CHARACTERISTICS OF KRILL SWARMS FROM PRYDZ BAY

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Abstract

The CCAMLR.AUS dataset available to the Subgroup on Survey Design was derived from a survey of Prydz Bay, Antarctica, in December 1990. Swarm length, depth, thickness, Mean Volume Backscattering Strength (MVBS) and interswarm length were calculated for swarms of euphausiids encountered along a 78 km transect over the continental shelf close to the CEMP study site at Magnetic Island. The euphausiid species was probably *Euphausia crystallorophias*. An increase in swarm length was seen with increasing distance from the coast.

Résumé

Le jeu de données CCAMLR.AUS dont disposait le sous-groupe sur la conception des campagnes d'évaluation était dérivé d'une campagne d'évaluation de la baie Prydz, en Antarctique, en décembre 1990. Pour les essaims d'euphausiacés rencontrés le long d'un transect de 78 km sur le plateau continental à proximité du site d'étude du CEMP à l'île Magnetic, on a calculé la longueur, la profondeur, l'épaisseur, l'intensité moyenne de rétrodiffusion par volume (MVBS), ainsi que la distance entre les essaims. Les euphausiacés concernés appartenaient vraisemblablement à l'espèce *Euphausia crystallorophias*. Une augmentation de la longueur des essaims a été remarquée à mesure que l'on s'éloigne de la côte.

Резюме

Набор данных "CCAMLR. AUS", имевшийся у Подгруппы по схеме съемки, был получен в результате съемки в заливе Прюдз, Антарктика, в декабре 1990 г. Были вычислены длина, глубина и плотность скопления, средняя сила объема обратного акустического рассеивания (MVBS) и расстояние между скоплениями эвфаузиид, обнаруженными вдоль 78-километрового разреза над континентальным шельфом вблизи участка исследования по Программе CEMP на острове Магнетик. Имеется предположение, что встреченные эвфаузииды относились к виду *Euphausia crystallorophias*. По мере удаления от побережья наблюдалось увеличение длины скоплений.

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Resumen

El fichero CCAMLR.AUS utilizado por el "Subgrupo para el Diseño de Prospecciones" contenía los datos de la prospección realizada en la bahía de Prydz, Antártida, en diciembre de 1990. Se calcularon el tamaño, profundidad y espesor de los cardúmenes, la reverberación media volúmetrica (MVBS) y la distancia entre cardúmenes, de los cardúmenes de eufáusidos encontrados a lo largo de un transecto de 78 km, efectuado en la plataforma continental cercana a la localidad del CEMP de la isla Magnética. La especie de euphausido era posiblemente *Euhausia crystallorophias*. Se constató un aumento del tamaño de los cardúmenes a medida que aumentaba su distancia de la costa.

1. INTRODUCTION

This paper explains the derivation of the CCAMLR.AUS dataset available to the Subgroup on Survey Design. The subgroup was set up by the CCAMLR Working Group on Krill (WG-Krill) and was directed "to establish:

(i) a set of initial parameters pertaining to the distribution of krill;

(ii) a set of options for the design of surveys; and

(iii) a set of methodologies for the determination of variances and other data required from these surveys."

The CCAMLR.AUS dataset is intended to complement similar data from the South African and FRG FIBEX cruises at 20°E and 55°W (Miller and Hampton, 1989a). This paper describes the methods used to produce the dataset and presents an initial analysis of the swarm characteristics it describes.

The dataset used in this analysis is relatively short (78 km transect length). However, it is believed to be representative of the swarm characteristics seen over the continental shelf in Prydz Bay in December 1990. The placement of the transect, close to a designated predator parameter monitoring site at Magnetic Island (CCAMLR, 1991), has direct relevance to the area that would have to be surveyed during the Ecosystem Monitoring Program, defined as within a radius of 100 km of a monitoring site (SC-CAMLR-IX, Annex 6, paragraph 101).

2. METHODS

Data were analysed from a single transect undertaken by Australian Antarctic Division using the RV *Aurora Australis* over the continental shelf in Prydz Bay, Antarctica. The transect was run due north from Davis Station on 18 December 1990 along 74°30'E longitude (Figure 1). Conditions were calm and ice free from 1200 hours until 2300 hours GMT when the ship encountered a band of pack-ice just before reaching the edge of the continental shelf.

