Short Notes

CCAMLR Science, Vol. 6 (1999): 125–132

STATUS OF THE POLISH FIBEX ACOUSTIC DATA FROM THE WEST ATLANTIC

P.N. Trathan
British Antarctic Survey
High Cross, Madingley Road
Cambridge CB3 0ET, United Kingdom

J. Kalinowski
Istituto di Ricerche Sulla Pesca Marittima
60100 Ancona, Italy

I. Everson
British Antarctic Survey
High Cross, Madingley Road
Cambridge CB3 0ET, United Kingdom

Abstract

Acoustic data from the Polish FIBEX survey in the West Atlantic were analysed using recent acoustic target strength estimates of krill (SC-CAMLR, 1991a). This analysis indicated that the acoustic densities of krill in the oceanic parts of the Drake Passage were low (3 g m^{-2}); however, the results also indicated that spatial variability was important and that parts of the shelf to the north of the South Shetland Islands were areas of high density. High acoustic densities of krill (77 g m^{-2}) were also present in the Bransfield Strait. These results are discussed in the context of spatial and seasonal variation which has previously been reported for the area and shown to be important.

Résumé

Analyse des données acoustiques de la campagne d'évaluation FIBEX menée par la Pologne dans l'ouest de l'océan Atlantique, par les estimations de la réponse acoustique du krill (SC-CAMLR, 1991a). Cette analyse met en évidence le fait que la densité acoustique est faible (3 g m^{-2}) dans les régions océaniques du passage Drake; toutefois, elle indique également que la variabilité spatiale est importante et que, dans certains secteurs du plateau, au nord des îles Shetland du Sud, la densité est parfois élevée. Dans le détroit de Bransfield, la densité de krill est également élevée (77 g m^{-2}). Ces résultats sont discutés dans le contexte de la variation spatiale et saisonnière qui a déjà été repérée dans la région et qui semble importante.

Резюме

Были проанализированы акустические данные, полученные в результате польской съемки (в рамках программы FIBEX) в западной части Атлантического океана, с использованием новых оценок акустической силы цели криля (SC-CAMLR, 1991a). Анализ показал низкую акустическую плотность криля в океанических зонах пролива Дрейка (3 г м$^{-2}$), в то же время результаты выявили важность пространственной изменчивости и высокую плотность в некоторых зонах шельфа к северу от Южных Шетландских о-вов. Высокая акустическая плотность криля (77 г м$^{-2}$) наблюдалась и в проливе Брансфилд. Эти результаты обсуждаются в контексте значительной пространственной и сезонной изменчивости, ранее регистрировавшейся в данном районе.

Resumen

Las estimaciones recientes de la fuerza del blanco del kril fueron utilizadas para analizar los datos acústicos de la prospección polaca FIBEX realizada en el Atlántico occidental (SC-CAMLR, 1991a). Este análisis indicó que las densidades de kril determinadas por métodos acústicos en las regiones oceánicas del Pasaje Drake fueron bajas (3 g m^{-2}); sin embargo, los resultados también indicaron que la variabilidad espacial era importante y que partes de la plataforma al norte del archipiélago de las Shetland del Sur incluían áreas de alta densidad. También se encontraron altas densidades de kril (77 g m^{-2}) en el Estrecho de Bransfield. Estos resultados se discuten en el contexto de las variaciones espacial y estacional que habían sido notificadas anteriormente para el área y que demostraron ser importantes.

Keywords: krill density, spatial and temporal variability, acoustic survey, FIBEX, West Atlantic, Poland, CCAMLR

INTRODUCTION

CCAMLR has set a precautionary catch limit for Antarctic krill in Area 48 (Conservation Measure 32/X). This catch limit (SC-CAMLR, 1991b, paragraphs 6.31 to 6.66) is based on estimates of krill biomass derived from the results of the First International BIOMASS (Biological Investigation of Marine Antarctic Systems and Stocks) Experiment (FIBEX) (BIOMASS, 1986). The FIBEX results were used as a basis for this precautionary limit as they were derived from a large-scale synoptic survey and were considered to be the best available for the West Atlantic.

