ANNEX 4

REPORT OF THE FIFTH MEETING OF THE WORKING GROUP ON KRILL

(Tokyo, Japan, 4 to 12 August 1993)

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INTRODUCTION

1.1 The Fifth Meeting of the Working Group on Krill (WG-Krill) was held at the Hotel Mariners Court, Tokyo, Japan, from 4 to 12 August 1993. The meeting was chaired by the Convener, Mr D.G.M. Miller (South Africa).

1.2 The Working Group was welcomed to Tokyo by Mr Michio Chinzei, the Director-General of the Fisheries Agency of Japan.

REVIEW OF THE MEETING OBJECTIVES AND ADOPTION OF THE AGENDA

2.1 The Convener briefly outlined the major objectives of the meeting (SC-CAMLR-XI, paragraph 2.97), which had been set out in detail and circulated prior to the meeting (SC CIRC 93/14).

2.2 A Provisional Agenda had also been circulated prior to the meeting. There were no additions or amendments and the Agenda was adopted.

2.3 The Agenda is included in this report as Appendix A, the List of Participants as Appendix B and the List of Documents submitted to the meeting as Appendix C.

2.4 The report was prepared by Drs D.J. Agnew (Secretariat), M. Basson (UK), Prof. D. Butterworth (South Africa), Drs W. de la Mare (Australia), R. Hewitt (USA), R. Holt (USA), V. Marín (Chile) and S. Nicol (Australia).

Fisheries Information

Data Submission

3.1 A summary of all fine-scale data from the krill fishery that had been submitted to the Secretariat was produced (Table 1). The Working Group noted the availability of this information and made use of it in its discussions.

Catch Levels

3.2 The following preliminary information from the commercial krill catch for the 1992/93 season was available:

Country	Subarea 48.1	Subarea 48.2	Subarea 48.3	Other	Total
Russia			2 948	50 (48.4)	2 998
Japan	31 784	4 089	17 636	5 762 (58.4.1)	59 271
Poland				15 863 (48)	15 863
Chile	3 262				3 262
Total	35 046	4 089	20 584	21 675	81 394

The total krill catch was substantially less than in 1991/92 (302 961 tonnes). Total catches in all statistical subareas were well below the precautionary catch limits set out in Conservation Measures 32/X, 45/XI and 46/XI. The Working Group noted that krill had been caught in Division 58.4.1 which is a statistical division not covered by a precautionary catch limit or other conservation measures.

Fishing Activities

3.3 Five Japanese krill fishing vessels operated in the Convention Area during 1992/93. Three vessels operated in waters off South Georgia (Subarea 48.3) between July and September 1992 and 11 717 tonnes of krill were caught. Between January and March 1993, four vessels operated in the South West Scotia Sea (Subarea 48.1) catching 23 700 tonnes. One vessel caught 5 762 tonnes off Wilkes Land (Division 58.4.1). In April 1993, one vessel fished in the central Scotia Sea (Subarea 48.2) and three vessels operated in the South West Scotia Sea (Subarea 48.1). In May one vessel operated in the central Scotia Sea (Subarea 48.2). Through April to June five vessels caught 18 092 tonnes of krill. A total of five vessels caught 59 271 tonnes of krill during the 1992/93 season. Japan plans to maintain its current fishing effort during 1993/94 with about five vessels catching a similar amount to the 1992/93 season.

3.4 The Japanese krill catch from Division 58.4.1 was taken by one vessel. This vessel had been deployed in the area to catch krill of different quality from that taken from the South Atlantic region. The experience of the Japanese fleet has been that catches off the South Shetlands (Subarea 48.2) contained larger and greener animals, as well as a greater proportion of gravid females than off Wilkes Land, depending on the fishing season. Such changes in fishing location were the result of Japanese consumer demand for a variety of krill products.

3.5 The Working Group noted that this implied some predictability in the characteristics of the krill concentrations being fished. In future it would be useful to obtain information on anticipated changes in product demands as this might affect the location and activities of the fishery. It was also noted that such information may provide useful data on biological aspects of krill in different areas. The Working Group noted that such information would be in accordance with the Scientific Committee's and Commission's requests for submission of plans on the operational characteristics and anticipated activities of the commercial krill fishery (SC-CAMLR-XI, paragraphs 2.94, 2.95, 5.40,16.4 and CCAMLR-XI, paragraphs 4.8 and 4.9).

3.6 Chile reported krill catches from one vessel fishing in two areas: north of Elephant Island and north of Livingston Island (Subarea 48.1). In total, 3 262 tonnes were taken between 3 March and 8 April 1993. Substantial catches of salps caused problems in the fishing operations in the Elephant Island region during this period and most of the catch came from the Livingston Island area. One Chilean fishing vessel would operate in the same regions during 1993/94.

3.7 Polish catches, as reported monthly to the Secretariat, increased from the 1991/92 level of 8 607 to 15 863 tonnes in 1992/93. Catches occurred in Subareas 48.1, 48.2 and 48.3 with no subdivision of the catch being reported. The Working Group agreed that details of future Polish fishing plans should be sought.

3.8 Russian fishing operations were confined to the period July and August 1992, when two vessels caught a total of 2 948 tonnes in the South Georgia area (Subarea 48.3), and one vessel caught 50 tonnes in Subarea 48.4. Although Russia was proceeding with privatisation of its fisheries operations and was concentrating on fishing grounds less remote than the Convention Area, there was a possibility that as many as three vessels would be sent to harvest krill during 1993/94, possibly in joint venture arrangements with other countries.

3.9 To the best available knowledge, no krill fishing was undertaken by Ukraine during 1992/93, although Ukrainian companies were reported to be keen to proceed with krill exploitation. Up to three vessels are likely to be deployed on the traditional fishing grounds during 1993/94.

3.10 The Republic of Korea undertook no krill fishing in 1992/93 and there were no plans to fish for krill in 1993/94.

3.11 Australia is still considering an application to harvest krill, but legal, administrative and financial delays have meant that this project is unlikely to proceed during 1993/94.

3.12 The Working Group noted press reports (*Fishing News International*) indicating India's interest in entering the krill fishery. The Working Group drew the Scientific Committee's attention to this and suggested that further information on India's krill fishing intentions be sought.

Data Submission

3.13 The Working Group appreciated that analyses of Japanese fine-scale catch and effort data had been presented in papers submitted to the present meeting and to earlier meetings (WG-Krill-93/25 and references therein; see also SC-CAMLR-XI, paragraph 2.92).

3.14 Japanese catch rates (catch-per-minute fishing) in the vicinity of the South Shetland Islands for 1991/92 (WG-Krill-93/25) indicated that there had been a substantial change in this index during the period April to May 1992. It was pointed out that this might represent a seasonally related change in local density rather than biomass over a large area. It might also reflect an unusual lack of ice in this area during this period which allowed late season fishing. The Working Group encouraged an examination of Japanese fishing log-books from the 1992/93 season to ascertain whether the observed decline in CPUE could be correlated with environmental factors such as sea-ice conditions.

3.15 Severe difficulties had been encountered in the acquisition of fine-scale data from 1991/92 from the fishing fleets of the former Soviet Union. These had been exacerbated by the privatisation of the Russian and Ukrainian fisheries.

Historical Commercial Krill Catch Data from the Former Soviet Union

3.16 At its 1992 meeting, the Scientific Committee had encouraged Members with previously unreported historic data on krill catches to evaluate the accessibility of these data, to assess the feasibility of processing these data into standard formats, and to submit the data to the CCAMLR Data Centre (SC-CAMLR-XI, paragraphs 2.23 to 2.25). In particular, it was noted that a considerable amount of historic data from the krill catches of the former Soviet Union has not yet been submitted to CCAMLR.

3.17 An inventory was compiled of the former Soviet Union's total krill catch data from Statistical Area 48, as submitted to CCAMLR on STATLANT forms. Those years for which the data had been submitted to the Data Centre in fine-scale formats were also identified. This inventory is attached as Table 2. Dr K. Shust (Russian Federation) indicated that there were three possible sources of historical fine-scale data:

(i) Summary reports that provide general accounts of fishing activities (e.g., catch totals, charts showing approximate locations of the fleet's fishing activities) for the years 1973/74 through 1976/77. These reports are believed to be accessible at either VNIRO (Moscow) or AtlantNIRO (Kaliningrad).

(ii) 15-day reports that had been prepared and submitted to regional fisheries offices throughout the duration of the fishery for the years 1977/78 through 1982/83. These reports are currently kept in various locations depending on the home port of vessels operating during a particular season (reports were submitted to the regional offices responsible for vessels operating out of that region's ports). It is believed that most of these reports should still be accessible through staff at the following facilities: VNIRO (Moscow), AtlantNIRO (Kaliningrad) or YugNIRO (Kerch).

(iii) Magnetic tape on mainframe computers, with fishery data for the years 1983/84 through 1991/92. These data require some manipulation to transform them into formats suitable for submitting to the CCAMLR Data Centre. The magnetic tape records are accessible through staff at VNIRO (Moscow).

3.18 Dr Shust presented examples of initial fine-scale summaries of historic data that he had prepared. The Data Manager noted that these summaries used a format that would be compatible with the database used by the Secretariat. As a next step, it was agreed that the historic data should be processed into fine-scale summaries for submission to CCAMLR. The possibility of reporting these historic data in a finer scale (e.g., 10 x 10 n miles or haul-by-haul) should also be investigated.

3.19 In addition to historic catch data from Statistical Area 48, it was recalled that the former Soviet Union had undertaken krill catches in Statistical Area 58 in the late 1970s and early 1980s. It was agreed that obtaining fine-scale information about the locations of catches during that period would be useful. It was noted that most of the catch data from the former Soviet Union in Statistical Area 58 are presently located at YugNIRO (Ukraine).

3.20 The Working Group welcomed the information provided by the historic catch data inventory and the examples of fine-scale summaries, and encouraged Dr Shust and his colleagues to proceed with processing and submitting these data to CCAMLR as soon as possible. The Working Group appreciated that this would not be a small task, and Members were encouraged to assist with this effort where possible. It was noted that scientists from Russia and the United States were collaborating in an attempt to expedite this work.

3.21 The Working Group drew the Scientific Committee's attention to the above situation and suggested that Members might investigate ways in which this work be facilitated.

Haul-by-haul Data and Length Frequency Analysis of Samples from the Commercial Krill Fishery

3.22 The Working Group noted that haul-by-haul and length frequency data from both the Japanese and Chilean krill fisheries had been used in analyses presented in WG-Krill-93/14 and 25. These papers were based on very fine-scale catch information and had enabled improved analyses of krill fishing fleet activities.

Length Frequency Data from the Fishery

3.23 It was noted that Japan has submitted length frequency data since they were initially requested in 1987 (CCAMLR-VI, paragraph 92). The collection and submission of haul-by-haul and length frequency information was again requested by the Working Group.

Location of Catches

3.24 The Working Group at its 1992 meeting (SC-CAMLR-XI, paragraph 2.91), requested that the Secretariat contact FAO to determine whether any krill catch information had been reported for FAO Statistical Area 41. FAO reported that it had no information on any krill catches in Area 41.

Reports of Observers/Use of Draft Observer's Manual

3.25 The Scientific Observers Scheme has only been in operation since its endorsement by the Commission at its Eleventh Meeting (CCAMLR-XI, paragraphs 6.10 and 6.11). As yet, no reports have been received by observers on commercial krill fishing vessels. Similarly, there has been no feedback on the utility of the draft Observer's Manual. The Working Group noted that it might be some time before such reports are available and the utility of the Observer's Manual can be effectively assessed.

By-catch of Young Fish in the Krill Fishery

3.26 Three papers reported on the by-catch of young fish in the krill fishery. These assessed the by-catch in research trawls off the South Shetland Islands in summer 1990/91 (WG-Krill-93/50), the by-catch during winter off South Georgia by the Japanese krill fishery (WG-Krill-93/51), and the by-catch by the Ukrainian fishery off South Georgia in 1992 (WG-FSA-93/8).

3.27 The results from these studies indicate that the by-catch of young fish during krill fishery operations in the South Shetlands might be much less than at South Georgia. The Working Group accepted, however, that it was difficult to assess the extent of such apparent differences given the different techniques and equipment used by research vessels when compared with commercial operations, and by differences in the analytical procedures used.

3.28 Japanese data from the South Georgia region indicated that a by-catch of fish occurred in a minority of hauls examined (20 out of 74 stations) and that only three fish species were involved, with *Lepidonotothen* [*Nototheniops*] *larseni* predominating (93.9% by number observed). The total number of fish in each haul was low.

3.29 Ukrainian results indicated that the fish by-catch of krill fishing operations may be substantial, although fish were only evident in 10 out of 55 stations sampled. *Champsocephalus gunnari* and *N. larseni* were dominant. Extrapolating the by-catch rate to the entire Ukrainian krill fishery off South Georgia, the estimated by-catch induced mortality of these two species in 1991/92 would have been 27.2 million individuals and 22.5 million individuals respectively.

3.30 It was noted that the largest by-catch of fish in the Ukrainian fishery occurred when krill catch rates were low. This might be because the fishery was targeting dense krill aggregations thereby minimising by-catch or possibly because the by-catch was highest when krill were more dispersed.

3.31 Full details of the methodology underlying the estimation of the average level of fish by-catch in the Ukrainian krill fishery were not provided in paper WG-FSA-93/8. The Convener will contact the senior author and encourage him to provide this information to WG-FSA.

3.32 The Working Group stressed that appropriate statistical procedures (see Pennington, 1983[1]) should be applied to take account of the large number of zero observations in studies of fish by-catch in krill fishing operations.

3.33 The Working Group recognised that different levels of by-catch might be induced by differences in the operational characteristics of various fishing fleets. This could include effects caused by different trawling speeds or towing depths.

3.34 Because there may also be seasonal or diurnal differences in by-catch, the Working Group suggested that the Working Group on Fish Stock Assessment (WG-FSA) might consider when the fish species most often encountered as by-catch would be most vulnerable to krill fishing operations.

Other Information

Excess Krill Mortality Associated with Commercial Trawling

3.35 A mathematical model of excess krill mortality associated with commercial krill trawling was presented in WG-Krill-93/34. This model updated that which was presented to the 1990 meeting of the Working Group (Zimarev *et al.*, 1990[2]), and indicated that mortality resulting from krill not being retained by trawl meshes could range between 1.5% and 26% of the landed catch depending on the fishing intensity.

3.36 One of the assumptions of the above model was that all krill coming into contact with the fishing net die. This may be a pessimistic assumption since at low densities some animals may pass through the mesh without damage. In addition, the model does not include hydrodynamic effects which could reduce the probability of krill striking parts of the net. The Working Group considered that these assumptions had important implications and suggested that it should be tested

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1 Pennington, M. 1983. Efficient estimators of abundance, for fish and plankton surveys. *Biometrics*, 39: 281-286.

2 Zimarev, Yu.V., S.M. Kasatkina and Yu. Frolov. 1990. Midwater trawl catchability in relation to krill and possible ways of assessing gross catch. *Selected Scientific Papers, 1990 (SC-CAMLR-SSP/7)*. CCAMLR, Hobart, Australia: 87-113.

experimentally. Factors to be taken into account in such experiments would include the size of the mesh and trawling speed.

