ANNEX 4

REPORT OF THE WORKING GROUP ON ECOSYSTEM MONITORING AND MANAGEMENT

(Taormina, Sicily, Italy, 17 to 28 July 2000)

CONTENTS

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INTRODUCTION

Opening of the Meeting

1.1 The sixth meeting of WG-EMM was held at the Hotel Caparena, Taormina, Sicily, Italy, from 17 to 28 July 2000. Dr R. Hewitt (USA), Convener, welcomed participants and outlined the program for the meeting.

1.2 During an evening reception hosted by Prof. M. Bolognari, Mayor of Taormina, Prof. L. Guglielmo (Italy) welcomed participants. Ambassador Jacoangeli, Ministry of Foreign Affairs, officially opened the meeting and outlined key challenges facing the management of Antarctica and the Southern Ocean, and recent progress including the establishment of the Committee on Environmental Protection and the work of CCAMLR. Prof. Bolognari also welcomed participants to Taormina and hoped that the meeting would be successful in furthering the work of WG-EMM.

1.3 On behalf of CCAMLR, Dr D. Miller, Chairman of the Scientific Committee, thanked Prof. Guglielmo for hosting the meeting in Taormina, and Ambassador Jacoangeli and Prof. Bolognari for their warm welcome.

Adoption of the Agenda and Organisation of the Meeting

1.4 The Provisional Agenda was introduced and discussed. With the addition of one item, '7.3 Future Meetings of WG-EMM', the Agenda was adopted (Appendix A).

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

1.6 The report was prepared by Prof. I. Boyd (UK), Drs A. Constable (Australia), D. Demer (USA) and I. Everson (UK), Mr M. Goebel (USA), Drs D. Miller (Chairman of the Scientific Committee), E. Murphy (UK), S. Nicol (Australia), P. Penhale (USA) and D. Ramm (Data Manager), Mr K. Reid (UK) and Drs P. Trathan (UK), W. Trivelpiece (USA), J. Watkins (UK) and P. Wilson (New Zealand).

HARVESTED SPECIES

Fisheries Information

Catch Status and Trends

2.1 In the 1998/99 season, 103 318 tonnes of krill were caught entirely from the Atlantic sector. The catch came from Subareas 48.1 (38%), 48.2 (49%) and 48.3 (13%). Most of the winter krill catch was taken from Subarea 48.2 in contrast to previous seasons when the winter fishery had concentrated in Subarea 48.3. Of the catches reported in 1998/99, 88% had been reported as fine-scale data, mostly by 10-day periods.

2.2 A Polish catch of 254 tonnes was reported from Area 47, in the southeast Atlantic and outside the CCAMLR Convention Area. The Working Group expressed interest in receiving biological information on krill caught in this area.

2.3 Argentina had reported catches in 1998/99 but no notification had been made to the Working Group prior to commencement. The Working Group indicated that prior notification of new entrants into the krill fishery was extremely useful for determining trends in the krill fishery and all nations intending to enter the fishery should be encouraged to notify the Secretariat of their intentions.

2.4 In the 1999/2000 season, a total of 82 913 tonnes of krill have been reported by 5 July 2000. Catches have been reported by Japan (51 508 tonnes; four vessels), Republic of Korea (3 785 tonnes; two vessels), Poland, (19 093 tonnes; five vessels), Ukraine (823 tonnes; two vessels) and Uruguay (7 704 tonnes; one vessel). The Secretariat had received no reports of catches by vessels from other nations. All catches reported were from Area 48 (WG-EMM-00/25).

2.5 Five Member countries expected to be fishing for krill in the 2000/01 season. Japan expects to send four vessels and to catch at similar levels to 1999/2000, the Republic of Korea would send two vessels and expected to catch ~10 000 tonnes, the USA expects to have two vessels fishing for krill, Russia may send two vessels and South Africa may send one vessel for 180 days to produce whole krill and produce meal. No information was available from Ukraine, Poland, Argentina or Uruguay which have fished in recent seasons, and there was also no further information on the krill fishing venture proposed by Canada, a non-Member nation, which had been discussed at previous meetings (SC-CAMLR-XVIII, paragraph 2.2).

Trends in Fishery Development

Economics

2.6 The average wholesale price of krill from the Sydney Fish Market ranged between A$2.65 and 6.91 per kg in the period between 1992 and 1999 (WG-EMM-00/25, Table 4). Information on krill prices from markets where larger quantities of krill were frequently traded was still not available despite requests by the Working Group for these figures (SC-CAMLR-XVIII, Annex 4, paragraph 2.11).

2.7 The Working Group acknowledged that there were difficulties in accessing economic information on the krill fishery but reiterated the need for this information. The Working Group noted that an economic analysis of the relationship between the fisheries for *Euphausia superba* and *E. pacifica* had been produced recently (Yoshida, 1995) which indicates that economic information on krill fisheries is available and is reliable enough for predictions to be made from these analyses. The Working Group strongly encouraged the completion and submission of an economic analysis of the Antarctic krill fishery so that the economic trends underlying the development of this fishery can be determined.

Conversion Rates

2.8 Some descriptive information on conversion rates for krill products was presented (WG-EMM-00/12), but there was little information on the exact conversion rates which relate the amount of krill caught to the different products of the krill fishery from different fishing fleets, fishing areas or seasons. The Working Group encouraged the provision of detailed information on conversion rates of krill from Members involved in the krill fishery.

2.9 Although data presented on conversion rates from the fishery were largely descriptive, it was noted that there was additional information in the literature, particularly in the series of FAO reports which have dealt with krill: Budzinski et al. (1985), Everson (1977), Grantham (1977) and Nicol and Endo (1997) which might allow a more rigorous approach to estimating the conversion rate of fresh to processed krill. Drs Everson, Miller and Nicol agreed to analyse the information in these reports and present a summary of the results to the next meeting of the Working Group.

Fishing Strategies

2.10 Analyses of haul-by-haul data from a vessel from the Polish krill fishery provided further information on commercial fishing strategies (WG-EMM-00/17). Between 7 and 9.5 hauls were carried out per day, each lasting 60 to 70 minutes. Hauls during the day were deeper and had higher catch rates (4.35–9.33 tonnes per haul) than those at night (0.8–3.33 tonnes per haul). There were also regional and seasonal differences in catch rates.

2.11 Further information from the Japanese krill fishery included analyses of CPUEs and body lengths, krill trawling positions and by-catch. Relatively stable CPUEs, expressed as catch per haul, may be a result of efforts to keep catches constant and krill in good condition for processing. Seasonal movements of the fleet in 1998/99 were associated with changes in CPUEs and with changes in the length frequency of the catch (WG-EMM-00/57).

2.12 Krill trawling positions north of the South Shetland Islands in the period between 1980/81 and 1998/99 were not correlated with krill densities from scientific surveys but were correlated with scientifically sampled salp densities (WG-EMM-00/58). When salp densities were high in the scientific surveys the krill trawlers were found further to the south possibly to avoid salp by-catch. The Working Group encouraged further development of the model used in this investigation. Highest by-catch of salps in the commercial fishery was found in hauls with low krill catch rates (WG-EMM-00/54).

Assessment of Trends in the Distribution of Fishing

2.13 Dr Constable proposed that the time series of fine-scale catches shown in WG-EMM-00/25, Annex 1, was sufficient to examine long-term trends in the distribution of catches across Area 48 using a multivariate technique known as non-metric Multidimensional Scaling (nMDS). Such a technique would allow the Working Group to assess whether significant shifts were occurring in the pattern of fishing, including location and amount caught (Appendix D).

2.14 The Working Group agreed that this procedure may provide a useful tool for determining when the pattern of fishing might be changing in a particular season or over years, both in terms of the spatial distribution of catches and their relative location to sensitive areas and in the amount taken in different areas. The Working Group thanked Dr Constable for providing this analysis and recommended that the Secretariat explore this procedure further for the next Working Group meeting. Such exploration could involve examining the relative sensitivity of the outputs to different data transforms and different spatial scales for pooling the data, the method by which the results are presented, and the summary information that would be required to interpret the results.

Observer Scheme

2.15 At previous meetings, WG-EMM had encouraged implementation of the CCAMLR Scheme of International Scientific Observation in order to provide information to include in assessments and also to provide greater insight into ecosystem analysis. The CCAMLR 2000 Krill Synoptic Survey of Area 48 carried out in January and February 2000 (hereafter referred to as 'the CCAMLR-2000 Survey') was seen as a valuable opportunity to obtain information on the krill fishery for comparison with direct field observations.

2.16 The USA had designated one CCAMLR international scientific observer who had been accepted on the stern trawler *Chiyo Maru No. 5* by Japan. The observer's scientific report was tabled as WG-EMM-00/12. In addition, a national observer had reported on activities on the Ukrainian stern trawler *Konstruktor Koshkin* in WG-EMM-00/4.

2.17 Other reports on national surveys were tabled indicating that data had been collected in accordance the CCAMLR scientific observer protocols.

2.18 Prior to the 1999/2000 season, the Working Group had limited success in requesting that CCAMLR international scientific observers be placed on krill fishing vessels. It noted with pleasure that the necessary bilateral arrangement had been set up between the USA and Japan to effect such placement in 2000. This was the second such venture between two countries. However, several difficulties had been encountered which the Working Group discussed in order to provide better guidance for future such arrangements (paragraph 2.29).

2.19 The main problems encountered were associated with the estimation of total catch, the representivity of samples for determination of by-catch, time budgets and factors to estimate the weight of fresh krill from product weights.

2.20 Currently it appears that the total catch is estimated from product weights and that these may be in error due to inappropriate conversion factors being applied and no account being taken of discards (see also SC-CAMLR-XVIII, paragraph 2.5). The Working Group considered this a high priority and requested the Secretariat to obtain information on the methods used by fishers to determine the total removals.

2.21 Following WG-EMM in 1999, the Secretariat had developed a questionnaire (WG-EMM-00/25), seeking information on krill fishing strategies, which had been sent to all Members on 4 May 2000. The Data Manager reported that no responses had been received. This was regretted and the Working Group reiterated the urgent need for such information. The Working Group also requested that the questionnaire be sent out again with a strong request for responses particularly from fishers and Members designating observers whether national or as part of the international scheme.

2.22 Whilst there was value in conversion factors determined from biochemical analyses of fresh krill and krill products, as outlined in paragraphs 2.8 and 2.9, these should not be seen as a substitute for direct estimates from on-board processing. In this context the current procedure was considered to be inadequate. The Working Group recommended that facilities should be made on board for observers to make such estimates.

2.23 Dr S. Kim (Republic of Korea) stated that the reported Korean catch was derived from the mass of fresh krill caught. The krill were immediately frozen into 12 kg blocks, the water content of which was about 18%. This was equivalent to a catch-to-product conversion of 1:1.

2.24 The Working Group noted that the catch reporting procedure described in paragraph 2.23 did not necessarily provide information on the discarded portion of the catch.

2.25 Dr S. Kawaguchi (Japan) indicated that Japanese krill fishing vessels collect and report catch discards. These are taken into account when reporting total krill catches. The methods for reporting landed and processed catches by the Japanese krill fishery have been detailed in SC-CAMLR-XVIII, paragraph 2.5, along with the current conversion factors for various krill products in relation to fresh weight.

2.26 The CCAMLR international scientific observer on the *Chiyo Maru No. 5* had indicated that there were problems interpreting the protocols as set out in the *Scientific Observers Manual*. The observer was now working elsewhere but had been debriefed by Mr C. Jones (USA) who would be requested to seek clarification on the nature of the problems. Following discussion with interested parties, these matters would be set out as a proposal for consideration at the WG-EMM meeting in 2001.

2.27 The Working Group noted that even though the Scheme of International Scientific Observation had been in place since the 1992/93 fishing season, this was the first year in which an observer had been designated under the scheme in Area 48. Whilst welcoming this development, the Working Group noted that this provided information for only a very small part of the commercial fishery. Accordingly, the Working Group recommended to the Scientific Committee that a greater level of implementation of the program, including wider reporting of observer information, ideally to the extent of including all vessels engaged in the fishery, should be made. Information provided by national observers should be compatible with information required under the CCAMLR scheme. This will facilitate comparability of information provided from a wider areal coverage.

2.28 Both the USA and South Africa (see paragraph 2.5) noted an intention to make the carrying of scientific observers part of the permit conditions for their vessels on entering the krill fishery.

By-catch of Fish in the Krill Fishery

2.29 The CCAMLR international scientific observer on the *Chiyo Maru No. 5* had analysed 20 kg subsamples of the krill catch from 22 hauls (WG-EMM-00/12). Five small fish had been found suggesting that the overall by-catch of finfish was low. However, the observer did not have free access to the sample catches.

2.30 The national observer working in June–July on board the Ukrainian vessel *Konstruktor Koshkin* also reported on fish by-catch. Several hauls in water 110–170 m deep to the west of the South Orkney Islands (Subarea 48.2) were found to contain mackerel icefish (*Champsocephalus gunnari*) (length range 5–7 cm, maximum 12 cm). The largest catch was at 60°41’S 46°23’W where 200 icefish per tonne of krill were taken. At other stations in the vicinity the catch rate was 1–20 per tonne of krill.

2.31 The Working Group noted that these catch rates did not appear to be large and, in the case of the Ukrainian information, were confined to a limited area. Thus, as well as providing information on the potential impact of krill fishing on juvenile fish, the primary reason for the sampling, the data could also provide information on the distribution of the juvenile fish. It was agreed that consideration should be given to stratifying the sampling program to take account of anticipated density of juvenile fish. It was also agreed that those hauls which had been examined for the presence of fish larvae should be clearly identified.

Regulatory Framework

2.32 WG-EMM noted that progress has been made in elaborating a regulatory framework for the development of CCAMLR fisheries (SC-CAMLR-XVIII, paragraphs 7.11 to 7.23).

2.33 The Commission (CCAMLR-XVIII, paragraphs 10.6 to 10.11) has noted that the development of a unified regulatory framework for CCAMLR fisheries is an iterative process which may take some time to complete. Such development requires consideration of:

(i) steps in the development of a fishery;
(ii) procedures to guide the development of a fishery; and
(iii) designation of status to different categories or levels of the fishery.

2.34 WG-EMM noted that the Commission had tasked a small ad hoc group convened by the Chairman of the Scientific Committee with developing the regulatory framework further. It was agreed that a key consideration of how the current and future krill fishery would fit into such a framework is of concern to WG-EMM and that the framework is uniform across all fisheries while accounting for the special needs of individual fisheries. The ad hoc group was therefore requested to note this concern and to ensure that it is included in the Working Group's deliberations.

2.35 WG-EMM also recognised the strategic importance of having a regulatory framework to guide fishery development and to facilitate the formulation of appropriate management measures for, and data collection requirements from, a fishery. The ad hoc group was therefore encouraged in its work.

Regional and Local Surveys

2.36 Over 20 papers were presented to WG-EMM with information on krill derived from local and regional surveys. These surveys cover a number of years and various research areas around the Antarctic. The discussion of these papers was structured according to the spatial and temporal relationship of each dataset to the CCAMLR-2000 Survey that was carried out in January and February 2000.

2.37 Papers relating to aspects of the CCAMLR-2000 Survey itself (i.e. those papers that discuss surveys that formed part of the actual synoptic survey) were considered first. Note, however, that the presentation of the estimate of B_0 (i.e. krill standing stock) and variance from the CCAMLR-2000 Survey are presented in paragraphs 2.84 to 2.95. Papers containing information on krill that were taken within Area 48 (i.e. within the region covered by the synoptic survey) and in the same season as the CCAMLR-2000 Survey were considered second. These papers included ancillary surveys that were carried out within parts of Area 48, krill data obtained from krill predator studies and observer or commercial fishery data collected from Area 48. Third, data from surveys outside Area 48 but still within the same season as the CCAMLR-2000 Survey were considered. Then any data presented from surveys conducted within Area 48 in seasons prior to the CCAMLR-2000 Survey were considered. Finally, data presented for surveys outside Area 48 in the seasons prior to the CCAMLR-2000 Survey were considered.

Krill Length-frequency Data, Biomass and Distribution during the CCAMLR-2000 Survey

2.38 WG-EMM-00/6 Rev. 1 presented an analysis of the krill distribution patterns in Area 48 using data collected by Japan, Russia, UK and the USA during the CCAMLR-2000 Survey in January and February 2000. A cluster analysis of the krill length data revealed that there were three geographically distinct clusters of krill found across the Scotia Sea. Krill forming cluster 1 were essentially small krill with a modal size of 26 mm and were distributed in the south and east of the Scotia Sea, from an area adjacent to the South Sandwich Islands up to the eastern end of South Georgia. Krill from cluster 3, the largest and most mature krill with a modal size of 52 mm, occurred in the western oceanic waters of the Drake Passage and the Scotia Sea. Krill in cluster 2, of a size range intermediate between cluster 1 and cluster 3, were found in the inshore waters around the Antarctic Peninsula, separating the other two clusters in the Scotia Sea, and at the northeastern part of the survey area.

2.39 The krill length-density distributions for Subareas 48.1, 48.2, 48.3 and 48.4 are also presented in WG-EMM-00/6 Rev.1. For the period of the CCAMLR-2000 Survey the population structure in each of these subareas was very different. The Working Group noted that, during this survey at least, it appeared that the population structure observed in any particular subarea was not representative of the overall population structure in Area 48.

2.40 The Working Group also noted that there were differences between the length-density distributions presented for the subareas and the length-frequency composition of clusters above. For instance the lengths of the dominant modal size classes were different. It was suggested that such changes were attributable to differences between presentation of length-density and length-frequency data. The Working Group recommended therefore that further comparisons should be undertaken when all the data had been transformed to length-density data.

2.41 The Working Group also recognised that care should be taken when conditions observed in a regional survey were assumed to apply to a much larger management region. The important role of the large-scale synoptic survey to set local and regional surveys in a context of variation at larger spatial and temporal scales was re-emphasised.

2.42 The general pattern observed in WG-EMM-00/6 Rev.1 above, was presented in more detail in length-frequency data from individual RMT8 net hauls undertaken as part of the Russian contribution to the CCAMLR-2000 Survey carried out in Subarea 48.4 (WG-EMM-00/33). Three types of krill were identified in this subarea: juvenile krill (modal sizes 25–29 mm), subadult krill (modal sizes 35–49 mm) and mature krill (modal sizes 50–56 mm). A distinct distribution pattern was observed with hauls containing predominantly small krill occurring to the southwest of the South Sandwich Islands and with the largest krill occurring to the north of the islands. The maximum krill density (estimated from RMT8 net hauls) detected within Subarea 48.4 during the CCAMLR-2000 Survey occurred in the southwest of the survey area (1.67 g/m^3). Densities in the north and northeast of the survey area were generally low (0.005 g/m^3). The distribution of acoustic density attributed to Antarctic krill (defined where the difference between mean volume backscattering strength at 120 and 38 kHz was between 2 and 16 dB) also showed a similar pattern with the highest density being confined to the southwest of the South Sandwich Islands.

2.43 The distribution of acoustically detected krill was contrasted with distribution of acoustic backscattering from other zooplankton organisms in Subarea 48.4 (WG-EMM-00/50). Acoustic backscattering from zooplankton (defined where the difference between mean volume backscattering strength at 120 and 38 kHz was greater than 16 dB) occurred over the entire area studied in Subarea 48.4, but formed a greater proportion of the acoustic backscattering in the northern area of the survey. Backscattering attributed to targets larger than krill (defined where the difference between mean volume backscattering strength at 120 and 38 kHz was less than 2 dB), and so considered to represent myctophid fish, were observed in the north of the study area in water associated with the ACC.

Krill Length-frequency Data, Biomass and Distribution during Ancillary Surveys Conducted in Area 48 in 1999/2000

2.44 WG-EMM-00/52 presents length-frequency data obtained during the Korean cruise on the north side of the South Shetland Islands during January 2000. These data were collected with a bongo net with a much smaller mouth opening than the RMT8 used on the CCAMLR-2000 Survey. The overall length-frequency distribution had a modal size of 50 mm and again very few krill smaller than 40 mm were caught.

2.45 WG-EMM-00/10 presents length-frequency data obtained during the Peruvian cruise on the north side of the South Shetland Islands during January 2000. These data were collected using Methot and Engel nets (13 of the 15 hauls taken with the larger Engel trawl) rather than the RMT8 net specified for the CCAMLR-2000 Survey. The overall length-frequency distribution of krill caught during this survey had a modal size of 49 mm and few krill below 44 mm were seen.

2.46 The length-frequency data from the Korean and Peruvian cruises described above are taken from surveys that cover exactly the same area as the South Shetland Island mesoscale survey box sampled by Japan during the CCAMLR-2000 Survey. Even though the nets used in these three studies are different there was a great similarity in the krill sampled both during the CCAMLR-2000 Survey and in these two ancillary surveys. In all cases it was noted that no juvenile krill had been sampled.

2.47 The biomass estimated during the Korean survey of the South Shetland mesoscale region in January 2000 (WG-EMM-00/52) was 475 000 tonnes (krill density 12 g/m^2, CV 14.52%). This estimate appears to be directly comparable, in terms of technique used and transects surveyed, with the estimate obtained for this region during the CCAMLR-2000 Survey (see Appendix G, Table 25b).

2.48 Although a biomass estimate was presented for the Peruvian survey of the South Shetland mesoscale region (WG-EMM-00/10), it was noted that the conversion factor used to obtain areal krill biomass density was significantly higher than that used during the B_0 Workshop for the CCAMLR-2000 Survey. In addition, the survey area was estimated using a different technique from that used for the CCAMLR-2000 Survey. The Working Group agreed that this survey result would be a valuable addition to the ancillary survey dataset once these discrepancies had been removed and encouraged reanalysis of the data.

2.49 Dr Hewitt informed the Working Group that the USA had conducted an ancillary survey in the South Shetland Island area in February and March 2000. Densities of krill in the region of 20–25 g/m^2 had been obtained.

2.50 WG-EMM-00/55 listed the datasets collected by Japan for the ancillary survey of the South Shetland mesoscale region in December 1999. Although no data analysis was presented, the Working Group noted that taken together the ancillary datasets of Japan, Republic of Korea, Peru and USA provided a very valuable dataset and encouraged the timely analysis of these data (see also paragraph 2.124).

2.51 WG-EMM-00/51 presents information on the length-frequency data obtained during the AtlantNIRO–BAS Core Programme cruise around South Georgia (Subarea 48.3) in January 2000. This survey repeated the Core Programme transects carried out between 1995/96 and 1998/99 by BAS. In 1999/2000 krill were generally small (modal size 32 mm) in the core box to the northeast of South Georgia, while larger krill (modal size 41 mm) were seen in the western core box to the northwest of South Georgia. Krill density in the South Georgia region during early January 2000 was generally very low. In the western BAS Core Programme survey box the mean net (RMT8) density was less than 0.2 g/1 000 m^3, while in the eastern Core Programme survey box the densities were higher but still low at 1.8–4.7 g/1 000 m^3. It was noted that no concentrations of krill suitable for commercial fishing were detected.

2.52 The Working Group were informed that further analysis of the South Georgia Core Programme data collected in this year would be undertaken at a joint analysis workshop between AtlantNIRO and BAS in Cambridge, UK, in September 2000.

2.53 The Working Group recognised that the regional and local surveys in Area 48 during the same period as the CCAMLR-2000 Survey had provided a rich source of information which could be used to address questions such as when is the best time to sample the biomass and characteristics of the krill population.

Krill Length-frequency Data Collected from Predators
in Area 48 during the CCAMLR-2000 Survey

2.54 Four papers presented information on the length frequency of krill in the diet of predators sampled during the CCAMLR-2000 Survey. The size of krill in the diet of fur seals and penguins (Adélie, chinstrap and gentoo) at Admiralty Bay, South Shetland Islands, is described in WG-EMM-00/41. The modal size of krill in both fur seal and penguin diets was in the 46–50 mm size class; however the penguins took smaller krill than the fur seals. Given the different time periods when fur seals and penguins were sampled (penguins from December to February, fur seals from February to March), it was suggested that much of this variability could be explained by krill growth (approximately 0.1 mm/day).

2.55 The mean size of krill in the diet of fur seals at Cape Shirreff on Livingston Island in the South Shetland Islands between December 1999 and March 2000 was 55 mm (SD 3.15) (WG-EMM-00/59). In this case, visual examination of the weekly length-frequency plots did not show any obvious evidence of growth, although the lack of apparent growth could be due to the fact that the krill were approaching their maximum size.

2.56 The size of krill in the diet of chinstrap and gentoo penguins at this site also showed a modal value in the 46–50 mm size class in the year of the CCAMLR-2000 Survey (WG-EMM-00/62). Comparable samples from the two previous seasons had shown that there had been a consistent increase in the modal size of krill taken during the time series (36–40 mm in 1997/98 and 41–45 mm in 1998/99).

2.57 A different pattern was observed for krill length-frequency distributions obtained from fur seals at Bird Island on South Georgia in the period between July 1999 and early February 2000 (WG-EMM-00/19). Over the winter period (September–October 1999) a single-size mode of 44 mm krill was present. This mode increased in size during November reaching 50 mm by early December and 58 mm by the end of December 1999. In early December a new size class of krill (mode 42 mm) appeared and increased in abundance such that it dominated the population structure by February. Such a pattern of bimodality had been observed in previous seasons, particularly 1991, 1994 and 1998.

2.58 The Working Group discussed some of the problems associated with using predator diet data to obtain information on the population structure of krill. It was noted that, while some degree of selectivity had been described in previous studies, there was good evidence to suggest that when small krill are found in net samples they are also sampled by many of the predators. It was also noted that work on modelling the effect of krill selectivity by predators on length-frequency distribution of krill in diets was being carried out and would be presented in due course.

2.59 The Working Group noted that many of the size differences observed in predator diets fitted well with known differences in the distribution of krill. Thus size differences of krill consumed by penguins feeding inshore and fur seals feeding offshore were entirely consistent with the distribution of krill determined from net sampling. In addition it was noted that differences in the size of krill taken by fur seals at Cape Shirreff and Admiralty Bay were consistent with differences in the size and distribution of krill from these sites.

2.60 The Working Group also noted that at times there were abrupt changes from one week to the next in the length-frequency distributions of krill (WG-EMM-00/19). Such changes could be brought about through the interaction of growth of krill and predator selectivity. The effect of changes in predator foraging areas or krill transport were also considered, although there was no suggestion from satellite tracking of predators at South Georgia that changes in foraging areas occurred through the season.

Krill Length-frequency Data from the Commercial Fishery in Area 48 during the CCAMLR-2000 Survey

2.61 WG-EMM-00/15 described the size and maturity of krill collected by a CCAMLR international observer during commercial fishing in Subarea 48.1 during February 2000. Krill were sampled from five regions to the northwest of the South Shetland Islands and the average length of krill was 49.1 mm (modal size 50 mm). Region 3 was located on the shelf to the northeast of Cape Shirreff and the smallest krill were found at this site (modal size 46 mm). There was a general trend for larger krill to be found offshore as has been seen previously in this area.

2.62 The Working Group noted that the small krill found in region 3 and the somewhat larger krill found in region 4 (modal size 50 mm) were within the foraging range of penguins and fur seals breeding at Cape Shirreff respectively.

2.63 The Working Group recognised that such data from the commercial fishery was a valuable addition to the data collected from scientific cruises and acknowledged the considerable effort by the Governments of Japan and USA and the Japan Deep Sea Trawlers Association in setting up such a collaborative venture (see also paragraph 2.18).

Krill Length-frequency Data, Biomass and Distribution from other Areas of the Southern Ocean during the CCAMLR-2000 Survey

2.64 The size of krill in the Ross Sea during January and February 2000 was described in WG-EMM-00/38. The majority of the krill were allocated to year classes 3+ and 4+ with modal sizes for male and female krill of 43–45 and 47 mm respectively. Relatively few krill smaller than 40 mm were found during the study.

2.65 The geometric mean density of *E. superba* in the surveyed area of the Ross Sea (from latitude 70°–77°S and from longitude 167.5°E–178°W) in January and February 2000 determined from 63 net (HPN) hauls was 9.4 g/1 000 m^3. This species was found dominating catches north of 74°S, while *Euphausia crystallorophias* dominated in catches south of 74°S. On 33 hauls carried out south of 74°S, the geometric mean density of *E. crystallorophias* was around 3.0 g/1 000 m^3 (WG-EMM-00/38). These were a mixture of targeted and oblique tows.

2.66 The Working Group recognised that data presented in WG-EMM-00/38 had shown the importance of *E. crystallorophias* in the Ross Sea where it may form a significant proportion of the krill biomass. The Working Group also noted that it was valuable to be able to separate these two euphausiid species acoustically (see also paragraphs 5.1 to 5.11).

Krill Length-frequency Data, Biomass and Distribution from Area 48 during Years prior to the CCAMLR-2000 Survey

2.67 The length-frequency distributions of krill taken by the commercial fishing vessel *Konstruktor Koshkin* around the South Orkney Islands from May to July 1999 (WG-EMM-00/4) indicated that two size groups of krill dominated the catches. The dominant group with a size between 39 and 45 mm were identified as krill probably from the 1996 year class, while the less abundant size group between 45 and 51 mm were identified as krill from the 1995 year class.

2.68 Information on krill length frequency in Subareas 48.1 and 48.2 during March and April 1998 (WG-EMM-00/5) indicated that krill from the successful 1995 spawning season were identified in the catches of adult krill. Krill of size 42–51 mm dominated the catches in Subarea 48.2, while krill of 38–46 mm dominated catches in Subarea 48.1. In both areas juvenile krill were present only in very small numbers although reference was made to the large number of krill larvae observed in 1997.

2.69 Length-frequency data from the Japanese commercial fishery in Subareas 48.1 and 48.2 during the 1998/99 season are given in WG-EMM-00/57. Plots of krill length sampled at 10-day intervals show that the catch was dominated by krill of size 40–50 mm. Within Subarea 48.2 there was evidence of some krill larger than 50 mm. Only a very small number of krill smaller than 40 mm were detected in the net hauls.

2.70 Information on the depth of trawling was available from WG-EMM-00/4, 00/15 and 00/17. Although there is much evidence to show that krill during the daytime are usually found deeper than during the night (e.g. WG-EMM-00/22) it was evident that sometimes during the day the commercial fishery fished close to the surface (within 20 m).

2.71 The Working Group was informed that near-surface aggregations were often detected in both the Japanese and Russian fisheries using sonar or echosounder. The implication of this for acoustic estimates of krill which are usually derived from depths greater than 10–15 m remains an issue for future consideration and study.

2.72 The scales of interannual variability in acoustic density of Antarctic krill at South Georgia were discussed in WG-EMM-00/56. The relative importance of temporal and spatial variability to observed changes in overall mean krill abundance was investigated using an analysis of variance of the individual survey transect mean krill densities. In the four-year period from 1996 to 1999, krill density around the northwest end of South Georgia was very consistent (12–27 g/m^2), while krill density to the northeast of the island tended to be higher than in the west and was highly variable from year to year (11–150 g/m^2). The variance over small temporal and spatial scales (within and between BAS Core Programme boxes in the same year) was similar to variation between years.

