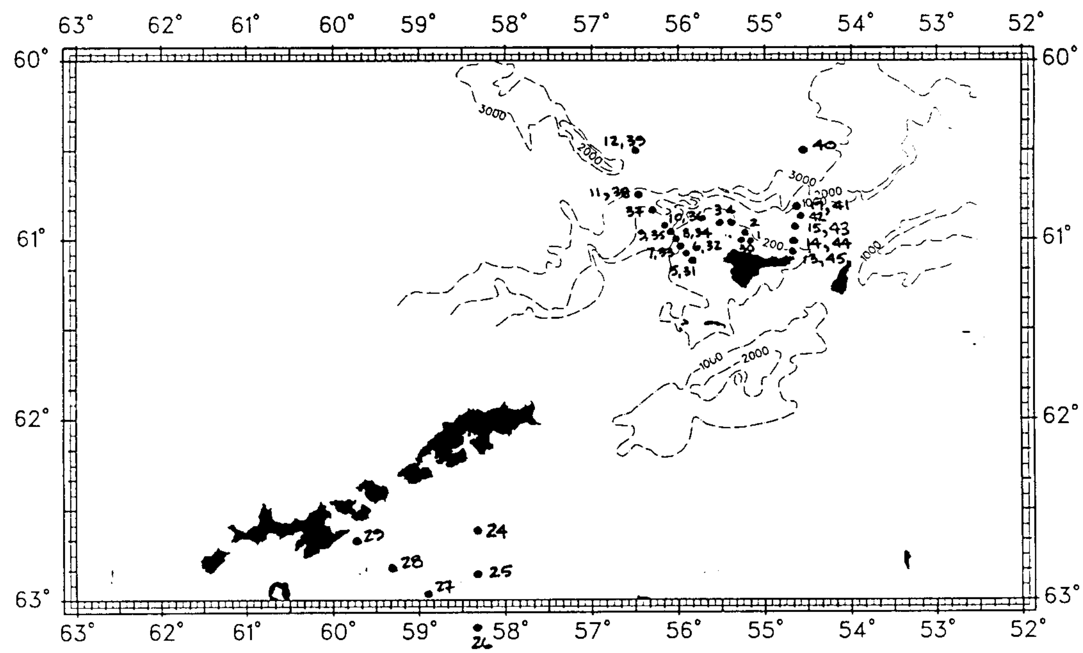


Figure 3.1.4 Extra stations (X Stations) included two transects across Bransfield Strait in the vicinity of King George Island and two transects across the shelf slope/break north of Elephant Island. The latter transects were occupied once during each leg.

### 3.2 Abstract of observations

**Leg I:** Krill were sparsely but widely distributed (specimens were taken at 35 out of 50 stations), with highest densities encountered nearshore north and south of King George Island, approximately 30 miles northeast of Elephant Island over deep water (ca 1500-3000m), and along the shelf/slope break north of Elephant Island. Krill biomass over the entire survey area was estimated to be 2.7 million tons; krill biomass in the Elephant Island area was midway between that estimated for the first and second surveys of this area in 1990, suggesting little change in abundance between years. Reproductively mature krill dominated the catches north of King George and Elephant Islands; mixed adult and juvenile catches were obtained in Bransfield Strait south of the islands and near shore north of Elephant Island. Mature male and female krill showed a degree of horizontal separation, with males being more abundant to the northwest of Elephant Island and females to the northeast. The mean length of mature individuals (44mm) was larger than that observed in January, 1990 (43mm) and in January-February, 1988 (41mm); noticeably absent in the catches were immature individuals in the 30-40mm size range. Phytoplankton biomass, integrated to 100m depth, ranged from 20 to 137 mg chl-a/$m^2$, with highest values northwest of Elephant Island and south of Clarence Island. Phytoplankton biomass was vertically stratified offshore from the shelf/slope break north of Elephant Island and deeply mixed on the shelf close to the island. A hydrographic front was delineated north of Elephant Island running parallel to the shelf/slope break, where low salinity, well stratified Bellingshausen Sea water abutted vertically mixed Bransfield Strait water. Strong westerly airflow, associated with high pressure over the southeast Pacific Ocean and low pressure systems over the Antarctic Peninsula, prevailed throughout most of the study period.

**Leg II:** Krill were less evenly distributed than they were during Leg I. Areas of highest densities were similar to that mapped during Leg I: along the shelf/slope break north of Elephant Island and over deep water (ca 2000-3000m) approximately 40 miles northeast of Elephant Island. Very few krill were encountered, however, around King George Island. Although the estimated krill biomass over the entire survey area was similar to Leg I, the portion in the Elephant Island area increased by approximately 50%. Similar to Leg I, reproductively mature krill dominated the catches north of Elephant Island; mean size (46mm) was 2mm larger than Leg I. Mixed catches of juvenile, immature and mature stages were taken only nearshore and between Elephant and King George Islands. In contrast to Leg I, immature stages were more abundant than juveniles, and fewer females had developing ovaries or were gravid. Gravid females were taken late in the reproductive season (12 March) northeast of Elephant Island. In a larger context, both the 1991 surveys and the 1990 surveys collected relatively few juveniles and immature stages. Chlorophyll-a concentrations were higher throughout the study area on Leg II. High phytoplankton biomass was observed northwest of Elephant Island, displaced slightly to the west from Leg I, primarily composed of small (<20um) cells. Larger cells composed high concentrations of phytoplankton biomass located south of Elephant Island and north of King George

Island. Although light radiation levels were considerably lower during Leg II, photo inhibition continued to be evident in the upper 20m. The hydrographic front north of Elephant Island separating Bellingshausen Sea water and Bransfield Strait water persisted through Leg II.

**3.3 Physical oceanography; submitted by Anthony Amos and Margaret Lavender, University of Texas at Austin, Marine Science Institute.**

**3.3.1 Objectives:** The main objective of the physical oceanography program was to describe the upper ocean water structure around the Elephant Island area in relationship to the observed distribution of biological organisms. This was accomplished by measuring the vertical density profile of the waters to a depth of 750m (where possible) over (1) a coarse grid of 50 stations (Surveys A and D, Figure 3.1.1) around Elephant Island, (2) a finer-scale grid to the north of Elephant Island (Surveys B and C, Figures 3.1.2 and 3.1.3), (3) closely spaced stations along two sections extending across the shelf-break, also to the north of Elephant Island, and (4) by continuously monitoring the meteorological conditions along the ship's track to study mechanisms maintaining the upper mixed layer and pycnocline. The grids and transects were repeated on Leg II of the cruise.

**3.3.2 Accomplishments:**

**CTD Stations:** Using a Sea-Bird SBE-9 CTD with a General Oceanics rosette sampler, a total of one hundred-sixty-seven (167) stations were occupied. The CTD had additional sensors attached ( a SeaTech 25cm transmissometer, Biospherical Instruments PAR light meter, and SeaTech *in-situ* fluorometer). Thus, real-time profiles of temperature, salinity, beam attenuation, downwelling light, and fluorometry were acquired. Data were displayed as multi-colored plots on a PC monitor, printed on a laser printer, and stored on removable cartridge disks. At each CTD station (on the uptrace), ten 10-liter water samples were collected, one at depth and the others from 100 m to the surface, at depth intervals suitable for chlorophyll-a sampling. Chlorophyll, DNA, HPLC, ABS phytoplankton, floristics and nutrient sampling were done by O. Holm Hansen's group. All water samples were analyzed for salinity by *Surveyor*'s Survey technicians using the ship's Guildline Autosal salinometer. A total of 1723 salinity determinations were made to verify the sampling depths and for *in-situ* calibration of the CTD.

Data were acquired at the rate of 6 scans/sec using the *Surveyor*'s rack-mounted Everex 386 computer and Seasoft software. On all but the first two stations of Leg I, the UTMSI CTD was used. This instrument has the capability of supporting the additional optical sensors. Data were stored on the ship's LAN network disk because our 44 Mbyte 5 1/4" Bernoulli removable cartridge disk system was not compatible with the Everex 386 computer. Over 60 Mbytes of raw CTD data were acquired.

**Weather Monitoring System:** An continuous weather/navigation system was installed aboard the *Surveyor* to collect environmental data throughout the cruise. Using a Data World 386 computer as a processor, information from the ship's Magnavox 1102/1107 GPS-Transit satellite navigation system, the ship's Coastal Climate Weatherpak anemometer, Weathermeasure air temperature, relative humidity and barometric pressure sensors, and three solar radiation sensors were acquired at 10-minute intervals. A sea-surface temperature probe was towed from the fantail to monitor sea-surface temperature SST data. SST and salinity data were also collected using the ship's thermosalinograph, and merged daily with the information from the UTMSI weather system.

Weathermeasure signal-conditioning units, a Hewlett-Packard model 3421-A data acquisition-control unit, both asynchronous communications ports and an IEEE-488 interface fed the data into the computer. Data were stored in daily files on the hard disk and transferred using 5 1/4" diskettes to the Everex for further processing. Files were closed and re-opened each time a line of data was written to protect from accidental erasure and backed up at 0000 hours (UT) daily. At any interval, comments could have been made (i.e. "CTD SU... START"), at which time a line of environmental and position data was stored. Thus, the system provided a log of all scientific activities for the cruise. Daily log sheets were provided to each scientific group on the ship, and to the Field Operations Officer and Navigator. Log sheets listed positional and environmental data on the hour and whenever an event occurred, and a daily summary of the cruise progress and mean and extreme weather conditions for that day.

**Computer Programs:** Several computer programs were written during the first leg to facilitate data acquisition and to process, analyze, display and store data. Other programs were modified to customize the systems to the *Surveyor*'s particular equipment set up and to digitize and plot data on polar and Mercator projection maps. A new program to make geostrophic computations more suitable for use with shallow CTD casts was written during this cruise.

**3.3.3 Preliminary Results and Discussion:** Data from the downtrace of each CTD station were averaged to 1-meter intervals and recorded on disk. It is these 1-meter data that are used to produce the diagrams presented here. No attempt has been made to adjust the salinity based on the sample salinities.

The study area encompasses several bathymetric and oceanographic regimes. The bathymetry of the Drake Passage rises north-to-south, from below 4,000 m in the trench-like Shackleton Fracture Zone to the continental slope and the shelf of the South Shetland Islands. The Elephant Island group is the northernmost of the South Shetland Islands. Based on last year's results (AMLR1990), the grid was expanded to the south of King George Island, to the west in the Drake Passage, and to the east of Clarence Island. South of Elephant Island, the station grid crosses the deep (below 2,000 m) basin of the northern Bransfield Strait, and in the east, reaches the slope of the Weddell Sea Basin.

North of Elephant Island, surface waters are those of the Continental Water Zone and its boundary (Nowlin and Clifford, 1982)[1], characterized by a shallow mixed layer beneath which a strong temperature minimum ("Winter Water") separates surface water from the deeper Circumpolar Deep Water (CDW). The core of the CDW rises to nearly 500 m close to the continent. Surface flow is generally to the east in the Drake Passage, but immediately adjacent to the South Shetlands, flow is westward as water from the Weddell Sea moves around the northern tip of the Antarctic Peninsula. Within the Bransfield Strait, Weddell Sea Water is recirculated and returns along the northern boundary of the Strait, mixing with Bellingshausen Sea water. A frontal zone separates the Bellingshausen from the Weddell-type water. During AMLR1991, this zone ran parallel to the shelf-break north of Elephant Island and appeared to be associated with high concentrations of krill.

The complicated hydrography around Elephant Island that represents the westernmost boundary of the Weddell-Scotia Confluence (WSC) and its interaction with the oceanic waters of the Bellingshausen can be revealed by plotting T/S diagrams from each vertical CTD profile. This region of water mass boundaries is thought to be favorable for krill in the Elephant Island area. Five water mass types similar to those encountered in 1990 were identified during Legs I and II of AMLR1991. Modified descriptions with additional comments are given below:

TYPE I: Drake Passage water; warm, low salinity surface water, strong sub-surface T-min ("Winter Water", approx. -1°C, salinity 34.0 ppt), CDW near 500 (Figure 3.3.1).

TYPE II: A transition water; T-min near 0°C, isopycnal mixing below T-min, CDW evident at some locations. There were some dramatic examples of transition water during this cruise, showing considerable mixing along isopycnals (Example Station A7, Figure 3.3.2).

TYPE III: Weddell-Scotia Confluence (WSC water; little evidence of a T-min, mixing with Type II, no CDW, temperature at depth generally > 0°C (Figure 3.3.3).

TYPE IV: Eastern Bransfield Strait water; deep temperature near -1°C, salinity 34.5 ppt, cooler surface temperatures (Figure 3.3.4).

TYPE V: Weddell Sea water; Little vertical structure, cold surface temperatures (near 0°C), limited to extreme SE corner of study area (Example Station D24, Figure 3.3.5).

Tentative boundaries for the study area are give in Figure 3.3.6 for Leg I and Figure 3.3.7 for Leg II. Uncertainties in the boundary between Type II and Type III water will be resolved as the data analysis progresses.

---

[1] Nowlin, W.D. Jr. and M. Clifford (1982) The kinematic and thermohaline zonation of the Antarctic Circumpolar Current at Drake Passage. J. Mar. Res. Suppl. 40:481-507.

The most distinct feature of the AMLR1991 hydrography was the front separating Bellingshausen Sea water from Weddell/Bransfield water. Its surface was marked by a meandering salinity gradient separating water of 33.5 ppt in the northwest from >34.3 ppt water over much of the southeastern part of the study area (Figures 3.3.8 and 3.3.9). Subsurface, an abrupt end to the <-1°C temperature minimum separated the stratified water column in the northwest from the generally well-mixed interior in the southeast.

Much of the study period during Leg I was dominated by a strong westerly airflow with a large high pressure dome over the southeast Pacific Ocean and low pressure systems to our south over the Palmer Peninsula. Figure 3.3.10 shows the surface winds, sea and air temperature conditions encountered. Air temperature exceeded sea temperature for the most part. Only when a ridge of high pressure passed to the south did southerly winds from the continent cool the air below the sea temperature (see Figure 3.3.10, 5-7 February).

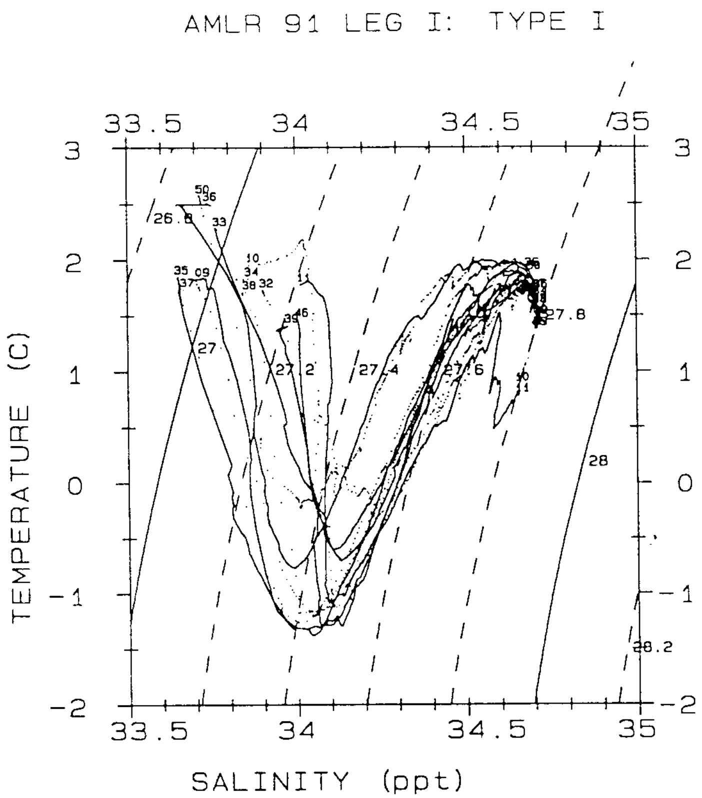


Figure 3.3.1 Temperature/salinity curve; Leg I, TYPE I water.

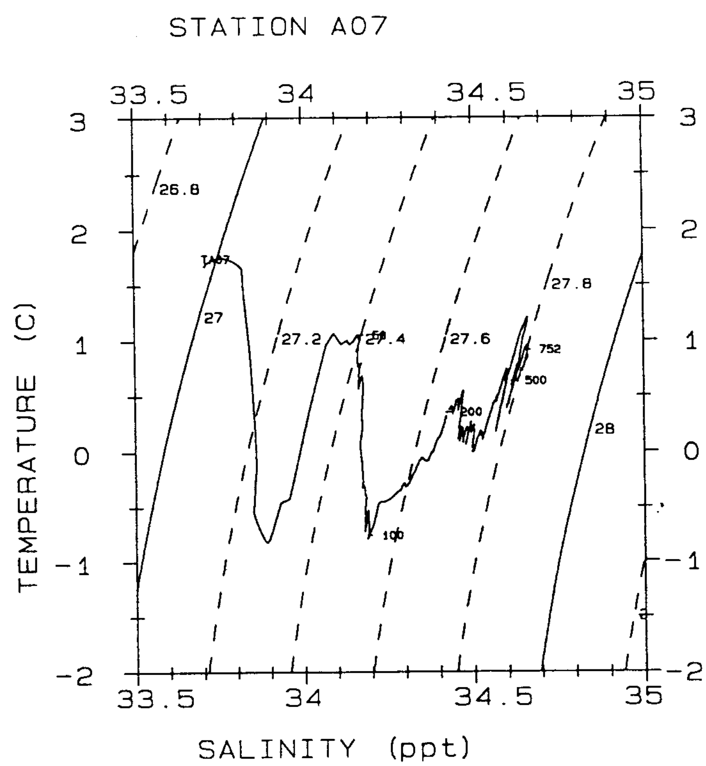


Figure 3.3.2 Temperature/salinity curve; Station A7, example of TYPE II water.

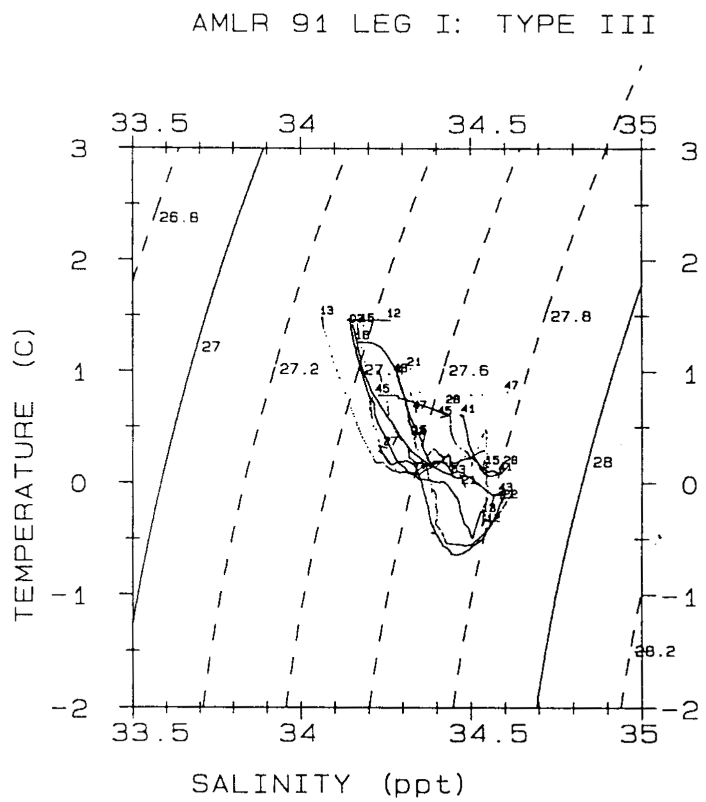


Figure 3.3.3 Temperature/salinity curve; Leg I, TYPE III water.

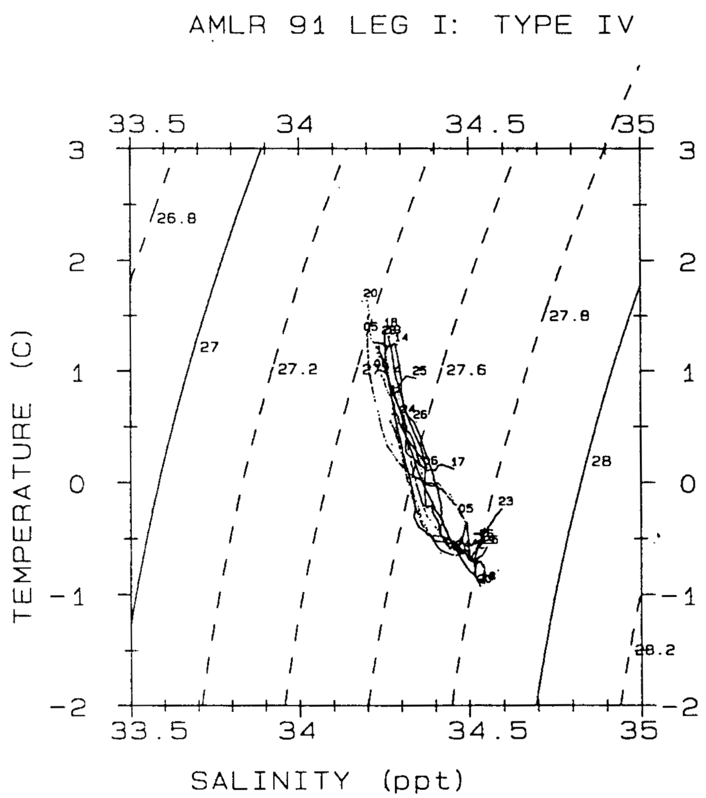


Figure 3.3.4 Temperature/salinity curve; Leg I, TYPE IV water.

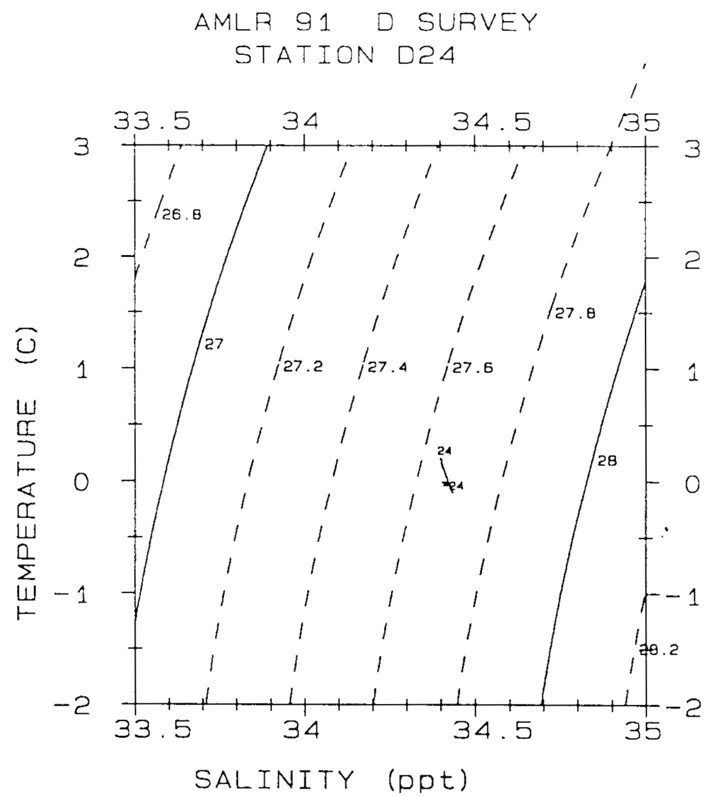


Figure 3.3.5 Temperature/salinity curve; Station D24, example of TYPE V water

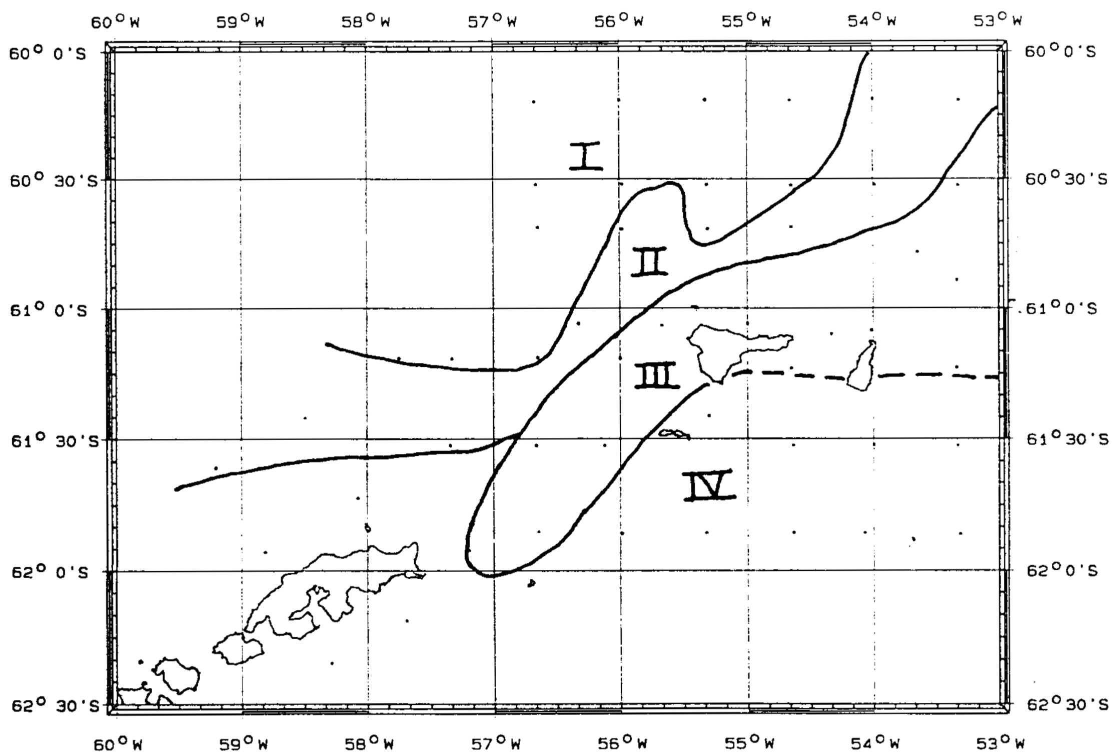


Figure 3.3.6 Water mass boundaries, Leg I.