3.37 Dr H. Hatanaka (Japan) drew the Working Group's attention to a paper, WG-Krill-92/29, tabled at the previous meeting, in which this topic was considered. It was concluded that the mortality rate during net retrieval seemed to be small in the case of the Japanese commercial fishery. He further pointed out that there are two aspects in the mortality during trawl hauling: krill escapement through meshes and mortality rate of such escaped animals, and that the latter is difficult to estimate.

3.38 The Working Group also agreed that the results of the model described above are important and consequently the model should be independently validated and sensitivity analyses should be carried out on the critical input parameters. The author was requested to provide the Secretariat with a copy of the computer code for validation; this would also be made available to interested Working Group members who could then undertake the necessary sensitivity analyses.

Development of CPUE Indices

3.39 The preliminary results of a joint US/Chilean study using a combination of catch-per-fishing time from the Chilean krill fishery and US acoustic survey data around Elephant Island in 1992 were presented to the Working Group. These results indicated that some of the parameters required for the Composite Index of Krill Abundance (SC-CAMLR-VIII, Annex 4, Appendix 7) such as the characteristic radius of concentrations, are extremely difficult to estimate. Furthermore, the acoustic survey data showed intense temporal variability and this has the potential to confound combined analyses of fisheries and acoustic survey data which are not collected simultaneously. Updated results will be submitted to the Scientific Committee in the near future.

3.40 Further discussion on the development and application of CPUE indices is reported in paragraphs 5.26 to 5.32.

ESTIMATION OF KRILL YIELD

Krill Flux in Statistical Area 48 and Other Areas

4.1 During the 1991 meeting, WG-Krill identified the need for hydrographic and other data which might be used to indicate possible immigration and emigration rates and retention times of krill in the various fishing grounds and statistical subareas. In particular, the Working Group specified that, as a first step, integrated mass flow paths across the boundaries of the Statistical Subareas in Area 48 should be calculated. At that meeting the Working Group also developed a simple model in the form of figures (SC-CAMLR-X, Annex 5, Figures 2 and 3) which hypothesised a number of krill flows in Statistical Area 48 on the basis of available knowledge of general hydrographic features.

4.2 A number of papers containing relevant information from geostrophic flow calculations and experiments with drifting buoys has been submitted to WG-Krill over the last three meetings. Based on this information, a revised table summarising information on possible water movements between subareas has been produced (Table 3).

4.3 The Working Group also received paper WG-Krill-93/11 which was a comprehensive bibliography of publications on Antarctic oceanography which might be useful in tackling this task.

4.4 The Working Group agreed that there was a considerable body of data that could be brought to bear on this question, and that a process was needed to calculate the integrated mass flows across the subarea boundaries in Statistical Area 48. It was also agreed that a high priority should be afforded to the development of methods which would allow the available information to be used in estimating possible ranges of immigration/emigration rates and retention times. It was reiterated that the transport of krill was not necessarily a purely passive process governed only by water movements since active migration of krill has been documented - Kanda *et al.* (1982)[3], Siegel (1988)[4].

4.5 Attention was drawn to the OPEN Program in Nova Scotia in which current meters and drifter buoys have been used to track a specified body of water in order to follow the development of recruits in a cod stock. It was suggested that similar methods could be used to follow a water mass containing a krill concentration in the Antarctic to determine the extent to which the concentrations and the water mass moved in concert.

4.6 Dr I. Everson (UK) drew attention to the results of Everson and Murphy (1987)[5] which indicated that in the Bransfield Strait the transport of krill was virtually coincident with the speed of water movement in that area.

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3 Kanda, K., K. Takagi and Y. Seki. 1982. Movement of the larger swarms of Antarctic krill *Euphausia superba* off Enderby Land during 1976-77 season. *J. Tokyo Univ. Fish*., 68 (1/2): 24-42.

4 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.

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

4.7 Results of surveys conducted over a very small area in Subarea 48.3 are presented in WG-Krill-93/35. The main aim of this study was to estimate krill transport rates rather than biomass *per se*. The authors conclude that, since transport rates are very similar to current speeds, the observed changes in biomass may be caused by krill transport.

4.8 It was noted that the application of geostatistical methods to these data would be particularly appropriate. The importance of estimating the variance of parameters or quantities (e.g., biomass) was again highlighted.

4.9 It was also noted that the small area that was deliberately chosen for the study may or may not be typical of the whole of the area around South Georgia. There are, for example, large areas with high retention capacity to the east of the islands. Other areas around the islands are less likely to retain krill. Although the study is useful in trying to estimate transport rates of krill, results should be interpreted with care.

4.10 The Working Group agreed that, as a first step, it would be useful to consider krill as passive drifters, at least with respect to horizontal transport, and that incorporation of active krill movement into the estimation of krill fluxes would follow at a later stage. Noting initiatives such as reported in WG-Krill-93/19, the Working Group further agreed that a special workshop was needed to bring together appropriate aspects to carry these calculations forward. A conceptual model and terms of reference for this workshop are presented in Appendix D.

Estimation of Effective Biomass

Techniques

4.11 Various techniques for estimating krill biomass have been identified in the past. Of these, two direct methods are acoustic surveys and net surveys. One indirect method is the use of indices (e.g., CPUE indices) to estimate relative abundance.

4.12 Four papers on technical details of acoustic methods were tabled: WG-Krill-93/6, 21, 24 and 48.

4.13 Dr K. Foote (Norway) presented WG-Krill-93/6. The background for this study, the Krill Target Strength Experiment (KTSE), was conducted under the aegis of British Antarctic Survey during the austral summer 1987/88. It consisted of, first, simultaneous measurements of the echo energy from encaged aggregations of live krill at 38 and 120 kHz; secondly, biological and physical measurements of the same specimens, including measurements of mass density of individuals and speed of sound in an animal; and thirdly, application of the fluid-sphere model.

4.14 Because there was rather poor agreement between the fluid sphere model predictions and KTSE measurements in the previous analysis, the deformed fluid-like cylinder model of Stanton (1989)[6] was applied in the new paper (WG-Krill-93/6). Using the same physical parameters and animal dimensions as were measured during the KTSE, new computations of target strength were performed, but as a function of krill orientation. Since the orientation was not measured during the experiment, the orientation distribution was inferred by requiring that the difference between predicted echo energy and that from two frequency measurement pairs be a minimum in a least squares sense.

4.15 The new results show a strong agreement between model predictions and measurements. The authors believe that the new model may prove useful in acoustic applications where krill number density is to be determined. They call particular attention to the importance of measurements of mass density and sound speed, as well as animal morphometry.

4.16 Such measurements are also important to another new model of krill scattering, that by Drs M. Furusawa and Y. Miyanohana (Japan), described in WG-Krill-93/21. The study developed a target strength (TS) model where krill is represented by a liquid prolate spheroid. As in the case of the model used in WG-Krill-93/6, the results in this study are also sensitive to the internal density, and sound speed of krill. One of the conclusions of this paper was that at low frequency the target strength is low, the signal to noise ratio (SNR) is low and results are sensitive to krill length, but not orientation. At high frequency, on the other hand, target strength is high, the SNR is high but results are sensitive to the orientation of krill. The authors recommended that a frequency of 70 kHz be used for krill surveys.

4.17 Consequently, it was noted that there were advantages in operating at more than one frequency. It was further noted that operating at dual frequencies allows for improved discrimination of targets. For example, the characteristic difference in mean volume backscattering strength (MVBS) at 38 and 120 kHz is around 5 dB for krill from field observations (Hampton, 1990[7]).

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6 Stanton, T.K. 1989. Sound scattering by cylinders of finite length. III. Deformed cylinders. *J. Acoust. Soc. Am.*, 86: 691-705.

7 Hampton, I. 1990. Measurements of differences in the target strength of Antarctic krill (*Euphausia superba*) swarms at 38 kHz and 120 kHz. In: *Selected Scientific Papers, 1990 (SC-CAMLR-SSP/7)*. CCAMLR, Hobart, Australia: 75-86.

4.18 Paper WG-Krill-93/24 presented results from target strength experiments on krill in tanks. Observations confirm the sensitivity of target strength to orientation of krill, as well as the physical characteristics of the animals (e.g., size, sex, maturity and reproductive stage).

4.19 A correction for acoustic survey bias introduced by the vertical migration of krill was proposed in WG-Krill-93/48. In each of five surveys, conducted in the Elephant Island area during the austral summer of 1992, krill were observed to be dispersed in the upper portion of the water column at night and more concentrated and deeper during the day, suggesting that substantial numbers of krill may be above the acoustic observation window during dark hours. A polynomial function was fitted to the data and subsequently used to adjust the original surveys; resulting biomass estimates were 2.3 to 99.6% higher than those disregarding bias due to diel vertical migration.

4.20 Alternative ways of correcting for animals in the surface layer, and therefore not detected by the downward-looking transducer, were discussed. There are many problems, particularly regarding noise (e.g., caused by bubbles or reflections from the sea surface), associated with upward and sideways-looking transducers. These techniques are, however, being investigated. The possibility of using recently-developed laser-based system (LIDAR) for looking at the surface layer was mentioned.

4.21 It was further noted that if the target-strength model is correct, then the TS of an animal with fixed orientation is the same whether the transducer is downward or upward-looking. For transducers looking in other directions, the TS will in general be different.

4.22 The importance of regular net hauls during acoustic surveys was again highlighted. Such hauls are essential for target identification and collection of biological data.

4.23 No further developments or technical matters regarding net surveys for the estimation of biomass were presented.

4.24 The use of CPUE indices for biomass estimation was briefly considered. Further discussion is given in paragraph 5.27.

Estimates of Biomass in Statistical Area 48

4.25 In SC-CAMLR-XI (Annex 4) possible problems with some aspects of the FIBEX data, which had been re-analysed to estimate total krill biomass in Statistical Area 48, were indicated. The principal question related to the data from the *Walther Herwig*. Estimates of biomass from these data were substantially higher than estimates from other survey vessels in adjacent areas.

4.26 Results of further exploratory analyses of the FIBEX acoustic data are presented in WG-Krill-93/31. Data from surveys in the West Atlantic sector were re-examined. The high densities of the *Walther Herwig* survey were largely due to the presence of a superswarm near Elephant Island although the occurrence of a high biomass there is not an unusual phenomenon. Furthermore, there was a good level of consistency between the distributions of MVBS and estimates of density from four of the vessels, *Itzumi*, *Eduardo L. Holmberg*, *Odissey* and *Walther Herwig*. While there is some uncertainty associated with the combinations of data collected at 50 kHz (*Walther Herwig* survey) with data collected at 120 kHz (all other vessels), it is concluded that this does not materially affect the estimated biomass.

4.27 Results in WG-Krill-93/31 show that data from the *Professor Siedlecki* survey do not provide distributions of MVBS and estimates of density that are consistent with the other surveys. The authors could find no explanation for this difference.

4.28 Whilst checking all FIBEX acoustic datasets, a further complication came to light regarding the data from *Eduardo L. Holmberg*. Following correspondence between Dr P. Trathan (British Antarctic Survey) and colleagues at Instituto Antártico Argentino it became clear that an incorrect value for integrator gain had been used for the analysis. Applying the correct integrator gain value resulted in a 10 dB increase in MVBS values. The distribution of corrected MVBS values has a mode close to that for *Itzumi* and the same as that for *Odissey* (WG-Krill-93/31). These corrected MVBS values give a tenfold increase in the estimated mean density of krill from that survey. The corrected values of density and standing stock appear in the version of WG-Krill-92/20 published in *Selected Scientific Papers, 1992 (SC-CAMLR-SSP/9)*.

4.29 WG-Krill-93/20 reports on a re-examination of data from the *Eduardo L. Holmberg* FIBEX survey for incorporation into the BIOMASS database in the appropriate standardised format. The results indicate the krill were concentrated to the western end of the South Orkney Islands. Density values are consistent with those from other FIBEX surveys (see Figure 1 in WG-Krill-93/20 and Figure 3 in WG-Krill-93/31).

4.30 The analyses presented in papers WG-Krill-93/31 and WG-Krill-93/20 basically resolve the questions about the *Walther Herwig* data but raise new questions regarding the *Professor Siedlecki* data. Fortunately, the area surveyed by the *Itzumi* overlaps largely with that surveyed by the *Professor Siedlecki*. Furthermore, the *Itzumi* survey covers the area of anticipated high krill density. In conclusion the Working Group therefore felt that, for the purposes of calculating effective biomass in Statistical Area 48 for use in the calculation of potential yield, there was no urgent need to resolve the questions regarding the *Professor Siedlecki* data.

4.31 Given the problems associated with the *Professor Siedlecki* survey data, the estimates of biomass from FIBEX given in Table 2 of the revised version of WG-Krill-92/20 were recalculated excluding those data. Results of recalculations are given in Table 4. The values differ materially from those given in SC-CAMLR-XI, Annex 4, Table 2 in the following ways:

(i) the total biomass for Subarea 48.1 is increased to 13.6 million tonnes due to the inclusion of the *Walther Herwig* and the exclusion of *Professor Siedlecki* data (paragraphs 4.26 and 4.27); and

(ii) the total biomass for Subarea 48.2 is increased to 15.6 million tonnes following correction of the integrator gain from *Eduardo L. Holmberg* (paragraph 4.28).

4.32 Annual acoustic estimates of krill biomass in the Elephant Island area for the years 1981 through 1993 were presented in WG-Krill-93/49. Survey results prior to 1992 were adjusted in consideration of the definition of krill target strength recommended by WG-Krill at its 1991 meeting. Average krill biomass densities during January to March were also presented for all years except 1982, 1983 and 1986, together with qualitative evaluations of krill recruitment from WG-Krill-93/8. In six out of seven cases, good (or bad) recruitment corresponded to an increase (or decrease) in krill density the following year. A table of these estimates, both in terms of abundance and areal density, is included below and attached as Figure 1:

Year	Month	Survey Area ($10^6 m^2$)	Biomass (10^3 t)	Adj. Biomass (10^3 t)	Areal Density (g/m^2)	Reference
1981	March	17 338	790*	1 187	68.5	Macaulay (unpub. ms)
1983	Oct/Nov	36 038	52	480	13.3	Klindt, 1986
1984	March	17 338	260	390	22.5	Macaulay (unpub. ms)
1984	Nov/Dec	34 663	380	2 200	63.5	Klindt, 1986
1985	March/April	31 840	16	81	2.5	Klindt, 1986
1987	January	17 338	660	992	57.2	Macaulay (unpub. ms)
1988	January	17 338	480	721	41.6	Macaulay (unpub. ms)
1989	February	17 338	950*	1 428	82.4	Macaulay (unpub. ms)
1990	early January	40 902	465	699	17.1	Amos *et al*. 1990
1990	late January	36 271	1 132	1 702	46.9	Amos *et al*. 1990
1990	early February	40 902	2 133	3 206	78.4	Amos *et al*. 1990
1990	late February	40 902	2 475	3 720	90.9	Amos *et al*. 1990
1991	late January	43 474	689	1 036	23.8	Macaulay & Mathisen, 1991
1991	late Feb-early Mar	42 960	822	1 236	28.8	Macaulay & Mathisen, 1991
1992	late January	36 271	2 220	2 220	61.2	Hewitt & Demer, in press
1992	early March	36 271	1 075	1 075	29.6	Hewitt & Demer, in press
1993	January	36 271	4 880	4 880	134.5	Hewitt & Demer, submitted
1993	February	36 271	3 220	3 200	88.2	Hewitt & Demer, submitted

* excluding biomass of observed superswarm

Amos, A.F., J.L. Bengtson, O. Holm-Hansen, V.J. Loeb, M.C. Macaulay and J.H. Wormuth. 1990. Surface water masses, primary production, krill distribution and predator foraging in the vicinity of Elephant Island during the 1989/90 austral summer. Document *WG-CEMP-90/11*. CCAMLR, Hobart, Australia: 65 pp.

