KRILL RESOURCES

Fishery Status and Trends

3.1 The krill catch for the 1990/91 season was 4.6% less than in 1989/90 and totalled 357 538 tonnes (Table 3.1).

Table 3.1: National krill landings (in tonnes) since 1983/84.

Member	Split-Year*							
	1984	1985	1986	1987	1988	1989	1990	1991
Chile	1 649	2 598	3 264	4 063	5 938	5 329	4 501	3 679
Germany	0	50	0	0	0	0	396	0
Japan	49 531	38 274	61 074	78 360	73 112	78 928	62 187	67 582
Republic of Korea	5 314	0	0	1 527	1 525	1 779	4 040	1 211**
Poland	0	0	2 065	1 726	5 215	6 997	1 275	9 571
Spain	0	0	0	379	0	0	0	0
USSR	74 381	150 538	379 270	290 401	284 873	301 498	302 376	275 495
Total	130 875	191 460	445 673	376 456	370 663	394 531	374 775	357 538

* The Antarctic split-year begins on 1 July and ends on 30 June. The column 'split-year' refers to the calendar year in which the split-year ends (e.g. 1989 refers to the 1988/89 split-year).

** From catch data tabled during the meeting.

3.2 The total krill catch by subarea since 1973 is illustrated in Figure 3.1.

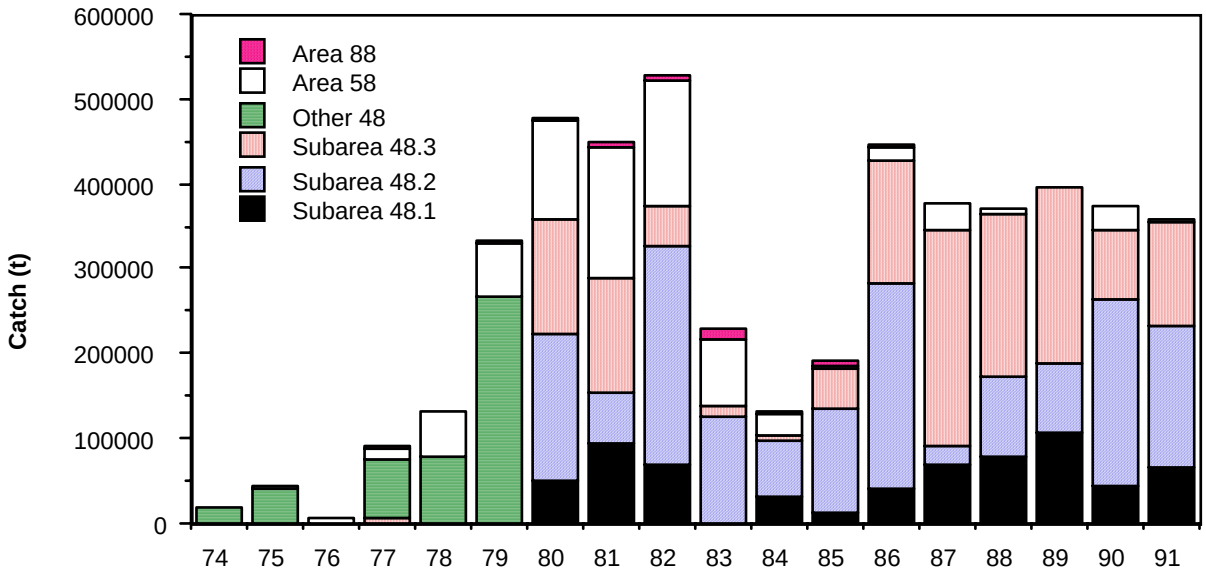

Figure 3.1: Total krill catches by subarea from 1973 to 1991. ('Other 48' refers to catches from Statistical Area 48 not allocated in Subareas 48.1, 48.2 or 48.3).

3.3 An analysis of the 1990/91 landings by area and subarea indicated a slight decrease in total catch from Statistical Area 48 compared with the previous two years. In this regard, Soviet catches in Subarea 48.2 decreased by approximately 61 000 tonnes compared with 1989/90, while in Subareas 48.1 and 48.3 they increased by 4 721 and 31 017 tonnes respectively.

3.4 In contrast to the above, there was a decrease in the overall catch in Subarea 58.4 (29 753 to 1 329 tonnes) and a slight increase in Statistical Area 88 (658 to 749 tonnes).

3.5 The total catch taken by the USSR was some 8% less than that taken in 1989/90 while catches by Japan were 8.7% greater. The latter was still some 9 000 tonnes below the 1988/89 level.

3.6 The total krill catch in 1990/91 by area and country is shown in Table 3.2

Table 3.2: Total krill catch in 1990/91 by area and country. The catch for 1989/90 is indicated in brackets.