Data were collected with a Simrad EK500 echosounder at a frequency of 120 kHz using a hull mounted transducer. The echosounder was fully calibrated prior to the survey. Data for single pings were stored as Mean Volume Backscattering Strength (MVBS) integrated in 25 m depth intervals over a 225 m range. The raw data were submitted to CCAMLR for the use of the Subgroup on Survey Design.

Unfortunately, no ground truthing was performed during this time. It is most likely however, that the swarms this far into Prydz Bay were predominantly *E. crystallorophias*. Surveys carried out in February showed that most of the euphausiids over the shelf (south of 67°S) were *E. crystallorophias* although there was some *E. superba* in the samples (S. Nicol and G. Hosie, pers. com.).

Analysis was performed at the CCAMLR Secretariat using a VAX minicomputer. The first depth layer, 0 to 25 m, was subject to a great deal of noise and was excluded from the analysis. Pings were designated as krill bearing if a single depth range had an MVBS value exceeding a threshold of -95 dB. Noisy pings were identified by having a krill thickness of greater than 125 m, and a characteristic pattern of increasing dB with depth (because of the Time Varied Gain correction), and were excluded from the analysis.

Once pings containing krill had been identified the characteristics of swarms were determined. Two key variables used were:

(i) the Intercepted Swarm Length (ISL), defined as the distance between the first ping encountering a swarm and the first ping to lose the swarm; and

(ii) the Between Swarm Distance (BSD), the distance from the last ping encounter with the swarm and the first encounter with the next swarm.

The latter is particularly important in determining the end or the continuation of a swarm if the ping sequence of a swarm has breaks in it where no krill are present, either because of breaks in the swarm structure or because of noise.

In the analysis the minimum BSD was set to 10 m and the minimum ISL to 2 m, to ensure that the shortest 'swarms', single ping encounters, were included, although these may not be considered true swarms in the classification of Miller and Hampton (1989b).

The time of each ping was available in the original data file, and distance was calculated using mean speeds derived from the ship's positional data. The ping data was analysed in five sections, each with slightly different ship speeds. Integrated MVBS* and mean swarm thickness were also calculated for each swarm, although swarm thickness calculated from these data will lack accuracy due to the EK500 integration interval of 25 m.

For the purposes of comparison, a biomass index was calculated using an assumed mean *E. crystallorophias* length of 27.5 mm, weight 200 mg (G. Hosie, pers. comm.), and the equations

$$TS = -127.45 + 34.85 \log10 \text{ (length in mm)}$$

(TS relationship for *E. superba* given by SC-CAMLR (1991), at 120kHz, extrapolated for *E. crystallorophias*).

$$\text{swarm radius (m)} = \lambda \ (2/\pi) \qquad \text{(Butterworth, 1988)}$$

$$\text{mean number density (individuals.m}^{-3}) \ \sigma_V = 10^{0.1(s_V - TS)}$$

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* Calculated using $MVBS_{swarm} = 10 \log_{10} \left(\frac{\sum_{i=1}^{n} 10^{0.1svi}}{n} \right)$,

where **n** = number of ping/depth intervals in the swarm, **svi** is the MVBS for a single ping depth interval.

swarm biomass index (kg) = $p. \lambda^2. (4/\pi).w.\sigma_v$

where λ = intercepted swarm length (m)
p = swarm thickness (m)
TS = target strength
s_v = observed MVBS
w = weight (kg)

3. RESULTS

The data sequence started at 1558 hours on 18 December and continued until 2213 hours when the data became very noisy as the ship started encountering ice. The ping rate was about one every second until 1808 hours (approximately 30 km from the start) when it dropped to one every six seconds. This leads to a somewhat distorted dataset, with minimum swarm length of about 18 m (1 ping) after 1808 hours compared with about 3.5 m before this time. Figures 2a and b show this clearly. The change in ping rate also effects the calculated BSD, which has a minimum value corresponding to 2 pings (about 36 m) after 1808 hours.

Intercepted swarm length, observed between swarm distance, swarm thickness, integrated MVBS and swarm biomass index are shown in Figures 3a to 3e. Length, BSD and biomass are approximately log normally distributed. The bars marked '*' in Figures 2a and b are distortions introduced by the decreased ping rate after 1800 hours discussed above, and the true modes lie at 3-3.5 and 4.4-4.6 for ln(length) and ln(BSD) respectively. Basic statistics for these parameters are given in Table 1. The mean swarm length of 24 m and BSD of 83 m indicate that the pattern of krill aggregations was one of many small swarms with a few much larger ones (more than 50% of total biomass index is contributed by a single large swarm).