Hewitt, R.P. and D.A. Demer. (In press). Dispersion and abundance of krill in the vicinity of Elephant Island in the 1992 austral summer. *Mar. Ecol. Prog. Ser.*

Hewitt, R.P. and D.A. Demer. (Submitted). AMLR Program: distribution and abundance of krill in the vicinity of Elephant Island in the 1993 austral summer. *US Antarctic Journ.*

Klindt, H. 1986. Acoustic estimates of the distribution and stock size of krill around Elephant Island during SIBEX I and II in 1983, 1984 and 1985. *Arch. FischWiss.*, 37: 107-127.

Macaulay, M.C. and O.A. Mathisen. 1991. AMLR Program: hydroacoustic observations of krill distribution and biomass near Elephant Island, austral summer 1991. *US Antarctic Jour.*, 26 (5): 203-204.

4.33 The total areas related to the abundance estimates in the above table differ greatly and the question was raised whether estimates for a standardised area would be more helpful for the Working Group for the CCAMLR Ecosystem Monitoring Program (WG-CEMP). Dr Hewitt indicated that, in principle, it would be possible to extract subsets of data from each survey, coinciding with a pre-defined area, and re-estimate abundance from this subset.

4.34 Preliminary results of the 1992/93 Korean Antarctic Research Program cruise are presented in WG-Krill-93/41. Only some of the data has so far been analysed but the authors intend to complete analyses and present final results to CCAMLR. The Working Group encouraged the authors to complete this work as soon as possible.

4.35 Dr S. Kim (Republic of Korea) also indicated that the intention was to continue the mesoscale surveys that have been conducted annually for the past five seasons around the South

Shetland Islands and in the Bransfield Strait. Scientists interested in being involved in the multidisciplinary survey planned for 1994 were invited to contact Dr Kim.

4.36 It was noted that results in WG-Krill-93/41 indicated the presence of *Thysanoessa* in areas where *Euphausia superba* were also found. Acoustically these species are very similar and acoustic survey results may therefore, in some cases, be contaminated by the presence of *Thysanoessa*.

4.37 The problem is that net hauls are only taken at intervals and do not provide information on the species composition for the sections of track between hauls. In this regard, multi-frequency systems may help in distinguishing between the two species.

4.38 Dr M. Naganobu (Japan) indicated that the Japanese RV *Kaiyo Maru* will conduct an austral summer cruise during the 1994/95 season to carry out an oceanographical and ecological survey in relation to the distribution and abundance of krill in the vicinity of the South Shetland Islands. He also noted that the US and the Republic of Korea plan similar research cruises during the same time and in this area. It is anticipated that there will be close coordination between these Members.

Other Areas

4.39 No new estimates of biomass were reported for areas other than Statistical Area 48.

Biomass Estimation for CEMP Integrated Study Regions

4.40 There has been a continuing request from WG-CEMP for estimates of krill biomass in ISRs (SC-CAMLR-X, Annex 7, paragraph 5.6). The Working Group noted that, aside from the changes in biomass estimates for Subarea 48.1 due to recalculation of FIBEX data, there have been no changes in estimates of krill biomass in the ISRs since last year's summary (SC-CAMLR-XI, Annex 4, Table 2, Figure 2).

Future Near-synoptic Acoustic Survey(s) in Statistical Area 48

4.41 The Working Group agreed that the primary purpose of a near-synoptic survey for krill would be to provide an estimate of B_o (pre-exploitation biomass extimated from a survey) used in the population model to estimate sustainable yield. It was further agreed that appropriate survey areas would be large portions of Statistical Area 48 and smaller portions of Statistical Area 58.

4.42 It was noted that some of the problems with the FIBEX survey data encountered last year had now been resolved (WG-Krill-93/20 and 31). These data are currently used to estimate B_o. It was further noted that the 1992/93 krill fishery took approximately 81 000 tonnes, well below the precautionary limit of 1.5 million tonnes, and that the fishery is not expected to increase substantially in the next year.

4.43 The Working Group thus concluded that a near-synoptic survey was a not a matter of immediate urgency, but that survey designs should be prepared which specify the resources required to achieve the desired precision. For example, during FIBEX approximately four ship-months were required to survey 1 000 000 km^2 (10%) of Statistical Area 48 with a 15% coefficient of variation (CV), and three ship-months were required to survey 1 777 000 km^2 (15%) of Statistical Area 58 with a CV of 32% (Table 4).

4.44 The Working Group agreed that there was a need to start developing plans and designs for future near-synoptic surveys. It was noted that planning and organising surveys would take at least two to three years. Therefore plans should be prepared as far in advance as possible to reduce the lead time should further specific surveys be required.

4.45 The basic aim of such a survey would be to estimate a value of B_o which is used in calculation of potential yield of krill. In addition to parts of Statistical Area 48, parts of Statistical Area 58 should be considered first. Areas where high krill abundance may be anticipated should be identified. There may also be other aggregation parameters that would be required for survey design.

4.46 The net hauls used for target identification can, in principle, be used to improve estimates of mean recruitment and its variability. Procedures to ensure that the necessary length density data (WG-Krill-93/12 and 13) are obtained should be taken into account in the survey design process.

4.47 The Working Group agreed that an *ad hoc* correspondence group, coordinated by the Convener, should be set up to tackle the problem of designing near-synoptic acoustic surveys to estimate B_o in the intersessional period. The group should report to WG-Krill at its next meeting.

4.48 The Working Group agreed that, for the purposes of monitoring and managing the krill fishery, additional surveys and/or indices of population abundance derived from catch and effort data will be required.

Collection of Other Essential Data

KRAM Project

4.49 The Scientific Committee has requested WG-Krill's advice (SC-CAMLR-XI, paragraph 2.32) on a Russian proposal (KRAM) to model interactions between krill aggregations and the subsequent design/implementation of acoustic surveys to estimate biomass (SC-CAMLR-XI-BG/13).

4.50 The Russian proposal was considered with respect to the following:

(i) the project's origins as a priority item in the various initiatives being developed by WG-Krill;

(ii) whether the future work of WG-Krill is likely to be hampered by non-acquisition of the kind of information envisaged to arise from the project; and

(iii) whether there is sufficient expertise within WG-Krill to undertake research of the type proposed.

4.51 It was agreed that many of the studies proposed by KRAM were, or already had been, addressed by specialists in the field of krill ecology both within and outside the CCAMLR community. Furthermore, although KRAM is of general interest, the kind of information envisaged to be of use in developing advice on krill management is likely to be somewhat different from that of KRAM.

4.52 WG-Krill members also felt that there is sufficient expertise on krill aggregation dynamics within the Working Group. In this regard, many participants indicated that the study of krill aggregation is a continuing research priority in their respective countries and that results pertinent to the work of WG-Krill are anticipated in the near future.

4.53 Consequently, WG-Krill recommended that there is no urgent need for the Scientific Committee to put aside funds to support KRAM. Nevertheless, given the anticipated need for near-synoptic krill surveys in the near future (paragraph 4.43 to 4.44), and in view of other associated initiatives, WG-Krill encouraged the KRAM proposers to seek funds from granting bodies for the project's implementation. In this connection, the Working Group expressed regret that the principal KRAM investigator had not attended the current meeting.

4.54 Details of the collection of other data are given in Table 6. Attention is drawn to the need for more information on length density from random net hauls to use in the estimation of the mean and variance of recruitment.

Refinement of Yield Estimate Calculations

Evaluation of Population Models

4.55 Prof. Butterworth presented WG-Krill-93/42, which detailed the results of modifications requested by the two previous meetings of the Working Group to the procedure used to relate krill yield to a pre-exploitation survey estimate of krill biomass. It was noted that the code for these computations had been validated by the Secretariat. It was noted further that algebraic errors detected by Dr K. Hiramatsu (Japan) in the evaluations presented at the previous meeting had been corrected, and that independent computations by Dr Hiramatsu had provided results essentially identical to those of WG-Krill-93/42. Accordingly, the Working Group concluded that adequate cross-checks had been carried out, and that the results presented could be accepted.

4.56 The major advance in these new results, compared to those used by the Working Group in 1991 as a basis to recommend precautionary catch limits for krill[8], was to take uncertainties in the values of a number of biological parameters (e.g., natural mortality, recruitment variability) into account by averaging results over the perceived ranges for these uncertainties. These new results did not differ greatly from those of Butterworth *et al*. (1992)[9]: the median depletions at the end of a 20-year period of harvesting were scarcely affected, while probabilities of the spawning biomass dropping below a certain critical level increased only slightly. Of the three different fishing seasons (summer, winter and all year) for which the revised calculations had been carried out, winter fishing offered marginal advantages (the risks of depletion are less for the same value of γ, where γ is the fraction of B_0 which is harvested each year).

4.57 One modification agreed by the previous meeting of the Working Group did produce a marked effect on results. This was the imposition of an upper bound of 1.5 on the effective annual fishing mortality, which means that the intended constant catch is not fully harvested in years when harvesting would involve removal of more than 80% of the exploitable biomass of krill. This led to marked reductions in the probability of the spawning biomass falling below small fractions of its median size in the absence of exploitation. Further, although median depletions were little affected for $\gamma < 0.2$, the 1.5 bound prevents these values from dropping to zero as γ is increased above 0.2.

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8 Butterworth, D.S., A.E. Punt and M. Basson. 1991. A simple approach for calculating the potential yield of krill from biomass survey results. In: *Selected Scientific Papers, 1991 (SC-CAMLR-SSP/8)*. CCAMLR, Hobart, Australia: 207-217.

9 Butterworth, D.S., G.R. Gluckman and S. Chalis. 1992. Further computations of the consequences of setting the annual krill catch limit to a fixed fraction of the estimate of krill biomass from a survey. Document *WG-Krill-92/4*. CCAMLR, Hobart, Australia.

4.58 It was noted that these computations could be updated relatively easily, given improved estimates for biological parameters and their associated uncertainties. WG-Krill-93/42 showed that results were sensitive to the length at 50% recruitment to the fishery (particularly for $\gamma > 0.2$), which emphasised the need to analyse newly available information in this regard with special care.

4.59 The Working Group agreed that this further work has been a valuable exercise and that the problems encountered at last year's meeting have been solved. Thanks were extended to all those involved in testing, validation and further development of the model.

4.60 The Working Group discussed the improvement of inputs into the model and the criteria to be used in selecting a value for γ (the multiplication factor that provided an estimate of potential yield).

4.61 In the case of inputs to the model, attention was drawn to results in WG-Krill-93/40 which show a difference in size at maturity between males and females. The current model effectively considers females only, with input parameters appropriate for females.

4.62 Other inputs include estimates of M (natural mortality) and recruitment variability. In this regard attention is drawn to papers WG-Krill-93/12 and 13 as well as paragraphs 4.65 to 4.73.

4.63 In the past, the choice of a γ value has mainly been with regard to the probability of the stock falling below a critical value (a 10% probability that the krill spawning biomass falls below 20% of its median pre-exploitation level over a period of 20 years). In addition to this criterion, the calculations presented in WG-Krill-93/42 allow the consideration of quantities such as average escapement of spawning biomass. This is of importance, not only with regard to the krill population, but also with regard to predators.

4.64 The Working Group was informed that the Secretariat had already incorporated the procedures for generating recruitment as set out in WG-Krill-93/13 into the computer code used for the calculations. It was agreed that further calculations using this new method for generating recruitment and updated parameters should be carried out and presented to WG-Krill at its meeting in 1994. Details of these calculations and other associated recommendations are given in Appendix E.

Evaluation of Demographic Parameters

4.65 Dr de la Mare introduced paper WG-Krill-93/12 which describes a method developed along the lines suggested in Appendix E of last year's WG-Krill report. The method is a modification of

McDonald and Pitcher's method for the decomposition of a mixture of length at age distribution into their separate components. The method uses numerical density at length data from random samples from net haul surveys. The statistical properties of these data are different from those usually considered in length decomposition problems so that the first modification of McDonald and Pitcher's method was to use a likelihood function based on Aitchison's delta distribution as the criterion for fitting a mixture distribution to the data.

4.66 The second modification was to define the parameters of the mixture distribution only in terms of the proportion of recruits in the samples, that is, the proportion of the sample in the youngest age class. This means that this proportion is estimated directly when fitting the mixture distribution to the data, and allows asymptotic confidence interval and a variance estimate to be made for the proportions of recruits. WG-Krill-93/12 described the results of the application of the method for a number of net haul surveys from the BIOMASS database and the Australian Antarctic Division. WG-Krill-93/12 described the assumptions needed for valid estimates of the proportion of recruits as:

(i) the net samples are representative of the length structure of a self-sustaining krill population, for the range of age classes considered;

(ii) increasing age leads to a monotonic increase in mean length at age, which gives rise to a mixture distribution; and

(iii) krill do not naturally shrink to the extent that the smallest component considered in the mixture becomes polluted with animals of greater ages.

4.67 The main potential problem with this approach is selectivity in the numerical density-at-length samples. There are two possible sources of bias. First, (gear) net selectivity may mean that the first age class is over- or under-represented. Different types of nets would have different selectivity characteristics. Second, the timing and positions of net hauls may be such that the entire population is not represented. This may be as a result of insufficient coverage and/or the inhomogeneous distribution of krill by size. Selectivity would lead to biased estimates of the mean and variance of proportional recruitment.

4.68 The Working Group agreed that it was essential to address these questions and to assess whether selectivity is indeed a serious problem. Here it is important to bear in mind that the estimates of the mean and variance of proportional recruitment are used in the potential yield calculations which may prove not to be particularly sensitive to this problem.

4.69 Three approaches should be considered. First, small-scale simulation studies to investigate the sensitivity of the potential yield calculations to selectivity should be undertaken. Second, field experiments to try to assess the selectivity of different types of gear should be encouraged. Third, more data from random net hauls should be analysed. Net hauls from acoustic surveys are appropriate for this analysis, provided that numerical densities at length (rather than only length frequencies) can be calculated.

4.70 It was also agreed that attention should be given to sampling design, particularly in areas where krill are known to segregate by maturity (or life history) stage (e.g., WG-Krill-93/8). When analysing existing datasets, information on time, location and gear type should be considered. In connection with net avoidance, for example, Everson and Bone (1986)[10] advise that RMT8 gear should ideally only be used at night (i.e., when dark).

4.71 In spite of the concerns about selectivity, the Working Group agreed that the results of WG-Krill-93/12 were encouraging. Estimates from this study offered a great improvement over previous estimates which were essentially educated guesses, since no information had been available.

4.72 Dr de la Mare then introduced WG-Krill-93/13 which describes a simulation model for krill recruitment which uses the information obtained from the application of the method presented in WG-Krill-93/12. The model produces random numbers of recruits each year required to match the observations on proportional recruitment.

4.73 The Secretariat was requested to validate the models and computer programs associated with the analyses presented in WG-Krill-93/12 and 13 (see Appendix E).