At the time the precautionary catch limit was set, the Scientific Committee of CCAMLR (SC-CAMLR) suggested that the FIBEX acoustic data should be re-analysed using recent acoustic target strength (TS) estimates (SC-CAMLR, 1991a, paragraph 3.78). This re-analysis was carried out by Trathan et al. (1992) who calculated estimates of acoustic density using TS estimates from BIOMASS (1986) and SC-CAMLR (1991a). The statistical methodology used to calculate estimates of acoustic density was otherwise as similar as possible to that used in the original FIBEX analysis (BIOMASS, 1986).

The version of the FIBEX acoustic dataset used by Trathan et al. (1992) was that archived at the BIOMASS Data Centre. This dataset was also the same as that used in the Post-FIBEX Acoustic Workshop (BIOMASS, 1986). It was therefore considered to be the best source available to enable direct comparison to be made between krill acoustic density estimates reported in BIOMASS (1986) and those based on new TS estimates (SC-CAMLR, 1991a).

Based on the re-analysis, Trathan et al. (1992) considered that there were areas of uncertainty regarding various parts of the FIBEX dataset. However, they felt it was not possible to resolve all of these concerns and so they were subsequently described by Trathan and Everson (1994). The principal concern highlighted by the re-analysis related to the status of the archived Polish FIBEX acoustic data. These data were stored in the BIOMASS Data Centre in a different format to that of the other FIBEX cruises, with acoustic integration data relating to time, rather than distance steamed. The acoustic values represented by these data were also substantially different from those of the other cruises.

Since the re-analysis by Trathan et al. (1992) a different archived source of the Polish FIBEX acoustic data has become available. This version of the dataset had been archived separately from that in the BIOMASS Data Centre. These data were stored with data relating to distance steamed and did not contain any of the inconsistencies reported by Trathan and Everson (1994). Thus, the purpose of this short note is to document the status of these data and to provide updated acoustic density estimates for the Polish FIBEX cruise.

METHODS

The Polish FIBEX cruise was carried out by the *Profesor Siedlecki* between 14 February and 12 March 1981. The survey collected acoustic data at 120 kHz using a Simrad EK120 echosounder and an analogue integrator; the data have previously been described by Kalinowski (1982). Calibration of the acoustic system was carried out prior to the survey using a hull-mounted hydrophone system specially customised for the *Profesor Siedlecki*. The methodology used was that described in BIOMASS (1980) which was the standard approach for acoustic calibration at the time of FIBEX (BIOMASS, 1986). Calibration was undertaken on two separate occasions; the first calibration was carried out by Simrad acoustic engineers at Horten, Norway, in December 1980, and the second was carried out by the ship's scientists at King George Island in January 1981.

MVBS Data

After completion of the FIBEX survey, krill aggregations were measured from the acoustic charts and the corresponding integrator deflections were determined. Hard copies of the acoustic integration data sheets were archived for future reference. For the analysis reported here, Mean Volume Back-scattering Strength (MVBS) values (dB normalised to 1 m^3) were calculated from the archived data sheets according to the formula given in BIOMASS (1986):

$$MVBS = 10 \log L - 10 \log \Delta R - SL - VR + 20 \log R_0 + 2\alpha R_0 - 10 \log (c\,\tau/2) - 10 \log \Psi + C$$

where L is the integrator deflection in millimetres for 1 n mile of transect, ΔR is the channel width (10–120 m), SL is the source level (224.1 dB/1μPa ref. 1m), VR is the receiving voltage response (-101.8 dB//1 V per 1μPa), R_0 is the time varied gain range (120 m), α is the absorption coefficient (0.045 dB/m), c is the speed of sound in seawater (1 450 m s^{-1}), τ is the pulse length (0.0006 s), 10 log Ψ is the equivalent beam pattern (-26 dB), and C is an equipment constant (20 dB).

MVBS values with time and positional data were loaded into a marine GIS (Trathan et al., 1993) and individual transects were identified by reference to BIOMASS (1986); transect labels were added to the data. For compatibility with the analyses reported in BIOMASS (1986), Trathan et al. (1992) and Trathan and Everson (1994), day and night-time acoustic intervals were identified using a program to determine sunrise and sunset (cf. program QLIGHT referred to in BIOMASS, 1986).