	Chile	Germany	Japan	Korea	Poland	USSR
Subarea 48.1	3679 (4501)		54720 (33936)	1211 (4040)	310	4721
Subarea 48.2			1924 (1)		6020	159313 (220517)
Subarea 48.3		0 (396)	9606		3241 (1275)	110715 (79698)
Subarea 58.4			1329 (28250)			(1503)
Statistical Area 88			3			746 (658)
TOTAL	3679 (4501)	0 (396)	67582 (62187)	1211 (4040)	9571 (1275)	275495 (302376)

3.7 Dr M. Naganobu (Japan) indicated that the Japanese krill fishery is likely to be around the current level during the forthcoming year. During the 1990/91 season, only six vessels (five in the Scotia Sea and one off Wilkes Land) operated in the Convention Area compared with eight vessels in 1989/90.

3.8 Dr J. Lee (Korea) reported that the Korean catch in 1990/91 of some 1 211 tonnes was taken by one vessel and included 846 tonnes of krill which had been discarded. In reply to questions from a number of Scientific Committee Members, Dr Lee explained that the high level of discarded krill was a unique event which could be attributed to a freezer breakdown aboard the vessel concerned and was unlikely to occur in future years. The Korean catch in the forthcoming 1991/92 season was also unlikely to increase dramatically from mean levels (± 2 000 tonnes) taken over the past few years.

3.9 Dr V. Marín (Chile) reported that the Chilean fishery had caught some 19% less in 1990/91 than in 1989/90 of which 251 tonnes were processed into meal and 1 265 tonnes into frozen krill. Based on current information, catch levels in 1991/92 were unlikely to change substantially.

3.10 In reporting the above, Dr Marín drew the Scientific Committee's attention to a paper he had tabled at the meeting of WG-Krill in Yalta in which haul-by-haul data from the Chilean krill fishery during the 1990/91 season had been analysed (see WG-Krill-91/39 and paragraph 3.20 below).

3.11 Dr K. Shust (USSR) indicated that Soviet catches were unlikely to increase in 1991/92, although slight fluctuations in overall catch levels could be expected as a result of variations in krill catchability and economic demands.

3.12 The Scientific Committee was informed that an application from an Australian company to harvest up to 80 000 tonnes of krill annually is currently under consideration by the Australian Government.

3.13 As emphasised at its Ninth Meeting (SC-CAMLR-IX, paragraph 2.11), the Scientific Committee once again reiterated the utility of reviewing Members' intended commercial krill fishing activities for the forthcoming season (see also paragraph 3.20 below).

3.14 Papers distributed at the meeting and relevant to the krill agenda item dealt with a proposal for a project aimed at modelling krill aggregation dynamics (SC-CAMLR-X/9), precautionary catch limits for krill (SC-CAMLR-X/10), krill catches and consumption by land-based predators (SC-CAMLR-X/BG/7), catch-per-unit effort and krill body length from the Japanese fishery in Subarea 48.1 (SC-CAMLR-X/BG/10), the consumption of krill by fish in Division 58.4.2 (SC-CAMLR-X/BG/11) and proposals for the format of observations to be made on commercial fishing vessels in the Convention Area (SC-CAMLR-X/8).

Report of the Working Group on Krill

3.15 The Third Meeting of the Working Group on Krill (WG-Krill) was held in Yalta, USSR from 22 to 30 July 1991. This meeting, which was attended by 39 participants from 15 Member countries, was preceded by a meeting of WG-Krill's Subgroup on Survey Design between 18 and 20 July 1991. The latter meeting was convened by Dr I. Everson (United Kingdom).

3.16 Having briefly outlined the objectives of both WG-Krill's (SC-CAMLR-IX, paragraphs 2.59 to 2.61; CCAMLR-IX, paragraphs 8.1 to 8.14) and the Subgroup's (SC-CAMLR-IX, Annex 4, paragraph 97) meetings, the Convener of WG-Krill, Mr D. Miller (South Africa), presented the reports of both meetings (SC-CAMLR-X/4).

3.17 The Working Group's and Subgroup's reports are attached in Annex 5.

3.18 In reviewing the reports, the Scientific Committee thanked the Conveners and all the participants for their input. There were some 75 background papers presented to the Working Group (43 papers) and Subgroup (32 papers) and the relevant lists of documents are given in Annex 5, Appendix C and Appendix D, Attachment 2 respectively.

3.19 The Scientific Committee endorsed both WG-Krill's and the Subgroup's reports and made use of their findings as a basis for discussion. In the interests of brevity and to avoid unnecessary duplication, only a brief summary of the two reports is given below. Wherever paragraphs of either the Working Group or Subgroup report were accepted with little or only minor revision, the reader is referred to the relevant paragraphs of Annex 5. Consequently, the following summary should be read in conjunction with the two reports.