There were no significant correlations between any of the independent swarm parameters (length, MVBS, depth, thickness or mean between swarm distance). Plots of swarm length and swarm biomass index with distance, however, show that maximum length and biomass both increased with distance from the shore; ln(swarm length) is positively correlated with distance (correlation coefficient = 0.472 n = 477). This effect is influenced by the change in ping rate after 30 km, but Figure 4 clearly shows that mean swarm biomass index started increasing before the 30 km point.

4. DISCUSSION

The analysis was hampered by the change in ping rate after 1808 hours (north of 67°51'38"S) and the loss of resolution that this resulted in. Resolution is also lost by the pre-integrations into 25 m depth intervals which results in the artificial lower limit of swarm thickness. These problems may be overcome in future but the difficulties encountered in interpreting these data highlights the importance of recording acoustic data with the highest resolution available. The loss of data on krill swarms shallower than 25 m is also a problem, particularly as many of the swarms in this transect were encountered between 25 and 50 m depth, as is the uncertainty about species composition and biological characteristics (length and weight).

Even though the distance of this transect is relatively small, there is a significant change in swarm length and estimated swarm biomass with distance from the shore, despite the high variances associated with the data (Anova result, $P < 0.001$). These are real changes in the quantity of prey available to predators within 100 km radius of a predator monitoring site at Magnetic Island, even though they relate to *E. crystallorophias* rather than *E. superba*. The fact that these characteristics change relatively fast within the ranges identified by CEMP as being important for prey surveys around predator monitoring sites has important consequences for survey design.

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Table 1. Krill swarm parameters. Intercepted length, between swarm distance and biomass have been log transformed; their corresponding exponential values are given in parentheses (n = 475).

	ln(Length) (m)	ln(BSD) (m)	MVBS (dB)	Depth (m)	Thickness (m)	ln(Biomass) (kg)
Min	1.194 (3.3)	2.754 (15.7)	-94.9	25	25	-6.956 (0.001)
Max	6.465 (642.3)	7.154 (1279.2)	-56.3	200	62.5	12.354 (232 tonnes)
Mean	3.184 (24.1)	4.417 (82.8)	-77.6 (0.171[1])	57.684	28.104	1.263 (3.54)
St Dev.	0.983	0.861	8.723 (0.034[1])	38.069	6.909	3.584

