ABUNDANCE, SIZE AND MATURITY OF KRILL (*EUPHAUSIA SUPERBA*) IN THE KRILL FISHING GROUND OF SUBAREA 48.1 DURING THE 1990/91 AUSTRAL SUMMER

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Abstract

Acoustic and net sampling surveys for krill were conducted in the krill fishing ground north of the South Shetland Islands from 18 January to 3 February 1991. Distinct offshore-inshore heterogeneities in abundance and maturity of krill were observed. The survey area was divided into four zones: oceanic, slope frontal, neritic and nearshore zones. The mean density of krill was low in the oceanic zone (8.5 g/m^2), intermediate in the frontal (37.3 g/m^2) and neritic (28.1 g/m^2) zones, and extremely high in the nearshore zone (134.7 g/m^2). The last zone corresponds to the shelf break or the shelf area where topographic eddies were generated, suggesting that hydrodynamic convergence might be responsible for accumulation of krill in this zone. The total biomass over the survey area was estimated to be 1.59±0.45 million tonnes (95% confidence limit), of which 1.22±0.42 million tonnes was concentrated in the fishing ground (frontal + neritic + nearshore zones). Information from other studies indicated that krill biomass in this region had been lower than expected until early February 1991. As for maturity stages of krill, spawning krill (modal body length 49 mm) were dominant in the oceanic and frontal zones, whereas less mature krill (modal length 45 mm) dominated in the neritic and nearshore zones. Juveniles, which were scarce in the survey described, were found restricted mainly to the nearshore zone. Gravid females were exceedingly abundant in the slope frontal zone, having a mean density of 23.9 g/m^2 (411 000 tonnes), as contrasted with a low 3.7 g/m^2 (163 000 tonnes) in the oceanic zone. Gravid females were nearly absent in the neritic and nearshore zones. This indicates that slope frontal features may be important for the formation of favourable conditions for krill spawning.

Résumé

Des campagnes d'évaluation du krill par méthode acoustique et par échantillonnage au filet ont été menées dans le lieu de pêche de krill situé au nord des îles Shetland du Sud du 18 janvier au 3 février 1991. Une hétérogénéité distincte est apparue en matière d'abondance et de maturité du krill entre le large et la côte. L'aire considérée a été divisée en quatre zones: la zone océanique, celle du bord de la pente, la zone néritique et la zone proche de la côte. La densité moyenne du krill était faible dans la zone océanique (8,5 g/m^2), intermédiaire dans les zones frontale (37,3 g/m^2) et néritique (28,1 g/m^2) et extrêmement haute dans la zone côtière (134,7 g/m^2). Cette dernière zone correspond à la bordure du plateau ou à la région du plateau d'où provenaient les

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tourbillons topographiques, ce qui laisse entendre que la convergence hydrodynamique pourrait être responsable de l'accumulation du krill dans cette zone. La biomasse totale de la zone considérée à été estimée à 1,59 ± 0,45 million de tonnes (intervalle de confiance de 95%), dont 1,22 ± 0,42 million de tonnes étaient concentrées dans le lieu de pêche (zones frontale + néritique + côtière). Des informations provenant d'autres études indiquaient qu'avant début février 1991, la biomasse de krill avait été plus faible qu'on aurait pu s'y attendre dans cette région. En ce qui concerne les stades de maturité du krill, le krill reproducteur (longueur modale du corps, 49 mm) était prédominant dans les zones océanique et frontale, alors que le krill à un stade de maturité moins avancé (longueur modale, 45 mm) dominait dans les zones néritique et côtière. Les juvéniles, rares dans la campagne d'évaluation décrite, étaient généralement restreints à la zone côtière. Les femelles gravides de la zone du bord de la pente, d'une densité moyenne de 23,9 g/m^2 (411 000 tonnes), étaient extrêmement abondantes par rapport à la faible densité de 3,7 g/m^2 (163 000 tonnes) observée dans la zone océanique. Les femelles gravides étaient pratiquement absentes des zones néritique et côtière. Ceci met en évidence l'importance potentielle des caractéristiques du bord de la pente dans la formation de conditions favorables à la reproduction du krill.

Резюме

С 18 января по 3 февраля 1991 г. проводились акустические съемки и выборочные траловые съемки на участке промысла криля к северу от Южных Шетландских о-вов. Наблюдались четкие неоднородности в численности и половозрелости криля в прибрежных водах и в открытом море. Съемка делилась на четыре зоны: океаническая, фронтального склона, неритическая и прибрежная. Средняя плотность криля была низкой в океанической зоне (8,5 г/м^2), средней в фронтальной (37,3 г/м^2) и неритической (28,1 г/м^2) зонах и очень высокой в прибрежной зоне (134,7 г/м^2). Последняя зона совпадает с границей шельфа или районом шельфа, где образовались топографические водовороты. Это указывает на то, что накопление криля в этой зоне возможно вызвано гидронамической конвергенцией. Оценка общей биомассы в районе съемки - 1,59 ± 0,45 миллиона тонн (доверительный интервал - 95%), из чего 1,22 ± 0,42 миллиона тонн было сконцентрировано на промысловом участке (фронтальная + неритическая + прибрежная зоны). Полученная в результате других исследований информация указывает на то, что до начала февраля 1991 г. биомасса криля в данном районе была ниже ожиданной. Что касается стадий зрелости криля, в океанической и фронтальной зонах преобладал нерестующий криль (модальная длина - 49 мм), тогда как "менее" зрелый криль (модальная длина - 45 мм) доминировал в неритической и прибрежной зонах. Молодь, численность которой была низкой в ходе описанной съемки, в основном ограничивалась прибрежной зоной. Икряные самки были исключительно многочислены в зоне фронтального склона, где средняя плотность составила 23,9 г/м^2 (411 000 тонн). По сравнению с этим, в океанической зоне средняя плотность была низкой - 3,7 г/м^2 (163 000). Икряные самки почти отсутствовали в неритической и прибрежной зонах. Это указывает на то, что особенности фронтального склона могут играть важную роль в формировании благоприятных условий для нереста криля.