Review of Fisheries Activities (Annex 5, paragraphs 3.1 to 3.14)

3.20 The Scientific Committee noted that WG-Krill had endorsed the principle that Members fishing for krill should provide the Commission with information on the number of fishery vessels expected to be operational during the forthcoming season along with their catching capacity (see also paragraph 3.13 above). Both items of information were seen as being helpful in the determination of likely levels of fishing effort being deployed in the Convention Area (Annex 5, paragraph 3.6).

3.21 The value of haul-by-haul data from the krill fishery, particularly in the vicinity of land-based predator colonies, as well as information from scientific observers based on Soviet commercial vessels was also noted (Annex 5, paragraphs 3.7 to 3.9). In this connection, the Scientific Committee agreed that the collection of biological and other data from commercial krill fishing vessels remains a top priority in WG-Krill's work. It was also acknowledged that only scientific observers will collect such data.

3.22 The Scientific Committee noted that despite this call for an investigation of the by-catch of young fish in the krill fishery (SC-CAMLR-IX, paragraph 3.19) only one paper had been tabled at WG-Krill and that no new data are yet available on the by-catch of larval fish in that fishery. Consequently, it reiterated its call for further investigation of the problem.

3.23 Finally, the Scientific Committee agreed that there is a critical need for work on the mortality of krill not retained in krill trawls if the impact of the fishery is ever to be fully assessed (Annex 5, paragraphs 3.11 and 3.12).

Information Necessary for Management of Krill Resources (Annex 5, paragraphs 4.1 to 4.14)

Survey Method and Biomass Estimations

Review of Subgroup on Survey Design's Work

3.24 The Scientific Committee noted that the Working Group had emphasised that simulation studies would have particular application in the development of specific survey designs which involve geostatistical analysis, particularly since they would also provide some indication of the robustness of various estimators. Further work on the application of geostatistics in the analysis of krill survey data and associated simulation studies were therefore encouraged (Annex 5, Appendix D, paragraph 4.7).

3.25 The spatial scales (micro - a few to 10s km, meso - 10s to 100s of km, and macro - 100s to 1 000s km) of application of the analytical techniques discussed by the Subgroup (Annex 5, Appendix D, paragraphs 48 and 56) were accepted by the Scientific Committee in their application to the monitoring of prey in relation to data from CEMP monitoring of predators.

Prey Surveys for CEMP (Annex 5, paragraphs 4.9 to 4.15)

3.26 In considering prey surveys for CEMP, the Subgroup developed a design applicable to prey information in the context of predator parameter A5 (Penguin Foraging Trip Duration) in the Antarctic Peninsula Integrated CEMP Study Region.

3.27 This survey design (Annex 5, Appendix D, Attachment 4) was accepted by the Scientific Committee. Although different in layout to the guidelines recommended last year (SC-CAMLR-IX, paragraph 2.47 and SC-CAMLR-IX, Annex 4, paragraph 100), it was agreed that if offered significant advantages in terms of standing stock estimation and the determination of krill distribution within a given area (Annex 5, paragraphs 4.11 to 4.13).

3.28 The Scientific Committee noted that WG-Krill had requested WG-CEMP to provide an indication of the types of information on krill distribution and aggregation likely to be important in improving understanding of predator/prey interactions.

Survey for Direct Abundance Estimation
(Annex 5, paragraphs 4.16 to 4.20)

3.29 The Scientific Committee endorsed the deliberations and guidance of the Subgroup and WG-Krill concerning the conduct of krill abundance surveys in the southwest Atlantic (Annex 5, Appendix D, Attachment 4, Survey Designs 2, 3 and 4).

Future Work on Krill Survey Design
(Annex 5, paragraphs 4.21 to 4.23)

3.30 The Scientific Committee endorsed WG-Krill's proposals on further work to be directed at developing general principles and specific details to be used in the design of krill abundance surveys (Annex 5, paragraph 4.21).

3.31 In this connection, a Soviet proposal outlining the construction of a model on which to base simulation studies using real acoustic survey data to develop survey designs and analytical procedures was considered (SC-CAMLR-X/9).

3.32 The Scientific Committee agreed that this was a useful proposal and encouraged further development of the projects. However, the Scientific Committee did not see its way clear to provide a financial contribution to support the Soviet proposal at this time.

Krill Biomass Estimation (Annex 5, paragraphs 4.24 to 4.31)

Acoustic Target Strength

3.33 In keeping with the priority that it had afforded to this topic at its last meeting (SC-CAMLR-IX, paragraph 2.32 and 2.33), the Scientific Committee noted the considerable progress in the refinement and re-assessment of krill acoustic target strength (Annex 5, paragraphs 4.24 to 4.30).

