ANNEX 4

REPORT OF THE FOURTH MEETING OF THE WORKING GROUP ON KRILL

(Punta Arenas, Chile, 27 July to 3 August, 1992)

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INTRODUCTION

1.1 The Fourth Meeting of the Working Group on Krill (WG-Krill) was held at the Hotel Cabo de Hornos, Punta Arenas, Chile, from 27 July to 3 August 1992. The meeting was chaired by the Convener, Mr D.G.M. Miller (South Africa).

1.2 Mr Miller welcomed the Working Group to Punta Arenas, commenting that this was the first time the Group had met in the Southern Hemisphere.

REVIEW OF THE MEETING OBJECTIVES AND ADOPTION OF THE AGENDA

2.1 The Convener reviewed the objectives of the meeting. The highest priority topics for consideration by the Working Group had been identified by the Scientific Committee (SC-CAMLR-X, paragraph 3.93) as:

- investigations of flux in Statistical Area 48 and other areas;
- estimation of total effective biomass in Statistical Area 48 and other areas;
- refinement of calculations of potential yield and precautionary limits, including further evaluation of the population models and demographic parameters used in such calculations; and
- further estimation of precautionary limits in various statistical areas and subareas.

2.2 In addition to the activities set out above, the Scientific Committee had endorsed specific additional objectives as:

- further work on by-catch of young fish in the krill fishery (SC-CAMLR-X, paragraph 3.22) and on possible escapement losses of krill not retained during trawling (SC-CAMLR-X, paragraph 3.23);

- additional information on krill demographic parameters should be reviewed (SC-CAMLR-X, paragraph 3.48);

- continued development of operational definitions of Article II in the context of particular management procedures and the associated mechanisms for monitoring the krill resource (SC-CAMLR-X, paragraphs 3.52 to 3.53);

- regions where overlap between fisheries and foraging predators may exist should be further defined in order to facilitate future refinement of precautionary krill limits (SC-CAMLR-X, paragraph 3.82);

- consideration of the costs to fishing nations, likely to be incurred in the collection of length frequency and haul-by-haul data (SC-CAMLR-X, paragraph 3.91).

2.3 The Scientific Committee had posed four questions that would assist the development of exact formulations of future conservation measures in Statistical Area 48:

(i) Within Subareas 48.1 and 48.2, does the consistent concentration of the krill fishery in particular parts of these subareas, reflect that:

(a) these are the only parts of these subareas where economic krill fishing is consistently possible;

and/or

(b) these are consistently the best parts of the subareas for krill fishing?

(ii) What is known about krill concentrations in the parts of these subareas further from land than 100 km?

(iii) How critical is the December through February period to the efficient operation of the krill fisheries in parts of Subareas 48.1 ad 48.2 to which they are currently restricted?

(iv) How does the abundance and distribution of krill in areas currently the focus of the fishery, change throughout the fishing season? In particular, what are the abundance and distribution characteristics immediately prior to and after the breeding seasons of penguins and fur seals (i.e., prior to December and after February).

2.4 A Preliminary Agenda had been circulated prior to the meeting. Two additions were made, 'Techniques' under Item 4(ii), which would cover considerations of target strength estimation and other procedures used for biomass surveys, and 'Editorial Considerations' under Item 7. With these additions the Agenda was adopted.

2.5 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.

2.6 The report was prepared by Drs D.J. Agnew (Secretariat), R. Hewitt (USA), R. Holt (USA), M. Basson (UK), D. Butterworth (South Africa), J. Watkins (UK), I. Everson (UK) and W. de la Mare (Australia).

REVIEW OF FISHERIES ACTIVITIES

3.1 The following documents were considered during the discussions of the Working Group under this agenda item: CCAMLR COMM CIRC 92/54, WG-Krill-92/6, 9, 13, 21, 29, 32, and 33.

Fisheries Information

Catch Levels

3.2 CCAMLR COMM CIRC 92/54 contained the first summary of monthly krill catch reports required by CCAMLR Conservation Measure 32/X. Conservation Measure 32/X became effective in May 1992, and reports from Member nations were due at the Secretariat by 30 June 1992.

3.3 Poland reported monthly catches from July 1991 through May 1992 totalling 6 887 tonnes; the bulk of these catches were taken in Subarea 48.3. The data reported by Russia including catches by Ukrainian vessels; monthly catches from November 1991 through June 1992 totalled 93 625 tonnes and 89% of the catch was taken in Subarea 48.2. No other Members reported monthly catches.

3.4 Dr M. Naganobu (Japan) reported that six Japanese fishing vessels operated during 1991/92 and that two were currently fishing. The 1991/92 catch was estimated to be similar to the 1990/91 catch (66 250 tonnes total).

3.5 Dr V. Marín (Chile) reported that one Chilean fishing vessel operated in Subarea 48.1 during January through March 1992 and caught 6 086 tonnes (WG-Krill-92/21). These catches had been reported to the Secretariat in haul-by-haul format, separated into two 45-day fishing periods.

3.6 There was no information available regarding catches of krill by other Members in 1991/92.

3.7 Dr K. Shust (Russia) reported that the Murmansk and Black Sea fishing fleets caught 7 014 tonnes of krill in Subarea 48.1, 101 422 tonnes in Subarea 48.2, and 39 305 tonnes in Subarea 48.3 during 1991/92. He also stated that this catch was substantially lower than in previous seasons. However, Russia was unlikely to increase krill catches beyond current levels in the near future.

3.8 From the above, it was concluded that at least 227 000 tonnes of krill were caught in 1991/92, with 30% from Subarea 48.1, 50% from Subarea 48.2, and 20% from Subarea 48.3. Of the total catch, approximately 60% was reported to the Secretariat by month.

3.9 Members noted the lack of compliance by some nations with Conservation Measure 32/X which calls for reports of monthly krill catches. It was also noted that the requirement to report monthly catches had only recently been established, and it is anticipated that compliance with this conservation measure will improve in the future.

Location of the Fishery

3.10 WG-Krill-92/13 described fine-scale catches of krill in Statistical Area 48 reported to CCAMLR for 1990/91. Similar to previous split-years, fishing began at South Georgia, then shifted to South Orkneys, then to the Antarctic Peninsula area, and finally returned to the South Georgia area during the winter of 1991.

3.11 Fine-scale catch data for 1990/91 (WG-Krill-92/13) indicated that krill were caught over shelf areas associated with islands, similar to the fishing patterns reported for 1987/88. During 1988/89 and 1989/90 fishing was less concentrated, particularly in Subarea 48.2. It was noted that CPUE from the Chilean fishery was low during these years. Krill recruitment from spawning in 1988/89 and 1989/90, as implied from length frequency data and reported in WG-Krill-92/15, was also poor.

3.12 The Chilean fishing vessel operated first north of Livingston Island, then north of Elephant Island, and finally back to the area north of Livingston Island; these were similar to the areas fished in 1990/91 (WG-Krill-92/21).

3.13 The distribution of CPUE, provided in WG-Krill-92/21 was very similar to the distribution of krill determined from acoustic surveys conducted during the same period and reported in WG-CEMP-92/15. In this regard, it was noted that an evaluation of the composite CPUE index, defined first by WG-Krill in SC-CAMLR-VIII, Annex 4, Appendix 7, might be made by considering haul-by-haul fishery data in combination with acoustic data collected on a similar scale.

Other Information from the Fishery

3.14 Differences in vertical migration patterns between male and female krill were described from samples collected during Russian krill fishing operations west of Coronation Island (WG-Krill-92/9). It was noted that fishing operations were focused on aggregations of krill that remained in the same area over three months. It was further noted that reports from previous years of fishing operations and research vessel activities described aggregations of krill in the same areas to the west of Coronation Island. The information contained in WG-Krill-92/9 was considered very useful and demonstrates the benefit of having observers aboard fishing vessels.

3.15 Length frequencies of krill sampled from the 1990/91 Chilean fishery indicate that juveniles were taken north of Elephant Island but not north of Livingston Island (WG-Krill-92/21). The length frequency distributions were similar to those reported last year by the US AMLR Program (WG-CEMP-91/11), where juveniles were caught north of Elephant Island but not north of King George Island.

3.16 The problems of catching large numbers of salps or “green” krill were discussed. It was recognised that discarding catches with large numbers of salps may affect observed length frequencies. Dr E. Acuña (Chile) indicated that the Chilean vessel discarded hauls with greater than 40% salps, but that this was a relatively rare event and only ever occurred during short trial hauls at a new location. Dr H. Hatanaka (Japan) commented that some Japanese fishing companies kept the catches including salps. “Green” krill are kept by both fleets but in the case of the Japanese fishery, movement away from regions of “green” krill is necessary to maintain product quality. The Russian fishery on the other hand utilises both “green” and “white” krill.

By-Catch of Young Fish

3.17 WG-Krill-92/32 described the numbers and size distribution of juvenile and adult fish caught during the course of Chilean krill fishing operations. Dr Acuña further explained that approximately

12% of the hauls were examined, and 10% of the total of 419 hauls contained fish as a by-catch. The Working Group noted that the relatively small numbers of large fish reported may still be a cause of concern. In response to a query from Dr Everson, Dr Acuña reported that juvenile fish (*Chionodraco spp.*) were included in the above analyses although there is still an attendant difficulty in separating small fish from krill in the catch and consequently the occurrence of small fish may be under-reported. It was also noted that information on the proportion of fish by-catch by weight would be useful information.

3.18 The abstract of WG-Krill-92/6 reported that there was no fish by-catch during Russian krill fishing operations conducted in Subarea 48.2. Juvenile *Champsocephalus gunnari* were caught, however, during krill fishing operations in Subarea 48.3. Dr Shust indicated that the tables contained in WG-Krill-92/6 would be translated and presented at the meeting of the Working Group on Fish Stock Assessment (WG-FSA) later this year. The Working Group strongly encouraged more reports of this type.

3.19 Attention was drawn to the fact that information on the presence of small fish, particularly the larval stages, is still lacking since they are difficult to observe. It is therefore still not possible to assess fully the possible effect of by-catch on the early life history stages of fish, particularly species subject to conservation measures. The Working Group draws the attention of WG-FSA to the above results in the context of the Scientific Committee's concern expressed in SC-CAMLR-X, paragraph 3.22.

Fishing Escapement Loss/Mortality

3.20 Both the Scientific Committee and Commission have expressed concern as to the lack of information on the mortality of krill which pass through the meshes of nets (see for example, SC-CAMLR-X, paragraph 3.23 and CCAMLR-X, paragraph 6.16).

3.21 In this connection, WG-Krill-92/29 was accompanied by a video of Japanese commercial fishing operations. The objective of showing the video was to suggest that little loss occurred through the codend of the trawl, and that many of the krill retained were still living. It was noted that Japanese fishermen carefully monitor the quantity of krill caught in the net throughout the course of the haul, and that the net is retrieved when an adequate amount of krill is caught. Japanese catches are 10 to 12 tonnes per haul if the krill is to be frozen and 30 tonnes per haul if the krill is to be peeled or reduced to meal. The Russian fishery on the other hand fishes for longer periods of time and catches are often of the order of 15 to 20 tonnes per haul.

3.22 The Working Group encouraged additional experiments to determine the amount and viability of krill passing through the wings, body, and codend of nets used in krill harvesting operations particularly during the towing process. Members with historical information from such experiments were encouraged to submit their results to the next meeting.

Reporting of Catch Data

3.23 Currently data on krill catch and effort are required to be reported by fine-scale rectangles (0.5° latitude x 1° longitude) from Subareas 48.1, 48.2, 48.3 and the Integrated Study Regions (ISRs).

3.24 Members noted that the Chilean fishery occurs in only 3 to 5% of Subarea 48.1. Similarly, total krill catches in Subarea 48.1 have occurred in 15% of the available fine-scale reporting rectangles. It was suggested that subareas, and even the fine-scale reporting blocks, are too large to determine the effects on krill predators of localised fishing. It was further noted, however, that more detailed reporting schemes would be difficult to implement for all catch and effort data, and that the present fine-scale reporting was adequate to define the temporal and spatial distribution of catches (for further discussion see paragraphs 3.11, 3.12, 4.15, 4.30, 4.31 and 6.17). The Working Group emphasised the continued request for reporting of haul-by-haul data within 100 km of CEMP sites (SC-CAMLR-IX, paragraph 2.63; CCAMLR-X, paragraph 4.10(ii)) if possible.

ESTIMATION OF KRILL YIELD

Krill Flux in Statistical Area 48

Immigration and Emigration Rates

4.1 The possible importance of krill movement with respect to the estimation of potential yield was emphasised at both the 1990 and 1991 meetings of WG-Krill and, at the 1991 meeting, the Working Group recommended that submissions on this topic be made.

4.2 Paper WG-Krill-92/25 presented figures and tables containing surface geostrophic flow in Statistical Area 48 and the Atlantic Sector of the Antarctic Ocean, based on oceanographic data accumulated since 1925. Geostrophic velocity and volume transport through specific observation lines were also presented based on oceanographic data collected by cruises of RV *Kaiyo Maru* over the last nine years.

4.3 The geopotential anomaly and vertical distribution of velocity and volume transport, based on data from the second leg of a survey conducted by RV *Kaiyo Maru* in the waters north of the South Shetland Islands (January/February 1991) were presented in WG-Krill-92/24.

4.4 It was pointed out that the picture of flow obtained from four Argos buoys released in the area to the north and north-west of Livingston Island presented in Figure 4 of WG-Krill-92/26, is somewhat different from the picture of geostrophic flows based on geopotential anomalies presented in WG-Krill-92/25.

4.5 The importance of scale and location in this regard was noted. Figure 5 in WG-Krill-92/24, for example, based on geopotential flow, shows a strong flow from the Pacific to the Atlantic Sector with a small counter flow along the shelf. This is not contradictory to the tracks of the Argos buoys, but these flows are defined on a much smaller scale than those in WG-Krill-92/25. Large errors in the estimation of krill migration rates can therefore be made if an inappropriate scale is used to determine the flux or flow of water.

4.6 It was also noted that the tracks of two of the buoys, released on the same date, to the northwest of Livingston Island were very close at one point but one buoy ended up around South Georgia whereas the other became entrained in the waters around Elephant Island. This suggests that it may be very difficult to predict where a body of water (with or without krill) may end up even if the flows are known.