[1] Mean and standard deviation of $\log_{10}(0.01\ Sv)$

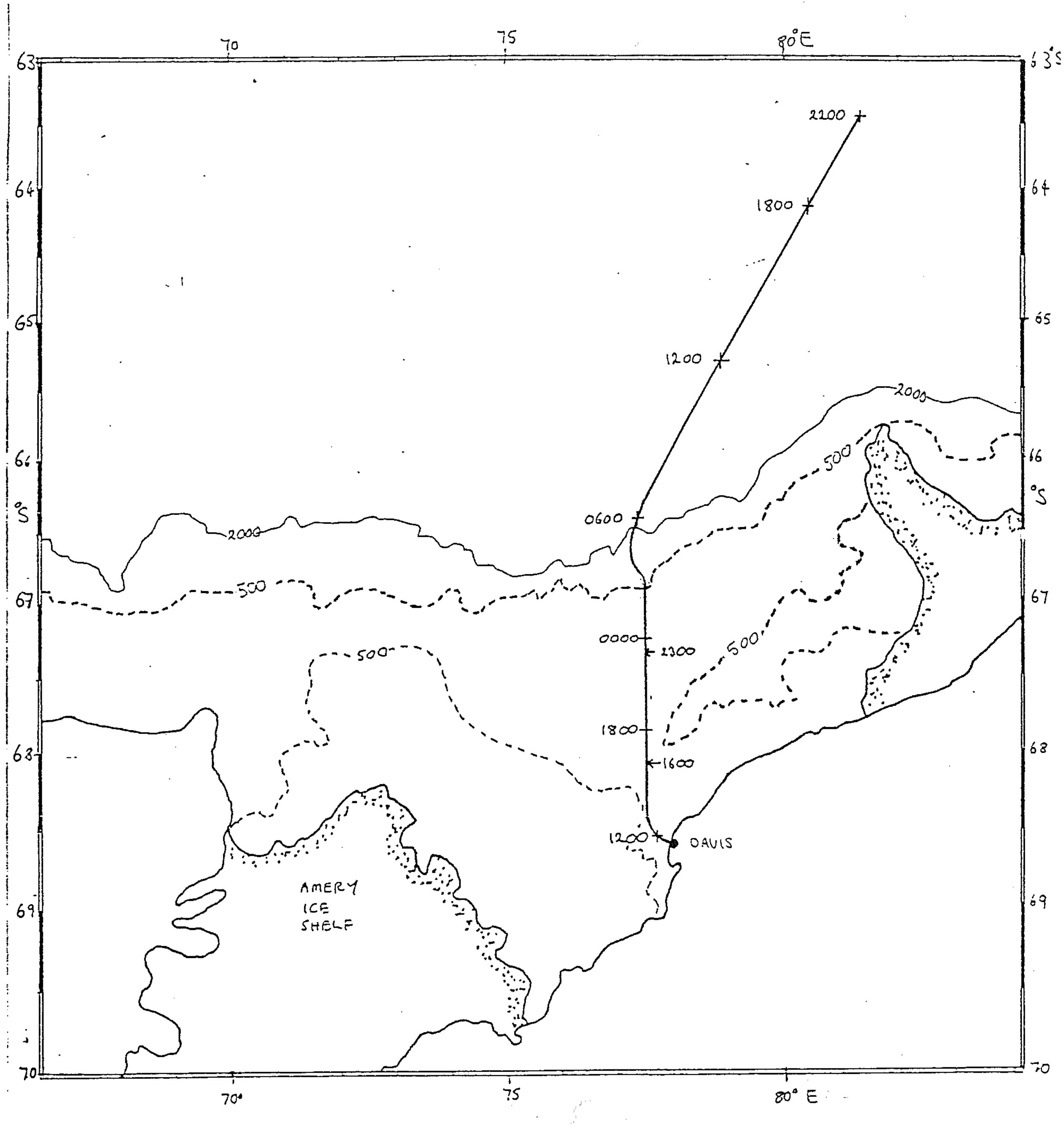

Figure 1: RV *Aurora Australis* cruise track 18 to 19 December 1990.

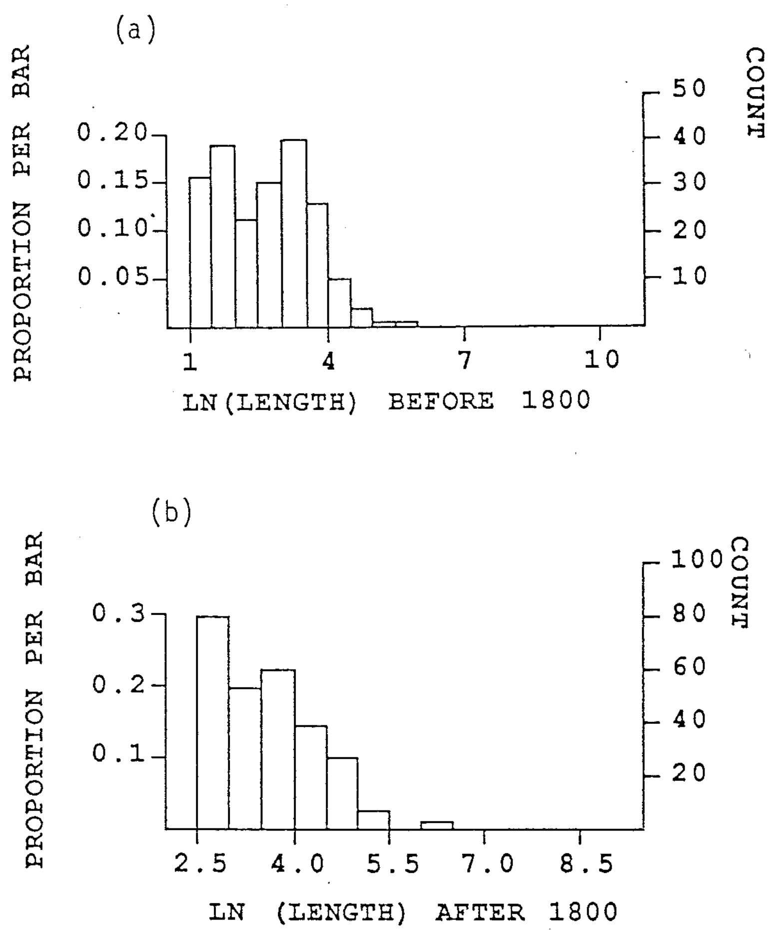

Figure 2: Log transformed intercepted swarm length before (a) and after (b) the change in ping rate at 1808 hours GMT.