Resumen

Del 18 de enero al 3 de febrero de 1991 se realizaron prospecciones acústicas y de muestreo mediante redes en la zona de pesca de kril al norte del archipiélago de las Shetland del Sur. Se observaron claras diferencias en la abundancia y madurez del kril entre las aguas de alta mar y las cercanas a la costa. El área de estudio se dividió en cuatro zonas: oceánica, talud frontal, nerítica y cercana a la costa. La densidad media del kril fue baja en la zona océanica (8.5 g/m^2), intermedia en la zona frontal (37.3 g/m^2) y nerítica (28.1 g/m^2), y extremadamente alta cerca de la costa (134.7 g/m^2). La última zona corresponde al borde de la plataforma continental o al área de la plataforma en donde se generan remolinos por accidentes topográficos, lo que sugiere que la convergencia hidrodinámica puede ser la causa de que el kril se acumule en esta zona. La biomasa total sobre el área estudiada se estimó en 1.59 ± 0.45 millones de toneladas (límite de confianza del 95%), de la cual 1.22 ± 0.42 millones de toneladas se concentraron en la zonas de pesca (frontal + nerítica + cercana a la costa). Según la información que se tenía de esta zona, de otros estudios realizados, la biomasa de kril fue menor de lo previsto hasta principios de febrero de 1991. En lo que respecta a los estados de madurez del kril, predominó el kril en desove (longitud modal de 49 mm) en las zonas océanica y frontal, mientras que el kril menos maduro (longitud modal de 45 mm) predominó en las zonas nerítica y cercana a la costa. Los juveniles, que resultaron escasos en la prospección estudiada, se limitaron a la zona cercana a la costa. Se encontró una gran cantidad de hembras grávidas en la zona del talud frontal con una densidad media de 23.9 g/m^2 (411 000 toneladas), comparado con una baja densidad (3.7 g/m^2) en la zona océanica (163 000 toneladas). Casi no se encontraron hembras grávidas en las zonas nerítica y cercana a la costa. Esto supone que las características del talud frontal podrían ser importantes en la formación de condiciones favorables para el desove del kril.

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1. INTRODUCTION

The Antarctic Peninsula region is known as a region rich in krill and has been actively studied. Siegel (1988) has provided the following information on the distribution and abundance of krill in this region: "In spring, as the pack ice retreats, krill abundance increases. In late December to early January it reaches its highest levels which last until the beginning of March. Interestingly, the krill stock shows a distinct spatial segregation in the maturity stages during the spawning season. Gravid and spawning adults occur along the continental slope and in oceanic waters, while nearer to the coast subadult krill dominate and juveniles are confined to coastal shelf waters."

In the Antarctic Peninsula region the krill fishing has regularly been conducted in the waters north of the South Shetland Islands, which corresponds to spawning and feeding grounds for adult and subadult krill (e.g., Siegel, 1988). As this area potentially overlaps with foraging grounds for krill-dependent predators during summer it has now become one of the "hot-spots". This paper presents information on biomass estimates and stock structure of krill in this fishing area during the 1990/91 summer, and also discusses mechanisms for the formation of persistent concentrations of krill by examining the relationship between the pattern of krill distribution and oceanographic structure.

2. MATERIALS AND METHODS

The cruise of RV *Kaiyo Maru* was conducted in two stages (Ichii *et al.*, 1991), although this paper deals only with research activities of the second leg. Leg 2 covered the waters from the north of Elephant Island to the north of Livingston Island from 18 January to 3 February 1991 (Figure 1). Transects ran in an offshore-inshore direction with 20 n miles between the transects. A zig-zag transect pattern in the offshore region of Livingston Island was caused by weather conditions which hampered operations. The cruise tracks running along the coast corresponded to the depth contour of approximately 150 m.

2.1 Oceanographic Observation

Oceanographic data were collected using a Sea-Bird SBE-19 CTD. CTD station depths were down to 1 000 m or closer to the sea bottom in shallower water.

For the study of subsurface current patterns around the islands, four drifting buoys (model C-2243, TOYOCOM, Japan) were released and tracked using the ARGOS system carried on TIROS-N and NOAA-A satellites. Typically, twelve locations per day were recorded for each buoy with an accuracy less than several hundred metres. From the 1987/88 survey krill were reported to be most abundant over the depth range of 30 to 40 m in this region (Anon., 1989). Therefore each buoy was deployed with a curtain drogue (4 m x 1 m) at 30 m depth to assess this subsurface circulation.

2.2 Hydroacoustic Survey

The echo sounder used was an FQ-50 with a digital integrator (Furuno Electric, Japan) operating at 200 kHz. The operating parameters of the acoustic system are summarised in Table 1. Throughout the survey period, excluding time spent on stations and towing sampling nets, the Mean Volume Back-Scattering Strength was continuously measured at the constant horizontal integration interval of 1 n mile for the depth range of 10 to 200 m or 10 m to bottom if shallower. The top depth of integration (10 m) was changed sometimes to 20 m to avoid surface noise. The target strength of krill used as a default value was -66.1 dB per 1 g wet weight of krill (Shimadzu *et al.*, 1989). The actual length compositions of krill during the current survey were fairly close to the length composition derived from target strength measurements.

The echo-integrator was calibrated with a hydrophone at the port of Tokyo before (29 October 1990) and after (26 March 1991) the cruise. Two calibration experiments showed little reduction in source level and receiving sensitivity.

2.3 Net Sampling

Samples of krill were collected by a rectangular frame trawl (the *Kaiyo Maru* Midwater Trawl (KYMT)), which has a mouth area of 9 m^2 and mesh size of 3.4 mm. The trawl was towed obliquely from a depth of about 100 m to the surface at a speed of about 3 knots, at pre-determined fixed locations (blind tows). When a dense swarm of krill was detected acoustically, the KYMT was towed horizontally at swarm depth (aimed tows).