4.74 WG-Krill-93/8 highlighted three interesting aspects of krill dynamics. A relatively long time series of data from the Antarctic Peninsula indicates that the distribution (or segregation) by maturity stage is quite consistent from year to year. There is some evidence that recruitment success may depend on the maturity stage of females at a specific time of year. The authors further hypothesised that the presence of salps may cause a reduction in the number of female krill in spawning condition compared to numbers observed when salps are absent.

4.75 It was noted that high salp abundance in a given year may lead to low krill recruitment in the following year. The issue of salps is also raised in WG-Krill-93/17 and 29.

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[10] Everson, I. and D.G. Bone. 1986. Effectiveness of the RMT8 system for sampling krill (*Euphausia superba)* swarms. *Polar Biol*., 6: 83-91.

4.76 Further attention should be given to the demography of salps and to problems associated with distinguishing between salps and krill in echo survey data. In order to support modelling exercises to investigate acoustic discrimination of krill and salps or to estimate relative scattering levels of the two, it is important that measurements be made of mass density and speed of sound in salp specimens. Morphometric data are also needed in acoustic modelling.

4.77 Dr Naganobu also indicated that WG-Krill-93/27 presents results of maturity of krill for the 1990/91 and 1991/92 seasons around the South Shetland Islands, which are very similar to results in WG-Krill-93/8. WG-Krill-93/26 deals with the relationship between krill and interannual variation of the ice edge, and gives some suggestions for possible interactions between salps, krill and oceanographic conditions.

4.78 WG-Krill-93/36 presents analyses of size data from the South Orkneys for the period October 1989 to June 1990. The author is encouraged by the Working Group to conduct further analyses with these data. It would, for example, be useful if growth curves could be fitted to the size frequency data.

4.79 WG-Krill-93/44 presents estimates of mortality (M) from samples taken in the Indian Ocean sector. It was noted that there are difficulties with methods that estimate M from relationships between M and growth parameters. Such estimates of M tend to have very large variances (Pauly, 1980[11]) and are generally not as reliable as estimates made directly from size frequency data.

4.80 The analyses in WG-Krill-93/12 and 13 can be used to estimate M directly from numerical density at size data, provided that samples are representative and from random net hauls. There is no need to separate all age classes in the data; it is enough to separate the first age class from the rest. This means that many of the problems encountered with the large degree of overlap in size for older age classes and the choice of number of age classes to fit do not arise.

4.81 One of the methods used in WG-Krill-93/44 was Pauly's method which requires an estimate of water temperature together with growth parameters to estimate M. The Working Group felt that these estimates should be interpreted with great caution since the reliability of the method for polar organisms is not known.

4.82 Demographic studies of krill in the Indian Ocean sector were presented in WG-Krill-93/45. The authors of this paper are encouraged to continue this work.

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11 Pauly, D. 1980. On the interrelationships between natural mortality, growth parameters, and mean environmental temperature in 175 fish stocks. *J. Const. Int. Explor. Mer.*, 39: 175-192.

4.83 The submission of papers WG-Krill-93/44 and 45 from a non-Member state (Ukraine) was noted with thanks.

ECOLOGICAL IMPLICATIONS OF KRILL FISHERY

Location and Timing of the Fishery

Statistical Subareas 48.1 and 48.2

5.1 The Scientific Committee had requested advice from WG-Krill on additional management measures aimed at ensuring that krill catches are not concentrated in areas close to predator colonies (SC-CAMLR-XI, paragraphs 2.78 and 5.39 to 5.43), particularly within Subarea 48.1.

5.2 The Scientific Committee further requested that the Secretariat should conduct simulation studies to analyse potential changes in fishing patterns with a view to presenting such data to WG-CEMP and WG-Krill (SC-CAMLR-XI, paragraphs 5.41 to 5.44). A Secretariat paper (WG-Krill-93/10) pertaining to this issue had been tabled.

5.3 WG-Krill-93/10 showed that during the 1992 season, 70% of the catches in Subarea 48.1 and 38% of those in Subarea 48.2 were taken in areas within 100 km from predator colonies. Dr Agnew stressed, however, that the lack of fine-scale data prevented more precise analyses, especially in view of the general lack of fine-scale data reported from Subarea 48.2.

5.4 WG-Krill-93/7, on the other hand, presented results from an analysis of Japanese very fine-scale data (10 n miles x 10 n miles) from Subarea 48.1 in relation to penguin distribution and food requirements. The paper showed that: (i) krill catches are concentrated near Livingston and Elephant Island in Subarea 48.1; (ii) the large penguin colonies in Subarea 48.1 are located on King George, Robert, Low and Nelson Islands; and (iii) subsequently the geographic overlap between the fishery and penguin foraging area during the critical period when animals are confined to their island breeding sites (December to March) is low.

5.5 Paper WG-Krill-93/7 also showed that current krill catches in Subarea 48.1 were low compared to the local krill biomass in that subarea and consequently suggested that the current fishery is very unlikely to have an adverse impact on the local krill biomass and hence on penguins.

5.6 Dr Marín commented that this study confirmed that there is no urgent need for additional precautionary measures in Subarea 48.1 to address fishery-predator concerns. Dr Hatanaka agreed with this opinion.

5.7 Dr Holt stated his belief that, since an allocation scheme may be necessary if fishing levels increase in the future, it is proper to study it now.

5.8 Dr J. Bengtson (USA) stated that WG-Krill-93/7 represented an important contribution to the evaluation of potential localised impacts of the krill fishery, and he welcomed the analyses provided by this paper. He noted, however, that the values for penguins' krill consumption used in the paper were provisional and the understanding of the specific nature of interactions between krill and its predators is still incomplete (e.g., how do krill distribution patterns affect the availability of krill biomass to predators, or how do krill move within the fishing grounds of Subarea 48.1). In addition, further work is needed to incorporate other krill predators such as fur seals, flighted seabirds, fish, and squid into austral summer krill consumption estimates. He noted that the paper, with its analyses of very fine-scale fishing data, offered a valuable foundation for continued research on these important topics.

5.9 Several Working Group members commented that WG-Krill-93/7 offered an important contribution to the continuing work of the Group and also served to emphasise the importance of reporting fine-scale catch data.

5.10 The Working Group specifically encouraged the development of analyses similar to those carried out in WG-Krill-93/7 in other subareas which fall outside Statistical Area 48.

Other Subareas

5.11 The Working Group acknowledged that the information presented on potential predator-krill-fishery interactions are only available for Subarea 48.1, and that there is general lack of such information for other subareas within Statistical Area 48 or for other areas. Consequently, similar analyses for other statistical areas and subareas were strongly encouraged.

Relation of Fishing to Krill Predators

Definition of Functional Relationships

5.12 WG-Krill-93/43 described an initial attempt to model the inter-relationships between krill, the fishery and dependent predators, following the framework developed by the Joint Meeting of WG-CEMP and WG-Krill in 1992 (SC-CAMLR-XI, Annex 8, Appendix 1).

5.13 The first requirement of the above model was to fix the parameters of the functional relationships relating predator survival rates to krill abundance. Members of WG-CEMP had provided information on the frequency of good, poor and bad years for adult predator survival and for the breeding success of four species of krill predator. This information was used to fix the levels of krill biomass, relative to the median level in the absence of exploitation, at which adult and juvenile survival rates (respectively) start to decline as krill biomass decreases. The adult survival rate estimates provided for the various predators were taken to represent the maximum value of this variable.

5.14 A "one-way" interaction model was developed, in which krill abundance fluctuations impact the predator population, but not *vice versa*. An immediate problem arose regarding the information supplied for two of the predator species: Adélie penguins and Antarctic fur seals. This information suggested that these two species would not be self-sustaining, even in the absence of a krill fishery, because the annual losses to natural mortality apparently exceed the maximum possible birth rate. WG-CEMP would be asked to examine whether there were perhaps biases in the estimates of population parameters provided, or errors in the manner in which they had been interpreted, which could explain this anomaly. Specific questions in this regard are detailed in paragraph 5.20.

5.15 The primary result of this modelling exercise was the indication that variability in the natural recruitment of krill results in predator populations being less resilient to krill fishing than deterministic evaluations would suggest. It was emphasised that it would be premature to attempt to draw quantitative conclusions about acceptable levels of krill fishing intensity at this initial stage of the exercise.

5.16 Some examinations of the sensitivity of the model developed relative to its assumptions were conducted. These indicated (*inter alia*) that predator populations were more resilient to krill fishing if the availability of other food sources for the predators were taken into account. A framework for developing a "two-way" interaction model, which accounts in addition for the effect of differing predator consumption levels on krill, was proposed. However, the Working Group considered that further work on this "two-way" model should first await clarification of questions concerning parameter values for the population dynamics of the various species of predators considered, and investigation of the resultant implications for the "one-way" model.

5.17 In considering the next steps for refining the model, it was agreed that the sensitivity of results to the following modifications should be examined in greater detail:

(i) different choices for S_J^M ;

(ii) values of $S_J(B=0)$ and $S_M(B=0)$ which are greater than zero (to reflect the availability to the predator of food sources other than krill).

5.18 Dr Hatanaka commented that factors other than krill biomass might influence breeding success and should also be considered.

5.19 Dr Butterworth stated that the model should only be viewed as preliminary and as a first step in an attempt to define possible functional relationships between krill, krill predators and the fishery.

5.20 The Working Group therefore agreed that in the interests of refining the model further, WG-CEMP should be requested to answer the following questions:

(i) What are the maximum rates of population increase which have been observed for closed populations (i.e., no immigration or emigration) of the predator species used in the model, as well as for other similar species?

(ii) What is the average life span of such predators (also, are life table data available) [Note: average lifetime ~ $(1-S_A)^{-1}$, where S_A is the adult survival rate]?

(iii) What were the proportions of "good", "poor" and "bad" years for each predator species during the period for which adult survival rates were estimated?

(iv) What are the maximum values of adult survival rates, as calculated from data in good years only (i.e., not including "poor" and "bad" years)?

(v) Do the values for the given survival rates correspond to populations that are stable, are increasing, or declining (and if changing, what is the magnitude of these changes)?

(vi) Are there identifiable biases in the population parameter estimates provided by WG-CEMP from the periods in which the estimates were derived (e.g., tag or band losses, sampling biases, etc.) and, if so, can these be quantified? and

(vii) Are data of the type already provided available for other relevant predator populations?

5.21 The Working Group felt that WG-CEMP's considerations of these issues would help to improve development of the current model.

5.22 WG-Krill-93/15 addressed interactions between demersal fish and krill in Subarea 48.1. This showed that krill is an important prey item for demersal fish.

5.23 These results were discussed, especially in relation to their inferred implication that large benthopelagic populations of krill may be present in the area studied. The attention of the Scientific Committee is drawn to this conclusion and the Working Group encouraged the further development of studies to evaluate the extent of krill population at depths greater than 200 m.

5.24 Dr Everson commented that the study also indicated that squid may be an important by-catch in the krill fishery but that no information on the species concerned had been provided.

5.25 The Scientific Committee's attention was drawn to this matter and the Working Group encouraged further analysis of the squid component in this particular study.

Status and Role of CPUE Indices

5.26 In the light of the discussion under item 3, the view that CPUE was likely to be more easily interpreted in a local context than in a larger, subarea or area, context was again expressed.

5.27 The Working Group agreed that it was important to distinguish between the use of CPUE information for the purpose of the estimation of krill biomass and for other purposes, such as the application in WG-KRILL-93/14, where CPUE is used as a measure of localised density. It is therefore still necessary to collect and submit catch and effort data (SC-CAMLR-XI, Annex 4, Table 6).

5.28 CPUE indices were discussed in terms of their potential utility in improving current understanding of the relationship between local krill abundance and the fishery.

5.29 The initial CPUE studies conducted by Butterworth (1988)[12] and Mangel (1988)[13] identified three basic parameters required for the construction of a CPUE index: searching time, towing time and total catch. One of the most difficult problems is the collection of search time data and this affects the practicality of this approach.

5.30 It was agreed that search time is a potentially important component of any CPUE index which attempts to relate krill distribution and abundance to fishery performance. Mr T. Ichii (Japan) indicated that in his experience efforts to collect search time information from the Japanese krill fishery had been futile given attendant difficulties in defining the exact characteristics of the krill fishing operation at any given time.

5.31 Both Drs Butterworth and de la Mare provided suggestions as to how search time could be estimated. The first approach involves estimating search time as a remainder component after subtraction from total time of the time spent on other activities (fishing time, processing time, etc.). The second would be to record a fishing vessel's activity at random instants.

5.32 The Working Group encouraged fishing nations to investigate the feasibility and cost of recording search time from the krill fishing operations along the lines outlined in paragraph 5.31 above. Such investigations should include an assessment of the cost-effectiveness of collecting the necessary data and submissions on the topic were encouraged. It was agreed that in all likelihood this evaluation could only really be achieved by the placement of Scientific Observers aboard fishing vessels.

Effects of Management Measures on Krill Fishing

5.33 At its 1992 meeting the Scientific Committee requested that the Secretariat design a simulation model to investigate the consequences of different extents and locations of closed areas on the krill fishery in Subarea 48.1 (SC-CAMLR-XI, paragraphs 5.41 and 5.42). A simple deterministic model of the fishery over the months December to March was described in WG-Krill-93/14. The model used CPUE data from the Chilean fishery to estimate the mean catch-per-fishing time in each of the fine-scale squares of Subarea 48.1 and the historical distribution of effort in the Chilean fishery to estimate a desirability function for each fine-scale square.

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12 Butterworth, D.S. 1988. A simulation study of krill fishing by an individual Japanese trawler. *Selected Scientific Papers, 1988 (SC-CAMLR-SSP/5)*, Part I. CCAMLR, Hobart, Australia: 1-108.

13 Mangel, M. 1988. Analysis and modelling of the Soviet Southern Ocean krill fleet. *Selected Scientific Papers, 1988 (SC-CAMLR-SSP/5)*, Part I. CCAMLR, Hobart, Australia: 127-235.

5.34 The model predicted a total catch of 9 600 tonnes per vessel over a four-month period. This total, and the distribution of catches predicted by the model, agreed well with the general level and distribution of catches from other fishing nations in Subarea 48.1 reported to CCAMLR.

5.35 Several management scenarios were considered by the paper. Prohibiting catches within 50 km of the South Shetland Islands from December to March caused a 24% reduction in catch. Prohibiting catches within 100 km of Elephant Island caused a 15% reduction in catch, but the same restriction at Livingston Island led to an increase of 39% in catch. Closing the latter two zones in alternate years would maintain the catch at its original level, but would have the effect of concentrating all the catch in the area which was open.

5.36 The Working Group commended the Secretariat for the preparation of the document in such a timely manner. It was agreed that the model was a good first attempt and that it could serve as a basis for further developments.

5.37 It was noted that mean catch rates were substantially larger at Elephant Island than at Livingston Island. This suggests that krill fishermen should be more successful if they fished only at Elephant Island but in fact fishing occurs at both locations. Several reasons were suggested why both locations are fished:

(i) fishermen may not maximise catch rates but catch only the amount that can be processed;

(ii) actual catch rates in an area during a fishing season may vary substantially from the mean rate (i.e., krill abundance may be low in an area during part of the season); and

(iii) other factors, such as the presence of salps or sea-ice, may constrain successful fishing.

5.38 Since actual CPUE rates in an area may differ substantially from the mean CPUE rate during the fishing season, it would be useful to have fine-scale data from vessels operating in different areas during the entire season to enable the model to be refined.