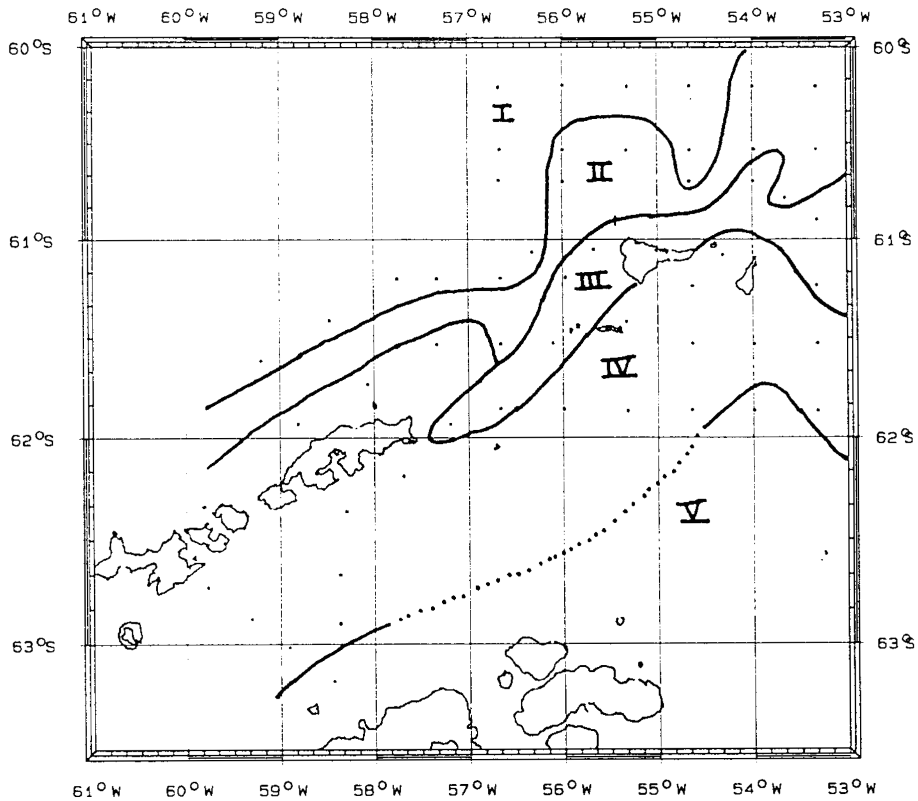


Figure 3.3.7 Water mass boundaries, Leg II.

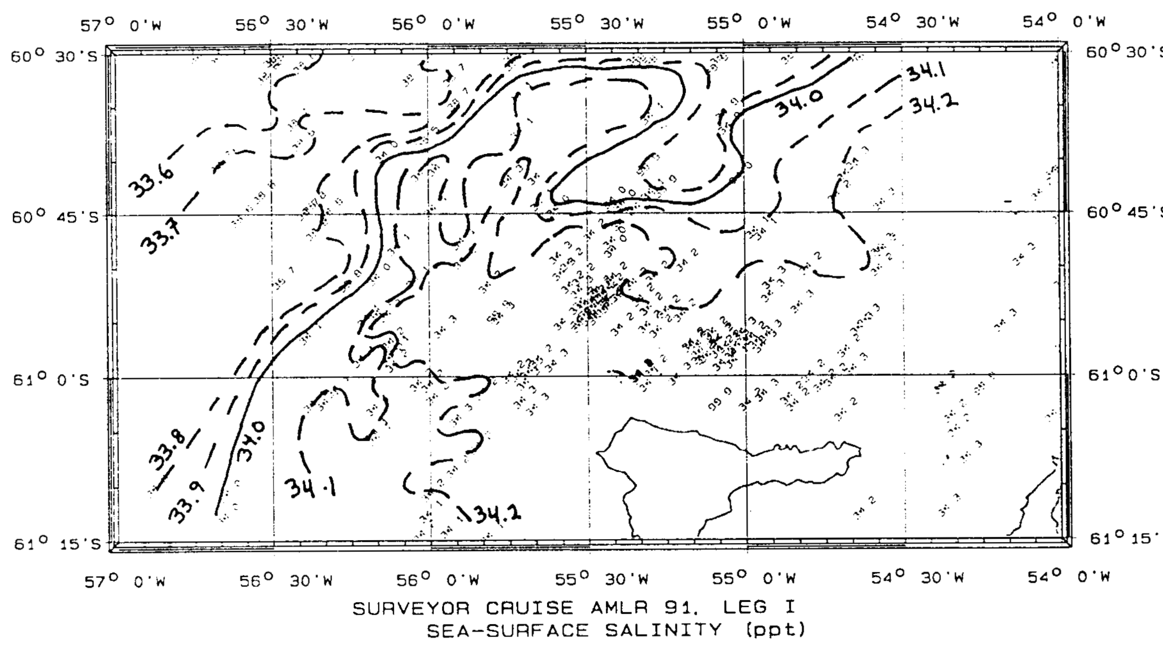


Figure 3.3.8 Leg I sea surface salinity in parts per thousand.

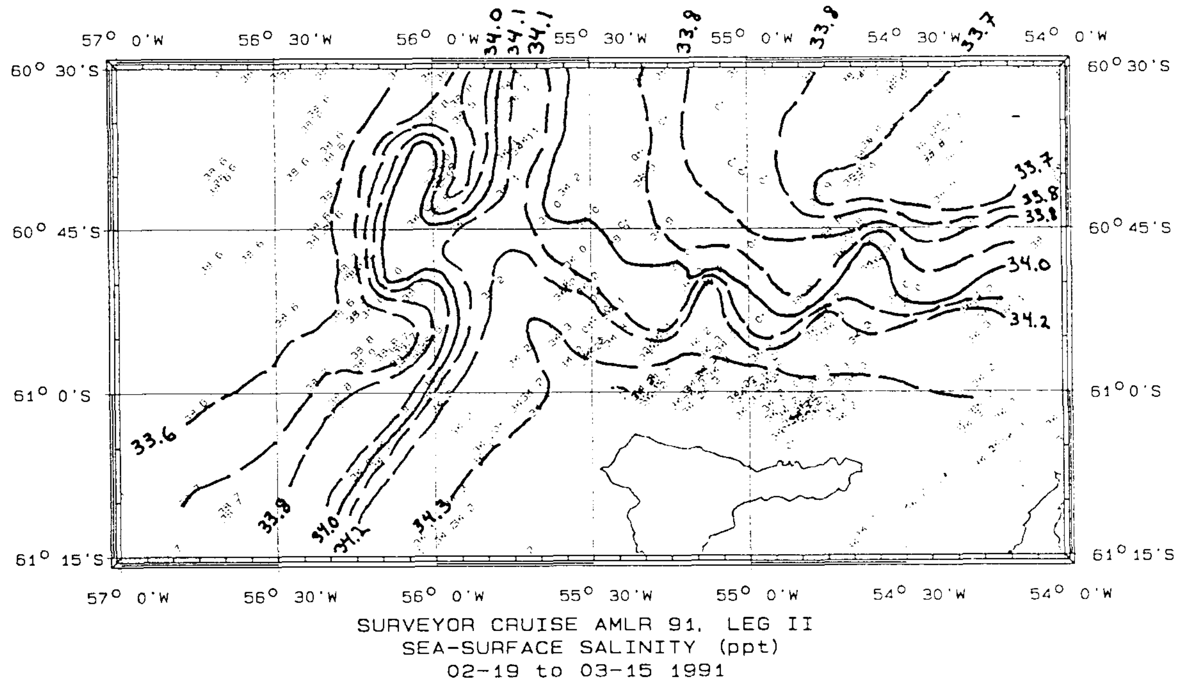


Figure 3.3.9 Leg II sea surface salinity in parts per thousand.

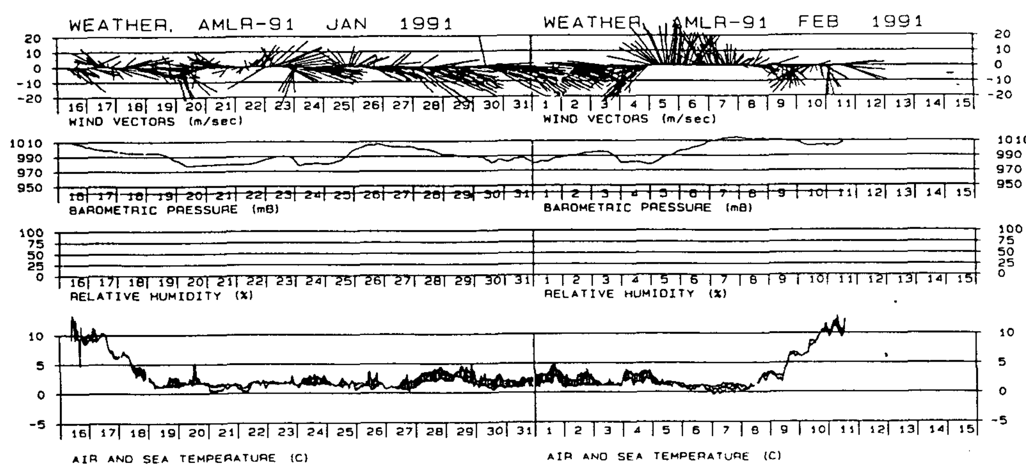


Figure 3.3.10 Leg I surface winds, barometric pressure, air and sea temperature.

**3.4 Phytoplankton; submitted by Osmund Holm-Hansen, E. Walter Helbling, Virginia Villafañe, Sergio Rosales, and Christian Bonert, Scripps Institution of Oceanography.**

**3.4.1 Objectives:** The overall objective of our project was to document the food reservoir available to zooplankton throughout the AMLR study area and to see if food availability was related to the observed distribution and abundance of krill. Specific objectives included (a) determination of the distribution of phytoplankton in the upper 250 meters of the water column in regard to total cellular organic carbon, cell size distribution, and floristic composition, (b) determination of the rate of photosynthesis as a function of solar irradiance as well as the integrated rate of primary production in the water column, and (c) analysis of the importance of physical mixing processes as factors controlling the distribution of phytoplankton and concomitantly the rate of primary production.

**3.4.2 Accomplishments:** The following types of data were obtained:

**Photosysnthetic pigments:** Chlorophyll-a (chl-a) concentrations were measured in water samples from 10 depths (surface to 100 m), which were obtained from CTD casts at 179 stations (50 in Survey A, 13 in Survey B, 22 in Survey C, 49 in Survey D, and 45 additional stations (X series)). In addition, selected water samples were filtered and the particulate material frozen in liquid nitrogen at -180°C for later determination of (a) all cellular pigments by High Performance Liquid Chromatography (HPLC) procedures and (b) the *in vivo* absorption spectrum from 280 to 750 nm. The distribution of phytoplankton biomass as indicated by chl-a concentrations was also estimated in surface waters throughout the entire cruise by measurement of *in vivo* chl-a fluorescence on ship's intake water. In addition, a submersible fluorometer attached to the rosette provided a profile of chl-a concentrations from the surface to 750 m depth (or close to the bottom for shallower stations) at all CTD stations.

**Rate of primary production:** During Surveys A and D water was obtained from eight depths from one of the morning CTD casts, and the rate of primary production was determined in a deck incubator, which simulates light levels found throughout the euphotic zone. This was done at 10 stations on each survey. As the ultraviolet portion of the solar spectrum (280 to 400 nm) is known to inhibit rates of photosynthesis in the upper 10-15 m of the water column, special experiments (using quartz glass vessels) were also carried out to estimate the degree of inhibition of photosynthesis (and hence less primary production) caused by UV radiation.

**Biomass and organic carbon concentrations:** For food web considerations, the available food supply is generally described in terms of particle size and organic carbon content. The following measurements were made in this regard: (a) total particulate organic carbon (POC); (b) the carbon/chl-a ratio in phytoplankton cultures grown for 1-2 weeks, so that all our chl-a data can be used to estimate biomass in terms of organic carbon; (c) Adenosine triphosphate (ATP) in selected water samples, so as to permit estimation of total microbial biomass, as well as to provide estimates of carbon/chl-a ratios independent of the estimates based on cultures; (d) transmissometer data (obtained continuously on ship's intake water, as well as during all profiles with the CTD-rosette unit), which can be used to estimate POC/particle concentrations. Also, water samples were preserved for later microscopic determination of phytoplankton cell numbers, sizes and shapes, from which total cellular volumes and organic carbon can be estimated.

**Solar irradiance:** Special attention was given to collecting data on the photosynthetic response as a function of incident radiation as well as the rate of attenuation of sunlight in the water column. Measurements included: (a) continuous monitoring of incident radiation with one PAR (Photosynthetically Available Radiation) meter (400 to 700 nm), as well as with two pyrheliometers; (b) continuous recording of PAR in the upper water column with every CTD cast; (c) recording of total PAR during on-deck incubations with an integrating light meter attached to the deck incubator.

**Species composition of phytoplankton crop:** Water samples were preserved for later microscopic determination of the dominant algal species, and cell size. Such factors are of significance in regard to krill feeding preferences. During the cruise we also measured the chl-a concentration in the nanoplankton fraction (less than 20 $\mu$m in size) in addition to the total crop.

**Nutrients:** Water samples from selected stations were frozen and will be analyzed later for nitrate, nitrite, silicic acid, and reactive phosphate. These data will be useful in estimating loss of photosynthate from the euphotic zone as well as serving as a chemical indicator of the various water masses found within the AMLR study area.

**3.4.3 Disposition of data and samples:** Water samples for inorganic nutrient assay were left at the Universidad Católica de Valparaiso, Chile, where they will be processsed with an autoanalyzer. Except for those samples processed during the cruise (e.g., all chl-a samples), all others will be returned to SIO for final processing. The entire data set, when completed, will be available to NOAA and to all AMLR investigators, either in hard copy or on computer disk.

**3.4.4 Tentative conclusions:** The statements below are mostly based on the chl-a distribution patterns, for which all data have been processed on the ship. Examination of the data suggests:

**Leg I:**

a) Although there is much spatial variability in phytoplankton biomass within the AMLR study area (see Figure 3.4.1 for surface chl-a concentrations, Figure 3.4.2 for integrated values from 0 to 100 m depth, and Figure 3.4.3 for chl-a in nanoplankton), the entire area seems to be considerably richer than nearby areas in the Bellingshausen Sea, Weddell Sea, Scotia Sea, or Drake Passage. The areas of highest phytoplankton standing stock are located south of Elephant Island and north-northwest of Elephant Island close to the continental shelf drop-off.

b) At most stations phytoplankton seem to be fairly uniformly distributed in an upper mixed layer which usually extends to 20-40m depth, with the biomass falling off rapidly below that depth. One area which does not follow this pattern is the shelf north of Elephant Island. In this region the phytoplankton biomass remains high to much greater depths; at stations A43 (Figure 3.4.4), for instance, the chl-a values at 250m depth are about 50% of the surface values. The appearance of both the *in vivo* fluorometer and transmissometer traces at these stations also are very different from most stations in that they are very jumpy and irregular. We do not know the cause(s) of these irregular traces, but it might be due to a clumpy characteristic of chain-forming diatoms. Analysis of our preserved water samples hopefully will provide us with an answer to this question. The fact that these stations either coincided or were close to the area of targeted krill netting is provocative in that there may be some causal relationship between the unusual biological results and dynamic physical processes in this region. Analysis of the entire AMLR data set hopefully will enlighten us on this point.

c) One has to be careful in interpreting the trace from the submersible fluorometer in the upper 20m of the water column because solar radiation decreases the fluorescence yield of chlorophyll-a. This is evident by the data in Figures 3.4.5 and 3.4.6, which show that at night (Figure 3.4.5D) the fluorescence trace parallels the extracted chl-a values (which are quantitative and accurate), whereas in bright sunshine (Figure 3.4.6D) the fluorescence values in the upper 10-30 m are very low as compared to the extracted chl-a values. The degree of depression in chl-a fluorescence seems to be directly correlated with the intensity of solar radiation and, judging from the depth characteristics of this suppression, is most likely related to the UV portion of the spectrum (below 400 nm).

d) Preliminary data obtained with a scintillation counter aboard ship indicates that the assimilation numbers obtained with a deck incubator (with neutral density screening) are high (2 to 3 mg carbon fixed per mg chl-a per hour for all the higher light samples), and thus these phytoplankton crops must be viewed as being very healthy and capable of high photosynthetic rates. This is in contrast to published data from this area which suggest that assimilation numbers were low (less than 0.5) and that much of the measured chl-a was in free chloroplasts, which had been released from diatoms as a result of stormy weather conditions. Radiocarbon data, coupled with all phytoplankton biomass estimates, indicates that productivity in the AMLR study area is significantly higher than reported for most Antarctic waters.

**Leg II:**

a) Most of the study area showed a small increase in chl-a concentrations as compared to the values present in Leg I. During Survey D (Figure 3.4.1B, 3.4.2B), three areas of high phytoplankton standing stock were observed: One area was to the north-northwest of Elephant Island close to the continental shelf drop-off. This feature was persistent since Survey A, but in Leg II it appeared displaced a little bit to the west as compared to its position in Leg I. The phytoplankton crop in this area was composed mainly of small cells in the nanoplankton fraction (size less than 20 $\mu$m), which accounted for more than 70 % of the total chl-a (Figure 3.4.3B). The second area was to the south of Elephant and Clarence Islands. In this region we found the highest chl-a concentration with a value of 4.2 $\mu$g chl-a/l, with the nanoplankton fraction accounting for less than 50 % of the total chl-a. The third area, located north of King George Island, had 2.1 $\mu$g chl/l. The phytoplankton crop was mainly composed of big cells, with the nanoplankton accounting for less than 40 % of the total chl-a.

b) At most stations, phytoplankton seems to be fairly uniformly distributed in an upper mixed layer which usually extends to 30-50m depth. However, at some of the inshore stations north of Elephant Island (i.e. C10, C16, etc.), phytoplankton biomass remains high to much greater depths, which was consistent with the findings in Leg I.

c) The mean solar irradiation levels (PAR) decreased to almost half of the values observed during Leg I (76 vs.42 Ein/m$^2$/day). However, from observations of *in vivo* fluorescence and extracted chl-a it is apparent that photo-inhibition is still occurring in the upper 20 m of the water column.

d) From the two transects done north of Elephant Island, it seems that higher phytoplankton biomass was associated with the shelf drop-off. However, the western transect showed much higher values of chl-a than the eastern one (maximum values 3 ug/l and 0.57 ug/l, respectively). In the western transect (station X31 to X39) chlorophyll-a values were stratified between stations X34-X38 (water depth 670m and 3200m, respectively), but they were distributed more homogeneously throughout the water column at both the shallower and deeper stations.

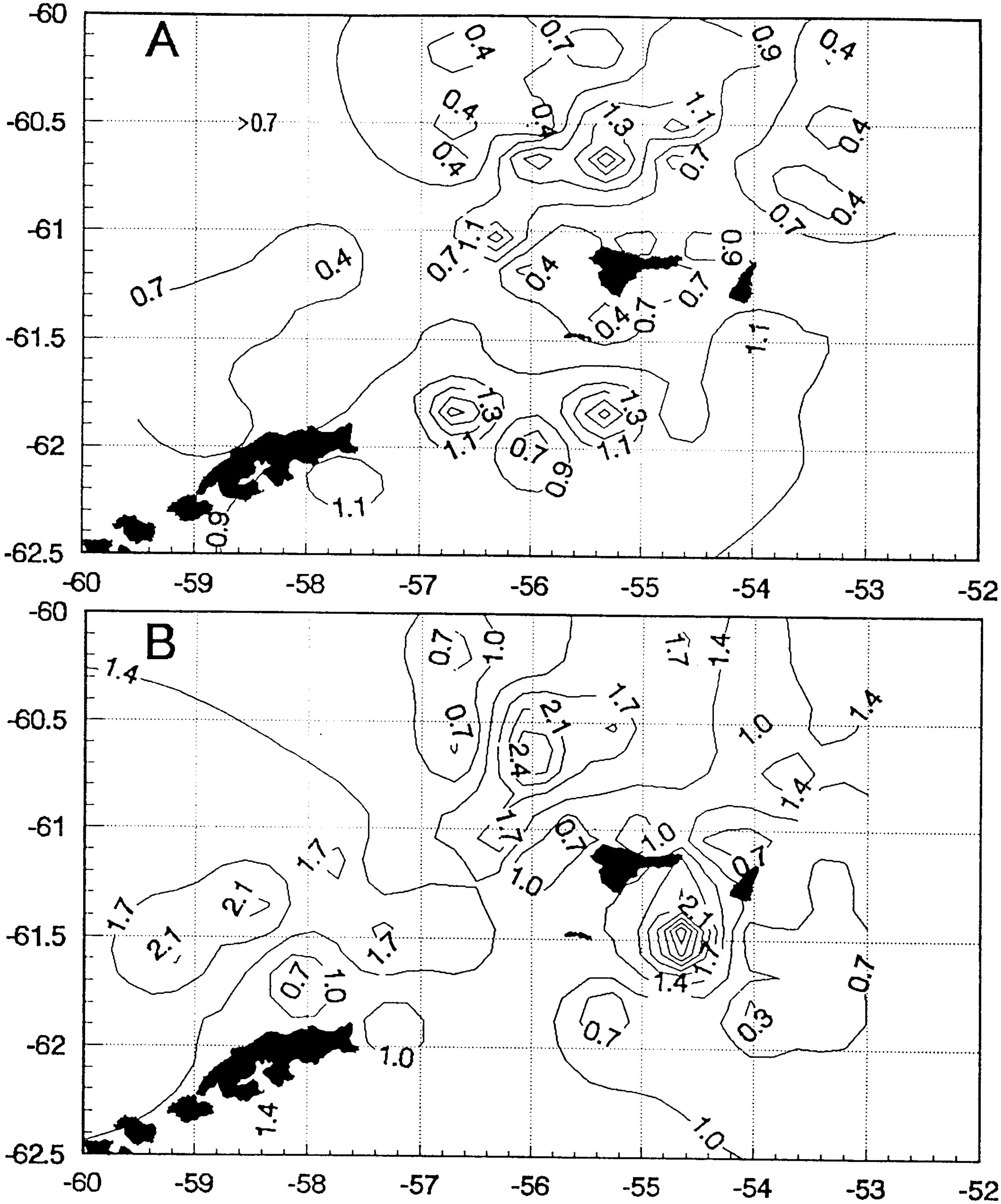


Figure 3.4.1 Distribution of chl-a (mg/l) at 5m depth during the two large-area surveys.
A) Survey A; B) Survey D.

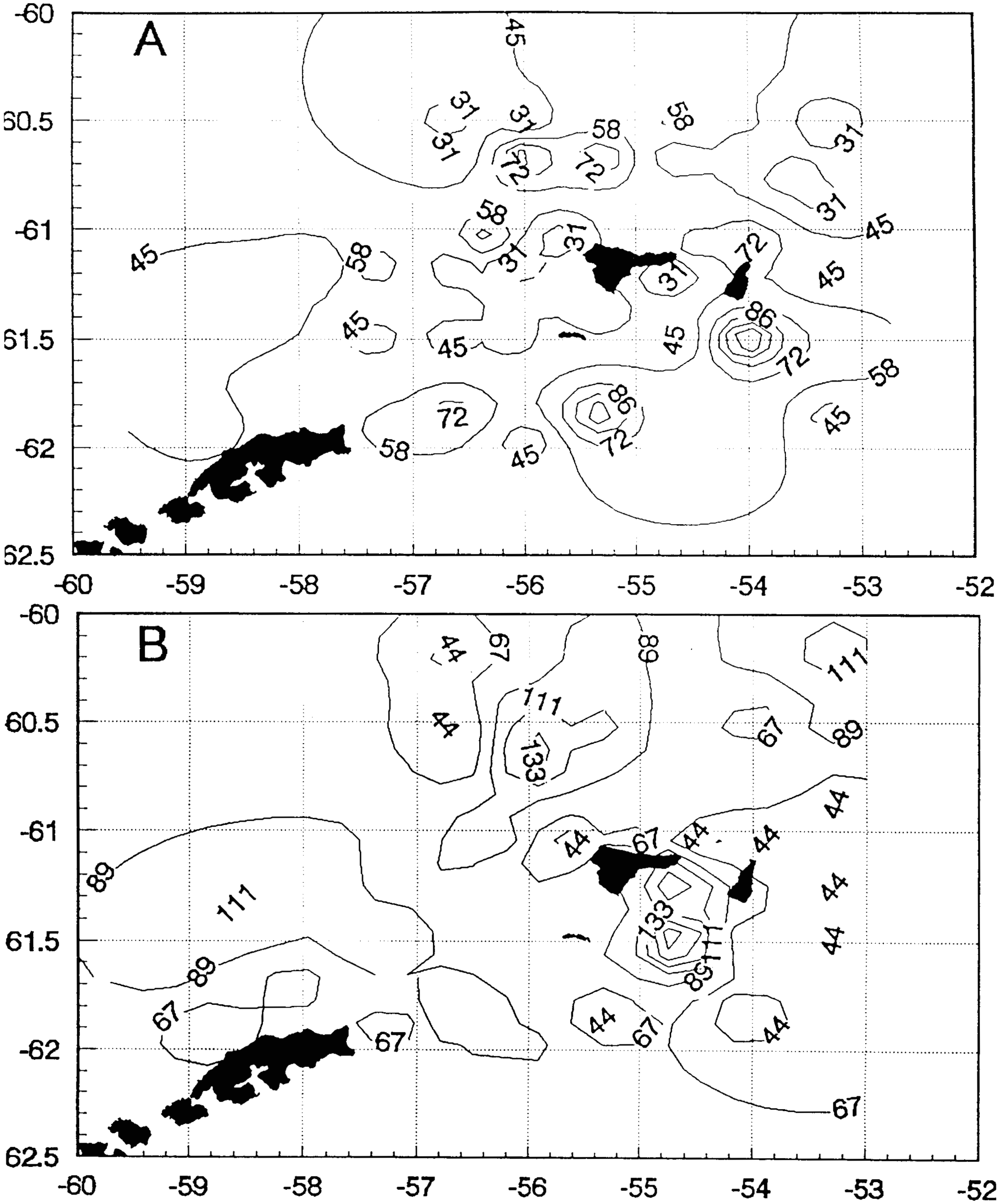


Figure 3.4.2 Distribution of integrated chl-a (mg/m$^2$) from 0 to 100m depth during the two large-area surveys. A) Survey A; B) Survey D.