A sample from each haul was preserved in a 10% (buffered) formalin-seawater solution for later examination in the laboratory ashore. 150 individuals of krill were randomly selected from each sample for measurement of body length and determination of maturity stage; all individuals were analysed for small catches of ≤150 krill. Body length was measured to the nearest millimetre from the tip of the rostrum to the end of the telson. All measurements were carried out by a single observer to avoid methodologically biased differences in length frequency data (Watkins *et al.*, 1985). Maturity stages were identified according to the classifications of Makarov and Denys (1981). The size and maturity stage compositions from each sample were weighted by their respective mean density, estimated acoustically over 10 n miles along the transect near its respective sampling station before being pooled.

3. RESULTS

3.1 Oceanographic Features

Figure 2 shows horizontal salinity distribution at 10 m depth. Three different regions were clearly distinguished: the oceanic (deeper than approximately 3 000 m), slope frontal (≈ 500 to 3 000 m depth) and inshore (≈ 150 to 500 m) region (Figure 3). The frontal region, known as CBW (Continental Boundary Waters), is characterised by a relatively sharp increase in salinity towards the south (from 33.7 to 34.2 ‰) and is restricted to a band along the island shelf slope.

The tracks of four buoys demonstrated subsurface current patterns in each region (Figure 4). In the oceanic region buoy 1 moved continuously towards the northeast on meandering and eddying currents, reaching as far as the South Georgia region, and then became trapped in the shelf break area west of South Georgia. In the frontal region buoys 2 and 3 drifted eastward at first, then became entrained in the inshore waters adjacent to Elephant and Livingston/King George Islands, respectively. These buoys demonstrated the existence of complex eddies along the shelf break or on the shelf to the north of South Shetland Island. Buoy 4 was deployed in the inshore region and became entrained in an erratically rotating current along the shelf break, before becoming trapped in Barclay Bay on the northern side of Livingston Island. Thus, all the buoys exhibited a distinct tendency to be trapped in topographical complex eddies generated along the shelf break or on the shelf.

3.2 Hydroacoustic Surveys

3.2.1 Stratification of Survey Region

Figure 5 shows the distribution of krill density along the transects. Krill density tended to decrease oceanward. In the oceanic region only occasional occurrences of dispersed aggregations were observed, while in the frontal region dispersed aggregations or small swarms were frequently detected. The inshore region was characterised by large and dense swarms concentrated along the shelf breaks or on the shelf where topographical eddies were generated. In order to reduce the variance in the biomass estimate for the inshore region, this region was divided into two zones: neritic and nearshore (Figure 6). The latter zone was defined as narrow bands along the 150 m depth contour where krill were frequently concentrated. The width of the nearshore zone was assumed to be 3 n miles because the area of high density appeared to be formed at least over this width along the coast. Consequently, for the estimation of total krill biomass over the survey region, this area was divided into four zones: oceanic, slope frontal, neritic and nearshore.

3.2.2 Day/Night Differences in Krill Density

Because of krill's tendency to migrate at night towards the surface, where they can be undetectable acoustically, the difference in overall mean density between day and night was checked using pooled data (densities over integration intervals) for each zone. Day and night densities were 7.9 and 10.7 g/m^2; 37.2 and 40.0 g/m^2; 25.7 and 39.7 g/m^2; and 165.0 and 72.6 g/m^2 in the oceanic, frontal, neritic and nearshore zones, respectively. Since no significant day/night difference in mean density was observed for each zone, all day- and night-time data were combined for subsequent analyses.

3.2.3 Estimation of Mean Density and Biomass

Mean density and sampling variance were estimated using a transect-based method adopted at the second post-FIBEX acoustic workshop (Anon., 1986). This method assumes that the transect means are independent, that the regression of expected number of animals on transect length should pass through the origin, and that the variance of the number of animals is proportional to transect length.

Mean density (g/m^2) for each zone, the variance (Var) of the mean and 95% confidence limits (CL) about the mean were calculated from:

$$\overline{d}_i = \frac{\sum_{k=1}^{N_i} d_{ik} L_{ik}}{\sum_{k=1}^{N_i} L_{ik}}$$

$$\mathrm{Var}(\overline{d}_i) = \frac{N_i}{N_i - 1} \frac{\sum_{k=1}^{N_i} (d_{ik} - \overline{d}_i)^2 L_{ik}^2}{\left(\sum_{k=1}^{N_i} L_{ik}\right)^2}$$

$$\mathrm{CL}(\overline{d}_i) = \pm\, t\,(N_i - 1, 0.05)\sqrt{\mathrm{Var}(\overline{d}_i)}$$

where $\overline{d}_i$ = mean density for i-th zone
d_{ik} = mean density for k-th transect in i-th zone
L_{ik} = length of k-th transect in i-th zone
N_i = number of transects in i-th zone
$t(\mu, \alpha)$ = student's t-distribution with μ degrees of freedom and proportion α in both tails.

Biomass (tonnes) for each zone, the variance and 95% confidence limits of the biomass were given by:

$$B_i = A_i \overline{d}_i$$

$$\mathrm{Var}(B_i) = A_i^2 \mathrm{Var}(\overline{d}_i),$$

$$\mathrm{CL}(B_i) = \pm\, t(N_i - 1, 0.05)\sqrt{\mathrm{Var}(B_i)}$$

where B_i = biomass for i-th zone
A_i = area for i-th zone.