4.7 The Working Group was of the opinion that when considering flow in the deep ocean, between island groups, geostrophic flow on a relatively large scale may be appropriate. Flows on a smaller scale in the area around an island, for example, may be described more realistically using satellite tracking of buoys.

4.8 Dr Naganobu commented that the general direction of the surface geostrophic currents in the northern shelf of the South Shetlands is toward the east, but below 50 m they move in the opposite direction. It is important to consider this current system in relation to the movement of the different life stages of krill in the area.

4.9 One possible disadvantage of using satellite tracking is that a large number of observations needs to be considered in order to obtain an overall picture of the patterns of flow. This is required because the knowledge of integrated mass flows over boundaries, combined with the density of krill in bodies of water, is most important for estimation of the total biomass in a given area.

4.10 At this stage, for convenience, the boundaries used are those that define the CCAMLR Statistical Subareas within Statistical Area 48. It will become necessary to consider whether these boundaries are appropriate and the information that would be necessary to do so should be identified.

4.11 The Working Group's attention was drawn to the WOCE (World Ocean Circulation Experiment) Program which includes the use of tracking buoys put in the open ocean. Members felt that similar studies that concentrate on shelf areas would complement the WOCE study and should provide useful information on krill movement.

4.12 The possible usefulness of models that simulate Southern Ocean circulation, such as FRAM (Fine Resolution Antarctic Model), was noted. Results of this model have been published as FRAM Atlas.

4.13 Dr Everson reported preliminary results of work undertaken with the FRAM at British Antarctic Survey. The study looked at the drift of particles seeded into the model at different locations. When the particles were totally passive and seeded into Drake's Passage, they ended up north of the Antarctic Polar Front (APF). When the particles were allowed to migrate vertically, however, they remained south of the APF. This implies that any model of krill movement should take into account the behaviour of krill, at least in terms of vertical migration.

4.14 Two major problems with the use of FRAM in trying to understand krill movement were identified. Firstly, FRAM only simulates summer conditions and, secondly, its spatial scale is greater than 10s of kilometres so that not much useful information on movement in shelf areas can be obtained.

4.15 Dr Hewitt reported that on one survey around Elephant Island, the geopotential anomalies were found to be complex (many eddy-like structures) and there was a high level of krill density. On another survey, also around Elephant Island, the geopotential anomalies were directed (fewer eddies and a predictable flow pattern) and there were fewer krill. In order to investigate this matter further, it was necessary to look on spatial scales of less than 10 km. There is therefore a need for local circulation models which accommodate much finer spatial resolution.

4.16 In this context, reference was made to the work by Hofman and colleagues (USA) who have developed very fine-scale models linking hydrographic conditions with egg and larval stages of krill.

4.17 Table 1 summarises current knowledge of flow rates in and between subareas in Statistical Area 48.

Residence Times

4.18 The Working Group noted that there were areas where krill concentrations consistently tended to occur year after year, but where local krill concentrations did not necessarily persist. This is particularly evident from data on the location of the fishery. There are also areas where, within a season, there is very little flow and local krill populations may be considered as quasi-stationary.

4.19 It was suggested that Statistical Area 58 may be one where water flow may be less complex and variable in the shelf region and may therefore be a good starting point for studying residence times in a system somewhat simpler than that in Statistical Area 48.

4.20 Dr Everson reported that a krill patch studied during acoustic investigations in the area of Bird Island, persisted for over two weeks (WG-Krill-92/31). Although the length frequency distribution of the krill sampled within the patch was also stable and the density was relatively constant, it was impossible to say whether the same group of animals remained in the area or whether animals were continuously moving into and out of the patch.

4.21 The view was expressed that, with respect to the formation and persistence of aggregations, small-scale flows, eddies and gyres are likely to be more important than large-scale flows. This is because the formation of krill aggregations is likely to be associated with primary production which in turn may depend on localised hydrographic conditions.

4.22 It is likely that krill are able to follow plumes of production and end up in areas of high primary productivity (i.e., food availability). Krill distribution should not therefore be assumed to be entirely passive and dependent on prevailing hydrography.

Influence of Hydrography

4.23 A study of seasonal changes in the oceanic structure of waters around the South Shetland Islands from a survey conducted by RV *Kaiyo Maru* was presented in WG-Krill-92/24. During the first leg of the survey (22 to 29 December 1990) the temperature of the Antarctic Surface Water over the insular shelf was consistently below O°C. On the second leg (18 January to 2 February 1991), however, the temperature in the same waters was consistently above zero.

4.24 The reason for this change in temperature is thought to be caused by the topographic upwelling of the Warm Deep Water and wind-driven coastal upwelling. The distribution patterns of temperature, salinity, density, dissolved oxygen and nutrient salts supported this conclusion.

4.25 One of the authors (Dr Naganobu) added that this upwelling phenomenon is important for primary production and that further analyses are being conducted to investigate this matter.

General Comments

4.26 In the 1991 report of WG-Krill various hypotheses about the movement and degree of mixing of krill between the subareas in Statistical Area 48 were proposed and graphically presented in Figures 2 and 3 in Annex 5 of SC-CAMLR-X. One model is that the populations in each subarea are effectively closed populations. Another model is that there is effectively a conveyer belt moving krill from Subarea 48.1 to 48.2 and on to 48.3. Current information does not exclude either of these possibilities although the general feeling was that a mixed model would probably be most appropriate.

4.27 It was noted that new information has been presented for Subarea 48.1 but that there was not much information available for Subarea 48.2 and no new information for Subarea 48.3. Members agreed that it was also important to consider statistical areas other than Statistical Area 48.

4.28 With respect to Statistical Area 58, it was felt that the system is likely to be simpler than that in Statistical Area 48. Several papers (SC-CAMLR-VI/BG/25 and WG-Krill-90/16) on the characterisation of water masses and the krill distribution as well as on the location of the fishery have been presented in the past. Biological surveys have also been conducted in Statistical Area 58 and, in general, these activities have been concentrated on the shelf area where krill concentrations consistently occur.

4.29 It was also noted that WOCE was focussing on this area.

4.30 The Working Group noted how valuable the fine-scale fisheries data from Statistical Area 48 have been, particularly in identifying areas of high krill density and the duration of these aggregations. These data are essential in the linking of krill distribution with fine-scale oceanographic features.

4.31 There seemed to be few difficulties in collecting these data, and the Working Group therefore recommended that fine-scale data be required for Statistical Areas (58 and 88). These data should be submitted in the same way as those for Statistical Area 48. The submission of fine-scale data for Statistical Areas 58 and 88 from past seasons would also be of great value to the Working Group and should be requested.

4.32 For future work on the influence of hydrography on krill distribution, it was felt that attention should also be given to the use of data on flux and retention times to integrate krill abundance with the flow of water masses in order to estimate overall krill biomass (or standing stock).

4.33 It was pointed out that the effective liaison between biologists, fishermen, fisheries managers and oceanographers has yielded a large amount of information for Subarea 48.1 and that there is a need to extend this cooperative work to the other areas.

Estimation of Biomass

Techniques

4.34 At the 1991 meeting of WG-Krill, recommendations were made regarding the relationship between target strength and length (of the target) that should be used in calculations of biomass, from acoustic surveys conducted at 120 kHz. This recommendation was adopted by the Scientific Committee (SC-CAMLR-X, paragraph 3.34).

4.35 Recommendations for further work regarding the estimation of krill target strength were also made (SC-CAMLR-X, Annex 5, paragraph 4.30). These can be summarised as:

(i) cage and *in situ* measurements of krill aggregations should be made over a range of acoustical frequencies and animal lengths and physiological condition;

(ii) *in situ* measurements of individual krill target strength should be made using dual- or split-beam echosounders;

(iii) the physical conditions of krill should be measured whenever possible;

(iv) the orientation and shape characteristics of krill should be determined whenever possible; and

(v) the above measurements should be used in theoretical models to predict the distribution of individual target strengths that would be expected from a natural aggregation of animals.

4.36 Paper WG-Krill-92/11 presents an overview of empirical values of target strength and theoretical models of target strength. Data from a wide variety of sources are reviewed with the aim of providing a generalised relation between target strength, size and frequency. Various problems are identified and the resulting recommendations are essentially the same as those above.

4.37 Paper WG-Krill-92/31 summarises information, addressing some of the above issues, from three papers submitted for publication by scientists from British Antarctic Survey. The results indicate that:

(i) the near surface bubble layer causes significant backscatter at 38 and 120 kHz but does not cause significant signal attenuation;

(ii) signal strength at 120 kHz was approximately 5 dB higher than at 38 kHz for 55 mm krill in a patch near South Georgia;

(iii) different types of echotraces can be identified from survey records; and

(iv) from target hauls with a Longhurst Hardy Plankton Recorder some of these target types could be identified as individual taxa.

4.38 Target identification, both with single-beam and dual-beam systems, is receiving a lot of attention and improved methods and systems are under development in many countries.

4.39 The estimation of the target strength of salps was discussed in some detail. Salps often occur in areas where krill are found. Although little work has been done on this problem, some members felt that it may be possible to distinguish salps from other taxa because the signals from 200 kHz and 120 kHz for salps appear to be different.

4.40 The Working Group indicated that further work on the effect of the physical condition and orientation of animals on target strength was needed.

4.41 The importance of calibration was emphasised particularly in the estimation of abundance and in situations when dual frequency systems are being used for target identification.

4.42 Paper WG-Krill-92/17 outlines the theory and procedures that have been used for calibrating an echo integration acoustic system with a standard sphere. Results of an extensive calibration of a Simrad EK500 scientific echosounder with a 120 kHz split-beam transducer in a refrigerated 10 m deep tank were presented. Calibration parameters were studied in relation to sphere material, water temperature, transmitted pulse length, target depth and time. Conclusions from this study indicate that the accuracy of the standard sphere as a reference TS value, temperature range and time contribute significant error to the calibration accuracy of an echo integration acoustic system. The Working Group agreed that acoustic calibrations should be undertaken for all the instrument settings used during a survey.

4.43 Paper WG-Krill-92/30 presented a procedure to correct for the effects of acoustic beam width when assessing the biomass of krill aggregations. The problem arises because, as a swarm passes into the beam, it is only fully insonified when a certain distance has been traversed; the distance is a function of the range to the swarm and the angle off-axis at which the swarm is first detected. This off-axis angle should be determined and used in preference to the values supplied by manufacturers. It was pointed out that beam width is infrequently measured although it is a very important parameter in the analysis of acoustic data.

4.44 A further important consideration in acoustic surveys is the choice of threshold levels for echo integration. This should be taken into account when considering results from acoustic surveys.

Statistical Area 48

4.45 In 1991 the Commission set a precautionary limit for krill in Statistical Area 48 (Conservation Measure 32/X), based on calculations undertaken by WG-Krill using estimates of krill biomass established from results of the FIBEX acoustic survey.

4.46 Krill target strength is an important parameter in the estimation of abundance from acoustic survey data. The Working Group agreed at its last meeting that the TS values used during the FIBEX analysis were too high and recommended that a revised TS/length relationship at 120 kHz be used.

4.47 The Scientific Committee had requested that the FIBEX data be re-analysed (SC-CAMLR-X, paragraph 3.78). A group of scientists from some Member nations undertook this task which consisted of:

(i) re-calculation of FIBEX results using the original TS relationship to check the database and programs;

(ii) re-calculation of FIBEX results using the new TS relationship; and

(iii) calculation of biomass estimates for each subarea.

Results are presented in WG-Krill-92/20.

4.48 Thanks were extended to BIOMASS Data Centre and British Antarctic Survey for their cooperation and assistance in this task.

4.49 The TS relationship recommended by the Working Group pertained to a frequency of 120 kHz. Two of the surveys conducted under FIBEX were not at 120 kHz, but at 50 kHz (*Walther Herwig*) and at 200 kHz (*Kaiyo Maru*). The recommended TS relationship had to be adjusted to obtain TS relationships at these other frequencies (Greene *et al.*, 1991*).

4.50 The results using the original TS are, in general, in close agreement with the original BIOMASS results. The ratio of densities obtained by using the original TS and the new TS is approximately 4 in most cases.

4.51 There are some exceptions. First, the Japanese survey was conducted at 200 kHz and the original TS relationship used was very close to the one recommended by WG-Krill, corrected for that frequency. Second, the German survey was conducted at 50 kHz. In this case, the new TS relationship is very different from that originally used; the densities obtained using the new TS relationship were 40.92 times greater than the densities obtained using original FIBEX relationship.

4.52 Biomass estimates from the re-analysed FIBEX data are shown in Table 2. The re-analysed mean density for the Indian Ocean Sector showed an almost two-fold increase over the original. In the West Atlantic Sector the increase was almost 10-fold, due to the fact that the *Walther Herwig* surveyed a relatively large area (see Table 2).

4.53 Some difficulties were encountered in assigning survey tracks used in FIBEX to CCAMLR subareas where transects crossed subarea boundaries. This was particularly true of the *Walther Herwig* survey where many transects crossed subarea boundaries. It was, however, possible to assign parts of survey tracks because of the comprehensive information contained in the dataset for this cruise.

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* GREENE, C.H., T.K. STANTON, P.H. WIEBE and S. MCCLATCHIE. 1991. Acoustic estimates of Antarctic krill. *Nature 349*: 110.

4.54 The authors stressed that the cruise tracks did not cover all of the subareas, particularly in the case of Subarea 48.3, and drew the Working Group's attention to the dangers of extrapolating beyond the area covered by tracks.

4.55 In discussion of the results of the survey the question of coverage was raised. Dr Everson explained that the survey was designed in such a manner that tracks would run in a north-south direction (Anon., 1980*). The tracks extended as far south as possible and, in a northerly direction, until no krill were found. The surveys in Subareas 48.1 and 48.2 are therefore likely to give reasonable estimates of krill biomass at the time.

4.56 In Subarea 48.3, however, technical problems prevented the survey proceeding as intended and only part of the area to the north of South Georgia was surveyed. This resulted in a much smaller area being surveyed in Subarea 48.3.