2.73 The Working Group noted with interest the observation that krill density at the western end of South Georgia was generally lower than in the east and that this was consistent with the observation that the pressure from land-based predators was likely to be higher at the western end of the island. However it was also noted that there was far less information on the demand from pelagic predators, although Everson (1984) indicated that historically whales had been very abundant at the eastern end of the island. The Working Group also noted that the commercial krill fishery tended to focus on the northeast of South Georgia, although there was often a westerly movement along the coast as the fishery season progressed (see also WG-EMM-00/25).

Krill Length-frequency Data, Biomass and Distribution from other Areas of the Southern Ocean during Years prior to the CCAMLR-2000 Survey

2.74 WG-EMM-00/39 presented data on krill size in the Ross Sea in 1997/98, two years before the CCAMLR-2000 Survey. This Ross Sea survey took place earlier in the season (December) than the Ross Sea survey in 1999/2000. In contrast to the latter, a large proportion (81%) of the krill population was in the size range 40–45 mm (mean length 41 mm) and there was also a substantial proportion (19%) of juvenile krill (10–25 mm; mean length 17.7 mm) detected in the net hauls.

2.75 An estimate of krill biomass of 1.95 million tonnes for the Ross Sea area (22 200 n miles^2; krill density 25.6 g/m^2) is presented in WG-EMM-00/37 and 00/39. These estimates were based on survey track lines which were determined at the time of the cruise according to where ice was encountered. The three-frequency method was used to separate *E. superba* from *E. crystallorophias* (WG-EMM-00/39).

2.76 The Working Group recognised the value of these estimates of biomass from the Ross Sea area where relatively little information had previously been available. The Working Group also recognised that at present there was no precautionary catch limit for krill in the Ross Sea (Subareas 88.1 and 88.2), but that a survey to undertake an estimate of B_0 should be encouraged.

2.77 Dr M. Azzali (Italy) informed the Working Group that Italy would consider carrying out such a survey in December 2001. The Working Group thanked Dr Azzali for this offer and asked that the design and protocols of any survey to estimate B_0 in the Ross Sea should have the prior approval of the Working Group. Such a procedure of submitting plans for approval prior to undertaking the survey had been followed previously for the Australian cruise in Division 58.4.1 and for the CCAMLR-2000 Survey.

2.78 The Working Group therefore requested Italy to bring forward plans for approval at the WG-EMM meeting in 2001 for a standardised survey design in the Ross Sea.

2.79 A total biomass of 6.67 million tonnes (CV 27%) of krill in Division 58.4.1 in January to March 1996 had been originally presented in WG-EMM-96/28. Since that time a more detailed analysis of the survey data had been undertaken and a revised biomass estimate of 4.83 million tonnes (CV 17%) had been calculated (WG-EMM-00/30). The change in the estimate of the biomass was due mainly to a correction of the absorption coefficient (α) used in the original estimate.

2.80 The Working Group agreed that this new estimate of the biomass and CV of krill in Division 58.4.1 now represented the best estimate available for this division and recommended that a new value of γ for this division should be calculated.

2.81 The density of krill found in Division 58.4.1 was very low (5.5 g/m^2) in comparison with many of the density estimates derived for different parts of Area 48. However, within this division the distribution of krill is not homogeneous. The density of krill in the western part of the division (80–115°E) was approximately twice that in the eastern part of the division (115–150°E) (WG-EMM-00/30). The proposal to subdivide this division is discussed further in paragraphs 2.96 to 2.119 and 6.6 to 6.19.

Summary of Observations on Krill Length-frequency Data, Biomass and Distribution

2.82 The Working Group noted that a consistent pattern had been observed by all the different sampling techniques utilised within the last few years in Subarea 48.1. Only large krill had been detected and it was generally assumed that these had originated from the last major spawning episode observed in the area which had taken place in 1994/95 and 1995/96.

2.83 In contrast, in Subareas 48.2 and 48.3, small krill had been detected in the 1999/2000 season that had not been seen in Subarea 48.1. The Working Group recognised that the more detailed analysis of the various attendant datasets should be accorded a high priority.

B_0 Workshop (results from the CCAMLR-2000 Survey in Area 48)

2.84 The workshop to analyse data from the CCAMLR-sponsored multinational, multiship acoustic survey for krill biomass in Area 48 undertaken in January and February 2000 was held at the Southwest Fisheries Science Center, La Jolla, California, from 30 May to 9 June 2000. The full report of the workshop was presented in WG-EMM-00/21 Rev. 1 and is attached as Appendix G. This report was presented to the Working Group by Dr Hewitt, the Convener of the workshop.

Data

2.85 The acoustic data and krill length-frequency data from the surveys conducted as part of the CCAMLR-2000 Survey by Japan, Russia, UK and USA had been made available prior to the workshop. In addition, CTD data from Japan, UK and USA were available prior to the workshop. All these data, including CTD data from Russia, are core datasets and copies of these data will be stored by the CCAMLR Secretariat.

Methodology

2.86 Data were processed through a series of stages which:

- delineated acoustic backscatter attributed to krill from other sources of backscattering;
- converted backscatter due to krill to an areal krill biomass density;
- summed areal krill biomass densities over the survey area; and
- estimated the uncertainty associated with an estimate of B_0.

The methods used are detailed in Appendix G.

Estimate of Krill Biomass for Area 48

2.87 The B_0 Workshop had agreed that the results obtained from the 120 kHz dataset would be used for the estimation of krill standing stock in Area 48. The estimate of 44.29 million tonnes (CV 11.38%) (Appendix G, Table 25b) was therefore endorsed as the best available for Area 48.

Variance associated with Estimate of Krill Biomass

2.88 The B_0 Workshop noted that it had only been possible to provide an estimate of the sampling variance of the survey (Appendix G, paragraphs 4.9). However, it was recognised that there are other components of uncertainty which should be identified so that they could be incorporated into the estimation of γ using the GYM. There was insufficient time to provide an estimate of combined measurement and sampling uncertainty and Dr Demer had offered to undertake such an analysis and present the results to WG-EMM-2000.

2.89 WG-EMM-00/49 presented this analysis of some of the components of uncertainty in the CCAMLR-2000 Survey. In addition to sampling variance which is traditionally given for acoustic surveys, this paper considered uncertainty that could arise from variation in physical parameter values used in the sonar equation (such as sound speed, absorption and equivalent two-way beam angle), the effect of noise and the detection probability of krill down through the water column. Finally uncertainty in the identification of krill, the estimation of TS and the effect of behaviour such as diurnal migration were considered.

2.90 Uncertainty of TS and krill delineation techniques were estimated using a DWBA model of krill TS and measured distributions of animal lengths derived from the survey and orientation distributions derived from literature. A combined measurement and sampling variance was estimated from a simulation which assumed that the three-frequency measurements provided independent estimates of krill biomass.

2.91 The overall variance (CV 11.33%) was similar to the sampling variance (CV 13.38%). Thus measurement variance may be considered negligible relative to the sampling variance due to the large number of measurements averaged to derive the final biomass estimate.

2.92 The Working Group recognised that this was an extremely thorough and well-documented study which demonstrated how an understanding of the factors contributing to the measurement of uncertainty in an acoustic survey had improved over the period that acoustic techniques had been used to estimate krill biomass.

2.93 While such an understanding of the uncertainty attached to acoustic surveys will no doubt be improved further in the future, the Working Group endorsed the level of uncertainty derived from this paper as the best estimate available at the present time.

2.94 WG-EMM-00/49 also considered some of the potential sources of bias, such as those arising from errors in species delineation or TS, that might arise in the calculation of B_0. The Working Group recognised that there had been insufficient time to investigate thoroughly the effect of such biases prior to this meeting and requested that such studies should be continued.

2.95 In a discussion on the identification of krill using multifrequency acoustics, the Working Group noted that there is no universal agreement on the exact dual-frequency algorithm to delineate krill (a different example of which can be seen in WG-EMM-00/37 and is discussed further in paragraphs 5.5 to 5.7) nor on the most appropriate level of spatial and temporal integration at which such delineation should occur. However it was agreed that unlike previous biomass estimates (i.e. FIBEX), the krill delineation algorithm had been accepted by all participants to the B_0 Workshop, was totally objective and was believed to represent the best available to the workshop at the time of analysis.

Estimation of Potential Yield

Estimation of γ

2.96 Last year, the Scientific Committee endorsed the need to re-estimate γ to take account of the variance in the estimate of biomass arising from the CCAMLR-2000 Survey in the South Atlantic (SC-CAMLR-XVIII, paragraph 6.40). No other analyses were presented to the Working Group regarding the revision of other parameters used in the estimation of γ, indicating that only the survey details would be altered in the input parameters to the assessment of yield (SC-CAMLR-XVIII, Annex 4, paragraph 7.16). The Working Group agreed to estimate γ using the GYM, which had been agreed by the Working Group to be used in place of the KYM (SC-CAMLR-XVI, Annex 4, paragraph 7.3), and has since been validated by the Secretariat (SC-CAMLR-XVII, paragraph 5.36). It was noted that the Scientific Committee had requested Members to participate in evaluating the GYM and to submit such tests to the Secretariat for archiving as appropriate (SC-CAMLR-VII, paragraph 5.36). The Working Group encouraged Members to continue with this work.

2.97 To this end the Working Group suggested that it would be advantageous to develop a pro-forma format for the submission and archiving of any tests of the GYM.

2.98 The Working Group considered whether to incorporate recruitment information more recent than that used in the estimation of parameters in 1994. It was agreed that more work was still required before such information could be used (see SC-CAMLR-XVI, Annex 4, paragraphs 3.27 to 3.29; SC-CAMLR-XVII, Annex 4, paragraphs 4.28 to 4.37). The parameters used in the estimation of γ are given in Table 1. The new survey CV is 0.114. GYM requires a single date to represent the survey period; this was taken as 1 February 2000 (see also paragraph 2.106).

2.99 The Working Group also considered the parameter values used for the fishing season. Although the Working Group recognised that the krill fishery also took place currently in the winter in Subarea 48.3, the fishery is still small compared to the likely estimate of yield. The Working Group has no information on how the effort will be spread across the year when the fishery is fully developed. The Working Group agreed therefore that the fishing season should remain as 1 December to 1 March in the model as it was likely to represent a more precautionary approach than spreading fishing effort throughout the year.

2.100 The results for Area 48 from running the GYM according to the decision rules were:

> recruitment criterion – 'that the probability that the spawning biomass falls below 20% of the median pre-exploitation spawning biomass after 20 years should not exceed 10%' –
> γ_1 = 0.118; and
>
> predator criterion – 'that the median spawning biomass should not fall below 75% of the pre-exploitation spawning biomass after 20 years' –
> γ_2 = 0.091.

According to the decision rules, the lowest γ is used. Thus, the Working Group agreed that the new γ is 0.091.

2.101 The new potential yield for krill in Area 48 is 4.0 million tonnes (γ = 0.091, B_0 = 44.29 million tonnes). The Working Group accepted this as the best estimate of potential yield available at the present time.

2.102 The Working Group noted that this result is slightly less than the previous Area 48 potential yield estimate of 4.1 million tonnes which had been calculated in 1994 (SC-CAMLR-XIII, Annex 5, Table 2).

2.103 The Working Group discussed a number of factors which were likely to have had an effect on the estimate of potential yield.

2.104 The Working Group recalled that γ_1 was sensitive to a change in the CV of the B_0 estimate but that γ_2, as used in the present estimate, was not (SC-CAMLR-XIV, Annex 4, paragraphs 4.51 to 5.57).

2.105 Apart from refinements in the algorithm associated with using the GYM (SC-CAMLR-XVI, Annex 4, paragraph 7.3), the main reason for the decrease in γ is the difference in timing of the surveys used in the model – the KYM had the surveys timed as one month after the start of the nominal growth period (1 November) whereas this survey (1 February) is three months later. Consequently, a reduction in γ would be expected because of the combined effects of growth and mortality occurring between the beginning of the year and the survey period (see Appendix E).

2.106 In addition, the GYM uses a single date to represent the CCAMLR-2000 Survey (1 February 2000, Table 1) although the survey had spanned the period 11 January to 10 February 2000. The Working Group noted that such an assumption had implications for the calculation of γ (see preceding paragraph). Thus a change in the date representing the survey, changed the estimated value of γ. The Working Group felt that the date used in the present calculation was likely to have resulted in a precautionary approach to the assessment of γ (Appendix E, Figure 1).

2.107 The Working Group recommended that the sensitivity of γ to changes in the date of the CCAMLR-2000 Survey used in the GYM should be investigated in the future.

2.108 The Working Group recollected that tests of the comparability of the KYM and GYM had been conducted in WG-FSA since 1995 and in WG-EMM in 1997. Given the improved transparency of the GYM over the KYM, the Working Group recommended that future work should concentrate on understanding the sensitivity and performance of the GYM to changing parameter values.

2.109 The Working Group noted that the rationale and methods for estimating and choosing parameters used in the yield model are embedded in the WG-Krill and WG-EMM reports and papers presented to those groups. The Working Group agreed that a compiled history of the yield assessment is necessary to facilitate future calculations and to ensure that a collective memory of these assessments is retained. This will involve collating relevant paragraphs of the reports, compiling descriptions and the rationale of estimation methods, including mathematical formulae and algorithms, and summarising the rationale for accepting estimates of the parameters. This will be facilitated by completing the archiving of the KYM (SC-CAMLR-XVIII, Annex 4, paragraph 6.8).

2.110 The Working Group requested that the Secretariat take on the responsibility of compiling the documentation of the yield model (paragraph 2.109). The Working Group further recommended that a subgroup should be formed which would coordinate analyses and tests to be carried out on the GYM in the future (see Table 3).

2.111 Dr Constable informed the Working Group that resources were available at the Australian Antarctic Division to help participants familiarise themselves with the use of the GYM. The Working Group thanked Dr Constable for the offer and also expressed gratitude to the Australian Antarctic Division for the considerable effort contributed to the development of the GYM.

2.112 The Working Group agreed that the same parameters in Table 1 would be used for a reassessment of γ for Division 58.4.1, except for details arising from the BROKE survey, including the CV (0.17) and the date of the survey (1 February). The results from the GYM were $\gamma_1 = 0.123$ and $\gamma_2 = 0.091$. The Working Group agreed that the $\gamma = 0.091$ would be applied to biomass estimates in Division 58.4.1 to determine precautionary catch limits in that region.

2.113 The new potential yield for krill in Division 58.4.1 is 0.44 million tonnes ($\gamma = 0.091$, $B_0 = 4.83$ million tonnes). The Working Group accepted this as the best estimate of potential yield available at the present time.

Subdivision of Potential Yield in Area 48

2.114 The Working Group reiterated the requirement to subdivide the potential yield in Area 48 as a method to distribute fishing effort and therefore to reduce the potential impact of commercial fishing on dependent species.

2.115 At the previous meeting of WG-EMM, a number of alternative approaches to the subdivision of potential yield for Area 48 had been proposed (SC-CAMLR-XVIII, Annex 4, paragraphs 8.55 and 8.61). Of these alternatives, the Working Group had considered that the most feasible in the short term were to subdivide the estimated krill yield from the survey based on (i) the proportion of survey in each statistical subarea, where proportions are estimated from the lengths of the survey tracks, and (ii) the area of krill distribution in each statistical subarea.

2.116 The Working Group noted that there had been insufficient time at the B_0 Workshop to determine the distribution range of krill from the CCAMLR-2000 Survey dataset. However, the importance of such an analysis was recognised and should be carried out as part of the future analyses to be coordinated by the CCAMLR-2000 Survey Steering Committee.

2.117 An estimation of the proportion of survey in each statistical subarea had been derived at the B_0 Workshop where the proportion was estimated from the lengths of the survey tracks in each subarea (Appendix G, Table 23). However, the Working Group noted that the lengths of survey tracks estimated in Table 23 contained both the large-scale and mesoscale transects and so was biased by the increased sampling intensity within the mesoscale survey areas.

2.118 The transect length within each statistical subarea, using the length of the large-scale transects plus the length of large-scale transects passing through mesoscale regions, was calculated using the information in Appendix G, Table 23. The results are given in Table 2.

2.119 The results of subdividing the potential yield of Area 48 between Subareas 48.1 to 48.4 on the basis of transect length are shown in Table 2.

Subdivision of Division 58.4.1

2.120 Division 58.4.1 is the second largest CCAMLR statistical reporting area. WG-EMM-00/30 presents evidence that this region is neither homogeneous in biological nor oceanographic characteristics. It is therefore suggested that Division 58.4.1 should be divided into two approximately equal subdivisions: 80–115°E and 115–150°E. Revised krill biomass estimates for the proposed west and east subdivisions are 3.04 million tonnes (CV 19%) and 1.79 million tonnes (CV 30%) respectively.

2.121 The Working Group noted that although a significantly greater biomass of krill was found in the western region, historically the commercial fishery had operated mainly in the eastern region of Division 58.4.1 for logistic reasons.

Future Work

2.122 The Working Group recognised the unique data resource that was now available from the CCAMLR-2000 Survey. A steering committee, comprising the principal scientists of the participating nations, the Convener of WG-EMM and a vice-chair of the CCAMLR Scientific Committee, was set up to coordinate the analyses of these datasets at future workshops and intersessionally. The draft terms of reference for this steering committee are given in Appendix F.

2.123 The Working Group recommended that the regional and local surveys in Area 48 during the same period as the CCAMLR-2000 Survey should be analysed to address questions such as when is the best time to sample the biomass and characteristics of the krill population.

2.124 The analysis of those surveys considered as ancillary surveys to the CCAMLR-2000 Survey could take place as part of the International Coordination Workshop. This workshop will be convened during the intersessional period by Dr Kim. The final aim of the workshop will be to construct a time series of krill abundance and distribution through the 1999/2000 season for Subarea 48.1.

2.125 The Working Group recognised that given the participation of several nations at the above workshop and need for ongoing analysis of the CCAMLR-2000 Survey results, some prioritisation of tasks was needed. For the moment the Working Group acknowledged that the CCAMLR-2000 Survey analyses should be given higher priority.

2.126 The DWBA model of scattering has the potential to describe TS more accurately and precisely than the presently used relationship of Greene et al. (1991). However the use of this model requires a much better understanding of the orientation of krill in nature. The Working Group encouraged the collection of such data.

2.127 The estimation of uncertainty and bias in acoustic survey estimates of biomass has been refined considerably (WG-EMM-00/49). However, further work on potential biases caused by presently-used krill delineation techniques are required.

2.128 The Working Group recommended that the proportion of krill occurring near the surface during daytime should be determined and its effect on acoustic surveys quantified.

2.129 Given the large number of papers submitted to the current meeting of WG-EMM, the Working Group requested that in future every paper should contain an abstract and two or three paragraphs after the abstract that highlighted the relevance of the paper to ecosystem analysis, assessment and management.

2.130 The Working Group requested future presentations on alternative methods to subdivide the precautionary catch limit.

2.131 The Working Group noted that several nations were involved in genetic population studies (Australia, Italy, Japan, Republic of Korea, Sweden and UK) for stock identification. Dr B. Bergström (Sweden) volunteered to coordinate an ad hoc Subgroup on Population Genetics to provide a forum to discuss progress and analyses.

2.132 The Working Group noted that myctophids are likely to form an important part of an alternative food web to the traditional krill food web. There is now the potential to estimate the biomass of myctophids acoustically and the Working Group encouraged further work on this topic (see paragraph 4.46).

DEPENDENT SPECIES

CEMP Indices

3.1 Dr Ramm presented a summary report on CEMP indices (WG-EMM-00/26).

3.2 The Working Group thanked Dr Ramm and his staff for the significant progress made in organising and summarising CEMP data. The Working Group noted that recommendations for improving the CEMP indices (SC-CAMLR-XVIII, Annex 4, paragraph 4.5) had been undertaken by the Data Manager including:

(i) summaries of anomalous trends presented in two ways: all variables by site and all sites within subareas by each variable;

(ii) providing electronic data forms (e-forms) for each of the standard methods;

(iii) notifying Members of data requirements and clarifications in submitted datasets; and

(iv) archiving inactive datasets.

3.3 It was pointed out that e-forms represent significant progress towards preventing transcription errors and improving the quality of the data.

3.4 It was suggested that a box be added to standard method data forms to indicate if data were collected according to the standard method protocol. Data providers should check the box if all data were collected as such. If not, providers should indicate the nature of, and reason for, any departure from the standard method.

3.5 Dr Ramm reported that 30 pages of the table listing CEMP data in the database were eliminated by archiving datasets which had only 1–2 years of data and which did not contain data for the immediate past season.

3.6 The Working Group reiterated its wish to have updated CEMP data available at WG-EMM each year. It also endorsed the value of the summaries and pointed out that work was underway to develop new methods (e.g. composite indices) for examining the data and focusing on specific questions of interest to CCAMLR.

CEMP Species – Seabirds

3.7 Dr Trivelpiece summarised a preliminary report of SCAR-BBS (WG-EMM-00/16). The final version of this report will be tabled at the SC-CAMLR meeting during October 2000. The report is the result of a workshop held in Bozeman, Montana, USA, from 17 to 21 May 1999. The group met in response to a request from SC-CAMLR for a statistical assessment of available population data on Southern Ocean seabirds. The criteria used for selection of data to be analysed were: continuous annual data of 10 years or more duration, discontinuous data of greater than 10 years duration with at least 50% coverage, and data of sufficient quality to be used as indicative of trends. The objective of the analysis was to determine whether there were statistically significant trends in the long-term seabird population data. Twenty-one seabird species were analysed. Five (four penguins and one albatross) were CEMP species. The preliminary results of the population trends are summarised below:

Adélie penguins –
Adélie penguin data were available from east Antarctica, the Antarctic Peninsula and the Ross Sea. In east Antarctica (Béchervaise Island, Syowa Station, Point Geologie and Casey Station), all populations increased significantly from the 1970s–1980s to the present at 3–4% per annum. At the Antarctic Peninsula (King George, Anvers and Signy Islands), populations were stable or declining slowly through the 1980s but all have declined significantly in the 1990s. There were significant non-linearities in the Ross Sea population data. Cape Royds exhibited a significant linear increase since 1959. Cape Crozier increased from the 1960s to 1987 and has decreased significantly since, while Cape Bird increased between the 1960s and 1987, declined between 1987 and 1994 and has increased significantly since.

Gentoo penguins –
Gentoo population data were available from three regions. In the Antarctic Peninsula region, the population at Port Lockroy has increased significantly, whereas the King George Island population has significant non-linearities in the data due to infrequent, strong cohorts that arise and dominate the population for 10+ years. This population is currently near its 25-year low. The gentoo population at Bird Island showed significant declines over 20 years. The Marion Island population increased significantly between 1975 and 1995, but this trend was based on only three counts. Since 1995, the population at Marion Island has declined significantly.

Chinstrap penguins –
The populations at King George and Signy Islands exhibited significant declines since the 1970s, with a greater rate of decline in the 1990s. The small population at Anvers Island increased significantly between its discovery in the 1970s, and the early 1990s, with indications that the population has stabilised during the 1990s.

Macaroni penguins –
Population data were available from Marion, Bird and Kerguelen Islands. The Marion Island population counts are from three small colonies, all of which exhibited significant declines. Total counts from Marion Island were not assessed as it was felt that the

counts had large error estimates associated with them; however, the Marion Island population as a whole was considered to be relatively stable. Bird Island populations increased by 20% between 1977 and 1986 but the population has declined by 48% since then. This represents a significant 5% per annum decline at Bird Island and the decline broadly reflects other colonies in the area, which have declined by up to 50% in the last 20 years. The population at Kerguelen Island was counted from aerial photographs three times between 1963 and 1999. The results indicate a stable population with a slight increase over the period.

Black-browed albatross –
Data were available from populations at Bird Island and the Kerguelen Islands. The Bird Island population declined significantly from 1976 to 1999, with the earlier period exhibiting the sharpest declines. The Kerguelen population did not show any significant trend, but the data suggested fluctuations in the population, with an apparent strong cohort every three to four years.

3.8 The Working Group recognised the thorough nature of this analysis and expressed its gratitude to SCAR-BBS for bringing it to the attention of WG-EMM. Recommendations arising from the workshop included:

(i) Counts need to be standardised, dates of counts need to be included in the historical database and methods used to obtain counts (e.g. aerial, ground, density etc.) must be clearly reported.

(ii) For the more complete and long-term datasets, investigation of potential interactions between population size and physical and biological environmental variables would be useful. Data holders were encouraged to undertake and collaborate in such work.

(iii) Comparison of population trends, and timings of population change, across populations and species on regional bases would be useful in future investigations.

3.9 The Working Group noted these recommendations. In order to assist SCAR-BBS with its future work, the Working Group made the following comments.

(i) It noted that, in some instances, shifts in distributions of a species or populations could complicate interpretations of declines. It is, therefore, important, whenever possible, to place local population counts in a regional context.

(ii) Where possible, it would be helpful if population data and trends of the same species among sites were presented at the same scales.

(iii) The Working Group recognised the utility of both statistical and demographic models to understand the significance of the status and trends in seabird populations. It may be possible to improve the current statistical models by developing a system by which each estimate of abundance could be weighted according to the SCAR Working Group's view of the reliability of the estimate.

(iv) Extending this approach, the Working Group suggested that it may be important to assess the possibility of apparently rapid changes in abundance from current understanding of the demographics of the species concerned. Therefore, it suggested that a compilation of demographic information alongside the data about trends in abundance would allow this type of assessment to be made.

3.10 Several other papers dealt with issues concerning CEMP status and trends of seabirds.

3.11 WG-EMM-00/40 examined chick provisioning and survival among Adélie penguins at Béchervaise Island. Breeding success and foraging behaviour were summarised for nine seasons including three poor years. Breeding success was negatively correlated with the distance of the sea-ice edge from the colony. Males foraged more inshore than females. Food availability during the guard stage of the breeding cycle was identified as the most important factor in distinguishing between years of varying food availability. The authors suggest that competition with fisheries for food, if it occurs during the early chick-rearing period, is likely to have the greatest impact on the penguin population at Béchervaise Island.

3.12 WG-EMM-00/41 reported length-frequency data from diet samples of Adélie, gentoo and chinstrap penguins and Antarctic fur seals during the 1999/2000 season at the NSF field camp in Admiralty Bay, King George Island. The mean length of krill in the penguin samples increased by 7 mm between the first and last sampling periods (15 December 1999 to 7 February 2000). This increase was consistent with growth of individual krill over the sampling period. Fur seal scat analyses of krill carapaces showed a mean krill size of 50–51 mm in the diets between 9 February and 3 March 2000. Both predators' diets were dominated by krill in the 46–50 mm size classes.

3.13 WG-EMM-00/62 summarised seabird research undertaken at the US AMLR field camp at Cape Shirreff during 1999/2000. Krill length-frequency data from diet samples also showed a dominant krill size group of between 46 and 50 mm. A three-year summary of krill sizes in stomach samples revealed an annually increasing mean size across the period, consistent with the hypothesis that the krill dominating the diets of the penguins at this site are largely from the strong 1995 cohort reported to previous meetings of the Working Group.

3.14 WG-EMM-00/13 reported on aspects of the CEMP monitoring program at Bouvetøya Island by Norwegian researchers in 1998/99. Macaroni penguin populations increased and chinstrap populations decreased relative to counts in the 1996/97 season. However, it was pointed out that a substantial portion of the chinstrap penguin colony washed away between the years, so the lower counts for that species may be due largely to a habitat change. The chinstrap penguins ate exclusively krill, while macaroni penguin diets were predominantly composed of fish with krill as an item of secondary importance.

CEMP Species – Pinniped Studies

3.15 Four papers presented information on Antarctic pinnipeds:

(i) WG-EMM-00/47 presented a general overview of pinniped research at Cape Shirreff by the US AMLR Program and gave a brief synopsis of conditions for fur seals at Cape Shirreff in the 1999/2000 season. It reported that indices of reproductive performance for adult females and for the growth of pups at Cape Shirreff in 1999/2000 were above average.

(ii) WG-EMM-00/48 used a comparative approach to examine how often three species of otariids exceeded their calculated aerobic dive limits. Such measures can be used in management of species because they define how close to their physiological limits individuals are working. Dive data collected for Antarctic fur seals at Cape Shirreff showed that, for that population, animals are working well within their physiological limits for diving. Therefore, it appears that fur seals from Cape Shirreff would be able to exploit prey deeper in the water column than is currently observed.

(iii) WG-EMM-00/13 presented an overview of fur seal research at Bouvetøya Island. This included the monitoring of adult female foraging/attendance cycles and pup growth rate using the CEMP standard methods.

(iv) WG-EMM-00/63 provided a report of the meeting of SCAR-GSS on the status and trends of Antarctic seal populations. This included Antarctic and sub-Antarctic fur seals, southern elephant seals and four species of ice seals. Both species of fur seal are increasing rapidly. In contrast, elephant seal populations are declining in the Indian Ocean but are probably stable or increasing slowly in the Atlantic. Less is known about current trends in ice seal population numbers. Results of the current APIS Program will be available in the near future and this will provide additional information about the status and trends of pack-ice seals. The report recommended removing Antarctic fur seal (*Arctocephalus gazella*) from the list of Specially Protected Species.

3.16 The Working Group thanked SCAR-GSS for providing the report. It was recognised that due to the short interval between the SCAR-GSS meeting and the current meeting, there were several outstanding issues involving the data presented in the text and tables as well as the clarification of the work conducted at the South Shetland Islands. Prof. Boyd was asked to liaise with the convener of SCAR-GSS to help ensure that an updated version of the report was made available for the Scientific Committee.

3.17 The Working Group noted that IUCN was invited to comment on the removal of Antarctic fur seal from the list of Specially Protected Species and to date no response had been received by the Secretariat. It is, therefore, too early for CCAMLR to form an opinion on this issue. It was also pointed out that a review of IUCN criteria for listing species was due to be published in October 2000 and this new information would be important to review the status of the Antarctic fur seal.

3.18 Dr R. Holt (USA) informed the Working Group that contrary to information presented in the text of the report, the US AMLR Program had conducted a census of all known fur seal pupping sites at the South Shetland Islands at approximately five-year intervals since 1987. He further indicated that it was US AMLR's intention to conduct a fur seal census of the South Shetland Islands in the near future. The Working Group agreed that documenting population changes in Antarctic fur seals in the South Shetland Islands is a high priority.

Predator Abundance Surveys

3.19 Discussion continued concerning the importance of estimating predator abundance regionally, giving high priority to standardising methods. Surveys of predator populations are needed to anchor the observed small-scale population trends at research sites in a larger regional context. It was suggested that a workshop on methodology was needed to assess problems associated with conducting large-scale (regional) population counts. The Working Group endorsed the idea of such a workshop.

3.20 It was noted that predator surveys should not be confined to penguins and seals but should include whales. Input by the IWC would be required and the Working Group noted that CCAMLR should continue to request updates on whale population abundance and information relevant to estimating krill consumption from the IWC.

Non-CEMP Species

3.21 WG-EMM-00/16 summarised the population trends of several non-CEMP seabird monitoring species that are of interest to the Working Group. King penguin populations at Crozet and Heard Islands have all shown significant increases over the last 20 to 30 years. Albatross populations at three sub-Antarctic Islands (Marion, Kerguelen and Possession) have all shown population increases since the 1980s, after significant declines in the 1970s.

However, the wandering and grey-headed albatross populations at Bird Island have exhibited significant declines since the 1960s. Giant petrel populations decreased at Marion Island, Mawson Base, and at several northern Antarctic Peninsula sites, whereas increases were reported at Possession and Anvers Islands.