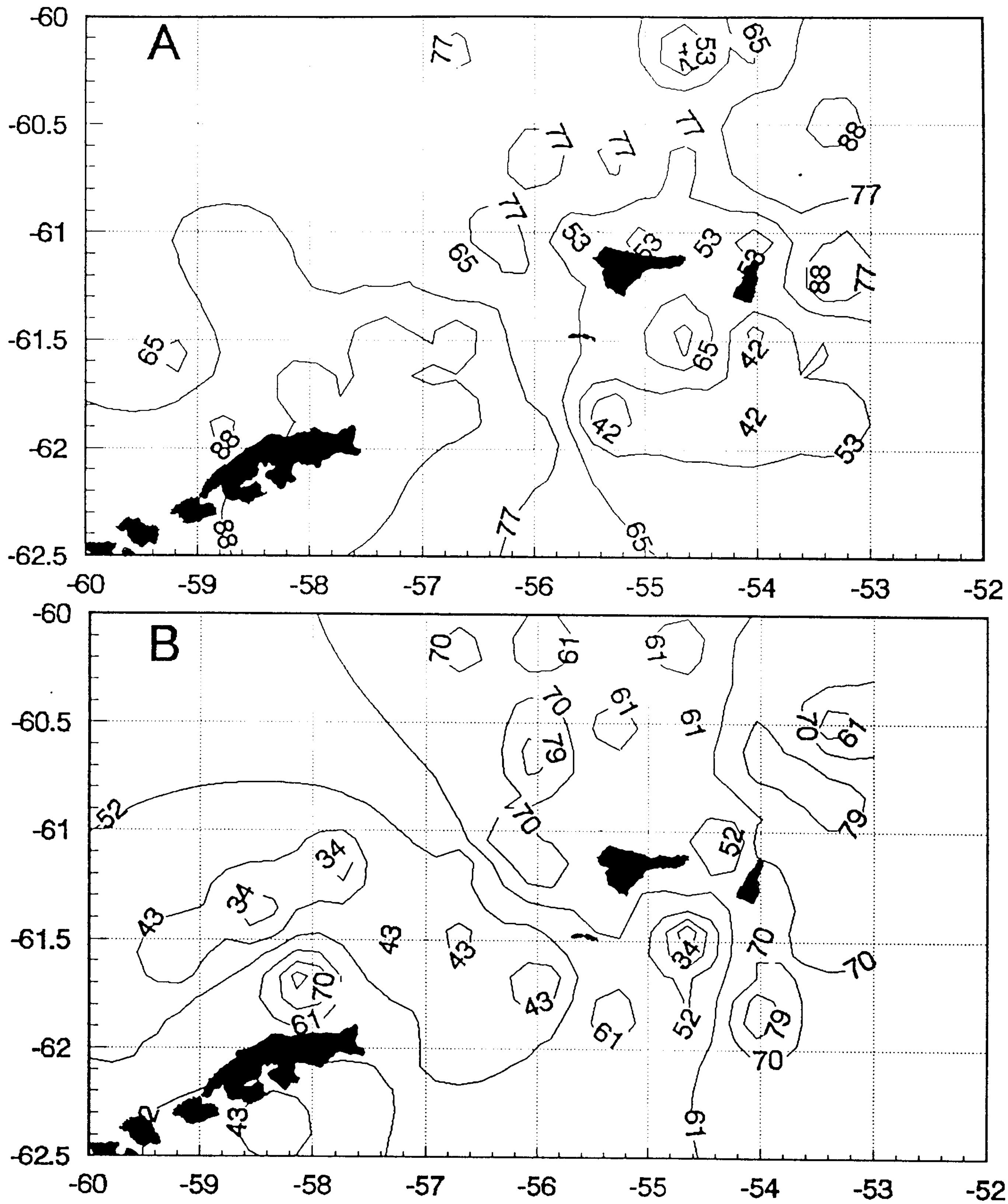


Figure 3.4.3 Distribution of chl-a in nanoplankton (less than 20mm) as a percentage of the total chl-a during the two large-area surveys. A) Survey A; B) Survey D.

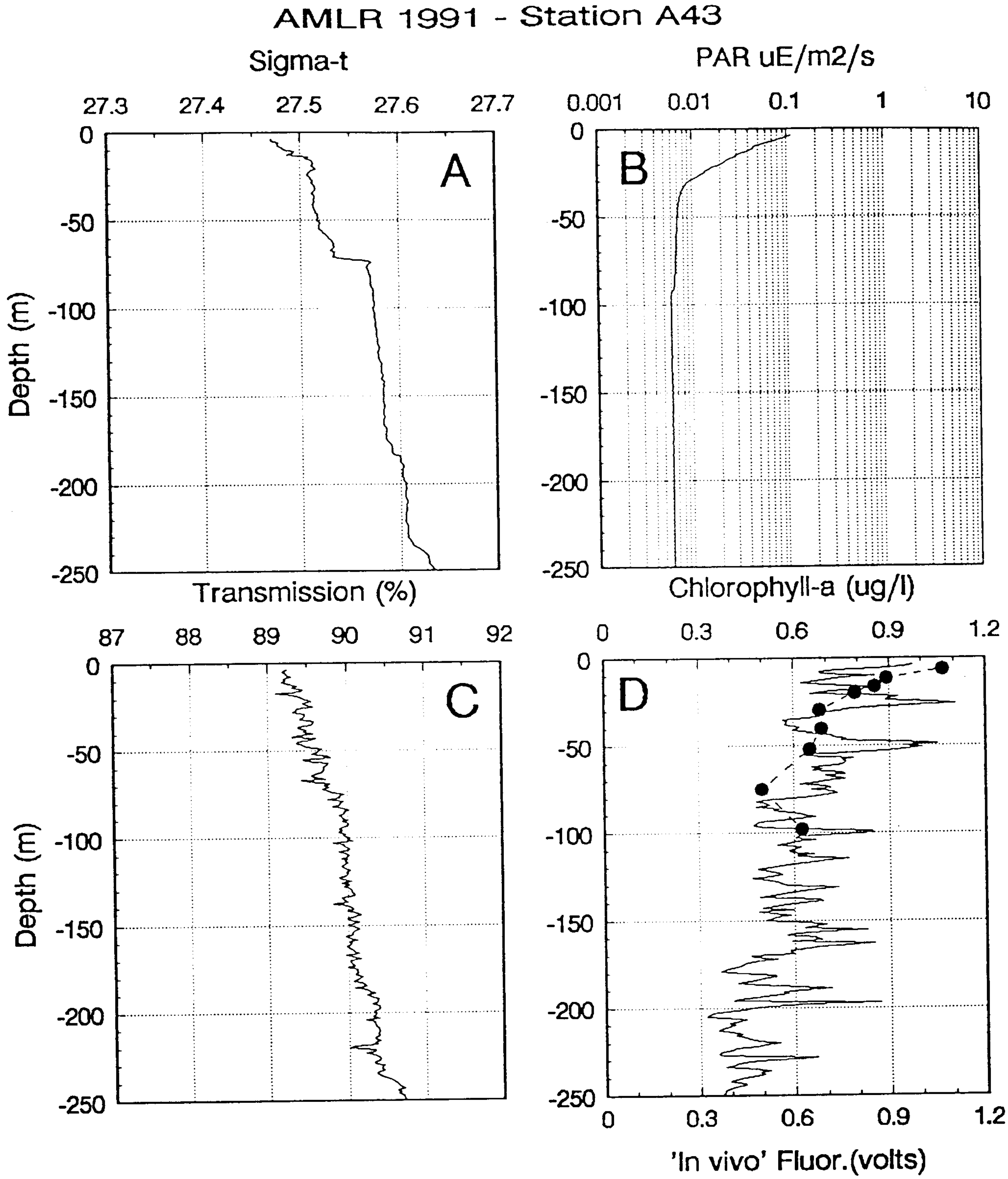


Figure 3.4.4 Physical-biological charactersitics of the upper water column at Station A43 during Survey A. A) Sigma-t; B) Photosynthetically Available Radiation (PAR) in mEinstein/m²/s; C) Light transmission (%); D) Distribution of chl-a as measured on extracted samples (solid dots) and estimated by *in-situ* fluorescence with a pulsed fluorometer (continuous line).

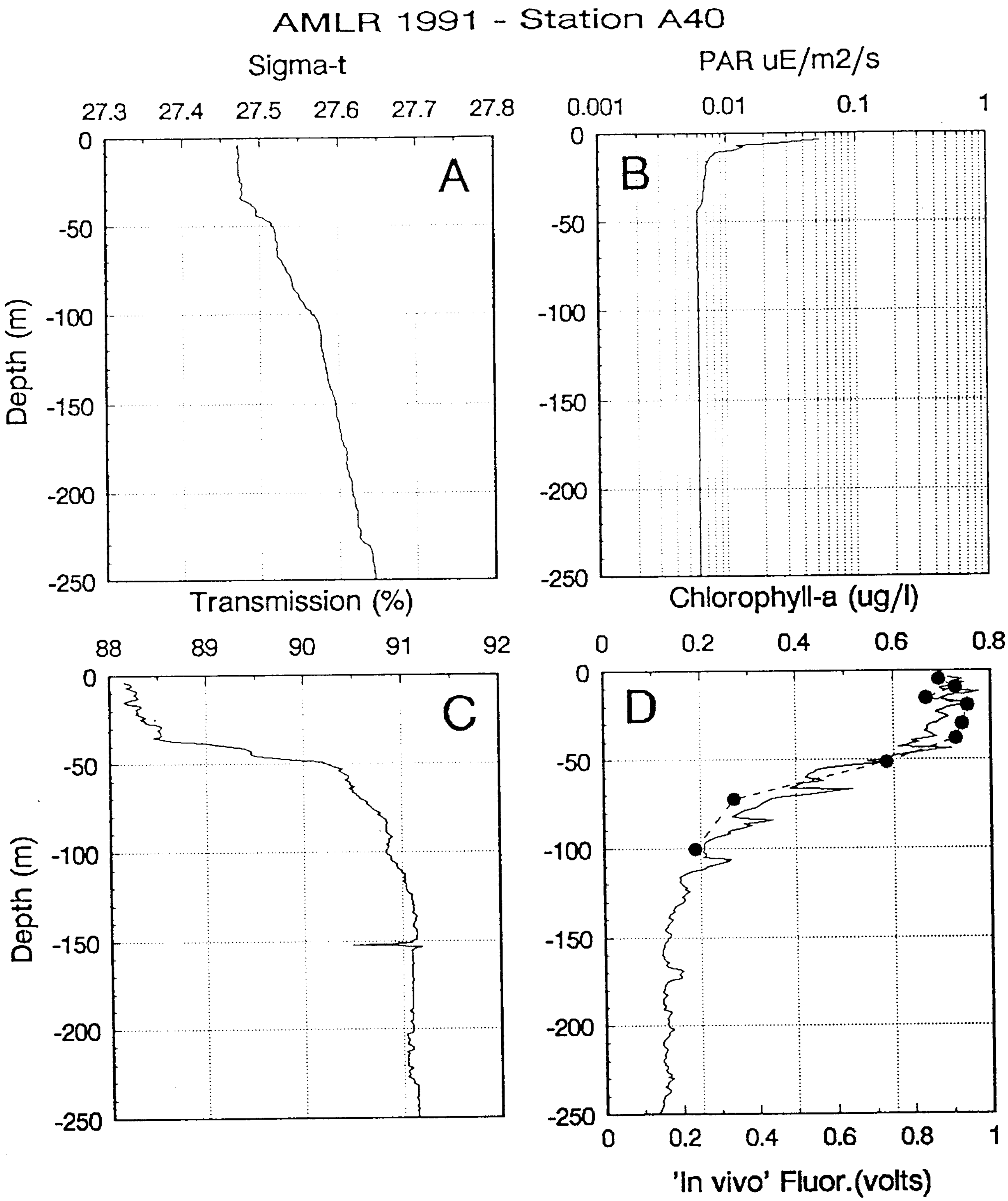


Figure 3.4.5 Physical-biological charactersitics of the upper water column at Station A40 during Survey A. A) Sigma-t; B) Photosynthetically Available Radiation (PAR) in mEinstein/m²/s; C) Light transmission (%); D) Distribution of chl-a as measured on extracted samples (solid dots) and estimated by *in-situ* fluorescence with a pulsed fluorometer (continuous line).

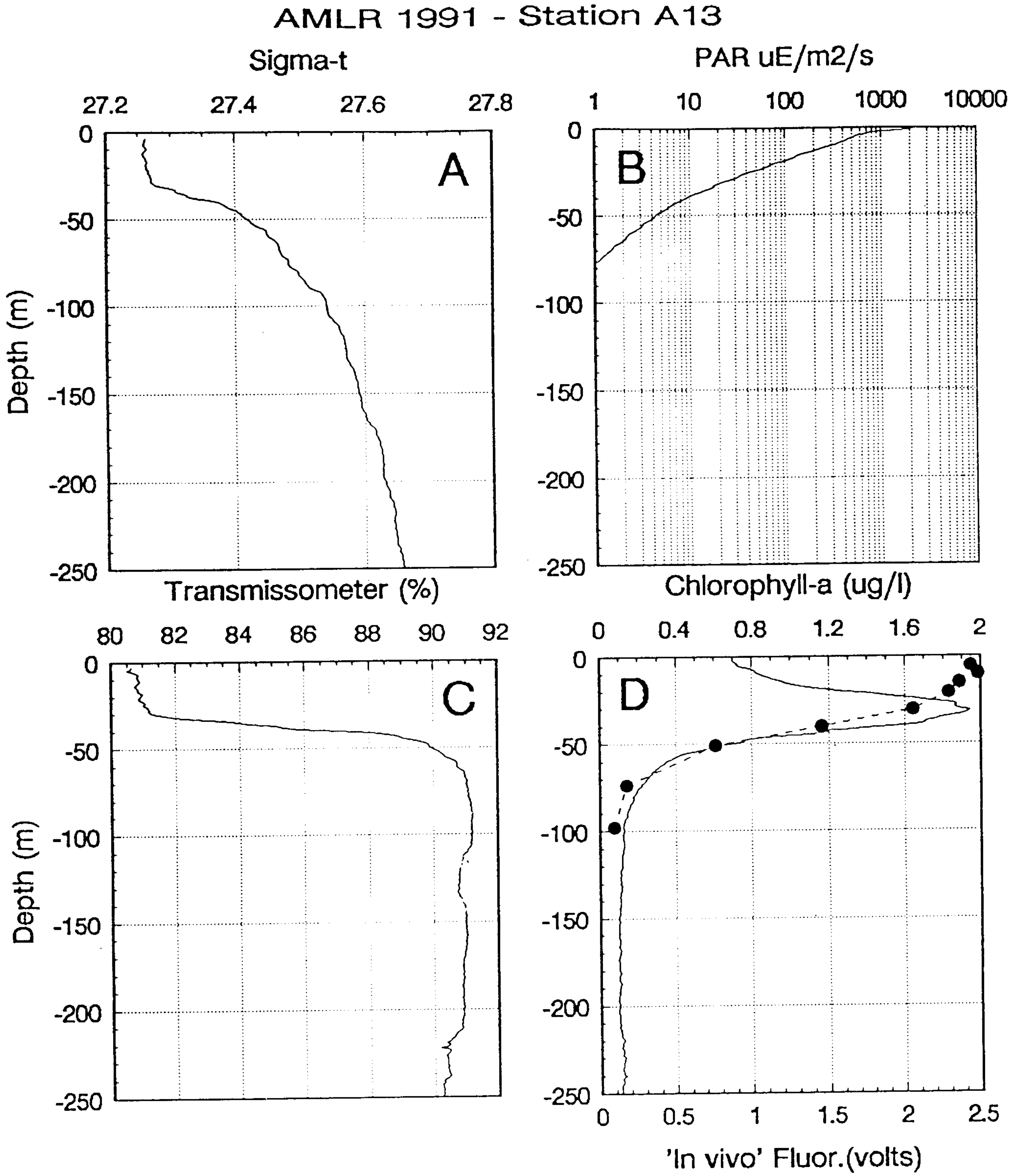


Figure 3.4.6 Physical-biological charactersitics of the upper water column at Station A13 during Survey A. A) Sigma-t; B) Photosynthetically Available Radiation (PAR) in $\mu$Einstein/m$^2$/s; C) Light transmission (%); D) Distribution of chl-a as measured on extracted samples (solid dots) and estimated by *in-situ* fluorescence with a pulsed fluorometer (continuous line).

**3.5 Hydroacoustic survey for prey organisms; submitted by Michael Macaulay and Ole Mathisen, University of Washington.**

**3.5.1 Objectives:** The field research involved a quantitative hydroacoustic survey of the population of krill (*Euphausia superba*) and other targets in the vicinity King George Island and Elephant Island. The primary objective was to describe the distribution and abundance of acoustically detectable targets which might be used as prey by the seals and penguins at Seal Island. This survey provides hydroacoustic data comparable to that resulting from the 1987-1990 AMLR surveys.

**3.5.2 Accomplishments:** Hydroacoustic sampling was done with two frequencies, 120 kHz and 200 kHz. These two frequencies have been used on all of the AMLR surveys to date. The method of data analysis is echo integration, which requires periodic sampling of the ensonified population for determination of length-frequency. Length-frequency data are used to calculate target-strength from established equations; the target-strength is then used to convert measurements of volume scattered sound into biomass estimates. The methods used, both hardware and software, are the same as have been used in previous surveys. The distribution of biomass along the trackline was contoured using a commercial software package. Contouring was done using a Kriging method and involves a least squares fit to the trends in the data; contour interval is 50 tons/n.mi.$^2$

Blocks used to calculate biomass are indicated on Figures 3.5.1 and 3.5.3. For 1991, these areas are designated "A" through "M" in an W-E direction and "1" through "5" in a N-S direction (eg. the northwest corner is block A1 and southeast corner is M5). The survey blocks used in 1990 were designated "C" through "F" in an W-E direction and "1" through "4" in a N-S direction (eg. the northwest corner is block C1 and southeast corner is F4). The total area in each block is 450 nm2 for the 1991 blocks and 900 nm2 for the 1990 blocks. These blocks correspond to blocks used to compute biomass in this area since 1987. The choice of size and positioning of the blocks was based on comparisons with other surveys in the area conducted since 1981. The data can easily be re-distributed in any convenient arrangement of area. The acoustic data are recorded in digital format so that other quantitative post-cruise analysis might be performed.

**Leg I:** Both survey grids proposed for this leg were completed, although the fine scale sections of Survey A and Survey B were modified from that originally given in the cruise plan to a zig-zag pattern, due to weather constraints on ship operations. 120 kHz and 200 kHz signals were recorded digitally for a total of 258 hours of recorded quantitative data for use in subsequent analyses. The sampling depths were from 6-10 m below the surface (nominal V-fin depth) to 250 m (limit of integration) or to the bottom whichever occurred first. The 200 kHz signal was completely analyzed in real-time to acoustic biomass/m$^3$ in 1 m depth bins for each 30 seconds along the trackline, using an assumed value for the target strength of -35.93 dB/kg (basically the BIOMASS value for a kilogram of 40-45mm krill). Concentrations of salps and other targets considered not to be krill were removed from the results presented in this report. The results of the analyses were made available on a daily basis. While the analyses were being performed, a real-time display of the vertical and horizontal distribution of the prey abundance was available for inspection. This display facilitated selection of sampling sites for bongo, MOCNESS and IKMT net deployment to obtain samples of prey and other organisms. The final analyses for Survey A are presented in Tables 3.5.1 and 3.5.2 and Figure 3.5.2; results for Survey B are shown in Figure 3.5.4.

The distribution of biomass by block on Survey A was computed using 100m spacing of the trackline data for the total survey area and for an area comparable to last year's Elephant Island survey (Table 3.5.1). Biomass was also computed using the same method as last year (ie. based on nautical mile spacing along the cruise track, Table 3.5.2). The results show that there is a 2.8 fold increase in the estimated biomass when using the finer spaced observations for the entire survey and for the Elephant Island area alone. This is accompanied by a reduction in the variance of the estimate (from 75% to 23%) as predicted by the statistical analysis performed on last year's four surveys. Those analyses indicated that increasing the number of observations and decreasing the block areas used to compute biomass would reduce the components of variance due to these effects and would reduce the overall variance of the estimated biomass. The number of data values used was expanded approximately ten-fold and the size of the area in each block was reduced to half the 1990 value.

In addition to the survey grids, data also were collected and analyzed for the time spent fishing horizontal MOCNESS tows which sampled layers of acoustic targets. Estimates of mean abundance as geometric means, arithmetic means, and peak values for depth-time bins corresponding to the net tows were calculated both with and without an offset in time to compensate for the MOCNESS net being behind the acoustic system. Color echograms of MOCNESS tows also were made and these analyses provided to J. Wormuth for comparison with the net catch data.

**Leg II:** During Leg II, data collected on the first survey (Survey C) were not analyzed because of problems with the V-fin face plate. Damage to the fin during rough seas and failure of the 200 kHz transducer resulted in some loss of data during the second survey (Survey D) The 120 kHz transducer was turned off during much of Survey D because of interference with the Southwest Fisheries Center V-fin. Signals at 120 and 200 kHz were recorded digitally for a total of 139 hours of recorded quantitative data for use in subsequent analyses. The final analyses for Survey D are presented in Tables 3.5.3 and 3.5.4 and Figure 3.5.5.

The distribution of biomass by block on Survey D was computed using 100m spacing of the trackline data for the total survey area and for an area comparable to last year's Elephant Island survey (Table 3.5.3). Biomass was also computed using the same method as last year (ie. based on nautical mile spacing along the cruise track, Table 3.5.4).

**3.5.3 Disposition of Data:** The files of analyzed data will be made available to other investigators in the form of MS-DOS format ASCII files. Acoustic surveys generate a large amount of data. For example, from Leg I, there are approximately 17 megabytes of data from the first survey, 8 megabytes from the second survey for a total of 54 megabytes. This would be approximately 70 megabytes if the files were turned into ASCII data. All data are available from Dr. Michael Macaulay, University of Washington, Applied Physics Laboratory, HN-10, Seattle WA 98195.

**3.5.4 Tentative conclusions:** The biomass of krill in the Elephant Island area during Survey A was about the same as last year (0.5 to 1.0 million tons in 1990 and 0.6 million tons by the same method for 1991) and, in fact, very similar to an intermediate value between last years first and second surveys. Survey A was conducted at approximately the same seasonal timing as the mid-point between last years surveys. No large swarms were observed. The total biomass by the new method is 2.7 million tons in the entire survey area and 1.97 million tons in the Elephant Island area. Results from Survey B suggested that the krill were similarly distributed in the areas which overlapped those from Survey A. This is in contrast to the dramatic changes in distribution observed last year in the same area. Approximately 700,000 tons of krill were found around King George Island during Survey A, which is almost 30% of the amount found in the entire survey area. The use of finer scale data and smaller blocks of area clearly reduces the variance for the estimated total biomass (from 75% to 23%), thus the use of units of observation on scales less than nm intervals is recommended.

The total biomass for Survey D during Leg II was slightly less than that of Survey A during Leg I. However, the biomass for the Elephant Island area was higher than Leg I due to a high abundance of krill in deeper water northeast of the island. Other areas of increased density were located east, southeast, and southwest of Elephant Island. The total biomass was lower because very few krill were detected around King George Island. No large swarms were observed. Survey D was later in the year than any previous AMLR survey.