4.57 In the case of the *Walther Herwig* survey in Subarea 48.1, the mean density appeared very high for a survey covering such a large area of deep water. This meant that the biomass estimate from the *Walther Herwig* survey contributes about 80% to the total estimate of biomass in Subarea 48.1. In Subarea 48.2 the density from the *Walther Herwig* was similar to that from other vessels. It was questioned whether the high density in Subarea 48.1 was representative of a real difference between the area surveyed by *Walther Herwig* and the area surveyed by all the other vessels. The Working Group discussed possible reasons such as inadequate target strength values and threshold effects, but could not satisfactorily explain the difference.

4.58 It was agreed that further analyses of the acoustic data together with the target net-haul data should be done. Such analyses might consider data from other vessels that used similar gear (nets) to that used on the *Walther Herwig* and could try to determine the relationship between density estimates from the acoustic method and those from net-hauls. The same exercise would be done with the *Walther Herwig* data and the results compared. This should allow validation of results from the *Walther Herwig* survey and, if necessary, calibration between results from the *Walther Herwig* and other vessels.

4.59 Results from acoustic surveys conducted in the vicinity of Elephant Island from mid-January to mid-March 1992 were presented in WG-CEMP-92/15. Two large-scale surveys (10s to 100s km) and two smaller scale (1 to 10s km) surveys were done using parallel transects. Distribution maps of krill density show, on the first large-scale survey, a wide band of krill around Elephant Island with the highest density to the north and northeast of the island. On the second large-scale survey the krill

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* ANON. 1980. *BIOMASS Report No. 40*.

had dispersed and the density was very low. The smaller scale surveys show that the highest densities are generally along the shelf and shelf break and to the north and northeast of the island.

4.60 Krill abundance decreased approximately two-fold over the two-month period of the survey. This was in marked contrast to the results from surveys conducted in 1990 and 1991 when krill abundance increased from mid-January to mid-March.

4.61 In discussion it was noted that the oceanography in this area is complex and that krill patches do not seem to persist for long periods of time. On a scale of 10s to 100s km krill can consistently be found in this area. No simple relationship has yet been found between krill density and, for example, hydrography or primary production.

4.62 A method for improving biomass estimates was suggested for subareas using the accumulated information from many krill surveys (Appendix D).

Other Estimates

4.63 Paper WG-Krill-92/7 reported results from the Italian Expedition in the Ross Sea (November 1989 to January 1990). Two acoustic surveys for krill estimation were conducted by RV *Cariboo*. The first acoustic survey (30 November 1989 to 5 January 1990) was near the Balleny Islands and in the central part of the Ross Sea. The second survey covered the same area as the first survey, and in addition an area previously covered with pack-ice. Preliminary results from these two surveys indicated that the mean area density of krill in the Ross Sea was similar to that estimated in the Indian Ocean Sector.

4.64 The Working Group noted that this was the first paper on the estimation of krill biomass in the Ross Sea submitted to CCAMLR.

4.65 Members indicated that krill were expected to be found in this area because minke whales are known to feed on krill and to be present in high densities in the area.

4.66 It was pointed out that the FIBEX target-strength relationship had been used. The authors had used this relationship for the purposes of comparison with FIBEX results in other statistical areas. The Working Group suggested that the data be re-analysed using the target-strength relationship recommended by WG-Krill in 1991 (SC-CAMLR-X, Annex 5, paragraph 4.30).

4.67 Reservations were also expressed about the way which the survey was designed and results analysed.

4.68 Paper WG-Krill-92/23 presented results of acoustic surveys in the Prydz Bay region, undertaken by the *Aurora Australis* in January/February 1991 and February/March 1992. The estimated biomass from the 1992 survey was substantially less than that in 1991. There was also a difference in the spatial distribution of krill density. High krill density was observed along the shelf break in 1991 but not in 1992. High krill density was also observed to the west of Prydz Bay in 1991 but not in 1992.

4.69 The paper indicated that the extent of bias in estimates of krill abundance due to the inclusion of biomass of other species, particularly *Euphausia crystallorophias*, cannot be assessed until the target strengths of the other species that occur in the same area as *Euphausia superba* are determined. The Working Group was informed that work was in progress to try and resolve this problem using a multi-beam system.

4.70 Some members questioned why the noise margin and threshold were changed between the surveys in 1991 and 1992. The authors were requested to clarify how this had been taken into account in the analysis.

Refinement of Yield Estimate Calculations

Evaluation of Population Models

4.71 At the previous meeting of the Working Group, estimates of potential yield had been based primarily on the formula $Y = d\lambda MB_0$. In this formula, $\mathbf{B_0}$ is an estimate of the biomass prior to the onset of exploitation, $\mathbf{M}$ is the natural mortality, and λ is a factor calculated so that the probability that the spawning biomass drops below 20% of its average pristine level over a 20-year period under a constant annual catch is 10%. The discount factor **d** was introduced to allow for uncertainty in estimates of parameter values, and the fact that a precautionary limit should be less than a possible ultimate catch level. Calculations made at that meeting had assumed d = 0.67; for recruitment variability $\sigma_R = 0.4$, the values of the product $\mathbf{d}\lambda M$ had been calculated to be 0.093 for $M = 0.6$ yr^{-1} and 0.14 for $M = 1.0$ yr^{-1}.

4.72 The previous meeting had also specified various refinements to the process used to calculate λ, to change the model into a more realistic representation of the krill fishery (SC-CAMLR-X, Annex 5, Appendix E). In particular, to take direct account of the uncertainty in estimates for various parameter values (instead of the *ad hoc* approach of applying a discount factor **d**), prior distributions had been specified for these values, with the refined calculations of λ to incorporate integration over these distributions. Thus, for example, results were to be integrated over uniform distributions for **M** and σ_R over the ranges [0.4, 1.0 yr^{-1}] and [0.4, 0.6] respectively.

4.73 Refined calculations requested by the Commission were carried out and reported in WG-Krill-92/4. For a fishing season over the whole year, the value of the factor $\lambda M = \gamma$ corresponding to a 10% probability of the spawning biomass falling below 20% of its average pristine level over a 20-year period of constant-catch harvesting had been evaluated to be 0.063.

4.74 Paper WG-Krill-92/28 contained results of calculations similar to those reported in WG-Krill-92/4, using a simplified version of the model. In the light of the results obtained, the author of WG-Krill-92/28 suggested that the values of γ listed in WG-Krill-92/4 were too low.

4.75 The Working Group agreed that when complex calculations of this nature, which may form the basis for subsequent management recommendations, are carried out, it is desirable as a matter of principle that they should be independently checked before being finally adopted. Accordingly, it recommended that the Secretariat be requested to check the calculations reported in WG-Krill-92/4 and 28, with particular regard to explaining the apparent differences in results.

4.76 During the course of discussions, further refinements to the model used in WG-Krill-92/4 were suggested. These are detailed in Appendix E which also specifies certain further sensitivity tests and output statistics which were requested.

4.77 The Working Group noted that the model in question is intended to assist with the development of broad initial advice on an appropriate precautionary catch limit, which is based on the results of a single biomass survey only. As such, it would be inappropriate to extend this particular model further to consider either:

(i) feedback-control management options (i.e., adjustment of the catch level during the harvesting period on the basis of additional surveys or other observations);

and

(ii) spatial effects, related (for example) to localised predator aggregations.

Rather, separate models should be developed to address these concerns specifically.

4.78 Dr Hatanaka stated that he considered it unrealistic that harvesting a proportion of the estimated krill biomass as small as 6.3% could deplete spawning biomass to as large an extent as indicated by the results reported in WG-Krill-92/4. He wished to stress his view that it would be premature to base management recommendations on that result.

4.79 At the time of the adoption of the report, Dr Shust indicated his agreement with this point of view.

Evaluation of Demographic Parameters

4.80 The results of yield estimate calculations using the model of WG-Krill-92/4 are particularly sensitive to the value of the recruitment variability parameter $s_{\mathbf{R}}$. It is clearly desirable that the values used in calculations should be based upon analyses of observations of the krill resource, rather than upon analogy with the values for other small pelagic fish species as in the case at present. Appendix E sets out a basis by which $s_{\mathbf{R}}$ might be estimated directly from length distribution results obtained on research surveys.

4.81 Paper WG-Krill-92/8 reported estimates of krill mortality ranging from 0.75 to 1.17 yr^{-1}. It was noted that these were compatible with results obtained previously by Siegel (1991*) .

4.82 Paper WG-Krill-92/15 reviewed length-weight relationships for krill, with particular attention to seasonal variation, to aid (*inter alia*) in biomass assessment from acoustic surveys. It was suggested that the precision of the results reported should be investigated by means of the methods similar to those applied by Morris *et al.* (1988**).

Refinement of Precautionary Catch Limit Estimates

4.83 At the previous meeting, the formula $Y=d\lambda MB_0$ had been used to provide an indication of an appropriate precautionary catch limit in Statistical Area 48. The value of 15.1 million tonnes used for $\mathbf{B_0}$ was based on the estimate (at that time) from the FIBEX survey in Subareas 48.1, 48.2 and 48.3, because of its near synopticity. The two values for $\mathbf{d}l\mathbf{M}$ indicated in paragraph 4.72 above had then indicated values of 1.40 and 2.11 million tonnes for $\mathbf{Y}$; it had been noted that these two

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* SIEGEL, V. 1991. Estimation of krill (*Euphausia superba*) mortality and production rate in the Antarctic Peninsula region. Document *WG-Krill-91/15*. CCAMLR, Hobart, Australia.

** MORRIS, D.J., J.L. WATKINS, C. RICKETTS, F. BUCHOLZ and J. PRIDDLE. 1988. An assessment of the merits of length and weight measurements of Antarctic krill *Euphausia superba*. *Brit. Ant. Surv. Bull. 79*: 37-50.

estimates were negatively biased because no account had been taken of flux factors and incomplete coverage of the total area by FIBEX. Two alternative methods had suggested precautionary limits of 1.5 million tonnes and between 1 and 2 million tonnes. Taking all these results into account, the Working Group had recommended a precautionary catch limit of 1.5 million tonnes (which corresponds to a value of 0.10 for the factor **d**l **M**).

4.84 Based on this previous value for **d**l **M**, and the value of $\gamma = 0.063$ from WG-Krill-92/4, together with the updated results for $\mathbf{B_o}$ from FIBEX as discussed in paragraphs 4.47 to 4.63 above (see also Table 2), precautionary catch limit estimates (**Y**) calculated in a manner and under assumptions similar to those of the previous year would be as follows (all units are million tonnes):

Subarea/Division		$\mathbf{B_o}$	**Y** = (dλM = 0.10)	**Y**(γ = 0.063)
48.1, 48.2, 48.3	(including *Walther Herwig*)	21.43	2.14	1.35
	(excluding *Walther Herwig*)	11.00	1.10	0.69
48.6		4.63	0.46	0.29
58.4.2		3.93	0.39	0.25

4.85 Values for Subareas 48.1, 48.2 and 48.3 in the table above have been reported for $\mathbf{B_o}$ estimates both including and excluding data from the *Walther Herwig*, for reasons discussed in paragraphs 4.58 and 4.59 above.

4.86 Conservation Measure 32/X adopted by CCAMLR in November 1991 required the Scientific Committee to provide advice on how the precautionary limit for Statistical Area 48 should be divided between subareas or bcal areas, once the total catch in Subareas 48.1, 48.2 and 48.3 exceeds 620 000 tonnes in any fishing season. Paper WG-Krill-92/16 sets out a number of options in this regard, which formed the basis for the Working Group's discussion of this issue.

4.87 In the light of these discussions, the Working Group developed seven alternative methods for allocating the precautionary limit to subareas. An allocation might be based on any one or a combination of these methods. These seven methods are as follows.

(i) FIBEX estimates of krill biomass including data from *Walther Herwig*
The most recent analyses of the FIBEX data set reported in WG-Krill-92/20 are used to allocate catch among subareas. Allocation is proportional to the biomass of krill estimated for each subarea. No allocation of krill is possible for Subareas 48.5 and 48.6, because no survey took place in these subareas during FIBEX.

(ii) FIBEX estimates of krill biomass excluding data from *Walther Herwig*

This alternative is similar to (i), except that the survey data from the *Walther Herwig* are excluded.

(iii) Historical catch

Allocation to subareas is in proportion to historical catches. The highest catch reported for each subarea, regardless of year, is used. These values are then totalled, and the result is used as the divisor in calculating the percentage allocation for each subarea.

(iv) Even division

Catches are allocated evenly to all six subareas.

(v) Linear extent of shelf break

This allocation is based upon the rationale that fishable concentrations of krill are found most frequently along the shelf break around islands, and that the linear length of the shelf break of each subarea may be proportional to the amount of krill resident at any one time in the subarea. Allocations for each subarea should then be proportional to the linear length of the shelf break (as defined by the 500 m isobath) in the respective subareas. Although this calculation could not be made during the Working Group's meeting, sufficient data are available for it to be performed.

(vi) Predator demand

Allocations to subareas are related to estimates of the amount of krill consumed in each subarea by pelagic and land-based predators. Estimates of predator consumption should include that by pinnipeds, seabirds, cetaceans and fish. Although this calculation could not be made during the Working Group's meeting, sufficient data are available for it to be performed. The exact form of the relationship between the allocations and the consumption estimates should be considered in the context of the estimates once available. The Working Group requested the Working Group for the CCAMLR Ecosystem Monitoring Program (WG-CEMP) to undertake this calculation as a matter of priority.

(vii) Local biomass adjusted for movement of krill

Allocations to subareas are proportional to some measure of local krill biomass, adjusted for krill movement. The mechanics of this scheme have yet to be specified, but would be intended to account for differences in the residence time of krill in the various subareas.

4.88 The Working Group also recognised the advice to the Commission from the Scientific Committee (CCAMLR-X, paragraph 6.16) that it may be necessary to supplement the allocation of the precautionary catch limit with other management measures to ensure that the catch was not entirely concentrated in the foraging range of vulnerable land-breeding predators.

ECOLOGICAL IMPLICATIONS OF KRILL FISHING

5.1 The ecological implications of krill harvesting have been identified as topics of major concern for the Scientific Committee. The Working Group discussed this item with respect to the location and timing of the fishery, the effects of management measures on krill fishing and CEMP studies. Some discussion of this topic had occurred under Agenda Item 3.

5.2 The Working Group had an extensive and valuable discussion on this topic and it was felt that the dialogue between scientists and those with practical experience with fisheries had led to a better appreciation of what measures would be considered as reasonable when considering management options.