3.22 The significant declines in many of the giant petrel populations were thought to be due to disturbance from nearby bases. The largely undisturbed population on Anvers Island was reported to have increased significantly; however, this population exhibits large interannual variability in the breeding population size. The Working Group noted that this dataset was based on chick counts, not breeding pairs and, therefore, caution was advised in interpreting the population trend at this site.

3.23 The Working Group noted the lack of population data for many petrel species, particularly the white-chinned petrel, as it is the most commonly killed seabird in the longline fishery.

3.24 WG-EMM-00/8 and 00/9 presented information of the diets of shags from Laurie Island, South Orkney Islands and the Danco Coast of the western Antarctic Peninsula respectively. The authors examined regurgitate pellets over four years at Laurie Island and reported the diet consisted of benthic fishes, molluscs and polychaetes in order of importance. They found significant interannual differences in the size classes of fish in the diets. The data from the Danco Coast was confined to the 1997/98 season. Results showed significant intra-annual differences in the size classes of fish in the diets. The authors suggest that data from shag diets might provide valuable information on the status and recovery of exploited fish stocks.

3.25 WG-EMM-00/11 examined the diet of snow petrels at Laurie Island during the chick-rearing period of the 1997/98 austral summer. Fish (myctophids) dominated the diet and krill was of secondary importance.

3.26 WG-EMM-00/36 reported a southerly range extension for the greater shearwater to the vicinity of the South Sandwich Islands in 1999/2000 and suggested this may signal a southward shift in the location of the Polar Front.

Indices of Key Environmental Variables

3.27 The Working Group considered various aspects of the environment with regard to topics relevant to fishing operations, topics relevant to spatial and temporal variability, and topics relevant to 1999/2000, the year of the CCAMLR-2000 Survey.

Environmental Influences on Fishing Operations

3.28 Environmental data from the national observer on board the krill fish cannery supertrawler *Konstruktor Koshkin* are reported in WG-EMM-00/04. This report considered the period from May to July 1999 when fishing operations were centred around the South Orkney Islands. It contains a description of meteorological conditions, details of sea-surface temperature, information about sea-ice, and summaries on the presence of icebergs. The report noted that the presence of drifting sea-ice complicated fishing operations during the night, but did not interfere with operations during the day. It also noted that wind strength and sea state did not interfere with fishing operations until July, when storm force winds became more frequent.

3.29 The Working Group noted that environmental information related to fishing activities was extremely useful. It provides evidence that will help the Working Group understand spatial patterns in the distribution of fishing effort and understand temporal patterns in the partitioning of fishing operations. The Working Group encouraged the presentation of similar contributions at future meetings.

Spatial and Temporal Environmental Variability

3.30 Data about spatial structure in the environment for Division 58.4.1 are reported in WG-EMM-00/30. Much of the information derives from a combined physical–biological survey for krill that was carried out during 1996 by the RSV *Aurora Australis* (Australia) (BROKE) and which has been presented at previous meetings of the Working Group (e.g. WG-EMM-96/29). WG-EMM-00/30 provided an overview of the circulation in the BROKE region (80°–150°E; 63°–66°S) presenting information to support the existence of a cyclonic gyre in the west (80°–115°E) of the area. Data from drifting sea-ice and from satellite-derived measurements of primary production (chl*a*) indicate the quasi-permanent status of the gyre. The paper highlights physical and biological differences across the region and suggests that the west of the region (80°–115°E) supports higher levels of biological production than the east (115°–150°E). The paper noted that the ACC is further offshore in the area of the gyre and concluded that the structure in the environment is probably a reflection of average summer conditions.

3.31 The Working Group noted that partitioning Division 58.4.1 on the basis of the physical environment would produce approximately evenly sized subdivisions and that this would be appropriate (paragraphs 2.120 and 2.121).

3.32 The Working Group also considered information relating to temporal variability, including indices of thermohaline structure in Area 48. In this respect, WG-EMM-00/34 detailed variability at South Georgia, the South Orkney Islands and at the South Shetland Islands. Variability at each of these locations was represented by a single CTD station that had been occupied on a number of past occasions. At each location the thermohaline structure was observed to vary between years, with structure restricted to a limited number of thermohaline states.

3.33 Temporal variability in the environment and the measurement of aspects that could have a direct effect on dependent species was also considered. Specific measurements have been discussed at previous meetings (e.g. WG-EMM-98/06; WG-EMM-99/12) and have led to the development of new standard methods for indices of F1 (sea-ice viewed from a CEMP site), F3 (local weather) and F4 (snow cover). Earlier meetings of the Working Group have reviewed F1, F3 and F4 (SC-CAMLR-XVIII, Annex 4, paragraph 8.86) and have suggested that it is not necessary (or appropriate) for Members to submit data in support of F3 to the CCAMLR Data Centre. However, WG-EMM-00/27 concluded that, given longer time series of data, it would be possible to derive meaningful CEMP parameters from automated weather stations. In preparation for approval by the Subgroup on Methods, WG-EMM-00/27 presented data from Béchervaise Island and from Edmonson Point as examples of F1, F3 and F4. The paper also presented information from microwave satellite data from the US National Snow and Ice Data Center that could help provide meaningful indices about sea-ice cover adjacent to CEMP sites. The Working Group welcomed the new information and encouraged further developments.

3.34 Temporal variability in average monthly atmospheric conditions is considered in WG-EMM-00/35. The paper used principal components analysis to examine variability in atmospheric pressure between 1970 and 2000, making preliminary conclusions that cyclical patterns (2–3 years and 4–6 years) were present in the atmosphere and that both zonal and meridional variability were important. WG-EMM-00/35 noted the existence of anomalous atmospheric conditions in the late 1990s, and suggested that these could have an impact on the ACC.

The Environment in 1999/2000; the Year of the CCAMLR-2000 Survey

3.35 Information about the environment during the year of the CCAMLR-2000 Survey was presented in a number of papers. Available information related to CEMP environmental indices, to satellite remote-sensing and to information from research vessels.

3.36 The CEMP environmental indices F2a (September sea-ice cover), F2b (proportion of year ice free), F2c (time sea-ice is within 100 km of a CEMP site) and F5 (sea-surface temperature) provide a standardised description of the environment. In considering the most recent index values presented in WG-EMM-00/26, the Working Group noted that virtually all were within normally observed ranges. Only the most recent value for F2b at Béchervaise Island deviated from the normally observed range. The Working Group also noted that the recent values for F2a were negative in Subareas 48.1, 48.2 and 48.3, but that the values were not sufficiently negative to be classed as deviates.

3.37 In considering the CEMP indices presented in WG-EMM-00/26, the Working Group noted that long-term baseline datasets were important, but that no current definitions were available that would help determine the minimum time period needed to provide adequate baselines. The Working Group also noted that recognition of trends away from baseline data could be difficult in certain circumstances.

3.38 Information derived from US NOAA satellites detailing sea-surface temperatures across the Scotia Sea was presented in WG-EMM-00/55. In addition sea-surface temperatures derived from GOES-E and MEOSAT-7 satellites were presented for the South Georgia region in WG-EMM-00/20. This paper presented information for the period 1999/2000 as well as for a limited number of previous years (1989/90 and 1990/91). After deriving monthly anomalies, the paper concluded that the area to the north of South Georgia was colder during the period of the CCAMLR-2000 Survey than it was during the comparable time of the historical data.

3.39 Information collected from research vessels participating in regional surveys undertaken in Area 48 (WG-EMM-00/51 and 00/52) and participating in the CCAMLR-2000 Survey (WG-EMM-00/21, 00/33 and 00/52) were considered by the Working Group.

3.40 In January 2000 the RV *Onnuri* (Republic of Korea) undertook a physical–biological survey in the vicinity of the South Shetland Islands (WG-EMM-00/52). This survey covered the South Shetland Island mesoscale strata of the CCAMLR-2000 Survey. CTD results from the survey showed a clear delineation in the hydrographic structure; this was manifested as distinct offshore and shelf/coastal regions. Offshore water showed a strongly defined temperature minimum near the surface, with the presence of warmer CDW at greater depths. Over the shelf, coastal water was cooler at depths with no evidence of CDW. Preliminary results from an ADCP were also discussed.

3.41 During January 2000 the RV *Atlantida* (Russia) undertook a mesoscale survey to the north of South Georgia; this is described in WG-EMM-00/51. The survey covered the same mesoscale areas previously occupied by the BAS Core Programme which has been reported to the Working Group in past years. The oceanographic environment during the occupation of the RV *Atlantida* showed considerable similarities with the structure previously described for the region; evidence of a strong shelf-break front and of mesoscale structure was evident in the data. Further analysis of the survey will be undertaken during a joint BAS–AtlantNIRO workshop in the near future.

3.42 Following the mesoscale survey at South Georgia, the RV *Atlantida* participated in the CAMLR-2000 Survey occupying the strata mainly located in Subarea 48.4 (WG-EMM-00/33). CTD data collected during the survey showed that conditions reflected the complex hydrographic structure determined during previous occupations of the area by Soviet Union and Russian survey vessels (1977, 1987 and 1990). Specifically, waters from the Weddell gyre (including waters of the Weddell Scotia Confluence) occupied much of the area surveyed. The warmer waters of the ACC occurred to the north and northeast of the survey area. The paper notes that the main concentrations of krill were associated with the colder Weddell-influenced waters.

3.43 CTD data from the RV *Atlantida* were not available during the CCAMLR-2000 Survey B_0 Workshop, however they have now been combined with the CTD data from the *Kaiyo Maru* (Japan), the RRS *James Clark Ross* (UK) and the *Yuzhmorgeologiya* (USA) in preparation for future analyses.

3.44 WG-EMM-00/21 described the CCAMLR-2000 Survey B_0 Workshop including details of the indices collected to describe the physical environment (Appendix G, Table 5). At the workshop the CTD dataset collected by the *Kaiyo Maru*, the RRS *James Clark Ross* and the *Yuzhmorgeologiya* was considered. When combined with the CTD data from the RV *Atlantida*, the dataset is the largest synoptic physical description of the Scotia Sea since FIBEX. The data were collected to previously agreed protocols using standard instrumentation and are of a very high quality. Though the station spacing was insufficient to resolve mesoscale features such as eddies, the data will allow large-scale environmental features to be mapped across the Scotia Sea (Appendix G, paragraphs 2.35 to 2.38).

Analytical Procedures and Combination of Indices

Combining Indices

3.45 Since the meeting of the Subgroup on Statistics in 1996, WG-EMM has been encouraging work to further develop CSIs aimed at combining the many predators indices determined in CEMP into a single index. At its 1998 meeting, WG-EMM requested that differences in approaches to estimate the CSI covariance be addressed (SC-CAMLR-XVII, Annex 4, paragraphs 7.1 to 7.4). Following results presented to WG-EMM's 1999 meeting, a number of key issues relevant to further consideration of the development and use of CSIs were identified (SC-CAMLR-XVIII, paragraphs 6.6 and 6.7).

3.46 WG-EMM-00/18 presented updated values for the CSIs of various land-based predators at Bird Island. The study focused on the indices which are most likely to reflect the food supply during the summer season. The results indicated that indices from land-based predators did not vary significantly from normal during 1999 or 2000. However, the low breeding population size of land-based predators in 2000 was not taken into account since this is more likely to be influenced by environmental conditions during the preceding winter. Consequently, the data presented only give an indication of food availability concurrent with the breeding season in each year.

3.47 WG-EMM noted that the information presented in WG-EMM-00/14 showed that 1984 and 1994 were years with particularly low predator performance followed by 1991 and 1978. This observation was consistent with previous analyses presented (e.g. WG-EMM-99/40) and future analyses along similar lines were encouraged.

3.48 WG-EMM-00/46 presented an algorithm to estimate the energy and carbon budgets for a variety of land-based predators. The algorithm provides a way to examine the overall consumption of prey by land-based predators and, using different input data, it would be possible to develop it further on a regional basis taking into account current knowledge on predator movement and distribution. The approach could also be adapted to other predator species such as fish or squid.

3.49 WG-EMM noted that the approach outlined in WG-EMM-00/46 was most sensitive to variability in predator demographic parameters. However, predator consumption rates can still be estimated with a reasonable level of confidence even when there is relatively high uncertainty associated with many demographic parameters. The Working Group encouraged further development of the algorithm, particularly as it may provide another index of the functional linkages between predators and prey.

3.50 WG-EMM-00/14 is a complete and revised version of work presented to the WG-EMM Subgroup on Statistics in 1997 and to WG-EMM in 1998. It presents a potential method for combining CEMP data into a single index for individual predator, prey and environmental parameters. Various criteria for including parameters in a single index were discussed. It was noted that the power of the procedure adopted by WG-EMM in 1996 to detect anomalies in CEMP data declines to low levels when more than a few anomalous levels are apparent in the data. The paper presented an iterative procedure using estimates of the mean and variance of the baseline data time-series. This approach was found to demonstrate consistently better statistical powers for combining CEMP data, regardless of the accumulation of anomalies.

3.51 In discussing the results presented in WG-EMM-00/14, the Working Group noted that an approach had been outlined for the further development of CEMP indices in their application by CCAMLR. It was agreed that further development of CEMP indices should be encouraged. Based on suggestions presented in WG-EMM-00/14, the Working Group endorsed the need to address the following issues in the further development of CEMP indices.

(i) Define the classes of index behaviour to be detected by the indices.

The obvious candidates are changing variability (range), trends, shifts and changes in the frequency of anomalies.

(ii) Select the normalising transformations required for various parameters.

(iii) Select a baseline dataset.

This dataset will be used to estimate the centering matrix for the multivariate data and the variances to be used in transforming the data into an approximately standard multinormal distribution. From these data, the covariance/correlation matrix can be estimated. As a stopgap, any missing correlation coefficients could be filled in from other data series if necessary. The parameters within an index should all be positively correlated. If they are not, their role in the formation of an index requires consideration. Examine the data for serial correlation.

(iv) Examine the statistical properties of the proposed index, including, for example:

(a) detecting anomalies;

(b) effects of missing data in various scenarios;

(c) effects on the index of the variability due to sampling versus that due to intrinsic variability;

(d) effects of serial correlation;

(e) effects of non-linear correlations between parameters;

(f) plotting the indices in the form of 'control charts' –

two types of charts could be examined:

- based on an index, with critical bounds (useful for displaying anomalies); and

- based on renormalised cumulative sum of the indices – a ‘cusum’ chart (useful for detecting the effects of a systematic shift in mean level). A randomisation procedure could be tested for the identification of drift.

(v) Examine the power of the indices to detect phenomena of interest, including, for example:

(a) consideration of the appropriate levels of the probability of making type I and type II errors – type II errors may have more important consequences than type I;

(b) the effect of the length and stability of baseline data;

(c) consideration of whether all parameters should have their normal range defined purely statistically, some parameters may have their anomalies defined on biological grounds;

(d) correlation between the three indices (predator–environment–prey);

(e) examination of possible improvements in the design of the CEMP Program to increase the power of the indices. This would include the exploration of experimental designs such as before-after-control-impact designs (Constable, 1992); and

(f) examination of how the indices could be included in the development of quantitative management advice (see Constable, 1992 for further discussion).

3.52 The Working Group recognised that the above represents a substantial program of work, but it should be feasible to make considerable progress over the next few years.

3.53 WG-EMM-00/60 addressed general questions relating to the ecosystem approach for managing CCAMLR fisheries, particularly for pelagic species such as krill. The paper focused on three general questions which included consideration of:

(i) How do pelagic fisheries impact incidentally on the ecosystem?
(ii) What are the conservation objectives for predators of fished species?
(iii) What approaches might be considered for achieving the conservation objectives?

3.54 In addressing conservation objectives for predators, WG-EMM-00/60 outlined general objectives as required by Article II of the CCAMLR Convention and indicated an approach for the development of operational objectives. To achieve conservation objectives, the paper suggested that estimates of total average production could be formulated as a basis for:

(i) assessment of precautionary yield using predator criterion;
(ii) monitoring ecosystem function; and
(iii) undertaking ecosystem assessments.

3.55 In carrying forward the approach outlined above, WG-EMM recognised that various operational objectives and performance criteria should be elaborated. Members encouraged the development of such aspects, taking particular note of how uncertainty could be taken into account in the formulation of decision rules for management purposes. In this regard, it was agreed that a review of CEMP parameters and their potential utility in management procedures is timely. Further discussion on this point is contained in paragraph 3.51.

Future Work

3.56 The Working Group discussed the need for additional information about predator populations. This was a high priority because of the need to:

(i) place the long-term monitoring of predator populations within a wider regional context;

(ii) provide information about the status and trends in abundance of key species together with appropriate confidence intervals on these estimates; and

(iii) as outlined in WG-EMM-00/46, provide accurate estimates of the total prey consumption by predators to better determine the level of competition between predators and the fishery.

3.57 The Working Group looked forward to receiving information on pack-ice seals from APIS, and also saw a need to update estimates of Antarctic fur seal abundance at the South Shetland Islands and to include pelagic predators such as whales by requesting input from the IWC.

3.58 The Working Group considered that the estimation of predator abundance was of sufficiently high priority that there should be a degree of coordination of survey effort and methodology throughout the CCAMLR community. There was a case for carrying out a synoptic survey of land-based predator populations, although it was also noted that several national programs were already planning regional surveys. The Working Group encouraged these initiatives and asked each program to submit a brief outline of their objectives to Dr Constable so that he can collate these and report to the Scientific Committee about the present level of activity. He will also consult with Working Group members and prepare a potential outline for the development and timing of a synoptic estimate of land-based predator populations.

3.59 The Working Group agreed that the following conditions would probably have to be met before such a survey could be seen as a practical option:

(i) all potential participants would have to participate in a workshop to decide on methodology;

(ii) a set of methods would probably have to be adopted to match the logistics and circumstances of each program or region;

(iii) there would have to be prior agreement such that estimates from different regional surveys could be combined and a standard procedure for calculating the error on estimates would have to be agreed; and

(iv) since many methods will rely on counts of the breeding population, there will be a requirement for demographic data to allow estimation of the size of portions of the populations that cannot be counted directly.

3.60 The Working Group agreed that monitoring of the key environmental variables identified in the CEMP standard methods should continue.

3.61 Future analysis of the CCAMLR-2000 Survey oceanographic results was encouraged particularly in respect of improving identification and definitions of key hydrographic features such as oceanic fronts.

3.62 The ground truthing of CEMP-derived indices of sea-ice distribution should continue using available satellite telemetry data on sea-ice.

3.63 Work on the issues identified in paragraph 3.51 is encouraged with a view to facilitating future consideration of the application of CSIs to CEMP data. In this respect, it is proposed that WG-EMM's next meeting will devote some time to a working session on the application of CSIs and Members' experience in their use.

3.64 Prof. Boyd will liaise with SCAR-GSS in order to convey the various views and queries expressed by WG-EMM in paragraph 3.16.

ECOSYSTEM ASSESSMENT

4.1 The Working Group considered the format of this item and agreed that there were four main components to the following discussion. The first component considered the krill-centred interactions that may be of interest to managing the krill fishery within the context of Article II of the Convention. The second involved fish and squid interactions and the third involved an assessment of the krill-centred ecosystem. The fourth involved further approaches to ecosystem assessment. In this connection, the Working Group also noted the request from the Scientific Committee (SC-CAMLR-XVIII, paragraphs 6.21 and 6.22) for guidance about status and trends of resources, dependent species, environmental variables, fisheries and also about the interactions between these components of the ecosystem. In the first three of these components of the discussion the Working Group addressed a series of key questions.

Krill-centred Interactions

Implications of Krill Distributions

4.2 The Working Group addressed the question 'What are the implications of geographical distribution for assessing which sections of the krill population are being exploited by the fishery and predators?'. In combination with this, the Working Group also addressed the question 'What is the interaction between krill distribution and oceanography?'.

4.3 The geographical stratification of the krill population is an important part of the ecosystem assessment of krill-centred interactions because a knowledge of which sections of the krill population are being exploited by both the fishery and predators has implications for management. Results from the CCAMLR-2000 Survey (WG-EMM-00/6) provided a comprehensive overview of the structure of krill populations in the Scotia Sea based on length-frequency distributions. It suggested, in particular, that krill to the south and east of South Georgia may be distinct from the populations in the remainder of the Scotia Sea, at least in terms of their length structure.

4.4 The CCAMLR-2000 Survey results (WG-EMM-00/6) also supported the view that, at the Antarctic Peninsula (Subarea 48.1), krill populations may be stratified according to the oceanography. Based on analyses of krill length frequencies from the fishery (WG-EMM-00/4), there was less certainty of congruence between krill distributions and oceanography to the east of the Antarctic Peninsula (Subarea 48.2). Although work relating the krill population structure to the oceanography from the CCAMLR-2000 Survey is still at an early stage, the Working Group welcomed and encouraged forthcoming analysis of the relationship between krill distributions and oceanography.

4.5 WG-EMM-00/6 also showed that there were few small krill in the region of the Antarctic Peninsula during the 1999/2000 season and this was supported by information about krill size from the diets of penguins in the region (WG-EMM-00/41). This is evidence of another year in which there has been poor krill recruitment in the region. Low levels of recruitment have now been recorded for the past three seasons.

4.6 The reasons for continued low recruitment are unclear, although variations in the extent of winter sea-ice are a possible cause. However, there was also a recognition that the spatial separation of age classes could lead to an impression of low recruitment at the Antarctic Peninsula. Smaller size classes of krill were present to the east of the Antarctic Peninsula (Subarea 48.2) (WG-EMM-00/6) and it is possible that there may be a relationship between these small krill and the large krill at the Antarctic Peninsula (Subarea 48.1).

4.7 Further information was available about the current status of the krill-centred ecosystem at South Georgia based on krill length-frequency information. Data from the CCAMLR-2000 Survey (WG-EMM-00/6) and also from the diets of fur seals (WG-EMM-00/19) showed that small krill were present in the region of South Georgia during summer. There was uncertainty about the origins of these small size classes, which were absent from the Antarctic Peninsula (Subarea 48.1) region. While it is possible that these krill may have originated from the Weddell Sea, the Working Group considered that further analysis of both the associated oceanography and the length-frequency distributions would be required before any conclusion could be reached.

4.8 WG-EMM-00/51 also noted that during January 2000, krill to the east of South Georgia were smaller than those to the west. This difference appears to be related to differences in origin in that smaller krill were associated with Weddell-influenced waters to the east, whilst larger krill were associated with ACC waters to the west.

4.9 The information from the diets and performance of fur seals at South Georgia suggested that there had been a transition from a domination by large krill during the early summer (October–December) to small krill during the middle to late summer (January–March), linked to changes in availability of krill over that period (WG-EMM-00/19). It was unlikely that this change had been caused by the fur seals shifting to new foraging locations so it was likely that it represented a progressive shift in the composition of the krill populations in the region through the summer. Further work is required to assess how the availability and size structure of krill in the predator foraging areas may be influenced by small-scale changes in oceanography of the region. This may affect the degree to which the predators have access to the earlier portion of the krill population which appears to have different properties than the west (WG-EMM-00/56).

Predator Responses to Changes in Krill Abundance

4.10 The Working Group addressed the question 'What are the implications of apparent lack of recruitment at the Antarctic Peninsula for predators and the fishery?'.

4.11 Although there was no evidence from the CEMP indices (WG-EMM-00/26), and from other papers placed before the Working Group (WG-EMM-00/41, 00/47 and 00/62), that the breeding performance of those populations were reduced in the current year, it was still possible that predators were exploiting a declining stock of krill at the Antarctic Peninsula. If this continued, it was likely that responses from the predator populations would be observed.

4.12 Since the response of krill predators to changes in krill populations was likely to be non-linear, there was a possibility that continuing lack of recruitment to the krill population will lead to declines in predator reproductive rates. However, the Working Group also recognised that occasional declines in reproductive rate were unlikely, of themselves, to lead to declines in the predator populations. Only if food continues to decline over a protracted period and there is a succession of years in which there is a low predator reproductive rate will there be a need to examine possible remedial measures.

4.13 There was a recognition that predator reproductive rates were most likely to respond to reductions in food before some other demographic variables, such as adult survival rate or recruitment. At present the Working Group has insufficient information to be able to distinguish between the effects of food shortages on reproduction as opposed to recruitment or adult survival.

Diet of Krill Predators

4.14 The Working Group considered the question 'Is there evidence of long- or short-term changes in the diets of krill predators that might suggest changes in the ecosystem or in krill availability?'.

4.15 WG-EMM-00/13 showed that, at Bouvetøya, Antarctic fur seals and chinstrap penguins fed predominantly on krill. Macaroni penguin diets also included krill as a major component. The Working Group welcomed these additional data from this site which is recognised as a krill-centred ecosystem that currently has no fishery. As such, the site provides an important comparison with other regions in which a krill fishery exists. These data provided further evidence of the importance of krill in the diets of predators at Bouvetøya.

4.16 WG-EMM-00/47 and 00/62 examined the diets of Antarctic fur seals and gentoo and chinstrap penguins at Cape Shirreff (Subarea 48.1). Krill was the dominant component of the diet although, amongst fur seals, there was more fish and squid in the diet than had been observed in the previous year.

4.17 With reference to WG-EMM-00/19 which showed a change in the diet of Antarctic fur seals at South Georgia from large to small krill through the breeding season, the Working Group considered that this was most likely to have been caused by changes in the availability of different size classes of krill through the summer. However, it is possible that these changes in the diet of fur seals could be due to changes in the selection of prey by the predator.

4.18 Predators have the potential to actively select prey of differing quality. At South Georgia, Antarctic fur seals often feed on myctophids later in the breeding season which could be explained by myctophids moving into the region. Consistency of foraging locations among individuals within a breeding season suggests that this may indeed be the case because there is no evidence that fur seals are travelling elsewhere to access myctophids. At Cape Shirreff, fur seals are observed to forage closer to shore when myctophids begin to appear in the diet.

4.19 Alternative components in the diet have important implications for understanding both how krill predators are likely to respond to reductions in prey and to our understanding of alternative energy pathways. These alternative pathways may have unforseen implications for the dynamics of the ecosystem.

4.20 It is, therefore, important to understand how predators select prey. Two alternatives were discussed. One involved predators switching foraging strategies to hunt for particular types of prey under each strategy. The alternative is that predators maintain a consistent foraging strategy involving hunting for specific size classes or patches of prey which are economical for the predator to exploit. This latter strategy does not imply that predators will forage for a particular species or type of prey. The importance of this distinction is that, in the former case, predator diet may not reflect the availability of prey because predators may switch foraging strategies for reasons other than to hunt the most abundant prey. In the latter case predator diets are more likely to reflect the natural density of prey in the foraging area. It was recognised that the balance between these alternatives may differ among predator species but there is currently too little data available to decide which of these possibilities was the most likely in each case. Several ongoing initiatives are likely to help to narrow down the answer to this problem.

4.21 The Working Group concluded that there was still insufficient knowledge of predator feeding tactics to be able to conclude that there was evidence of short-term changes in krill density from predator diets, although the evidence to date suggests that it may be possible to make progress in this field. There was more evidence that predator diet reflected changes in the gross structure of the available krill populations. In the long-term, the case of the declines of macaroni penguins at the west end of South Georgia in conjunction with a shift in diet away from krill may indicate a change in the feeding conditions for macaroni penguins that is detrimental to population growth.

4.22 In the past, most of the attention of the Working Group has been focused on the diets of land-based predators. There is a recognition that, whenever practical, the diets of pelagic predators of krill should also be included within ecosystem assessments. In particular, there may be opportunities in future to sample the diet of fish, such as the mackerel icefish, within the context of observer programs associated with fisheries or in association with scientific surveys. From the beginning, CCAMLR had sought to include the widest possible range of species within CEMP but there had been a need to narrow down to tractable species and circumstances. There was a recognition of the opportunities offered by monitoring fish and the Working Group encouraged the collection of data about fish diets when opportunities arise, although it also considered that the development of a regular monitoring procedure for this was not feasible at this stage.

Status and Trends of Krill Predator Populations

4.23 The Working Group addressed the question 'Is there evidence of long- or short-term changes in the populations of krill predators that suggest changes in the ecosystem?'.

4.24 In this regard, the Working Group noted information contained in the reports from SCAR-BBS and SCAR-GSS (WG-EMM-00/16 and 00/63).

4.25 Although, overall, the data about bird populations show that there are no consistent Antarctic-wide trends in the abundance of seabirds that are predators of krill, two features were noted. These were: (i) the general decline in the abundance of Adélie and chinstrap penguins at sites on the northern end of the Antarctic Peninsula, and (ii) that the main indicators for macaroni penguins show that this species may be in a long-term decline, especially at South Georgia. The Working Group recognised that these apparent changes in populations could be caused by the results of regional redistributions of animals or to local effects rather than region-wide effects. However, it is important to continue tracking these changes and to understand their implications in the context of the whole region.

4.26 Detecting changes in the abundance of predators is a high priority for the Working Group but there was a particular need to detect significant declines in abundance and to identify the probable causes of these declines. At its previous meeting the Working Group had expressed its interest in developing a system for assessing predator populations according to the IUCN criteria for threatened species (SC-CAMLR-XVIII, Annex 4, paragraphs 7.74 to 7.77). However, experience of the lack of recovery of long-lived fish populations that were heavily exploited in Area 48 during the 1970s has provided an example of population depletion that should be avoided in future (SC-CAMLR-XVIII, Annex 5, paragraph 3.137). This has shown that when long-lived predators, which also tend to have low rates of recruitment, are driven to very low levels, it is unlikely that recovery can be achieved within the 20–30-year time period specified in Article II of the Convention. Therefore, if krill predators are driven down to the levels at which the IUCN criteria for threatened species become relevant, then the management measures put in place to prevent such a process could be deemed to have failed.

4.27 Fur seal populations continue to increase at a very high rate within Area 48. The Working Group considered that it was inevitable that fur seals were having an effect on the krill-centred ecosystem and there was evidence from South Georgia that they were also affecting icefish (WG-EMM-00/22). The Working Group noted that past notions of there being a krill surplus following the reduction of whale populations in the region probably no longer apply and that we may expect to see evidence of competition amongst predators and between predators and the fishery for a limited supply of krill. An example of such a competitive interaction may be present at the west end of South Georgia (Subarea 48.3) which is at the centre of the fur seal expansion. Macaroni penguin populations in this area have been in long-term decline (WG-EMM-00/16) and there has been a shift in diet away from krill (WG-EMM-00/26). This may be evidence of a competitive interaction with fur seals.

4.28 The increasing number of Antarctic fur seals illustrates that populations of predators may not be in a stable state. Consequently, management objectives will need to take this into account.

Assessment of the Impacts of Predators on Krill

4.29 The Working Group addressed the question 'What are the impacts of predators on krill populations?'.

4.30 The assessment of the krill consumption by predators has been highlighted as an important area of research for this Working Group at most of its past meetings. WG-EMM-00/46 provided a potential way forward in this respect. The paper presented an algorithm for calculating the impacts of predators on their prey populations. The intention was to begin to apply this algorithm spatially and temporally to predators in order to build up a view of the spatial and temporal impacts of predators on krill, including impacts on krill population structure through the selection of specific size classes of krill by predators.