3.34 The Scientific Committee endorsed the conclusion of WG-Krill that the BIOMASS function for krill target strength at 120 kHz should not be used to convert measurements of volume backscattering strength to biomass. Pending a more formal review of the problem, the Scientific Committee recommended that the following definition, derived from Green *et a1*. (1991: *Nature 349*: 110) should be used:

$$TS\ (dB) = -127.45 + 34.85\ X\ Log_{10}\ (length\ in\ mm).$$

3.35 The Scientific Committee also endorsed the suggestions concerning additional measurements of krill target strength (Annex 5, paragraph 4.30(ii)).

Estimation of Yield and Production (Annex 5, paragraphs 4.32 to 4.51)

3.36 Refinement of estimates of krill yield and production were afforded high priority by the Scientific Committee at its last meeting (SC-CAMLR-IX, paragraphs 2.21 to 2.28 and 2.40).

3.37 The Scientific Committee therefore noted WG-Krill's attempts to produce such estimates (Annex 5, paragraphs 4.32 to 4.42) and endorsed its conclusion that further work is necessary to investigate the sensitivity of λ (the numerical factor relating potential yield to unexploited biomass and natural mortality) to various factors.

3.38 The urgent need for length frequency data from commercial krill catches was re-emphasised in the context of refining estimates of age-at-first-capture, one of the factors likely to affect λ.

3.39 In general, there was agreement that the approach followed by WG-Krill in the estimation of krill potential yield emphasises the need for the refinement of important input parameter values, particularly natural mortality (**M**) and recruitment variability.

3.40 Once again major problems associated with estimating emigration and immigration rates in the calculation of $\mathbf{B_0}$, initial biomass, were noted. The Scientific Committee agreed that further calculations should be undertaken for WG-Krill's next meeting along the lines set out in Appendix E of WG-Krill's report.

3.41 Dr M. Mangel (USA) stated that he considered the approach outlined above to provide a useful basis for addressing a difficult problem. He shared the Working Group's reservations concerning the compensatory nature (Annex 5, paragraph 4.38) of some of the assumptions underlying the model considered by the Working Group, the need to improve allowance for local predator demands (Annex 5, paragraph 4.39) as well as to take more specific account of all components of the krill stock (i.e., other than spawning animals) and the strong need for length frequency data from the fishery (Annex 5, paragraph 4.21).

Distribution and Movement (Annex 5, paragraphs 4.52 to 4.82)

3.42 The Scientific Committee took particular note of WG-Krill's deliberations on the effects of water movement on the distribution of krill.

3.43 The Scientific Committee recognised that the direct estimation of the krill biomass effectively available on a given fishing ground or in a subarea could require synoptic surveys over much larger areas. Alternatively, krill movements (i.e., fluxes) could be investigated directly which would require knowledge of krill input, export and residence times in a particular area or region.

3.44 The Scientific Committee therefore agreed that the various hypotheses developed by WG-Krill (Annex 5, paragraph 4.74) provide a useful framework for further development of analyses aimed at understanding the dynamics of krill fluxes between subareas of the Scotia Sea. Consequently, Members were urged to prepare submissions to WG-Krill's next meeting on the potential magnitude of key fluxes in this region, particularly in the context that such information is crucial to further assessment of krill potential yield in the subareas concerned.

3.45 The Scientific Committee emphasised that any reports or publications from surveys aimed at assessing the role of movement of krill should provide full details of survey

techniques and analyses. Details on the statistical (i.e., coefficients of variation, etc.) and operational (survey design criteria and coefficients of variation, etc.) constraints of such surveys should also be provided in survey reports.

3.46 Furthermore, the influence of krill flux on the distribution of specific components of the krill population (e.g. length and/or maturity stages) and the estimation of yield in certain subareas should be explored. The role of vertical migration should also be considered.

Demographic Parameters (Annex 5, paragraphs 4.83 to 4.94)

3.47 The three tables of published krill demographic parameter values produced by the Working Group were noted by the Scientific Committee (Annex 5, Tables 2 to 4). The Scientific Committee also acknowledged that WG-Krill had not had sufficient time to thoroughly examine these values or the way in which they had been derived. It was agreed that this should be undertaken at the Working Group's next meeting and that a review of length/weight relationships for various sized animals be included.

3.48 The Scientific Committee urged Members who have additional information on krill demographic parameters to submit these to the next meeting of WG-Krill.

Advice to WG-CEMP (Annex 5, paragraphs 5.1 to 5.15)

3.49 Having already considered matters relevant to krill (prey) survey design (see paragraphs 3.26 to 3.28 above), the Scientific Committee endorsed WG-Krill's requests to WG-CEMP (Annex 5, paragraph 5.9) for additional information concerning krill's role as a prey item for various predators. WG-CEMP's response to this request was considered in more detail under Agenda Item 6 (see paragraphs 6.53 to 6.57 below).