Location and Timing of the Fishery

5.3 Specific questions, posed by the Scientific Committee (SC-CAMLR-X, paragraph 6.36), were considered.

5.4 Responses to questions (i) and (ii), summarised as: 'Why is fishing concentrated at certain times and locations?' and 'What is known of krill concentrations more than 100 km from land?' are set out below.

General Points

5.5 Currently fishing fleets prefer to operate close to islands because concentrations of krill tend to occur in predictable locations there. Such situations are found in summer north of the South Shetlands, west of the South Orkneys in summer and in winter around South Georgia.

5.6 Fleets have tended to encounter sufficient krill on these traditional grounds without needing to search much farther afield. Steady catch rates on these grounds indicate a ready supply of krill but give no substantial indication of the status of the resource.

5.7 Evidence from historical whale catches suggests that krill concentrations can occur at distances greater than 100 km from land. Krill fishing fleets do not look for such concentrations since much greater searching time is required to find such transient and mobile concentrations. Open ocean concentrations also tend to be smaller.

5.8 Icebergs, because they produce substantial quantities of ‘growlers’ and ‘bergy’ bits when grounded in summer, and pack-ice are avoided by the fishing fleets.

Subarea 48.1

5.9 The start of the fishing season is dependent on two factors, the absence of ice and the feeding state of the krill.

5.10 The primary areas of commercial fishing are to the north of Livingston, King George and Elephant Islands. Research sampling and commercial fishing have shown that these areas contain predictably good krill concentrations.

5.11 In most years the area is generally clear of ice by November. At this time krill are feeding on the spring bloom of phytoplankton. Such “green” krill are unsuitable for processing by the Japanese fishery. During the second half of December there are only a few Japanese vessels fishing and these actively search for “white” (non-feeding) krill. As the season progresses fewer “green” krill tend to be present so that by mid-February about half of the krill are green. The peak of the Japanese fishery occurs in February at which time it is easier to find “white” krill. By March nearly all of the krill are “white” and fishing continues until sea-ice encroaches into the area at the start of winter (Figure 1).

5.12 At the start of the season fishing is concentrated in the offshore part of the shelf in order to catch the larger krill. Fishing moves shorewards as the season develops.

5.13 Some fishing vessels move northeastwards along the shelf with the intention of fishing on the same concentration for a period of several days. Other fishing vessels remain more or less in the same location and fish on concentrations as they pass through the area. The coastal movement is more consistent in the Livingston and King George Island regions than around Elephant Island.

5.14 Based on a questionnaire and other studies, WG-Krill-92/21 showed that the Chilean fishery operates in a similar manner to that of the Japanese and generally begins in late January so as to avoid sea-ice and "green" krill; it continues for approximately one and a half months. For safety reasons the master of the fishing vessel is encouraged to fish close to the islands.

5.15 Both the Chilean and Japanese fisheries avoid locations where "green" krill are found. The Chilean fishery avoids gravid females while the Japanese fishery targets them. Operationally this means that a vessel would make a short trial tow at a location and, providing the catch was suitable for processing, would remain at that location making longer tows providing a catch rate of around 10 tonnes per haul. If the trial catch was unsuitable, the vessel would move to a new location, perhaps only a few miles away, and make a further trial haul.

Subarea 48.2

5.16 Russian vessels which can use "green" krill tend to fish on concentrations of krill that are found to the west of Coronation Island. Fishing in this area generally commences in December, as soon as ice conditions permit. Hourly catch rates are much higher in this subarea than in their Subarea 48.1 fishery.

5.17 Although krill concentrations generally occur at the same location in Subarea 48.2, they are less predictable here than on the South Shetlands shelf (Subarea 48.1). Consequently in some years the fleet fishes in other locations, sometimes a large distance from the shelf. Such a situation occurred in 1978, a season when fishing was concentrated around 58°S, 42°W.

5.18 The Russian fishery is aimed at catching krill for two types of product. One of these products requires high quality large krill, the other can accept a large proportion of "green" krill. Vessels fishing for krill to produce the high quality product commence fishing in December in Subarea 48.1 and January in Subarea 48.2.

5.19 Russian regulations on the manning of fishing vessels limit the operational period to a total of 150 days at sea. This restricts individual fishing vessels to around three months on the fishing grounds in any one season.

Subarea 48.3

5.20 Fishing tends to be concentrated on the shelf and at the shelf break at South Georgia. Very few catches have been reported more than 100 km from land.

5.21 The South Georgia fishery is conducted throughout the winter and Russian fishing captains are encouraged not to commence fishing in the area before May.

5.22 The absence of ice around South Georgia means that the fishery can continue throughout the year.

5.23 Large catches have been reported from the summer months but these tend to follow research surveys when high concentrations have been detected (WG-Krill-92/14).

5.24 This season (1991/92) a single Japanese trawler moved to Subarea 48.3 when fishing in the coastal area of Subarea 48.1 was impractical due to ice. Preliminary reports indicate that good economical catch rates have been achieved by this vessel operating close to South Georgia.

Division 58.4.2

5.25 This area is not currently the focus of a fishery but in the past Japanese and Russian vessels have operated in a narrow band close to the shelf break. The timing of the fishery is dependent on the amount of sea-ice present.

5.26 Although fishing has been concentrated in the same general area the precise locations are dependent on the locations of patches along an extensive length of shelf. Open ocean concentrations tend to be less predictable as is the case in similar areas in the Atlantic Sector.

Responses to Questions on Variation in Krill Abundance

5.27 Responses to questions (iii) and (iv) of SC-CAMLR-X, paragraph 6.36, summarised as: 'How critical is the December through February period to the fishery?' and 'How does abundance and distribution vary throughout the fishery season' were considered.

5.28 Dr J. Bengtson (USA), Convener of WG-CEMP, explained that the reason for specifying the critical period from December through February was based on the requirements of land-based predators. Penguins that are rearing chicks have restricted foraging ranges from the end of November until February and lactating fur seals have a restricted foraging range from December through March.

5.29 The Data Manager provided a breakdown of catches by month for Subareas 48.1 and 48.2 (Table 3). Between 1988 and 1991 catches were reported from October through to June. In Subarea 48.1 large catches were usually taken from January through to March or April. In Subarea 48.2, while large catches were also taken from January through to March, in some years equally large catches were taken as early as November or as late as June.

5.30 An analysis of catches with respect to distance from predator colonies (WG-Krill-92/19) indicated that, in Subarea 48.1, virtually all of the catches were taken less than 100 km from the colonies. The peak catches have been occurring in the range 41 to 60 km at the start of the season and in the range 21 to 40 km by January or February.

5.31 A similar analysis of data from Subarea 48.2 indicated no clear cut pattern.

5.32 Recent catches within the critical period from December to March and within 100 km of colonies are summarised below:

Year	Total Annual Catch		Percent in Critical Period	
	Subarea 48.1	Subarea 48.2	Subarea 48.1	Subarea 48.2
1987		19 902		78
1988	78 918	94 659	85	54
1989	105 554	82 406	90	5
1990	42 477	220 518	89	13
1991	64 641	167 257	74	53

5.33 Examination of these tabulated results indicates that in Subarea 48.1 fishing is concentrated in the months and locations that are critical to land-based predators. Fishing at these times and in these locations is presently required to provide catches most suitable for the current market demand.

5.34 In Subarea 48.2 much less fishing occurs during the critical period and within 100 km of land-based predator breeding sites, while in Subarea 48.3 the bulk of the fishing is restricted to the winter months.

5.35 Research undertaken in Subarea 48.1 (Siegel, 1988) has shown that the krill distribution extends to its maximum range beyond the shelf break in the summer and to a minimum during the winter. Krill abundance increases from October to reach a maximum in February and then decreases to a winter minimum.

Relation of Fishing to Krill Predators

5.36 Consideration of the functional relationships between krill, its principal predators and the krill fishery is a central requirement of Article II of the Convention.

5.37 The topic was considered at two spatial scales, the Southern Ocean scale and that related to localised krill/predator interactions.

5.38 At the Southern Ocean scale there are still problems in reconciling the best estimates of krill standing stock, mortality and production with estimates of predator consumption.

5.39 The need for careful thought in considering possible krill/predator/fishery interaction models was emphasised. Consequently, the Working Group agreed that strategic approaches to improve model specification and the selection of basic parameter requirements should be encouraged. The main aims of a model of this kind at this stage might be:

(i) to determine the level of escapement* needed to satisfy predator demands; and
(ii) to determine how krill standing stock responds to changes in fishing mortality.

5.40 In the first instance, it was felt that a simple approach to reconcile estimates of predator consumption with those of available krill biomass and mortality offers an appropriate starting point.

5.41 This accounting exercise was undertaken for Subareas 48.1 and 48.2 (Appendix F). A simple model linking predator consumption, krill biomass and estimated mortality rates (**M**) in Subarea 48.1 indicated that there was general agreement between mortality rates used in the estimation of potential yield (see paragraphs 4.84 and 4.85) and those calculated from preliminary estimates of predator consumption.

5.42 Similar calculations were requested for Subarea 48.2. Results of these calculations are also presented in Appendix F. The Working Group did not have time to review these results and consider their implications.

5.43 On the local scale, particularly in the vicinity of CEMP monitoring sites, there has been considerable progress which should lead to quantifying some of the functional relationships between

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* In a fisheries management context, escapement is meant to refer to the average level of biomass of the exlpoited stock for a given level of fishing. Proportional escapement is the ratio of this exploited biomass to the average biomass of the stock before the start of the fishery (pristine biomass).

krill and its predators. These topics will be included in the discussions of the forthcoming Joint Meeting of WG-Krill and WG-CEMP.

5.44 Additional topics raised in consideration of possible functional relationships included the minimum levels of local krill standing stock and aggregation patterns necessary to support a fishery and some consideration of the effects on predators of a fishery when the krill standing stock or density were low.

5.45 Dr Bengtson noted that WG-CEMP is in the process of refining estimates of the prey requirements of krill predators. It is anticipated that these efforts will lead to the development of interim estimates prior to the 1992 meeting of the Scientific Committee. It is also expected that the interim estimates will be further refined during an interactive workshop, tentatively scheduled for 1993, which would incorporate information on the abundance, distribution, energetics, and prey needs of predators into relevant models being considered by WG-CEMP. Subsequent to that meeting, it is likely that WG-CEMP will request detailed information from WG-Krill on the distribution, abundance and biological characteristics of krill at different temporal and spatial scales.

Effects of Management Measures on Krill Fishing

5.46 The following options for management measures to control fishing in specific areas were discussed:

(i) closed areas;
(ii) closed seasons;
(iii) catch limit based on historical catches;
(iv) realtime feedback to adjust catch level based on krill survey results;
(v) realtime feedback to limit fishing when predator indices are low;
(vi) combination of closed area and closed season; and
(vii) applying one set of measures to areas where CEMP monitoring is in progress and a different set of measures to other areas where similar predator colonies are known to exist.

5.47 The imposition of closed seasons and areas would have the effect of forcing fishing activities away from some traditional fishing grounds, where information was being collected on land-based predators, into areas where other predators might be at as much or even greater risk. It was agreed that the exclusion of fishing from the ISRs was contrary to the requirements of CEMP.

5.48 WG-Krill had discussed precautionary limits based on historical catches at its previous meeting (SC-CAMLR-X, Annex 5, paragraph 6.38 *et seq*.). There was no further discussion of historical catches.

5.49 Realtime feedback approaches have the advantage that they can take account of local changes. They are not easy to implement because they require continual monitoring and rapid response time. Such approaches are also likely to be disruptive to commercial fishing.

5.50 A combination of closed area and closed season such that fishing would be permitted for part of an area for part of a season has the advantage that it can afford protection to predators at certain restricted times and locations. It has the disadvantage that it is not easy to enforce.

5.51 The concept of applying additional restrictions to fishing activity in the vicinity of predator colonies not subject to CEMP monitoring rather than those within the ISRs was seen as offering some advantages. These need to be considered in the context of the krill requirements of pelagic predators and an overall strategy which takes pelagic and shore-based predators into account. WG-CEMP was requested to ensure that this concept was considered when reviewing its strategy to investigate the functional relationships among predators, prey and environmental conditions.

Liaison with WG-CEMP

5.52 The draft agenda for the Joint Meeting with WG-CEMP was discussed. The main aims of the meeting were seen as being the discussion of:

- krill catch rates with respect to current estimates of predator consumption (i.e., the question of krill escapement);
- the overlap of predator foraging ranges with commercial fishing activity; and
- krill fishing activity and predator information that might be needed for management.

5.53 To assist WG-CEMP in its ecosystem assessment efforts, WG-Krill had been requested to provide the most recent estimates of krill biomass (or relative biomass) in each of the ISRs (and other subareas or meso-scale survey areas as estimates become available) (SC-CAMLR-X, Annex 7, paragraph 5.6). The most recent analyses of krill biomass for portions of three ISRs are provided in Table 4. The coverage of these surveys in respect to the area of the ISRs is shown in Figure 2. The

Working Group stressed that these biomass estimates are only applicable to the area covered by the surveys and should not be extrapolated to cover the total areas of the ISRs.

ADVICE ON KRILL FISHERY MANAGEMENT

Precautionary Limits on Krill Catches in Various Areas

6.1 The Working Group considered revised estimates of krill abundance in Statistical Areas 48 and 58 obtained from reanalysis of the FIBEX data carried out in response to a request from the 1991 meeting (SC-CAMLR-X, paragraph 3.78). The Working Group also reviewed the results from the model for the calculation of the potential yield (**Y**), revised in accordance with the specifications set out in SC-CAMLR-X, paragraphs 201 to 203. Potential yield calculations based on the revised method and data are set out in the table below. The table includes biomass estimates obtained using FIBEX acoustic survey data, both including and excluding the data from the vessel which used 50 kHz echo sounding apparatus (discussion on this matter is given in paragraphs 4.58, 4.59 and 4.86).

Subarea/Division		$\mathbf{B_0}$ (10^6 tonnes)	**Y** (10^6 tonnes)
48.1 + 48.2 + 48.3	(including 50 kHz data)	21.43	1.35
	(excluding 50 kHz data)	11.0	0.69
48.6		4.63	0.29
58.4.2		3.93	0.25 - 0.39

6.2 The Working Group noted that it had recommended in paragraphs 4.76, 4.77 and 4.81 that some aspects of potential yield calculations required further consideration. It also noted the problems identified during the reanalysis of the FIBEX data and proposed further investigations to determine the validity of the estimates from 50 kHz data (paragraph 4.59).