The total biomass (B_t) for an area consisting of M zones, and the variance of the total biomass were computed as the sum of the zonal biomass $\left(\sum_{i=1}^{M} B_i\right)$ and variance $\left(\sum_{i=1}^{M} \mathrm{Var}(B_i)\right)$, respectively. 95% confidence limits of the total biomass were estimated from:

$$CL(B_t) = \pm\, t\left(\sum N_i - M, 0.05\right)\sqrt{\mathrm{Var}\left(\sum_{i=1}^{m} B_i\right)} \text{ (Mackett, 1973).}$$

The estimates of mean density and biomass for each zone are shown in Table 2. The mean density was as high as 135.1 g/m^2 in the nearshore zone, while only 8.5 g/m^2 in the oceanic zone, with intermediate values of 37.3 and 28.1 g/m^2 in the frontal and neritic zones, respectively. The coefficient of variation (CV) was higher in the nearshore zone (33%) than other zones (24 to 26%) due to the extremely patchy distribution of krill and the smaller number of transects in this zone. The total biomass over the survey region was estimated to be 1.59±0.45 million tonnes (95% confidence limit), of which 1.22±0.42 million tonnes was concentrated in the areas of fishery operation ("frontal" + "neritic" + "nearshore"). A statistically valid CV (14%) was obtained for the total biomass.

3.2.4 Spatial Distribution of Lengths and Maturity Stages of Krill

The krill stock showed a distinct offshore-inshore separation in size and maturity classes (Figure 7). Large krill (modal length 49 mm) were dominant in the oceanic and slope frontal zones, whereas medium-sized krill (modal length 45 mm) dominated in the neritic and nearshore zones. Small krill (modal length 30 mm) were scarce except in the nearshore zone where they represent about 30% of the stock. According to the growth curve for krill (Siegel, 1987), length modes of 45 mm and 30 mm correspond approximately to ages 3+ and 1+ years respectively. The 49 mm length mode is possibly composed of mostly age 4+ and older, considering the clear difference in maturity stages between krill with modal lengths of 49 and 45 mm (Figure 7).

All krill were at the spawning stage in the oceanic and frontal zones. Almost all females were gravid (stage IIID) and all males had fully developed spermatophores (IIIB). On the other hand, krill were less mature in the neritic and nearshore zones: females were not gravid (IIIBC), and a large component (35 to 45%) of males were immature (IIA1-IIA3). Juveniles were generally restricted to the nearshore zone where they constituted 27% of the stock. The percentages of gravid females in the population were 43%, 64%, 4% and 3% in the oceanic, slope frontal, neritic and nearshore zones respectively. Multiplying the mean densities of krill by these percentages, mean densities of gravid specimens were calculated to be extremely high in the slope frontal zone (23.9 g/m^2), as contrasted with the lower values (3.7 g/m^2) in the oceanic zone, while such krill were virtually absent from the neritic and nearshore zones (Table 3). Gravid biomass amounted to 594 000 tonnes over the survey region, of which as much as 411 000 tonnes was concentrated in the slope frontal zone.

4. DISCUSSION

The present study divided the inshore region into the two zones ("neritic" and "nearshore"). This clearly reduced the coefficient of variation of the biomass estimate for the inshore region (from 38% to 21%), with only a small change in the biomass estimate (decrease by 10%). Since the inshore region showed great spatial variability in krill abundance, the number of transects should be increased (e.g., by setting cruise tracks diagonally across depth contours) to obtain more reliable estimates.

Krill density and biomass in the 1990/91 season for this region were at lower levels until early February, approaching normal levels from mid-February onward (AMLR, 1991). This low density in early summer influenced krill-eating predators at Seal Island: 20% decline in the number of penguins occupying nests compared to last season, and longer feeding trips of Antarctic fur seals in early January (five to nine days) compared to late February (one to three days) (AMLR, 1991). Ichii *et al.* (1991) also reported that the density at the localised fishing ground north of Livingston Island was approximately less than half of that three years ago (149 g/m^2 in 3 February 1991 vs 342 g/m^2 in 21 January 1988). Later in this season (late February to early March) krill biomass in the Elephant Island region was estimated to be as much as 2.12 million tonnes, the same level as in the previous season (AMLR, 1991). Hence, the estimate of total krill biomass obtained in this study should be regarded not as an underestimation but as a true reflection of lower biomass at the end of January in the 1990/91 season.

The krill stock showed distinct offshore-inshore heterogeneities in abundance and biological characteristics, which evidently resulted from both biological and hydrographic factors:

(i) low values of Chl *a* were observed in the oceanic zone compared to the other three zones during the survey (Ichii *et al.*, 1991). This implies that the least favourable feeding environment might be responsible for the lower krill density in this zone;

(ii) the krill spawning stock distribution was closely associated with the slope frontal zone, indicating that krill use this zone as spawning grounds. In the Indian Ocean sector a spawning ground appeared to coincide with the continental slope front region (Ichii, 1990). The slope region is favourable for spawning for the following reasons. Firstly, spawning must be much more successful in deeper waters (the frontal and oceanic zones) than in the shallow coastal region (the neritic and nearshore zones) because in the shallow region sinking krill eggs would soon reach the seabed and become exposed to predation by benthic animals, resulting in a lower survival rate. Secondly, comparing the two deeper zones (slope frontal and oceanic) the former zone may be more favourable in that the upwelling deep water may assist upward movement of early larval stage krill (Marr, 1962) and that the higher phytoplankton concentration may provide a better feeding environment for spawning krill;

(iii) the neritic and nearshore zones are characterised by sluggish circulation around the islands. Areas of dense krill concentration tended to coincide with the shelf break or be on the shelf, where topographic convergent eddies were generated. The hydrodynamic convergence, therefore, might be responsible for aggregating krill into the nearshore zone. This mechanical accumulation might also cause the frequent occurrence of juveniles, which are poorer swimmers than adults, in this zone.

Krill trawlers which had been operating over the frontal, neritic and nearshore zones during the study period operated only in the last two zones by the end of February, 1991. Post-spawned krill were observed in their catches (Kawaguchi, personal communication). Siegel (1988) and Brinton (1991) suggested that, after spawning, adult krill leave the oceanic and frontal zones where larvae occur at that time in surface waters, and migrate into the neritic and nearshore zones. It is therefore considered that toward the end of the spawning season more and more post-reproductive krill were moving into the neritic and nearshore zones, probably leading to a considerable part of the krill biomass aggregating in those zones.