Density Calculation

The 21 survey transects were divided into two strata according to BIOMASS (1986), thus stratum 1 (transects 1 to 11) covered areas of the Drake Passage and stratum 2 (transects 12 to 21) the Bransfield Strait. Estimates of the mean weight density for each integration interval were calculated and combined to form estimates for each transect and each stratum using the methods described in Trathan et al. (1992); a full statistical description of the methodology is given in Jolly and Hampton (1990). Density estimates were calculated for day and night-time intervals separately, and for day and night-time intervals combined.

Density estimates were calculated using the target strength/length (in mm) relationship reported in BIOMASS (1986) and the target strength/length relationship later recommended by WG-Krill (SC-CAMLR, 1991a):

$$TS = 19.90 \log \mathit{length} - 95.7$$
(BIOMASS, 1986)

$$TS = 34.85 \log \mathit{length} - 127.45$$
(SC-CAMLR, 1991a).

Density estimates were prepared using a single krill length-frequency distribution calculated from the combined net hauls taken during the cruise (cf. Trathan et al., 1992). The length-to-weight relationship reported in BIOMASS (1986) was used to provide mean weight (in mg) from length (in mm) data:

$$\mathit{weight} = 0.000925\ \mathit{length}^{3.55}.$$

Although the use of a single length-frequency distribution could introduce bias, this is likely to be small based on the geographic distribution of krill of different sizes found during FIBEX (BIOMASS, 1991).

RESULTS

MVBS Data

The track surveyed by the *Profesor Siedlecki* in the Drake Passage and the Bransfield Strait is shown in Figure 1. Data were not collected during part of transect 1 due to problems with the acoustic system during the early part of the cruise.

Much of the survey covered areas where acoustic returns were negligible. The minimum MVBS detectable was -87.5 dB and is documented in BIOMASS (1986, Appendix F). MVBS values above this level varied with a maximum of -49.26 dB and with the majority of values around -77 dB. The bell-shaped frequency distribution was of a similar form to that obtained from the other FIBEX cruises; however, it differed markedly from that of the Polish FIBEX MVBS values stored at the BIOMASS Data Centre which were heavily skewed towards -90 dB (see Trathan and Everson, 1994).

Density Calculation

Density estimates for the Drake Passage and for the Bransfield Strait calculated from daytime and night-time intervals and from day and night-time intervals combined are presented in Table 1. These indicate that there were substantial differences in density between strata, with the highest biomass levels occurring in the Bransfield Strait. North of the South Shetland Islands the variability in density was particularly marked and