6.3 The Working Group noted that the range of the revised potential yield calculations (based on $\gamma = 0.063$) for the whole of Statistical Area 48 of 0.98 to 1.64 million tonnes was within the range calculated by the Working Group in 1991 (SC-CAMLR-X, Annex 5). Although the lower end of the revised range was less than the precautionary catch limit adopted by the Commission in Conservation Measure 32/X, the Working Group noted that the potential yield figures were based on biomass estimates with limited coverage of the areas of krill abundance particularly in Subarea 48.3, and where 50 kHz data are excluded. It was noted that in Subarea 48.3 the estimate of krill biomass was substantially lower than that which would be compatible with estimates of the amount of krill consumed by predators. Accordingly, the Working Group recommends that the precautionary catch limit of 1.5 million tonnes for Statistical Area 48 contained in Conservation Measure 32/X need not be revised at this time.

6.4 The Working Group used the revised FIBEX estimate for Division 58.4.2 to estimate the potential yield of krill in this division. It was agreed to calculate the potential yield using the same model and parameters developed in 1991 and the revised model used at this meeting. The Working Group noted that the model used last year has been refined and that further work, detailed in paragraph 4.77, was pending on the revised model. Accordingly, the Working Group agreed that the figures in the table jointly represented the best scientific advice on a precautionary catch limit for Division 58.4.2 which can be given at this time. Dr Hatanaka, however, reiterated his concern expressed in paragraph 4.78 and his opposition to the use of the revised model.

6.5 The Working Group recommended that an attempt should be made to validate the 50 kHz data from FIBEX, using available information from net haul data and acoustic data at other frequencies. The Working Group emphasised that if the validity of the FIBEX results remained in doubt, consideration would need to be given in the near future to the institution of a near-synoptic survey for krill in Statistical Area 48 as a whole. The primary justification for such a survey would be to improve available estimates of $\mathbf{B_0}$ uncoupled from possible flux effects and to be used in revised calculations of krill potential yield.

Possible Ecological Effects of Catch Limits

Allocation of Limits to Subareas

6.6 The Working Group considered the options described in paragraph 4.87 as the basis for developing advice on how the precautionary catch limit in Statistical Area 48 could be allocated to subareas. The Working Group developed Table 5 as a summary of options which could be applied at this time, or which can be further developed in the near future.

6.7 The Working Group considered that the best approach to this problem in principle was to allocate the catch limits to subareas in proportion to the total krill biomass in each subarea, with adjustments being made to take into account the conservation of dependent species in accordance with the Convention's objectives. Such an approach would require the combination of methods used in columns 1 and 2 of the table with those proposed for further development in columns 7 and 8.

6.8 Dr Shust indicated that in his view the first two options of subdividing yield into subareas using FIBEX biomass estimates (paragraph 4.87) did not take into account the flux of krill between subareas. For this reason he favoured option (vii) as the most appropriate for subdividing yield because it takes krill flux specifically into account.

6.9 Catches in recent seasons have been well below the trigger level of 620 000 tonnes stipulated in Conservation Measure 32/X to institute an allocation scheme. Therefore, it is unlikely that the implementation of an allocation scheme will be necessary in the immediate future. While this allows time for refinement of the scheme, the Working Group advises that the average of columns 1, 2 and 3 plus 5% (given in column 4) is currently the most practical interim allocation procedure to use.

6.10 The interim approach allocates part of the total catch to each subarea, but with the total allocation exceeding 100%. This would allow limited flexibility in catches in each subarea, provided that the total catch remains within the 1.5 million limit. This approach takes account of the proportion of the total krill biomass in each subarea, while also making *ad hoc* allowance for the likely under-estimation of the biomass in Subarea 48.3 from the FIBEX results.

Additional Management Measures

6.11 Dr Holt introduced a proposal in accordance with a scheme suggested at SC-CAMLR-X for the protection of land breeding dependent species (see SC-CAMLR-X, paragraphs 3.81 to 3.84 and 3.105). He noted that the data available to the Working Group showed that the current fishery in Subarea 48.1 occurred virtually exclusively within the foraging range of land-based predators. Accordingly he suggested that a management zone be established within Subarea 48.1, defined as all areas within 60 n. miles of land, and that a precautionary catch limit be set for the amount of krill which can be taken in any one season within the zone. He suggested that the precautionary limit for the zone could be set at the level of the maximum historic catch in Subarea 48.1 of 106 000 tonnes.

6.12 The Working Group agreed that full consideration of this proposal would require advice from WG-CEMP, and that further discussion would take place at the Joint Meeting of WG-Krill and WG-CEMP in Viña del Mar. The Working Group noted that the relevant information on the amount and distribution of krill fishing, as well as current estimates of krill abundance in Subarea 48.1 were available in this report, and in WG-Krill-92/18.

6.13 Dr Naganobu queried the necessity of such a proposal given the current status of the Japanese fishery. Krill are so abundant that fishing vessels are able to take a sufficient amount of krill for their needs with ease. He suggested that this indicates that the krill stock is large enough to support both predators and the fishery.

6.14 Reservations were expressed about Dr Naganobu's rationale. These were based on the reasons advanced in paragraph 5.6. Operationally, "fleets have tended to encounter sufficient krill on these traditional grounds without needing to search much farther afield. Steady catch rates on these grounds indicate a ready supply of krill but give no substantial indication of the status of the resource." Nevertheless, some members expressed other reservations about the proposal put forward in paragraph 6.11.

6.15 It was suggested that the Joint Meeting should consider the criteria that are necessary to determine whether the proposed catch limit was either more than, or substantially less than, catches compatible with the protection of dependent predators within the proposed zone. It was also suggested that not all foraging areas for land-based predator colonies would necessarily require identical levels of protection against possible effects of krill fishing. For example, it may not be desirable to protect all predator colonies monitored under CEMP because restricting the fishery at too low a level may reduce the ability of CEMP to identify the potentially deleterious effects of fishing over various geographic scales (see paragraph 5.51).

Designation of Management Regions

6.16 Dr S. Nicol (Australia) introduced WG-Krill-92/22 which discussed the problem of the considerable disparity in the size of statistical subareas and divisions in Statistical Area 58. He suggested that such large subareas should be partitioned to take into account both features of the distribution of krill, the distribution of fishing, and other practical management considerations.

6.17 The Working Group noted that statistical areas and subareas were not necessarily appropriate management regions for the krill fishery. It was agreed that a flexible scheme for designating management areas is required. The Working Group considered that these areas could be based on aggregates of fine-scale catch reporting units (0.5° latitude by 1° longitude). Such a scheme could be used to designate fishing grounds, or areas of specific ecological interest (for example, as defined by foraging ranges of land-breeding predators) with respect to management. However, operation of such a scheme would not necessarily lead to the alteration of existing statistical areas, or the designation of smaller statistical divisions.

Refining Operational Definitions of Article II

6.18 The following four concepts (from SC-CAMLR-IX, Annex 4, paragraph 61) have been endorsed by the Scientific Committee and Commission.

"(i) aim to keep the krill biomass at a level higher than might be the case if only single-species harvesting considerations were of concern;

(ii) given that krill dynamics have a stochastic component, focus on the lowest biomass that might occur over a future period, rather than the mean biomass at the end of that period as might be the case in a single-species context;

(iii) ensure that any reduction of food to predators which may arise because of krill harvesting is not such that land-breeding predators with restricted foraging ranges are disproportionately affected in comparison with predators present in pelagic habitats; and

(iv) examine what level of krill escapement would be sufficient to meet the reasonable requirements of krill predators".

6.19 No specific proposals for operational definitions have been developed from these concepts. However, operational definitions depend on the details of particular management procedures. An example of this linkage occurs in the calculation of precautionary catch limits based on potential yield. In this case, the proportion of krill biomass which can be taken depends on an operational definition with a fixed probability that krill biomass might fall below 20% of its average unexploited value. This operational definition has been developed in accordance with concept (ii). However, it will require further refinement as information becomes available about the required escapement of krill in accordance with concept (iv). As progress is made in the development of management procedures, the Working Group will need advice from the Commission on policy matters such as how frequently and by how much catch levels can alter. Such policy matters also have to be expressed as operational definitions for the purposes of developing an overall management procedure.

Other Possible Approaches and their Development

6.20 The Commission has endorsed the concept of feedback management as the approach to be developed for the long-term management of the krill fisheries. A feedback management procedure requires information about the state of the ecosystem, which is compared with operational objectives to determine the amount by which catch levels have to be altered. The Working Group recognised that the first priority in developing a feedback procedure is to determine what information about the abundance of krill stocks is likely to be available on a regular basis. In principle, three types of information can be expected:

(i) information derived from the fisheries, such as CPUE data;
(ii) information collected independently from the fisheries, such as surveys;
(iii) information collected on krill dependent predators by CEMP;

6.21 Some Members of the Scientific Committee have expressed reservations about the usefulness of CPUE in managing krill fisheries.

6.22 The Working Group agreed that surveys carried out independently of the fishery will provide reliable data on which to base feedback management. However, there is a tradeoff between the frequency of surveys and the results achieved by a feedback management procedure, either in terms of risk to the stocks or size of catches. The Working Group will need to investigate what scale and frequency of surveys will be likely to be feasible in the future. Advice from the Scientific Committee in this regard would be helpful. This information can be used to undertake some simulation studies on possible long-term feedback management procedures. It was suggested that consideration be given to a range of survey techniques, such as egg surveys. Alternative methods may provide some independent validation of acoustic surveys.

6.23 Information on the interactions of predators, prey and environmental conditions will become available from CEMP, and methods of using this in a feedback management procedure will need to be developed in consultation with WG-CEMP and others as appropriate.

Data Requirements

6.24 The Working Group was pleased to note that a considerable number of papers had been received which contained information relevant to data requirements set out in the report of its last meeting (SC-CAMLR-X, Annex 5, Table 8). An updated table of information requirements is included here as Table 6.

6.25 The Working Group was informed that some catches of krill and acoustic surveys may have occurred in FAO Statistical Area 41, and perhaps others immediately outside the Convention Area.

The Working Group requested the Secretariat to contact FAO and other relevant organisations to determine whether data from these catches is available, and can be added to the CCAMLR database.

6.26 The requirement to submit fine-scale catch and effort data from Subareas 48.1, 48.2 and 48.3 and the ISRs should be expanded to apply to any catches of krill in the Convention Area (paragraph 4.31).

Scientific Observer Scheme

6.27 The Working Group was pleased to receive a draft manual for scientific observers on fishing vessels prepared by the Secretariat incorporating material provided by Russian Scientists. The Working Group also received a paper providing further guidelines for the preparation and reporting of material collected aboard commercial krill trawlers (WG-Krill-92/10).

6.28 A subgroup consisting of Drs Marín, Naganobu, Nicol and Watkins, was convened by the Science Officer to consider the draft manual. Because the manual is a substantial document, the subgroup was not able to give detailed consideration to it in the time available at the meeting. However, a number of amendments were incorporated. The subgroup agreed that the draft manual was reasonably comprehensive and would prove useful.

6.29 The Working Group agreed that Members should give further consideration to the manual and forward suggested amendments to the Secretariat by 30 September, so that the revised draft can be presented to the Scientific Committee. It was suggested that the draft edition of the manual be made available to Members for trial use during the next fishing season.

Future Work

6.30 Future work defined by WG-Krill is listed in Table 7.

OTHER BUSINESS

Krill Surplus

7.1 The Working Group briefly discussed the matter of krill surplus, the perception that there is a potential for a large sustainable catch of krill following the removal of a large proportion of whale biomass from the Antarctic marine ecosystem (SC-CAMLR-X, Annex 5, paragraph 8.3). The

Scientific Committee had been unable to provide guidance as to how to pursue this matter (SC-CAMLR-X, paragraph 3.86). The Working Group agreed that any further deliberations should more appropriately be addressed by the forthcoming Joint Meeting of WG-Krill and WG-CEMP.

Editorial Considerations

7.2 The Working Group noted that references to working group reports were often made as "Anon., ...", and that other inconsistencies in citations in both papers and reports were frequent. A sheet describing the standard format adopted by the Secretariat for citations of the reports of the Working Groups and Scientific Committee, Working Group documents and papers published in the *Selected Scientific Papers* was circulated (Appendix G). The Working Group strongly recommended that authors conform to the formats described in this paper for all future citations in papers and reports.

7.3 The minimum data requirements for reporting acoustic survey results were discussed. The suggested minimum requirements are given in Appendix H. The Working Group also emphasised the need to report data in standard acoustic units and that these should be defined in the papers. The reporting of basic data (Mean Volume Backscattering Strength, MVBS) is preferable to only reporting derived results (such as t/km^2) alone. Whenever derived results are presented, detailed descriptions of the procedures and calculations underlying their derivation must be provided.

7.4 The current ruling for the submission of papers to working group meetings is that papers submitted more than 30 days before the meeting will be circulated to participants by the Secretariat in advance of the meeting. All other papers must be submitted to the Secretariat by 9 am on the first day of the meeting.

7.5 Concern was expressed that many papers submitted for consideration by the Working Group this year had not been submitted in advance, and were therefore unavailable for review by participants until after the start of the meeting. It was emphasised that the Working Group was required to give advice to the Scientific Committee based on the best available scientific information, and in order to do this, papers should be available in plenty of time to allow all participants to thoroughly evaluate their contents, especially when the papers address substantive issues.

7.6 The Working Group recommended the following additional requirements for paper submission:

- submission of papers prior to the 30 day deadline is strongly encouraged; such papers will be circulated to participants in advance of the meeting;

- papers submitted after the 30 day deadline and before 9 am on the first day of the meeting will be accepted for consideration at that meeting, on the condition that participants provide sufficient copies for distribution to all Working Group members at or before 9 am on the first day. The Secretariat will advise participants of the required number of copies for the meeting at the time of the first circulation of papers; and

- papers will not be accepted for consideration by the Working Group if submitted after 9 am on the first day of the meeting. Such papers could be re-submitted for a future meeting of the Working Group.

7.7 For the purpose of the above, participants wishing to receive papers before the meeting must inform the Secretariat of their intention to participate before the 30 day deadline.