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REFERENCES

AMLR. (ROSENBERG, J. and R. HEWITT, Eds). 1991. AMLR 1990/91 Field Season Report: Objectives, Accomplishments and Tentative Conclusions. Southwest Fisheries Science Center Administration Report LJ-91-18. Document *WG-CEMP-91/11*. CCAMLR, Hobart, Australia: 97 pp.

ANON. 1986. Post-FIBEX Data Interpretation Workshop. Frankfurt, Federal Republic of Germany. September 1984.

ANON. 1989. Showa 62-nendo Kaiyo-maru chousa koukai houkokusho (Report of *Kaiyo maru*'s fifth Antarctic research cruise). Fisheries Agency of Japan: 301 pp.

BIOMASS. 1984. *Report Series*, 40: 106 pp.

BRINTON, E. 1991. Distributon and population structures of immature and adult *Euphausia superba* in the western Bransfield region during the 1986/87 summer. *Deep Sea. Res.*, 38 (8/9): 1169-1193.

ICHII, T. 1990. Distribution of Antarctic krill concentrations exploited by Japanese krill trawlers and minke whales. *Proc. NIPR Symp. Polar Biol.*, 3: 36-56.

ICHII, T., H. ISHII and M. NAGANOBU. 1991. Krill (*Euphausia superba*) distribution in relation to water movement and phytoplankton distribution off the northern South Shetland Islands. In: *Selected Scientific Papers, 1991 (SC-CAMLR-SSP/8)*. CCAMLR, Hobart, Australia: 123-140.

MACKETT, D.J. 1973. Manual of methods for fisheries resource survey and appraisal; Part 3 - standard methods and techniques for demersal fisheries resource survey. *FAO Fish. Tech. Pap.*, 124: 39 pp.

MAKAROV, R.R. and C.J. DENYS. 1981. Stages of sexual maturity of *Euphausia superba* Dana. *BIOMASS Handbook*, 11: 1-13.

MARR, J.W.S. 1962. The natural history and geography of the Antarctic krill (*Euphausia superba* Dana). *Disc. Rep.*, 32: 33-464.

SHIMADZU, Y., T. KOIKE and T. SUGURO. 1989. Target strength estimation of Antarctic krill, *Euphausia superba* by cooperative experiments with commercial trawler. Document *SC-CAMLR-VIII/BG/30*. CCAMLR, Hobart, Australia: 10 pp.

SIEGEL, V. 1987. Age and growth of Antarctic Euphausiacea (Crustacea) under natural conditions. *Mar. Biol.*, 96: 483-495.

SIEGEL, V. 1988. A concept of seasonal variation of krill (*Euphausia superba*) distribution and abundance west of the Antarctic Peninsula. In: SAHRHAGE, D. (Ed.). *Antarctic Ocean and Resources Variability*. Springer-Verlag, Berlin Heidelberg: 219-230.

WATKINS, J.L., D.J. MORRIS and C. RICKETTS. 1985. Nocturnal change in the mean length of a euphausiid population: vertical migration, net avoidance, or experimental error? *Mar. Biol.*, 86: 123-127.

Table 1: Operating parameters of the echosounder Furuno FQ-50.

Frequency	200 kHz
Equivalent beam width	0.007 sr
Pulse duration	1.8 ms
Depth range	0 to 200 m
Depth channel	10* to 200 m (9 channels)
Integration interval	1 n mile
Attenuator	20 dB
Threshold	15 dB
TVG	20 log R
Gain constant	78.9 dB

* The top depth integration was changed to a maximum of 20 m when the sea was rough.

Table 2: Mean density and biomass of krill in each zone.

Zone	Area ($10^3 km^2$)	Mean Density (g/m^2)			Biomass (10^3 tonnes)			CV %	n
		E	V*	CL	E	V**	CL		
Oceanic	44.0	8.5	4.2	4.7	374	8131	204	24	10
Frontal	17.2	37.3	91.5	21.6	642	27069	372	26	10
Neritic	10.3	28.1	47.3	15.9	289	5018	163	24	9
Nearshore	2.1	135.1	2020.6	124.8	284	8911	262	33	5
Total	73.6				1589	49129	453	14	34

E - Mean, V - Variance, CL - 95% confidence limit, CV - coefficient of variation, n - number of transects, * g^2/m^4, ** 10^6 tonnes.

Table 3: Mean density and biomass of gravid krill in each zone.

Zone	% of Gravid Krill in the Population	Mean Density (g/m^2)	Biomass (10^3 tonnes)
Oceanic	43	3.7	163
Frontal	64	23.9	411
Neritic	4	1.1	11
Nearshore	3	4.1	9
Total	37		594