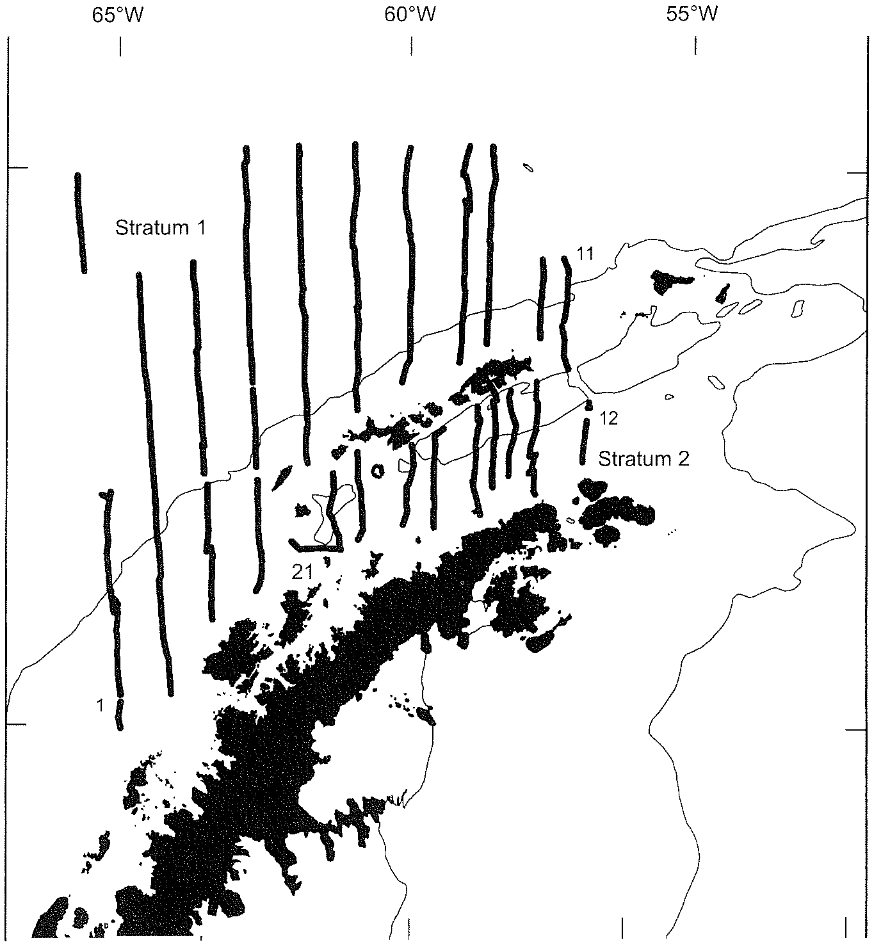

Figure 1: Location of acoustic transects in the Drake Passage (stratum 1; transects 1 to 11) and Bransfield Strait (stratum 2; transects 12 to 21). The 1 000 m isobath is shown for reference.

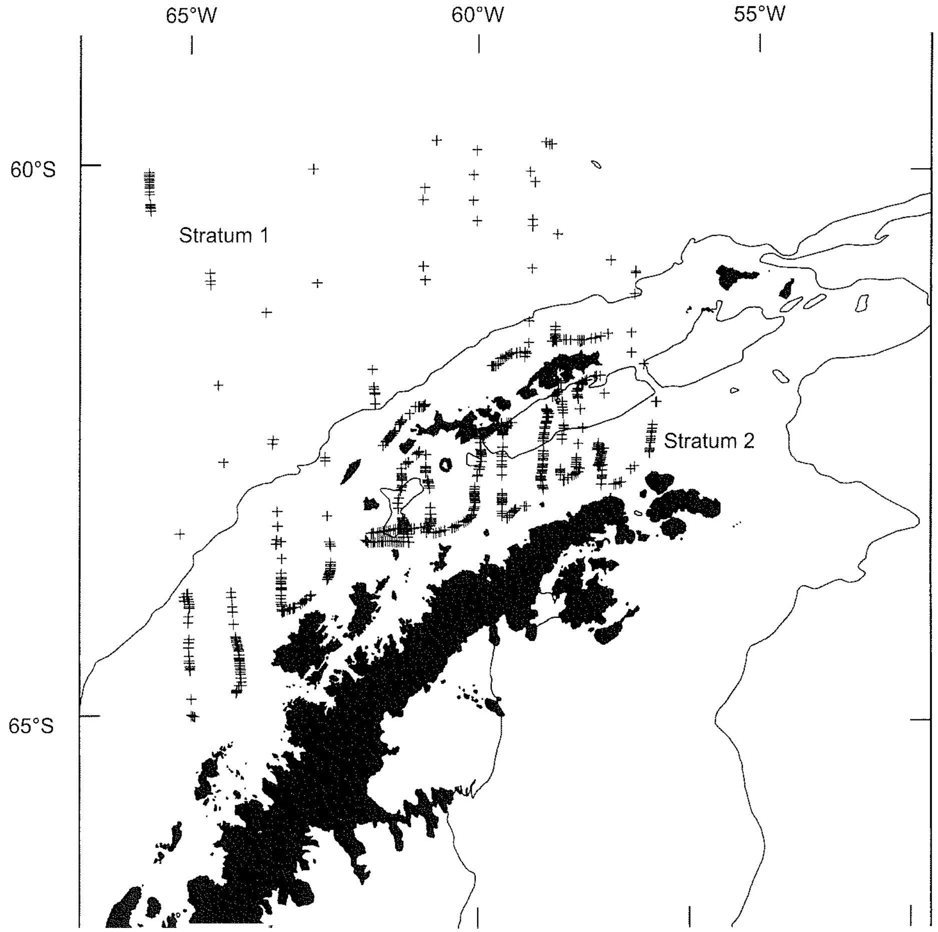

Figure 2: Location of acoustic transects in the Drake Passage (stratum 1) and Bransfield Strait (stratum 2) where the MVBS value was greater than -87.5 dB (including those values on transect heads). The 1 000 m isobath is shown for reference.