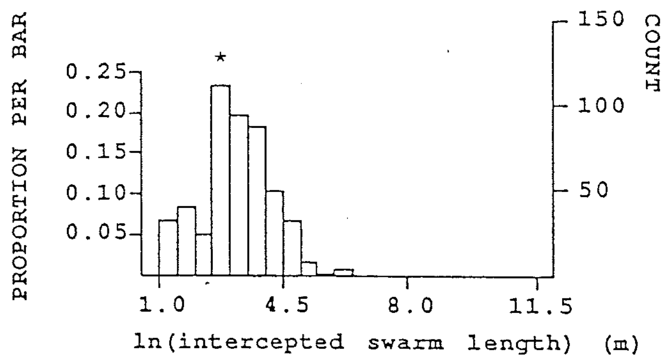

Figure 3(a): Log transformed swarm length.

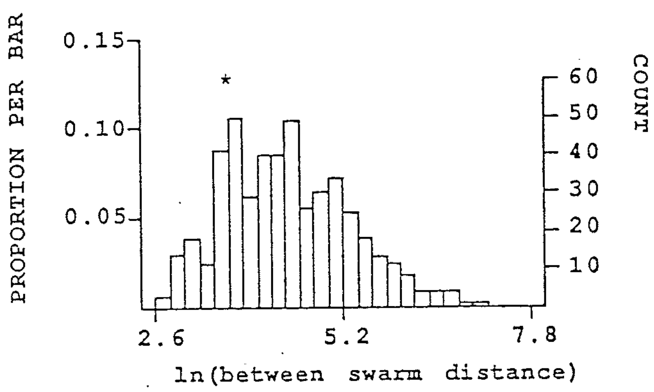

Figure 3(b): Log transformed between swarm distance.

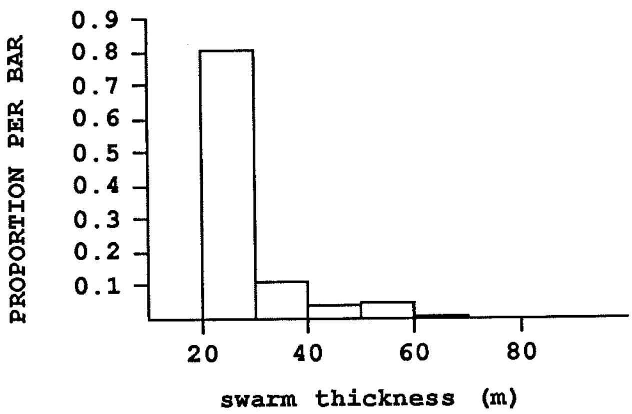

Figure 3(c): Swarm thickness.

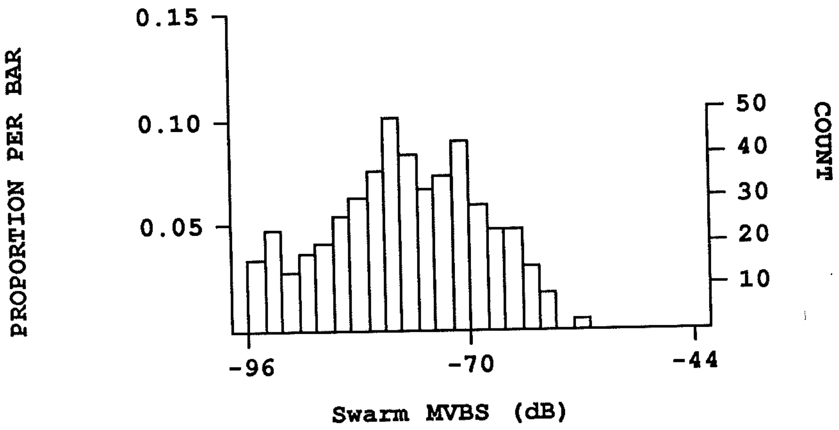

Figure 3(d): Swarm MVBS.