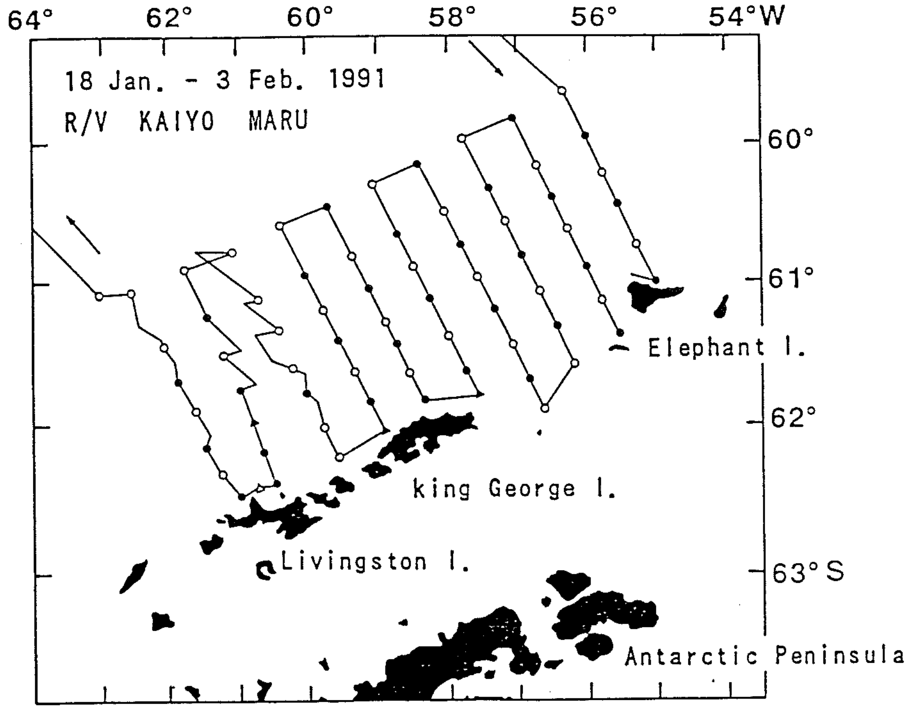

Figure 1: Cruise track and stations off the South Shetland Islands.

- o CTD stations
- • CTD and KYMT (blind tow) stations
- Δ KYMT (aimed tow) station
- ▲ CTD and KYMT (aimed tow) stations

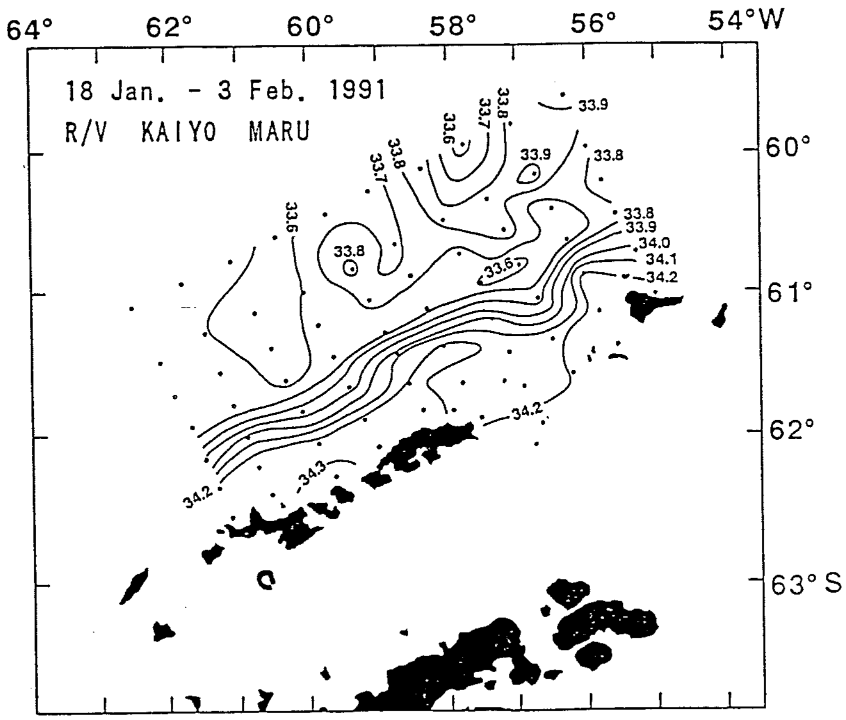

Figure 2: Distribution of salinity at 10 m depth.

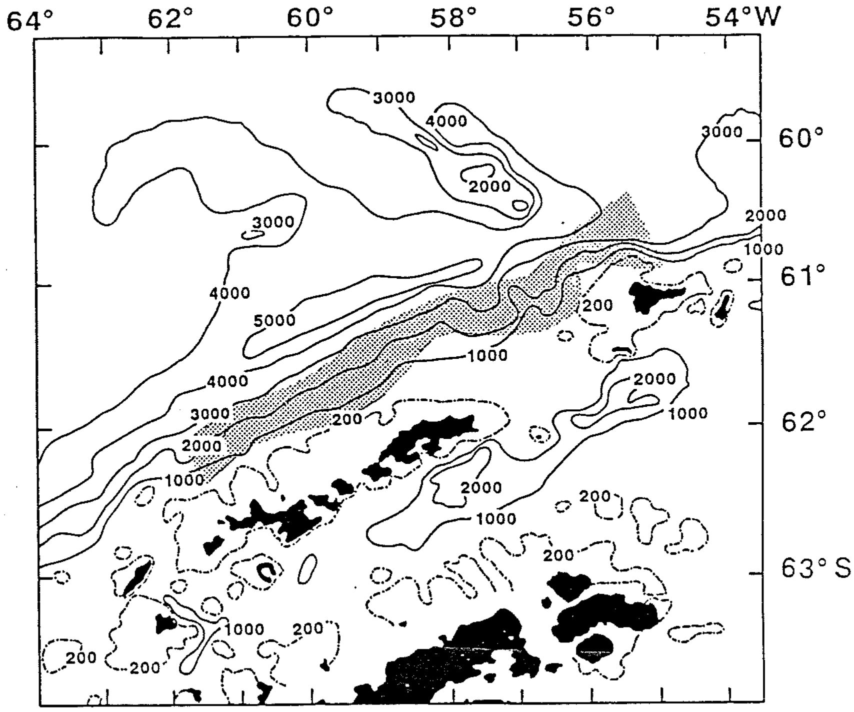

Figure 3: Bathymetric chart around the South Shetland Islands. Depth in metres. Shaded area indicates the slope frontal zone.