Table 1: Estimated krill density and krill biomass from the Polish FIBEX acoustic survey in the West Atlantic; results based on the target strength estimate recommended by SC-CAMLR (1991a).

Strata	Area (10^3 km^2)	Transects	Day				Night			
			TL (km)	Density (g m^{-2})	CV (%)	Biomass (t x 10^3)	TL (km)	Density (g m^{-2})	CV (%)	Biomass (t x 10^3)
1	160.1	1–11	2166.2	2.99	44.1	478.70	1059.9	6.85	49.1	1097.17
2	29.1	12–21	626.3	76.61	33.2	2229.35	363.2	66.45	70.2	1933.61

Strata	Area (10^3 km^2)	Transects	Day + Night			
			TL (km)	Density (g m^{-2})	CV (%)	Biomass (t x 10^3)
1	160.1	1–11	3226.1	4.26	28.8	681.87
2	29.1	12–21	989.5	72.88	31.8	2120.81

Table 2: Estimated krill density and krill biomass from the Polish FIBEX acoustic survey in the West Atlantic; results based on daytime acoustic intervals and the (old) target strength estimate of BIOMASS (1986) and the (new) target strength estimate recommended by SC-CAMLR (1991a).

Strata	Area (10^3 km^2)	Transects	TL (km)	Old		New	
				Density (g m^{-2})	Biomass (t x 10^3)	Density (g m^{-2})	Biomass (t x 10^3)
1	160.1	1–11	2166.2	0.71	112.87	2.99	478.70
2	29.1	12–21	626.3	18.07	525.72	76.61	2229.35

in these areas density estimates were sensitive to the precise allocation of acoustic intervals to transects. The majority of high-density sampling intervals fell within the heads of the transects close to the South Shetland Islands (Figure 2). Differences were also evident between daytime and night-time density estimates, particularly in the Drake Passage; however, these differences were less pronounced than those between strata.

Density estimates from the *Profesor Siedlecki* calculated on the basis of the old TS value of BIOMASS (1986) and on the basis of the new TS reported by SC-CAMLR (1991a) are shown in Table 2. This comparison indicates that the acoustic density based on the new TS estimates is considerably higher than that based on the old TS estimates. The new overall density estimate for both strata is approximately 4.24 times greater than the estimate based on the old TS value; this is consistent with the overall increase in density (4.86) derived from the assessment of all FIBEX cruises that collected data at 120 kHz (Trathan et al., 1992).

DISCUSSION

Although the FIBEX survey was carried out a long time ago and more recent and more sophisticated methodologies are now available, the FIBEX dataset is historically important and significant changes must therefore be documented. In addition, there are two reasons why the *Profesor Siedlecki* survey results are uniquely important and why they should be considered in the context of the other FIBEX vessels. Firstly, the *Profesor Siedlecki* surveyed large areas that were not covered by other FIBEX vessels, and, secondly, it surveyed areas where effort was duplicated. This latter point is of particular importance as the new Polish FIBEX dataset now enables a direct comparison to be made for those areas covered by more than one ship. However, in making such a comparison, various important issues must be taken into account; these include small-scale spatial variability, small-scale temporal variability and the regional oceanographic context.

Spatial Variability

The highest density values from the *Profesor Siedlecki* survey occurred in the Bransfield Strait and in the area to the north of the South Shetland Islands where high densities have been reported previously (e.g. Kalinowski, 1982; Ichii et al., 1991) and which has been the focus of commercial fishing activity in recent years (cf. Everson and Goss, 1991; Ichii et al., 1994; Ichii and Naganobu, 1996). Low density values tended to be away from the shelf and over deep water.