Table 3.5.1 Total survey area biomass by block. Survey A 1991, based on 100 m data.

| Box | Distance | Area | x-bar | Biomass | Range | |
|---|---|---|---|---|---|---|
| | n.mi. | $n.mi.^2$ | $tons/n.mi.^2$ | tons | tons | tons |
| A4 | 17.630 | 337.000 | 484.81 | 163380.0 | 130480.0 | 196260.0 |
| B3 | 17.290 | 150.000 | 67.97 | 10196.0 | 5600.0 | 14790.0 |
| B4 | 17.290 | 440.000 | 97.28 | 42803.0 | 19170.0 | 66430.0 |
| C3 | 20.550 | 450.000 | 235.41 | 105930.0 | 86190.0 | 125670.0 |
| C4 | 15.380 | 300.000 | 45.44 | 13633.0 | 10700.0 | 16560.0 |
| D3 | 13.580 | 450.000 | 80.77 | 36347.0 | 25630.0 | 47060.0 |
| D4 | 14.880 | 300.000 | 25.85 | 7755.0 | 4320.0 | 11180.0 |
| D5 | 11.060 | 300.000 | 493.60 | 148080.0 | 103910.0 | 192240.0 |
| E3 | 13.450 | 450.000 | 100.99 | 45448.0 | 34400.0 | 56490.0 |
| E4 | 29.380 | 450.000 | 281.36 | 126610.0 | 98550.0 | 154670.0 |
| E5 | 11.620 | 225.000 | 176.90 | 39802.0 | 17590.0 | 62000.0 |
| F1 | 28.630 | 450.000 | 87.96 | 39584.0 | 30590.0 | 48570.0 |
| F2 | 18.500 | 225.000 | 436.71 | 98261.0 | 78450.0 | 118060.0 |
| F3 | 27.290 | 450.000 | 125.98 | 56689.0 | 48520.0 | 64850.0 |
| F4 | 22.080 | 450.000 | 104.04 | 46820.0 | 36750.0 | 56880.0 |
| G1 | 26.040 | 450.000 | 53.54 | 24092.0 | 20060.0 | 28110.0 |
| G2 | 34.790 | 450.000 | 585.17 | 263330.0 | 222110.0 | 304540.0 |
| G3 | 21.090 | 300.000 | 44.53 | 13360.0 | 6570.0 | 20140.0 |
| G4 | 34.130 | 450.000 | 44.93 | 20218.0 | 11650.0 | 28770.0 |
| H1 | 29.290 | 450.000 | 131.68 | 59254.0 | 50600.0 | 67900.0 |
| H2 | 36.640 | 450.000 | 278.60 | 125370.0 | 100720.0 | 150010.0 |
| H3 | 16.580 | 300.000 | 117.20 | 35160.0 | 11760.0 | 58550.0 |
| I1 | 22.070 | 450.000 | 73.60 | 33118.0 | 17910.0 | 48310.0 |
| I2 | 28.630 | 450.000 | 644.65 | 290090.0 | 239830.0 | 340340.0 |
| I3 | 12.140 | 300.000 | 1.15 | 343.8 | 140.0 | 530.0 |
| I4 | 29.000 | 450.000 | 14.15 | 6366.7 | 4570.0 | 8160.0 |
| J1 | 22.130 | 450.000 | 175.30 | 78884.0 | 50650.0 | 107110.0 |
| J2 | 31.650 | 450.000 | 153.10 | 68893.0 | 56340.0 | 81440.0 |
| J3 | 22.840 | 450.000 | 22.78 | 10253.0 | 7880.0 | 12620.0 |
| K1 | 14.670 | 300.000 | 892.33 | 267700.0 | 220010.0 | 315380.0 |
| K2 | 39.590 | 450.000 | 170.31 | 76641.0 | 63920.0 | 89350.0 |
| K3 | 22.780 | 450.000 | 61.71 | 27768.0 | 21780.0 | 33750.0 |
| K4 | 29.740 | 450.000 | 60.36 | 27162.0 | 17270.0 | 37040.0 |
| L1 | 34.451 | 450.000 | 138.11 | 62151.0 | 48790.0 | 75500.0 |
| L2 | 29.670 | 450.000 | 45.15 | 20319.0 | 17200.0 | 23430.0 |
| L3 | 27.570 | 450.000 | 68.34 | 30751.0 | 19800.0 | 41700.0 |
| L4 | 12.270 | 300.000 | 30.27 | 9080.3 | 5600.0 | 12560.0 |
| M1 | 23.970 | 450.000 | 44.04 | 19820.0 | 13780.0 | 25850.0 |
| M2 | 22.660 | 450.000 | 95.45 | 42952.0 | 34590.0 | 51300.0 |
| M3 | 27.260 | 450.000 | 52.35 | 23556.0 | 14190.0 | 32910.0 |
| M4 | 24.190 | 450.000 | 209.38 | 94220.0 | 78740.0 | 109690.0 |
| Total for blocks F1 - M4, equivalent to 1990 survey area: | | | | | | |
| | 772.342 | 12525.000 | | 1972207.0 | 1550770.0 | 2393350.0 |
| Total for blocks A4 - M4, 1991 Survey A: | | | | | | |
| | 954.452 | 16377.000 | | 2712191.0 | 2087310.0 | 3336700.0 |

Table 3.5.2 Total survey are biomass by block. Survey A 1991, based on nm data.

| Box | Distance | Area | x-bar | Biomass | Range | |
|---|---|---|---|---|---|---|
| | n.mi. | n.mi.$^2$ | tons/n.mi.$^2$ | tons | tons | tons |
| X4 | 17.460 | 337.000 | 137.18 | 46228.0 | -14670.0 | 107120.0 |
| A3 | 37.440 | 600.000 | 75.22 | 45134.0 | -10740.0 | 101010.0 |
| A4 | 32.420 | 740.000 | 5.34 | 3948.0 | 1110.0 | 6770.0 |
| B3 | 27.550 | 900.000 | 38.91 | 35018.0 | 18770.0 | 51250.0 |
| B4 | 44.950 | 750.000 | 65.64 | 49230.0 | 13370.0 | 85080.0 |
| B5 | 21.330 | 525.000 | 141.22 | 74139.0 | -51020.0 | 199290.0 |
| C1 | 52.270 | 900.000 | 16.67 | 15002.0 | 9600.0 | 20390.0 |
| C2 | 54.250 | 675.000 | 183.44 | 123820.0 | 29410.0 | 218230.0 |
| C3 | 47.090 | 750.000 | 36.20 | 27150.0 | 7010.0 | 47280.0 |
| C4 | 57.490 | 900.000 | 14.44 | 12993.0 | 6050.0 | 19920.0 |
| D1 | 51.460 | 900.000 | 34.22 | 30801.0 | 12700.0 | 48890.0 |
| D2 | 62.440 | 900.000 | 165.96 | 149360.0 | 79160.0 | 219550.0 |
| D3 | 28.550 | 600.000 | 1.75 | 1052.0 | -650.0 | 2750.0 |
| D4 | 29.690 | 450.000 | 2.82 | 1268.0 | -120.0 | 2650.0 |
| E1 | 35.670 | 750.000 | 208.98 | 156740.0 | 41150.0 | 272310.0 |
| E2 | 71.420 | 900.000 | 52.03 | 46825.0 | 29410.0 | 64230.0 |
| E3 | 139.180 | 900.000 | 70.03 | 63030.0 | 36030.0 | 90020.0 |
| E4 | 36.900 | 600.000 | 2.89 | 1735.5 | 410.0 | 3050.0 |
| F1 | 58.710 | 900.000 | 28.95 | 26052.0 | 11450.0 | 40640.0 |
| F2 | 50.160 | 900.000 | 30.12 | 27108.0 | 12770.0 | 41440.0 |
| F3 | 57.060 | 900.000 | 0.08 | 75.2 | 0.0 | 140.0 |
| F4 | 38.080 | 750.000 | 8.02 | 6018.8 | 2720.0 | 9310.0 |
| Total for blocks C1 - F4, equivalent to 1990 survey: | | | | | | |
| | 870.420 | 12675.000 | | 689030.6 | 277100.0 | 1100800.0 |
| Total for blocks X4 - F4, 1991 Survey A | | | | | | |
| | 1051.570 | 16527.000 | | 942727.6 | 233920.0 | 1651320.0 |

Table 3.5.3 Acoustic estimate of krill biomass by block. Survey D 1991, based on 100m sample data.

| Box | Distance | Area | x-bar | Biomass | Range | |
|---|---|---|---|---|---|---|
| | n.mi. | n.mi.$^2$ | tons/n.mi.$^2$ | tons | tons | tons |
| A4 | 18.740 | 337.0 | 40.16 | 13535.0 | 11320.0 | 15740.0 |
| B3 | 13.900 | 150.0 | 19.58 | 2937.8 | 1960.0 | 3910.0 |
| B4 | 20.440 | 440.0 | 23.48 | 10332.0 | 8070.0 | 12590.0 |
| C3 | 14.300 | 350.0 | 1.61 | 562.6 | 440.0 | 680.0 |
| C4 | 10.820 | 300.0 | 580.36 | 174110.0 | 122670.0 | 225540.0 |
| D3 | 13.750 | 350.0 | 20.93 | 7327.2 | 5770.0 | 8880.0 |
| D4 | 17.820 | 350.0 | 138.75 | 48563.0 | 32720.0 | 64400.0 |
| E3 | 12.210 | 350.0 | 139.23 | 48729.0 | 25900.0 | 71550.0 |
| F1 | 26.730 | 450.0 | 35.45 | 15953.0 | 3700.0 | 28200.0 |
| F2 | 13.860 | 350.0 | 23.14 | 8100.4 | 4230.0 | 11970.0 |
| F3 | 27.140 | 450.0 | 90.69 | 40809.0 | 27000.0 | 54610.0 |
| F4 | 19.010 | 450.0 | 144.59 | 65066.0 | 40140.0 | 89980.0 |
| G1 | 16.180 | 450.0 | 98.83 | 44474.0 | 24010.0 | 64930.0 |
| G2 | 11.640 | 250.0 | 90.50 | 22624.0 | 13950.0 | 31290.0 |
| G3 | 13.870 | 250.0 | 20.92 | 5229.6 | 3700.0 | 6750.0 |
| G4 | 31.380 | 450.0 | 72.98 | 32842.0 | 28710.0 | 36960.0 |
| H1 | 28.670 | 450.0 | 334.54 | 150540.0 | 125210.0 | 175870.0 |
| H2 | 34.430 | 450.0 | 746.90 | 336100.0 | 285360.0 | 386840.0 |
| H3 | 20.580 | 400.0 | 21.07 | 8425.9 | 2680.0 | 14160.0 |
| I1 | 26.390 | 450.0 | 47.33 | 21297.0 | 15410.0 | 27170.0 |
| I2 | 27.670 | 450.0 | 620.93 | 279420.0 | 245060.0 | 313770.0 |
| I3 | 12.540 | 200.0 | 30.71 | 6142.6 | 3940.0 | 8340.0 |
| I4 | 25.430 | 450.0 | 130.69 | 58811.0 | 43470.0 | 74140.0 |
| J1 | 24.500 | 450.0 | 69.79 | 31408.0 | 24690.0 | 38120.0 |
| J2 | 18.070 | 450.0 | 645.19 | 290330.0 | 215280.0 | 365380.0 |
| J3 | 18.710 | 400.0 | 61.74 | 24698.0 | 17030.0 | 32360.0 |
| J4 | 23.300 | 300.0 | 32.36 | 9709.3 | 7830.0 | 11580.0 |
| K1 | 28.530 | 450.0 | 93.77 | 42198.0 | 27160.0 | 57220.0 |
| K3 | 14.220 | 400.0 | 225.20 | 90078.0 | 56280.0 | 123860.0 |
| L1 | 9.210 | 450.0 | 234.18 | 105380.0 | 51230.0 | 159520.0 |
| L2 | 20.020 | 300.0 | 458.11 | 137430.0 | 114560.0 | 160300.0 |
| L3 | 26.610 | 350.0 | 151.35 | 52973.0 | 42410.0 | 63520.0 |
| L4 | 31.040 | 400.0 | 130.96 | 52385.0 | 42820.0 | 61940.0 |
| M1 | 31.280 | 450.0 | 67.09 | 30190.0 | 25170.0 | 35200.0 |
| M2 | 27.940 | 450.0 | 279.95 | 125980.0 | 100430.0 | 151520.0 |
| M3 | 24.970 | 450.0 | 48.42 | 21790.0 | 17100.0 | 26470.0 |
| M4 | 21.940 | 450.0 | 20.75 | 9338.7 | 7340.0 | 11330.0 |
| Totals for blocks F1-M4, equivalent to 1990 survey area: | | | | | | |
| | 655.860 | 11700.0 | | 2119723.0 | 1615900.0 | 2623300.0 |
| Totals for blocks A4-M4, 1991 Survey D: | | | | | | |
| | 777.841 | 14327.0 | | 2425819.0 | 1824750.0 | 3026590.0 |

Table 3.5.4 Acoustic estimate of krill biomass by block. Survey D 1991, based on nm sample data.

| Box | Distance | Area | x-bar | Biomass | Range | |
|---|---|---|---|---|---|---|
| | n.mi. | n.mi.$^2$ | tons/n.mi.$^2$ | tons | tons | tons |
| X4 | 18.380 | 337.0 | 13.35 | 4500.7 | -710.0 | 9710.0 |
| A3 | 27.690 | 600.0 | 8.85 | 5311.0 | -2380.0 | 13000.0 |
| A4 | 30.200 | 740.0 | 0.67 | 493.8 | -70.0 | 1060.0 |
| B3 | 24.310 | 900.0 | 4.22 | 3796.2 | -2700.0 | 10290.0 |
| B4 | 19.210 | 337.0 | 1.94 | 655.3 | -510.0 | 1820.0 |
| C1 | 41.130 | 900.0 | 0.54 | 486.6 | 170.0 | 800.0 |
| C2 | 23.610 | 675.0 | 6.30 | 4254.3 | -2060.0 | 10570.0 |
| C3 | 39.940 | 750.0 | 24.58 | 18439.0 | 2220.0 | 34650.0 |
| C4 | 50.920 | 900.0 | 15.71 | 14143.0 | 6150.0 | 22120.0 |
| D1 | 54.920 | 900.0 | 52.25 | 47024.0 | 20680.0 | 73360.0 |
| D2 | 60.800 | 900.0 | 488.75 | 439880.0 | 106520.0 | 773230.0 |
| D3 | 32.760 | 600.0 | 0.13 | 78.9 | 10.0 | 140.0 |
| D4 | 26.340 | 450.0 | 0.18 | 79.9 | 0.0 | 160.0 |
| E1 | 142.080 | 900.0 | 30.83 | 27750.0 | 18690.0 | 36800.0 |
| E2 | 19.470 | 750.0 | 96.38 | 72286.0 | -12780.0 | 157350.0 |
| E3 | 33.700 | 900.0 | 23.19 | 20875.0 | 8590.0 | 33150.0 |
| E4 | 23.430 | 600.0 | 12.66 | 7593.6 | -4340.0 | 19520.0 |
| F1 | 38.010 | 900.0 | 30.18 | 27160.0 | -4000.0 | 58320.0 |
| F2 | 47.570 | 750.0 | 180.26 | 135200.0 | 60270.0 | 210120.0 |
| F3 | 51.420 | 900.0 | 1.52 | 1368.5 | -360.0 | 3090.0 |
| F4 | 52.730 | 750.0 | 7.07 | 5300.3 | 3370.0 | 7230.0 |
| Totals for blocks C1-F4, which is equivalent to 1990 survey area: | | | | | | |
| | 738.831 | 12525.0 | | 821919.2 | 203130.0 | 1440610.0 |
| Totals for blocks X4-F4, the 1991 D survey: | | | | | | |
| | 858.621 | 15439.0 | | 836676.2 | 196760.0 | 1476490.0 |

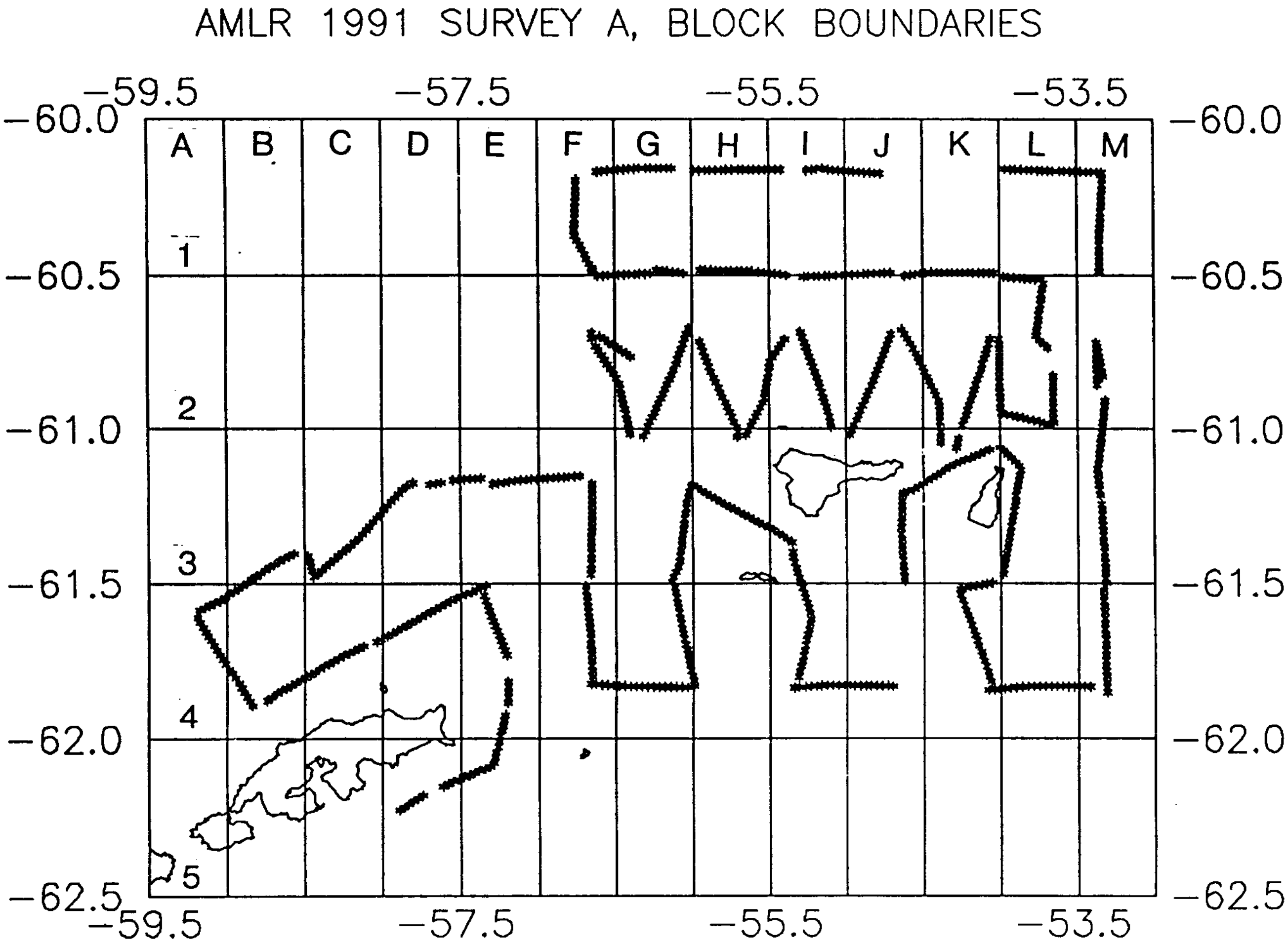


Figure 3.5.1 Survey A cruise track, boundaries of the blocks of area used for biomass calculation and distribution of biomass with 100m spaced data points.

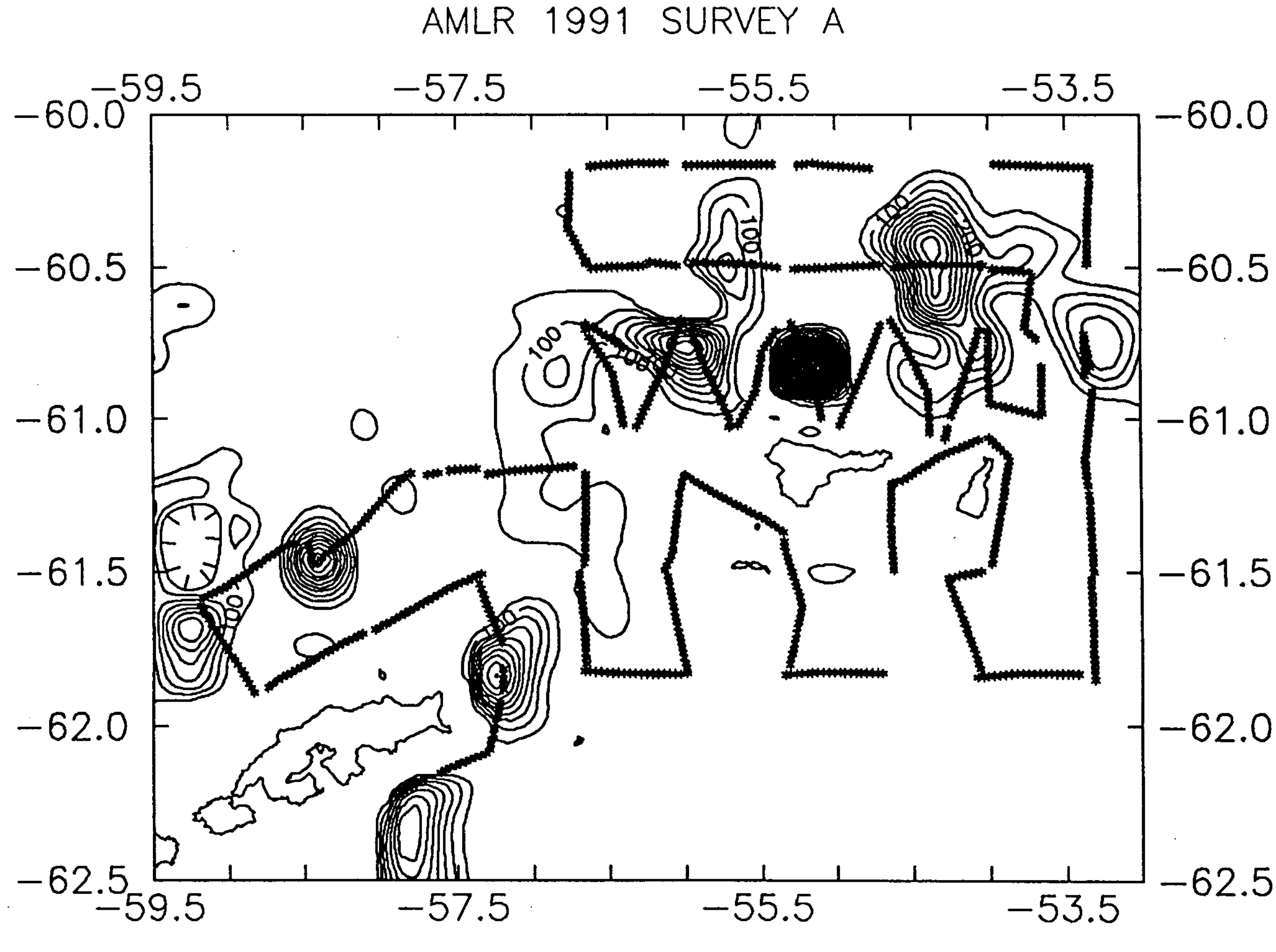


Figure 3.5.2 Survey A contour plot of the biomass distribution.

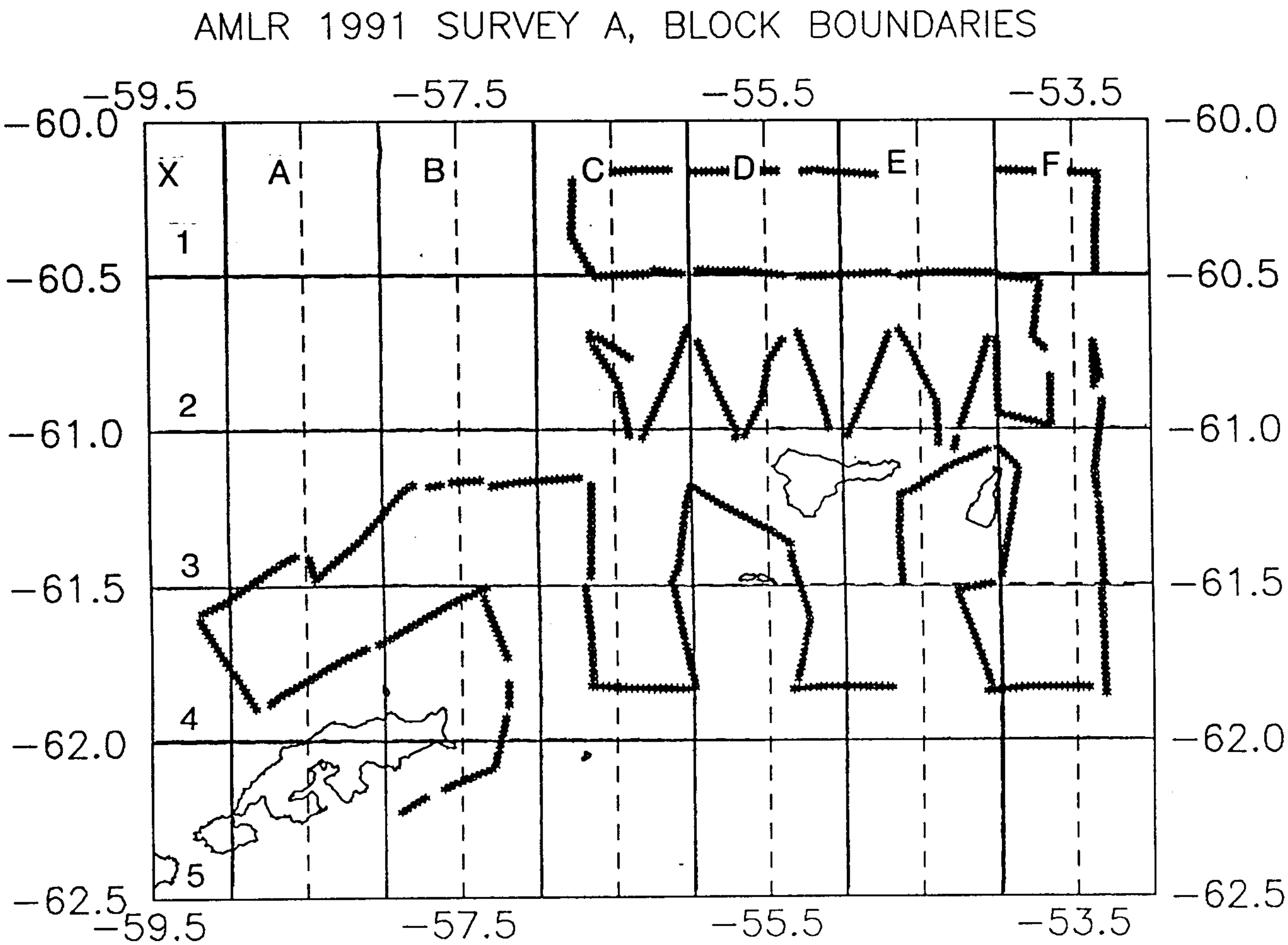


Figure 3.5.3 Survey A cruise track, boundaries of the blocks of area used for biomass calculation and distribution of biomass comparable to those used in 1990 using nautical mile spaced data points.