4.31 The algorithm emphasised the importance of gaining good data about predator population sizes and demography because the CV around the estimated prey consumption rate was most sensitive to uncertainties in these parameters. It also showed that uncertainty around the metabolic rate could lead to an upward bias in the estimated food consumption.

4.32 The Working Group reiterated its view that this was an important area of work and encouraged further development of this approach.

Distribution of Predators relative to Krill

4.33 Although the analysis in WG-EMM-00/46 concentrated on fur seals and macaroni penguins at South Georgia and was based on data for these species during 1991, the Working Group noted that potential krill predation at South Georgia was substantially greater than at the South Shetland Islands. Therefore, the impacts of predators are likely to be greater at South Georgia. There was also recognition of the relatively high level of predation pressure that probably exists at the western end of South Georgia (Subarea 48.3).

4.34 Dr Everson pointed out that, compared with the Bering Sea, the frequency of observations of predators at sea to the west of South Georgia did not suggest there were unusually high densities of avian predators in the region. However, both Prof. Boyd and Dr Trivelpiece considered that this observation did not take into consideration the substantial differences between the avifaunas of the Bering Sea and the Southern Ocean. Much of the food consumed by predators to the west of South Georgia was due to penguins which, due to diving, have a much lower visibility at sea than the auks found in the Bering Sea. This raised the issue of how best to use data from ship observations of predators. It was agreed that this was an important topic and the Working Group encouraged comparative analysis of ship- and satellite-based observations of predators at sea.

4.35 New data are becoming available from the satellite tracking of predators throughout their annual cycle. Dr Trivelpiece informed the Working Group about data showing chinstrap penguins that breed at the South Shetland Islands (Subarea 48.1) moving as far afield as the South Sandwich Islands (Subarea 48.3) during winter. Prof. Boyd also informed the Working Group of the results of tracking female fur seals in the winter which showed about half the animals tracked left the Southern Ocean and were observed over the Patagonian shelf in winter. Although these are only preliminary reports of ongoing studies, these data suggest that there is a substantial redistribution of foraging effort by krill predators in winter and that some krill predators are moving out of the Southern Ocean in winter.

4.36 The Working Group agreed that this information about the redistribution of krill predators in winter compared with the breeding season was important because it will improve information about the possibility of overlap between krill predators and the fishery.

4.37 The Working Group considered the question 'Can data from mackerel icefish be incorporated into the CEMP time series to be use in ecosystem assessments?'.

4.38 Discussion of ways in which it may be possible for ecosystem assessments of interactions between predators and krill to include spatial scales associated with pelagic predators, as well as those from land-based predators, was centred on information about variability in condition indices of icefish (WG-EMM-00/44 and 00/45). Even though it is recognised that the suite of land-based predators that is available can cover many different spatial and temporal scales, a pelagic predator like the icefish has the potential to integrate conditions across a region. The icefish, which moves up from the bottom to feed on krill rather than down from the surface as in the case of land-based predators, may also be exploiting a different part of the krill population from land-based predators. Although the movement patterns of icefish are imprecisely known, it is thought that there are different icefish populations associated with each region of continental shelf, such as at South Georgia, and they could be used to assess the krill-centred ecosystem at that spatial scale and across the whole of the year.

4.39 The icefish condition index appears to respond rapidly to changes in krill availability, which makes it a useful index to measure fluctuations in krill. The gonadal development is subject to considerable interannual variation. It is suggested that this may be because of the greater uncertainty surrounding the prey availability for this bentho-pelagic predator (WG-EMM-00/45). While the statistical properties of the condition index, like those of some other CEMP indices, remain to be fully investigated, a series of data from 1973 to the present showed that many of the fluctuations in the condition index were associated with similar changes in indices of performance from the land-based predators.

4.40 Therefore, the icefish condition index has potential to provide important information about the fluctuations in the krill available to icefish. However, it was noted by the Working Group that there were a number of questions remaining to be addressed. These were:

(i) What is the linkage between icefish and krill?
(ii) What density of krill is optimal for feeding icefish?
(iii) How can data be collected regularly from both icefish and krill to address the above questions using fish surveys and the fishery?

Functional Relationships between Predators and Krill

4.41 The Working Group considered the question 'How can empirical functional relationships between krill and predators be used to provide advice and what actions need to be taken with respect to the fishery?'.

4.42 WG-EMM-00/44 had shown a non-linear relationship between krill density and the mackerel icefish condition index. Since its initial meeting in Siena, Italy, in 1995, the Working Group has highlighted the need to understand the functional relationships between predators and krill and the relationship from the icefish adds to several that have been developed for CEMP parameters. These relationships can only be developed from continuous effort over many years, as in the case of CEMP, but also including independently derived estimates of krill density in the region of interest. Therefore, they are a highly valued product of the research effort being directed at understanding krill–fisheries–predator interactions.

4.43 The report of the Siena meeting (SC-CAMLR-XIV, Annex 4) laid out a mechanism for incorporating functional relationships into a strategic model of the ecosystem. Subsequent work by Prof. D. Butterworth (South Africa) had examined the relationships between krill density and predator populations and made assumptions about the form of these functional relationships. This concept has been extended at the present meeting by Dr Constable (WG-EMM-00/60). The Working Group welcomed the data about functional relationships. At present, they may be best applied in a qualitative sense in that the current data confirm the non-linearities of these relationships and they probably indicate the type of non-linearity. Of particular interest is that krill density needs to decline to relatively low levels before a predator response is detected. However, the Working Group also recognised the need to link the indices of predator performance used in these functional relationships to the demography of the predator populations.

4.44 The Working Group recognised that it eventually needs to move towards a predictive framework for its advice and that quantitative functional relationships between predators and krill are essential to make this possible. These functional relationships could have a certain amount of generality in that they may be phenotypically determined at the level of individuals although further work would be required in order to examine what effects population density might have on the functional relationship at a population level. Therefore, there is a need to understand the factors which determine the form of functional relationships.

Fish and Squid-centred Interactions

The Importance of Fish and Squid

4.45 During its discussions of krill-centred interactions, the Working Group returned to the issue that krill-centred interactions cannot be viewed in isolation from interactions with other components of the ecosystem. The issues raised about mackerel icefish as a predator of krill also raised the issue that icefish are themselves prey for land-based predators. This complexity needs to be reflected in the deliberations of the Working Group and it is important to develop a robust management structure for fisheries within the ecosystem that considers this complexity.

4.46 The role of myctophids as alternative prey to krill for some predators was a recurring issue and it was also recognised that myctophids may be predators of krill in some circumstances. The Working Group agreed that, with the recent completion of the CCAMLR-2000 Survey, there is an opportunity to analyse the acoustic data from the survey to examine the density of other targets, including myctophids. Although there are difficulties with net sampling myctophids because the nets used to sample krill are not effective for sampling myctophids, these samples are likely to be sufficient to examine species composition. The Working Group strongly encouraged the analysis of the CCAMLR-2000 Survey data to obtain additional information about myctophid biomass and distribution.

Diet of Fish and Squid Predators

4.47 The Working Group considered the question 'What are the implications of studies of the diet of squid and fish predators for ecosystem assessment?'.

4.48 WG-EMM-00/8 and 00/9 examined the fish prey of South Georgia and Antarctic shags from the South Orkney Islands for 1995–1998 and for the Antarctic Peninsula during 1998 respectively. The papers showed that this coastal species of predator had a wide range of fish prey in its diet. The prey species were those expected to be associated with a near-shore benthic forager. However, with the presence of *Gobionotothen gibberifrons* in diets at both sites, but particularly at the South Orkney Islands, where this species had been exploited heavily in the past, it was suggested that the shag could be used as a convenient coastal monitoring species for fish populations.

4.49 Dr Everson commented that *Notothenia rossii* occurred only sporadically in the diet which was not surprising since this was a more offshore species. In contrast, *G. gibberifrons* is known to be a coastal species so it was not surprising that it occurred in the diet. It was surprising, however, that at the South Orkney Islands, shags did not have mackerel icefish in their diets and, since icefish occurred in the regions concerned, Dr Everson considered that this was evidence that shags must have been ignoring icefish as a prey item. Mr Reid pointed out that shags at South Georgia have icefish in their diets.

4.50 These data from shags may be of importance to CCAMLR in that Article II of the Convention states that depleted populations should be rebuilt and there may be information from the diets of shags to assess the progress that is being made towards this objective. However, in the absence of a direct assessment of the resource concerned, it is difficult to determine the utility of this index. Nevertheless, the Working Group recommended continued submission of information about the diets of shags.

4.51 Dr E. Fanta (Brazil) suggested that it may be possible to use a region as a case study to examine the food-web interactions of all predators, including the land-based and fish predators. This would provide information to help interpret the relative importance of finding specific prey in the diet of some predators. It was recognised that this would require quite specific circumstances in which there were relatively few predators and a fish fauna that was comparatively well known and easy to study, but the Working Group recognised the need for such studies. In this case, there was perhaps a need to develop linkages with other programs operating in the region, such as the Palmer LTER and SCAR.

Status and Trends of Squid and Fish Predators

4.52 The report from SCAR-GSS (WG-EMM-00/63) showed continued declines in elephant seal populations in the Indian Ocean. This population is thought to be distinct from the population in the Atlantic which appears to be stable or increasing very slowly. The Working Group considered the question 'Are the declines in the elephant seal populations an issue that is of interest to CCAMLR?'.

4.53 Dr Constable amplified some of the points raised in WG-EMM-00/63 by pointing out that there was evidence that the elephant seal populations at Macquarie Island appeared to be stabilising after a long period of decline.

4.54 The Working Group recognised that elephant seal diets were not well documented but that the information available suggested they fed on fish and squid. In the case of elephant seals in the Indian Ocean, tracking studies indicate that they rely heavily on foraging south of the Antarctic Polar Front and that foraging extends further afield from the breeding colonies in older age classes.

4.55 The toothfish fishery in the Southern Ocean is the most likely fishery that would influence elephant seals at this stage. Current data indicate that toothfish are a relatively minor component of the diet of elephant seals and that toothfish in the diet are likely to be juveniles. At Heard Island, the current escapement of 80% for juvenile toothfish should be sufficient to maintain this item in the diet of elephant seals (SC-CAMLR-XVI, Annex 4, paragraph 6.89). However, the high level of illegal fishing for toothfish may mean that recruitment of juvenile toothfish may become impaired in the long term. If this occurs, then toothfish may become less important in the diet of elephant seals.

4.56 The decline in elephant seal numbers began before the toothfish fishery so this fishery is not the cause of the decline in elephant seals. The central question is whether the toothfish fishery may impede recovery of these seals. The Working Group agreed that consideration of the consequences of illegal fishing on the recruitment of toothfish would be worthwhile to help answer this question. Also, there are few quantitative data on the diet of elephant seals. More information on the relative importance of toothfish in the diet of elephant seals from different regions will help determine the potential effects of the toothfish fishery on this species.

4.57 The Working Group noted from the report of SCAR-BBS (WG-EMM-00/16) that king penguin populations have been showing a consistent increase in abundance among sites. Since king penguins mainly feed on myctophids, the Working Group addressed the question 'Does this change in abundance suggest the presence of a long-term change in the ecosystem?'.

4.58 Dr Trivelpiece informed the Working Group that recent increases in the numbers of South Polar skuas at the Antarctic Peninsula reported in WG-EMM-00/16 may be linked to an increasing occurrence of myctophids in their diet. In the 1970s and 1980s there were no myctophids in the diet when *Pleuragramma* was the dominant prey species. During this period there were several years when South Polar skuas failed to produce any chicks when *Pleuragramma* was absent from the diet. During the 1990s myctophids increased in the diet and this has been associated with increased reproductive success and a lack of any years of complete productive failure. It appears probable that this has occurred because of a greater availability of myctophids in recent years.

4.59 Dr V. Siegel (Germany) also informed the Working Group that net sample data from the Antarctic Peninsula and Elephant Island regions (Subarea 48.1) suggest that there was a change in the species composition of fish in the region during the late 1980s because, until then, *Pleuragramma* larvae were caught but none have been caught in surveys during the 1990s. Dr Hewitt also considered that, based on the US AMLR Program time series of hydroacoustic surveys of the region over the past 10 years, myctophids may have increased at the South Shetland Islands.

4.60 Although several indicators suggested that myctophids increased in abundance over the past 10 years, the Working Group agreed that there was too little information available to conclude that the abundance of myctophids had increased. Information from the CCAMLR-2000 Survey could make a very useful contribution to knowledge of myctophids as a resource in Area 48.

4.61 Dr Everson pointed out that WG-FSA provides annual summaries of the standing stock (with CV), mortality rate and growth coefficients of key species and that it may be useful if these were made available to WG-EMM because they would provide additional information about the status and trends of fish which could be related to information about dependent species.

Effects of Environment on Predator Distributions

4.62 Stimulated by WG-EMM-00/36, the Working Group addressed the question 'What is the interaction between physical oceanography and predator distributions and its relevance to possible changes in the distribution of predators in the future?'.

4.63 A meeting 'Interannual Variability in the Southern Ocean' was held in Cambridge, UK, during August 1999 and the proceedings will be published in the *Journal of Geophysical Research* which will develop the theme of linkages between the biotic and physical components of the Southern Ocean ecosystem.

4.64 WG-EMM-00/36 suggested that there had been a southerly shift in the Polar Front based on changes in the distribution of seabirds. Dr M. Naganobu (Japan) confirmed this and described changes in the position of the Polar Front from a data time series based on the WOCE transect across the Drake Passage. He hypothesised linkages between this variability and the El Niño / La Niña process in the Pacific Ocean.

4.65 Although, in some regions, the position of the Polar Front can be remarkably static between years, there is quite probably a linkage between ENSO and the Southern Ocean anomaly precession that has been recognised to exist in historical datasets. Since the early days of krill research it has been recognised that frontal variability could influence krill populations and, by implication, the foraging locations of krill predators.

4.66 The Working Group recognised the importance of these studies of the physical system and its interaction with the biology of the ocean and it encouraged further work. There are important opportunities to relate oceanography with biology, including the distribution of predators, through the analysis of recently collected datasets from research cruises that included observations of predators as well as the physical and biological oceanography.

Status of the Krill-centred Ecosystem

Development of Assessment Methods

4.67 The Working Group was reminded of paragraphs 8.5, 8.17 and 8.18 of the 1998 report of WG-EMM (SC-CAMLR-XVII, Annex 4). These outlined a process to develop a robust way of using CEMP parameters for carrying out an ecosystem assessment. Substantial progress has been made in some areas. As discussed under paragraphs 4.41 to 4.44 there has been progress in demonstrating the relationship between CSIs and prey (SC-CAMLR-XVII, paragraph 8.17(b)), although there is a continuing need to bring forward these data to WG-EMM for explicit consideration.

4.68 In addition, information from the tracking of predators at sea provides the spatial and temporal scale of relevance for each predator species. Data on this subject have been submitted to WG-EMM in past years and the Working Group encouraged continuation of this process.

4.69 Particular consideration needs to be given to the requirement to demonstrate how CSIs can be interpreted in relation to the demography and abundance of the indexed species. The Working Group recognised that this was a substantial task. Demographic information about long-lived predators is not easily obtained and is mainly rooted in long-term mark–recapture studies. These can take decades to produce useful results and only in the past few years have the datasets begun to yield the type of information that would be required in order to examine the relationships with CSIs.

4.70 There is a general recognition that the assessment of breeding population size in CEMP species needs to be set within the context of changes in the total population within a region of interest. This arises because it is not normally possible to measure total population size on a regular basis and, therefore, sub-sections of the whole population are monitored. Periodic regional surveys need to be carried out in order to validate the local population assessments. The Working Group recognised that several national programs now have plans in place to undertake the necessary work to undertake regional surveys of predator populations and the Working Group welcomed these initiatives.

Current Status

4.71 Further to its assessment of the current status of the krill-centred ecosystem, the Working Group examined the CEMP indices for evidence of changes in predator behaviour and reproductive success. Based on plots of anomalies in WG-EMM-00/26, it noted that:

(i) the number of Adélie penguins breeding at Signy and Laurie Islands (Subarea 48.2) was unusually low;

(ii) the number of breeding pairs of Adélie penguins declined significantly and is the second lowest count in the 21-year time series from Admiralty Bay (Subarea 48.1);

(iii) the highest fledging success of macaroni penguins occurred at Bird Island (Subarea 48.3) in a 24-year time series;

(iv) only four of 18 CEMP indices from Bird Island were negative;

(v) the largest occurrence of fish in the diet of macaroni penguins occurred at Bird Island in an 11-year time series;

(vi) the greatest fur seal pup growth rate occurred at Bird Island in an 11-year time series;

(vii) the September sea-ice index was generally lower than normal at most sites in a 21-year time series; and

(viii) recent data about overlap between the fishery and predators does not suggest that the overlap has increased.

4.72 This information, in addition to other information brought to the Working Group under this agenda item, suggests that the current year was not anomalous. On balance, the indicators from CEMP show that there was above-average conditions for reproduction during the summer. However, it is difficult to know what density-dependent processes may be operating. For example, if breeding population size declined, as appeared to be the case for penguins at the South Orkney Islands, then reduced competition for food in the local area might lead to relatively small changes in breeding success even though there could have been low krill density.

4.73 Nevertheless, based on comparisons between the results of the CCAMLR-2000 Survey and recent smaller-scale surveys, the krill densities during 1999/2000 were at the lower end of the normal range of variability.

4.74 The Working Group considered the continued lack of recruitment of krill in Subarea 48.1 and the potential responses of predators in the future. Declines in krill density in the region based on hydroacoustic surveys appear to be related to this apparent lack of recruitment. At present, there are no indicators that suggest any adverse effects of low krill density on predators.

4.75 WG-EMM-00/40 showed that penguins may be most sensitive to krill shortages during the early phases of chick rearing. While different species are likely to respond in different ways, this suggests that, in general, the CEMP monitoring would have detected reduced prey availability during the critical breeding phase of the annual cycle.

Historical Status of the Ecosystem

4.76 WG-EMM-00/18 presented an analysis of 14 CEMP parameters from Bird Island across a time period from 1977 to the present using Antarctic fur seals and macaroni and gentoo penguins. The analysis was based on the CSI approach outlined in WG-EMM-00/14. The analysis also suggested that the breeding performance of predators was not significantly different from normal in 1999/2000. However, it also showed that significant reductions in predator breeding performance had occurred during 1978, 1984, 1991 and 1994, but there was no indication of a trend in breeding performance or that the frequency of years of significantly reduced reproductive performance had changed through time.

4.77 Attention is drawn to paragraphs 4.56 to 4.59 for discussion of further indications of the historical status of the ecosystem.

4.78 The Working Group considered the results of the current estimate of B_0 in light of the past estimate based on the FIBEX survey carried out in 1980. In this connection, the Working Group drew attention to the reasons for wishing to replace the FIBEX estimate with a more reliable one (SC-CAMLR-XV, Annex 4, paragraph 4.61).

4.79 There were important differences between the current CCAMLR-2000 Survey and the FIBEX survey in the way in which they were carried out. These were:

(i) CCAMLR-2000 and FIBEX surveys covered substantially different areas. The coverage of the CCAMLR-2000 Survey (2 065 000 km^2) was aimed at encompassing both the regions where krill fisheries occur and regions of open ocean, thus covering five times more area than FIBEX (396 000 km^2) which coincided with the locations of the krill fishery.

(ii) Unlike the CCAMLR-2000 Survey, the different ships involved in FIBEX did not use identical hydroacoustics and sampling methods.

(iii) Since the time of FIBEX there have been many improvements in technology, statistical sampling methods and in our understanding of the use of hydroacoustics to carry out biological surveys. These were applied to the recent CCAMLR-2000 Survey but not the FIBEX survey.

4.80 The direct comparison of the total biomass estimated from the two surveys (B_0 = 44.3 million tonnes; FIBEX = 32.7 million tonnes) is confounded by the different total areas covered by the two surveys. Similarly the direct comparison of the mean density of krill in the two surveys (B_0 = 21.4 g/m^2; FIBEX = 77.6 g/m^2) is confounded by the concentration of the FIBEX survey on regions of known high krill density.

4.81 Comparison between the two estimates may also not be valid when the results are placed within the context of the variability observed in mesoscale surveys conducted in the years between FIBEX and B_0. Although it may be possible to use these intervening surveys to attempt to assess the overall change in the krill populations between the two surveys, the

Working Group recognised that this would require considerable additional work without any guarantee that the work would provide an answer to the original question. However, the Working Group noted that, based on the changes in krill density observed in the mesoscale survey box off Elephant Island, the CCAMLR-2000 Survey may have taken place during a period of relatively low krill abundance in what may be a long-term cycle of krill abundance. In this circumstance, the estimate of B_0 from the recent survey will be precautionary.

4.82 Beyond this, the Working Group agreed that it was not possible to make a comparison between the results of the two surveys. It was also agreed that the result of the recent CCAMLR-2000 Survey was the best available estimate of B_0.

4.83 Dr Azzali informed the Working Group of historical changes in krill abundance with a 20 000 n mile^2 survey box in the Ross Sea. During 1994/95, the krill biomass was approximately 3 million tonnes but this had declined to approximately 2 million tonnes in 1997/98. Data from more recent estimates remain to be analysed. In 1994/95 the krill biomass was centred on 75°S and 175°E; in 1997/98 it was centred on 72–73°S and 175°E and in 1999/2000 the centre of biomass was at 71°S. Dr Azzali considered that this change in distribution was caused by the change in the timing of the three surveys since the 1994/95 survey took place in November whereas the surveys in 1997/98 and 1999/2000 took place in December and January respectively.

4.84 It was suggested that the movement of krill spatial pattern from south to north could be in relation to front-ice that moves in the same direction from November to January. The decrease of krill biomass can be due to dispersion of the population into Pacific waters.

4.85 It was observed that it is necessary to acquire more information in this field, including environmental parameters.

Further Approaches to Ecosystem Assessment

4.86 At the WG-EMM 1999 meeting there was a debate about how to carry out ecosystem assessments. During the debate there was a discussion about the relative merits of the different types of data being collected and a broad discussion about the best ways to develop the ecosystem approach. The development of the ecosystem approach within CCAMLR was documented in the WG-EMM 1995 report, and during the 1999 meeting, the Working Group was reminded of the original objectives and the history of the development of the ecosystem approach.

4.87 At the 1999 meeting the Working Group participants were encouraged to undertake intersessional work to produce new frameworks for the development of the ecosystem approach. Participants were also encouraged to take account of approaches adopted elsewhere in the world (SC-CAMLR-XVIII, Annex 4, paragraphs 9.1 to 9.9).

4.88 Three papers were submitted to the WG-EMM 2000 meeting that addressed the general issues involved developing ecosystem assessments. These papers presented a range of discussions about the history of the ecosystem approach in CCAMLR. They also proposed a number of initiatives to develop the approach.

4.89 WG-EMM-00/43 presented a discussion of the way forward for ecosystem assessments and suggested a three-pronged approach to conservation questions associated with the Antarctic krill fishery. The three elements were:

(i) identification and monitoring of key processes governing krill recruitment and transport, and those controlling the viability of krill predator populations;

(ii) elaboration of resource management rules based on monitoring results; and

(iii) research activities designed to reduce uncertainty, monitor performance and improve the management scheme.

4.90 A number of questions were posed about the operation of the key elements of the system with the focus on identifying key processes. The paper emphasised the key objectives of maintaining the viability of the krill population and the viability of the predator populations. These objectives should be the basis for the system management with monitoring of the critical processes assessed through decision rules that dictate the management response.

4.91 On process monitoring, the paper discussed a range of aspects. The paper highlighted the need to review the CEMP monitoring program with a view to understanding the extent and adequacy of the existing program. This would also help to understand how to develop the program. The program development may require an increase in the spatial scale of monitoring, additional monitoring sites may need to be set up, pelagic predators may need to be included and the spatial extent and frequency of krill surveys may need to be extended. Consideration may also need to be given to further large-scale surveys of the form of the CCAMLR-2000 Survey.

4.92 A key issue that the paper highlighted was the potential value of an experimental approach, such as undertaking experimental fishing, to examine directly the effects of fishing on local prey and predator populations.

4.93 WG-EMM-00/60 developed the theme of achieving conservation objectives for predators of fished species (paragraphs 3.53 and 3.54). Consideration of the conservation literature indicated that such objectives had not yet been developed in relation to the predators. The objectives need to include a consideration of how the system is changing and how to maintain a system exposed to exploitation. In developing these objectives, it will be particularly important to consider non-linearities to take account of potential phase shifts in the system.

4.94 The paper highlighted that the fishery removed production in the form of the fished species that is then not available to the predators. This could be the focus of objectives centered on the question ‘What is the target level for the production of predators?’. Once objectives are in place, decision rules can be specified, such as closing the fishery when krill abundance is below a critical level or altering fishing if an anomalous year in predator production is reported to avoid adverse effects of successive anomalies.

4.95 The decision rules could be set to develop along with the fishery. Hence, an expansion of the fishery could trigger the development of further monitoring and may require a modified management regime.

4.96 In WG-EMM-00/22 the historical basis for the development of the CCAMLR approach was described. The paper highlighted the original Article II principles of conservation and emphasised how these had been developed within CCAMLR leading to the development of the ecosystem approach described by WG-EMM in 1995 that has guided much of the work over the last five years.

4.97 The paper noted the problems of analysing local-scale system dynamics by highlighting the temporal and spatial changes in prey availability. The paper also discussed the merits of the CEMP program highlighting its strengths, but also noting issues that the program cannot address. The paper highlighted, through the use of the mackerel icefish example, how different scales of variation can be monitored using predator indices to examine the changing availability of krill.

4.98 To develop the ecosystem approach the paper suggested four simple questions that capture the essence of the problem:

(i) Is the availability of krill changing?
(ii) Are populations of dependent species in decline?
(iii) How much krill is required by the dependent species?
(iv) What is the extent of overlap between krill fishing and the foraging by dependent species?

4.99 The paper made the suggestion that adopting the icefish example (paragraph 4.97) more generally may allow the development of the use of predator monitoring of prey availability to match the scale of the variation. The paper also highlighted that the ratio of the predator demand to fishery demand would be an appropriate way to monitor fishing impact.

4.100 The paper presented a decision process as a conceptual figure that describes how local decisions could be included in the large-scale conservation framework. The figure highlighted that local-scale information needs to be integrated to address the large-scale krill fishery questions. The local-scale monitoring can then be used to trigger local management actions based on fishery and predator assessments.

4.101 The Working Group thanked the authors of the three papers for their efforts in developing the ecosystem approach. The Working Group noted that the papers were together an extremely useful contribution to the debate and that a number of similar points were emphasised. All three papers highlighted the need to consider what requires monitoring, how appropriate indices may be derived and how these should be used.

4.102 The Working Group favourably viewed the conceptual framework presented in Figure 8 of WG-EMM-00/22, included in this report as Figure 1. The figure highlighted some of the relationships that would need to be considered in any decision process and emphasised where our management intentions may break down. The Working Group noted that the scale on the right of the diagram could vary in relation to the scale of the predator issues being addressed, e.g. colony, island, regional and population.

4.103 Figure 1 also emphasises the need to develop knowledge of predator population dynamics. While a better understanding of the dynamics is being developed, the monitoring indices would need to be used to identify significant indications of a decline in predator performance. The key question here is ‘Are the current CEMP parameters good proxies that give an indication of any population changes?’.

4.104 The Working Group considered that in developing the ecosystem approach the emphasis should be on developing decision rules that are robust and maintain the objectives of conservation while allowing rational use. Development of Figure 1 would be a useful focus for this effort.

4.105 Developing such conservation objectives was addressed in WG-EMM-00/60 (paragraph 4.93) and the approach adopted in this paper of considering overall predator production was noted as being both novel and useful. The Working Group noted that it could provide a potentially powerful and cost-effective framework for developing an ecosystem approach.

4.106 The predator production assessment could be applied at a number of levels. The current CCAMLR approach focuses on detailed analyses of particular species. Another approach would be to assess the overall level of production and set in place only broad decision rules for the various species. The latter approach has a lot of potential in a system like the Southern Ocean where the interaction dynamics are uncertain. The Working Group encouraged the further development of the approach alongside the more traditional species-based views.

4.107 There was a broad discussion in the Working Group about the development of the theoretical approaches to ecosystem analyses and assessments for conservation. A key question in this regard is ‘How to characterise an ecosystem?’. This needs to include consideration of the expected dynamics of different populations so that bounds could be determined for the expected behaviour of different system components. Such a theoretical consideration would need to include aspects of biodiversity that included a focus on species. The key element will be to link aspects of food-web dynamics that are the focus of CCAMLR efforts to broader species-based views. The two views are linked because the loss of a species would be regarded as a failure under Article II of the Convention.

4.108 The Working Group felt that it would be useful to develop models of the system that allow the examination of different plausible scenarios of system behaviour and management procedures. These simulation models should be robust and include the current level of knowledge and uncertainty in the system. The analyses would have to take account particularly of the uncertainty in predator population size and demographics. Different management rules could then be examined given different levels of system monitoring. This would allow the decision rules to be evaluated. The decision process adopted should include subsidiary rules that account for unforseen but extreme changes in the system outside the boundaries of expected behaviour. This could be expressed as an 'exceptional circumstance rule' in the management regime.

4.109 Management measures may not only involve placing controls on the fishing activities, but may also involve enhanced monitoring to provide feedbacks. Generally, more information should lead to better management.

4.110 Development of the ecosystem dynamics was encouraged and this should include the effects of change and variability and the importance of alternative pathways in food webs.

4.111 The Working Group noted that the concept of permitted biological removals (PBRs) used in some marine systems within the USA is an example of the type of approach that could be explored in the CCAMLR region. It was also suggested that the potential for biological effects, such as disease, that could rapidly change the viability of predator populations could also be considered.

4.112 The suggestion of including the economics of the fishery was made (paragraphs 2.6 and 2.7). It was noted that although many of the key aspects of the krill fishery may not be economically based, including operational effects in a multinational fishery would be valuable. The economics also include the cost of managing the fishery, including monitoring. A successful management procedure is one that achieves the objectives while ensuring the costs of managing the fishery are commensurate with the value of the fishery.

4.113 The Working Group noted that the Southern Ocean ecosystem is highly variable in space and time and that this should be an important focus in any review of the value of particular monitoring datasets and in the development of any management strategies.

4.114 In response to the debate at WG-EMM-99 about the development of the ecosystem approach within CCAMLR, the Secretariat was asked to undertake a review of the status of various tasks initiated at WG-EMM-95 and later meetings. This review was prepared by Dr E. Sabourenkov (Science Officer) in WG-EMM-00/29.

4.115 The Working Group thanked the Secretariat for undertaking this task which had produced an extremely useful review that would help to focus the efforts of the group in developing the ecosystem analysis approach. This was a broad and useful summary and the Working Group requested it should be updated annually.

4.116 The paper helps to clarify the Working Group's progress in developing an ecosystem approach to managing krill fisheries.

Such a management procedure can be summarised in two statements. It requires:

(i) a predictive assessment of yield; and
(ii) the appropriate monitoring and decision process to provide the feedback to manage the harvesting.

4.117 The Working Group considered that it was currently in a much better position to judge the development of such procedures as a result of the success of the CCAMLR-2000 Survey and the now extensive basis of the CEMP time series. The Working Group considered that a realistic time scale for having a solid basis in place for the process was five years, and 5–10 years for the development of a full management procedure.