5.39 The Working Group noted that it would also be valuable if information were available from the fishery concerning specific effects likely to seriously impact on the fishery as a result of closing localised areas in Subarea 48.1. This information would include such factors as economic considerations, product quality, and constraints on fishing operations (e.g., induced by vessels having to move from ice-free to ice-bound areas).

5.40 Finally, the Working Group noted that management options considered to date have been based predominantly upon statistical area divisions. As indicated at previous meetings, it may be necessary to include consideration of krill "functional" ecological units (WG-Krill-93/37) in future investigations of management approaches to address the potential problem of overlap between the fishery and localised predators.

Liaison with WG-CEMP

5.41 At its 1992 meeting, the Scientific Committee recognised that a flexible scheme for designating specific management areas, fishing grounds or areas of specific ecological interest is required (SC-CAMLR-XI, paragraph 2.108). The Committee further directed that WG-Krill and WG-CEMP should continue their close liaison on the development of a feedback management procedure to take account of information on interactions among krill, krill predators, the fishery and the environment (SC-CAMLR-XI, paragraph 2.109).

5.42 The Working Group recognised the utility of information on investigating predator/prey interactions presented in several documents (WG-Krill-93/7, 14, 37, 43, 47 and WG-CEMP-93/4). The Working Group encouraged additional interaction between the two groups to further develop information (see below) for use in predator/prey interaction models.

5.43 In addition, little information is available concerning predator/prey interactions in other areas (e.g., Subareas 48.2, 48.3 and Statistical Area 58). Therefore, the Working Group suggested a high priority be placed upon obtaining this information.

5.44 Several specific areas where interaction between the two groups would benefit have already been identified elsewhere in this report (see paragraph 6.23).

5.45 The Scientific Committee had also encouraged Members to develop models to evaluate the statistical performance and cost-effectiveness of possible experimental harvesting regimes designed to distinguish between natural variation in predator performance and effects due to fishing (SC-CAMLR-XI, paragraph 6.10). No submissions on this topic had been received but it was pointed out that the continuing development of the potential yield and krill-predator interaction models will enable future progress on this matter.

ADVICE ON KRILL FISHERY MANAGEMENT

Precautionary Limits on Krill Catches in Various Areas

Estimates of Potential Yield

6.1 The standard approach which has been adopted in the past by the Working Group for estimating the potential yield (Y) of krill in an area has been to multiply an estimate of krill biomass for the area (which is taken to reflect a pre-exploitation level B_0) by a factor γ i.e., $Y = \gamma B_0$. A model of krill population dynamics (discussed in paragraphs 4.55 to 4.64, above) is then used to predict the implications of different choices of γ for future krill spawning biomass levels.

6.2 It was noted that considerable progress had been made since the previous meeting in regard to the components of this formula. There was now agreement concerning the best estimate of B_0 for Subareas 48.1 + 48.2 + 48.3 obtainable from the FIBEX data (paragraph 4.27), and the formulae and associated computer code used to predict the consequences of alternative choices for the value of γ had been validated.

6.3 In discussions, two values of γ were suggested as appropriate for estimating potential yield: $\gamma = 0.1$ and $\gamma = 0.165$. The implications of these alternatives for future krill spawning biomass levels, expressed as proportions of median levels in the absence of exploitation, are as follows. (These results are taken from the calculations of WG-Krill-93/42, and apply to fishing conducted throughout the year; of the three fishing seasons examined in that paper, such whole-year fishing was considered to best reflect the current practice in the krill fishery.)

Statistic	g = 0.1	g = 0.165
Probability of biomass falling below 0.2 over 20-year harvest period	0.02	0.10
Biomass level at the end of 20 years:		
median	0.78	0.62
lower 5% -ile	0.41	0.24

WG-Krill-93/42 showed that results for values of γ in this range are relatively insensitive to alternative fishing seasons, and to a number of other variations of the krill population dynamics model.

6.4 The choice of $\gamma = 0.165$ is consistent with the criterion used previously by the Working Group for selection of this value: a 10% probability that the krill spawning biomass falls below 20% of its median pre-exploitation level over a 20-year period of harvesting.

6.5 Some account should also be taken of the Commission's agreed concepts (SC-CAMLR-IX, Annex 4, paragraph 61) in relation to operational definitions of Article II. The first of these concepts is that the aim should be to keep krill biomass at a level higher than if only single species harvesting considerations were of concern (which would typically be about 50% of the median pre-exploitation level). The second concept indicates that, given the fluctuations induced in the krill spawning biomass as a result of recruitment variability, the lower tail of this spawning biomass distribution needs to be taken into consideration as well. Accordingly, results for the median and lower 5% -ile of this distribution are given in the table in the preceding paragraph. It is to be noted that these calculations incorporate the consequences of survey sampling variance in the estimate of krill biomass B_o.

6.6 A case can be made for the choice of $\gamma = 0.1$ at the present time, on the grounds that the associated spawning biomass distribution statistics reflected in the table in paragraph 6.3 would certainly seem consistent with the agreed concepts associated with Article II, as referenced in paragraph 6.5.

6.7 It was noted that a firmer choice of a value for γ in the context of Article II would be possible only after further development of the recently initiated krill-predator modelling studies (paragraphs 5.12 to 5.16). Values suggested at present for γ should certainly be reconsidered once such studies are sufficiently advanced.

6.8 Other factors to be taken into account in considering estimates of potential yield for krill at this time are that:

(i) the estimates of B_o from FIBEX are now some 12 years old;

(ii) predictions of statistical distributions of krill biomass for different γ values remain based on educated guesses for ranges of certain biological parameters - data-based estimates for these parameters will be available for the 1994 meeting of the Working Group (see paragraphs 4.65 to 4.83); and

(iii) it will be possible to take these estimates, together with other refinements of the krill population dynamics model (see Appendix E), into account in providing improved predictions for various choices of γ, at the 1994 meeting.

6.9 Taking cognisance of all these points, the Working Group believed that at this time a range of potential yield estimate (Y) should be provided for each Statistical Area, based upon the best estimate of B_o for that area and the two values put forward for γ. The current best estimates of potential yield are therefore as follows, and are shown together with the preliminary catch levels reported for the 1992/93 season for comparative purposes:

Area/Division	B_o (10^6 tonnes)	γ (10^6 tonnes) $\gamma = 0.1$		$\gamma = 0.165$	1992/93 Catch (10^6 tonnes)
48.1 + 48.2 + 48.3	30.8	3.08	-	5.08	0.08
48.6	4.6	0.46	-	0.76	0
58.4.2	3.9	0.39	-	0.64	0

Immediate substantial increases in these present catch levels are not anticipated (see paragraphs 3.3 to 3.12).

6.10 Attention is drawn to the fact that fishing took place in Division 58.4.1 during the 1992/93 season, but that no range of potential yield estimates is provided for this division in the preceding table because of the absence of any survey in this division.

6.11 Priority should accordingly be given to planning a survey of Division 58.4.1. As this division is large, some subdivision may be necessary because of logistical constraints. Information (e.g., regarding the operational areas of the past and present fisheries in this Division) should be provided at the Working Group's next meeting to allow this matter to be addressed.

6.12 Revisions of the existing B_o estimate for Division 58.4.2, together with another estimate from a subsequent survey in part of this Division, should be available for consideration at the Working Group's next meeting.

6.13 Modifications of Table 5 of the report of the Working Group's 1992 meeting, which presented various options for allocating a precautionary catch limit for this Statistical Area amongst its constituent subareas, were necessary due to the revisions of the FIBEX estimates of biomass in Statistical Area 48. These amendments are reflected in Table 5.

Possible Ecological Effects of Catch Limits

6.14 This matter is discussed in paragraphs 5.33 to 5.40 above.

Refining Operational Definitions of Article II

Formulation of Policy Questions to Commission

6.15 The Commission has already agreed to four concepts in this regard (SC-CAMLR-IX, Annex 4, paragraph 61). As indicated in paragraph 6.5 above, the present method used to provide estimates of the potential krill yield is already able to take some account of the first two of these concepts.

6.16 The process of moving from these concepts to operational definitions which relate directly to management advice, has started with the initiation of models of krill predator interactions (paragraph 5.12 to 5.16 above), but it will probably be some time yet before these models are sufficiently developed to be relied upon to provide the quantitative information required. The ultimate definitions themselves may be of a composite nature, including the satisfying of multiple criteria; for example, criteria for each of the three statistics reported in the table in paragraph 6.3, rather than a criterion in terms of one of these only.

6.17 It was considered that the best approach to seeking advice from the Commission on this matter would be to offer a specific range of alternatives, together with the anticipated consequences of each, and to ask the Commission to indicate its preference amongst these. Consideration should be given to the formulation of questions to the Commission in this manner at the next meeting of the Working Group.

6.18 The Commission's attention should also be drawn to the fact that advice from the Scientific Committee on best estimates of, say, the potential yield of krill will change from one year to the next as the basis for the scientific calculations improves with time. Thus, for example, the range of estimates for this yield (in 10^6 tonnes) for Subareas 48.1 + 48.2 + 48.3 has changed over the past three meetings from 1.40-2.11 in 1991, to 0.69-2.14 in 1992, to 3.08-5.08 this year. In the light of the level of variability which this indicates, the Commission may wish to consider the frequency (annual or less regularly) at which it might wish to adjust precautionary catch limits (up or down) in response to updated scientific assessments.

Other Possible Approaches and Their Development

6.19 Discussion in this regard in relation to the location, timing and intensity of krill fishing may be found in paragraphs 5.1 to 5.10.

Data Requirements

6.20 The Working Group discussed Table 6 from the report of the Group's 1992 meeting, which detailed these requirements at that time, in the light of subsequent developments reported at this meeting. The resultant modified list of requirements is appended as Table 6.

Future Work of WG-Krill

6.21 Points to be highlighted under this heading are further developments of the model used to assess the potential yield of krill, a workshop to evaluate krill flux in Statistical Area 48, the implementation of future surveys, and development of Operational Definitions of Article II in the course of a continuing dialogue with WG-CEMP. More details of these and other planned activities may be found in Table 7, which was developed by the Working Group by updating the corresponding table from the report of the previous meeting in the light of progress made through the year.

6.22 Three administrative points were also raised under this agenda item. First, in future, papers submitted to the Working Group must indicate on their cover page which agenda item they are intended to address, and how they relate to the plan for future work detailed in Table 7.

6.23 Secondly, a preliminary agenda for a Joint Meeting of WG-Krill and WG-CEMP to be held in 1994 (SC-CAMLR-XI, paragraph 6.15) will be drawn up by the Conveners in consultation with members of the groups. The Conveners would attempt to draw terms of reference for the meeting to be presented at SC-CAMLR-XII.

6.24 Thirdly, Members were asked to give consideration to the most appropriate format for future meetings of WG-Krill and WG-CEMP to facilitate discussion of this matter at the next Scientific Committee meeting. Given the convergent nature of many of the matters under consideration by these two groups, some form of combination of their annual meetings might be more appropriate. This exercise might profitably include a reconsideration of WG-Krill's present terms of reference.

OTHER BUSINESS

Exploratory Fisheries

7.1 At its 1992 meeting, the Commission had agreed that it would be useful to develop a procedure for evaluating fisheries during their exploratory phase, and had requested the Scientific Committee and its working groups to consider this matter during 1993 (CCAMLR-XI, paragraphs 4.32 and 4.33).

7.2 In response to the Scientific Committee's request that Members develop and submit papers outlining possible approaches to this issue (SC-CAMLR-XI, paragraph 3.51), a draft document has been prepared by the US Delegation (CCAMLR-XII/5). The authors indicated that this draft was being developed for submission to the Commission at its 1993 meeting, and was being made available now to allow review and comment by WG-Krill and WG-CEMP.

7.3 WG-Krill considered the draft document and agreed that it represented a useful start in responding to the requests of the Commission and Scientific Committee concerning exploratory fisheries. Suggestions for refining the definition of "exploratory fisheries" and for improving the clarity of other elements of the draft were made to the authors, who indicated their intention to submit a revised draft to WG-FSA, the Scientific Committee and Commission.

GLOBEC

7.4 Prof. J.-O. Strömberg (Sweden) reported on the progress within the International Global Ocean Ecosystem Dynamics (GLOBEC.INT) program. The program which started as a US initiative became international as the Scientific Committee on Oceanic Research (SCOR) in 1991 decided to accept it as one of its major activities. It is now co-sponsored by IOC, ICES and PICES and to its Southern Ocean component by SCAR. The scientific aim of GLOBEC.INT is "to understand the effects of physical processes on predator-prey interactions and population dynamics of zooplankton, and their relation to ocean ecosystems in the context of global climate system and anthropogenic change".

7.5 During the meeting of the Southern Ocean Working Group the key scientific questions to be addressed were formulated. These questions were formulated with regard to the ecology and dynamics of zooplankton, top predators and their interactions and are listed in Appendix F. Full details are given in the Report of GLOBEC.INT Southern Ocean Working Group.

7.6 The GLOBEC Southern Ocean Working Group suggested that many of the questions be examined within the context of a conceptual model that would be developed for the Southern Ocean prior to the development of a field program.

7.7 The GLOBEC Southern Ocean Working Group realised the considerable overlap with interests in other international scientific groups, among those, CCAMLR and its Working Groups on Krill and CEMP, and decided to assume close contacts with these. There is considerable overlap in membership between the GLOBEC Southern Ocean Working Group and WG-Krill. This should guarantee good liaison between the two groups and help ensure that duplication is avoided.

7.8 WG-Krill agreed that although the specific aims of CCAMLR and the GLOBEC program are very different there is a large area of common ground or common interest and there is a clear need for interaction between CCAMLR and the GLOBEC Southern Ocean program.

7.9 It was felt that a two-way process would be useful and that CCAMLR working groups should make GLOBEC working groups aware of their areas or topics of top priority. The Working Group also draws the Scientific Committee's attention to the fact that there are likely to be areas of overlap between the work of these groups, and that liaison between CCAMLR and GLOBEC would serve to reduce duplication and enhance the work of WG-Krill. Submission of papers describing the work of GLOBEC should be encouraged for consideration under specific agenda items of future meetings of WG-Krill.

7.10 The Working Group further recommended that the Scientific Committee should consider nominating an observer to the GLOBEC program. The work of WG-Krill would be greatly assisted if this observer could be present at the Working Group's meetings in addition to those of the Scientific Committee.

Bibliography of Antarctic Oceanography

7.11 The Working Group thanked the Secretariat for compiling this Bibliography (WG-Krill-93/11) and Members for supplying the data for it. It was noted that the bibliography would continue to be developed especially in regard to its initiative towards a workshop on krill flux (paragraph 4.10), which would attempt to synthesise much of the information contained in the papers listed in the bibliography.

7.12 The Working Group was informed that the Bibliography can be obtained from the Secretariat either in ASCII format or as a bibliographic database in "Endnote" format.

ADOPTION OF THE REPORT

8.1 The report of the meeting was adopted.

8.2 In closing the meeting the Convener thanked the rapporteurs, the various task group conveners and the Secretariat for their support and hard work during the meeting. He also thanked the participants for the large number of submitted papers, their input and good humour throughout the meeting. A substantive agenda had been addressed and the Convener indicated that many worthwhile initiatives were now under way within WG-Krill. This, in his opinion, is a strong indication of the prevailing spirit of cooperation and friendliness which has come to characterise the Working Group's meeting.