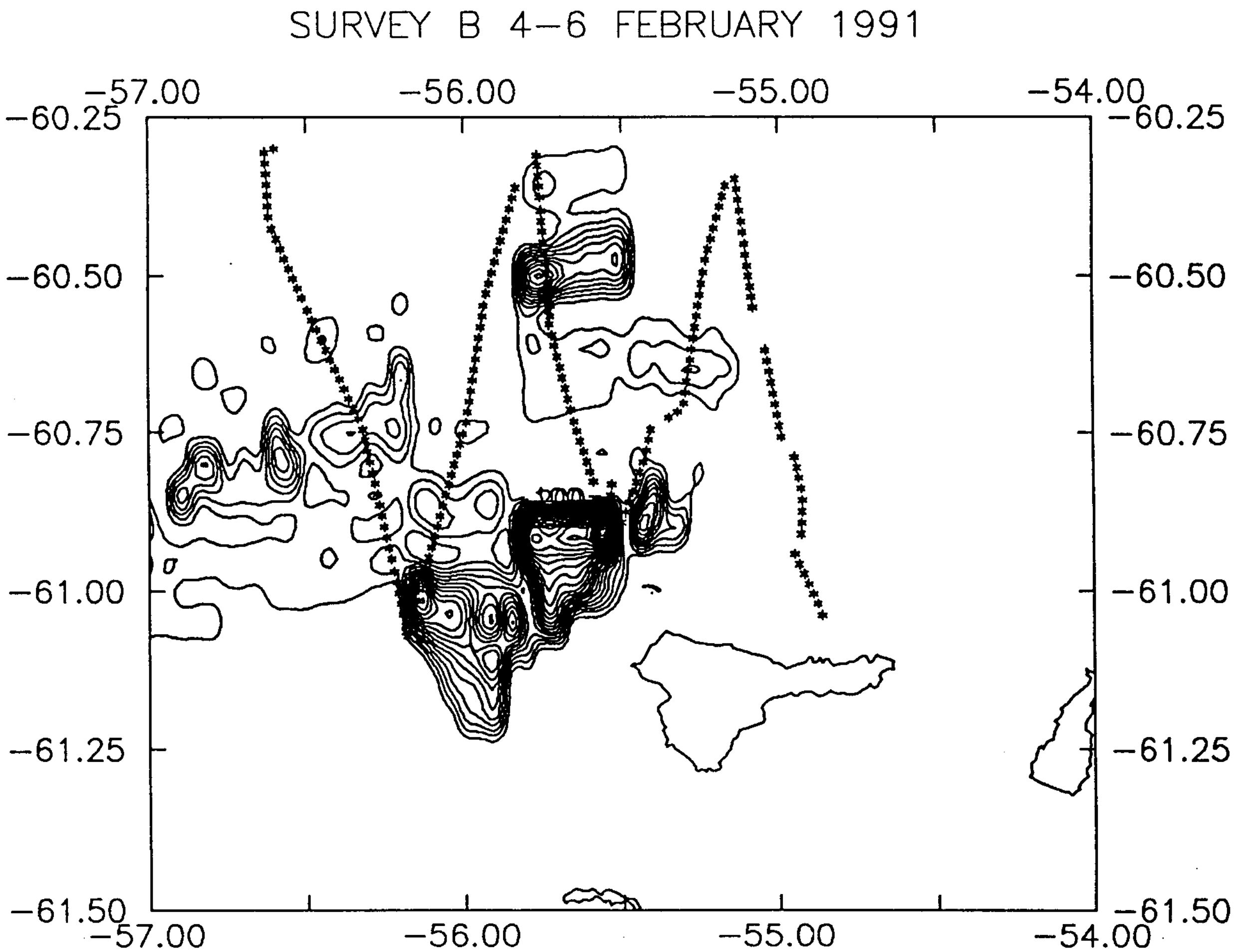


Figure 3.5.4 Survey B contour plot of the biomass distribution.

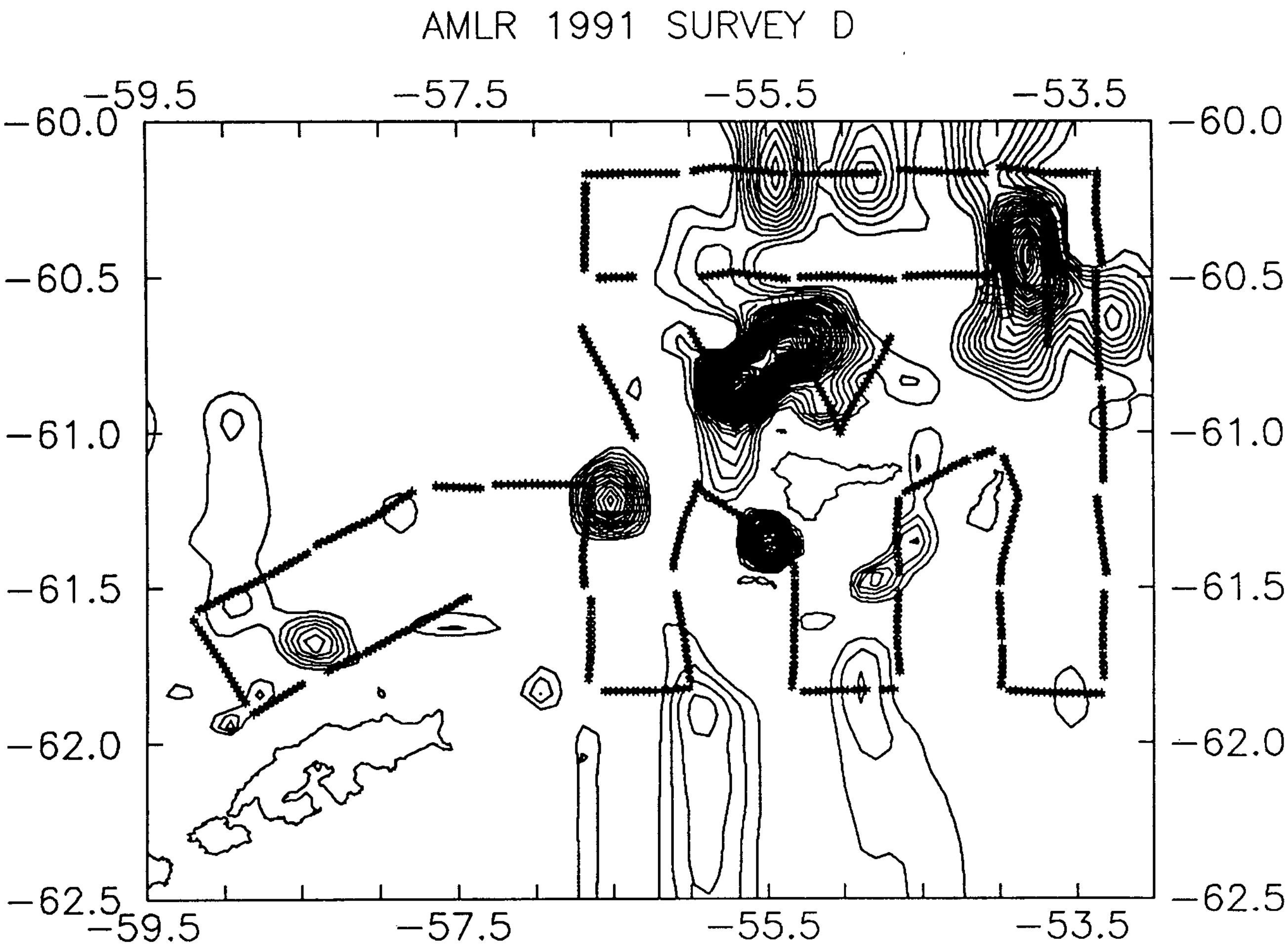


Figure 3.5.5 Survey D contour plot of the biomass distribution.

## 3.6 Direct krill sampling (bongo and IKMT nets); submitted by Valerie Loeb, Moss Landing Marine Laboratories.

**3.6.1 Objectives:** The objective of this work was to provide information on the demographic structure of krill stocks in the Elephant Island-King George Island survey area. Essential demographic information includes length, sex ratio, reproductive condition, and maturity and moult stages. Information useful for determining the relationship between krill distribution and population structure and ambient environmental conditions was derived from net samples taken at the CTD/phytoplankton stations within large- and small-scale survey areas. Additional sampling was done during Leg II to: (a) compare the relative krill catch efficiencies of bongo and IKMT nets; (b) augment the spatial coverage of Survey D in Bransfield Strait; and (c) provide additional information on krill stock structure north of Elephant Island two weeks after the Survey D sampling operations there.

**3.6.2 Accomplishments:** Krill were primarily obtained from 70 cm diameter bongo nets and a 6' Isaacs-Kidd Midwater Trawl (IKMT); additional material from Leg II was obtained from 1m$^2$ MOCNESS nets (Table 3.6.1). Bongo nets were used to collect krill, other small nekton and zooplankton during broad-scale Surveys A and D; the IKMT net was used during finer-scale Survey B, and both bongo and IKMT nets used during finer-scale Survey C, north of Elephant Island. The IKMT was used to collect larger quantities of krill and midwater fishes in extra sampling undertaken north of Elephant Island after Survey D.

The bongo frame was fitted with 333um and 505um mesh nets for tows at Stations A1-36 and at all Leg II stations; the 333um mesh net was replaced by 2mm stretch mesh for Station A37-50 tows. The IKMT was fitted with a modified net and cod end. Each net had a General Oceanics flowmeter mounted in the mouth. All tows were fished obliquely to a depth of approximately 160m. Tow depth was derived from electronic flow meters during Leg I; these became non-functional during Leg II and so tow depth was estimated from wire angle and meters of wire out. Krill were also obtained from open oblique 0-170m MOCNESS net samples (333um mesh) taken over the north shelf of Elephant Island following Survey D. A total of 49 bongo and 2 IKMT tows were made during large Survey A; 13 IKMT samples were taken during finer-scale Survey B; 22 bongo and 20 IKMT tows were made during Survey C; 49 bongo tows were made during large Survey D (Table 3.6.1). Additional samples were obtained from 6 bongo tows, 8 IKMT tows and 3 MOCNESS tows following Survey D.

**Shipboard Analyses:** Krill collected by the bongo and IKMT nets and three of the MOCNESS nets were examined on board to provide information on the relative abundance and composition of stocks encountered during each survey. All samples of 100 individuals or less were completely analyzed; for larger samples a minimum of 100 individuals were measured, sexed and staged. All krill were counted for samples of < ca.

1500 individuals (<2-liters). Volumes of larger samples were measured, and the numbers of krill in 1-liter aliquots were used to estimate total abundance. Measurements were of standard length; stages were based on the classification scheme of Makarov and Denys (1981). Bongo tow abundance estimates are based on the average of the two net catches.

### 3.6.3 Results:

**Leg I:** The 64 net tows collected during this leg yielded 2887 krill; 1566 of these were staged for use in demographic descriptions (Tables 3.6.1 - 3.6.3).

**Large-Scale Survey A Bongo Samples, 21 January - 1 February.** A total of 549 krill were collected by 33 of the 49 bongo net tows made during Survey A; the average abundance estimate was 1.7 (+/- 3.1) $m^{-2}$ (Table 3.6.2). The 13 Survey B IKMT tows collected 2039 krill; catches ranged from 1 to 1193 individuals, and the overall average abundance estimate was 4.2 (+/- 7.1) $m^{-2}$. The larger abundance estimate from the IKMT may in part be attributed to concentration of fishing effort in the relatively krill-rich area north of Elephant Island. However, the larger mouth area of the IKMT (8x that of each bongo net) and net modifications may also have increased catch efficiency, especially in locations of elevated krill abundance.

Largest bongo tow abundance estimates occurred at stations south of King George and to the west and north of Elephant Island; largest IKMT catches were at stations between the shelf break and ca. 3000m bottom depths (Figures 3.6.1 and 3.6.2). These catches reflect the overall pattern of acoustically detected krill biomass.

Most of the krill collected in the broad survey area were reproductively mature; juveniles contributed 15% and immature stages 6% of the total (Table 3.6.3). Juveniles were generally restricted to the Bransfield Strait waters where in two cases they constituted 72-100% of the catch (Figure 3.6.1). Only 10% of the males were immature; fewer females (3%) were immature. Among the females, 35% exhibited ovarian development and 44% were gravid; none appeared to have recently spawned.

Krill lengths ranged from 21-55mm, with an overall mean of 44mm (Table 3.6.3, Figure 3.6.3). The 40-49mm and 50-56mm size classes dominated (58.9% and 22.6%, respectively). Juveniles ranged from 21-33mm, with a mean length of 26mm; immature forms were from 29-49mm, with an overall mean of 40mm. Male and female sizes were similar (47mm mean).

**Small-Scale Survey B IKMT Samples, 3-6 February.** Juveniles were collected only at one station located over the northwest shelf of Elephant Island (Figure 3.6.2). The overall maturity and size composition of krill was similar to that of the broader Survey A area (Table 3.6.3). Minor differences are attributed to the low numbers of juveniles and slightly larger proportions of gravid females. Here the 20-29mm size class contributed only 1.6% of the total (vs. 13% in Survey A) and 84% of the females had ovarian development or were gravid. The low abundance of small juveniles and of immature and mature stages within the 30-39mm size class is reflected in the size frequency distributions (Figure 3.6.4).

In both Surveys A and B males outnumbered females by 1.6:1, and there were indications of some spatial separation of the sexes. Dominance by one sex occurred in 11 of the 24 larger sized catches: males comprised between 67-97% of the total individuals in eight; females between 73-92% in three (Figures 3.6.1 and 3.6.2).

**Leg II.** The 108 samples collected during this cruise leg yielded ca. 27,000 krill, about 3,000 of which were staged and measured (Table 3.6.1).

**Small-Scale Survey C Bongo and IKMT Samples, 20-24 February.** Over 22,000 krill were collected by the bongo and IKMT samples collected at 22 Survey C stations north of Elephant Island (Table 3.6.4). The majority of the individuals came from one IKMT haul made in inshore waters northeast of Elephant Island; the remaining 1,800 krill were equally caught by the IKMT and bongo nets. The overall abundance estimates (median abundances), size frequency distributions and maturity stage composition in the catches of the two sampling devices were similar (Tables 3.6.4 and 3.6.5) indicating equal catch efficiencies except perhaps at large krill densities (e.g., $>50m^{-2}$).

Largest catches by both the bongo and IKMT generally occurred to the northeast of the island (Figures 3.6.5 and 3.6.6). As during Leg I, Survey B, reproductively mature forms dominated the assemblages north of Elephant Island (82% of total), but males and females were more evenly represented (1.1:1 vs. 1.6:1; Table 3.6.5). Juvenile and immature stages primarily occurred in the inshore waters but numerically dominated (69%) only one sample taken there. Males were dominant (68-94%) in seven of the 15 larger catches, while females dominated only one (77%). The majority of the females (57%) had ovarian development or were gravid. The size frequency distributions (Table 3.6.5; Figure 3.6.7) reflect the large size of the dominant mature forms (49mm mean length); the less abundant juvenile and immature stages averaged 32mm and 43mm, respectively. The overall size frequency distribution from this survey (pooled bongo and IKMT samples; Figure 3.6.7) is quite similar for Survey B (Figure 3.6.4); however, immature stages within the 30-39mm class had a greater representation in the later survey.

**Large-scale Survey D Bongo Samples, 26 February-7 March.** A total of 282 krill were collected by 27 of the 49 bongo tows made during large-scale Survey D (Table 3.6.4). The frequency of occurrence (55%) and mean abundance (0.9 krill $m^{-2}$) were less than those observed during January large survey A (67%; 1.8 $m^{-2}$). Largest catches occurred to the north of Elephant Island in both shelf and offshore waters; catches around King George

Island were, with one exception, small (Figure 3.6.8). As in Survey A, large mature forms dominated the total catch (71%; Table 3.6.6). In contrast to that survey, juveniles were less abundant (4% vs. 15%), immature stages more abundant (25% vs. 6%) and fewer females were with developing ovaries or gravid (33% vs. 79%). None of the females appeared to have spawned. Juvenile and immature stages were primarily caught to the east of King George Island and over the northern shelf of Elephant Island, while mature forms were most abundant offshore (Figure 3.6.8) .

Krill lengths averaged somewhat larger than those monitored in Survey A (46mm vs. 44mm) due to fewer juveniles representing the 20-29mm size class and larger proportions of 50-56mm krill than in the earlier survey (Table 3.6.6; Figure 3.6.9). Juveniles collected in this survey averaged 33mm and immature stages 43mm.

**Bransfield Strait, 8 March.** Six bongo net samples were collected across the Bransfield Strait to the south and west of King George Island (Table 3.6.7) to explore the possibility of elevated abundances of small juveniles and immature stages there relative to the "downstream" Survey D area. These net tows yielded only 23 mostly large, mature krill ($0.5m^{-2}$ mean abundance; 44mm mean length).

**Additional Samples (Figure 3.6.10), North Elephant Island, 11-13 March.** The three MOCNESS samples taken near Seal Island on the north shelf of Elephant Island yielded an average of 79 krill $m^{-2}$. These samples contained a mixture of immature and mature stages which had an overall size distribution smaller than those encountered offshore: juveniles averaged 32mm, immatures 41mm and mature stages 46mm; the total mean length was 43mm (Table 3.6.8). Females dominated these samples (79%) and included recently spawned individuals but no gravid stages. These samples were taken from water associated with the Weddell-Scotia Sea confluence and may include individuals of both Bransfield Strait and Weddell Sea origin.

The eight IKMT samples, taken further offshore and to the east (Table 3.6.7), contained larger (49mm mean) primarily mature (90%) forms; females dominated (67% of total) but most of these were gravid and none appeared to have recently spawned. These krill were taken from water associated with the Bransfield Strait.

**3.6.4 Disposition of data and samples:** All of the krill demography data have been digitized and are available upon request. Hard copies of the bongo tow data will be given to Dr. John Wormuth. The 333u mesh bongo samples from Stations A1-36 and the Leg II stations, and the 505um mesh samples from Stations A37-50 will be sent to Dr. Wormuth's lab at Texas A&M University for analysis of the non-krill components; the remaining bongo samples and IKMT samples will be sent to the Southwest Fisheries Science Center. Krill, salp and amphipod specimens for museum collections have been supplied to Ole Mathisen and Tony Amos. Myctophids collected by the IKMT and bongo nets during Leg

II have been retained by Enzo Acuna, Universidad Catolica del Norte, Coquimbo, Chile. Portions of two large IKMT krill catches have been preserved in alcohol for mitochondrial DNA analysis in Australia.

**3.6.5 Tentative conclusions:** The relatively low abundance values of 1990 and 1991 could be in part due to the paucity of juvenile and immature stages in the Elephant Island area during both years. Juveniles made up only 15% of the total this year and were virtually absent last year; immature stages were collected in low numbers both years. The continued paucity of smaller size classes (e.g., 20-39mm) in the large survey area over the January-March period is notable and reflects little input of small juveniles and of immature and mature forms of 30-39mm lengths into the study area during this time. The generally low numbers of juvenile and immature krill and presence of reproductively active and gravid forms late in the season is thought provoking. The paucity of the presumably younger, smaller stages could result from year class failures in recent years and the gravid females may be older individuals spawning for a second time during the 1990-91 summer season. Alternatively, the large sized late spawners could be precocious, fast growing and sexually mature young of the year as hypothesized by Ed Brinton and Mark Huntley. This would also explain the sparse numbers of smaller krill.

The bongo and IKMT have been shown to equally efficient krill samplers in other than high density conditions. The advantage of the IKMT over bongo nets is the larger overall krill catch size which is important for demographic analyses; the disadvantage is loss of the smaller zooplankton fraction which is important for assessment of other elements of the pelagic ecosystem. It is recommended that both net systems be used in a standardized fashion in future sampling operations to fulfill both needs. This could possibly be done by alternating between the two net systems or by deploying the IKMT in conjunction with the bongo net at alternate stations during routine surveys. Shipboard analysis proved to be an effective way of assessing krill distributional patterns relative to hydrographic conditions in a more or less real-time manner and should be continued.

Table 3.6.1 AMLR1991 net samples used for krill demographic studies.

| | BONGO NETS | | | IKMT | | | MOCNESS | | |
|---|---|---|---|---|---|---|---|---|---|
| | # tows | # krill | # staged | # tows | # krill | # staged | # tows | # krill | # staged |
| **Leg I** | | | | | | | | | |
| Survey A | 49 | 549 | 546 | 2 | 299 | 151 | | | |
| Survey B | | | | 13 | 2039 | 869 | | | |
| Leg I Total | 49 | 549 | 546 | 15 | 2338 | 1020 | | | |
| **Leg II** | | | | | | | | | |
| Survey C | 22 | 846 | 778 | 20 | 21529 | 854 | | | |
| Survey D | 49 | 282 | 277 | | | | | | |
| **Extra Stations** | | | | | | | | | |
| Bransfield Strait | 6 | 23 | 23 | | | | | | |
| North of Elephant Island | | | | 8 | 3661 | 539 | 3 | 621 | 539 |
| Leg II Total | 77 | 1151 | 1078 | 28 | 25190 | 1393 | 3 | 621 | 539 |
| AMLR1991 Total | 126 | 1700 | 1624 | 43 | 27528 | 2413 | 3 | 621 | 539 |

Table 3.6.2 AMLR1991 Surveys A and B krill abundance.

| | Total krill 505u | #/m² 505u | #/1000m³ 505u | Total krill (others) | #/m² (others) | #/1000m³ (others) | Total krill | Mean #/m² | Mean #/1000m³ |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | 333u & | 333u & | | | |
| Stations A1-A50 | | | | | 2mm | 2mm | | | |
| Total | 273 | | | 276 | | | 549 | | |
| Maximum | 62 | 18.0 | 95.0 | 54 | 14.2 | 81.7 | 89 | 15.9 | 84.1 |
| Minimum | 0 | 0.0 | 0.0 | 0 | 0.0 | 0.0 | 0 | 0.0 | 0.0 |
| Average | 6 | 1.7 | 9.9 | 6 | 1.8 | 10.7 | 11 | 1.7 | 10.1 |
| STD | 11 | 3.3 | 19.1 | 11 | 3.3 | 19.4 | 19 | 3.1 | 17.7 |
| | | | | | | | | 505u & | 505u & |
| Stations A1-A36 | | | | | 333u | 333u | | 333u | 333u |
| Total | 217 | | | 161 | | | 378 | | |
| Maximum | 62 | 18.0 | 95.0 | 27 | 13.8 | 73.1 | 89 | 15.9 | 84.1 |
| Minimum | 0 | 0.0 | 0.0 | 0 | 0.0 | 0.0 | 0 | 0.0 | 0.0 |
| Average | 6 | 1.9 | 11.1 | 5 | 1.5 | 9.1 | 11 | 1.7 | 10.0 |
| STD | 12 | 3.8 | 21.6 | 8 | 2.8 | 16.1 | 19 | 3.2 | 18.2 |
| | | | | | | | | 505u & | 505u & |
| Stations A37-A50 | | | | | 2mm | 2mm | | 2mm | 2mm |
| Total | 56 | | | 115 | | | 171 | | |
| Maximum | 21 | 5.7 | 36.4 | 54 | 14.2 | 81.7 | 62 | 8.2 | 49.0 |
| Minimum | 0 | 0.0 | 0.0 | 0 | 0.0 | 0.0 | 0 | 0.0 | 0.0 |
| Average | 4 | 1.2 | 6.9 | 10 | 2.6 | 15.2 | 12 | 1.8 | 10.2 |
| STD | 6 | 1.6 | 9.8 | 17 | 4.4 | 26.1 | 20 | 2.7 | 16.2 |

**Surveys A and B IKMT tows**

| | North of Elephant Island (n=13) Total krill | Mean #/m² | Mean #/1000m³ | All tows (n=15) Total krill | Mean #/m² | Mean #/1000m³ |
|---|---|---|---|---|---|---|
| Total | 2039 | | | 2338 | | |
| Maximum | 1193 | 25.8 | 159.2 | 1193 | 25.8 | 159.2 |
| Minimum | 1 | 0.0 | 0.1 | 1 | 0.0 | 0.1 |
| Average | 157 | 4.2 | 27.2 | 156 | 3.9 | 24.9 |
| STD | 307 | 7.1 | 43.7 | 291 | 6.9 | 42.5 |

Table 3.6.3 AMLR1991 Surveys A and B krill maturity stage and size composition.