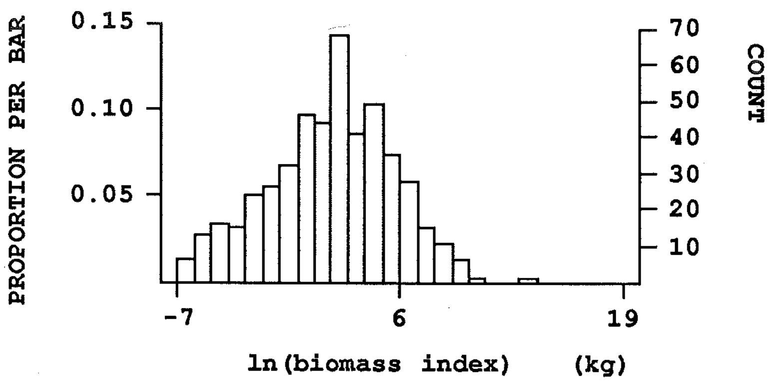

Figure 3(e): Log transformed swarm biomass index.

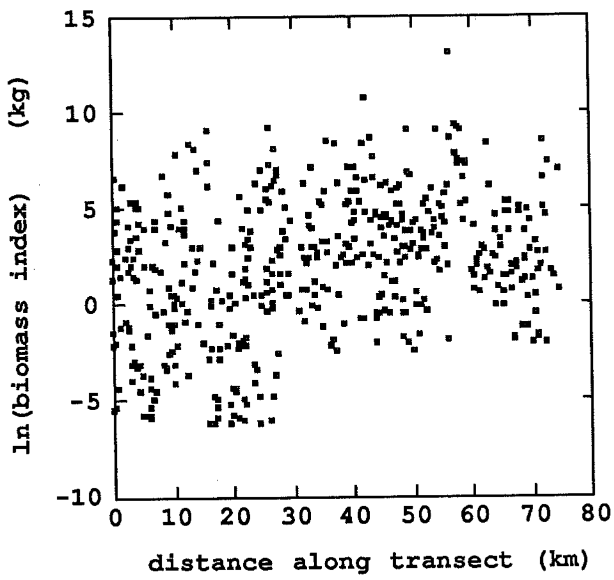

Figure 4(a): Change in swarm biomass with distance.

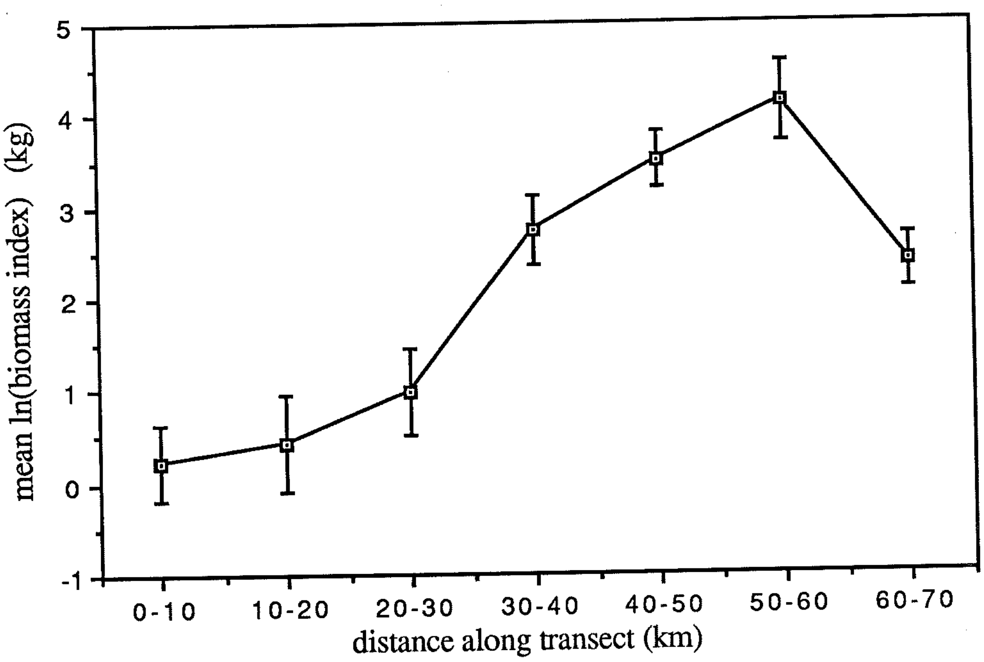

Figure 4(b): Mean swarm biomass from Prydz Bay on 18 December 1990, taken over 10 km distances (± standard errors).

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