Future Work

4.118 A number of papers described aspects of future data collection, synthesis and the development of national and international science programs relevant to the generation of the CCAMLR ecosystem approach.

4.119 WG-EMM-00/61 presented a plan for developing a broad view of the status of ecosystems covering physical, chemical and biological variables across a range of trophic levels. This paper considered how to characterise an ecosystem that the Working Group emphasised as a key issue for ecosystem assessment. The Working Group noted that the inclusion of physical and chemical data and other variables relating to the broader operation of the ecosystem, covering other zooplankton and pelagic predators, will be a valuable development. This will help to address the importance of food-web pathways other than krill to land-based predators in the operation of the ecosystem.

4.120 WG-EMM-00/42 compared target strength from net sample and predator diet data and provided a potential way of calibrating rapid acoustic surveys with a reduced requirement for net-based sampling. The Working Group considered that extending the temporal and spatial scale of ship-based sampling using predator diet data was extremely valuable. The Working Group encouraged the further development of such techniques and the application that could extend the spatial and temporal coverage of sampling of the krill populations.

4.121 WG-EMM-00/53 detailed the development of the Southern Ocean GLOBEC Program. The paper highlighted the current status of the program cruise plans. The paper also gave details of the US Southern Ocean GLOBEC cruise plans. The Working Group thanked the authors for providing details of the Southern Ocean GLOBEC program and considered that it was important that there was active interaction between CCAMLR scientists and Southern Ocean GLOBEC scientists.

4.122 It was pointed out that a number of CCAMLR scientists are also active participants of the Southern Ocean GLOBEC Program. The Working Group noted that the interaction with Southern Ocean GLOBEC is likely to be extremely important as a number of the key science issues of interest to CCAMLR overlap with the goals of Southern Ocean GLOBEC. Southern Ocean GLOBEC is emphasising krill and land-based predators within the field program.

4.123 Aspects of overwintering and spring survival of different stages of krill, interactions in the plankton and impacts of predators are all being addressed within Southern Ocean GLOBEC and this relates to key CCAMLR issues of krill recruitment variation, links to environmental variation and quantifying the mortality rates of krill. The Working Group considered that the active interaction with Southern Ocean GLOBEC was important and the two-way process of communication of CCAMLR and GLOBEC goals and plans should be actively encouraged.

4.124 The Working Group discussed future interactions with other groups whose work may be of relevance to the questions being addressed by CCAMLR. It is important for the Working

Group to have access to, and synthesise all, the relevant information for making ecosystem assessments and for developing sound management based on the most up-to-date knowledge.

4.125 Two types of interactions were possible. One was on the personal level where individual members of the Working Group could represent CCAMLR at meetings they may be attending. The other is to send a formal representative to the meetings of other groups and to invite participation in the activities of the Working Group.

4.126 To a very great degree the second of these types of approach was in hand. The useful reports from SCAR-GSS and SCAR-BBS that had been considered at the current meeting were cited as successful formal connections and Dr Fanta was thanked for representing CCAMLR very successfully at the SCAR WG-Biology. There are also useful connections in place with the IWC.

4.127 However, the Working Group saw a need to alter the structure of its meetings to make it easier for participants with external expertise in particular fields to be able to attend the meetings without the need to become involved in the detailed business. It is essential that this was a two-way process so that these participants can benefit from their contacts with the Working Group and vice versa. In the past, one of the benefits of holding the Working Group meetings in different locations has been that it has provided an opportunity for locally-based scientists to contribute to the meeting.

4.128 The Working Group suggested that its meeting could include one or two short, 2–3 day, science thematic sessions each year. The Working Group also suggested that for such sessions, it was important to identify the key issues for discussion with external experts, develop an agenda and invite external experts. The Working Group suggested this should start next year with a focus on the review of monitoring data, identification of new monitoring requirements and methods for analysing and integrating the information.

4.129 Some concern was expressed as to whether the science profile of CCAMLR was sufficiently high in the international science community. The Working Group considered that it was extremely important that the science of CCAMLR was exposed to the broadest possible audience. This would be beneficial in terms of ensuring the correct direction of CCAMLR-based research through international feedback, but would also help to clarify where interactions with other groups would be valuable. Working Group members were encouraged to communicate the objectives and research of WG-EMM and CCAMLR generally to the broadest possible audience.

4.130 WG-EMM-00/31 presented a proposal by scientists from the University of British Columbia (UBC) (Canada) to undertake the development of an ECOPATH-based model of the Southern Ocean ecosystem. The UBC science proposal will be funded by a variety of academic, government and industry sources, including Biozyme Systems Inc. of Vancouver, BC, Canada. The proposal relates to earlier discussions by the Working Group on the development and application of such a modelling approach.

4.131 The Working Group reiterated its earlier interest in seeing the execution of such a feasibility study for ECOPATH applied to the Southern Ocean ecosystem. The Working Group noted that this technique could be a useful exercise for reviewing the available information and for highlighting important gaps in the data. The Working Group noted again that the key questions related to the examination of the effects of uncertainty or indeed gaps in the available data. Central to this was how such uncertainty affected the outcomes from the model and how this can be used to feed back into the development of management procedures. The UBC group has a lot of experience in the application of ECOPATH in areas such as the Bering Sea and clarification of the process in such areas would be useful for the group.

4.132 The Working Group has in place programs for the compilation or collection of data that will be important in such an analysis. Other data may require input of expertise and data that is beyond the scope of the coverage of CCAMLR scientists. However, the Working Group noted that participation in such an exercise could help to clarify issues of priority of data collection.

4.133 The Working Group considered it important that clarification was obtained on the current status of the proposal and how the feasibility study would address the issues of data quality and uncertainty and the development of management procedures. This would help to clarify the level of input required by CCAMLR scientists. Dr Miller was asked to communicate with the UBC group to address these questions. The Working Group considered that the proposed international workshop would be most valuable if it could be associated with a WG-EMM meeting.

4.134 On the question of the CCAMLR Data Manager attending an ECOPATH training course at UBC and undertaking the initial phase of model development, the Working Group considered that this would be useful. It would give the Secretariat, and hence the Working Group, the initial skills in developing an ECOPATH model analysis. The Working Group considered that this would be most useful if the questions described in paragraphs 4.131 to 4.133 formed a key part of the interaction with UBC. The Scientific Committee is the forum where any decision would be made about the overall work priorities for the Data Manager. The priorities for the future work of the Working Group are given in Table 3.

4.135 It was also acknowledged that many of the key questions of identifying appropriate parameter values and taking a proactive science role in the project might be better done by one or more of the Working Group participants. It was suggested that concentrating on specific areas of the Southern Ocean where a full range of appropriate data are available could be useful. This may be better pursued by direct UBC links with a single national group. Such a group would have better access to the relevant scientific expertise and data required to properly parameterise an ECOPATH model. Some form of collaboration within the project, possibly by a visit by UBC to a single national group such as BAS could be another useful way to proceed. Such an interaction would help to clarify the data requirements for a broader application in the CCAMLR region.

4.136 Dr Azzali emphasised that it was important that the Working Group maintained a broad view of the operation of the whole Antarctic marine ecosystem including areas such as the Ross Sea. The Working Group agreed that it was important that knowledge of the operation of the Southern Ocean ecosystems outside the main areas of fishing would give important insights into the dynamics of the ecosystem and the potential effects of exploitation.

4.137 WG-EMM advocated additional studies providing comparisons of water masses to krill taxa and demographics (e.g. WG-EMM-00/52).

METHODS AND DESIGNATION OF CEMP SITES

Harvested Species Methods

5.1 Twenty-two papers included methods to describe the abundance, dispersion, population structure, recruitment, growth and production of krill. Of these papers, seven could be categorised as methods for integrated or ecosystem investigations, five included methods to glean scientific information from krill fishery data, five were directly associated with the CCAMLR-2000 Survey, three described methods to indirectly derive information about krill from their predators, and two dealt specifically with acoustical measurement methods. New and noteworthy methods were highlighted.

5.2 In 1998 acoustical surveys were conducted using an unusual transmission frequency of 80 kHz in the areas around Coronation, Elephant and King George Islands (WG-EMM-00/5). WG-EMM encouraged an investigation of the advantages and disadvantages of using this frequency (relative to 38, 120 and 200 kHz) for acoustical surveys of krill or other taxa.

5.3 WG-EMM-00/21 detailed the methods used in the CCAMLR-2000 Survey. Most notably: (i) krill were identified and delineated from other sound scatterers using a delta mean volume backscattering strength (ΔMVBS) criteria of 2–16 dB (Sv120-Sv38); and (ii) target strengths (TS) were calculated using the TS-length model, adopted by SC-CAMLR in 1991, and krill lengths measured from RMT8 samples during the survey.

5.4 WG-EMM recognised great value in the standardisation of acoustical survey protocols. However, so as not to stifle advancement in acoustical surveying techniques, it was suggested that protocols for data collection be defined separately from data processing methods (to the extent that such a separation is possible).

5.5 A three-frequency method for identifying, delineating and assessing *E. superba* and *E. crystallorophias* was presented in WG-EMM-00/37. Volume backscattering strengths (Sv) were averaged in 2 m depth by 1 n mile distance bins. Three permutations of the differences in Sv (ΔMVBS; 120-38 kHz, 200-120 kHz and 200-38 kHz) were used to discriminate the two species. It was noted that the three ΔMVBS coefficients depended significantly on the length of species:

- if euphausiids with lengths greater than 30 mm, ΔMVBS120-38 was between 5 and 15 dB; ΔMVBS200-120 was less than 5 dB; and ΔMVBS200-38 was less than 20 dB;

- if *E. crystallorophias* with lengths less than 30 mm, ΔMVBS120-38 was greater than 15 dB; ΔMVBS200-38 was greater than 20 dB; and ΔMVBS200-120 was greater than 5 dB;

- if *E. superba* with lengths less than 30 mm, ΔMVBS120-38 was between 5 and 15 dB; ΔMVBS200-38 was less than 20 dB; and ΔMVBS200-120 was greater than 5 dB; and

- if nekton, ΔMVBS120-38 was less than 5 dB.

The authors also noted that aggregation densities and thresholding may limit the detectability of scatterers at all three frequencies. If the aggregation is detectable only at 120 and 200 kHz, then ΔMVBS 200-120 greater than 5 dB indicates *E. crystallorophias* and ΔMVBS 200-120 less than or equal to 5 dB indicates *E. superba*.

5.6 Application of this multifrequency method for delineating taxa in a 1997/98 survey of krill in the Ross Sea yielded 8.87% less krill than one obtained using results of net samplings.

5.7 As the length classes of *E. superba* and *E. crystallorophias* were generally different in this study, there was a discussion about the effectiveness of the method for discriminating these two species when length-classes overlap. The authors noted that other factors (e.g. physiological condition, shape, or animal orientation) probably provide enough variation in the three-frequency descriptors to enable discrimination for these two species, even when they have similar length classes (less than 30 mm). WG-EMM agreed that this and other multifrequency methods for taxa delineation have great merit and encouraged their continued development and application.

5.8 In WG-EMM-00/39, the acoustical estimation of mean krill lengths, based on the fluid sphere scattering model (assuming length equals 12.07 times the equivalent spherical radius), were 9% less than the mean lengths determined from net catches. Three size classes were calculated using the three-frequency measurements within each layer. It was noted that the high accuracy of the acoustical length estimation suggests that nearly all of the variability in ΔMVBS coefficients is due to animal length. In that view, the effectiveness of the three-frequency method to discriminate two euphausiid species with overlapping length-frequency distributions was questioned. The numerical abundance of krill estimated using the fluid sphere model was 20 to 100 times greater than estimated from the catch. The Working Group noted that much more work is required before these biases can be understood.

5.9 In WG-EMM-00/49, a method was offered to estimate the total variance (measurement and sampling variance) for the CCAMLR-2000 estimate of B_0. Assuming each of the three frequencies (38, 120 and 200 kHz) provided independent estimates of B_0, average densities were randomly selected for each interval from one of the three frequencies and probability density functions of B_0 and CVs were simulated using the sampling methods of Jolly and Hampton, 1990.

5.10 The paper noted that the total CV does not account for possible biases. Multiple sources of potential bias were outlined for future investigations. WG-EMM encouraged such investigations and advocated quantification and reporting of bias and imprecision in all measurements relevant to WG-EMM's work.

5.11 WG-EMM-00/42 described a method to estimate TS using a TS versus krill length relationship and krill lengths sampled by Antarctic fur seals. These TS estimates can be used to accurately convert integrated volume backscattering areas, sampled with concurrent and proximate shipboard acoustical surveys, to krill biomass. A correction factor has been developed to compensate TS for the proportion of krill in the diet smaller than 40 mm. It was noted that this method does not replace the need for net sampling, rather it is a tool for sampling krill lengths when net sampling concomitant with acoustical surveys is not possible.

CEMP Methods

5.12 WG-EMM 00/27 described environmental data collected in accordance with draft CEMP Standard Methods F1, F3 and F4 at Edmonson Point and Béchervaise Island. The data indicated a relationship between the CEMP indices F1 (sea-ice extent viewed from the CEMP site) and A6 (breeding success) for Adélie penguin.

5.13 It was recognised that the report of WG-EMM from 1999 recommended that Standard Methods F1 and F4 be accepted at this meeting, after consideration by the Subgroup on Methods. Membership and the role of this subgroup was discussed. It was agreed that the membership and relevant expertise of the subgroup be as follows: Prof. Boyd (predator methods – seals), Dr Constable (statistics), Dr Murphy (environment), Mr Reid (Convener), Dr Siegel (prey), Dr Trivelpiece (predator methods – birds).

5.14 The subgroup recommended the acceptance of Standard Methods F1 and F4 as tabled in WG-EMM 99/12. By means of clarification, the subgroup recommended that where Members wish to collect data on sea-ice extent or snow cover at a CEMP site, they should follow Standard Methods F1 and F4 respectively. However, submission of these data were not obligatory and Members were encouraged to report any observations of unusual environmental conditions that may have undue influence on other CEMP indices.

5.15 WG-EMM-00/32 presented information on the size of individual colonies of Adélie penguins at Béchervaise Island. These data indicated that the overall breeding population had increased by 5% between 1991 and 1999. However, the subset of colonies used for the CEMP parameter A3 indicated a 24% increase over the same period. Dr Constable indicated that the construction of a database of the Béchervaise Island Adélie penguin study was nearing completion and that this would be used to address issues relating to inter-colony dynamics within the study area.

5.16 WG-EMM-00/35 reported the initial findings of a long-term study of atmospheric data from the South Georgia region which showed a number of fluctuations over a range of time scales. The subgroup recognised the potential importance of this approach and encouraged further work.

Designation and Protection of CEMP Sites

5.17 The Subgroup on Designation and Protection of CEMP sites was charged with the following tasks during the intersessional period:

(i) undertake minor technical revisions of the management plans for Cape Shirreff and Seal Islands CEMP sites;

(ii) consider further development of a methodology for the assessment of proposals for marine protected areas put forward by the ATCM;

(iii) consider details of the proposal put forward by New Zealand on Balleny Islands SPA; and

(iv) consider and evaluate CEMP site maps.

5.18 The intersessional group was chaired by Dr Penhale and coordinated by Dr Sabourenkov. Members included Drs Constable, Fanta, K. Kerry (Australia), Naganobu, D. Torres (Chile), K. Shust (Russia) and Wilson. Drs M. Gambi and S. Kawaguchi joined the subgroup in Taormina.

5.19 In addition to its designated tasks, the subgroup also considered a proposal to reorganise the conservation measures related to CEMP Conservation Measures 18/XIII, 62/XI and 82/XIII. At the meeting of WG-EMM, the group considered WG-EMM-00/23 Rev. 1, a proposal for an SSSI at Terra Nova Bay.

5.20 The Working Group recommended that the Scientific Committee approve the revision of the Seal Islands Management Plan (Conservation Measure 18/XIII, Annex 18/B). The Working Group also recommended that WG-EMM approve the revision of the Cape Shirreff Management Plan (Conservation Measure 18/XIII, Annex 18/B), pending minor technical revisions.

5.21 The Working Group discussed a proposal by Dr Penhale to reorganise the current conservation measures related to CEMP sites. The current organisation is as follows:

(i) Conservation Measure 18/XIII includes the procedure for according protection to CEMP sites, information to be included in management plans for CEMP sites (Annex 18/A) and the management plans, codes of conduct and background and history for both Seal Islands and Cape Shirreff CEMP sites (Annex 18/B plus appendices).

(ii) Conservation Measure 62/XI includes the designation of protection of the Seal Islands CEMP site.

(iii) Conservation Measure 82/XIII presents the designation of protection of the Cape Shirreff CEMP site.

5.22 The intent of a reorganisation of the conservation measures was to separate the procedures for according protection of CEMP sites (including guidance to writing management plans and the Code of Conduct, which apply to all plans) from the designation of individual sites with associated management plans.

5.23 Thus, one measure would include the procedure of according protection to CEMP sites, the information to be included in management plans for CEMP sites and the Code of Conduct. A second measure would include the Protection of the Seal Islands CEMP site, with annexes to include the management plan and the background information. A third would include the Protection of the Cape Shirreff CEMP site, with annexes to include the management plan, the background information and the history of protection.

5.24 The Working Group approved this reorganisation and requested that the Secretariat draft these changes prior the meeting of the Scientific Committee for consideration at that time.

5.25 The Working Group reviewed the CEMP site maps provided in response to a request by the Secretariat on behalf of the Scientific Committee (SC-CAMLR-XVIII, paragraph 4.24) for improved site maps. Deficiencies such as general poor quality, inadequate information on the location of colonies monitored at present and in the past, and information on the history of colonies had been noted. Maps were requested from 11 Member countries and were received from Australia, Japan, New Zealand, Norway and the UK. Maps were not received from Argentina, Brazil, Chile, Italy, South Africa and the USA.

5.26 The maps provided by New Zealand were viewed as meeting the criteria and should provide an excellent example for others to follow. The maps from Norway and the UK were also considered as meeting the criteria. The maps provided by Australia, which provided excellent information when viewed as the colour originals on the CCAMLR website, were difficult to assess when printed in black and white. The map from Japan would benefit from minor technical improvements.

5.27 The Working Group recommended that the subgroup review the criteria provided in the ATCM system for the production of maps of protected areas and in Conservation Measure 18/XIII, Annex 18/A, part A, as background to develop guidance for CCAMLR Members who plan to produce maps of CEMP sites. The importance of readability in black and white was noted.

5.28 The Working Group noted that WG-EMM-00/32, which described the Australian CEMP site at Béchervaise Island, provides a good example of the type of detailed colony information which would assist the interpretation of monitoring data submitted to the CEMP database.

5.29 Dr Kerry proposed that additional information on sites where monitoring is being undertaken at present or has been reported in the past would be of value. Such information could include maps, possibly in GIS format, which allow for fine-scale resolution of individual colonies; a description of individual colonies outlining their history with respect to human interference and research undertaken; annual updates on each of the study colonies outlining activities undertaken, problems encountered, unusual events etc.; and photographs of each colony with regular updates.

5.30 The Working Group agreed that such additional information could be useful and encouraged Members to provide such ancillary information, if practical, on an individual country website.

5.31 A link from the CEMP map section of the CCAMLR website could facilitate interested parties in finding any ancillary information provided.

5.32 Dr Gambi made a presentation on the Italian management plan for the Terra Nova Bay site (WG-EMM-00/23 Rev. 1). The presentation focused on the values to be protected (the unique marine benthic community located near Terra Bay Station and an Adélie penguin colony), the description of the area and the long-term research program that had been established in the area.

5.33 It was noted that this plan had been simultaneously submitted to both the SCAR WG-Biology and WG-EMM. At its 10 to 14 July 2000 meeting in Tokyo, Japan, WG-Biology welcomed the concept of the plan, but referred it to the next meeting of GOSEAC for consideration.

5.34 The Working Group recognised that it was premature to make recommendations to the Scientific Committee with regard to approval of the plan in the absence of comments from GOSEAC. Although some members felt that the plan should not be discussed at this time, others felt that it was appropriate to provide scientific advice to the originators of the plan.

5.35 Drs Naganobu and Kawaguchi noted that the Terra Nova Bay plan had been submitted directly from Italy to the Secretariat for transmission to WG-EMM rather than the plan being submitted from the ATCM directly to the Commission. Thus, in the absence of a charge from the Commission to WG-EMM to review the plan, he felt that the plan should not be discussed at this time.

5.36 Dr Miller stated that WG-EMM should be able to formulate scientific advice based on submissions from Members to the Working Group; thus, he concluded that such a scientific review of the Terra Nova Bay marine protected area would fall within the rules of procedure. He also noted policy matters should be referred to the Commission. In order to facilitate the work of the Commission, he suggested that an examination of marine protected areas in other parts of the world might prove of value.

5.37 Those who commented on the scientific aspects of the Terra Nova Bay plan noted the strong scientific basis for protection and the productive research that had been conducted at the site. Recommendations for improvement to the plan included: a clearer identification of the marine and terrestrial boundaries of the plan, the addition of the Adélie penguin colony in the management plan, the inclusion of more detailed management discussion (e.g. helicopter landing sites) and other minor technical improvements.

5.38 The Working Group considered the Balleny Islands management plan (WG-EMM-00/7) at the request of the Commission (CCAMLR-XVIII, paragraph 4.9). Dr Wilson introduced the scientific justification and the details of the Balleny Islands plan. Although some members felt that the subgroup should be prepared to make a recommendation regarding approval to WG-EMM, others felt that this was premature.

5.39 In terms of the details of the plan, it was noted that the plan had been modified based on advice from GOSEAC in 1999 and that the modified plan had been recommended for approval by SCAR by WG-Biology during its 10 to 14 July 2000 meeting.

5.40 Those who viewed the plan positively agreed that the values described in the plan were justified on the basis of available data. These values included the outstanding biodiversity of both the terrestrial and marine fauna and flora. The area was viewed as an excellent representative of a unique marine and terrestrial ecosystem. It was noted the area, which has been predominantly undisturbed, includes important breeding sites, as well as foraging habitat, for birds and seals. The reduced marine area was viewed as more scientifically justifiable than that in the previous version of the plan and it was noted that detailed maps had been provided. It was noted that the proposed boundary bisected the Balleny Seamount. A recommendation was made to adjust the boundary to include this seamount, as it is expected to be a significant habitat for fish species.

5.41 Dr Shust felt that the scientific basis for the protection of the Balleny Islands was not sufficiently described and that the threats to the Balleny Islands ecosystem had not been adequately detailed. The suggestion was made that additional scientific research would be required prior to presenting the plan for approval. He recommended that the area to be managed be reduced in size to one or two of the islands containing major wildlife concentrations.

5.42 Dr Y. Lee (Republic of Korea) felt that the scientific rationale for the plan was not strong. He noted that there has been very little research conducted in the area. In particular, the lack of information on foraging areas for marine birds and seals and the lack of recent penguin surveys were considered important deficiencies. Compared to the limited area (approximately 6 x 10 km) of the Terra Nova Bay plan, the large area (approximately 200 x 350 km) of the Balleny Islands plan does not seem justifiable.

5.43 Drs Naganobu and Kawaguchi expressed reservations on the discussion of the Balleny Islands plan at this time. Concerns raised included the issue that the subgroup has just begun to consider further development of a methodology for the assessment of proposals which include marine protected areas. They felt that these methods should be agreed on prior to consideration of plans. Secondly, CCAMLR Members have been securing the practical coordination between rational use of marine resources and their protection through surveys, analyses and discussions. The Balleny Islands plan does not consider the field approaches of CCAMLR. Thirdly, the protection of marine sites is a serious issue for CCAMLR's approach to fishing regulation and needs to be considered carefully prior to the accordance of protection.

5.44 Dr Shust also felt that the Balleny Islands plan did not consider the field approaches of CCAMLR and that the protection of marine sites is a serious issue for consideration with regard to CCAMLR's approach to fishery regulation.

5.45 Dr Naganobu felt that progress could be made in the Commission through a philosophical discussion which would focus on the principle of protection in the ATCM and the principle of rational use in CCAMLR.

5.46 Dr Miller drew the Working Group's attention to Article II of the Convention, which strives to balance rational use with conservation of resources.

5.47 Dr Penhale referred the Working Group to the underlying principles related to CCAMLR's review of management plans for marine protected areas proposed by the ATCM (Articles 4 and 5 of the Protocol and Article 6 of Annex V, paragraph 2). CCAMLR's interest would thus focus on whether the proposed plans are consistent with the achievement of the objectives and principles of CCAMLR.

5.48 The Working Group noted that marine areas in both the Terra Nova Bay and the Balleny Islands management plans are not located near sites of current commercial fishing interests. Dr Fanta felt that protection of marine areas of high biodiversity is of value for the objectives of CCAMLR.

5.49 Dr Wilson suggested that WG-EMM does at least approve the Balleny Islands proposal, in principle, pending consideration by the Commission of the arguments concerning rational use of resources. The importance of this proposal was also recognised by the recent SCAR WG-Biology meeting which recommended the plan be approved by SCAR. He suggested that rational use does not mean the whole of the ocean should be open to fishing activity. The Balleny Islands proposed SPA will make a significant contribution to representative biodiversity protected areas which will provide valuable non-treatment or control areas against which rational use can be measured. Furthermore, the Balleny Islands proposal does not create a precedent; there are other marine protected areas in the ATCM area.

5.50 Most members of the subgroup and WG-EMM felt that the focus should be on whether the values in these proposals were scientifically defensible rather than on the policy concerning the maintenance of those values and that the assessment of the amount of data required to assess the proposal is a matter for the ATCM. Policy was viewed as the responsibility of the Commission and the ATCM. In that case, the Commission may ask the Scientific Committee to clarify whether such proposals would prejudice or enhance the work of the Commission. Such information may help the Commission provide advice to the ATCM on these proposals. These

Members noted that the Commission has used Article IX of the Convention to close areas, which are of importance to some fishing activities, indicating that the Commission recognises the value of closed areas for achieving its objectives.

5.51 Most members supported the scientific validity of creating the Balleny Islands SPA which includes a marine component for the protection of high biodiversity values. However, some members did not agree (paragraphs 5.41 to 5.45); therefore the Working Group could not recommend to the Scientific Committee that the plan be approved.

5.52 The Working Group considered further development of a methodology for the assessment of proposals for marine protected areas put forward by the ATCM. Using guidance from CCAMLR-XIII (paragraphs 11.16 to 11.18), experience from past reviews, and a consideration of the interests of CCAMLR, the Working Group discussed the development of a methodology.

5.53 Some members noted that management plans transmitted by the ATCM were written to further the objectives of the ATCM; thus, such plans may not necessarily further the aims of CCAMLR. This should not be viewed as a negative aspect of the plan. The main focus of the overall CCAMLR review process should be on whether the plan would prejudice the objectives of CCAMLR.

5.54 Nevertheless, the review of management plans presents the opportunity for CCAMLR to review the scientific questions to be addressed, to review any plans for proposed scientific research or monitoring to be conducted in the area, to evaluate whether the closure of a marine area could be of value to CCAMLR, and to evaluate the positive and negative aspects of the plan with respect to fisheries.

5.55 In evaluating the application of marine protected areas by CCAMLR for its own purposes, the Working Group suggested that an examination of marine protected area development in other parts of the world may be useful.

5.56 While there was not sufficient time available for a complete review of the topic, some progress was made in the development of a methodology for the assessment of marine protected areas put forward by the ATCM.

5.57 As a starting point, the Working Group agreed that future reviews should include an assessment of the information relevant to the attributes to the area, including *inter alia*:

(i) information on the values for which protection is required; and
(ii) sufficient details in the text, maps and figures for a scientific review.

5.58 The review should also include an assessment of available information relevant to CCAMLR and its objectives, including *inter alia*:

(i) the location of breeding seabirds and seals in the area;

(ii) the location of any known foraging areas of seabirds and seals that may breed in, or are associated with, the proposed management area;

(iii) a description of known marine fauna;

(iv) a description of current or potential fisheries in the area; and

(v) the location and details of research directly relevant to CEMP.

5.59 Additionally, the review should draw to the attention of CCAMLR any other matters which may be relevant to the implementation of Article II of the Convention.

5.60 The value of transmitting to the ATCM the scientific interests and concerns of CCAMLR with respect to the review of marine protected areas was recognised as a means to improve the process and thus further the aims of both bodies.

5.61 The Working Group recognised the need for further work on the development of a methodology for the review of management plans for marine areas put forward by the ATCM and recommended that its deliberations on this topic be transmitted to the Scientific Committee.

5.62 Membership of the subgroup was reviewed and it was agreed that Dr Lee be included in the subgroup (paragraph 5.18).

5.63 The Working Group wished to convey its thanks to the subgroup for its work and to Dr Sabourenkov for his valuable contributions, particularly for coordinating the tasks and providing the required background documents.

Future Work

5.64 WG-EMM encouraged further investigations of biases associated with the CV for the CCAMLR-2000 Survey. It also advocated quantification and reporting of bias and imprecision in all measurements relevant to WG-EMM's work.

5.65 WG-EMM recommended the continued development of other multifrequency methods for delineation between *E. superba* and *E. crystallorophias*, and encouraged their application.

5.66 The Subgroup on Methods was re-established (paragraph 5.13) and will be convened by Mr Reid.

5.67 The Working Group recommended that the Subgroup on Designation and Protection of CEMP Sites develop criteria as guidance for the production of CEMP site maps.

5.68 The subgroup was requested to continue its work on the development of a methodology for the assessment of marine protected areas put forward by the ATCM, pending comment on the topic from the Scientific Committee and CCAMLR.

ADVICE TO THE SCIENTIFIC COMMITTEE

Precautionary Catch Limits for Area 48

6.1 Following the CCAMLR-2000 Survey, the Working Group agreed that the current estimate of biomass of krill is 44.29 million tonnes (CV 11.38%) (paragraph 2.87). The Working Group also endorsed the new estimate of γ of 0.091. According to the calculation where yield is the product of these two estimates, the Working Group recommended that the potential yield for krill in Area 48 be set at 4 million tonnes.

6.2 The Working Group reiterated the requirement to subdivide the potential yield in Area 48 as a precautionary method to distribute fishing effort (paragraph 2.114) and agreed that such a subdivision, at this stage, should be based on the percentage of the survey undertaken in each subarea (paragraph 2.119, Table 2). The recommended precautionary catch limits for each subarea are:

48.1 1.010 million tonnes
48.2 1.100 million tonnes
48.3 1.060 million tonnes
48.4 0.830 million tonnes.

6.3 The Working Group noted that the precautionary catch limit for krill had not been adjusted since the first calculation of 1.5 million tonnes pending the undertaking of the CCAMLR-2000 Survey. The current recommendation is consistent with revised estimates of the potential yield considered in this Working Group in previous years (e.g. SC-CAMLR-XIII, Annex 5). The Working Group emphasised that the current estimate of yield is based on a well-planned survey to obtain a reliable estimate of biomass in Area 48 (SC-CAMLR-XVIII, Annex 4, Appendix D; Appendix G to this report) coupled with agreed protocols for the analysis of the data and the method for subdividing the yield between subareas. As such, the Working Group had confidence in its recommendations.