| | Bongo Survey A | | | IKMT Surveys A&B | | | Total Surveys A&B | | |
|---|---|---|---|---|---|---|---|---|---|
| | n | % | Average Length (mm) | n | % | Average Length (mm) | n | % | Average Length (mm) |
| **Maturity stages** | | | | | | | | | |
| Juveniles | 80 | 14.7 | 26.3 | 32 | 3.1 | 29.5 | 112 | 7.2 | 27.2 |
| Immature | 34 | 6.2 | 40.2 | 66 | 6.5 | 42.0 | 100 | 6.4 | 41.4 |
| Mature | 432 | 79.1 | 47.5 | 922 | 90.4 | 47.4 | 1354 | 86.5 | 47.4 |
| Total staged | 546 | | | 1020 | | | 1566 | | 45.6 |
| Total measured | 541 | | 43.9 | 995 | | 46.5 | 1536 | | |
| Males | 287 | 52.6 | 47.0 | 603 | 59.1 | 46.9 | 890 | 56.8 | 47.1 |
| Females | 179 | 32.8 | 46.8 | 385 | 37.7 | 47.1 | 564 | 36.0 | 46.9 |
| Males - immature | 29 | 5.3 | | 63 | 6.2 | | 92 | 5.9 | |
| Males - mature | 258 | 47.2 | | 540 | 52.9 | | 798 | 51.0 | |
| Females - immature | 5 | 0.9 | | 3 | 0.3 | | 8 | 0.5 | |
| Females - mature | 174 | 31.9 | | 382 | 37.4 | | 556 | 35.5 | |
| Females - gravid | 142 | 26 | | 322 | 31.5 | | 464 | 29.6 | |
| **Size categories** | | | | | | | | | |
| 20-29 mm | | 13.3 | | | 1.6 | | | 5.7 | |
| 30-39 mm | | 5.2 | | | 5.9 | | | 5.7 | |
| 40-49 mm | | 58.9 | | | 67.7 | | | 64.6 | |
| 50-56 mm | | 22.6 | | | 24.7 | | | 24.0 | |

Table 3.6.4 AMLR1991 Surveys C and D krill abundance.

| **Survey C bongo tows (n=22)** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Total krill 505u | #/m$^2$ 505u | #/1000m$^3$ 505u | Total krill 333u | #/m2 333u | #/1000m3 333u | Total krill | Mean #/m$^2$ | Mean #/1000m$^3$ |
| Total | 479 | | | 367 | | | 846 | | |
| Maximum | 148 | 38.0 | 220.8 | 89 | 17.7 | 108.4 | 205 | 26.3 | 153.1 |
| Minimum | 0 | 0.0 | 0.0 | 0 | 0.0 | 0.0 | 0 | 0.0 | 0.0 |
| Average | 22 | 5.3 | 32.9 | 17 | 3.9 | 25.2 | 38 | 4.6 | 29.0 |
| STD | 38 | 9.4 | 55.3 | 27 | 6.0 | 36.6 | 62 | 7.4 | 44.4 |
| Median | | 1.0 | 5.8 | | 0.6 | 3.9 | | 0.6 | 4.4 |
| **Survey C IKMT tows (n=20)** | | | | | | | | | |
| | Total krill | #/m$^2$ | #/1000m$^3$ | | | | | | |
| Total | 21514 | | | | | | | | |
| Maximum | 20600 | 378.7 | 2981.8 | | | | | | |
| Minimum | 0 | 0.0 | 0.0 | | | | | | |
| Average | 1076 | 20.9 | 160.9 | | | | | | |
| STD | 4483 | 82.2 | 647.5 | | | | | | |
| Median | 14 | 0.7 | 5.3 | | | | | | |
| **Survey D bongo tows (n=49)** | | | | | | | | | |
| | Total krill 505u | #/m$^2$ 505u | #/1000m$^3$ 505u | Total krill 333u | #/m$^2$ 333u | #/1000m$^3$ 333u | Total krill | Mean #/m$^2$ | Mean #/1000m$^3$ |
| Total | 141 | | | 141 | | | 282 | | |
| Maximum | 24 | 11.56 | 67.23 | 42 | 8.66 | 53.79 | 65 | 9.87 | 57.37 |
| Minimum | 0 | 0.00 | 0.00 | 0 | 0.00 | 0.00 | 0 | 0.00 | 0.00 |
| Average | 3 | 0.86 | 5.68 | 3 | 0.86 | 5.53 | 6 | 0.86 | 13.84 |
| STD | 6 | 1.90 | 12.09 | 7 | 2.01 | 12.37 | 13 | 1.89 | 11.84 |

Table 3.6.5 AMLR Survey C maturity stage and size composition in bongo and IKMT nets.

| | Bongo Nets | | | IKMT Nets | | | Total Bongo & IKMT Nets | | |
|---|---|---|---|---|---|---|---|---|---|
| | n | % | Avg. Length (mm) | n | % | Avg. Length (mm) | n | % | Avg. Length (mm) |
| **Maturity stages** | | | | | | | | | |
| Juvrniles | 42 | 5.1 | 31.6 | 23 | 2.7 | 31.4 | 65 | 4.0 | 31.6 |
| Immature | 80 | 9.7 | 41.7 | 159 | 18.6 | 43.0 | 237 | 14.5 | 42.6 |
| Mature | 701 | 85.2 | 48.8 | 672 | 78.7 | 48.6 | 1330 | 81.5 | 48.7 |
| Total staged | 778 | | | 854 | | | 1632 | | |
| Total measured | 778 | | 47.1 | 854 | | 47.1 | 1632 | | 47.1 |
| Males | 412 | 50.1 | 48.4 | 446 | 52.2 | 47.9 | 833 | 51.0 | 48.1 |
| Females | 369 | 44.8 | 47.6 | 385 | 45.1 | 47.1 | 734 | 45.0 | 47.3 |
| Males - immature | 62 | 7.5 | | 97 | 11.4 | | 159 | 9.8 | |
| Males - mature | 350 | 42.5 | | 349 | 40.9 | | 674 | 41.3 | |
| Females - immature | 18 | 2.2 | | 62 | 7.3 | | 78 | 4.8 | |
| Females - mature | 351 | 42.6 | | 323 | 37.8 | | 656 | 40.2 | |
| Females - gravid | 227 | 27.6 | | 207 | 24.2 | | 418 | 25.6 | |
| **Size Categoreies** | | | | | | | | | |
| 20-29 mm | | 1.0 | | | 0.8 | | | 0.9 | |
| 30-39 mm | | 10.5 | | | 8.3 | | | 9.4 | |
| 40-49 mm | | 50.3 | | | 56.4 | | | 53.5 | |
| 50-56 mm | | 38.2 | | | 34.5 | | | 36.2 | |

Table 3.6.6 AMLR1991 Survey D krill maturity stage and size composition in bongo nets.

| | n | % | Average Length (mm) |
|---|---|---|---|
| **Maturity stages** | | | |
| Juveniles | 12 | 4.3 | 32.8 |
| Immature | 69 | 24.9 | 43.1 |
| Mature | 196 | 70.8 | 47.8 |
| Total staged | 277 | | |
| Total measured | 273 | | 46.0 |
| Males | 126 | 45.5 | 47.9 |
| Females | 139 | 50.2 | 45.4 |
| Males - immature | 32 | 11.6 | |
| Males - mature | 94 | 33.9 | |
| Females - immature | 37 | 13.4 | |
| Females - mature | 102 | 36.8 | |
| Females - gravid | 46 | 16.6 | |
| **Size categories** | | | |
| 20-29 mm | | 0.4 | |
| 30-39 mm | | 12.1 | |
| 40-49 mm | | 57.1 | |
| 50-56 mm | | 30.4 | |

Table 3.6.7 AMLR1991 krill abundance in extra tows, 8-13 March.

**Bongo tows in western Bransfield Strait**

| | Total krill 505u | #/m$^2$ 505u | #/1000m$^3$ 505u | Total krill 333u | #/m$^2$ 333u | #/1000m$^3$ 333u | Total krill | Mean #/m$^2$ | Mean #/1000m$^3$ |
|---|---|---|---|---|---|---|---|---|---|
| Total | 15 | | | 8 | | | 23 | | |
| Max. | 7 | 2.0 | 11.4 | 4 | 1.5 | 8.5 | 11 | 1.7 | 9.9 |
| Min. | 0 | 0.0 | 0.0 | 0 | 0.0 | 0.0 | 0 | 0.0 | 0.0 |
| Average | 3 | 0.6 | 3.7 | 1 | 0.4 | 2.3 | 4 | 0.5 | 3.0 |
| STD | 3 | 0.8 | 4.9 | 2 | 0.5 | 3.2 | 5 | 0.7 | 4.0 |

**MOCNESS tows on north shelf of Elephant Island**

| | Total krill | Mean #/m$^2$ | Mean #/1000m$^3$ |
|---|---|---|---|
| Total | 621 | | |
| Max. | 280 | 114.9 | 676.1 |
| Min. | 136 | 61.5 | 361.7 |
| Average | 207 | 79.4 | 467.1 |
| STD | 59 | 25.1 | 147.8 |

**IKMT tows north of Elephant Island, 11 March (n=8)**

| | Total krill | Mean #/m$^2$ | Mean #/1000m$^3$ |
|---|---|---|---|
| Total | 3661 | | |
| Max. | 1480 | 54.0 | 254.9 |
| Min. | 0 | 0.0 | 0.0 |
| Average | 458 | 15.3 | 84.0 |
| STD | 543 | 18.6 | 98.6 |

Table 3.6.8 AMLR Leg II krill matrity stage and size composyion in MOCNESS and IKMT samples collected north of Elephant Island, 11-13 March.

| | MOCNESS Tows (WSC water) | | | IKMT Tows (Bransfield Strait water) | | |
|---|---|---|---|---|---|---|
| | n | % | Average Length (mm) | n | % | Average Length (mm) |
| **Maturity stages** | | | | | | |
| Juveniles | 15 | 4.9 | 32.3 | | | |
| Immature | 117 | 38.4 | 41.2 | 53 | 9.8 | 46.3 |
| Mature | 173 | 56.7 | 45.9 | 486 | 90.2 | 49.2 |
| Total staged | 305 | | | | | |
| Total measured | 305 | | | | | |
| Males | 75 | 24.6 | 43.7 | 176 | 32.7 | 48.5 |
| Females | 215 | 70.5 | 44.1 | 363 | 67.3 | 49.1 |
| Males - immature | 45 | 14.8 | | 31 | 5.8 | |
| Males - mature | 22 | 9.8 | | 145 | 26.9 | |
| Females - immature | 72 | 23.6 | | 22 | 4.1 | |
| Females - mature | 143 | 46.9 | | 341 | 63.3 | |
| Females - gravid | | | | 234 | 43.4 | |
| Females - spent | 45 | 14.8 | | | | |
| **Size categories** | | | | | | |
| 20-29mm | | 0.3 | | | 0.0 | |
| 30-39mm | | 20.3 | | | 0.2 | |
| 40-49mm | | 70.8 | | | 56.5 | |
| 50-59mm | | 8.5 | | | 43.3 | |

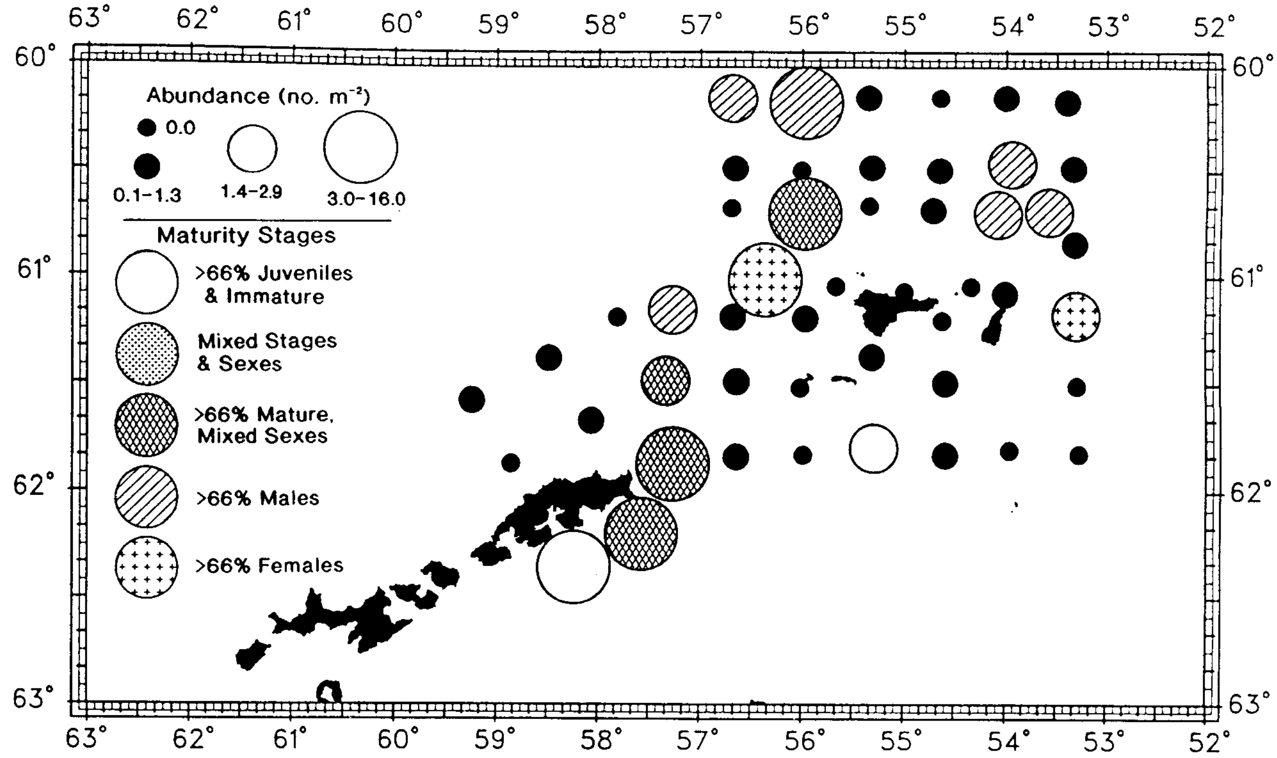


Figure 3.6.1 Survey A. Krill abundance and maturity composition in bongo samples.

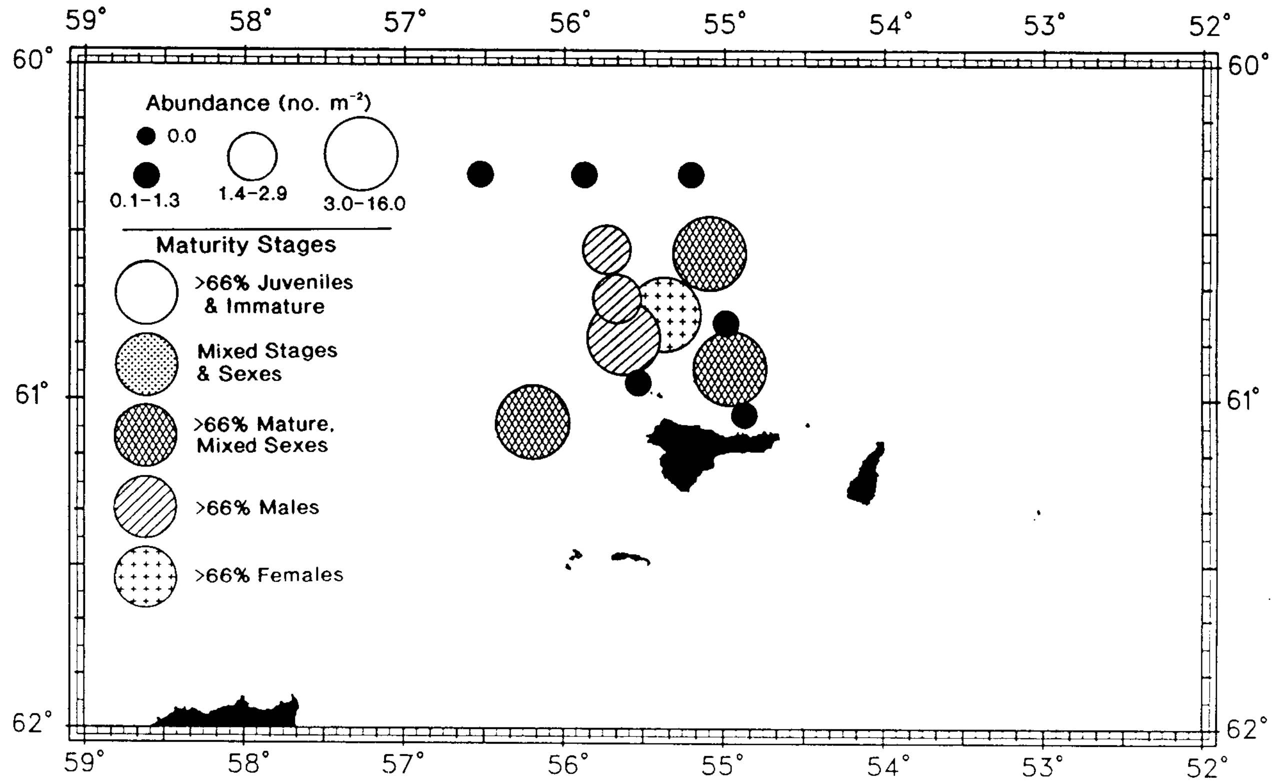


Figure 3.6.2 Survey B. Krill abundance and maturity composition in IKMT samples.

**AMLR1991 Survey A bongo samples (n=541)**

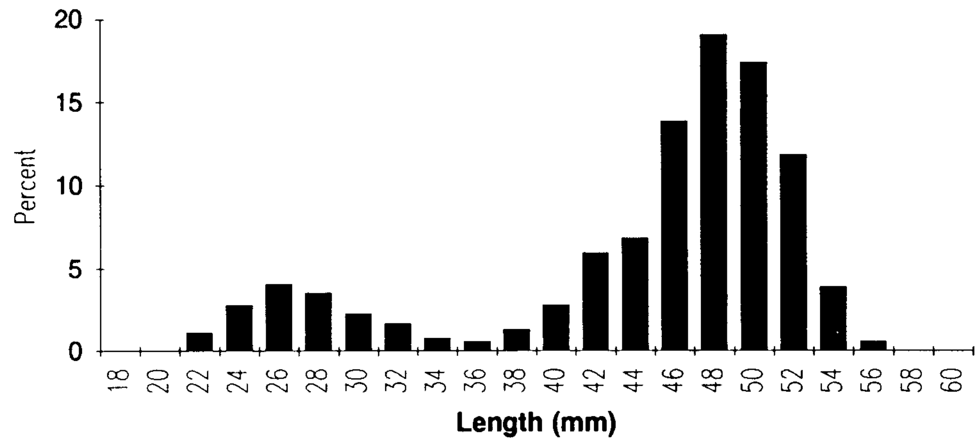


Figure 3.6.3 Krill size frequency distributions in Survey A bongo samples, totals.

**AMLR1991 Survey B IKMT samples (n=995)**

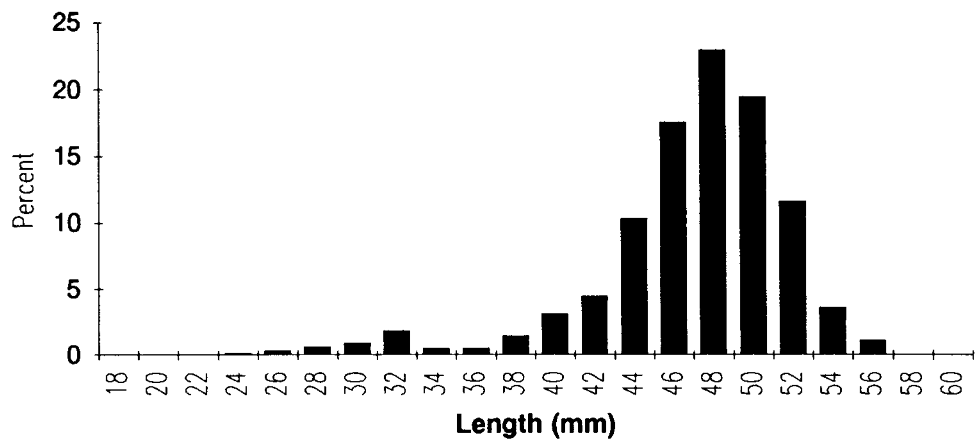


Figure 3.6.4 Krill size frequency distributions in Survey B IKMT samples, totals.

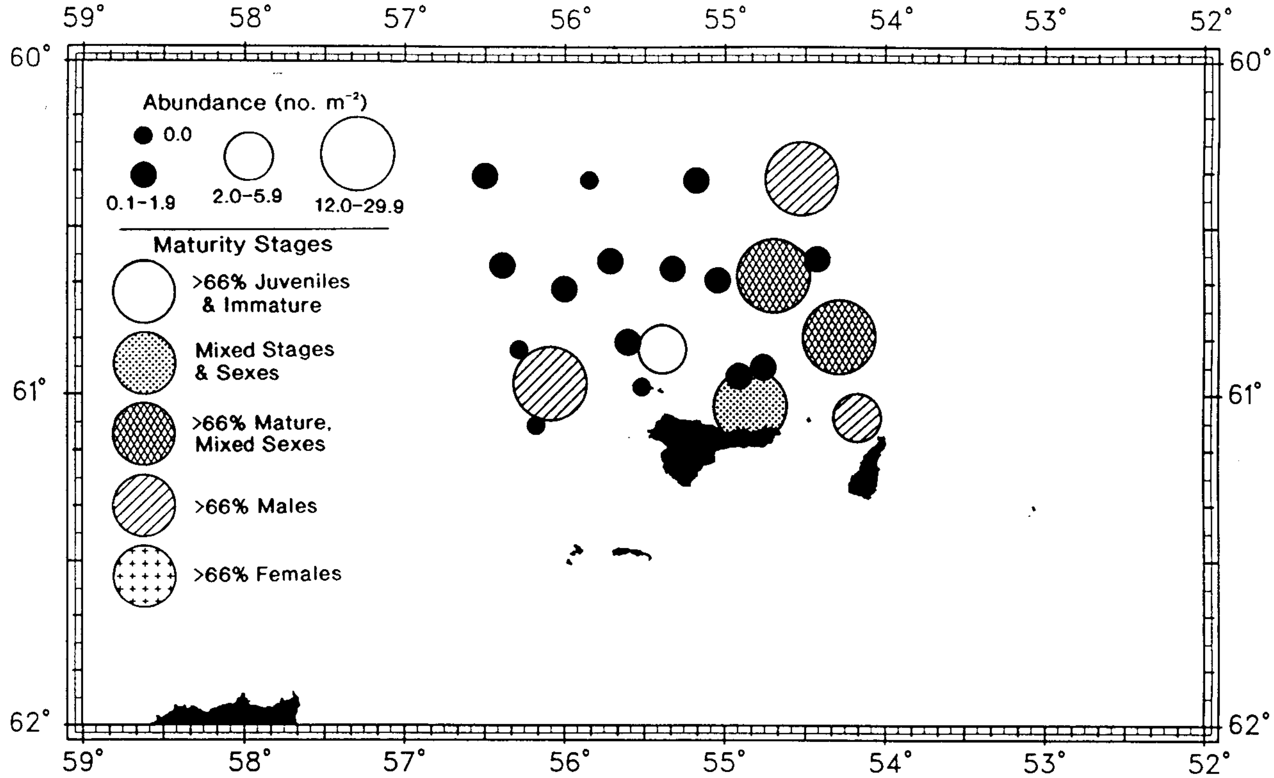


Figure 3.6.5 Survey C. Krill abundance and maturity composition in bongo samples.

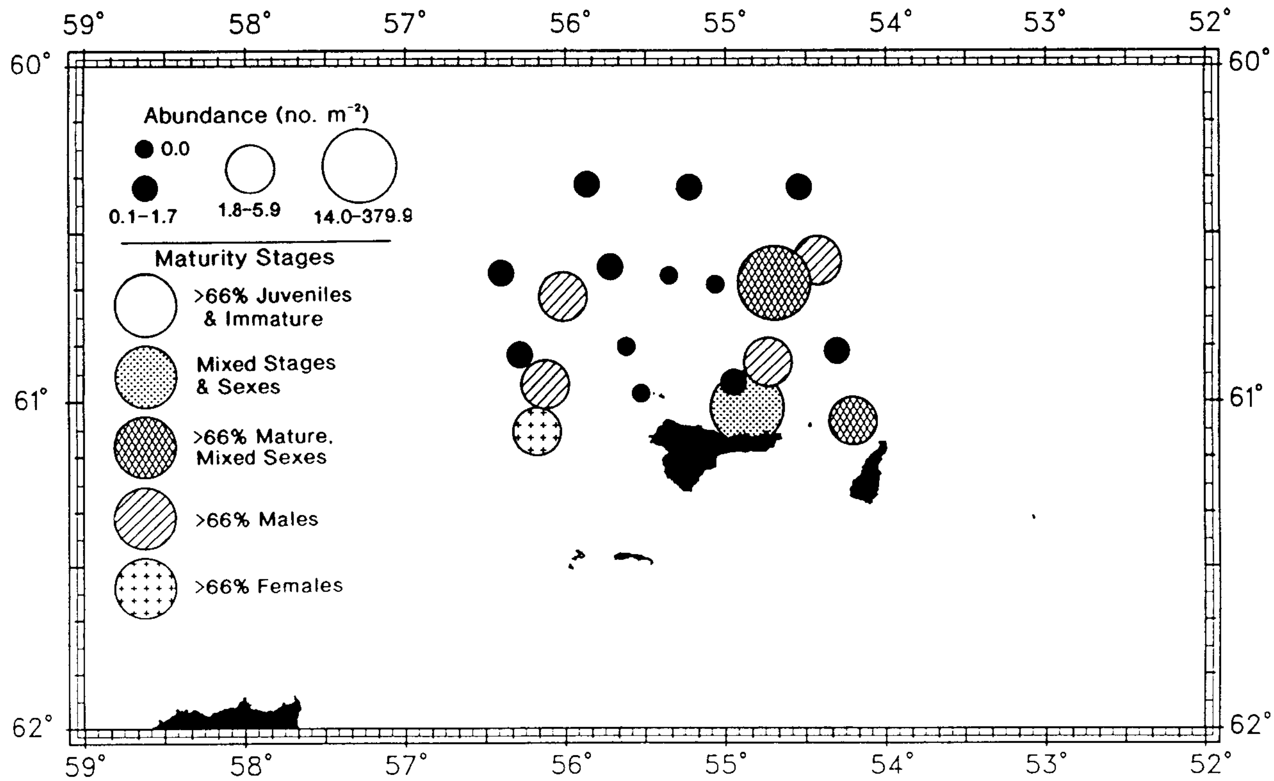


Figure 3.6.6 Survey C. Krill abundance and maturity composition in IKMT samples.