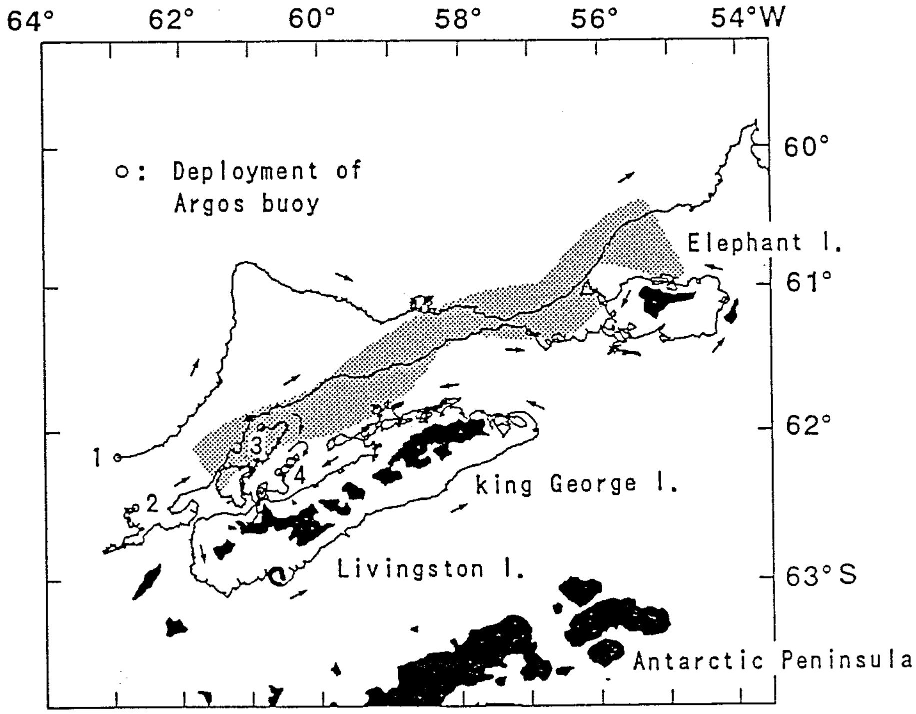

Figure 4: Subsurface (30 to 35 m depth) circulation derived from the paths of four satellite-tracked buoys. Shaded area indicates the slope frontal zone.

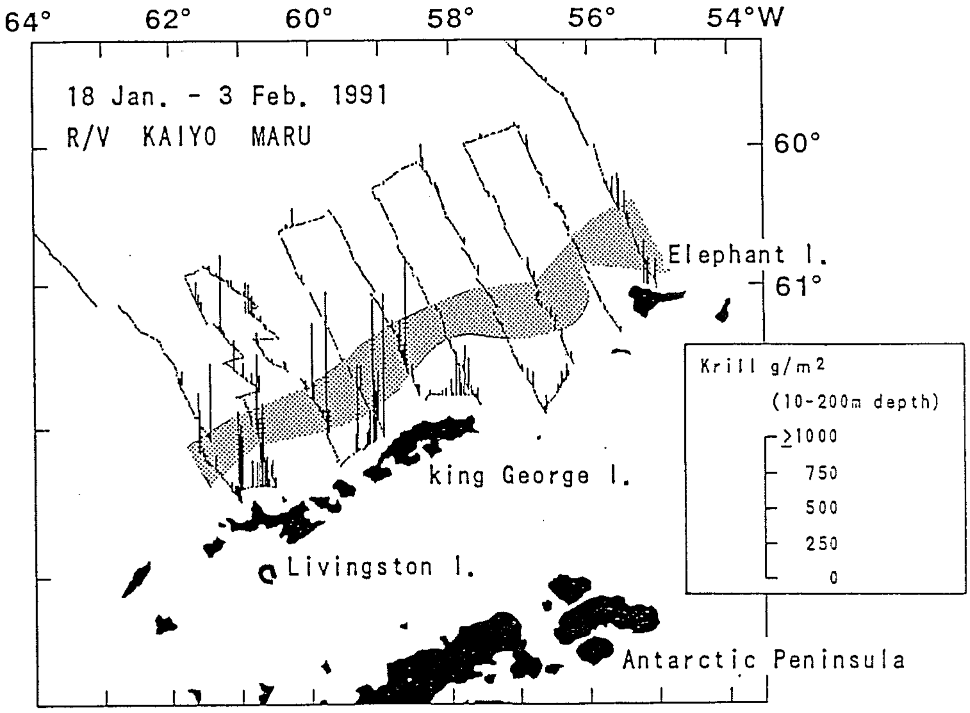

Figure 5: Mean densities of krill per n mile of the transect. Shaded area indicates the slope frontal zone.

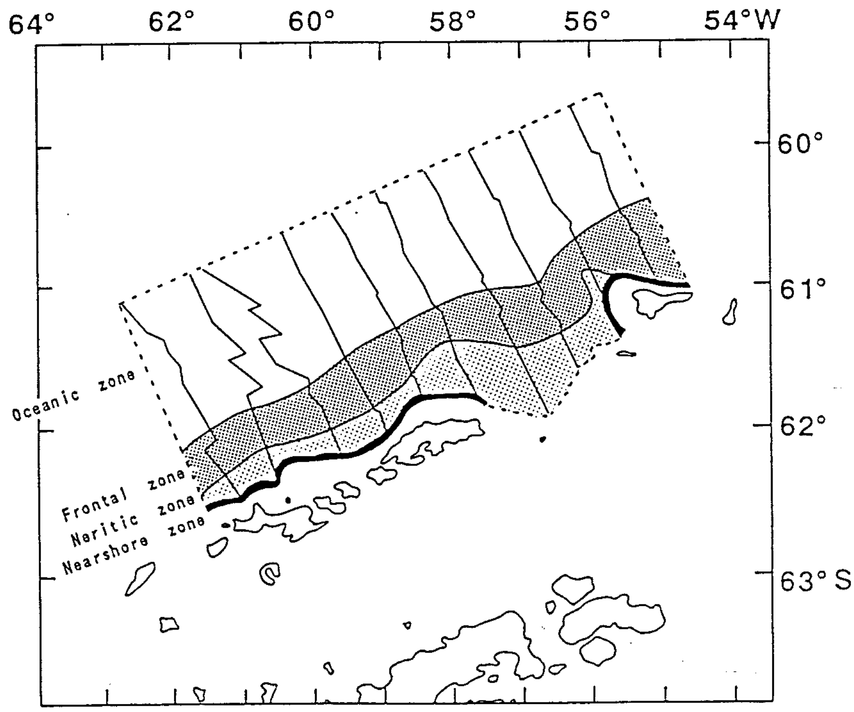

Figure 6: Stratification of the survey area and transects for each zone. The nearshore zone is defined as 3-n mile wide belts along the 150 m depth contour. Cruise tracks along these narrow belts were used as transects for the nearshore zone.