3.50 Particular note was taken of WG-Krill's concern with obtaining realistic estimates of krill eaten by predators in various geographic areas, especially as these may relate to estimating the potential yield of krill stocks and in the calculation of the required krill escapement from the fishery. In this context, the Scientific Committee noted the need for an on-going dialogue between WG-Krill and WG-CEMP concerning the need for operational definitions of Article II with respect to krill fishing and predator monitoring (SC-CAMLR-IX, paragraph 2.19) (see also paragraphs 6.34 to 6.39, 6.60 and 12.4 below).

3.51 The Scientific Committee agreed that that there is a need for closer evaluation of the potential impact of highly-localised commercial krill catches on land-based predators. Also, since the variability in the ratio between krill consumption by predators and commercial krill catch levels is unknown, this should be taken into account when assessing interactions between the fishery and other krill consumers (see also paragraphs 3.66 to 3.68).

Development of Approaches to Managing the Krill Fishery (Annex 5, paragraphs 6.1 to 6.30).

Operational Definitions of Article II (Annex 5, paragraphs 6.1 to 6.7)

3.52 Despite requests from the Scientific Committee and Commission in 1990 (SC-CAMLR-IX, paragraph 2.19 and CCAMLR-IX, paragraph 4.17), it was noted that no further operational definitions of Article II had been received by WG-Krill since its last meeting (SC-CAMLR-IX, Annex 4, paragraph 61).

3.53 The Scientific Committee agreed that this matter requires further attention and that it should be considered in the context of (a) particular management procedure(s) and the associated mechanisms for monitoring the krill resource.

Possible Approaches to Managing the Krill Fishery and their Development (Annex 5, paragraphs 6.4 to 6.30)

3.54 The Scientific Committee noted that WG-Krill had continued to develop approaches to management of the fishery in keeping with the former's request (SC-CAMLR-IX, paragraph 2.60).

3.55 WG-Krill had set out the various advantages and disadvantages for seven management approaches which may be applicable to the krill fishery, namely: reactive management (Annex 5, paragraphs 6.5 to 6.10); predictive management (Annex 5, paragraphs 6.11 to 6.15); open and closed areas (Annex 5, paragraphs 6.16 to 6.19); indicator species (or other indirect methods (Annex 5, paragraphs 6.20 to 6.24)); pulse fishing (Annex 5, paragraphs 6.25 and 6.26); and feedback management (Annex 5, paragraphs 6.27 to 6.29).

3.56 The Scientific Committee agreed that reactive management does not constitute a viable long-term strategy for management of the krill fishery and that the development of a

feedback management procedure for krill should be a long-term aim. In the meantime, the various other approaches discussed by WG-Krill provide the basis for the formulation of advice on precautionary measures for the krill fishery that had been requested by the Commission (CCAMLR-IX, paragraphs 8.1 to 8.14 and paragraphs 6.27 to 6.29 below).

3.57 The Delegations of Chile and Spain stated that it would be desirable to develop studies concerning the inter-relations of krill and the fishing fleet, with the idea of incorporating the principle of management based upon controlling the fishing effort.

Precautionary Limits on Krill Catches
(Annex 5, paragraphs 6.56 to 6.66)

3.58 The Scientific Committee noted that in dealing with the Commission's request for an indication of the best estimate of a precautionary limit for krill in various statistical areas and an identification of the various options on which such a limit could be established (CCAMLR-IX, paragraph 8.5), WG-Krill had taken cognisance (Annex 5, paragraphs 6.31 and 6.32) of reservations expressed last year by the USSR, Japan and Korea (CCAMLR-IX, paragraph 8.7).

3.59 Nevertheless, the Working Group had recognised that the rationale underlying the consideration of precautionary measures is the prevention of an inordinate expansion of the fishery at a time when information available for predicting potential yield is limited. The Scientific Committee agreed that such measures should be considered as short-term, require regular review and should only be applied on an interim basis to be superseded as soon as improved information on which to base management decisions becomes available (Annex 5, paragraph 6.34).

3.60 The Scientific Committee also agreed with WG-Krill that initially the provision of estimates for precautionary limits should be expressed in the form of catches (Annex 5, paragraph 6.33). It recognised, however, that such limits could be formulated in different terms (e.g. closed areas or effort controls) to achieve similar aims.

3.61 The inherent difference between precautionary measures based on whole statistical areas as opposed to individual subareas was recognised (Annex 5, paragraphs 6.35 and 6.36).