8.3 Finally, the Convener conveyed his, and the Working Group's thanks, to the local organisers (Dr Naganobu and Mr Uno), the Fisheries Agency of Japan and the Japan Deep Sea Trawlers Association, the Mariner's Court Hotel and the Japanese Government for their hospitality.

8.4 Dr K.-H. Kock (Germany), Chairman of the Scientific Committee, echoed the above sentiments, and expressed his thanks on behalf of the CCAMLR Scientific Committee.

8.5 Mr E. de Salas, Executive Secretary of CCAMLR, congratulated the Convener for conducting the meeting in an efficient and productive fashion.

Table 1: Summary of fine-scale data from the krill fishery.

Nationality	Subarea/ Division	Year	STATLANT Catch	Fine-scale Catch	%
CHL	48.1	1987	4 063	3 886	96
CHL	48.1	1988	5 938		0
CHL	48.1	1989	5 329	5 394	100
CHL	48.1	1990	4 501	4 501	100
CHL	48.1	1991	3 679	3 679	100
CHL	48.1	1992	6 066	6 066	100
CHL	48.2	1987	123	123	100
DDR	48.3	1990	396		0
ESP	48.1	1987	181	180	99
ESP	48.2	1987	198	199	100
JPN	48.1	1988	71 814	71 817	100
JPN	48.1	1989	75 912	75 912	100
JPN	48.1	1990	33 936	33 936	100
JPN	48.1	1991	54 720	54 720	100
JPN	48.1	1992	61 598	61 607	100
JPN	48.2	1986	16 929	16 929	100
JPN	48.2	1987	9 826	9 826	100
JPN	48.2	1988	1 298	1 298	100
JPN	48.2	1989	3 016	3 016	100
JPN	48.2	1990	1	0.22	22
JPN	48.2	1991	1 924	1 925	100
JPN	48.2	1992	272	263	97
JPN	48.3	1991	9 606	9 606	100
JPN	48.3	1992	12 405	12 405	100
KOR	48.1	1987	1 503	1 503	100
KOR	48.1	1988	1 111		0
KOR	48.1	1989	1 615	1 614	100
KOR	48.1	1990	4 040	4 040	100
KOR	48.1	1991	1 211	1 211	100
KOR	48.1	1992	519	519	100
KOR	48.2	1987	24	24	100
KOR	48.2	1988	414		0
KOR	48.2	1989	164	164	100
POL	48.1	1988	55	55	100
POL	48.1	1989	1 823	1 337	73
POL	48.1	1991	310	310	100
POL	48.1	1992	641	642	100
POL	48.2	1988	3 059	3 059	100
POL	48.2	1989	2 732	2 730	100
POL	48.2	1991	6 020	6 020	100
POL	48.2	1992	2 742	2 741	100
POL	48.3	1988	2 101	2 100	100
POL	48.3	1989	2 442	2 442	100
POL	48.3	1990	1 275	1 275	100
POL	48.3	1991	3 241	3 241	100
POL	48.3	1992	5 224	5 226	100

Table 1 (continued)

Nationality	Subarea/ Division	Year	STATLANT Catch	Fine-scale Catch	%
RUS	48.1	1992	8 925		0
RUS	48.2	1992	100 475		0
RUS	48.3	1992	42 295		0
SUN	48.1	1989	20 875	20 875	100
SUN	48.1	1991	4 721	4 721	100
SUN	48.2	1987	9 731	9 731	100
SUN	48.2	1988	89 888	89 888	100
SUN	48.2	1989	76 494	76 494	100
SUN	48.2	1990	220 517	220 517	100
SUN	48.2	1991	159 313	159 313	100
SUN	48.3	1988	188 391	189 432	100
SUN	48.3	1989	203 912	203 912	100
SUN	48.3	1990	79 698	79 698	100
SUN	48.3	1991	110 715	110 715	100
SUN	48.6	1988	104	104	100
SUN	58.4.1	1990	1 503	1 503	100
SUN	58.4.2	1988	6 490	6 490	100
UKR	48.1	1992	636	636	100
UKR	48.2	1992	19 697	19 064	97
UKR	48.3	1992	41 386	40 465	98

Table 2: Summary of historic Soviet/Russian krill data in Statistical Area 48.

[Total = tonnes caught as reported on STATLANT forms; fine = percent of catch reported as fine-scale data]

Year		48.?	48.1	48.2	48.3	48.4	48.5	48.6
1974	total				19 139			
	fine				0			
1975	total				41 352			
	fine				0			
1976	total	609						
	fine	0						
1977	total			68 301				
	fine			0				
1978	total	78 837						
	fine	0						
1979	total	266 386						
	fine	0						
1980	total		49 439	173 539	133 774			
	fine		0	0	0			
1981	total		89 108	60 540	135 252			217
	fine		0	0	0			0
1982	total		64 045	257 269	46 868			
	fine		0	0	0			
1983	total		39	116 497	11 480			735
	fine		0	0	0			0
1984	total			53 881	8 440			
	fine			0	0			
1985	total			101 520	45 335			
	fine			0	0			
1986	total			224 744	141 994			
	fine			0	0			
1987	total		319	9 731	254 480			
	fine		0	100	0			
1988	total			89 888	188 391			
	fine			100	101			
1989	total		20 875	76 494	203 912			
	fine		100	100	100			
1990	total			220 517	79 698			
	fine			100	100			
1991	total		4 721	159 313	110 715			
	fine		100	100	100			
1992	total		8 925	100 475	42 295	30		
	fine		0	0	0	0		

Data sources for potential fine-scale reporting:

1974 to 1977: summary reports, located at VNIRO and AtlantNIRO
1978 to 1983: 15-day reports, located at VNIRO, AtlantNIRO, and YugNIRO
1984 to 1992: magnetic tape, located at VNIRO

Table 3: Estimates of flow in Statistical Area 48.

Subarea	Location	Speed (cm/s)	Direction	Reference
48.1	Deep	5.5 - 10.9	East	SC-CAMLR-XI, Annex 4, Table 1
	Deep	3.4 - 5.1	East	SC-CAMLR-XI, Annex 4, Table 1
	Deep	30.0 - 40.0	East	SC-CAMLR-X, Annex 5, Table 1
	Deep	12.8-16.0	East	WG-Krill-93/38
	Coastal	0.8 - 1.6	East	SC-CAMLR-XI, Annex 4, Table 1
	Coastal	19.0	East	SC-CAMLR-X, Annex 5, Table 1
	Coastal	5.0 - 10.0	East	SC-CAMLR-X, Annex 5, Table 1
	Coastal	3.7	West	WG-Krill-93/38
	Bransfield Strait	26.0 - 64.0	East	SC-CAMLR-X, Annex 5, Table 1
	Bransfield Strait	19.9	East	WG-Krill-93/38
48.2	Deep	5.8 - 12.5	East	SC-CAMLR-XI, Annex 4, Table 1
	Coastal	0.8	East	SC-CAMLR-XI, Annex 4, Table 1
48.3	Deep	1.9 - 2.5	East	SC-CAMLR-XI, Annex 4, Table 1
	Deep	4.7 - 5.8	East	SC-CAMLR-XI, Annex 4, Table 1
	Deep	0.2	West	SC-CAMLR-XI, Annex 4, Table 1
	Deep	16.0	East	WG-Krill-93/38
	Deep	43 - 49		WG-Krill-93/35
	Coastal	4.2		WG-Krill-93/30
	Coastal	10.0		WG-CEMP-92/32

Deep = surface currents over deep water (open ocean)
Coastal = surface currents over the shelf

Table 4: Results of the recalculation of krill biomass from the FIBEX cruises.

	ρA (gm^{-2})	Area ('000 km^2)	Coefficient of Variation	Biomass (thousand tonnes)
Details for Subarea 48.1				
Professor Siedlecki (Bransfield)	21.9	29.1	37.7	638
Professor Siedlecki (Drake)	1.5	160.1	31.1	240
Itzumi (Bransfield)	159.6	26.5	19.7	4 229
Itzumi (E Drake)	66.9	8.3	65.0	555
Itzumi (W Drake)	91.9	4.7	43.1	432
Walther Herwig (SW)	94.2	89.4	38.0	8 420
Details for Subarea 48.2				
Odissey (Scotia A)	89.3	68.3	20.1	6 103
Odissey (Scotia B)	16.8	33.3	7.5	558
Eduardo L. Holmberg	82.8	83.8	34.9	6 937
Walther Herwig (E)	35.6	56.5	40.1	2 009
Combined results				
Area 41 *Walther Herwig* (NW)	48.9	75	29.6	3 658
Subarea 48.1 (excluding *Professor Siedlecki*)	105.8	128.9	24.0	13 636
Subarea 48.2	64.5	241.9	18.1	15 606
Subarea 48.3	59.7	25.3	38.0	1 510
Subarea 48.1+2+3			14.3	30 752
Subarea 48.6 *Agulhas*	8.0	576	23.0	4 608
Division 58.4.2 *Nella Dan + Marion Dufresne + Kaiyo Maru*	2.3	1 711	32.0	3 935

Table 5: Re-calculation of the percentages used for allocation of a precautionary catch limit for krill in Statistical Area 48 among the various subareas.

		FIBEX Estimate	Historical Catch 1980-1992	Average of Columns 1 and 2 plus 5%
Krill-predator interactions considered?		N	N	N
Data availability?		Y	Y	Y
Provisional allocations:				
Antarctic Peninsula	48.1	39%	19%	34%
South Orkney Islands	48.2	44%	44%	49%
South Georgia	48.3	4%	37%	26%
S. Sandwich Islands	48.4		<0.01%	5%
Weddell Sea	48.5		<0.01%	5%
Bouvet Island region	48.6	13%	0.02%	12%

Table 6: Data requirements. This table lists the requests of WG-Krill-92, and adds additional requests of the Fifth Meeting of the Working Group.

Data Requested by WG-Krill-92	Data/Work Submitted	Data Requested by WG-Krill-93
Examination of the precision of estimates of krill length/weight relationships	Not done	Continued requirement
Demograhic data, especially as parameters for the yield model	WG-Krill-93/40, 44	Continued requirement (Appendix E)
Influence of hydrography on krill distribution	WG-Krill-93/22, 26, 28, 30, 33, 39	Continued requirement for Workshop (paragraph 4.10 and Appendix D), and continued submission to the Bibliography requested (paragraph 7.11)
Length frequency data submission	Length frequency data from Chile and Japanese fishery	Now established; continuing
Haul-by-haul data	Chile only	Continued requirement
Finer scale data submission	Japanese 10 nm x 10 nm data reporting	Now established; continued requirement
Number and capacity of fishing vessels	-	-
Estimates of biomass for ISRs	Calculated at Workings Groups 1992 and 1993	Continued requirement
Monthly catch reporting	Proceeding	Now established
Data on amount and viability of krill passing through a net	1993/94	Validation of assumptions of WG-Krill-93/34 recommended and validation of code by Secretariat requested (paragraphs 3.36 and 3.38)
New data on krill flux	(see above)	-
Historical fine-scale catches	Information provided by Russia (paragraphs 3.16 to 3.21)	Progress on submission of historical fine-scale data encouraged (paragraph 3.20)
Secretariat requested to contact FAO concerning catches in Statistical Area 41	Done	-
Minimum data requirements from acoustic surveys required (SC-CAMLR-XI, Annex 4, Appendix H)	Partial compliance	Continued requirement
		Net haul density data shoud be submitted for calculation of ΔR (Appendix E)

Table 7: Future work requirements. This table lists the requests of WG-Krill-92, and adds additional requests of the Fifth Meeting of the Working Group.

Work Requested by WG-Krill-92	Data/Work Submitted	Future Work Requested by WG-Krill-93
Operational definitions of Article II	No progress	Continued requirement
Further analysis of net haul and acoustic data for FIBEX	WG-Krill-93/20, 31, Table 4	-
Models of functional relationships between krill, predators, and fishery	WG-Krill-93/43	Refinement of parameters and model of functional relationships (paragraph 5.17)
Validation of potential yield model	Done	-
Estimation of S_R and correlation of M and growth rate	WG-Krill-93/12, 13	Further validation of R/M model and input parameters (Appendix E)
Examination of effect of physical condition and orientation on krill target strength	WG-Krill-93/6, 21, 24	Further work, especially on upward-looking and multi-frequency transducers encouraged (paragraphs 4.17 and 4.20)
Survey designs	WG-Krill-93/5	An *ad hoc* group will correspond (organised by D. Miller) in the intersessional period to investigate the problems of survey design and sampling regimes for krill data (B_o, ΔR) required by WG-Krill (paragraphs 4.44 to 4.48)
Analysis of fine-scale fisheries data	WG-Krill-93/7, 10, 11	Further detailed quantitative analysis of overlap of predators and fishery in all CCAMLR areas requested of the Secretariat (paragraph 5.10)
Further consideration of the *Observers Manual*	No comments	Awaiting use in field
Evaluate Composite CPUE Index	Paragraph 3.39	Methods of estimating search time for use in the Composite CPUE Index should be investigated (paragraph 5.31)
		The Composite Index should be used in conjunction with size/maturity state information to infer within-season krill movement.

Table 7 (continued)

Work Requested by WG-Krill-92	Data/Work Submitted	Future work Requested by WG-Krill-93
Liaison between fishermen, biologists and managers	None	Continued requirement.
Investigations of the scale and frequency of surveys applicable to feedback management approaches	None	Continued requirement
Consideration of a near-synoptic survey of Statistical Area 48	Paragraphs 4.41 to 4.48	(above)
Subdivision of results from existing surveys in line with WG-Krill-92 (SC-CAMLR-XI, Annex 4, Appendix D)	-	Continued requirement
Clarification of noise margins and thresholds for Prydz Bay surveys	-	Continued requirement for reporting at the next meeting of WG-Krill
Modelling to evaluate feedback control management options and spatial effects related to localised predator aggregations	-	Continued requirement
Completion of precautionary catch limit allocation table	Done at Working Group (Table 5)	
		Evaluate the statistical performance and cost-effectiveness of possible harvesting regimes (paragraph 5.45)
		A workshop on krill flux should be held in 1994 (paragraph 4.10)

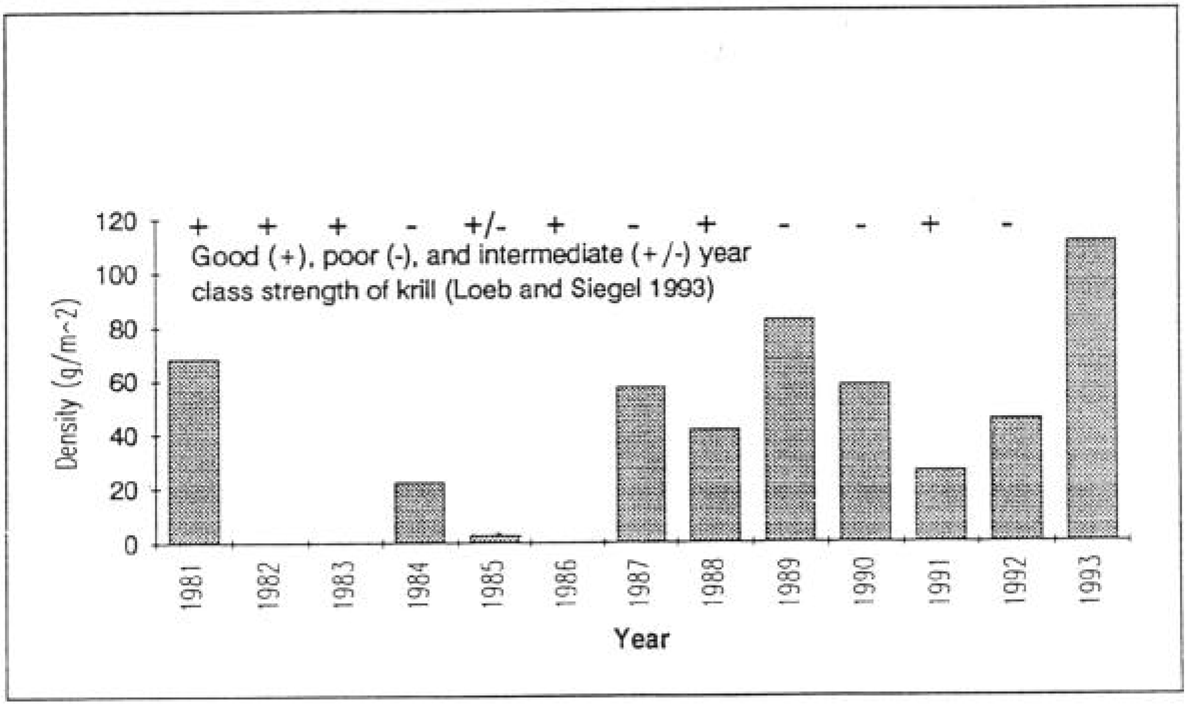

Figure 1: Average krill biomass density during January to March in the vicinity of Elephant Island appears to be variable and may reflect the effects of variations in year class strength according to Loeb and Siegel (1993).