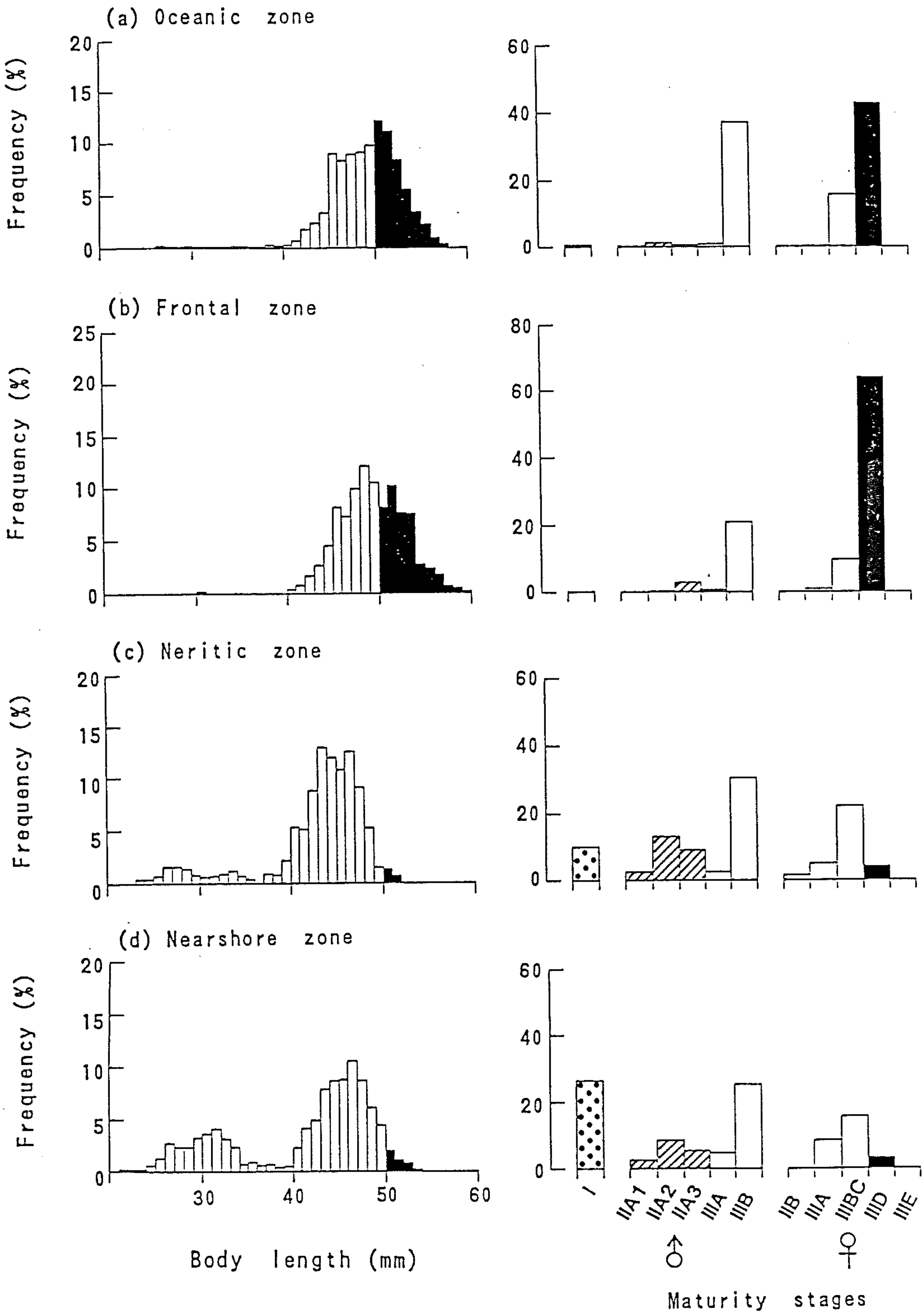

Figure 7: Length and maturity compositions of krill by zones.
Left: solid bars indicate krill larger than 50 mm
Right: bold dotted, shaded and solid bars indicate juveniles, subadult males and gravid females, respectively.

Légendes des tableaux

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- o stations de CTD
- • stations de CTD et KYMT (chalutage non contrôlé)
- Δ station de KYMT (trait dirigé)
- ▲ stations de CTD et KYMT (trait dirigé)

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Figure 5: Densités moyennes du krill par mille n. du transect. La partie hachurée correspond à la zone du bord de la pente.

Figure 6: Stratification de la zone d'étude et des transects pour chaque zone. La zone proche de la côte est définie comme étant formée de ceintures de 3 milles n de large le long de la courbe de niveau de 150 m environ. Les trajets de la campagne le long de ces ceintures étroites ont servi de transects pour la zone proche de la côte.

Figure 7: Composition en longueurs et en fonction de la maturité du krill par zones.
A gauche : les barres pleines correspondent au krill de taille supérieure à 50 mm
A droite : les barres en caractères gras pointillées, hachurées ou pleines correspondent respectivement aux juvéniles, aux mâles subadultes et aux femelles gravides.

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