6.4 The Working Group recognised that these recommendations may be revised from time to time in the future as new analyses and estimates of parameters come to hand, as is the usual practice in WG-FSA. The Working Group reiterated that the current recommendations are based on the best scientific evidence available.

Regulatory Framework for CCAMLR Fisheries

6.5 The Working Group noted the general points for consideration by the Scientific Committee contained in its earlier discussion in paragraphs 2.32 to 2.35.

Consideration of other Management Measures

6.6 The Working Group agreed that the new estimate of biomass of krill for Division 58.4.1 of 4.83 million tonnes (CV 17%) (paragraphs 2.79 and 2.80) was now the best scientific evidence available. Combined with the estimate of γ for this division (paragraph 2.112) of 0.091, the precautionary yield would be 440 000 tonnes (paragraph 2.113). The Working Group recommended that this yield be considered by the Scientific Committee to be the best scientific estimate available at this time.

6.7 Dr Naganobu indicated that the basis of the new estimate for Division 58.4.1 will need to be reviewed by Japanese experts prior to consideration by the Scientific Committee.

6.8 The Working Group agreed that the precautionary yield for Division 58.4.1 should be subdivided to account for the size of the area and the need to distribute catches across the area, as for Area 48. It was noted that this division was 4.68 million km^2 compared to the combined area for Subareas 48.1, 48.2, 48.3 and 48.4 of 3.42 million km^2. The Working Group agreed that, unlike Area 48 which is subdivided on the basis of bathymetry and island groups, Division 58.4.1 would best be subdivided based on oceanographic features that are likely to separate ecological units. It agreed that the best scientific evidence available for such a subdivision is based on the difference in characteristics of the east and west parts of the division separated approximately at the longitude 115°E (paragraph 2.120).

6.9 Given the available evidence, the Working Group agreed that a subdivision at longitude 115°E would result in a subdivision of the biomass of krill in Division 58.4.1 into 3.04 million tonnes in the western section and 1.79 million tonnes in the east (paragraph 2.120). A subdivision of the yield based on the relative proportion of the krill biomass in each of these sections would result in precautionary yields of 277 000 tonnes and 163 000 tonnes in the western and eastern sections respectively. The Working Group recommended that the Scientific Committee consider this subdivision as the best method currently available.

6.10 Dr Naganobu indicated that he does not have difficulty with a subdivision in principle. However, he was unable to accept the subdivision of Division 58.4.1 at this stage without further consideration, for the following reasons:

(i) oceanographic data have not been used previously to subdivide areas;

(ii) the proposed line of subdivision at 115°E may not be a fixed feature but may vary from one year to the next according to oscillations such as those that might arise from variation in the Antarctic low pressure trough; and

(iii) there is no krill fishing in this area at this stage and such fishing is unlikely in the near future.

6.11 The Working Group recommended that, in general, the Scientific Committee should consider further the overall issue of subdividing large statistical units into management units based on ecological knowledge. This would help focus survey, monitoring and management requirements as well as ensuring that large catches are not taken from within small-scale areas.

6.12 The Working Group also recommended an examination of how useful small management units with local conservation measures would be for helping the Commission achieve the objectives in Article II of the Convention.

6.13 The Working Group recommended that the Scientific Committee request that nations provide prior notification to the Secretariat of their intention to fish for krill (including new entries to the fishery). These notifications should be received well in advance of the annual meeting of WG-EMM so that the Working Group could consider the total potential fishing pressure in the coming seasons (paragraph 2.3).

6.14 The Working Group wished to inform the Scientific Committee that quantitative information on conversion rates for krill products from the fishery was still lacking and this was impeding understanding of the development of the krill fishery (paragraph 2.8).

6.15 The Working Group drew the Scientific Committee’s attention to the continued absence of detailed economic information from the krill fishery. This information would allow the Working Group to better predict future trends in the fishery (paragraph 2.7).

6.16 The Working Group recommended a greater level of implementation of the CCAMLR Scheme of International Scientific Observation in the krill fishery (paragraph 2.27).

6.17 The Working Group recommended that the Scientific Committee approve the revision of the Seal Islands Management Plan and the Cape Shirreff Management Plan (Conservation Measure 18/XIII, Annex 18/B) (paragraph 5.20).

6.18 The Working Group recommended that the Scientific Committee endorse the reorganisation of the conservation measures related to CEMP sites (paragraphs 5.21 to 5.24). A draft will be prepared by the Secretariat prior to the next meeting of the Scientific Committee.

6.19 The Working Group drew the attention of the Scientific Committee to the discussions of the Working Group and issues for consideration regarding:

(i) a proposal to the ATCM regarding protection of a marine area at Terra Nova Bay (paragraphs 5.32 to 5.37);

(ii) the proposal to the ATCM regarding protection of a marine area around the Balleny Islands (paragraphs 5.38 to 5.51); and

(iii) methods for the assessment of proposals made to the ATCM on the protection of marine areas (paragraphs 5.52 to 5.62).

Future Work

6.20 The Working Group encouraged members to further test the GYM and to submit these tests to the Secretariat for archiving (paragraphs 2.96 and 2.97) and to use the GYM to undertake future work examining the sensitivity of estimates of krill yield to changes in parameter values (paragraph 2.108).

6.21 The Working Group discussed the now extensive nature of the CEMP database and other datasets and recommended that these data be used to review the types of data that could be used in short- and longer-term management approaches. The Working Group noted that paragraphs 3.51 and 3.55 provide a guide to this work.

6.22 The Working Group noted that interpretation and assessment of changes in CEMP indices may require information on the region-wide characteristics of the populations of monitored species (paragraph 3.56). To this end, the Working Group considered whether it would be feasible to undertake a large-scale assessment of land-based predator populations (paragraphs 3.58 and 3.59). The Working Group recommended that the Scientific Committee consider whether such surveys could be undertaken over the next few years following the intersessional communication on this issue amongst members of the Working Group (paragraph 3.58).

6.23 The Working Group noted that precautionary catch limits have only been adopted for Area 48 and Divisions 58.4.1 and 58.4.2. It discussed the need to undertake surveys of krill biomass in areas for which CCAMLR has no survey data following the advanced protocols used in the survey of Division 58.4.1 or the recent CCAMLR-2000 Survey. The Working Group endorsed the need to carry out these surveys as soon as is practicable, particularly in areas where fishing has occurred in the past, such as Subarea 88.1 in the Ross Sea, and in Division 58.4.2, and looks forward to receiving proposals for review. In addition, the Working Group recommended surveys to be undertaken in other areas that may be important in ecosystem monitoring, such as adjacent to Bouvet Island (Subarea 48.6).

6.24 The Working Group discussed its future role and the manner in which it would undertake its work. These discussions are reflected in paragraphs 4.128, 4.129 and 7.10 to 7.17.

6.25 The Working Group noted that increased interaction with other research groups and international bodies might be of benefit to the Working Group and CCAMLR, particularly regarding specific questions considered at its meetings (paragraphs 4.51 and 4.122 to 4.129).

6.26 The Working Group wished to bring to the attention of the Scientific Committee a request by scientists from UBC to undertake development of an ECOPATH-based model of the Southern Ocean ecosystem in Area 48. This was discussed and actions detailed in paragraphs 4.130 to 4.135. The Working Group requested that the Scientific Committee consider the role of the Data Manager in this program of work, given the priorities of the Working Group detailed in Table 3 and the overall requirements of the Secretariat for the coming year.

6.27 The Working Group noted that the proposal to develop an ECOPATH model was submitted by authors from a non-Member nation. The Working Group advised the Scientific Committee that proper discussion of issues raised by such papers was best achieved with full national representation and participation in the Working Group's scientific activities. This is best achieved when the nation is a full Member of the Commission.

FUTURE WORK

Future Intersessional Work of WG-EMM

7.1 Future work identified by the Working Group is detailed in the relevant sections of this report. This work is summarised in Table 3, together with the persons identified to take the work forward, and the references to paragraphs where the tasks are described. High priority items for the Secretariat are shown in the table.

7.2 Outstanding tasks identified by WG-EMM from 1995 to 1999 were reviewed in WG-EMM-00/29 prepared by Dr Sabourenkov. The Working Group's discussions are reflected in paragraphs 4.114 to 4.117.

Future Meetings of WG-EMM

7.3 Dr Miller introduced WG-EMM-00/64 which outlined the costs and implications of holding meetings of WG-EMM in various locations worldwide. This paper was prepared in response to the Commission's request that the Scientific Committee consider the possibility of holding future meetings of WG-EMM in Hobart (SC-CAMLR-XVIII, paragraphs 13.7 to 13.10). This request was made following consideration by SCAF of measures to reduce the overall operational costs of CCAMLR.

7.4 The Working Group considered two key aspects of holding meetings in Hobart:

- the financial implications; and
- the impact on the work of WG-EMM and the Scientific Committee.

7.5 Budget implications and the impact on the work were evaluated with reference to past meetings of Working Groups held in Hobart (WG-FSA) and elsewhere (WG-CEMP, WG-Krill and WG-EMM).

Financial Implications

7.6 Based on financial information provided by the Secretariat, Dr Miller concluded that the holding of the meetings of WG-EMM in Hobart, Australia, would reduce the travel costs of the Commission (Secretariat) budget by approximately A$30 100–36 200 per meeting (i.e. no travel required for staff). However, at the same time, meeting support activities (e.g. document production, hire of equipment etc.) would incur a cost of approximately A$5 000 per meeting to the Commission budget. The net savings to the Commission budget would be in the order of A$25 100–34 300 per meeting, or a maximum net saving of about A$1 491 per Member per meeting.

7.7 The Working Group noted that the relatively remote location of Hobart for most Member countries would also increase the travel costs of participating countries by approximately A$1 700 per participant per meeting. As an example, Dr Holt advised that it would have cost the delegation from the USA an extra A$10 200 (6 x A$1 700) to attend WG-EMM-2000 had that meeting been held in Hobart rather than in Taormina.

7.8 Dr Miller indicated that the overall net savings to Members if the meetings of WG-EMM were held in Hobart would be in the order of A$347–613 per Member per meeting (see WG-EMM-00/64).

7.9 The Working Group noted that an additional cost incurred by meetings held at the CCAMLR Headquarters in Hobart, and not included in WG-EMM-00/64, was the general disruption to the Secretariat's work resulting from hosting large, two-week, meetings. The Secretariat already hosts one such meeting each year (WG-FSA) which inevitability involves all staff, either directly with the meeting, or indirectly through work-related interactions (e.g. requests for data and analyses, publications etc.) and the sharing of office space and facilities. Meetings of WG-EMM held at the Headquarters would add to this type of disruption.

Impact on the Work

7.10 In considering the impact that Hobart-based meetings would have on the work of WG-EMM, the Working Group discussed, in broad terms, the future direction of its work. It was agreed that key aspects of this work included, or will include, *inter alia*:

- the development of an integrated management scheme for krill fisheries;
- the involvement of experts from within, and outside, CCAMLR to help in this development;
- the involvement of new scientists, including new perceptives on research and the problems under consideration;
- the involvement of other national scientists, managers and industry representatives; and
- the promotion of the work of CCAMLR and its role in managing the marine resources in the Southern Ocean.

7.11 The development of an integrated management scheme for krill fisheries was a long-term goal of WG-EMM, and this may require another 5–10 years to establish (paragraph 4.117). This timing is similar to other major developments in resource management, such as the Revised Management Plan for Whales developed by the IWC over a period of approximately 10 years. The implementation of a management scheme for the krill fisheries would lead to regular fishery assessments, similar to those conducted by WG-FSA, and further long-term developments.

7.12 The Working Group discussed the ways in which its meetings could be used to facilitate future work. It was agreed that it was essential to hold meetings in various parts of the world so that:

- the work of CCAMLR could be promoted in the host countries;
- young scientists in each of the Member countries would have the opportunities to participate in the work of WG-EMM; and
- WG-EMM could visit laboratories with expertise relevant to its work.

7.13 Examples of some of the advantages of this process are evident from previous meetings of WG-EMM. For example, a large number of national scientists and students participated in the meetings of the working groups (see WG-EMM-00/64, Figure 1). Dr Kawaguchi informed the group that, even though many of these scientists may only attend one meeting, their exposure to the work of WG-EMM is valuable. It was also noted that meetings in the USA had allowed the introduction of valuable expertise. Such opportunities provide the impetus for some national scientists to remain in contact with WG-EMM and make further contributions by presenting papers at future meetings.

7.14 The Working Group also agreed that the development and the promotion of its work would be improved by changing the format of the meetings (paragraphs 4.127 and 4.128). Options for future meetings would include, for example:

- 1-day or 2-day symposium where key papers could be presented and discussed – this would allow scientists not involved in the work of CCAMLR to attend part of the meeting and contribute expertise and ideas in areas of interest, such as fisheries management (e.g. ICES);

- a 3-day thematic workshop where specific work could be developed, such as the development of CEMP indices, assessments of populations and models of their dynamics, or the GYM – this focus would allow invited experts to contribute to the work of WG-EMM over a short period of time; and

- plenary sessions where the core work of WG-EMM would be developed.

7.15 Dr Miller examined the potential impact on the work of WG-EMM and the Scientific Committee if the meetings were to be held in Hobart (WG-EMM-00/64). WG-EMM currently has the highest level of participation of any CCAMLR working group, past and present, and this was attributed directly to the roving location of meeting venues.

7.16 In contrast, meetings in Hobart would provide limited opportunities for participation by national scientists and students. The cost of reaching Australia, and Hobart in particular, from Europe, the Americas and Asia would be prohibitive to most junior scientists and students. These costs may also be prohibitive to some key scientists. Prof. Boyd advised that the level of participation in WG-EMM by the UK would be diminished if the Working Group meetings were held in Hobart because of the increased costs involved with reaching this venue. This echoed comments from Dr Holt about the cost of participation of delegates from the US AMLR Program (paragraph 7.7).

Recommendation

7.17 The Working Group agreed that a key element of its work was the ability to hold its meetings where it was deemed most beneficial to its current work; this was unlikely to include Hobart on a regular basis. It was agreed that Dr Hewitt would develop a paper on the format for undertaking the work of WG-EMM at future meetings for consideration by the Scientific Committee. Dr Miller agreed to update the analyses in WG-EMM-00/64 and append this information to the paper to be prepared by Dr Hewitt.

CCAMLR WEBSITE

8.1 Dr Ramm presented an update of the developments of the CCAMLR website (www.ccamlr.org), as these related to the work and recommendations of WG-EMM (WG-EMM-00/28). Many sections of the website are now available in the four official languages of CCAMLR. However, the webpages of WG-EMM, and other working groups, will remain in English only as this is the working language. WG-EMM documents can be accessed from the MAIN INDEX, by selecting MEMBERS under the Scientific Committee heading. The MEMBERS button leads to an entry screen where the user name and password are required to proceed.

8.2 The responsibility for issuing user names and passwords to persons has been devolved to each Member country. The Secretariat provides each Scientific Committee contact (nominated by the Commission contact) with the user names and passwords required to access the secure webpages of the Scientific Committee, and it is the responsibility of each Scientific Committee contact to issue this information to those members of their scientific team they consider appropriate. Scientific Committee contacts were listed in Appendix 1 of WG-EMM-00/28.

8.3 Recent additions to the website arising from the recommendations of WG-EMM-99 included:

- documents for WG-EMM-2000;
- CCAMLR bibliography related to the work of WG-EMM;
- *CCAMLR Scientific Abstracts*;
- *Statistical Bulletin*, Volume 12;
- CEMP site maps; and
- monitoring of hits and visit rates.

8.4 In addition, guidelines for submitting material for the website were reiterated in WG-EMM-00/28.

8.5 The Working Group congratulated the Secretariat, and in particular Ms R. Marazas, Webmaster, for the continued high-quality development of the CCAMLR website. Those who had used the site had found it to be a very useful tool in providing information about CCAMLR, including access to meeting documents. Information on hit and visit rates indicated that others had also made use of the site, with a total of 13 168 visits from 56 countries over the period 1 January to 6 July 2000 (mean visit rate: 492 visits per week).

8.6 The Working Group encouraged the Secretariat to consider the website as a living document, which would require frequent, small changes so that it remained attractive to repeat users. For example, the appearance of the homepage could be varied by changing the background graphics. The structure of the website could also be tuned to visitor usage. Some participants had also found the MEMBERS button, used to access secure webpages, cryptic; an explicit description of this button, such as MEMBERS AREA, was suggested.

8.7 The Working Group discussed the approach used this year by the Secretariat to distribute meetings papers via the website. Meeting documents submitted by the pre-meeting distribution deadline (16 June) had been made available via the website in portable document format (pdf). This format allowed most participants to access and print all/any of the available papers in advance of the meeting, thus providing early access to the information, as well as some savings in Secretariat resources. The Secretariat had also offered to airmail hard copies of available WG-EMM documents to participants; no request had been received. Papers submitted after 16 June were distributed in the document bundle issued on the first day of the meeting. Finally, papers in the pre-meeting distribution were made available on request on the first day of the meeting.

8.8 The Working Group noted that a small number participants had experienced difficulties accessing the secure webpages or printing documents, or had encountered lengthy download times. It was believed that these sorts of problems would be resolved with further technological advances. Many participants had brought hard copies of the early papers to the meeting, and this had saved considerable photocopying at the meeting. Overall, the Working Group supported the approach taken this year, and agreed that this approach should apply to the distribution of papers for WG-EMM-2001; a copy of the agenda should be included in the bundle of papers issued on the first day.

8.9 The process of archiving electronic copies of meeting documents was also discussed. The Working Group recommended that all WG-EMM-2000 documents should remain on the secure webpages for a period of 3–12 months following the meeting. To achieve this, participants were requested to provide electronic copies of papers submitted in paper format, including those submitted at the start of the meeting.

8.10 In the longer term, the Working Group proposed that meeting documents should be removed from the website, and archived on CD-ROM for distribution to interested parties. This may eventually lead to an electronic reference library for use by WG-EMM. Removing archived papers from the website would also remove the need to maintain these documents on secure webpages.

8.11 Dr Constable advised that he had scanned a considerable amount of CCAMLR material into a personal electronic library, and that he would be prepared to provide this material to the Secretariat if this was thought useful. Other participants may also have other material available, and the Working Group encouraged the Secretariat to make use of this scanned material where suitable.

OTHER BUSINESS

Future Meetings

9.1 The Working Group received indications that three initiatives were under way for hosting future meetings of WG-EMM. Dr Bergström advised that he is looking into the feasibility of hosting the 2001 meeting of WG-EMM at the Kristineberg Marine Research Station, Sweden. Dr Wilson advised that New Zealand was interested in hosting the 2002 meeting in Christchurch. Prof. Boyd informed the Working Group that the UK was looking into the feasibility of hosting a meeting of WG-EMM within two to three years. The Working Group welcomed this news, and noted that this tentative plan fitted well within the structure discussed for future meetings (see section 7).

9.2 Concern was expressed about the timing of recent meetings, and WG-EMM agreed that the best time for its meetings was from early June (the end of the field seasons) until early August. The early August cut-off was necessary so that the Secretariat could edit and translate the report of WG-EMM prior to the annual meeting of the Scientific Committee. The Working Group also urged local organisers to avoid time conflicts, when possible, with other major Antarctic meetings.

9.3 The Working Group agreed that Dr Hewitt should endeavour to develop the agenda and format of the 2001 meeting by January–February 2001, pending the outcome of SC-CAMLR-XIX in reference to paragraph 7.17, so that participants could focus their intersessional work and meeting papers (see also paragraph 7.14). The Working Group agreed that certain agenda items may not need to be addressed at each meeting. For example, detailed consideration of CEMP indices may be given once every two to three years. This type of schedule would allow WG-EMM to afford detailed consideration of key elements of its work on a rotational basis.

Meeting Papers

9.4 Once again the Working Group expressed concern at the large number of meeting papers submitted on the first day of the meeting. At this meeting, as in recent other meetings of WG-EMM, only approximately 30% of the meeting papers had been submitted by the pre-meeting distribution deadline (16 June, one month prior to the meeting). The majority of the papers were submitted in the last few days prior to the meeting, or on the first day of the meeting. This practice places a large burden on all participants.

9.5 In a move to alleviate this burden, the Working Group agreed that full papers (including the synopsis; see next paragraph) must be submitted electronically to the Secretariat at least two weeks prior to the start of the meeting. The Working Group agreed that papers for WG-EMM-2001 which did not comply with this principle would not be accepted at the 2001 meeting. The Working Group agreed to review this process at future meetings.

9.6 The Working Group agreed that each paper submitted at future meetings should include a synopsis which would consist of an abstract of the paper and a summary of the findings, as these relate to the nominated agenda items (see also paragraph 2.129). The Working Group also agreed that each synopsis should be no longer than one page, and be submitted on an electronic pro-forma to be developed by the Secretariat.

9.7 The Working Group also agreed that the Secretariat's paper (WG-EMM-00/29), which documents the development and completion of tasks put forward by WG-EMM, should be updated each year, and distributed to WG-EMM with the preliminary agenda. This would serve to remind participants of the tasks at hand, and help focus work at the meetings.

ADOPTION OF THE REPORT

10.1 The report of the sixth meeting of WG-EMM was adopted.

CLOSE OF THE MEETING

11.1 In drawing the meeting to a close, Dr Hewitt thanked all participants for working so hard over the past two weeks, and for contributing to the detailed discussions on ecosystem monitoring and management. He also thanked Prof. Guglielmo for hosting the meeting in Taormina, and Prof. J. Rydzy (Italy) for proposing this venue at the last meeting of WG-EMM. Dr Hewitt also thanked the two Secretariat staff supporting the meeting, Ms G. Tanner and Dr Ramm, for their dedicated efforts under trying circumstances.

11.2 Prof. Boyd, on behalf of the Working Group, thanked Dr Hewitt for leading the group through the meeting. The meeting had been highly profitable, and Dr Hewitt had done a fantastic job. Prof. Boyd also thanked Dr Constable for his intellectual input in so many of the issues discussed, and for his deep knowledge of the workings of CCAMLR.

11.3 Earlier, Dr Miller, prior to leaving the meeting, had also congratulated Dr Hewitt on his excellent convenership of his first meeting of WG-EMM. Dr Miller had thanked all participants and the rapporteurs, for their enthusiastic contributions during the meeting.

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Table 1: Parameters input to the GYM for evaluating γ_1 and γ_2 for krill in Area 48 based on the CV and timing of the CCAMLR-2000 Survey. Parameters are based on the assessment undertaken at WG-Krill-94 (SC-CAMLR-XIII, Annex 5, paragraphs 4.51 to 4.110).

Category	Parameter	Estimate
Age structure	Recruitment age	0
	Plus class accumulation	7
	Oldest age in initial structure	7
Recruitment (R) and natural mortality (M)	M and R dependent on proportion of recruits in stock where:	
	Proportion of recruits	0.557
	Standard deviation of proportion	0.126
	Age of recruitment class in proportion	2
	Data points to estimate proportion	17
von Bertalanffy growth	Time 0	0
	L_∞	60.8 mm
	k	0.45
	Proportion of year from beginning in which growth occurs	0.25
Weight at age	Weight–length parameter – A	1.0
	Weight–length parameter – B	3.0
Maturity	L_{m50}	32.0–37.0 mm
	Range: 0 to full maturity	6 mm
Spawning season		1 December–28 February
Estimate of B_0	Survey time	1 February
	CV	0.114
Simulation characteristics	Number of runs in simulation	1 001
	Depletion level	0.2
	Seed for random number generator	-24189
Characteristics of a trial	Years to remove initial age structure	1
	Observations to use in median SB_0	1 001
	Year prior to projection	1
	Reference start date in year	1 November
	Increments in year	365
	Years to project stock in simulation	20
	Reasonable upper bound for annual F	5.0
	Tolerance for finding F in each year	0.0001
Fishing mortality	Length, 50% recruited	30–39 mm
	Range over which recruitment occurs	9 mm
	Fishing selectivity with age	
Fishing season		1 December–1 March

Table 2: Transect length (large-scale transects including sections passing through mesoscale regions), percentage of total transect length, and subdivision of potential yield within statistical subareas in Area 48.

Subarea	Transect Length (km)	% of Total Transect in each Subarea	Subdivision of Potential Yield (million tonnes)
48.1	4 218	25.2	1.008
48.2	4 613	27.6	1.104
48.3	4 419	26.4	1.056
48.4	3 493	20.8	0.832

Table 3: List of tasks identified by WG-EMM as future work. The paragraph numbers (Ref.) refer to this report unless stated otherwise. √√ – high priority items for the Secretariat.

Ref.	Topic and Task	Actioners	
		Secretariat	WG-EMM
	HARVESTED SPECIES		
	Trends in the krill fishery		
2.7	Complete and submit an economic analysis of the fishery.		General request
2.8	Provide detailed information on conversion rates for krill products (see also paragraph 2.14).		Members involved in krill fisheries
2.9	Analyse published information on conversion rates for krill products.		Drs Everson and Nicol
2.12	Develop the model used to analyse the fishing positions in relation to salp density and krill density (see WG-EMM-00/58).		Dr Kawaguchi
2.13	Notify the Secretariat, well in advance of the meeting of WG-EMM, of intentions to conduct krill fishing in the following season.		Members intending to fish for krill
App. D	Assess changes in fishing patterns.	√√	General request
	Observer scheme for the krill fishery		
2.20	Obtain information on methods used by Flag States to determine the total removals.	√	
2.21	Re-distribute the draft questionnaire seeking information on krill fishing strategies, and provide feedback and ideas.	√	Members involved in krill fisheries and Members designating national and international observers
2.22	Provide facilities on board so that observers may directly estimate conversion rates for krill products.		Members involved in krill fisheries
2.26	Develop a proposal to improve the sampling protocols described in the *Scientific Observer Manual*.		Mr Jones
2.31	Develop a stratified sampling strategy for finfish by-catch which takes account of the anticipated density of juvenile fish.		General request
	Regulatory framework for fisheries		
2.35	Develop a framework to guide fishery development.		Ad hoc task group convened by Dr Miller
	Estimation of potential yield		
2.97	Develop a pro-forma for the submission and archiving of GYM tests.	√√	Dr Constable and others
2.108	Understand the sensitivity and performance of the GYM to changing parameter values.		General request
2.110	Evaluate the GYM and submit results to the Secretariat.	√	Dr Constable and others
2.110	Compile the documentation on the KYM, including its historical development.	√√	

(continued)

Table 3 (continued)

Ref.	Topic and Task	Actioners	
		Secretariat	WG-EMM
	CCAMLR-2000 Survey		
2.122	Coordinate the analyses of the data at future workshops and intersessionally.		Drs Hewitt, Naganobu, Nicol, Sushin,Watkins
2.123	Analyse regional and local surveys in Area 48 during the same period as the CCAMLR-2000 Survey to complement the synoptic information.		Scientists involved with these surveys
2.124	Analyse data from ancillary surveys during an International Coordination Workshop.		Dr Kim (workshop convener)
2.126	Develop a better understanding of the orientation of krill.		General request
2.127	Investigate the potential biases caused by the currently used krill delineation techniques.		General request
2.128	Determine the proportion of krill occurring near the surface during daytime and its effect on acoustic survey estimates.		General request
2.130	Consider alternative methods to subdivide the precautionary catch limit.		General request
2.131	Coordinate an ad hoc subgroup on population genetics of krill and provide a forum to discuss progress and analyses.		Dr Bergström (subgroup coordinator)
2.132	Estimate the biomass of myctophids from acoustic data.		General request
3.61	Analyse oceanographic data with the aim of improving the identification and definition of key hydrographic features.		General request
	DEPENDENT SPECIES AND THE ENVIRONMENT		
	CEMP Indices		
3.4	Add a box to the CEMP eforms to indicate if data were collected according to the standard methods.	√	
3.5	Update information on CEMP indices and report to WG-EMM-2001.	√√	
3.47, 3.63	Further develop the application of CSIs intersessionally and during a working session at WG-EMM-2001.	√	General request
3.49	Further develop the algorithm to estimate the energy and carbon budgets of land-based predators.		General request
3.51	Further develop the CEMP indices along the points identified at the meeting.		General request
3.55	Review CEMP parameters and their potential utility in management procedures.		General request
3.55	Review the historical development of CEMP indices and the ecosystem assessments.	√	
3.55	Make available the CEMP database at WG-EMM-2001.	√√	
3.60	Continue monitoring CEMP environmental indices.	√	CEMP data providers

(continued)

Table 3 (continued)

Ref.	Topic and Task	Actioners	
		Secretariat	WG-EMM
	CEMP Species		
3.8, 3.9	Convey the appreciation of WG-EMM, and comments arising from the meeting, to SCAR-BBS for submitting WG-EMM-00/16.	√	
3.16	Liaise with the SCAR-GSS to clarify issues raised by WG-EMM, and help ensure that the updated report is submitted to SC-CAMLR.		Prof. Boyd
3.18	Document population changes in Antarctic fur seals in the South Shetland Islands.		US AMLR
3.19, 3.59	Convene a workshop to assess problems associated with conducting large-scale population counts.		General request
3.20	Request updates on whale population abundance and information relevant to estimating krill consumption.	√	
3.56	Estimate the large-scale abundance of land-based predator populations.		General request
3.58	Collate program outlines for collaborating in a synoptic survey of land-based predator populations, and present at SC-CAMLR-XIX.		Dr Constable (coordinator) and Program Leaders
	APIS		
3.57	Request information on pack-ice seals.	√	
	Environment		
3.29	Present environmental information related to fishing activities at future meetings.		General request
3.33, 3.62	Further develop indices on the extent of sea-ice adjacent to CEMP sites.		General request
	ECOSYSTEM ANALYSIS		
4.4	Further develop the ecosystem approach.		General request
4.120	Further develop techniques for extending the spatial and temporal coverage of sampling krill populations.		General request
4.123	Interact with SO-GLOBEC.		General request
4.129	Promote the work of CCAMLR outside the CCAMLR community and seek input on issues of interest to WG-EMM.	√√	General request
4.133	Communicate with UBC regarding questions concerning ECOPATH.		Dr Miller
4.134	Acquire the initial skills in developing an ECOPATH model analysis, subject to approval by SC-CAMLR.	√	
4.137	Conduct further studies to compare water masses to krill taxa and demographics.		General request

(continued)

Table 3 (continued)

Ref.	Topic and Task	Actioners	
		Secretariat	WG-EMM
	METHODS AND DESIGNATION OF CEMP SITES		
5.64	Further investigate biases associated with the CV for the CCAMLR-2000 Survey.		Dr Demer and others
5.65	Further develop the application of multi-frequency methods for delineation between *E. superba* and *E. crystallorophias.*		Dr Azzali and others
5.66	Reconvene the Subgroup on Methods and address issues raised by WG-EMM.		Mr Reid
5.67	Develop criteria to guide the production of CEMP site maps.		Subgroup on the Designation and Protection of CEMP sites
5.68	Develop a method to assess marine protected areas put forward by the ATCM .		Subgroup on the Designation and Protection of CEMP sites
6.18	Redraft CEMP conservation measures.	√√	
	FUTURE MEETINGS OF WG-EMM		
4.127	Structure future meetings to make it easier for participants with external expertise.		Dr Hewitt
7.17	Update the analyses in WG-EMM-00/64.		Dr Miller
7.17	Develop a paper to present the views of WG-EMM to SC-CAMLR.		Dr Hewitt
	CCAMLR WEBSITE		
8.6	Consider the website as a living document which would require frequent, small changes so that it remained attractive to repeat users.	√	
8.8	Apply the approach used to distribute WG-EMM-2000 documents at WG-EMM-2001; a copy of the agenda should be included in the bundle of papers issued on the first day.	√√	
8.9	Leave all available WG-EMM-2000 documents on the secure webpages for a period of 3–12 months following the meeting (participants were requested to provide electronic copies of papers submitted in paper format, including those submitted at the start of the meeting).	√√	General request