APPENDIX A

AGENDA

Fifth Meeting of the Working Group on Krill
(Tokyo, Japan, 4 to 12 August 1993)

1. Welcome

2. Introduction
   - (i) Review of the Meeting Objectives
   - (ii) Adoption of the Agenda

3. Review of Fisheries Activities
   - (i) Fisheries Information
     - (a) Data Submission (Fine-scale/Other)
     - (b) Catch Levels
     - (c) Location of Catches
     - (d) Reports of Observers
       - (i) By-catch of Young Fish
       - (ii) Length Frequency/Haul-by-haul Data
       - (iii) Use of Draft Observer Manual
   - (ii) Other Information
     - (a) Fishing Escapement Loss/Mortality
     - (b) Development of CPUE Indices
     - (c) Future Fishing Plans

4. Estimation of Krill Yield
   - (i) Krill Flux in Statistical Area 48 and Other Areas
     - (a) Immigration/Emigration Rates
     - (b) Residence Times
     - (c) Influence of Hydrography
     - (d) Effects on Estimates of Yield
   - (ii) Estimation of Effective Biomass
     - (a) Techniques
       - (i) KRAM Project
       - (ii) CPUE Indices
     - (b) Statistical Area 48

        (c) Other Areas
        (d) Future Near-synoptic Survey(s) in Statistical Area 48
        (e) Collection of Other Essential Data
    (iii) Refinement of Yield Estimate Calculations
        (a) Evaluation of Population Models
        (b) Evaluation of Demographic Parameters
    (iv) Review of Precautionary Catch Limits
        (a) Statistical Area 48
        (b) Other Statistical Areas

5. Ecological Implications of Krill Fishing
    (i) Location and Timing of the Fishery
        (a) Statistical Subareas 48.1 and 48.2
        (b) Other Subareas
        (c) Relation of Fishing to Krill Predators
            (i) Definition of Functional Relationships
            (ii) Status and Role of CPUE Indices
    (ii) Effects of Management Measures on Krill Fishing
        (a) Krill Management Measures and Krill Predators
        (b) Location, Timing and Intensity of Fishing
    (iii) Liaison with WG-CEMP
        (a) Future Development of Management Measures
            (i) Role of Experimental Fishing

6. Advice on Krill Fishery Management
    (i) Precautionary Limits on Krill Catches in Various Areas
        (a) Estimates of Potential Yield
        (b) Possible Ecological Effects on Catch Limits
    (ii) Refining Operational Definitions of Article II
        (a) Formulation of Policy Questions to Commission
    (iii) Other Possible Approaches and Their Development
    (iv) Data Requirements
    (v) Future Work of WG-Krill

7. Other Business

8. Adoption of the Report

9. Close of the Meeting.

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(Tokyo, Japan, 4 to 12 August 1993)

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APPENDIX C

LIST OF DOCUMENTS

Working Group on Krill
(Tokyo, Japan, 4 to 12 August 1993)

WG-KRILL-93/1	AGENDA
WG-KRILL-93/2	LIST OF PARTICIPANTS
WG-KRILL-93/3	LIST OF DOCUMENTS
WG-KRILL-93/4	GEOGRAPHIC ASPECTS OF *EUPHAUSIA SUPERBA* RESOURCES EXPLOITATION R.R. Makarov (Russia) (Submitted previously as WG-CEMP-92/31)
WG-KRILL-93/5	REQUIREMENTS TO KRILL ACOUSTIC SURVEYS W.D. Tesler (Russia)
WG-KRILL-93/5 Rev. 1	THE PREPARATION OF RECOMMENDATIONS AND STANDARD PROCEDURES FOR KRILL ACOUSTIC SURVEYS W.D. Tesler (Russia)
WG-KRILL-93/6	FURTHER ANALYSIS OF TARGET STRENGTH MEASUREMENTS OF ANTARCTIC KRILL AT 38 AND 120 KHZ: COMPARISON WITH DEFORMED CYLINDER MODEL AND INFERENCE OF ORIENTATION DISTRIBUTION Dezhang Chu (USA), Kenneth G. Foote (Norway), Timothy K. Stanton (USA)
WG-KRILL-93/7	AN ASSESSMENT OF THE IMPACT OF KRILL FISHERY ON PENGUINS IN THE SOUTH SHETLANDS T. Ichii, M. Naganobu and T. Ogishima (Japan)
WG-KRILL-93/8	STATUS OF THE KRILL STOCK AROUND ELEPHANT ISLAND IN 1991/92 AND 1992/93 V. Loeb (USA) and V. Siegel (Germany)
WG-KRILL-93/9	FINE-SCALE CATCHES OF KRILL IN AREA 48 REPORTED TO CCAMLR FOR THE 1991/92 FISHING SEASON Secretariat
WG-KRILL-93/10	KRILL CATCH DISTRIBUTION IN RELATION TO PREDATOR COLONIES 1987 TO 1992 Secretariat

WG-KRILL-93/11 BIBLIOGRAPHY OF ANTARCTIC OCEANOGRAPHY, HYDROLOGY AND RELATED ASPECTS OF KRILL (*EUPHAUSIA SUPERBA*) DISTRIBUTION AND MIGRATION
Secretariat

WG-KRILL-93/12 ESTIMATING KRILL RECRUITMENT AND ITS VARIABILIITY
W. de la Mare (Australia)

WG-KRILL-93/13 MODELLING KRILL RECRUITMENT
W. de la Mare (Australia)

WG-KRILL-93/14 PRELIMINARY MODEL OF KRILL FISHERY BEHAVIOUR IN SUBAREA 48.1
D.J. Agnew (Secretariat)

WG-KRILL-93/15 TROPHIC ECOLOGY OF DEMERSAL FISH COMMUNITIES IN WATERS TO THE SOUTH OF ELEPHANT ISLAND, NORTH OF LIVINGSTON ISLAND, NORTH OF ANTARCTIC PENINSULA AND EAST OF SMITH ISLAND, WITH NOTE ON THE ECOLOGICAL ROLE OF THE KRILL
Masanori Takahashi (Japan)

WG-KRILL-93/16 A REVIEW ON THE FEEDING CONDITIONS OF THE BALEEN WHALES IN THE SOUTHERN OCEAN
Akito Kawamura (Japan)

WG-KRILL-93/17 DISTRIBUTION OF SALPS NEAR THE SOUTH SHETLAND ISLANDS; THEIR ECOLOGICAL SIGNIFICANCE IN THE AREA
J. Nishikawa, M. Naganobu, T. Ichii and K. Kawaguchi (Japan)

WG-KRILL-93/18 COMPARISON OF THE DISTRIBUTION OF PARTICULATE MATTERS AND THE COMPOSITION OF PARTICULATE ORGANIC MATTER IN SUFACE WATERS BETWEEN THE COASTAL AND OCEANIC AREAS OFF THE NORTHERN SOUTH SHETLAND ISLANDS IN SUMMER
Akihiro Shiomoto and Haruto Ishii (Japan)

WG-KRILL-93/19 SOME IDEA OF NUMERICAL MODEL FOR ASSESSMENT OF *EUPHAUSIA SUPERBA* BIOMASS
Michio J. Kishi and Mikio Naganobu (Japan)

WG-KRILL-93/20 REPORT OF AN EXAMINATION OF THE ACOUSTIC DATA FROM RV *EDUARDO L. HOLMBERG* COLLECTED DURING THE FIBEX STUDY
Inigo Everson (UK) and Adrian O. Madirolas (Argentina)

WG-KRILL-93/21 PREDICTION OF KRILL TARGET STRENGTH BY LIQUID PROLATE SPHEROID MODEL
Masahiko Furusawa and Youichi Miyanohana (Japan)

WG-KRILL-93/22	HYDROGRAPHIC FLUX IN STATISTICAL AREA 58 OF CCAMLR IN THE SOUTHERN OCEAN Mikio Naganobu (Japan)
WG-KRILL-93/23	CHLOROPHYLL DISTRIBUTIONS AROUND THE SOUTH SHETLAND ISLANDS Haruto Ishii, Taro Ichii and Mikio Naganobu (Japan)
WG-KRILL-93/24	ORIENTATION OF ANTARCTIC KRILL IN AN AQUARIUM Yoshinari Endo (Japan)
WG-KRILL-93/25	CPUES AND BODY LENGTH OF ANTARCTIC KRILL DURING 1991/92 SEASON IN THE FISHING GROUNDS NORTH OF LIVINGSTON ISLAND T. Ichii (Japan)
WG-KRILL-93/26	NOTE ON RELATIONSHIP BETWEEN THE ANTARCTIC KRILL AND ANNUAL VARIATION OF ICE EDGE DURING 1979 TO 1992 M. Naganobu and S. Kawaguchi (Japan)
WG-KRILL-93/27	NOTE ON MATURITY OF KRILL IN RELATION TO INTERANNUAL FLUCTUATIONS OF FOOD EVIRONMENT IN THE SEAS AROUND THE SOUTH SHETLAND ISLANDS M. Naganobu and S. Kawaguchi (Japan)
WG-KRILL-93/28	ESTIMATES OF PRIMARY PRODUCTION BY ICE ALGAE AND PHYTOPLANKTON IN THE COASTAL ICE-COVERED AREA NEAR SYOWA STATION, ANTARCTICA Hiroo Satoh, Kentaro Watanabe and Takao Hoshiai (Japan)
WG-KRILL-93/29	ENVIRONMENTAL GRADIENTS OF THE ANTARCTIC KRILL (*EUPHAUSIA SUPERBA* DANA) IN THE WHOLE OF THE ANTARCTIC OCEAN Mikio Naganobu and Yuzo Komaki (Japan)
WG-KRILL-93/30	WINTER GUT CONTENTS OF THE ANTARCTIC KRILL (*EUPHAUSIA SUPERBA* DANA) COLLECTED IN THE SOUTH GEORGIA AREA Yasuto Nishino and Akito Kawamura (Japan)
WG-KRILL-93/31	STATUS OF THE FIBEX ACOUSTIC DATA FROM THE WEST ATLANTIC P.N. Trathan and I. Everson (UK)
WG-KRILL-93/32	AN ADDRESS TO CITIZEN'S MARINE SUMMIT Inigo Everson (UK)
WG-KRILL-93/33	A NOTE ON THE CHLOROPHYLL MEASUREMENT BY SATELLITE REMOTE SENSING IN THE ANTARCTIC OCEAN T. Ogishima, M. Naganobu and S. Matsumura (Japan)

WG-KRILL-93/34	PEAK MORTALITY OF KRILL, FISHED WITH MIDWATER TRAWLS AND FEASIBLE CRITERIA OF KRILL TRAWLS ECOLOGICAL SAFETY Yu. V. Kadilnikov (Russia)
WG-KRILL-93/35	KRILL DISTRIBUTION AND BIOMASS VARIABILITY WITHIN SUBAREA 48.3 IN JUNE 1991 S.M. Kasatkina, E.N. Tymokhin, P.P. Fedulov and K.E. Shulgovskiy (Russia)
WG-KRILL-93/36	GROWTH OF KRILL AROUND THE SOUTH ORKNEY ISLANDS IN 1989/90 V.I. Latogursky (Russia)
WG-KRILL-93/37	ON PROBLEM OF NATURAL SUBDIVIDING OF ANTARCTIC KRILL'S GEOGRAPHIC AREA (AN APPLICATION TO THE MONITORING OF FISHING) R.R. Makarov and L.L. Menshenina (Russia)
WG-KRILL-93/38	FACTORS INFLUENCING ANTARCTIC KRILL DISTRIBUTION IN THE SOUTH SHETLANDS T. Ichii, H. Ishii and M. Naganobu (Japan)
WG-KRILL-93/39	ESTIMATION OF CHLOROPHYLL DISTRIBUTIONS OBTAINED FROM SATELLITE IMAGES (NIMBUS-7/CZCS) IN THE ANTARCTIC OCEAN Noritsuga Kimura, Yoshihiro Okada, Satsuki Matsumura and Yasuhiro Sugimori (Japan)
WG-KRILL-93/40	KRILL LENGTH AND AGE AT MATURITY V. Siegel (Germany) and V. Loeb (USA)
WG-KRILL-93/41	ABUDANCE OF *EUPHAUSIA SUPERBA* IN THE WESTERN BRANSFIELD STRAIT REGION DURING THE KARP CRUISE IN THE 1992/93 SUMMER Seung-Min Choi and Suam Kim (Republic of Korea)
WG-KRILL-93/42	FURTHER COMPUTATIONS OF THE CONSEQUENCES OF SETTING THE ANNUAL KRILL CATCH LIMIT TO A FIXED FRACTION OF THE ESTIMATE OF KRILL BIOMASS FROM A SURVEY D.S. Butterworth, G.R. Gluckman, R.B. Thomson and S. Chalis (South Africa)
WG-KRILL-93/43	POSSIBLE EFFECTS OF DIFFERENT LEVELS OF FISHING ON KRILL ON PREDATORS - SOME INITIAL MODELLING ATTEMPTS D.S. Butterworth and R.B. Thomson (South Africa)
WG-KRILL-93/44	NATURAL MORTALITY RATES OF THE ANTARCTIC KRILL *EUPHAUSIA SUPERBA* DANA IN THE INDIAN SECTOR OF THE SOUTHERN OCEAN E.A. Pakhomov (Ukraine)