7.8 A number of questions relating to publication policy were raised by members of the Working Group. It was acknowledged that the scientific work of CCAMLR was being increasingly recognised within the scientific community, and that this was very beneficial to the work of the Commission. Dr Everson suggested that CCAMLR should encourage scientists who publish papers in the refereed literature to include references to CCAMLR in abstracts and key-word listings, and also to make a point of highlighting the relevance of the work to CCAMLR where appropriate.

7.9 It was also suggested that reprints of papers with relevance to CCAMLR be lodged with the Secretariat in order to build up a reference library of use to scientists working on CCAMLR related topics.

7.10 It was pointed out that CCAMLR has no in-house peer reviewed journal. Dr Butterworth emphasised the value that such a publication would provide in heightening the scientific profile of CCAMLR and providing a single authoritative source for papers addressing matters of importance.

7.11 The Executive Secretary informed the Working Group that the Secretariat has prepared a paper that addresses future developments in publication policy for consideration by the Scientific Committee. These developments include a proposal for a peer review journal for the publication of papers submitted to meetings of the Scientific Committee and Working Groups.

7.12 The Convener expressed the additional concern that under the present rules for publication of working papers, the originators of data must give their permission for any publication which uses their data. Under these rules it was possible that papers which presented analyses that were used extensively by the Working Group would not be available in the published literature.

7.13 Given these concerns, the Working Group recommended that the Scientific Committee take up the subject of publication policy of scientific papers at its next meeting.

ADOPTION OF THE REPORT

8.1 The Report of the Fourth Meeting of the Working Group on Krill was adopted.

CLOSE OF THE MEETING

9.1 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 their input and good humour throughout the meeting. The prevailing spirit was such that a large and complicated agenda had been thoroughly addressed. Finally, the Convener conveyed the Working Group's and his heartfelt thanks to the local organiser, Dr Marín, the Hotel Cabo de Hornos and the Chilean Government for their hospitality in hosting the meeting.

Table 1: Estimates of flows between subareas (Statistical Area 48).

Subarea	Location	Speed x10 → m s^{-1}	Direction	Reference
48.1	Deep	5.5 - 10.9	East	WG-Krill-92/24
	Deep	3.4 - 5.1	East	WG-Krill-92/25
	Deep	30.0 - 40.0	East	SC-CAMLR-X, Annex 5, Table 1
	Coastal	0.8 - 1.6	East	WG-Krill-92/25
	Coastal	26.0 - 64.0	East	SC-CAMLR-X, Annex 5, Table 1
	Coastal	5.0 - 10.0	East	SC-CAMLR-X, Annex 5, Table 1
	Coastal	19.0	East	SC-CAMLR-X, Annex 5, Table 1
48.2	Deep	5.8 - 12.5	East	WG-Krill-92/25
	Coastal	0.8	East	WG-Krill-92/25
48.3	Deep	1.9 - 2.5	East	WG-Krill-92/25
	Deep	4.7 - 5.8	East	WG-Krill-92/25
	Deep	0.2	West	WG-Krill-92/25

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

Table 2: Results of the recalculation of krill biomass from the FIBEX cruises. For Subareas 48.1 and 48.2 the results for the *Walther Herwig* are given separately and in combination with the results from the other cruises.

Area/ Subarea/ Division	Strata Used	Density (g.m^{-2})	Area ('000 km^{2})	Coefficient of Variation	Biomass (million tonnes)
41	*Walther Herwig* (NW)	48.9	75	29.6	3.66
48.1	*Professor Siedlecki + Itzumi*	11.0	194	98.3	2.12
	Walther Herwig (SW)	94.2	89	38.0	8.42
	Combined	37.2	283	35.0	10.54
48.2	*Odissey + Eduardo L. Holmberg*	39.7	185	19.3	7.37
	Walther Herwig (E)	35.6	57	40.1	2.01
	Combined	38.8	242	17.6	9.38
48.3	*Odissey*	59.7	25	38.0	1.51
48.6	*Agulhas*	8.0	576	23.0	4.63
58.4.2	*Nella Dan + Marion Dufresne + Kaiyo Maru*	2.3	1 711	32.0	3.93

Table 3: Catch (tonnes) of krill in Subareas 48.1 and 48.2, 1988 to 1991, derived from Statlant B data. The percentage of each nation's catch taken in each month is also given.

		1988		1989		1990		1991	
		tonnes	%	tonnes	%	tonnes	%	tonnes	%
Subarea 48.1									
Chile	January			57	9	1009	22		
	February	5504	93	2750	52	2858	64	861	23
	March	434	7	2135	40	634	14	2818	77
	April			387	7				
Japan	December	128	0.1	1913	3	1663	4	101	1
	January	17705	25	24626	32	11220	33	11697	21
	February	21314	30	26569	35	9779	30	12127	22
	March	22597	32	14435	19	6737	20	17588	32
	April	10070	13	8369	11	4537	13	13207	24
Korea	December	692	62			504	13		
	January	419	38	196	12	1872	46	917	76
	February			681	42	1664	41	294	24
	March			738	46				
Poland	December			80	5			97	31
	January			407	22			213	69
	February	55	100	638	35				
	March			698	38				
USSR	October							688	15
	November							1587	34
	December							2446	51
	January			9920	48				
	February			4094	20				
	March			6861	32				
Total		78918		105554		42477		64641	
Subarea 48.2									
Japan	December	456	35	11	1			36	100
	January	11	1						
	February								
	March	831	64	2799	92				
	April			206	7			1304	69
	May					1	100	584	31
Korean	December	44	10						
	January	370	90						
	February			164	100				
Poland	December							1	
	January			1137	42			1658	28
	February	421	14	1595	58			1560	26
	March	1332	44					1514	25
	April	1306	42					1287	21
USSR	October			553	2	538	0.2	2405	2
	November	325	0.3	3394	4	9104	4	10252	7
	December	391	0.3	27513	36	27776	13	15362	10
	January	15693	18	20131	26	18591	8	13530	8
	February	14158	16	17668	23	16542	8	25572	16
	March	19296	21	7235	9	25981	12	28978	18
	April	39375	44			43763	20	45381	28
	May	650	0.6			57195	25	17833	11
	June					21027	10		
Total		94659		82406		220518		167257	

Table 4: Most recent biomass estimates from ISRs (see Figure 2).

		Year	Status	Area ('000 km^2)	Density (g.m^{-2})	Biomass (10^6 tonnes)	Reference
South Georgia	Acoustic	1981	recalculated from FIBEX data	25	59.7	1.51	WG-Krill-92/20
Peninsula	Acoustic	1981	recalculated from FIBEX data with *Walther Herwig*	283	37.3	10.54	"
			recalculated from FIBEX data without *Walther Herwig*	196	11.0	2.12	"
Prydz Bay	Acoustic	1992	Australian survey	268	7.4	1.98	WG-Krill-92/23

Table 5: Various options for allocating the precautionary catch limit of 1.5 million tonnes of krill in Statistical Area 48 among the various subareas.

<table>
<tr><th></th><th></th><th>FIBEX Estimate with Walther Herwig</th><th>FIBEX Estimate without Walther Herwig</th><th>Historical Catch</th><th>Average of Columns 1, 2, 3 Plus 5%</th><th>Even Division</th><th>Linear Extent of Shelf Break</th><th>Predator Demands</th><th>Local Biomass Adjusted for Krill Movement</th></tr>
<tr><td>Krill-predator interactions considered?</td><td></td><td>N</td><td>N</td><td>N</td><td>N</td><td>N</td><td>N</td><td>Y</td><td>N</td></tr>
<tr><td>Data availability?</td><td></td><td>Y</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td><td>?</td></tr>
<tr><td>Provisional allocations:</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Antarctic Peninsula</td><td>48.1</td><td>40%</td><td>12%</td><td>17%</td><td>28%</td><td>17%</td><td rowspan="6">Yet to be calculated</td><td rowspan="6">Yet to be calculated</td><td rowspan="6">Yet to be calculated</td></tr>
<tr><td>South Orkney Islands</td><td>48.2</td><td>36%</td><td>53%</td><td>42%</td><td>49%</td><td>17%</td></tr>
<tr><td>South Georgia</td><td>48.3</td><td>6%</td><td>9%</td><td>41%</td><td>24%</td><td>17%</td></tr>
<tr><td>S. Sandwich Islands</td><td>48.4</td><td>0%</td><td>0%</td><td><0.01%</td><td>5%</td><td>17%</td></tr>
<tr><td>Weddell Sea</td><td>48.5</td><td>0%</td><td>0%</td><td>0%</td><td>5%</td><td>17%</td></tr>
<tr><td>Bouvet Island region</td><td>48.6</td><td>18%</td><td>26%</td><td>0.1%</td><td>20%</td><td>17%</td></tr>
</table>

Table 6: Data requirements. This table lists the requests of WG-Krill-91, and adds additional requests of the Fourth Meeting of the Working Group.

Data Required by WG-Krill-91	Data Submitted at WG-Krill-92	Data Requested by WG-Krill-92
Review of demographic parameters	-	Examination of the precision of estimates of krill weight/length relationships (paragraph 4.83)
Krill movement	WG-Krill-92/24, 25	Work on the influence of hydrography on krill distribution should be encouraged (paragraph 4.33)
Observer reports from commercial fishery	WG-Krill-92/6, 10, 33, 21	
Length frequency data submission	Length frequency data from commercial fishery by USSR, Poland, Korea, 1990 and 1991	Continued requirement
Haul-by-haul data submission, irrespecitve of proximity to CEMP sites	Chile only	Continued requirement (paragraph 3.24)
Number and capacity of fishing vessels (Members' Activities Reports)	-	Continued requirement
Estimates of biomass for ISRs (request of WG-CEMP)	Calculated at Working Group	Continuing (paragraph 5.53)
		Reporting of monthly catches should proceed in compliance with Conservation Measure 32/X (paragraph 3.10).
		Data on the amount and viability of krill passing through a net should be reported (paragraph 3.23).
		New data on krill flux in Subareas 48.2, 48.3 and in other areas (paragraph 4.28).
		Fine-scale data - should be submitted for all catches of krill in the Convention Area, - fine-scale data from historical catches in Statistical Area 58 are requested.
		Secretariat is requested to contact FAO and Members concerning krill catches in Statistical Area 41 (paragraph 6.22).
		Minimum data requirements when reporting acoustic surveys, set out in Appendix H should be adhered to.

Table 7: Future work requirements. This table lists the requests of WG-Krill-91, and adds additional requests of the Fourth Meeting of the Working Group.

Work Required by WG-Krill-91	Data Submitted at WG-Krill-92	Future work Requested by WG-Krill-92
Operational definitions of Article II	-	
Estimation of total effective biomass, including reworking the FIBEX data	WG-Krill-92/20, 23, 26, 27, 25	Further analyses of net haul and acoustic data for the *Walther Herwig* and other FIBEX cruises (paragraphs 4.59 and 6.5).
Suggestions of methods to take account of predator needs	WG-Krill-92/16	Further work is required to improve models of the functional relationship between krill, its principal predator and the krill fishery (paragraph 5.39).
Estimates of potential yield - reworking of $Y = \lambda MB_0$ model	WG-Krill-92/4, 22	- Secretariat asked to validate the potential yield model and calculations described in WG-Krill-92/4 and 28 (paragraph 4.76) - Estimation of $\mathbf{s_R}$ and its correlation with **M** and growth rate (Appendix E) and further refinements to the yield model should be made (paragraph 4.77).
Acoustic target strength	WG-Krill-92/11, 17, 31	Examination of the effect of physical condition and orientation on krill target strength required (paragraph 4.41).
Acoustic survey designs	-	-
Analysis of fine-scale fisheries data	WG-Krill-92/18, 19, 21	Continued requirement
Investigation of sampling regimes for krill	-	-
Biological data - observer forms will be compiled and an observer manual drafted	Completed by the Secretariat	- Members should give further consideration to the Observer Manual and forward suggestions by 30 December (paragraph 6.25).

Table 7 (continued)

Work Required by WG-Krill-91	Data Submitted at WG-Krill-92	Future work Requested by WG-Krill-92
Analysis of acoustic and bridge log data from the commercial fishery	-	Continued requirement Haul-by-haul data should be used to evaluate the Composite CPUE Index (paragraph 3.13). More reports of liaison between fishermen, biologists and managers should be compiled (paragraph 4.34). Investigations of the scale and frequency of surveys applicable to feedback management approaches (paragraph 6.19). Consideration of a near-synoptic survey in Statistical Area 48 (paragraph 6.5). Subdivision of results from existing surveys should be investigated in the light of Appendix D. Clarification of the noise margins and thresholds for Prydz Bay surveys if required (paragraph 4.41). Further modelling is required to evaluate feedback control management options (paragraph 4.77) and spatial effects related to localised predator aggregations. Work is required for completion of the precautionary catch allocation table (paragraph 6.7): shelf break extent, predator demands and biomass adjusted for krill movement (flux and retention times) (paragraph 4.33).