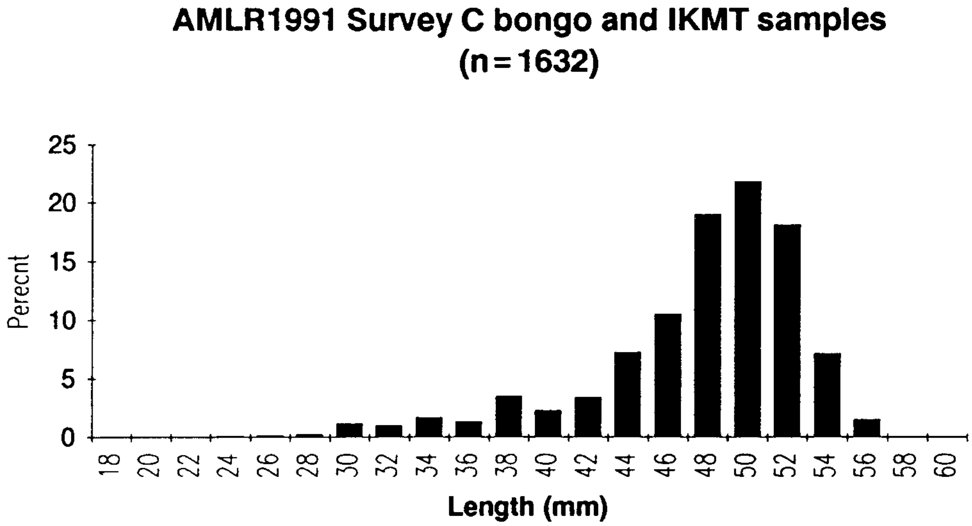


Figure 3.6.7 Krill size frequency distributions in pooled Survey C bongo and IKMT samples, totals.

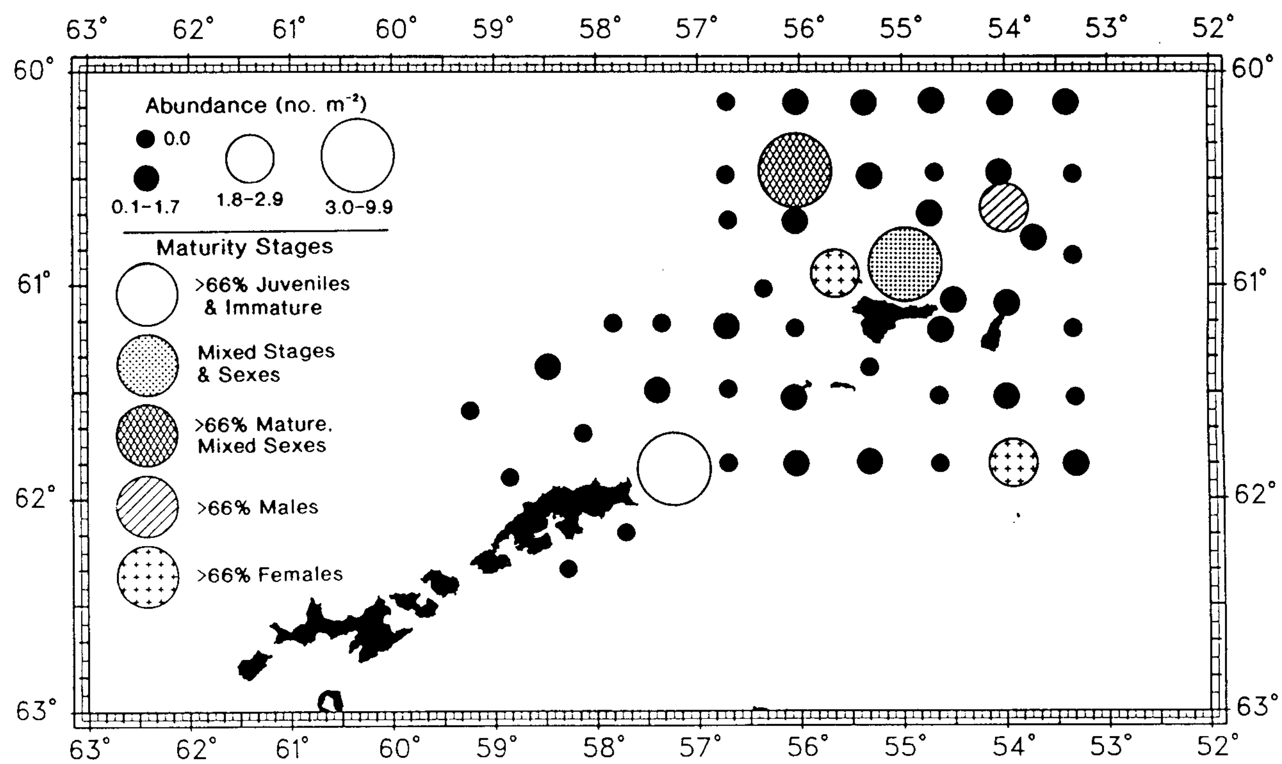


Figure 3.6.8 Survey D. Krill abundance and maturity composition in bongo samples.

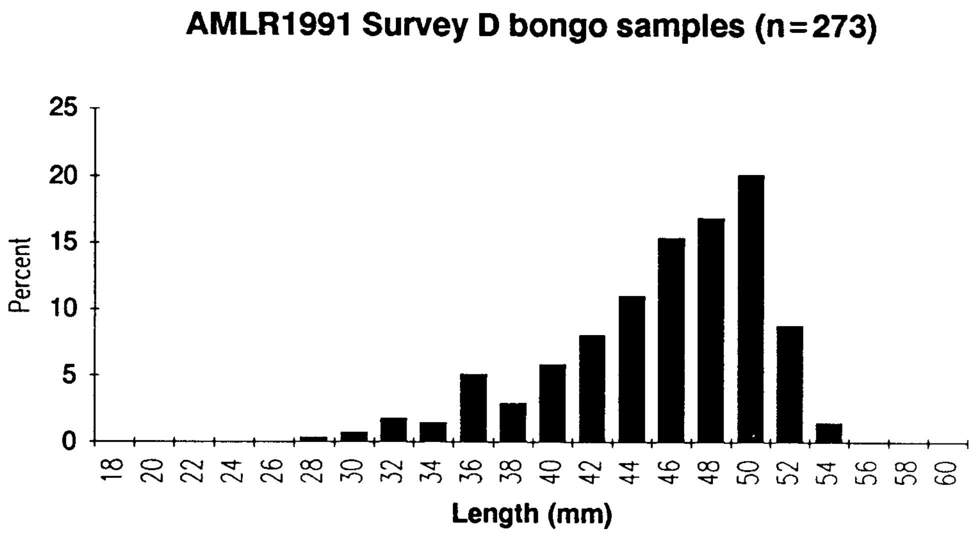


Figure 3.6.9 Krill size frequency distributions in Survey D bongo samples, totals.

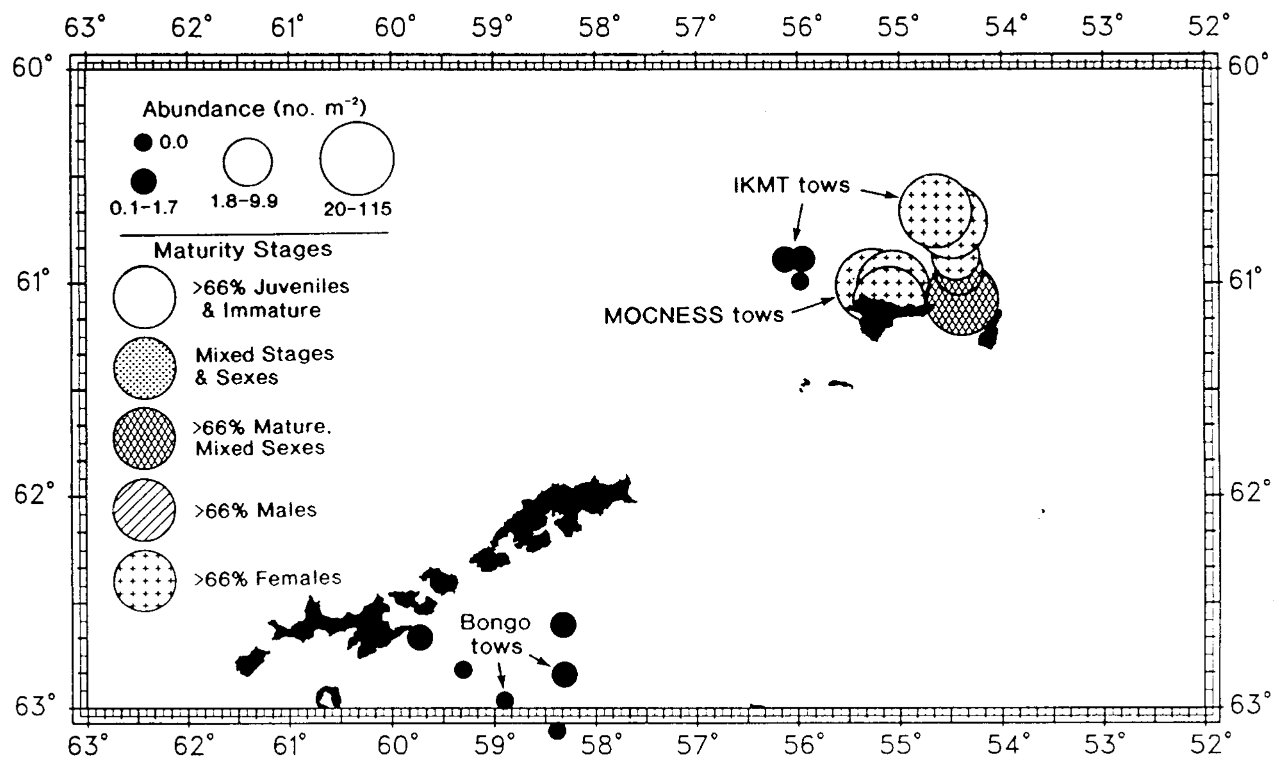


Figure 3.6.10 Extra Samples. Krill abundance and maturity composition in bongo, MOCNESS and IKMT samples.

**3.7 Direct sampling (MOCNESS); submitted by John H. Wormuth, Stephen Berkowitz and Walter Nordhausen, Texas A&M University.**

**3.7.1 Objectives:** The first objective was to describe the horizontal and vertical variations of krill abundance, and demography on scales of 25-50m vertically and 100-400m horizontally. A second objective was to correlate the krill data with data collected by other components of the AMLR 1991 program such as primary production, phytoplankton biomass, circulation patterns and other hydrographic data. The third objective was to provide length frequency data to the acoustic component of the program and gut fullness data for growth estimates. The fourth and final objective was to provide crucial continuity to the AMLR data base which now covers 1987-1990.

**3.7.2 Results:**

**Leg I:** A total of 12 MOCNESS tows were taken at various locations. These tows all fished in the upper 200m. Some sampling depths were guided by acoustic profiles and others were taken while no acoustic systems were operating. The first tow (MOC1-132) was taken at Station A23 as a shake-down tow and sampled standard depths (every 25m) to 200m. The second tow (MOC1-133, Station X01) was taken at a location where acoustic targets were expected, but none were encountered so standard depths were sampled again. Tows (MOC1-134 - MOC1-140, Stations X02-X08) all encountered good acoustic targets and the depths sampled were adjusted to these targets. Tows MOC1-141 - MOC1-143 were taken to standard depths since no acoustic systems were operating. For most tows, krill were enumerated before the sample was preserved.

Table 3.7.1 shows the basic data for all MOCNESS tows. Krill counts were not done on the first two tows; concentrations are left blank in the table. These values can only be underestimates. The average per net concentration of krill in the quantified MOCNESS samples was 58 per 1000m$^3$ (stanadrd deviation = 101).

M. Macaulay provided acoustic data to match the depths and times for all MOCNESS nets in real time and with a 2 minute lag to allow for the spatial lag of the net relative to the V fin. He also provided hard copies of all associated echograms. These data have been analyzed statistically, both parametrically and non-parametrically. R-squared values (N=63) ranged from .042 to .029.

**Leg II:** A total of 6 MOCNESS tows were taken at various locations. The first tow was taken 30 nm north of Elephant Island to a depth of 500 m in an attempt to find eggs and/ or early larval stages of *Euphausia superba*. Three adults but no early life stages were found at this off shore location. A second tow closer inshore was conducted to 250 m (bottom depth 280m). No krill were found. MOCNESS sampling was then interrupted due to the emergency detour to King George Island.

A second MOCNESS series of three tows was conducted after a preliminary acoustic survey on the shelf north of Elephant Island. Technical problems with the SWFC V-fin during the first two tows did not allow for comparison of depth stratified catches with associated acoustic targets. All tows were done to 170 m with special emphasis on the top 40 m. The first tow caught 2003 specimens in 2909 $m^3$ filtered; overall density of 689 krill per $1000m^3$. Highest abundances were found in the top 40 m with up to 2500 krill per 1000 $m^3$. The next tow (intended to be taken at the same location, but in reality about 2 nm farther offshore in slightly deeper water) caught only 249 krill in $1772m^3$ water filtered. The third tow was again conducted in the intended area and even though the SWFC V - fin showed no targets, the MOCNESS caught 1304 krill in $2035m^3$ water filtered; overall density of 641 krill per $1000m^3$ was similar to the first tow. The highest abundance was found in the upper 10m with 7300 krill per 1000 $m^3$.

A final attempt to qualitatively compare MOCNESS catches with acoustic targets was done after the very fine-scale survey at the end of Leg II. 1167 krill were caught in $3351m^3$ (348 per $1000m^3$) water filtered of which 93 % were found in the top twenty meters. This was depth of the major portion of the acoustic return. It is encouraging to note that high densities of salps were encountered at greater depth which did not show on the acoustics system.

Table 3.7.1 MOCNESS tows during AMLR1991 Leg I.

| Station # | Tow # | Latitude | Longitude | Volume | $\#/m^3$ | Depth |
|---|---|---|---|---|---|---|
| A23 | 132-1 | -61 30.65 | -54 10.4 | 500 | | 0-25 |
| | 132-2 | -61 30.65 | -54 10.4 | 527 | | 25-50 |
| | 132-3 | -61 30.65 | -54 10.4 | 540 | | 50-75 |
| | 132-4 | -61 30.65 | -54 10.4 | 334 | | 75-100 |
| | 132-5 | -61 30.65 | -54 10.4 | 340 | | 100-125 |
| | 132-6 | -61 30.65 | -54 10.4 | 1034 | | 125-150 |
| | 132-7 | -61 30.65 | -54 10.4 | 392 | | 150-175 |
| | 132-8 | -61 30.65 | -54 10.4 | 135 | | 175-200 |
| | 132-9 | -61 30.65 | -54 10.4 | 301 | | 200-225 |
| X01 | 133-1 | -60 57.29 | -55 4.73 | 976 | | 0-200 |
| | 133-2 | -60 57.29 | -55 4.73 | 461 | | 200-175 |
| | 133-3 | -60 57.29 | -55 4.73 | 288 | | 175-150 |
| | 133-4 | -60 57.29 | -55 4.73 | 172 | | 150-125 |
| | 133-5 | -60 57.29 | -55 4.73 | 170 | | 125-100 |
| | 133-6 | -60 57.29 | -55 4.73 | 318 | | 100-75 |
| | 133-7 | -60 57.29 | -55 4.73 | 272 | | 75-50 |
| | 133-8 | -60 57.29 | -55 4.73 | 204 | | 50-25 |
| | 133-9 | -60 57.29 | -55 4.73 | 155 | | 25-0 |
| X02 | 134-1 | -60 56.99 | -55 1.86 | 304 | | 0-60 |
| | 134-2 | -60 56.99 | -55 1.86 | 410 | | 60-85-63 |
| | 134-3 | -60 56.99 | -55 1.86 | 241 | | 63-75 |
| | 134-4 | -60 56.99 | -55 1.86 | 390 | 0.01 | 75-100-75 |
| | 134-5 | -60 56.99 | -55 1.86 | 170 | 0.047 | 75-100 |
| | 134-6 | -60 56.99 | -55 1.86 | 300 | 0.06 | 100-115-100 |
| | 134-7 | -60 56.99 | -55 1.86 | 511 | 0.035 | 100-75 |
| | 134-8 | -60 56.99 | -55 1.86 | 476 | 0.099 | 75-89 |
| | 134-9 | -60 56.99 | -55 1.86 | 385 | 0.044 | 89-94 |
| X03 | 135-1 | -60 56.2 | -54 59.0 | 941 | 0 | 0-100 |
| | 135-2 | -60 56.2 | -54 59.0 | 1600 | 0.004 | 100-75 |
| | 135-3 | -60 56.2 | -54 59.0 | 684 | 0 | 75-100 |
| | 135-4 | -60 56.2 | -54 59.0 | 257 | 0.004 | 100-125 |
| | 135-5 | -60 56.2 | -54 59.0 | 1788 | 0.011 | 125-100 |
| | 135-6 | -60 56.2 | -54 59.0 | 1569 | 0.001 | 100-125-100 |
| | 135-7 | -60 56.2 | -54 59.0 | 477 | 0.002 | 100-75 |
| | 135-8 | -60 56.2 | -54 59.0 | 427 | 0 | 75-50 |
| | 135-9 | -60 56.2 | -54 59.0 | 765 | 0 | 50-0 |
| X04 | 136-1 | -60 57.56 | -55 1.40 | 1514 | 0.005 | 0-100 |
| | 136-2 | -60 57.56 | -55 1.40 | 1367 | 0.026 | 100-115-82 |
| | 136-3 | -60 57.56 | -55 1.40 | 603 | 0.033 | 82-55 |
| | 136-4 | -60 57.56 | -55 1.40 | 537 | 0 | 55-65 |
| | 136-5 | -60 57.56 | -55 1.40 | 516 | 0.017 | 65-100 |
| | 136-6 | -60 57.56 | -55 1.40 | 199 | 0.05 | 100-75 |
| | 136-7 | -60 57.56 | -55 1.40 | 190 | 0 | 75-50 |
| | 136-8 | -60 57.56 | -55 1.40 | 231 | 0 | 50-25 |
| | 136-9 | -60 57.56 | -55 1.40 | 112 | 0 | 25-0 |

| | | | | | | |
|---|---|---|---|---|---|---|
| X05 | 137-1 | -60 53.92 | -55 29.24 | 1322 | 0.015 | 0-100-70 |
| | 137-2 | -60 53.92 | -55 29.24 | 318 | 0.189 | 70-65 |
| | 137-3 | -60 53.92 | -55 29.24 | 369 | 0.005 | 65-62 |
| | 137-4 | -60 53.92 | -55 29.24 | 350 | 0.18 | 62-40 |
| | 137-5 | -60 53.92 | -55 29.24 | 243 | 0.457 | 40-60 |
| | 137-6 | -60 53.92 | -55 29.24 | 397 | 0.272 | 60-113 |
| | 137-7 | -60 53.92 | -55 29.24 | 402 | 0.057 | 113-60 |
| | 137-8 | -60 53.92 | -55 29.24 | 508 | 0.035 | 60-30 |
| | 137-9 | -60 53.92 | -55 29.24 | 331 | 0 | 30-0 |
| X06 | 138-1 | -60 54.42 | -55 30.04 | 2035 | 0.001 | 0-112 |
| | 138-2 | -60 54.42 | -55 30.04 | 831 | 0.097 | 112-125 |
| | 138-3 | -60 54.42 | -55 30.04 | 345 | 0.232 | 125-150 |
| | 138-4 | -60 54.42 | -55 30.04 | 491 | 0.118 | 150-175-150 |
| | 138-5 | -60 54.42 | -55 30.04 | 410 | 0.137 | 150-100 |
| | 138-6 | -60 54.42 | -55 30.04 | 235 | 0.549 | 100-75 |
| | 138-7 | -60 54.42 | -55 30.04 | 225 | 0.6 | 75-50 |
| | 138-8 | -60 54.42 | -55 30.04 | 418 | 0.084 | 50-25 |
| | 138-9 | -60 54.42 | -55 30.04 | 297 | 0 | 25-0 |
| X07 | 139-1 | -60 53.92 | -55 30.71 | 591 | 0.005 | 0-50 |
| | 139-2 | -60 53.92 | -55 30.71 | 382 | 0.018 | 50-75 |
| | 139-3 | -60 53.92 | -55 30.71 | 371 | 0.102 | 75-82 |
| | 139-4 | -60 53.92 | -55 30.71 | 439 | 0.091 | 82-117 |
| | 139-5 | -60 53.92 | -55 30.71 | 476 | 0.034 | 117-75 |
| | 139-6 | -60 53.92 | -55 30.71 | 303 | 0.175 | 75-76 |
| | 139-7 | -60 53.92 | -55 30.71 | 401 | 0.117 | 76-71 |
| | 139-8 | -60 53.92 | -55 30.71 | 335 | 0.245 | 71-100 |
| | 139-9 | -60 53.92 | -55 30.71 | 304 | 0.079 | 100-125 |
| X08 | 140-1 | -60 53.03 | -55 28.46 | 635 | 0.027 | 0-100 |
| | 140-2 | -60 53.03 | -55 28.46 | 404 | 0.037 | 100-55 |
| | 140-3 | -60 53.03 | -55 28.46 | 315 | 0.054 | 55-65 |
| | 140-4 | -60 53.03 | -55 28.46 | 471 | 0.051 | 65-39-48 |
| | 140-5 | -60 53.03 | -55 28.46 | 421 | 0.017 | 48-37 |
| | 140-6 | -60 53.03 | -55 28.46 | 451 | 0.004 | 37-30-33 |
| | 140-7 | -60 53.03 | -55 28.46 | 417 | 0.005 | 33-47 |
| | 140-8 | -60 53.03 | -55 28.46 | 475 | 0.105 | 47-61-53 |
| | 140-9 | -60 53.03 | -55 28.46 | 510 | 0.149 | 53-38 |
| X09 | 141-1 | -60 52.41 | -55 27.74 | 1179 | 0.003 | 0-224-200 |
| | 141-2 | -60 52.41 | -55 27.74 | 233 | 0 | 200-175 |
| | 141-3 | -60 52.41 | -55 27.74 | 381 | 0.003 | 175-150 |
| | 141-4 | -60 52.41 | -55 27.74 | 389 | 0.036 | 150-125 |
| | 141-5 | -60 52.41 | -55 27.74 | 280 | 0.071 | 125-100 |
| | 141-6 | -60 52.41 | -55 27.74 | 354 | 0.051 | 100-75 |
| | 141-7 | -60 52.41 | -55 27.74 | 279 | 0 | 75-50 |
| | 141-8 | -60 52.41 | -55 27.74 | 348 | 0.003 | 50-25 |
| | 141-9 | -60 52.41 | -55 27.74 | 265 | 0 | 25-0 |

| | | | | | | |
|---|---|---|---|---|---|---|
| X10 | 142-1 | -60 51.8 | -55 29.71 | 1183 | 0.002 | 0-200 |
| | 142-2 | -60 51.8 | -55 29.71 | 446 | 0 | 200-175 |
| | 142-3 | -60 51.8 | -55 29.71 | 455 | 0.002 | 175-150 |
| | 142-4 | -60 51.8 | -55 29.71 | 315 | 0.032 | 150-125 |
| | 142-5 | -60 51.8 | -55 29.71 | 309 | 0.039 | 125-100 |
| | 142-6 | -60 51.8 | -55 29.71 | 234 | 0.021 | 100-75 |
| | 142-7 | -60 51.8 | -55 29.71 | 246 | 0 | 75-50 |
| | 142-8 | -60 51.8 | -55 29.71 | 286 | 0 | 50-25 |
| | 142-9 | -60 51.8 | -55 29.71 | 290 | 0 | 25-0 |
| X11 | 143-1 | -60 52.03 | -55 29.78 | 781 | 0 | 0-200 |
| | 143-2 | -60 52.03 | -55 29.78 | 463 | 0.011 | 200-175 |
| | 143-3 | -60 52.03 | -55 29.78 | 337 | 0 | 175-150 |
| | 143-4 | -60 52.03 | -55 29.78 | 296 | 0.003 | 150-125 |
| | 143-5 | -60 52.03 | -55 29.78 | 232 | 0 | 125-100 |
| | 143-6 | -60 52.03 | -55 29.78 | 298 | 0.03 | 100-75 |
| | 143-7 | -60 52.03 | -55 29.78 | 242 | 0.087 | 75-50 |
| | 143-8 | -60 52.03 | -55 29.78 | 334 | 0.096 | 50-25 |
| | 143-9 | -60 52.03 | -55 29.78 | 241 | 0 | 25-0 |
| | | | | Average | 0.049 | |
| | | | | STD | 0.101 | |

**3.8 Abundance and distribution of the Antarctic euphausiid *Thysanoessa macrura* in the eastern Bransfield Strait and around Elephant Island; submitted by Walter Nordhausen, Scripps Institution of Oceanography.**

**3.8.1 Objectives:** All Bongo net samples (mesh 333um) from the large survey D and the transects in the eastern Bransfield Strait were analyzed for adult and juvenile *Thysanoessa macrura*. Oblique net tows were done (depth permitting) to 160 meter. All *T. macrura* were measured to the closest millimeter and analyzed to maturity stage. Fresh caught specimens were grouped according to maturity stage and freeze-dried for a detailed analyses of their lipid compounds.