WG-KRILL-93/45	ANTARCTIC KRILL, *EUPHAUSIA SUPERBA* DANA, DEMOGRAPHY STUDIES IN THE SEAS OF SODRUZHESTVO AND COSMONAUTS (INDIAN OCEAN SECTOR OF ANTARCTICA) E.A. Pakhomov (Ukraine)
WG-KRILL-93/46	VACANT
WG-KRILL-93/47	PENGUIN FORAGING BEHAVIOR IN RELATION TO THE DISTRIBUTION OF PREY Donald A. Croll, Roger P. Hewitt, David A. Demer and John K. Jansen (USA)
WG-KRILL-93/48	BIAS IN ACOUSTIC BIOMASS ESTIMATES OF *EUPHAUSIA SUPERBA* DANA TO DIEL VERTICAL MIGRATION David A. Demer and Roger P. Hewitt (USA)
WG-KRILL-93/49	ACOUSTIC ESTIMATES OF KRILL BIOMASS IN THE ELEPHANT ISLAND AREA: 1981-1993 David A. Demer and Roger P. Hewitt (USA)
WG-KRILL-93/50	FISHES IN PELAGIC CATCHES IN THE VICINITY OF THE SOUTH SHETLAND ISLAND DURING THE 6TH ANTARCTIC EXPEDITION OF RV *KAIYO MARU*, 1990/1991 Tetsuo Iwami, Taro Ichii, Haruto Ishii and Mikio Naganobu (Japan)
WG-KRILL-93/51	FISHES CAUGHT ALONG WITH THE ANTARCTIC KRILL IN THE VICINITY OF THE SOUTH GEORGIA ISLAND DURING THE AUSTRAL WINTER MONTHS OF 1992 Tetsuo Iwami (Japan)

OTHER DOCUMENTS

WG-CEMP-93/4	PARAMETERS FOR A MODEL OF THE FUNCTIONAL RELATIONSHIPS BETWEEN KRILL ESCAPEMENT AND CRABEATER SEAL DEMOGRAPHIC PERFORMANCE Peter L. Boveng and John L. Bengtson (USA)
WG-FSA-93/8	STUDY OF BY-CATCH OF ANTARCTIC FISH JUVENILES AT KRILL *EUPHAUSIA SUPERBA* DANA FISHERIES IN THE SOUTH GEORGIA AREA IN 1992 E.A. Pakhomov and S.A. Pankratov (Ukraine)
CCAMLR-XII/5	EVALUATING NEW AND EXPLORATORY FISHERIES Delegation of the United States of America

SC-CAMLR-XII/BG/3	REPORT OF A COORDINATION MEETING OF THE CONVENERS OF THE WORKING GROUPS ON KRILL, CEMP AND FISH AND THE CHAIRMAN OF THE SCIENTIFIC COMMITTEE
SC-CAMLR-XI/BG/13	PROPOSALS ON KRILL AGGREGATION MODEL PROJECT (KRAM PROJECT) Delegation of Russia

TERMS OF REFERENCE FOR THE WORKSHOP ON EVALUATING KRILL FLUX FACTORS

The Terms of Reference for the Workshop on Evaluating Krill Flux Factors are as follows:

(i) Determine the transport of water masses across boundaries of selected areas of ocean in terms of velocity profiles normal to the boundaries, integrated over the depth range 0 to 200 m.

(ii) Determine krill density along each of the selected boundaries.

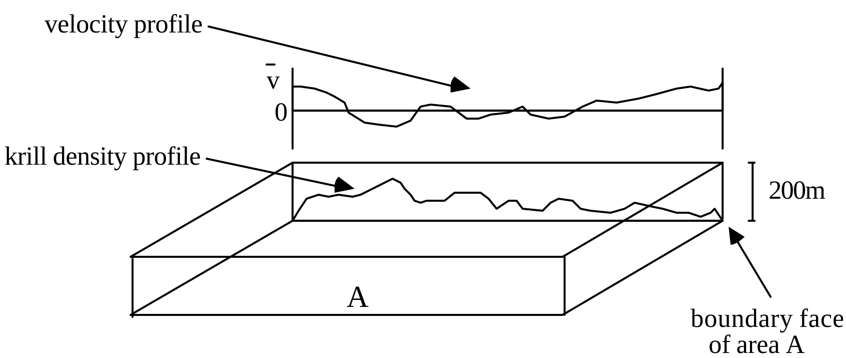
(iii) Using information from (i) and (ii), calculate the passive krill fluxes across the boundaries.

(iv) Determine the mean retention time of particles in selected small areas.

(v) Propose methods for further studies on the question of krill fluxes.

CONCEPTUAL FRAMEWORK

2. A selected area consists of a slice of water 200 m deep.



For each boundary face a normal velocity profile needs to be calculated, integrated over the depth range 0 to 200 m. The convention will be: positive values into area, negative values - outwards. The velocity profile should ideally be given as an average value for each nautical mile of boundary.

3. A krill density profile for each boundary face should also be calculated, integrated over the same depth range, and at the same one nautical mile boundary resolution. If possible, these should be calculated for various times of the year.

4. The krill flux across each boundary is the product of the two profiles. It is not necessary or expected that the net inward krill flux is equal to the net outward krill flux over the time-scale of interest.

5. To investigate interannual variability in krill flux, both velocity and krill density profiles should be calculated for as many years as possible.

6. The subareas for which these calculations are to be carried out are 48.1, 48.2 and 48.3, and the smaller areas defined in Figure D.1. Velocity and krill density profiles are required along the boundaries for January to March in Subareas 48.1 and 48.2, and January to April, June and August in Subarea 48.3.

Velocity and krill density profiles and mean retention times are required for each 0.5° latitude 1° longitude rectangle in the hatched areas, for the same months as the subarea of which they form part.

7. Mean retention times of particles in the small areas designated in Figure D.1 should be calculated for as many years as possible.

Regional Definitions

Subarea 48.3 bounded by 50°S, 57°S, 30°W, 50°W
Subarea 48.2 bounded by 57°S, 64°S, 30°W, 50°W
Subarea 48.1 bounded by 60°S, 65°S and the northwest coast of the Antarctic Peninsula, 50°W, 70°W
Region A bounded by 52°S, 57°S, 30°W, 46°W
Region B covers the whole of Subarea 48.2
Region C bounded by 60°S, 64°S, 50°W, 70°W excluding the area northwest of a line between 62°S, 70°W; 62°S, 66°W; 61°S, 66°W; 61°S, 63°W; 60°S, 63°W.

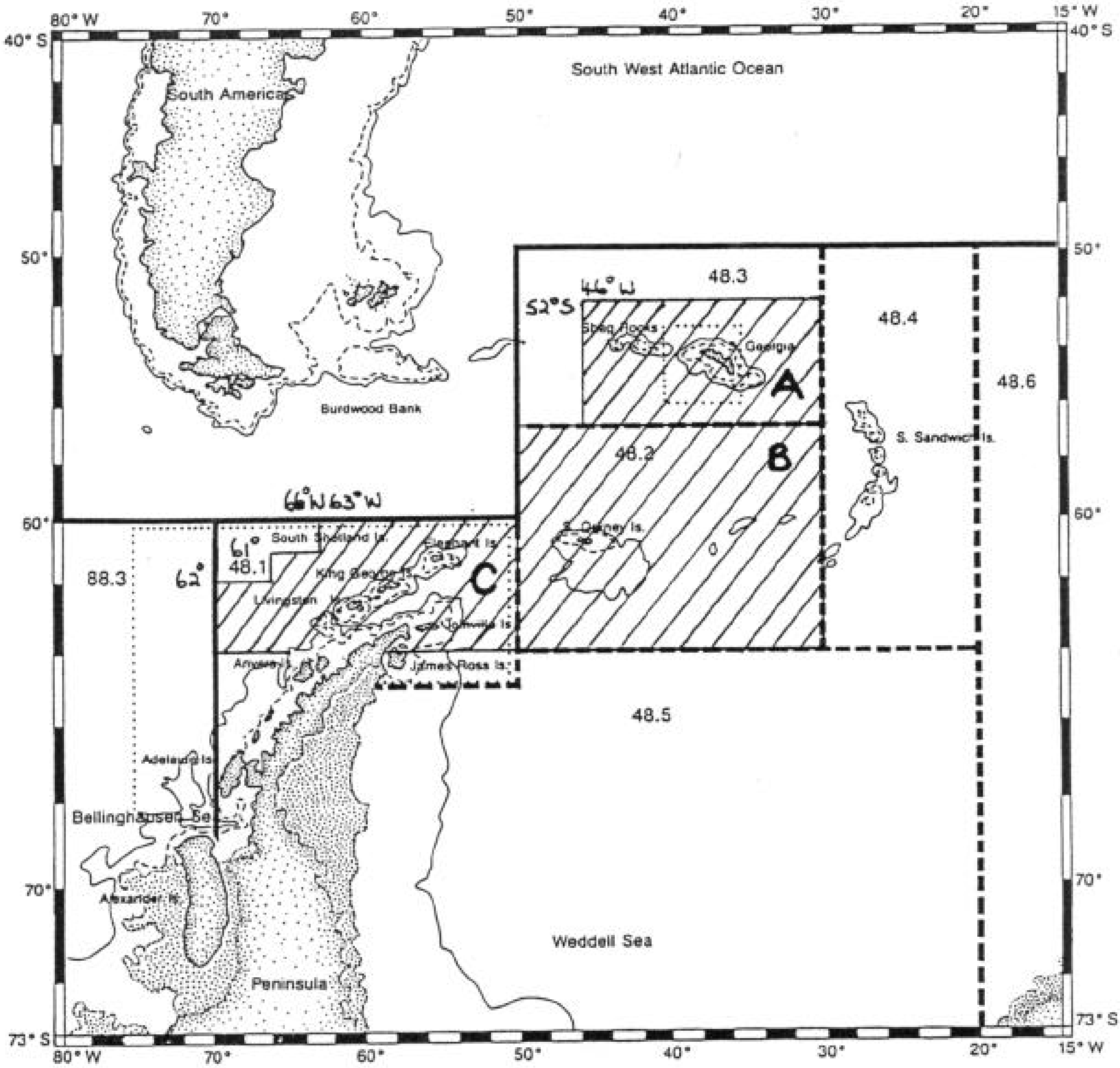


Figure D.1: Atlantic Antarctic area showing regions where velocity and krill density profiles are to be calculated.

YET FURTHER REFINEMENTS OF THE CALCULATION OF THE FACTOR g RELATING KRILL YIELD TO SURVEY BIOMASS ESTIMATES

1. Updated Estimates for M and σ_R

Attempts will be made to obtain further datasets for krill trawl surveys to which the calculation methods developed in WG-Krill-93/12 can be applied. It was noted that the BIOMASS datasets had already been exhausted in this regard. The properties of each dataset to which the analysis is applied will be documented carefully, so that any censoring which may be necessary at the next WG-Krill meeting prior to the combination of results for different datasets, can be carried out on the basis of objectively pre-defined criteria. [Responsibility: D. Agnew]

Calculations will be carried out for any additional datasets obtained, and attempts will be made to investigate the quantitative consequences of any bias arising from net selectivity effects. [Responsibility: W. de la Mare]

2. Updated Estimates for l_r and l_m

Length frequency datasets from various national fisheries will be examined to obtain estimates of the parameters of the selectivity functions for each. Analyses of maturity data will be examined in the same way to provide estimates of the parameters of the maturity function. [Responsibility: D. Agnew]

Model calculations will be repeated for the revised estimates. [Responsibility: D. Butterworth]

3. Sex Differentiation

To allow for deliberate avoidance of gravid females by the fishery, the model will be sex-disaggregated. During the months of summer fishing (December to February), 20% by number of mature females present at the start of December will remain unavailable to the fishery. While in standard calculations, spawning biomass will be calculated in terms of the maturity vs length function for females, in this case results will be reported separately for males and females, taking account of the difference in maturity-at-length functions for the two sexes. [Responsibility: D. Butterworth]

4. Age Dependence of M

Calculations will be repeated under the assumption that M for ages 0, 1 and 2 is double that for older ages. (This does not require modifications of the methods developed in WG-Krill-93/13.) [Responsibility: D. Butterworth, W. de la Mare]

5. Growth Rate - Natural Mortality Correlation

A number (10 to 20) of species - preferably ones closely related to krill - for which both M and the von Bertalanffy growth rate parameter κ are reasonably well determined will be selected to allow estimation of the distribution of the κ/M ratio. This approach will be used, given estimates of M provided under 1 above, to generate associated values for the von Bertalanffy growth parameter β used in the krill model. [Responsibility: M. Basson, D. Butterworth]

6. Validation

The algebra and associated computer code for the methods developed in WG-Krill-93/12 and 13 will be checked. The methods will also be tested by application to a few simulated datasets. [Responsibility: D. Agnew, K. Hiramatsu]

7. Miscellaneous Aspects and Tests

Results for different γ values for the new estimation technique [1 above] for which M and σ_R are correlated, are to be compared with those from the existing method based on uncorrelated values generated from uniform distributions. [Responsibility: W. de la Mare]

Unless specifically necessary, all calculations need be carried out for the summer (December to February) fishing season option only.

All parties contributing to work on these further refinements are to report on progress in February 1994. [Responsibility: All]

All the computer programs required for these calculations are to be prepared so that they may be run for updated estimates during the 1994 meeting of the Working Group. [Responsibility: D. Agnew, D. Butterworth, W. de la Mare]

The code for the computer programs will be cleared of extraneous comments, and appropriately documented, after the 1994 meeting. [Responsibility: D. Agnew]

Adjunct

The following data are required to calculate krill length density distribution for determining recruitment proportions:

1. Survey design [station list, haul type (oblique, horizontal, etc.), time of day].

2. Gear type, mesh size, etc.

3a. Krill density in each haul by 2 mm length class (hauls with no krill must be included in the data).

OR

3b. The data needed to calculate the density:

- time the net was fishing, flow meter readings, OR volume filtered;
- mouth area of net;
- total weight of krill in the haul; and
- length frequency distribution of a sample and the weight of the length frequency sample, OR total numbers at length in the haul.

INTERNATIONAL GLOBAL OCEAN ECOSYSTEM DYNAMICS (GLOBEC.INT) PROGRAM

GLOBEC.INT Scientific Steering Committee will set up the following Working Groups (WG):

(i) WG on Population Dynamics and Physical Variability (Dr D.H. Cushing, Chair);
(ii) WG on Sampling and Observation Systems (Prof. T. Dickey, Chair);
(iii) WG on Numerical Modelling (Prof. A. Robinson, Chair);
(iv) WG on PRUDENCE (dealing with old data);
(v) WG for GLOBEC-Southern Ocean Program (Prof. J.-O. Strömberg, Chair);
(vi) WG for ICES/GLOBEC Cod and Climate Program (Dr K. Brander, Chair); and
(vii) WG for PICES/GLOBEC Subarctic Pacific Program (Dr D. Ware, Chair).

2. The matters to be considered by Southern Ocean GLOBEC with regard to zooplankton (incuding krill) are:

- zooplankton overwintering strategies;
- seasonal and geographical variations in the distribution of Southern Ocean key zooplankton species, especially in relation to the physics of the environment;
- factors affecting successful reproduction;
- factors relating to larval survival and recruitment to the adult population;
- the distribution of Southern Ocean zooplankton in relation to the distribution of food biomass and reproduction;

and for predators:

- effects of variability in the physical and biological environments on predator population dynamics;
- the role of ice in affecting foraging performance, reproductive success and survival of top predators;
- krill variability and its allocation between several top predator species;
- the effect of predator foraging activities on altering the distribution and abundance of krill; and
- the nature of the functional relationships between krill availability and performance and survival of its predators.