(continued)

Table 3 (continued)

Ref.	Topic and Task	Actioners	
		Secretariat	WG-EMM
	OTHER BUSINESS		
9.2	Avoid time conflicts, when possible, with other major Antarctic meetings when organising future meetings of WG-EMM.	√	Dr Hewitt and hosts
9.3	Develop the agenda and format of the 2001 meeting by January–February 2001, and distribute together with an updated version of WG-EMM-00/29.	√√	Dr Hewitt
9.5	Submit advance notifications of papers, or a synopsis, or full papers (including the synopsis) electronically to the Secretariat at least one month prior to the start of the meeting.		General request

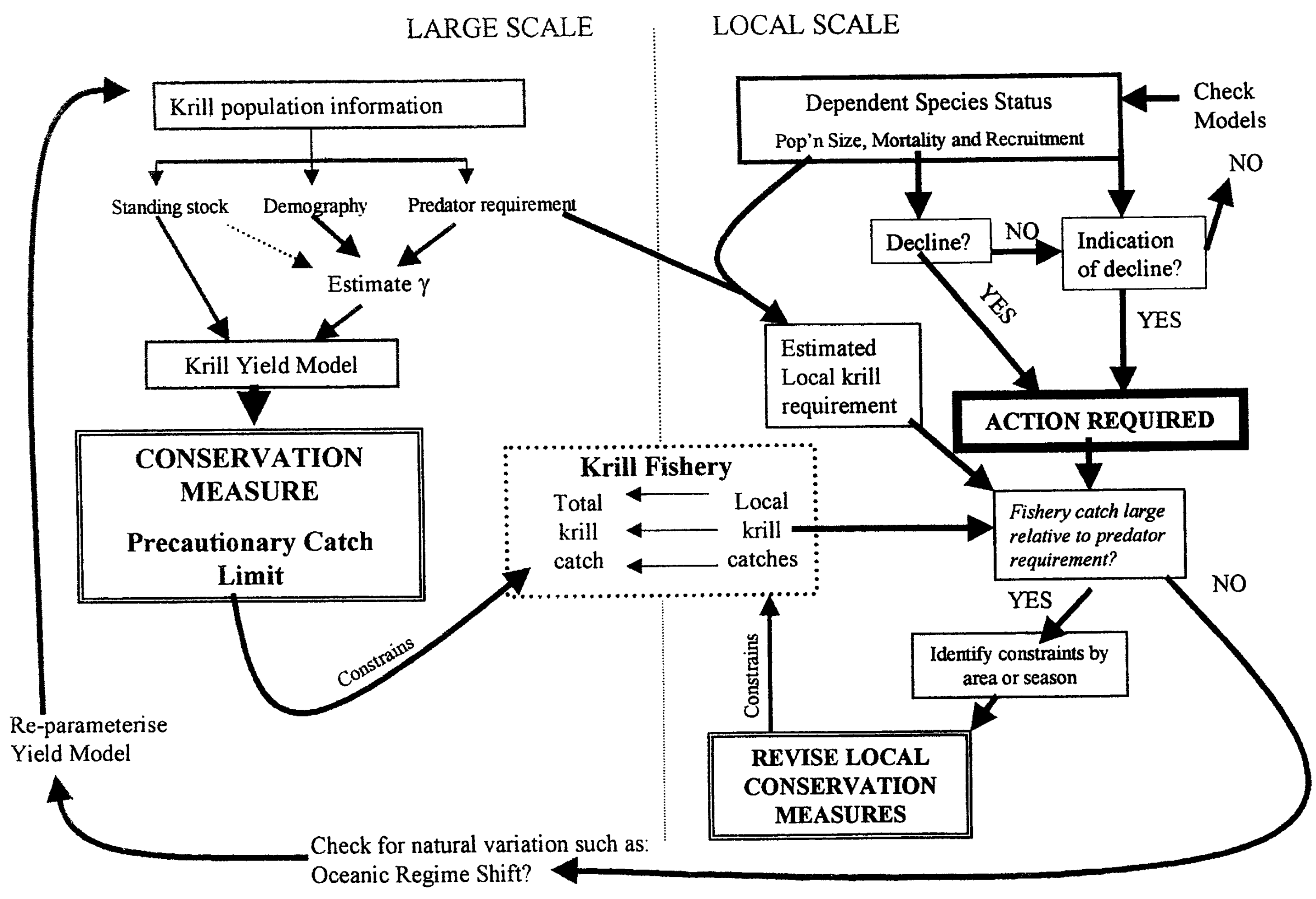

Figure 1: Decision processes incorporating information from dependent species into a mechanism to provide advice for management of a krill fishery.

APPENDIX A

AGENDA

Working Group on Ecosystem Monitoring and Management
(Taormina, Sicily, Italy, 17 to 28 July 2000)

1. Introduction

    1.1 Opening of the Meeting
    1.2 Organisation of the Meeting and Adoption of the Agenda

2. Harvested Species

    2.1 Fisheries Information
        (i) Catches Status and Trends
        (ii) Trends in Fishery Development
        (iii) Observer Scheme
        (iv) Regulatory Framework for CCAMLR Fisheries
    2.2 Regional and Local Surveys
    2.3 B_0 Workshop (results from the CCAMLR-2000 Survey in Area 48)
        (i) Data
        (ii) Methodology
        (iii) Estimate of Krill Biomass for Area 48
        (iv) Variance Associated with Estimate of Krill Biomass
    2.4 Estimation of Potential Yield
    2.5 Future Work

3. Dependent Species and the Environment

    3.1 CEMP Indices
    3.2 Status and Trends of other Species
    3.3 Indices of Key Environmental Variables
    3.4 Analytical Procedures and Combination of Indices
    3.5 Future Work

4. Ecosystem Analysis

    4.1 Krill-centred Interactions
    4.2 Fish and Squid-centred Interactions
    4.3 Status of the Krill-centred Ecosystem
    4.4 Further Approaches to Ecosystem Assessment
    4.5 Future Work

5. Methods and Designation of CEMP Sites

    5.1 Harvested Species Methods
    5.2 CEMP Methods
    5.3 Designation and Protection of CEMP Sites
    5.4 Future Work

6. Advice to the Scientific Committee

    6.1 Precautionary Catch Limits for Area 48
    6.2 Regulatory Framework for CCAMLR Fisheries
    6.3 Consideration of Possible Management Measures
    6.4 Future Work

7. Future Work

    7.1 Outstanding Tasks from 1995 to 1999
    7.2 Review of Future Work under Agenda Items 2.5, 3.5, 4.5, 5.4 and 6.3
    7.3 Future Meetings of WG-EMM

8. CCAMLR Website

9. Other Business

10. Adoption of the Report

11. Close of the Meeting.

APPENDIX B

LIST OF PARTICIPANTS

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(Taormina, Sicily, Italy, 17 to 28 July 2000)

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APPENDIX C

LIST OF DOCUMENTS

Working Group on Ecosystem Monitoring and Management
(Taormina, Sicily, Italy, 17 to 28 July 2000)

WG-EMM-00/1	Provisional Agenda and Provisional Annotated Agenda for the 2000 Meeting of the Working Group on Ecosystem Monitoring and Management (WG-EMM)
WG-EMM-00/2	List of participants
WG-EMM-00/3	List of documents
WG-EMM-00/4	Report of national observer on the work carried out aboard the vessel *Konstruktor Koshkin* in Subarea 48.2 in May–June 1999 V. Bibik (Ukraine)
WG-EMM-00/5	Ecosystem studies carried out during the second Ukrainian Marine Antarctic Expedition in Subareas 48.2 and 48.1 in 1998 V. Bibik and P. Gozhik (Ukraine)
WG-EMM-00/6 Rev. 1	Krill distribution patterns in the Atlantic sector of the Antarctic during the CCAMLR-2000 Survey V. Siegel (Germany), S. Kawaguchi (Japan), F. Litvinov (Russia), V. Loeb (USA) and J. Watkins (United Kingdom)
WG-EMM-00/7	Draft management plan for Specially Protected Area (SPA) No. 4 – Balleny Islands, northern Ross Sea, Antarctica New Zealand
WG-EMM-00/8	Changes in the diet of the South Georgia shag *Phalacrocorax georgianus* at the South Orkney Islands along four consecutive years R. Casaux and A. Ramón (Argentina)
WG-EMM-00/9	Fish in the diet of breeding Antarctic shags *Phalacrocorax bransfieldensis* at four colonies in the Danco Coast, Antarctic Peninsula R. Casaux, A. Baroni and E. Barrera-Oro (Argentina)
WG-EMM-00/10	Second report on distribution, abundance and biological aspects of krill (*Euphausia superba*) north of South Shetland Islands (Survey 0001 RV *Humboldt* – 23 to 28 January 2000 – XI Peruvian Antarctic Expedition) M. Gutiérrez, N. Herrera and J. Quiñones (Peru), X. Chalen (Ecuador) and A. Antony (India)
WG-EMM-00/11	Preliminary results on the diet of the snow petrel *Pagodroma nivea* at Laurie Island, Antarctica, during the 1997/98 breeding season G. Soave, V. Ferretti, N. Coria and R. Casaux (Argentina)

WG-EMM-00/12	Final report of scientific observations of commercial krill harvest aboard the Japanese stern trawler *Chiyo Maru No. 5*, 31 January to 1 March 2000 W. Rain (CCAMLR Observer)
WG-EMM-00/13	Studies of seabirds and seals at Bouvetøya 1998/99 K. Isaksen (Norway), O. Huyser, S. Kirkman, R. Wanless and W. Wilson (South Africa)
WG-EMM-00/14 Rev. 1	Utilising data from ecosystem monitoring for managing fisheries: development of statistical summaries of indices arising from the CCAMLR Ecosystem Monitoring Program W. de la Mare and A. Constable (Australia) (*CCAMLR Science*, 7: 101–117)
WG-EMM-00/15	Notes on the commercial krill harvest of the Japanese stern trawler *Chiyo Maru No. 5* in Subarea 48.1 C. Jones (USA)
WG-EMM-00/16	A statistical assessment of the status and trends of Antarctic and sub-Antarctic seabirds (prepared for the SCAR Bird Biology Subcommittee and SC-CAMLR) Working draft as of June 2000 E.J. Woehler (Australia), J. Cooper (South Africa), J.P. Croxall (United Kingdom), W.R. Fraser (USA), G.L. Kooyman (USA), D.G. Miller (South Africa), D.C. Nel (South Africa), D.L Patterson (USA), H.-U. Peter (Germany), C.A. Ribic (USA), K. Salwicka (USA), W.Z. Trivelpiece (USA) and H. Weimerskirch (France)
WG-EMM-00/17	Haul data analysis from the Polish krill fishery in 1997–1999 E. Jackowksi (Poland)
WG-EMM-00/18	Combined standardised indices of predator performance from Bird Island, summer 1977–2000 I. Boyd (United Kingdom)
WG-EMM-00/19	A description of the ecosystem status at South Georgia during winter 1999–summer 2000 K. Reid (United Kingdom)
WG-EMM-00/20	Status of the South Georgia subarea (48.3) on satellite monitoring of the sea surface temperature, December 1999–January 2000 G. Vanyushin and A. Korobochka (Russia)
WG-EMM-00/21 Rev. 1	Report of the B_0 Workshop (La Jolla, USA, 30 May to 9 June 2000)
WG-EMM-00/22	Ecosystem management I. Everson (United Kingdom) (*CCAMLR Science*, 8: submitted)
WG-EMM-00/23 Rev. 1	Management plan for a new Site of Special Scientific Interest (SSSI) Terra Nova Bay, Victoria Land, Ross Sea Italy

WG-EMM-00/24	Secretariat work in support of WG-EMM Secretariat
WG-EMM-00/25	Krill fishery information Secretariat
WG-EMM-00/26	CEMP indices 2000: analysis of anomalies and trends Secretariat
WG-EMM-00/27	Development of environmental indices F1, F3 and F4 S. Olmastroni and S. Corsolini (Italy), K. Kerry and J. Clarke (Australia) and D. Ramm (CCAMLR Secretariat)
WG-EMM-00/28	Update on the CCAMLR website Secretariat
WG-EMM-00/29	History of development and completion of tasks put forward by WG-EMM (1995–1999) Secretariat
WG-EMM-00/30	A proposal to subdivide CCAMLR Statistical Division 58.4.1 using environmental data S. Nicol and T. Pauly (Australia)
WG-EMM-00/31	Evaluating the ecosystem impact of harvesting krill in the Southern Ocean: an ECOPATH with ECOSIM feasibility study Prof. T. Pitcher (University of British Columbia)
WG-EMM-00/32	Béchervaise Island, MacRobertson Land, Antarctica – CCAMLR Ecosystem Monitoring Program (CEMP) Monitoring Site: description, maps and colony photographs K. Kerry, L. Meyer, W. Papps, J. Clarke and L. Irvine (Australia)
WG-EMM-00/33	Krill distribution pattern due to water structure and dynamics near the South Sandwich Islands in January–February 2000 (Krill Synoptic Survey 2000) V. Sushin, P. Chernyshkov, V. Shnar, F. Litvinov and K. Shulgovskiy (Russia)
WG-EMM-00/34	Interannual variations of water thermochaline structure on South Georgia Island, South Orkney Islands and Shetland Islands shelves P. Chernyshkov, V. Shnar, O. Berezhinsky and I. Polischuk (Russia)
WG-EMM-00/35	Interannual hydroclimate fluctuations of the Atlantic part of the Antarctic since 1970 to 2000 G. Chernega, I. Polischuk and P. Chernyshkov (Russia)
WG-EMM-00/36	Some changes observed in Antarctic seabird distribution and behaviour F. Litvinov (Russia)

WG-EMM-00/37	A multiple-frequency method for identifying and assessing the Antarctic krill stock in the Ross Sea (1989/90, 1997/98 and 1999/2000) M. Azzali, J. Kalinowski and G. Lanciani (Italy) (*CCAMLR Science*, 8: submitted)
WG-EMM-00/38	Summer distribution, abundance and structure of krill populations (*Euphausiasuperba* and *Euphausia crystallorophias*) sampled by plankton net in the western Ross Sea (January–February 2000) M. Azzali, A. Sala and G. Brancato (Italy) (*CCAMLR Science*, 8: submitted)
WG-EMM-00/39	Comparative studies on the biological and acoustical properties of krill aggregations (*Euphausiasuperba* Dana) samples during the XIII Italian Expedition to the Ross Sea (December 1997–January 1998) M. Azzali, J. Kalinoswki, G. Lanciani and I. Leonori (Italy) (*CCAMLR Science*, 8: submitted)
WG-EMM-00/40	Chick provisioning and chick survival to fledging J. Clarke, K. Kerry, L. Irvine and B. Philips (Australia)
WG-EMM-00/41	The length-frequency distribution of krill in the diets of predators at Admiralty Bay, King George Island, Antarctica in the austral summer of 1999–2000 W.Z. Trivelpiece, K. Salwicka, L. Shill and S. Trivelpiece (USA)
WG-EMM-00/42	The use of predator-derived krill length-frequency distributions to calculate krill target strength K. Reid and A.S. Brierley (United Kingdom) (*CCAMLR Science*, 8: submitted)
WG-EMM-00/43	Contribution to a discussion of the ecosystem approach to management of the krill fishery. R.P. Hewitt and E.H. Linen Low (USA) Extract from *The fishery on Amtarctic krill: defining an ecosystem approach to management*. In: *Reviews in Fishery Science*, 8 (3), 2000.
WG-EMM-00/44	Variations in condition indices of mackerel icefish at South Georgia from 1972 to 1997 I. Everson (United Kingdom) and K.-H. Kock (Germany) (*CCAMLR Science*, 8: submitted)
WG-EMM-00/45	Interannual variation to the gonad cycle of the mackerel icefish I. Everson (United Kingdom), K.-H. Kock (Germany) and J. Ellison (United Kingdom)
WG-EMM-00/46	A generalised algorithm for estimating energy and carbon budgets in marine predators I.L. Boyd (United Kingdom)

WG-EMM-00/47	Pinniped research at Cape Shirreff, Livingston Island, Antarctica, 1999/2000. M.E. Goebel (USA) (Extract from: *US AMLR 1999/2000 Field Season Report*)
WG-EMM-00/48	Aerobic dive limit: how often does it occur in nature? D.P. Costa, N.J. Gales and M.E. Goebel (USA) (In: P. Pongonis (Ed.), *Proceedings of the Kooyman Symposium 2000*)
WG-EMM-00/49	Some components of uncertainty in the CCAMLR 2000 acoustical survey of krill D.A. Demer (USA)
WG-EMM-00/50	Distribution of krill as a fraction of Antarctic zooplankton within the South Sandwich Islands area in summer 2000 S.M. Kasatkina and A.P. Malyshko (Russia)
WG-EMM-00/51	Krill distribution related to water structure and dynamics on the South Georgia shelf in January 2000 (AtlantNIRO-BAS Core Programme 1999/2000) V.A. Sushin (Russia), P.P. Chernyshkov (Russia), F.F. Litvinov (Russia), J.L. Watkins (United Kingdom) and A.S. Brierley (United Kingdom)
WG-EMM-00/52	Hydrography and acoustic biomass estimates of Antarctic krill (*Euphausia superba*) near the South Shetland Islands, Antarctica, during January 2000: preliminary results D. Kang, Y. Lee, H.-C. Shin, W. Lee and S. Kim (Republic of Korea)
WG-EMM-00/53	Collection of informative manuscripts regarding SO-GLOBEC activities on Antarctic krill S. Kim (Republic of Korea) and E. Hofmann (USA)
WG-EMM-00/54	Some notes on by-catch of fishes and salps caught by the fishery vessel *Niitaka Maru* in the vicinity of the South Shetland Islands (January to February 1999) T. Iwami, S. Kawaguchi and M. Naganobu (Japan)
WG-EMM-00/55	Notes on the eighth Antarctic survey by the RV *Kaiyo Maru*, Japan in 1999/2000 M. Naganobu, S. Kawaguchi, T. Kameda, Y. Takao and N. Iguchi (Japan)
WG-EMM-00/56	Scales of interannual variability in Antarctic krill biomass at South Georgia A.W. Murray, A.S. Brierley and J.L. Watkins (United Kingdom)
WG-EMM-00/57	CPUEs and body lengths of Antarctic krill during the 1998/99 season in Area 48 S. Kawaguchi (Japan)

WG-EMM-00/58	Analysis of krill trawling positions in the area north of the South Shetland Islands (Antarctic Peninsula area) from 1980/81 to 1998/99 S. Kawaguchi (Japan) (*CCAMLR Science*, 8: submitted)
WG-EMM-00/59	Krill length distribution in fur seal diet at Cape Shirreff, Livingston Island, 1999/2000 M.E. Goebel (USA)
WG-EMM-00/60	The ecosystem approach to managing fisheries: achieving conservation objectives for predators of fished species A.J. Constable (Australia) (*CCAMLR Science*, 8: submitted)
WG-EMM-00/61	Towards an ecosystem status assessment for South Georgia 'Variability of Southern Ocean Ecosystems' Project Team
WG-EMM-00/62	Seabird research at Cape Shirreff, Livingston Island, Antarctica, 1999–2000 T.M. Carten, W.Z. Trivelpiece, M.R. Taft and R.S. Holt (USA)
WG-EMM-00/63	Excerpts from the Report of the Meeting of the SCAR Group of Specialists on Seals Report to CCAMLR WG-EMM, July 2000
WG-EMM-00/64	Report to WG-EMM on implications of meeting schedules Chairman of the Scientific Committee

APPENDIX D

AN EXAMPLE OF AN EXAMINATION OF TRENDS IN KRILL CATCHES IN AREA 48 USING NON-METRIC MULTIDIMENSIONAL SCALING (nMDS)

by Dr A. Constable (Australia)

A preliminary examination of this approach was undertaken by Drs Constable and Ramm and presented to the Working Group in Figures 1(a)–(c). Total catches from each fine-scale area in Area 48 (368 areas in all) were pooled for each three-month period in a split-year – winter (July–September), spring (October–December), summer (January–March) and autumn (April–June). The pattern of catches across all fine-scale areas was then compared for every season between 1980/81 and 1998/99 split-years using nMDS in the Primer statistical package (Clarke and Warwick, 1994). In this procedure, similarities between fishing patterns are determined for all pairwise comparisons of seasons using the Bray-Curtis similarity index. A fourth-root transformation was used to facilitate comparisons between the distribution of catches with only a small weight on that distribution by the total catch in the season. These similarities are then compared using the nMDS routine to provide X-Y coordinates for comparing the overall similarities of seasons (see Clarke, 1993 for discussion of the technique). The distance between points on the graph indicates the similarity between those points, such that close points are more similar in their fishing pattern than distant points. The axes in this context provide a relative measure of distance but do not imply the role of particular factors.

2. The overall results are decomposed to show the similarity of points from the same seasons across years (Figures 1(a) and (b)). The respective split-years are indicated by the last two digits of the year and the lines help indicate the general movement of the fishery from one year to the next. Close points indicate little change in fishing pattern while more distant points show a substantial change in fishing pattern across Area 48. Figure 1(a) shows the segregation of autumn and winter fishing patterns with the latter being concentrated to the north around South Georgia. For autumn, the higher catches of the 1980s are evident as well as the fishing pattern being similar throughout the 1990s. Figure 1(b) shows that the fishing patterns in spring and summer were similar in the 1980s but became segregated in the 1990s. The spring pattern has been much more variable than the tighter pattern in summer.

3. The results are pooled into one figure, Figure 1(c), for the years from 1991 to the present, which is the period when the fishing pattern is expected to have been more stable. These results show a basic separation of seasons, with fishing in winter being reasonably tightly constrained around South Georgia, the spring pattern likely to be near to the retreating ice edge, the summer pattern concentrating near the Antarctic Peninsula and the autumn pattern moving northwards. The shift in fishing pattern in the winter of 1999 probably arises from increased fishing around the South Orkneys.

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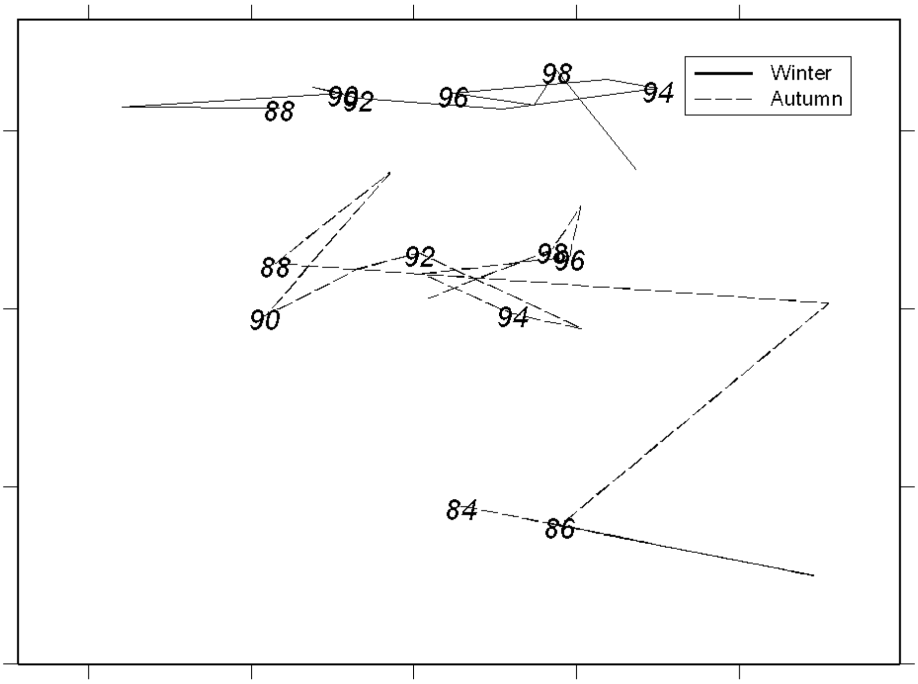
Clarke, K.R. and R.M.Warwick. 1994. *Change in Marine Communities: An Approach to Statistical Analysis and Interpretation*. Natural Environment Research Council, Plymouth Marine Laboratory, Plymouth, UK.



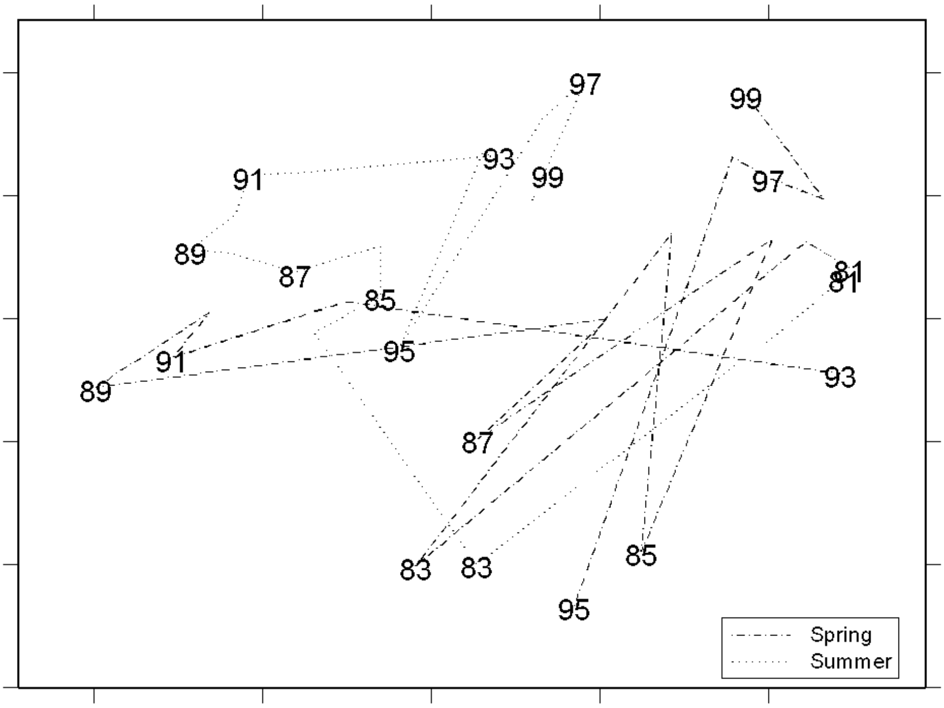


Figure 1: Comparisons of the pattern of krill fishing in Area 48 for each of four seasons since 1980/81 to 1998/99 (see text for details) (Stress = 0.22): (a) winter and autumn fishing patterns; (b) spring and summer fishing patterns; and (c) combined fishing patterns across nine fishing seasons between 1990/91 and 1998/99.

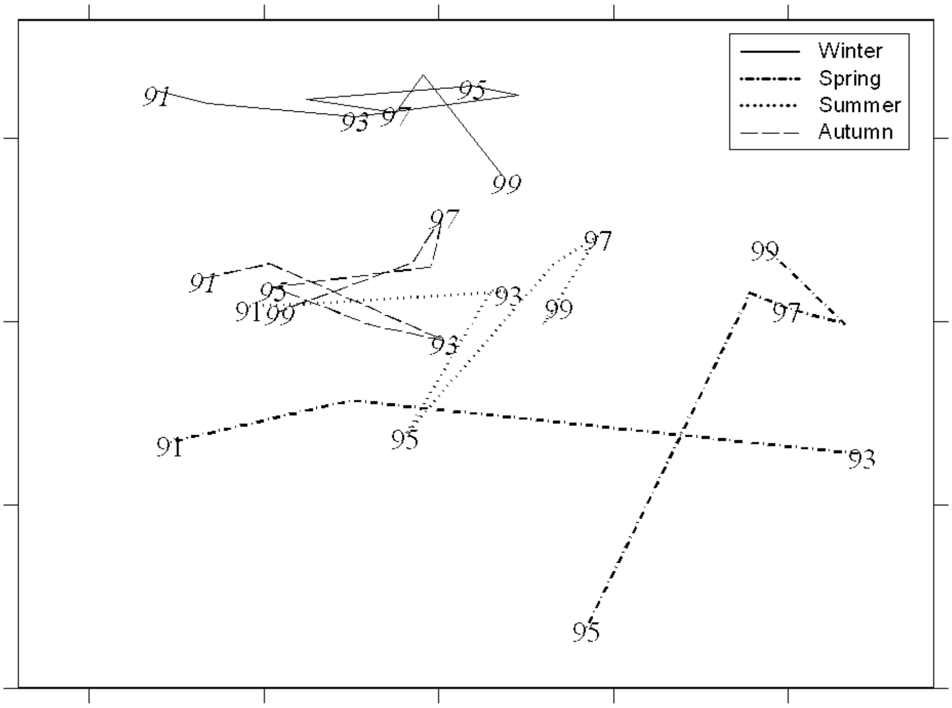


Figure 1 (continued)

EXAMINATION OF POTENTIAL CHANGES IN γ ARISING FROM THE YIELD CALCULATIONS AS A RESULT OF SURVEYING BIOMASS AFTER DIFFERENT FRACTIONS OF THE YEAR

Dr A. Constable (Australia)

The aim of the yield calculations for krill is to determine γ such that the long-term precautionary yield satisfies the agreed decision rules:

(i) recruitment criterion – ‘that the probability that the spawning biomass falls below 20% of the median pre-exploitation spawning biomass after 20 years should not exceed 10%’ –

$\gamma_1 = 0.118$;

(ii) predator criterion – ‘that the median spawning biomass should not fall below 75% of the pre-exploitation spawning biomass after 20 years’ –

$\gamma_2 = 0.091$; and

(iii) choose the lower γ of the two.

2. This γ is used to estimate yield, Y, according to the equation

$$Y = \gamma B_0 \tag{1}$$

where B_0 is the estimate of pre-exploitation biomass.

3. The expectation from a survey at a different time is that the same yield would arise from the calculation. Thus, it is expected that

$$\gamma_{s2} B_{s2} = \gamma_{s1} B_{s1} \tag{2}$$

4. Rearranging this equation to determine the new γ gives

$$\gamma_{s2} = \frac{\gamma_{s1} B_{s1}}{B_{s2}} \tag{3}$$

5. A simple deterministic formulation of the population model can be used to illustrate the relationship between the two γs, such that biomass at a given time, t, in the year is governed by the weight, w, at age, a, and mortality, M,

$$B_{s1} = R \sum_a e^{-M(a+t)} w_{a+t} \tag{4}$$

where R is an estimate of recruitment at age 0. Biomass at another time, f, in the year is given relative to the first biomass according to the equation

$$B_{s2} = e^{-M(f-t)} R \sum_a e^{-M(a+t)} w_{a+f-t} \quad (5)$$

6. This shows that the second γ will be influenced by the combination of mortality and growth.

7. The relationship between the two γs for a deterministic application of the parameters in Table 1 (main Text) is given in Figure 1 with M = 0.8 and R = 1. The ratios are relative to the first survey being undertaken one month after the beginning of the year.