3.62 WG-Krill had considered two alternative bases for specifying precautionary limits in Statistical Area 48. Briefly, these were based on historical catches (Annex 5, paragraphs 6.38

to 6.41) and estimates of potential yield (Annex 5, paragraphs 6.42 to 6.55) derived via the formula $Y = \lambda MB_o$. The Working Group also used a model-based approach to derive an appropriate level of fishing effort in relation to the available krill stock and to the demands of associated predators (Annex 5, paragraphs 6.56 to 6.59).

3.63 With respect to the general approach based on historical catches in Statistical Area 48, the Scientific Committee noted the following objections raised during the Working Group's meeting (Annex 5, paragraph 6.41):

(i) there is little scientific basis in relation to assessment of the stock;

(ii) the limits could be unnecessarily restrictive if the stock is capable of yielding much greater amounts of krill than have been taken historically; and

(iii) it takes no account of changes in fishing effort due to economic and other factors.

3.64 Some Members noted that the use of historical catches is a mechanistic approach and therefore has less empirical justification than an approach based on stock assessment.

3.65 A number of Scientific Committee Members felt that despite the above limitations, historical catches did indeed provide a useful basis on which to develop precautionary measures since *inter alia*:

(i) there is no evidence thus far to suggest that historical catch levels in Statistical Area 48 had significantly impacted either on krill stocks or on associated predators dependent on these stocks for food;

(ii) historical catch levels did in fact provide some indication of economic trends and/or possible operational variability in the fishery; and

(iii) given the uncertainties associated with the derivation of precautionary limits based on estimates of krill potential yield (see paragraphs 3.66 to 3.70 below), historical catches offer a conservative approach to the setting of such limits.

3.66 In estimating a precautionary limit in Statistical Area 48 based on the yield approach (Annex 5, paragraphs 6.42 to 6.55), the Working Group noted that the resultant figure would be higher than appropriate for such a limit on krill catches since:

(i) the precautionary limit should be below the possible ultimate level for the fishery, since later growth of the fishery as it approached such a limit should take place under an improved management procedure (e.g. feedback control would be exercised); and

(ii) allowance should be made for uncertainty in the estimates of the parameters used in the $Y = \lambda M B_0$ calculation.

3.67 For these reasons, WG-Krill had attempted to introduce a discount factor **d** into the above formula. A component of this factor would take account of the escapement of krill from the fishery necessary to meet predator demands, although such demands would to some extent be implicitly assumed in the estimate of **M** (Annex 5, paragraphs 6.43 to 6.49).

3.68 The Scientific Committee acknowledged that there is uncertainty associated with the estimation of an appropriate discount factor, especially in relation to the need to take explicit account of predator demands. However, this is not the only, or necessarily the most appropriate means of taking into account predator requirements. For example, closed areas and seasons may be more effective in reducing the possible impact of fishing close to predator colonies.

3.69 The Scientific Committee also noted WG-Krill's efforts to take account of possible flux effects when using localised surveys of krill biomass to derive precautionary limits by subarea (Annex 5, paragraphs 6.51 to 6.53). Consequently, it endorsed the Working Group's preferred basis for calculation of a precautionary limit in Statistical Area 48 which, being based on a direct estimate of biomass (i.e., of $\mathbf{B_o}$) in the area as a whole during FIBEX, exhibited little necessity for a flux adjustment (Annex 5, paragraph 6.54).

3.70 The above estimate for a precautionary limit on the krill catch in Statistical Area 48 was comparable to those obtained by the Working Group using other methods. Such methods attempted to account for fluxes (paragraph 3.69) or were derived via various approaches (Annex 5, paragraph 6.56 to 6.59).

3.71 Based on all the approaches considered by WG-Krill, the Scientific Committee noted that its best estimate for a precautionary catch limit on krill in Statistical Area 48 stands at 1.5 million tonnes which corresponds to a potential yield in the order of 2.2 million tonnes and a $\mathbf{B_0}$ of 15 million tonnes.

3.72 The resultant estimate for a precautionary limit on the krill catch in Statistical Area 48 derived by the latter method, was comparable to those obtained whereby specific allowances were made for fluxes (paragraph 3.70) as well as those derived via a number of other approaches (Annex 5, paragraphs 6.56 to 6.59).

3.73 The Scientific Committee acknowledged the Soviet and Japanese views with respect to the limit in paragraph 3.71. These views are contained in Annex 5, paragraphs 6.63 and 6.65 to 6.66 respectively.

3.74 There was general agreement within the Scientific Committee that the limit referred to above would not necessarily constitute a conservative catch limit since some account would also need to be taken of total krill mortality arising from fishing (see paragraph 3.23 above).

3.75 The Scientific Committee appreciated that a shortage of time had precluded the Working Group undertaking similar precautionary limit calculations for other areas and recommended that these calculations should be performed as soon as possible.

3.76 The Scientific Committee agreed that the above estimate for Statistical Area 48 should be divided on a subarea basis so as to allow for the possibility of separate krill stocks in subareas.