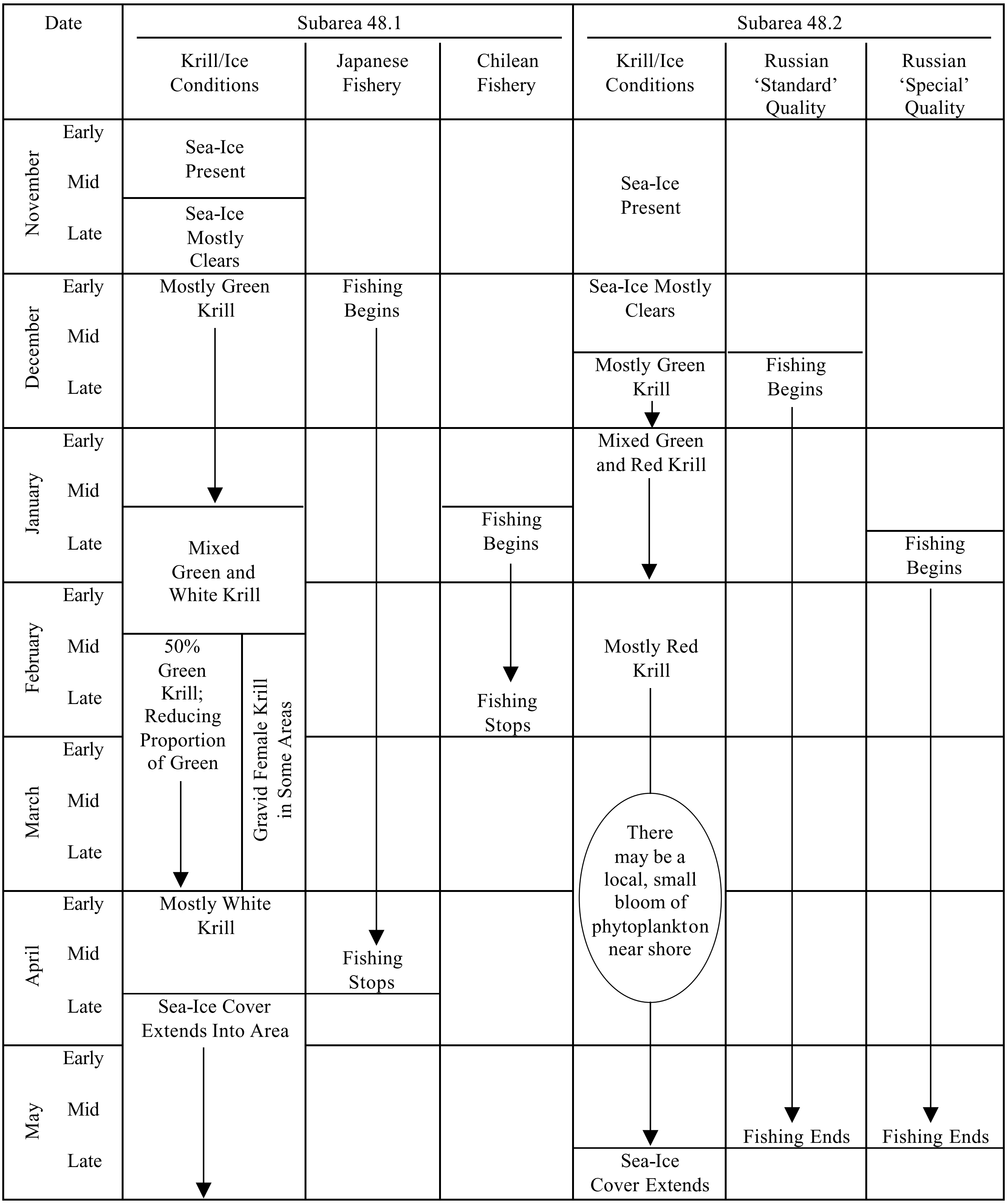

Figure 1: Schematic diagram of the timing of krill fishing in Subareas 48.1 and 48.2 relative to krill and sea-ice conditions. Krill discoloured by full guts are termed ‘green’, whereas krill without discolouration are termed ‘white’ (Japanese/Chilean) or ‘red’ (Russian).

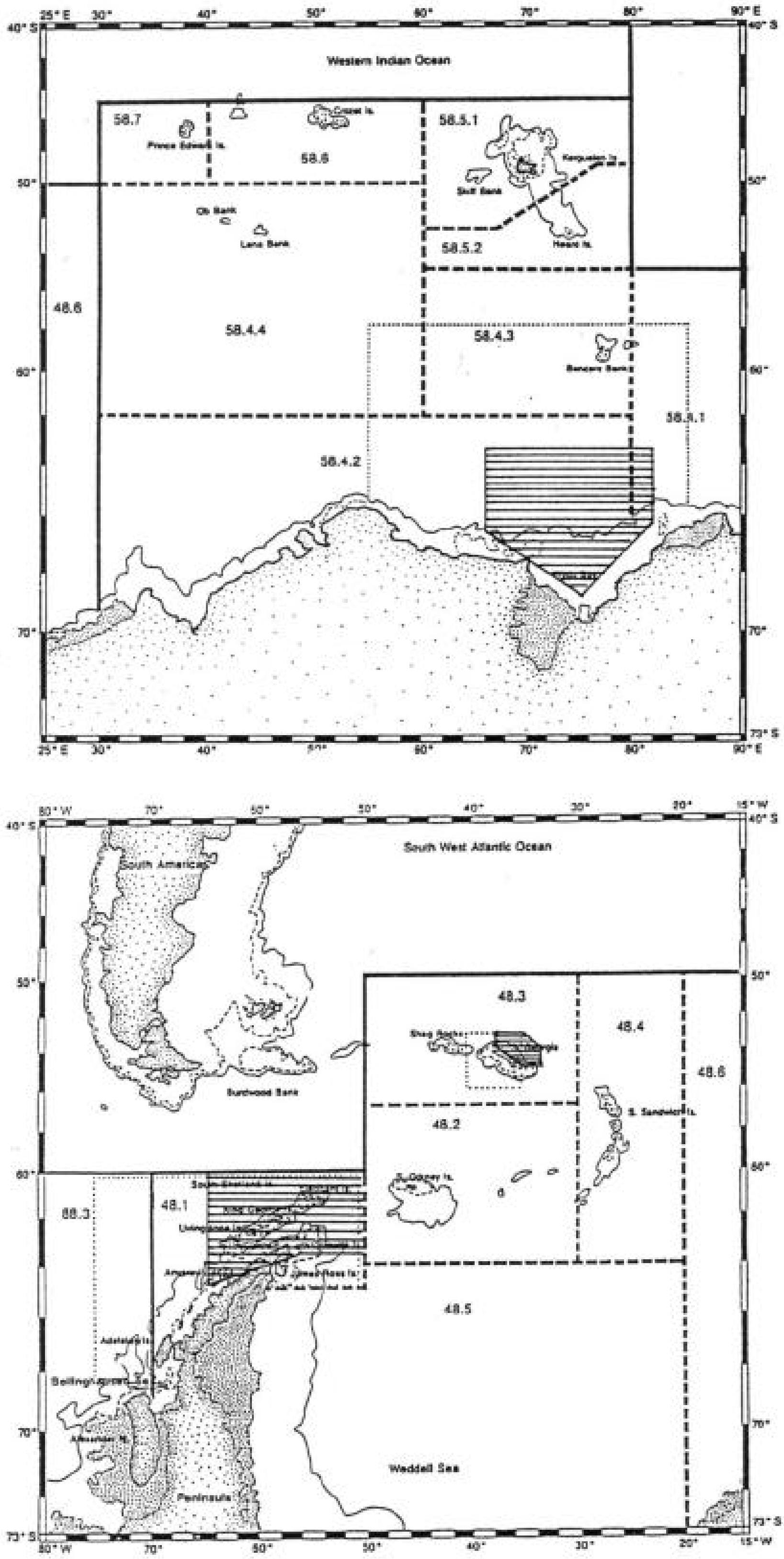

Figure 2: Survey areas in ISRs (see Table 4).

AGENDA

Fourth Working Group on Krill
(Punta Arenas, Chile, 27 July to 3 August 1992)

1. Welcome

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

3. Review of Fisheries Activities
   (i) Fisheries Information
      (a) Catch Levels
      (b) Location of Catches
      (c) Reports of Observers
         - By-Catch of Young Fish
         - Length Frequency/Haul-by-Haul Data
   (ii) Other Information
      (a) Distribution and Abundance
      (b) Fishing Escapement Loss/Mortality

4. Estimation of Krill Yield
   (i) Krill Flux in Statistical Area 48
      (a) Immigration/Emigration Rates
      (b) Residence Times
      (c) Influence of Hydrography
   (ii) Estimation of Initial Biomass ($\mathbf{B_0}$)
      (a) Techniques
      (b) Statistical Area 48
      (c) Other Areas
   (iii) Refinement of Yield Estimate Calculations
      (a) Evaluation of Population Models
      (b) Evaluation of Demographic Parameters

(iv) Refinement of Precautionary Catch Limit Estimates

(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

(ii) Effects of Management Measures on Krill Fishing

(a) Location, Timing and Intensity of Fishing

(b) Krill Management Measures and Krill Predators

(iii) Liaison with WG-CEMP

6. Advice on Krill Fishery Management

(i) Precautionary Limits on Krill Catches in Various Areas

(a) Estimates of Potential Yield

(b) Possible Ecological Effects of Catch Limits

(ii) Refining Operational Definitions of Article II

(iii) Other Possible Approaches and their Development

(iv) Data Requirements

(v) Scientific Observer Scheme

(vi) Future Work of WG-Krill

7. Other Business

(i) Krill Surplus

(ii) Editorial Considerations

8. Adoption of the Report

9. Close of the Meeting.

LIST OF PARTICIPANTS

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(Punta Arenas, Chile, 27 July to 3 August 1992)

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LIST OF DOCUMENTS

Working Group on Krill
(Punta Arenas, Chile, 27 July to 3 August 1992)

WG-KRILL-92/1	DRAFT AGENDA
WG-KRILL-92/2	LIST OF PARTICIPANTS
WG-KRILL-92/3	LIST OF DOCUMENTS
WG-KRILL-92/4	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 and S. Chalis (South Africa)
WG-KRILL-92/5	STATE OF THE ANTARCTIC KRILL (*EUPHAUSIA SUPERBA* DANA) RESOURCES IN THE SODRUZHESTVA SEA AREA (STATISTICAL DIVISIONS 58.4.2 AND 58.4.3) IN 1988 TO 1990 V.A. Bibik and V.N. Yakovlev (Russia)
WG-KRILL-92/6	REPORT OF BIOLOGICAL OBSERVATIONS CARRIED OUT ON BOARD THE KRILL FISHING VESSEL *MORE SODRUZHESTVA* IN APRIL TO AUGUST 1991 V.I. Latogursky (Russia)
WG-KRILL-92/7	ACOUSTIC ESTIMATION OF KRILL (*EUPHAUSIA SUPERBA*) BIOMASS AND BEHAVIOUR IN THE ROSS SEA Massimo Azzali (Italy)
WG-KRILL-92/8	POSSIBLE APPROACHES TO THE EVALUATION OF THE ANTARCTIC KRILL MORTALITY L.G. Maklygin and V.I. Latogursky (Russia)

WG-KRILL-92/9	DIURNAL CHANGES OF SOME BIOLOGICAL CHARACTERISTICS OF *EUPHAUSIA SUPERBA* DANA IN SWARMS (WESTWARD OF THE SOUTH ORKNEY ISLANDS, 24 MARCH TO 18 JUNE 1990 - BASED ON DATA REPORTED BY BIOLOGIST-OBSERVER) A.V. Vagin, R.R. Makarov and L.L. Menshenina (Russia)
WG-KRILL-92/10	A GUIDELINE FOR COLLECTION, ANALYSING AND PREPARATION OF REPORT ON MATERIAL COLLECTED BY A BIOLOGIST-OBSERVER ON BOARD A COMMERCIAL TRAWLER (DRAFT) V.I. Latogursky and R.R. Makarov (Russia)
WG-KRILL-92/11	STATUS OF KRILL TARGET STRENGTH Kenneth G. Foote (Norway), Dezhang Chu and Timothy K. Stanton (USA)
WG-KRILL-92/12	VARIABILITY OF KRILL STOCK COMPOSITION AND DISTRIBUTION IN THE VICINITY OF ELEPHANT ISLAND DURING AMLR INVESTIGATIONS 1988-1992 V. Loeb (USA) and V. Siegel (Germany)
WG-KRILL-92/13	FINE-SCALE CATCHES OF KRILL IN AREA 48 REPORTED TO CCAMLR 1990 TO 1991 Secretariat
WG-KRILL-92/14	MANAGING SOUTHERN OCEAN KRILL AND FISH STOCKS IN A CHANGING ENVIRONMENT I. Everson (UK)
WG-KRILL-92/14 Rev. 1	MANAGING SOUTHERN OCEAN KRILL AND FISH STOCKS IN A CHANGING ENVIRONMENT I. Everson (UK)
WG-KRILL-92/15	REVIEW OF LENGTH-WEIGHT RELATIONSHIPS FOR ANTARCTIC KRILL V. Siegel (Germany)
WG-KRILL-92/16	ALTERNATIVE METHODS FOR DETERMINING SUBAREA OR LOCAL AREA CATCH LIMITS FOR KRILL IN STATISTICAL AREA 48 G. Watters and R.P. Hewitt (USA)
WG-KRILL-92/17	CALIBRATION OF AN ACOUSTIC ECHO-INTEGRATION SYSTEM IN A DEEP TANK, WITH SYSTEM GAIN COMPARISONS OVER STANDARD SPHERE MATERIAL, WATER TEMPERATURE AND TIME David A. Demer and Roger P. Hewitt (USA)

WG-KRILL-92/18 KRILL CATCH DISTRIBUTION IN RELATION TO PREDATOR COLONIES, 1987-1991
Secretariat

WG-KRILL-92/19 DISTRIBUTION OF KRILL (*EUPHAUSIA SUPERBA* DANA) CATCHES IN THE SOUTH SHETLANDS AND SOUTH ORKNEYS
D.J. Agnew (Secretariat)

WG-KRILL-92/20 KRILL BIOMASS IN AREA 48 AND AREA 58: RECALCULATION OF FIBEX DATA
P.N. Trathan (UK), D. Agnew (Secretariat), D.G.M. Miller (South Africa), J.L. Watkins, I. Everson, M.R. Thorley, E. Murphy, A.W.A. Murray and C. Goss (UK)

WG-KRILL-92/21 CHILEAN KRILL FISHING OPERATIONS 1992: ANSWERING SC-CAMLR-X, PARAGRAPH 6.36
Victor H. Marín, Darío Rivas and Antonio Palma (Chile)

WG-KRILL-92/22 MANAGEMENT SUBDIVISIONS WITHIN THE CCAMLR AREA WITH SPECIAL REFERENCE TO AREA 58
Stephen Nicol (Australia)

WG-KRILL-92/23 ESTIMATION OF THE BIOMASS OF KRILL IN PRYDZ BAY DURING JANUARY/FEBRUARY 1991 AND FEBRUARY/MARCH 1992 USING ECHO INTEGRATION
I. Higginbottom and T. Pauly (Australia)

WG-KRILL-92/24 CHARACTERSITICS OF OCEANIC STRUCTURE IN THE WATERS AROUND THE SOUTH SHETLAND ISLANDS OF THE ANTARCTIC OCEAN BETWEEN DECEMBER 1990 AND FEBRUARY 1991: OUTSTANDING COASTAL UPWELLING?
M. Naganobu, T. Katayama, T. Ichii, H. Ishii and K. Nasu (Japan)