**3.8.2 Results:** *Thysanoessa macrura* were found at all but two stations and all 5 water masses. The abundance was fairly homogeneous over the study site with the exception of the northern and north-western stations (Figure 3.8.1A.). The highest numbers were found in the eastern Bransfield Strait with up to 1800 individuals per 1000 $m^3$. The distribution of larval *T. macrura* was very different. The persistent highest numbers were found at the northern and north-western stations in the water of the Drake Passage and a few adjacent stations (Figure 3.8.1B.). Up to 8300 larvae were found per 1000 $m^3$. Furcilia 6 was the dominant stage; also caught were a few furcilia 5 as well as some early juveniles just past the furcilia 6. This distinct cohort indicates a single spawning period prior to the survey.

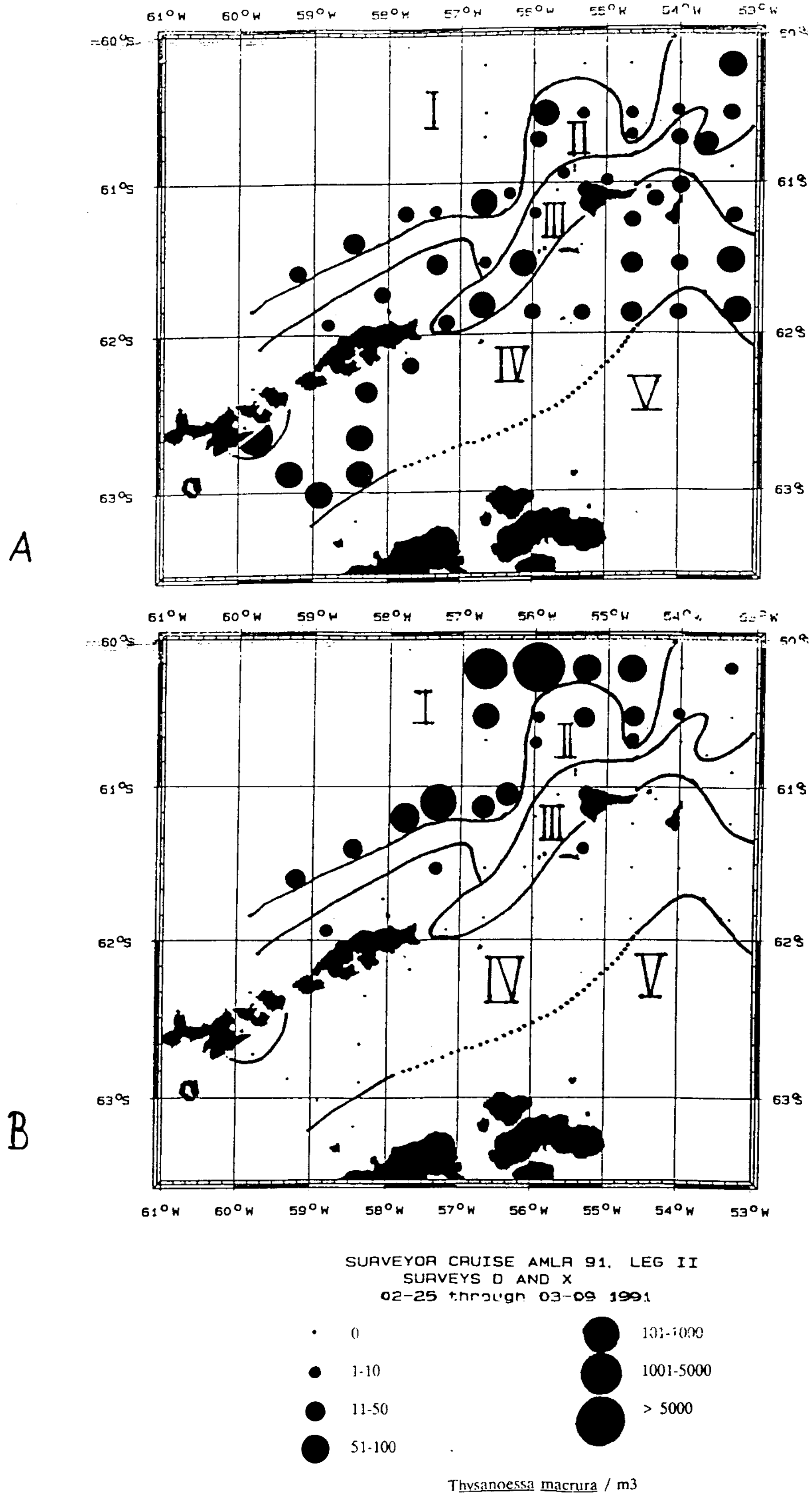


Figure 3.8.1 Distribution of *Thysanoessa macrura* adult (A) and larvae (B) during Survey D and the transects across the Bransfield Strait and the water masses, as identified by Amos in Section 3.3 of this report..

**3.9 Fishes caught during AMLR 1991 LEG II around Elephant Island and the Bransfield Strait; submitted by Enzo S. Acuña, Universidad Católica del Norte.**

**3.9.1 Results, Survey C:** Bongo net and modified IKMT net tows were conducted at 22 fixed stations. Two species of myctophid fishes were caught at six stations, all corresponding all to night time samples, which means that fish were captured in 27.3% of the stations and 75% of the night time stations. This is certainly explained by the expected vertical distribution of the myctophids, which are known to migrate vertically to shallower waters at night.

The species caught were *Electrona antarctica*, with a total of 38 specimens and a size range between 3.6 to 10.0 cm SL, and *Gymnoscopelus braueri*, with a total of 20 specimens captured and a size range between 5.5 and 9.8 cm SL. The stations, type of net, bottom depths, numbers caught and size ranges are summarized in Tables 3.9.1 and 3.9.2.

**3.9.2 Results, Survey D:** The large-area survey included only bongo net sampling. During these stations, only nine fishes were caught: the myctophids *Electrona antarctica* and *Gymnoscopelus nicholsi*, and the paralepidid *Notolepis coatsi*. The stations, bottom depths, numbers caught and size ranges are summarized in Table 3.9.3.

**3.9.3 Results, IKMT transects:** Finally, two special transects using the IKMT were done exclusively to capture fish during night tows. During these tows a total of 85 specimens were captured all from four species of myctophids. The stations, bottom depths, numbers caught and size ranges are summarized in Table 3.9.4.

Table 3.9.1. *Electrona antarctica*. Number captured by station, type of net, tow depth and size range.

| Station | Tow depth | Type of net | Number caught | Size range |
|---|---|---|---|---|
| C5 | 176 | IKMT | 5 | 4.9 - 9.6 |
| | | Bongo 505 | 3 | 5.8 - 6.7 |
| | | Bongo 333 | 2 | 5.4 - 5.9 |
| C6 | 172 | IKMT | 2 | 6.4 - 6.7 |
| | | Bongo 505 | 2 | 6.4 - 8.6 |
| C17 | 170 | IKMT | 6 | 6.0 - 9.5 |
| | | Bongo 505 | 2 | 7.1 - 8.0 |
| | | Bongo 333 | 1 | 10.0 |
| C18 | 172 | IKMT | 3 | 3.6 - 5.4 |
| C19 | 150 | IKMT | 10 | 5.8 - 9.6 |
| | | Bongo 505 | 2 | 4.3 - 4.7 |
| TOTAL | | | 38 | 3.6 -10.0 |

Table 3.9.2. *Gymnoscopelus braueri*. Number captured by station, type of net, tow depth and size range.

| Station | Tow depth | Type of net | Number caught | Size range |
|---|---|---|---|---|
| C5 | 176 | IKMT | 3 | 8.3 - 9.4 |
| | | Bongo 505 | 3 | 8.4 - 9.7 |
| | | Bongo 333 | 3 | 8.5 - 9.8 |
| C6 | 172 | IKMT | 2 | 8.2 - 8.5 |
| | | Bongo 333 | 1 | 8.8 |
| C19 | 150 | IKMT | 5 | 7.0 - 9.4 |
| | | Bongo 505 | 2 | 5.5 - 9.5 |
| C20 | 141 | IKMT | 1 | 7.6 |
| Total | | | 20 | 5.5 - 9.8 |

Table 3.9.3. Fishes caught during Survey D. Number captured by station, type of net, tow depth and size range.

| Station | Tow depth | Type of net | Number caught | Size range |
|---|---|---|---|---|
| *Electrona antarctica* | | | | |
| D25 | 150 | Bongo 505 | 1 | 7.9 |
| D8 | 172 | Bongo 505 | 2 | 6.3 - 7.5 |
| | | Bongo 333 | 1 | 8.5 |
| D4 | 144 | Bongo 505 | 1 | 7.3 |
| | | Bongo 333 | 1 | 6.3 |
| X29 | 160 | Bongo 505 | 1 | 7.8 |
| Total | | | 7 | 6.3 - 8.5 |
| *Gymnoscopelus nicholsi* | | | | |
| D4 | 144 | Bongo 505 | 1 | 15.3 |
| *Notolepis coatsi* | | | | |
| D30 | 169 | Bongo 505 | 1 | 22.8 |

Table 3.9.4. Fishes caught during X Stations north of Eleplant Island. Number captured by station, tow depth and size range.

| Station | Tow depth | Type of net | Number caught | Size range |
|---|---|---|---|---|
| *Electrona antarctica* | | | | |
| X30 | 172 | IKMT | 10 | 3.9 - 9.0 |
| X31 | 218 | IKMT | 11 | 6.3 - 9.5 |
| X32 | 258 | IKMT | 15 | 4.2 -10.3 |
| X33 | 172 | IKMT | 21 | 5.4 - 7.9 |
| X34 | 212 | IKMT | 4 | 7.0 - 9.5 |
| X35 | 201 | IKMT | 3 | 3.8 - 8.0 |
| Total | | | 64 | 3.8 -10.3 |
| *Gymnoscopelus braueri* | | | | |
| X30 | 172 | IKMT | 2 | 10.5 -10.6 |
| X31 | 218 | IKMT | 2 | 7.0 -10.2 |
| X32 | 258 | IKMT | 7 | 5.8 -10.2 |
| X33 | 172 | IKMT | 4 | 8.0 - 9.3 |
| X34 | 212 | IKMT | 2 | 8.5 - 9.7 |
| Total | | | 17 | 5.8 -10.6 |
| *Gymnoscopelus nicholsi* | | | | |
| X30 | 172 | IKMT | 1 | 14.4 |
| *Krefftichthys anderssoni* | | | | |
| X30 | 172 | IKMT | 1 | 7.6 |
| X32 | 258 | IKMT | 2 | 4.2 - 4.6 |
| Total | | | 3 | 4.2 - 7.6 |

**3.10. Polycyclic aromatic hydrocarbons studied in the coastal area of Elephant Island and Antarctic waters. Thermal structure and geostrophy at Drake Passage 1991; submitted by Rebeca Dorion Guesalaga and Christian Bonert Anwandter, Servicio Hidrográfico y Oceanográfico de la Armada de Chile.**

**3.10.1 Objectives:** Two research projects were conducted by personnel of the Servicio Hidrográfico y Oceanográfico de la Armada de Chile (SHOA). Objectives of the first project related to the increasing oil pollution hazard in the Antarctic zone. Ship traffic and Antarctic Bases could became a source of oil spills in the marine environment, not only as a result of accidents, but also from regular activities. Among oil components, polycyclic aromatic hydrocarbons (PAH) are the most important marine environment contaminants due to their dangerous effects on marine communities and ecosystems. The main objective of this experiment is to study PAH's concentration in sediments and benthic species in the Elephant Island area and surface antarctic waters.

The objectives of the second project were to continue with the XBT and CTD observations started during the AMLR 1990 cruise for monitoring the thermal structure of the upper layers of the Drake Passage, identifying mesoscale features of the Antarctic Circumpolar Current, and making new computations of the geostrophic flow across the Polar Front.

**3.10.2 Accomplishments:** Ten samples of sediments, water and biological tissues were obtained at the beginning of Leg I during the Seal Island re-provision. During Leg II four samples of sediments and benthic organisms were taken from the beach at Seal Island. These samples were wrapped in aluminium foil and stored frozen. Fourteen surface seawater samples were also taken from the ship during Leg II, 5 samples in the Elephant Island area and 9 samples in the Bransfield Strait zone. The positions of the sampling sites are shown in Figure 3.10.1. Three additional samples of seawater were taken during the track between Punta Arenas and the east mouth of the Strait of Magellan. Separation of PAH took place aboard NOAA Ship *Surveyor* and the extracts were stored in the dark. All the samples will be analyzed by UV-fluorescence method in SHOA's laboratory in Valparaiso.

Fourteen Expendable Bathythermograph (XBT) observations were done at the beginning of Leg I in the Drake Passage (January 17-18). These measurements were done from about 15 nm SW of the Beagle Channel mouth to about 40 nm offshore of Elephant Island. XBT's were launched at approximately 30 n.mi. intervals and to a depth of 460 m, using the SEAS (Shipboard Environmental Acquisition System) unit of the ship. During February 8-9 six deep CTD (Sea-Bird SBE-9) casts were made at the end of Leg I, distributed according to the Polar Front determined to be at approximately 58°S from the XBT section (see Figure 3.10.2). In the CTD transect, the Polar Front was located at approximately at 57°30'S.

Twelve XBT observations were done while crossing Drake Passage at the beginning of Leg II (February, 18-19) from about 60 nm southeast of Isle de los Estados to about 12 nm offshore of Elephant Island.. Figure 3.10.3 shows a preliminary description of the thermal structure of the upper layers of the Drake Passage based on the data from the XBT-line. It is possible to locate the Polar Front at approximately at 57 30'S. During the return crossing of the Drake Passage (March, 14-15), 4 deep CTD casts (2000 m) were planed at the location of the Polar Front, which was determined from the temperature section obtained from the XBT data. However, due to sea conditions, only one CTD cast was performed at 58 00'S , 61 04'W. An additional XBT was launched for calibration purposes.

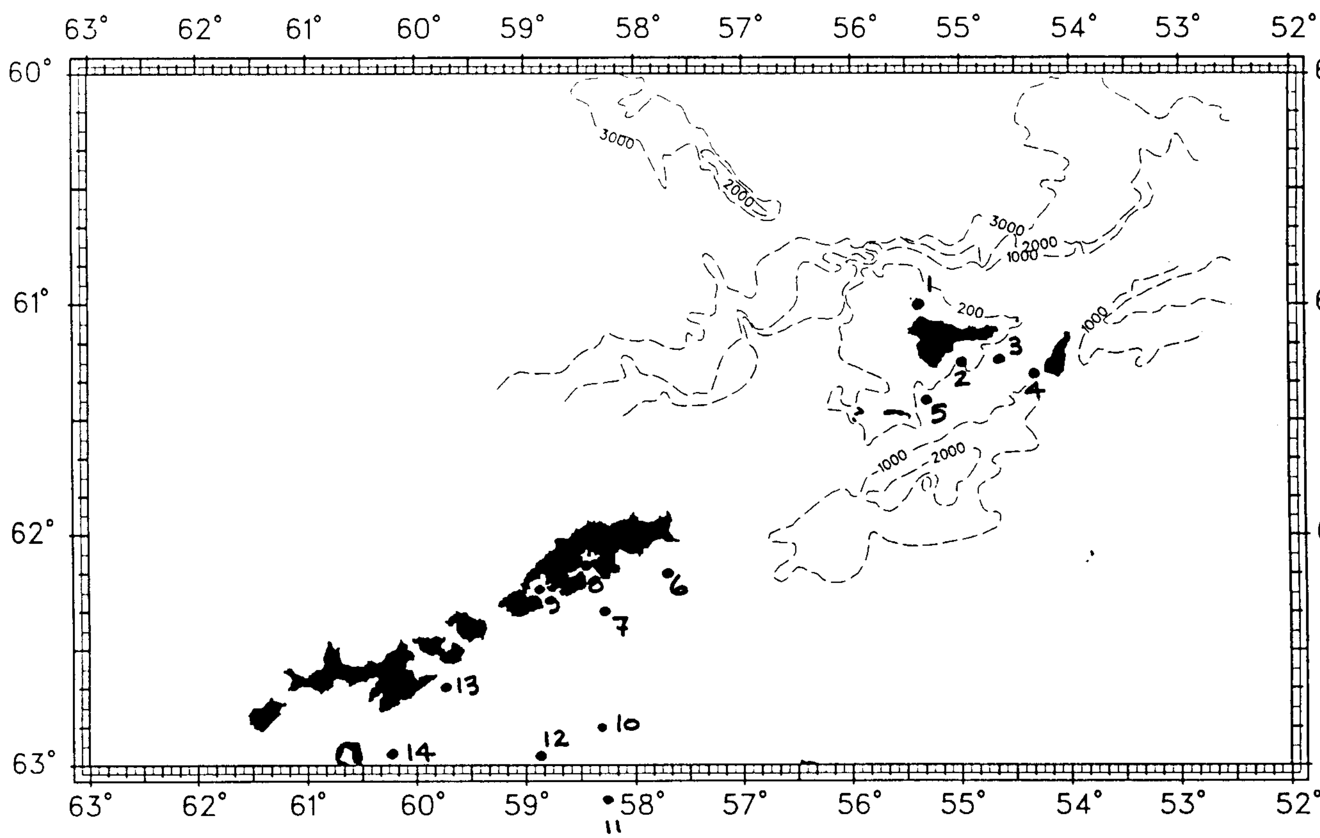


Figure 3.10.1 Positions of seawater sampling sites for PAH determination during Leg II.

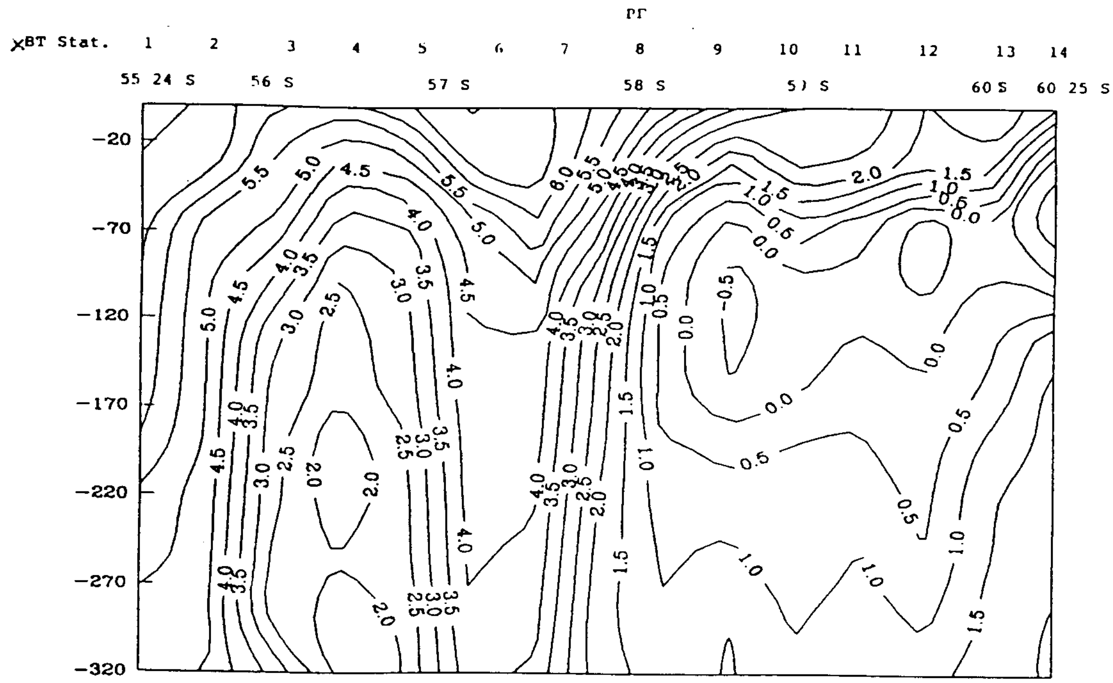


Figure 3.10.2 Temperature section across Drake Passage on January 17-18, between Beagle Channel mouth and Elephant Island.

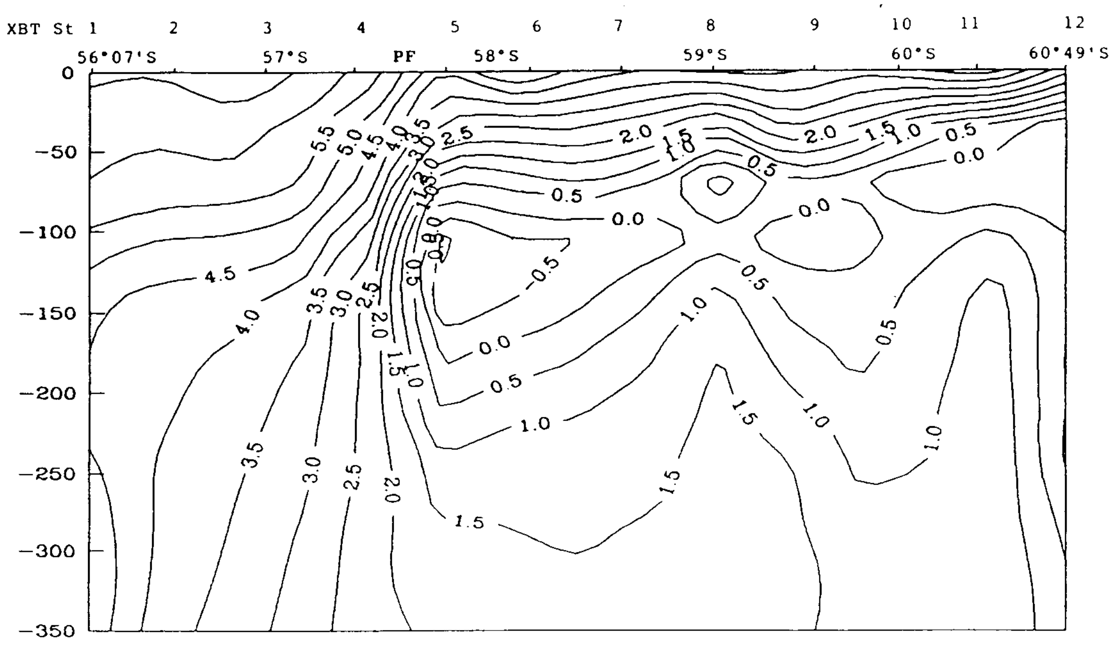


Figure 3.10.3 Preliminary temperature section across Drake Passage (18-19 February 1991) during the track between Isla de los Estados and Elephant Island. PF denotes Polar Front.

## 4. Personnel

### 4.1 Seal Island

John Bengtson, National Marine Mammal Laboratory
Peter Boveng, National Marine Mammal Laboratory
Donald Croll, National Marine Mammal Laboratory
Michael Goebel, National Marine Mammal Laboratory
John Jansen, National Marine Mammal Laboratory
Yoshihisa Mori, National Institute of Polar Research, Japan
Jorge Alvarado, Instituto Antartico Chileno

### 4.2 Palmer Station

William Fraser, Old Domimion University

### 4.3 NOAA Ship *Surveyor,* Leg I

Roger Hewitt, Southwest Fisheries Science Center
Michael Macaulay, University of Washington
Ole Mathisen, University of Alaska
David Demer, Scripps Institution of Oceanography
Teresa Klinger, University of California at Riverside
Valerie Loeb, Moss Landing Marine Laboratories
John Wormuth, Texas A&M University
Stephen Berkowitz, Texas A&M University
Osmund Holm-Hansen, Scripps Institution of Oceanography
Walter Helbling, Scripps Institution of Oceanography
Sergio Rosales, Universidad Católica de Valparaiso, Chile
Anthony Amos, University of Texas, Institute of Marine Science
Margaret Lavender, University of Texas, Institute of Marine Science
Christian Bonert, Servicio Hidrográfico y Oceanográfico de la Armada, Chile

### 4.4 NOAA Ship *Surveyor,* Leg II

Roger Hewitt, Southwest Fisheries Science Center
Patricia Morrison, University of Washington
Rita Horner, University of Alaska
David Demer, Scripps Institution of Oceanography
Susan Chivers, Southwest Fisheries Science Center
Jeanette Zamon, Cornell University
Valerie Loeb, Moss Landing Marine Laboratories
Walter Nordhausen, Scripps Institution of Oceanography
Enzo Acuña, Universidad Católica del Norte, Chile
Walter Helbling, Scripps Institution of Oceanography
Virginia Villafañe, Scripps Institution of Oceanography

Sergio Rosales, Universidad Católica de Valparaiso, Chile
Margaret Lavender, University of Texas, Institute of Marine Science
Barney Trams, University of Texas, Institute of Marine Science
Rebeca Dorion Guesalaga, Servicio Hidrográfico y Oceanográfico de la Armada

**4.5 Japanese Research Vessel *Kaiyo Maru*, Leg I**

John Bengtson, National Marine Mammal Laboratory
Peter Boveng, National Marine Mammal Laboratory
John Jansen, National Marine Mammal Laboratory

**4.6 Japanese Research Vessel *Kaiyo Maru*, Leg II**

Rennie Holt, Southwest Fishereis Science Center

**4.7 Chilean Research Vessel *Alcazar***

John Bengtson, National Marine Mammal Laboratory
Peter Boveng, National Marine Mammal Laboratory
Jorge Alvarado, Instituto Antartico Chileno