3.77 The division referred to in paragraph 3.75 may be achieved in a number of different ways. Results contained in paper SC-CAMLR-X/10 represented an attempt to calculate limits for individual subareas within Statistical Area 48 based on *pro-rata* division of FIBEX data. Some Members expressed reservations concerning results of the analysis in this paper, however, other Members regarded these results as a useful first attempt to break down the areal precautionary limit on a subarea basis.

3.78 The Scientific Committee recognised that in order to refine precautionary limits by subareas of Statistical Area 48, it is essential that the FIBEX data be re-analysed taking into consideration the appropriate re-definition of the survey strata which would be applicable at subarea level. This task was afforded high priority.

3.79 Dr Naganobu indicated that in his view any subareal division in the calculation of precautionary limits is premature at this stage. In his opinion, this is because the available scientific information on which to base any subarea divisions is still subject to considerable uncertainty. He agreed, however, that further research was needed and drew the Scientific

Committee's attention to the following topics which had been identified by WG-Krill (Annex 5, paragraph 7.16) and which he considered should be addressed in this regard.

(i) Investigations of flux in areas and subareas.

(ii) Estimation of total effective biomass in areas and subareas.

(iii) Refinement of calculation of potential yield including further evaluation of the underlying population models and demographic parameters used in such calculation.

He added that more surveys are necessary to address these problems and to collect the data required.

3.80 The need to consider even finer spatial breakdowns than statistical subareas was emphasised as important in the context of containing the potential impact of localised fishing within restricted predator foraging areas.

3.81 One way of limiting the possible localised impact of the fishery would be to use historical fine-scale catch data in combination with predator foraging range information to identify areas of potential overlap in space and time between the fishery and predators feeding on krill. In these areas, some level of historical catch (i.e., lowest, mean or highest) could then be applied in the setting of finer-scale precautionary limits.

3.82 The further definition of regions where potential overlap between fisheries and foraging predators may occur was thus seen as a priority task for the future calculation and division of precautionary krill limits at scales finer than that of a statistical subarea.

3.83 The potential impact of localised fishing can also be addressed by applying an approach which combines the precautionary limit for Statistical Area 48 derived from the estimate of yield with the approach based on historical catches. This entails limiting krill catches from existing fishing grounds near land-based predator colonies to the highest catches ever taken on these grounds. Thus the potential impact on local predators would be contained close to historic levels.

3.84 Alternatively, a combination of procedures could be applied. For example, closure of specific areas where the fishery and predators are found could be implemented for specific periods or in a variable manner. With respect to the latter, there may be some benefit in

ensuring that detailed information is obtained on fishing carried out in close proximity to some predator colonies in an attempt to determine functional relationships between the fishery, krill stock and predator stock concerned. Also, closure of specific areas to fishing where predator monitoring studies are underway would allow monitoring of predator stocks remote from any possible fishery effects.

3.85 In all instances, the application of any precautionary limit based on catch limitations will necessitate a complementary catch reporting system at a spatial and temporal scale appropriate to that to which the limit is being applied.

3.86 With respect to re-assessment of the so-called 'krill-surplus' perception raised at WG-Krill (Annex 5, paragraph 8.3), the Scientific Committee noted the views of WG-CEMP (Annex 7, paragraph 7.19). After some discussion, the Scientific Committee was unable to provide WG-Krill with specific guidelines as to the most effective way to pursue this matter further.

New and Developing Fisheries (Annex 5, paragraphs 7.5 to 7.9)

3.87 The Scientific Committee endorsed WG-Krill's comments on this matter and agreed that the definition suggested by the Secretariat should be expanded for assessment purposes (see also discussions under Agenda Item 9, Development of Approaches to Conservation of Antarctic Marine Living Resources).

CCAMLR Scheme of International Scientific Observation
(Annex 5, paragraphs 7.10 to 7.12)

3.88 The Scientific Committee noted WG-Krill's deliberations on this matter and endorsed the observer forms which the Working Group has developed (see also discussions under Agenda Item 10, CCAMLR Scheme of International Scientific Observation).

Data Requirements

3.89 In view of the continued shortage of much of the information requested at its last meeting (SC-CAMLR-IX, paragraphs 2.63 to 2.68) and highlighted by the Working Group (Annex 5, Table 6), the Scientific Committee reiterated its request for such information in

view of the continued need to monitor the krill fishery. In particular, it endorsed WG-Krill's request that:

(i) length frequency data from fine-scale reporting areas should be submitted to the Secretariat, even though the collection of such data may, to a large extent, only be possible by specially trained personnel; and

(ii) haul-by-haul data from the commercial fishery should be collected and submitted to the Secretariat. It was recognised that the collection and submission of such data may, on occasion, be problematic.