WG-KRILL-92/25 HYDROGRAPHIC FLUX IN THE WHOLE OF STATISTICAL AREA 48 IN THE ANTARCTIC OCEAN
M. Naganobu (Japan)

WG-KRILL-92/26 ABUNDANCE, SIZE AND MATURITY OF KRILL (*EUPHAUSIA SUPERBA*) IN THE KRILL FISHING GROUND OF SUBAREA 48.1 DURING 1990/91 AUSTRAL SUMMER
T. Ichii, H. Ishii and M. Naganobu (Japan)

WG-KRILL-92/27 DIFFERENCES IN DISTRIBUTION AND POPULATION STRUCTURE OF KRILL (*EUPHAUSIA SUPERBA*) BETWEEN PENGUIN AND FUR SEAL FORAGING AREAS NEAR SEAL ISLAND
T. Ichii, H. Ishii (Japan), J.L. Bengtson, P. Boveng, J.K. Jansen (USA) and M. Naganobu (Japan)

WG-KRILL-92/28	COMMENT ON "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" (WG-KRILL-92/4) H. Hiramatsu (Japan)
WG-KRILL-92/29	AN ARGUMENT AGAINST BIG INCIDENTAL KRILL MORTALITY STATED IN WG-KRILL-91/6 Etuo Sakitani (Japan)
WG-KRILL-92/30	PROCEDURE TO CORRECT FOR ACOUSTIC BEAM WIDTH EFFECTS WHEN ASSESSING THE BIOMASS OF KRILL AGGREGATIONS B. Barange, D.G.M. Miller and I. Hampton (South Africa)
WG-KRILL-92/31	SUMMARY OF SOME RECENT STUDIES COMPARING ECHOLEVELS AT 38 AND 120 KHZ Inigo Everson (UK)
WG-KRILL-92/32	FISHES CAPTURED AS BY-CATCH DURING THE 1991 CHILEAN ANTARCTIC KRILL FISHERY Enzo Acuña S., Armando Mujica R. and Hector Apablaza P. (Chile)
WG-KRILL-92/33	KRILL POPULATION BIOLOGY DURING THE 1991 CHILEAN ANTARCTIC KRILL FISHERY Armando Mujica R., Enzo Acuña S. and Alberto Rivera O. (Chile)

OTHER DOCUMENTS

WG-KRILL/CEMP-92/4	CCAMLR ECOSYSTEM MONITORING AND A FEEDBACK MANAGEMENT PROCEDURE FOR KRILL A. Constable (Australia)
WG-CEMP-92/15	DISTRIBUTION AND ABUNDANCE OF KRILL IN THE VICINITY OF ELEPHANT ISLAND IN THE 1992 AUSTRAL SUMMER Roger P. Hewitt and David A. Demer (USA)
WG-CEMP-92/16	AMLR 1991/92 FIELD SEASON REPORT; OBJECTIVES, ACCOMPLISHMENTS AND TENTATIVE CONCLUSIONS Delegation of the USA
SC-CAMLR-XI/BG/5	SCIENTIFIC OBSERVERS MANUAL FOR OBSERVATIONS ON COMMERCIAL FISHING VESSELS (DRAFT) Secretariat

KRILL SURVEYS - USE OF RESULTANT INFORMATION

Ideally, one would wish to have a time series of comparable estimates of biomass from surveys of the complete extent of each subarea. The resultant information would be used:

(i) in the short term, to improve estimates of $\mathbf{B_o}$; and

(ii) in the longer term, as the basis for management under feedback-control.

2. In practice, problems will arise. Some (many) surveys will not cover the full extent of the subarea concerned. There will be problems concerning comparability, e.g. surveys could take place at different times of year, and use different methodologies (e.g., trawl, hydroacoustic). One would nevertheless like to make use of <u>all</u> the data available. Linear model analysis is an approach which might allow all (or at least most) of the data to be integrated to provide a "single" "best" result. This applies not only to the future, but also to the present where it might be desirable to combine the FIBEX results with the data from other surveys in a methodologically defensible manner.

3. The underlying approach would be to obtain estimates of density for small sectors (e.g., 0.5° latitude by 1° longitude) within each subarea. These density estimates could then be integrated to provide an abundance estimate for the whole subarea. The linear model would need to make allowance for seasonal effects, and could treat trawl survey results as indices of relative density when combining them with the hydroacoustic data. To improve precision, and perhaps allow extrapolation within the subarea, a simple model of spatial factors might be attempted, rather than estimation of independent indices for each small sector.

4. A pre-requisite for attempting such analyses would be the subdivision of existing survey results on whatever small sector grid might be chosen.

5. There may be several problems associated with the practical implementation of this approach in the absence of a satisfactory simple model of spacial factors.

- As mentioned above, with typical transect spacings such as during FIBEX (10 to 50 n miles) it is possible that some longitudinal lines of fine-scale rectangles would not contain any transect.

- Division of transects into 0.5° latitude units may only leave one section of transect per rectangle. Since the density estimator is the transect mean it would be impossible to provide a variance estimator.

- Dividing transects longitudinally may also lead to skewed estimates of variance as a result of possible serial correlation effects that would have to be taken into account in the statistical treatment of the results.

APPENDIX E

FURTHER REFINEMENTS OF THE CALCULATION OF THE FACTOR γ RELATING YIELD TO SURVEY BIOMASS ESTIMATES

MODIFICATIONS

1. Stock/Recruit Relationship

Previous calculations have assumed that median recruitment is a constant independent of spawning biomass (except that WG-Krill-92/4 assumed that recruitment became zero if the total recruited biomass was harvested in a particular year). Instead, it will be assumed that median recruitment decreases proportionately to spawning biomass, for spawning biomass below 20% of its average pristine level.

2. Inability to Harvest Specified Fixed Catch

Previous calculations allowed fishing mortality to increase to large values in certain years, in order to attempt to take the specified fixed catch every year, to the extent that on occasions the entire recruited biomass could be harvested. Instead, to place some realistic limit on the proportion of the recruited biomass which could be harvested in any year, an upper bound of 1.5 yr^{-1} will be placed on the fishing mortality **F** for fully selected age-classes (this bound relates to an effective annual fishing mortality; thus, for a three month fishing season for example, the actual upper bound would be 6.0 yr^{-1}). This limitation means that the specified fixed catch will not always be taken in every year during the harvesting period.

3. Prior Distributions for **M**, σ_R and Growth Rate

The previous calculations assumed that estimates of these parameters were uncorrelated; values for M and σ_R were drawn independently from their specified distributions, while the krill growth rate was fixed. However, the available length frequency data imply some relationship between these parameters: a higher value of M would correspond to a faster growth rate and a lower value of σ_R.

Values for **M** (in yr^{-1}) will be drawn from the uniform distribution [0.4,1.0] as before. A value of σ_R will then be generated by the process detailed in Adjunct 1 below. Finally, the growth curve parameter k will be scaled to $\mathbf{M}$. The precise details of this procedure will be finalised by correspondence between Drs Agnew, Basson, Butterworth and de la Mare.

SENSITIVITY TESTS

1. Age Dependence of **M**

Given a value for **M** generated from $\mathbf{U}[0.4,1.0\text{yr}^{-1}]$, this value will be doubled to obtain the natural mortality for krill of ages 0, 1 and 2 years.

2. 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 the mature female numbers present at the start of December will remain unavailable to the fishery.

3. Recruitment Distribution

Censor the lower tail of the log-normal distribution so that recruitment cannot be less than 20% of the median value of the censored distribution. (The 'median value' is that for the appropriate spawning biomass.)

4. Age at First Capture

The original model has a selectivity-at-length profile with a width of 10 mm and a length at 50% vulnerability, $\mathbf{l}^{\mathbf{r}}_{\mathbf{50}}$, chosen from $\mathbf{U}[38,42\text{mm}]$. Change this to a width of 20mm, with $\mathbf{l}^{\mathbf{r}}_{\mathbf{50}}$ selected from $\mathbf{U}[35,37\text{mm}]$.

ADDITIONAL OUTPUTS

1. Statistics are to be provided for a 10- as well as a 20-year period of harvesting.

2. Statistics (median, 5%- ile and 95%- ile) are to be provided for the average P/B ratio during the harvesting period.

Adjunct 1

Method for estimating and modelling recruitment variability in krill potential yield calculations.

1. Length frequency samples and survey densities will be used to estimate representative length compositions (from research surveys, weighted by density estimates) for selected areas and years (for example, as in Loeb and Siegel, WG-Krill-92/12). This will be done for as many cases as possible; there is no need for there to be a time series for a given area. Single length compositions from disparate areas will be considered as independent, at least at this stage.

2. A size range which represents 2 year old krill will be selected to form an index of recruitment. Possibly the McDonald and Pitcher method will be used to estimate the number of 2 year olds in the sample, perhaps using growth curves to fix the modal length of 2 year olds for cases where there are no clear modes in the length composition. The ratio of 2 year olds to the total 2+ sample size is a Heinke estimate which provides an index of gross recruitment.

3. Parameters characterising the distribution of Heinke estimates will be estimated.

4. For a selected value of $\mathbf{M}$, $s_{\mathbf{R}}$ will be chosen so that the distribution of Heinke indices produced by the model is in accordance with that estimated from the length samples.

ATTEMPTS AT A BASIC ACCOUNTING FOR SUBAREAS 48.1 AND 48.2

D.J. Agnew

I attempt here to relate South Shetland Islands predator consumption, krill biomass in Subarea 48.1, and estimated values of **M**, developing the methodology from that discussed in WG-Krill-92/19.

2. Biomass estimates for Subarea 48.1 from Table 2.1 of WG-Krill-90 (SC-CAMLR-IX, Annex 4), Siegel (WG-Krill-91/15) and the FIBEX estimates excluding the *Walther Herwig* (Table 6 of WG-Krill-92/20) provide estimates of biomass between 0.5 and 2 million tonnes.

3. Siegel (WG-Krill-91/15) estimated production/biomass ratios for the South Shetlands of 0.94 and 0.83 (SC-CAMLR-X , Annex 5, paragraph 4.51) and therefore estimated total effective biomass during the summer months as about 2 million tonnes.

4. WG-Krill-91/15 also estimated residence times of three months in the southern Drake Passage.

5. WG-Krill-92/19 estimates total consumption by penguins in the South Shetlands as 280 thousand tonnes in the period December to February (estimates derived from independent models by Croxall *et al*. and Croll). This does not include fur seals, or pelagic predators; in order to consider these predators in the accounting, we may estimate total consumption = 1.5 x penguin consumption, although there is no empirical evidence for this factor.

6. Estimates of natural mortality **M** were given in Table 6 of WG-Krill-91 (SC-CAMLR-X, Annex 5); WG-Krill-92/4 uses values between 0.4 and 1.0.

7. If we assume that the predation mortality experienced by the part of the krill population resident in the South Shetlands over these three months is $^1/_4$ of the total natural mortality then we can use

$$\text{Consumption} = \text{Biomass} \times (1-\exp(-M/4))$$

to see if biomass, consumption and estimates of **M** are roughly in agreement.

8. Calculating **M** from Biomass and Consumption ('000 tonnes)

	Consumption - December to February	
	280	420
Biomass estimate: 2 000	**M** = 0.6	**M** = 0.94

9. Calculating Biomass from Consumption and **M** (biomass, consumption in '000 tonnes)

	Consumption - December to February	
	280	420
M = 0.4	2 900	4 400
M = 1.0	1 300	1 900

10. Parameter estimates from Subarea 48.2 are:

Biomass	7 m tonnes	(FIBEX, excluding *Walther Herwig*)
Consumption (penguins only)	153 000 tonnes	(December to February; WG-Krill-92/19)

Residence time: probably similar to Subarea 48.1 (see Table 1 of this report)

11. Calculating **M** from Biomass and Consumption ('000 tonnes)

	Consumption	
	153	229
Biomass: 7 000	0.09	0.13

12. Calculating Biomass from Consumption and **M** (biomass, consumption in '000 tonnes)

	Consumption	
	153	229
M = 0.4	1 600	2 400
M = 1.0	690	1 034

13. It is apparent from these calculations that the estimates do not balance well. This implies that either total consumption is underestimated (penguin consumption is a minor part of it) or Biomass and/or **M** are overestimated. For example, calculating Consumption from Biomass and **M**

	M	
	0.4	1.0
Biomass: 7 000	670	1 550

REFERENCES TO CCAMLR PUBLICATIONS AND DOCUMENTS

SC-CAMLR Document:

MILLER, D.G.M. and I. HAMPTON. 1988. Krill aggregation characteristics: Spatial distribution patterns from hydroacoustic observations. Document *SC-CAMLR-VI/BG/13*. CCAMLR, Hobart, Australia: 25 pp.

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Statistical Bulletin:

CCAMLR. 1990. *Statistical Bulletin, Vol. 2 (1980-1989)*. CCAMLR, Hobart, Australia: 109 pp.

DETAILS THAT SHOULD BE INCLUDED IN REPORTS OF ACOUSTIC SURVEYS OF KRILL BIOMASS AND/OR DISTRIBUTION

Papers should include, where appropriate, reference to the following topics:

1. SURVEY DETAILS

   Objectives, timing

   Design rationale - random/regular

   Map - including coastlines, bathymetry, acoustic transects, sampling sites.

   Number of transects and transect spacing

   Target trawls - type of net used, aimed or not, number of samples, duration of tows, depth range, time of day

2. ACOUSTIC SYSTEM

   Type and make

   Frequencies used

   Hull mounted or towed body ?

   Split-beam / dual-beam / single beam ?

   Echo integration, echo counting, swarm counting ?

   Integration intervals (vertical)

   Averaging intervals (horizontal)

3. CALIBRATION METHOD

   Methodology, equipment, location, water temperature, results

4. ANALYSIS OF RESULTS

   TS relationships

Length/weight relationships

Biomass variance estimates

Strata definitions

Method of calculation of areal density and volume density

S_a - surface density calculation

Methods used to generate distribution maps and abundance estimates

5. RESULTS

Distribution maps

Biomass estimates and variance estimates

Sizes of krill from target trawls, means and ranges

Any other relevant survey results

Basic data from which derived units arise should be presented

Standard units for reporting acoustic results should be used throughout