During the survey the distribution of krill was extremely patchy, particularly where densities were highest. For example, to the north of the South Shetland Islands considerable variability occurred within very short distances. In this region there were a number of high-density sampling intervals, most of which occurred close to the islands within the heads of the survey transects (Figure 2). Here the densities were considerably higher than those just offshore. For example, on the transect head to the north of King George Island the average density was 106 g m^{-2}, whereas the average density for the stratum as a whole was only 3 g m^{-2} (cf. Table 1). Although this level of variation is appreciable, it is in accord with levels reported previously. For example, Ichii et al. (1992) reported densities of 135 g m^{-2} within the narrow zone close (within 3 n miles) to the South Shetland Islands, and densities of only 8 g m^{-2} in the offshore oceanic zone.

Temporal Variability

In addition to the high levels of spatial variability recorded in the region, considerable temporal variability has also been reported. For instance, Siegel (1988) reported a study based on net-derived densities of krill that highlighted a seasonal increase in abundance between December and March, followed by a rapid decrease in abundance from March to June. Siegel (1988) suggested that the timing of this pattern varied between years, but that the main features were always obvious. Evidence of such seasonal changes has also been found in acoustic survey results. For example, Ichii et al. (1991), recorded rapid changes in acoustic density between late December 1990 (46 g m^{-2}) and early February 1991 (157 g m^{-2}).

The *Profesor Siedlecki* survey was carried out between 14 February and 12 March 1981. Therefore, given the general seasonal model suggested by Siegel (1988), the *Profesor Siedlecki* acoustic density estimates should reflect biomass levels that were close to the seasonal maximum. However during 1981, the year of FIBEX, minimum net densities were actually present by the middle of March (Siegel, 1988), therefore it is feasible that the *Profesor Siedlecki* acoustic survey results reflect density estimates that were well below the seasonal maximum. Although we cannot determine if the results actually reflect the seasonal minimum, it is probable that they reflect a period when biomass has decreased.

During FIBEX, part of the *Profesor Siedlecki* survey area was sampled by the *Itzumi*. This survey was carried out between 28 January and 28 February 1981, that is two weeks earlier than the *Profesor Siedlecki*, within a period when the biomass levels may be expected to be higher (cf. Siegel, 1988). The *Itzumi* density estimates based on the new TS estimates (SC-CAMLR, 1991a) indicate that biomass levels were higher earlier in the season, with 160 g m^{-2} in the Bransfield Strait (cf. stratum 1) and between 67 g m^{-2} (eastern shelf) and 92 g m^{-2} (western shelf) north of the South Shetland Islands (Trathan et al., 1992).

Regional and Local Context

Spatial and temporal variability in krill distribution and abundance is a marked feature of the southwest Atlantic. Many factors contribute to the observed levels of variability, however one of the most important is thought to be flux due to water movement (SC-CAMLR, 1994). The FIBEX survey was a large-scale synoptic survey that encompassed much of the surface flow between the Antarctic Peninsula and South Georgia (cf. Orsi et al., 1995). It therefore sought to minimise the effects of krill advection within the region. At a smaller scale, however, such fluxes may not be minimised, and in some areas where water movement is swift, large changes in krill biomass could result. For example, after a detailed examination of acoustic biomass along a series of small-scale transects west of King George Island, Everson and Murphy (1987) suggested krill movement occurred at approximately the speed of the surface current. Everson and Murphy (1987) further suggested that krill could potentially move through the Bransfield Strait within a period as short as one or two weeks.

Given the potential for krill flux in the Bransfield Strait, comparisons between the *Profesor Siedlecki* survey and other surveys should be made with caution, particularly where different areas were surveyed, or where surveys were carried out at different times. However, despite this caution, the range of krill density values from the *Profesor Siedlecki* survey appear to be consistent with those reported from other FIBEX survey results (Trathan et al., 1992), particularly when viewed in the context of the seasonal model suggested by Siegel (1988).

CONCLUSIONS

Following a close re-examination of the Polish FIBEX results for the West Atlantic sector, we conclude that there is a high level of consistency between the results from that vessel and the results from other vessels in the survey. Thus, the acoustic density data from the *Profesor Siedlecki* survey provide abundance estimates that are consistent with other FIBEX cruises, albeit that the *Profesor Siedlecki* survey was undertaken at a slightly later time.