3.90 In this respect, Chilean fisheries have been able to provide haul-by-haul data, while USSR fisheries have experienced technical difficulties with the implementation of this requirement, and the Japanese and Korean Delegations have indicated that they are unable to report haul-by-haul data as a result of legislation in their countries.

3.91 Dr R. Holt (USA) indicated that in his view the continued lack of submitted length frequency and haul-by-haul data (paragraphs 3.89(i) and (ii)) constituted an unfortunate cycle of events based on the assertion that the collection of such data was too expensive or too hard. In this connection, the Scientific Committee agreed that some indication of the cost incurred by fishing operators in the collection of such data would be useful.

Future Work of WG-Krill

3.92 The Scientific Committee noted that the work of WG-Krill has progressed well. In particular, the specification of prey survey designs, the refinement of potential yield estimates (including investigation of krill fluxes between subareas within Statistical Area 48), the estimation of precautionary limits and discussions on the development of various management approaches, were seen as being particularly important achievements.

3.93 The Scientific Committee thus endorsed the following topics as having the highest priority for the Working Group's work in the forthcoming year:

- 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 pertinent population models and demographic parameters used in such calculations; and

- further estimation of precautionary limits in various statistical areas and subareas.

3.94 The Working Group should continue to address problems associated with survey design, development of approaches to management and continued liaison with WG-CEMP on matters of concern.

3.95 In order to address these issues, which are fundamental to the development of advice on krill, the Scientific Committee recommended that WG-Krill should meet during the intersessional period for approximately one week during 1992.

3.96 This meeting is scheduled for 4 to 12 August 1992 and an offer by Chile to host it in Punta Arenas was gratefully accepted.

Advice to the Commission

General Advice

3.97 WG-Krill should hold an intersessional meeting during 1992 in order to continue review of commercial fishing activities, further refine estimates of potential yield and precautionary limits and sustain momentum in the development of approaches to structuring advice on krill resources.

3.98 The krill length-acoustic target strength relationship contained in paragraph 3.34 should be endorsed, as should the guidelines from the conduct of krill (prey) surveys in paragraph 3.27.

3.99 The collection of haul-by-haul data from the fishery should continue and wherever possible should be submitted to the Secretariat as a matter of priority. Similarly, the submission of length frequency data from the fine-scale reporting areas should also be encouraged.

3.100 Current estimates of krill potential yield based on the $Y = \lambda MB_0$ approach should be refined with respect to investigation of the sensitivity of the vital numerical parameter λ.

3.101 In an attempt to refine subarea estimates of precautionary limits for krill and catches in Statistical Area 48, re-analysis of the basic FIBEX data should be undertaken as soon as possible. The involvement of the BIOMASS Data Centre and the subsequent costs likely to be incurred as a result should be formally acknowledged.

3.102 Estimates of precautionary limits for krill should be carried out for other statistical areas as a matter of urgent priority.

Specific Advice on the Status of Krill Stocks

3.103 The Scientific Committee agreed that reactive management - the practice of taking management action only when the need for it has become apparent - is not a viable long-term strategy for the krill fishery. Some form of feedback management, which involves the continuous adjustment of management measures in response to information, is to be preferred as a long-term strategy. In the interim, a precautionary approach is desirable and in particular, a precautionary limit on annual catches should be considered.

3.104 The Scientific Committee considered that for Statistical Area 48, an annual catch limit of 1.5 million tonnes based on estimates of potential yield is the best available.

3.105 There are important caveats associated with this catch limit.

- First, the limit needs to be divided into subareas to allow for the possible interactions between krill populations in these subareas.

- Second, it may need to be supplemented by other management measures to ensure that the catch is not entirely concentrated in the foraging range of colonies of vulnerable land breeding predators. Currently much of the krill catch in Statistical Area 48 is taken in such areas (SC-CAMLR-X/BG/7 and WG-Krill-91/39).

- Third, the limit has not involved an allowance for possible unreported mortality of krill associated with fishing operations (although there was very limited information on the matter).

3.106 Some Members of the Scientific Committee proposed an alternative approach to setting a precautionary catch limit which was aimed at meeting the caveats as presented in paragraph 3.105. This is to set a precautionary limit based on historical catches.

3.107 Two such options were reviewed. One was based on the maximum catch in the area as a whole in any one year: 425 900 tonnes. The second was based on summing the maximum catch in each subarea: 619 500 tonnes.

3.108 A further approach was proposed which would combine the precautionary limit of 1.5 million tonnes for Statistical Area 48, with the highest historic catches in the subareas. The latter would be used to provide an upper limit to catches on the existing fishing grounds near predator colonies.

3.109 Other Members were opposed to setting a precautionary TAC on historical catches. They did not believe such a method had any scientific basis (paragraphs 3.63 and 3.64).