As the FIBEX dataset is of great historic interest, it is recommended that these data be archived as part of the BIOMASS database.

ACKNOWLEDGEMENTS

We are grateful to Mark Thorley, manager of the Natural Environment Research Council (NERC) Antarctic Environmental Data Centre, for making available relevant FIBEX data.

REFERENCES

BIOMASS. 1980. Calibration of hydro-acoustic instruments. *BIOMASS Handbook*, 1: 53 pp.

BIOMASS. 1986. Post-FIBEX Acoustic Workshop. *BIOMASS Rep. Ser.*, 40: 106 pp.

BIOMASS. 1991. Non-acoustic Krill Data Analysis Workshop (Cambridge, UK, 29 May to 5 June 1991). *BIOMASS Rep. Ser.*, 66: 59 pp.

Everson, I. and E. Murphy. 1987. Mesoscale variability in the distribution of krill *Euphausia superba*. *Mar. Ecol. Prog. Ser.*, 40 (1–2): 53–60.

Everson, I. and C. Goss. 1991. Krill fishing activity in the south-west Atlantic. *Ant. Sci.*, 3 (4): 351–358.

Ichii, T. and M. Naganobu. 1996. Surface water circulation in krill fishing areas near the South Shetland Islands. *CCAMLR Science*, 3: 125–136.

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.

Ichii, T., H. Ishii and M. Naganobu. 1992. Abundance, size and maturity of krill (*Euphausia superba*) in the krill fishing ground of Subarea 48.1 during the 1990/91 austral summer. In: *Selected Scientific Papers, 1992 (SC-CAMLR-SSP/9)*. CCAMLR, Hobart, Australia: 183–199.

Ichii, T., M. Naganobu and T. Ogishima. 1994. An assessment of the impact of krill fishery on penguins in the South Shetlands. *CCAMLR Science*, 1: 107–128.

Jolly, G.M. and I. Hampton. 1990. A stratified random transect design for acoustic surveys of fish stocks. *Can. J. Fish Aquat. Sci.*, 47: 1282–1291.

Kalinowski, J. 1982. Distribution and stocks of krill in the Drake Passage and the Bransfield Strait, during the BIOMASS-FIBEX expedition 1981. *Pol. Polar Res.*, 3–4: 243–251.

Orsi, A.H., T. Whitworth III and W.D. Nowlin Jr. 1995. On the meridional extent of the Antarctic Circumpolar Current. *Deep-Sea Res.*, 42: 641–673.

SC-CAMLR. 1991a. *Report of the Tenth Meeting of the Scientific Committee (SC-CAMLR-X)*. CCAMLR, Hobart, Australia: 427 pp.

SC-CAMLR. 1991b. Report of the Third Meeting of the Working Group on Krill. In: *Report of the Tenth Meeting of the Scientific Committee (SC-CAMLR-X)*, Annex 5. CCAMLR, Hobart, Australia: 107–204.

SC-CAMLR. 1994. Report of the Sixth Meeting of the Working Group on Krill. In: *Report of the Thirteenth Meeting of the Scientific Committee (SC-CAMLR-XIII)*, Annex 5. CCAMLR, Hobart, Australia: 213–295.

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.

Trathan, P.N. and I. Everson. 1994. Status of the FIBEX acoustic data from the West Atlantic. *CCAMLR Science*, 1: 35–48.

Trathan, P.N., D.J. Agnew, D.G.M. Miller, J.L. Watkins, I. Everson, M.R. Thorley, E.J. Murphy, A.W.A. Murray and C. Goss. 1992. Krill biomass in Area 48 and Area 58: Recalculation of FIBEX Data. In: *Selected Scientific Papers, 1992 (SC-CAMLR-SSP/9)*. CCAMLR, Hobart, Australia: 157–181.

Trathan, P.N., E.J. Murphy, C. Symon and P. Rodhouse. 1993. Ecological and oceanographic relationships in the Southern Ocean. *GIS Europe*, 2 (6): 34–36.

Liste des tableaux

Liste des figures

Список таблиц

Список рисунков

Lista de las tablas

Lista de las figuras