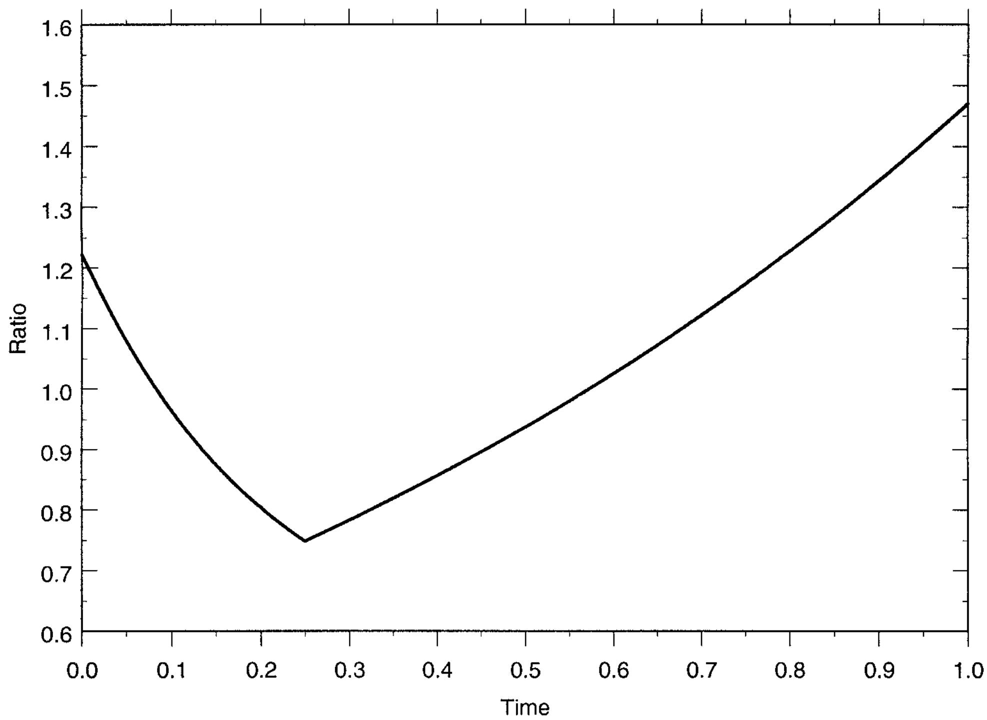


Figure 1: The ratio of the two γs for a deterministic application of the parameters in Table 1 (main text) with M = 0.8 and R = 1. The ratios are relative to the first survey being undertaken one month after the beginning of the nominal growth period (1 November). Time is the fraction of the year.

APPENDIX F

DRAFT TERMS OF REFERENCE FOR THE CCAMLR-2000 SURVEY ANALYSIS STEERING COMMITTEE

The Steering Committee shall comprise the principal scientist form each ship participating in the CCAMLR-2000 Survey (Japan, Russia, UK and USA) plus a vice-chair of the Scientific Committee. The present composition is therefore Drs R. Hewitt (USA), M. Naganobu (Japan), S. Nicol (Vice-chair, Scientific Committee), V. Sushin (Russia) and J. Watkins (UK).

2. The Steering Committee should act in a proactive way to promote and coordinate the analyses and publication of results relating to the CCAMLR-2000 Survey.

3. Specifically the Steering Committee should:

(i) Science Tasks –

(a) Define analyses to be undertaken collaboratively.

(b) Define analyses to be conducted unilaterally.

(ii) Analysis –

(c) Ensure that all analyses are coordinated and agreed by the Steering Committee prior to commencing work.

(c) Define, coordinate and promote analysis workshop(s).

(e) Coordinate analyses of data not undertaken at workshops.

(f) Act as a two-way information conduit such that Steering Committee members are made aware of individual analyses being conducted in each member's country, and that individual scientists are made aware of this information.

(iii) Publication –

(g) Oversee production of a special issue in a peer-reviewed international journal.

(h) Establish an Editorial Board for this issue.

(i) Produce a proposed publication list for the special issue.

(j) Act as arbitrators/mediators for conflicts in all publication authorships.

(k) Ensure that all manuscripts are brought to the attention of the Steering Committee prior to submission.

(l) Maintain a register of all publications relating to the CCAMLR-2000 Survey.

APPENDIX G

REPORT OF THE B_0 WORKSHOP
(La Jolla, USA, 30 May to 9 June 2000)

REPORT OF THE B_0 WORKSHOP

(La Jolla, USA, 30 May to 9 June 2000)

INTRODUCTION

1.1 A workshop to analyse data from the CCAMLR-sponsored multinational, multiship acoustic survey for krill biomass in Area 48 undertaken in January and February 2000 was held at the Southwest Fisheries Science Center, La Jolla, California, from 30 May to 9 June 2000. The workshop was convened by Dr R. Hewitt (USA). A List of Participants is included in this report as Attachment A.

1.2 Dr R. Neal, Deputy Director, Southwest Fisheries Science Center, welcomed participants to the workshop and wished them a profitable meeting.

1.3 A Provisional Agenda had been prepared by the Convener and this was adopted. The Agenda is included as Attachment B.

1.4 This report was prepared by Dr I. Everson (UK) in consultation with workshop participants.

Aims

1.5 The primary aims of the workshop had been agreed by WG-EMM at its 1999 meeting as the estimation of B_0 of Antarctic krill (*Euphausia superba*) and its associated variance in CCAMLR Statistical Area 48 (SC-CAMLR-XVIII, Annex 4, paragraph 8.37). It had been agreed that a key step in this estimation would comprise a multiship acoustic survey of Area 48 (CCAMLR-2000 Survey) to be undertaken in early 2000 (SC-CAMLR-XVIII, paragraph 6.36).

1.6 The workshop noted that the term 'B_0' denotes a krill standing stock being estimated (SC-CAMLR-XII, paragraphs 2.39, 2.41 to 2.47). It is used as a proxy for krill pre-exploitation biomass in the CCAMLR Generalised Yield Model (GYM) used to estimate krill sustainable yield, and to scale the krill biomass probability distribution over time in the estimation of γ with the GYM. In this report 'B_0' and 'standing stock' are used interchangeably.

1.7 WG-EMM would use the estimate of B_0 produced by the workshop to estimate potential yield using the GYM. This would be used to advise on a precautionary catch limit for Area 48, and this precautionary catch limit would be subdivided for smaller management areas as appropriate (SC-CAMLR-XVIII, Annex 4, paragraph 8.50).

1.8 WG-EMM had considered several methods by which catch limits might be subdivided and had agreed that the most tractable were likely to be by proration by:

(i) the proportion of the survey in each statistical subarea where the proportions are estimated from the lengths of survey tracks (SC-CAMLR-XVIII, Annex 4, paragraphs 8.55(iii) and 8.61); and

(ii) the area of krill distribution in each statistical subarea (SC-CAMLR-XVIII, Annex 4, paragraphs 8.55(iv)(b) and 8.61).

1.9 The workshop had been requested to provide estimates of the relative proportions of the survey track length within each statistical subarea (SC-CAMLR-XVIII, Annex 4, paragraph 8.61).

Preparation

1.10 Plans for the CCAMLR-2000 Survey had been set in motion during the 1996 WG-EMM meeting. The underlying theme was that since the krill biomass estimate from the 1981 FIBEX survey, on which the current CCAMLR precautionary catch limit for krill is based, had been made 15 years previously, a new estimate of this limit was a high priority. While a standing stock estimate remained the primary aim, it was recognised that additional oceanographic sampling during the CCAMLR-2000 Survey could provide much new information of value to ecosystem assessments undertaken by WG-EMM. The scope of the overall study had as a result been broadened whilst still retaining the same primary objective as outlined in paragraph 1.5.

1.11 Plans for the CCAMLR-2000 Survey had been finalised at a meeting in Cambridge, UK, in 1999 (SC-CAMLR-XVIII, Annex 4, Appendix D). At that meeting the main survey transects were delineated, methods for krill sampling agreed and the scope of ancillary sampling discussed.

1.12 The following computing facilities were available at the workshop: five computers were running Windows 2000 and had the acoustic data analysis software Echoview, Versions 1.51.38 and 2.00.62 installed. All computers had the package Microsoft Office and two had the numerical analysis packages Surfer, Transform and MatLab installed. All computers were networked to a central file server, colour and black and white printers and a video projector. Additional computers were made available on the network as needed.

INFORMATION AVAILABLE AT THE WORKSHOP

Survey Design

2.1 The CCAMLR-2000 Survey design had been agreed by WG-EMM in 1999 and consisted of a large-scale survey to cover much of Subareas 48.1, 48.2, 48.3 and 48.4 with randomly spaced transects. This large-scale survey was divided into three strata. Within the large-scale area there are four mesoscale regions that are considered to have a high abundance of krill and therefore to be of importance to commercial fishing fleets. These regions lie to the north of South Georgia, north of the South Orkney Islands, and north of the South Shetland Islands, and around the South Sandwich Islands. Additional mesoscale strata were designated for these regions. In some instances the large-scale survey transects crossed the mesoscale survey boxes. The sections of large-scale survey transects which went through these are indicated in Table 1. These were excluded from the analyses.

Definition of Strata

2.2 The area surveyed within each stratum was calculated from the nominal transect lengths and the 125 km wide zone within which each transect was placed (see Figure 1a, b, c). The land and mesoscale survey areas were excluded from the estimated areas for the large-scale survey.

2.3 The estimated strata areas were as follows:

Large-scale strata:

Antarctic Peninsula	473 318 km^2
Scotia Sea	1 109 789 km^2
East Scotia Sea	321 800 km^2

Mesoscale strata:

South Shetland Islands	48 654 km^2
South Orkney Islands	24 409 km^2
South Georgia	25 000 km^2
South Sandwich Islands	62 274 km^2

2.4 At WG-EMM-99 it had been agreed that sampling according to the design outlined above would be used for the estimation of standing stock in Area 48. However, it was recognised that additional sampling programs would be in progress within Area 48 at approximately the same time as the CCAMLR-2000 Survey. It had also been agreed that data arising from such surveys should not be included in the analyses leading to the estimation of B_0, but would provide useful information to support the Area 48 B_0 analysis.

Sampling Program

B_0 Sampling

2.5 Vessels from Japan (*Kaiyo Maru*, Scientist-in-Charge (SIC) Dr M. Naganobu), Russia (*Atlantida*, SIC of Acoustic Program, Dr S. Kasatkina), UK (*James Clark Ross*, SIC Dr J. Watkins) and USA (*Yuzhmorgeologiya*, SIC Dr Hewitt) had participated in the CCAMLR-2000 Survey. The survey tracks of all participating vessels are shown in Figure 2.

2.6 All participating vessels were equipped with Simrad EK500 echosounders operating at 38, 120 and 200 kHz (Tables 2 and 3). Echosounders were set according to protocols agreed at the planning meeting (paragraph 1.11 above; SC-CAMLR-XVIII, Annex 4, Appendix D). On each vessel, acoustic data were logged using the SonarData echolog_EK Version 1.50 software.

Survey Activities

2.7 SICs on each vessel gave a brief presentation outlining key results from their respective research cruises. Summary information on the cruises of direct relevance to the workshop aims is set out in Table 4. All vessels undertook a sampling program more extensive than the requirements of the CCAMLR-2000 Survey protocol. Details of this additional sampling are set out in Table 5.

2.8 Dr Watkins noted that the *James Clark Ross* had encountered a large number of icebergs in the vicinity of Shag Rocks and the southern side of South Georgia (Subarea 48.3). This caused the vessel to divert from the planned survey transect (SS07). It was noted that this may be a more general problem with other transects (see also paragraph 3.51).

2.9 Due to adverse weather conditions causing the vessel to fall behind schedule, the fifth transect (AP13) allotted to the *James Clark Ross* had been sampled from north to south, (the reverse direction to that of the original plan). Time constraints meant that the last 100 km of the final transect (AP19) had not been sampled by the *James Clark Ross*.

2.10 Dr Kasatkina reported that the *Atlantida* had undertaken a large-scale and mesoscale survey in the vicinity of the South Sandwich Islands (Subarea 48.4) according to a plan designed to fit into the overall CCAMLR-2000 Survey plan agreed by WG-EMM (SC-CAMLR-XVIII, Annex 4, paragraphs 8.4 to 8.6). All transects on the survey had been sampled.

2.11 Dr Kasatkina reported that an acoustic calibration of the *Atlantida* had been undertaken in Horten, Norway, prior to the vessel heading south to participate in the CCAMLR-2000 Survey. The second acoustic calibration, (the first calibration for the CCAMLR-2000 Survey), had been made at Stromness Harbour, South Georgia. High winds had made this calibration very difficult. The second calibration for the survey was undertaken under much more favourable weather conditions at the end of the survey.

2.12 In Subarea 48.4 (South Sandwich Islands) the interaction of two Antarctic water masses was observed: cold water of the Weddell Sea and warmer water of the southern flow of Antarctic Circumpolar Current. The boundary between the two water masses represented the Weddell Gyre frontal zone. Northward transport of cold Weddell Sea waters along the South Sandwich Islands arc was observed up to 54°S. In general, species composition of catches was mixed (krill, other euphausiids, juvenile fish, jellyfish, myctophids, salps). Krill ranging from 21–60 mm total length were caught. The highest krill catches were observed in the Weddell Sea Water.

2.13 Dr Naganobu noted that during Leg 1 of their cruise, the *Kaiyo Maru* had undertaken a mesoscale survey as part of the International Coordination Study in the vicinity of the South Shetland Islands (Subarea 48.1), before commencing the CCAMLR-2000 Survey (SC-CAMLR-XVIII, paragraph 5.10). Leg 2 of the cruise was the CCAMLR-2000 Survey and this had been undertaken without difficulty. Also during Leg 2 a second mesoscale survey was conducted in the vicinity of the South Shetland Islands that was part of the CCAMLR-2000 Survey.

2.14 Dr Hewitt noted that the *Yuzhmorgeologiya* had undertaken the CCAMLR-2000 Survey as planned although due to time constraints the final part of the last transect (AP17) had been curtailed. He also noted that since relatively few large acoustic targets had been encountered, only a small number of targeted net hauls had been undertaken. Surface chlorophyll measurements in Subarea 48.1 confirmed the observations from SeaWIFS satellite data that there is tongue of oligotrophic water offshore of the South Shetland Islands.

2.15 In general discussion it was noted that target net hauls had indicated that myctophids were present in deep water (>300 m). It was therefore likely that they might be the cause of most of the acoustic backscatter in deep water attributable to biological targets.

2.16 Two shallower target tows, that had been aimed at scatterers which were assumed to have been krill, caught *Themisto gaudichaudii* (Amphipoda) and *Thysanoessa*.

2.17 All vessels had encountered large numbers of icebergs in the vicinity of South Georgia. These were thought to have been due to the breakup of two large icebergs – A10 which had come from the Weddell Sea and B10 from the Bellingshausen Sea.

National Surveys

Korean Survey

2.18 Dr D. Kang (Republic of Korea) described a cruise to estimate the abundance and distribution of krill in the vicinity of the South Shetland Islands where a hydroacoustic survey was conducted by the RV *Onnuri* as a part of the Korea Antarctic Research Program. The survey was conducted from 9 to 19 January 2000 using a Simrad EK500 echosounder operating at 38, 120 and 200 kHz. The acoustic data were obtained from the eight transects comprising the South Shetland Islands mesoscale box (total transect length = 459 n miles, area = 38 802 km^2). Krill were collected using Bongo nets (mesh size: 0.333 mm, 0.505 mm) to determine their size composition and stage of development. In addition, a Conductivity Temperature Depth probe (CTD) and on-station Acoustic Doppler Current Profiler (ADCP) were used to understand the physical structure of the water column at 11 stations.

2.19 The length–weight relationship of krill sampled during the survey was $w = 0.0035\ L^{3.2108}$ where w was the mass (mg) and L was the total length (mm); the median length was 50 mm. The conversion factor for integrated volume backscattering to areal krill biomass density at 120 kHz was 0.1556. The mean density of krill in the area surveyed was 12 g/m^2 with a coefficient of variance of 14.5%. Krill swarms with relatively higher densities appeared to the north of Smith Island, north and east of King George Island, and north and south of Elephant Island. The mean density of krill observed during the survey was much lower than that observed during a similar survey in 1998 (151 g/m^2).

US AMLR Survey

2.20 Mesoscale sampling in the vicinity of Elephant Island, undertaken by the *Yuzhmorgeologiya* as part of the US AMLR Program, was described by Dr Hewitt. The design consisted of three survey boxes: one to the north of the South Shetland Islands, one north of Elephant Island and the third south of the eastern end of the South Shetland Islands. As in previous years, a sharp frontal zone was noted north of the South Shetland Islands shelf break and this became more diffuse towards Elephant Island. Mean densities of krill were 28 g/m^2 in the northern South Shetland box, 26 g/m^2 in the Elephant Island box and 17 g/m^2 in the southern South Shetland box.

2.21 The variations in the krill density estimates over the past eight years in the Elephant Island area were described by a cyclical function (Hewitt and Demer, in press). The relatively low standing stock observed during the survey was considered to be indicative of poor recruitment over recent seasons; 1994/95 producing the last strong year class.

Japanese Survey

2.22 A survey along the northern side of the South Shetland Islands undertaken by *Kaiyo Maru* was described by Dr Naganobu. The survey was carried out by sampling closely spaced stations in and around the krill fishing grounds. Data on seasonal krill flux during the 1999/2000 season were collected during a series of repeat surveys. The first survey was undertaken in December 1999 and the second in January and February 2000. Large-scale oceanographic transects were sampled using CTD along two longitudinal sections: one in the Drake Passage (WOCE Line SR1) and the other in the Indian Ocean sector. A series of 12 laboratory experiments was undertaken aboard the vessel to estimate the instantaneous growth rate of krill. A further 500 individual krill were transported alive to Japan for further biological experiments.

Russian Survey

2.23 A small-scale survey at South Georgia that had been planned as part of the BAS Core Program could not be undertaken by *James Clark Ross* due to unforeseen circumstances. That survey was undertaken by the *Atlantida* and the results will be analysed at a joint workshop between scientists from Russia and the UK.

Krill Length Frequencies

2.24 Krill length-frequency data from the station hauls sampled by all vessels participating in the CCAMLR-2000 Survey had been analysed by Dr V. Siegel (Germany). The analysis had been undertaken in two parts: an agglomarative hierarchical cluster analysis to determine whether there were recognisable groupings of krill length-frequency distributions over the survey area, and a geographical consideration of the distribution of such clusters.

2.25 Four types of linkage method were used to compare the results from the different fusion methods on the station groupings:

(i) single linkage;
(ii) complete linkage;
(iii) unweighted Pair Group Average (UPGA); and
(iv) Ward's Method.

2.26 In the first step, each object (station) represents a cluster of its own and the distance between objects is determined by the distance measure (e.g. Euclidean Distance). In principal, objects which have a minimal distance value (single linkage) are fused. Another approach is to group objects (stations) into different (dissimilar) clusters by identifying the maximum distance (furthest neighbour, complete linkage). The latter method is usually recommended for data which naturally form groupings of objects.

2.27 The results of the single linkage method showed no separation of stations into distinct clusters, but the dendrogram formed a 'chain' of stations. This often occurs if few objects have similar distance values. Results from all other three linkage methods clearly indicated a separation of stations into at least three distinct clusters.

2.28 Interpretation of the results using Ward's method caused some difficulty since, from the dendrogram, Cluster 2 appeared to be more similar to Cluster 1 than to Cluster 3, although the resulting overall length-frequency distribution of Cluster 1 was distinctly different from those of Clusters 2 and 3 (see below).

2.29 The UPGA method uses the average distance between all pairs of objects (stations). The dendrogram of this linkage showed a greater similarity between Clusters 2 and 3 and a greater dissimilarity of these two to Cluster 1. This was in concordance with the resulting composite length-frequency distributions of the relevant clusters.

2.30 The complete linkage method (using the greatest instead of the average distance) provided a dendrogram very similar to the UPGA method, and the three clusters were even more distinct than for the previous method. Therefore, the result of the complete linkage method was thought to be the most appropriate to describe the geographical distribution of the various clusters and the related composite length-frequency distributions (Figure 3). Grouping the length-frequency distributions, weighted by catch rates, indicated that each of the clusters had a reasonably tight length-frequency distribution. The aggregated length-frequency distributions are shown in Figure 4.

2.31 The locations of hauls on which these clusters were based fitted into a pattern which appeared similar to the water circulation pattern in the region (paragraphs 2.33 to 2.38). Cluster 1 was composed of small krill of median length 26 mm and occurred from the northern sector of the Weddell Sea and extended across to the north of South Georgia. The distribution of Cluster 2, with a median length of 48 mm, extended from the Bransfield Strait eastwards to the east of the South Orkney Islands, then across the Scotia Sea to the north of South Georgia and the northern part of the South Sandwich Islands. The distribution of Cluster 3, median length 52 mm, extended from the Drake Passage eastwards to include Elephant Island and the South Orkney Islands. The distribution of the clusters is shown in Figure 5 and the latitudinal positions of the cluster boundaries along the transects are indicated in Table 6.

2.32 A small subgroup discussed the future analysis of zooplankton samples. Its report is included as Attachment C.

Physical Oceanography

2.33 A summary of physical oceanographic information was provided by Dr M. Brandon (UK). Routine collection of physical oceanographic data formed an integral part of the CCAMLR-2000 Survey. Data from 157 oceanographic stations sampled by the *Kaiyo Maru*, *James Clark Ross* and *Yuzhmorgeologiya* were available in advance of the workshop. Together with data from the remaining stations sampled from the *Atlantida*, these data represent the largest synoptic dataset since FIBEX in 1981. In comparison with the FIBEX study the CCAMLR-2000 Survey covered a greater area.

2.34 All sampling was undertaken according to predetermined protocols and the submitted data had been combined into an overall database. Plots of potential temperature against salinity indicated very good consistency between sampling vessels. This enabled mapping of key water masses across the region.

2.35 Considering the transects from west to east, the main direction of flow of the Antarctic Circumpolar Current, the constraining effect of the Drake Passage was clearly evident in the proximity of the Southern Antarctic Circumpolar Current Front and the Continental Water Boundary. Both these fronts were close to the Antarctic Peninsula. Similarly the Sub-Antarctic Front and Antarctic Polar Front were close together at the central section of the Drake Passage.

2.36 As the Antarctic Circumpolar Current enters the Scotia Sea it becomes less topographically constrained and spreads out. Although a large dataset was collected during the CCAMLR-2000 Survey, it was not sufficient to resolve individual eddies.

2.37 All of the transects were south of the Polar Front. The Weddell Scotia Confluence is observed extending from the Antarctic Peninsula to the vicinity of the South Orkney Islands. Proceeding further east, and particularly in the region east of the South Orkney Islands, Weddell Sea Water becomes the dominant water mass.

2.38 The general distribution of water masses over the region during the CCAMLR-2000 Survey is shown in Figure 6.

METHODS

Acoustic Data Preparation

3.1 The steps required to produce an estimate of B_0 from acoustic data as agreed at WG-EMM-99 (SC-CAMLR-XVIII, Annex 4, paragraphs 8.41 to 8.49) were reviewed. The steps are:

(i) Delineate volume backscattering attributed to krill from all other volume backscattering. Two methods were proposed to accomplish this step: one based on the difference between mean volume backscattering strength (MVBS) at 120 and 38 kHz, the other based on an algorithm that makes use of volume backscattering at three frequencies. Once volume backscattering attributed to krill was delineated, it would be summed over a depth range and averaged over a time/distance interval (integrated).

(ii) Convert integrated backscattering area attributed to krill to areal krill biomass density. Two methods were proposed to accomplish this step: one using length-frequency data to estimate a distribution of target strengths (TS) based on the TS-length model adopted by SC-CAMLR in 1991, and the other using *in situ* TS measurements. The workshop agreed to make initial assessments using published TS to size relationships and, if time permitted, to extend the assessments using *in situ* TS results.

(iii) S areal krill biomass densities over the survey area. Two methods were proposed to accomplish this step: one is an application of the method of Jolly and Hampton (1990), which assumes that the mean density for each transect within a stratum is a representative sample of the stratum mean, and the other uses an approach based on geostatistical methods. The workshop agreed to use the Jolly and Hampton method.

(iv) Estimate the uncertainty associated with an estimate of B_0. It was agreed that the estimate of uncertainty should include both sampling errors (transect to transect variance) and measurement errors.

3.2 The workshop agreed that the 120 kHz data should be used for the estimation of krill standing stock. Data at 38 and 200 kHz would be used along with those at 120 kHz to aid with target delineation and also provide information to incorporate into the estimate of uncertainty of the standing stock estimate.

3.3 Acoustic datasets from all participating vessels were available for analysis at the workshop. These included raw data (EK5 files), annotations including positional data (EV files), calibration data, transect start and stop times, and noise measurements.

3.4 Recent developments had been made with the Echoview software and these were described to the workshop by Mr I. Higginbottom (SonarData, the Echoview developer). The main advances from Version 1.51 to Version 2.00 had been to permit the simultaneous analysis of data from multiple frequencies and echosounders.

3.5 Version 1.51 EV files had been submitted prior to the workshop by SICs for each participating survey vessel. These were converted to Version 2.00 EV files for use at the workshop. However, several questions remained to be resolved before the EV files could be used to address the steps outlined in paragraph 3.1.

3.6 After some discussion it was agreed that prior to integrating and analysing the acoustic data, consideration needed to be given to the following: draft correction, allowance for noise, surface layer exclusion, calibration, sound velocity, absorption coefficient, wavelength, bottom detection algorithm, transect sections to be excluded and equivalent two-way beam angle.

Draft Correction

3.7 The workshop considered that no changes were needed to the draft correction for any of the vessels. A draft correction for the *James Clark Ross* had to be removed.

Allowance for Noise

3.8 Two general methods were considered:

(i) setting a threshold (either fixed or time-varied) and accepting all integrated values greater than the threshold (termed the thresholding approach); and

(ii) estimating a time-varied volume backscattering strength due to noise and subtracting this from integrated values (termed the subtraction approach). In the case of negative values being derived these were reset to -999 dB.

3.9 The workshop concluded that the subtraction approach would provide better estimates of volume backscattering strength (S_v). Initial estimates of noise at each frequency on each transect as provided by SICs were used. During subsequent inspection of echograms several noise levels were modified. The final values used are listed in Table 7.

Calibration

3.10 Calibration was an integral part of the overall CCAMLR-2000 Survey plan with two calibration periods scheduled for each vessel. Calibrations were undertaken prior to the start of the survey at Stromness Harbour, South Georgia, by all vessels. The second calibration was undertaken on completion of the survey at Stromness by the *Atlantida* and at Admiralty Bay, King George Island by the other three vessels.

3.11 All calibrations were undertaken using the standard sphere method. Dr D. Demer (USA) had obtained a set of 38.1 mm diameter Tungsten Carbide spheres from the same manufacturing lot. He had arranged for these spheres to be bored and fitted with monofilament loops. These spheres had been distributed to the SIC on each vessel. Standard copper spheres 60, 23 and 13.7 mm diameter, provided by each vessel, were also used for calibration.

3.12 Temperature and salinity at the calibration sites were similar and within the range of a large part of the CCAMLR-2000 Survey area. In a few instances inclement weather had slightly prejudiced the quality of the results, but in spite of this all calibrations were within or close to the specification for the equipment. For the *Yuzhmorgeologiya* and the *James Clark Ross* the mean values of the two calibrations were used. For the *Atlantida* the second calibration and for the *Kaiyo Maru* the first calibration were considered to be the better of the two. The measured values of S_v gain and TS gain along with those selected for application to the acoustic analyses are shown in Tables 8 and 9. Summary calibration data from each survey vessel are set out in Table 10 and details of the calibration parameters are set out in Table 11.

Sound Velocity (c)

3.13 In advance of the CCAMLR-2000 Survey a default value for the velocity of sound in water (c), derived from CTD analyses in previous seasons, of 1 449 m/s had been agreed. Physical oceanographic sampling during the survey indicated that a better estimate for c would be 1 456 m/s. Although only a slight modification, the workshop agreed that data should be analysed using this value.

Absorption Coefficient (α)

3.14 The absorption coefficient (α) is dependent on sound velocity, temperature and salinity. Default values of α had been agreed in advance of the CCAMLR-2000 Survey; these were 0.010 dB/m at 38 kHz, 0.026 dB/m at 120 kHz and 0.040 dB/m at 200 kHz. Using the equations of Francois and Garrrison (1982), the following revised values, appropriate to the actual survey conditions, were agreed: 0.010 dB/m at 38kHz, 0.028 dB/m at 120 kHz and 0.041 dB/m at 200 kHz.

Wavelength (λ)

3.15 The slight change in the accepted value of sound velocity required a recalculation of the wavelength. Using the nominal resonant frequency of the transducers the following values were determined for wavelength (λ):

200 kHz:	1 456/200 000	=	0.00728 m
120 kHz:	1 456/119 050	=	0.01223 m
38 kHz:	1 456/37 880	=	0.03844 m

Bottom Detection Algorithm

3.16 Bottom as detected by the EK500 was visually verified from the echograms and adjusted, if necessary, to ensure that bottom echoes were excluded from the integrated layers.

Equivalent Two-way Beam Angle

3.17 This parameter, provided by the manufacturer for a nominal sound speed of 1 473 m/s, was adjusted for a sound velocity of 1 449 m/s by the *James Clark Ross* and the *Atlantida* and set in the EK500 prior to the CCAMLR-2000 Survey. No such adjustments were made for the *Kaiyo Maru* and the *Yuzhmorgeologiya* prior to the survey. The workshop accepted that no additional change was necessary (see Table 12).

Surface Exclusion Layer

3.18 A surface layer exclusion depth of 15 m had been applied to data from the *Yuzhmorgeologiya* and the *Atlantida*, and 20 m for data from the *James Clark Ross* and the *Kaiyo Maru*. These values had been set by the various operators based on previous experience. Whilst there might be some merit in standardising the depth for analysis, it was agreed that given that krill may occur near the surface, it was important to review the data files and make adjustments to include any near-surface targets or exclude any intensive surface noise spikes. This was carried out by a combination of changing the overall depth of the surface exclusion layer or editing small fragments of the surface exclusion layer around individual targets (see Table 7 for details).

3.19 The foregoing decisions on values for draft correction, noise, calibration, sound velocity, absorption coefficient, wave length, bottom detection and two-way beam angle were incorporated into revised EV files for each transect (Table 10).

3.20 Each participating group had provided a complete set of data at the three frequencies. Consequently the datasets included data collected during the following types of activity:

(i) large-scale synoptic survey transects;
(ii) mesoscale survey transects;
(iii) net hauls;
(iv) CTD stations;
(v) calibrations; and
(vi) vessel ‘down time’ due to bad weather or other causes.

3.21 All of these data are indexed by date, time and position. The date and time for the start and end of each transect are set out in Tables 13 to 19. The EV files were further annotated to include only valid acoustic transect periods after the start time, between station periods and down time along the transects, and before the end time.

Delineation of Volume Backscatter Attributed to Krill

3.22 Two options were considered for the identification of krill targets on echocharts. In the past several workers had applied a subjective visual classification to echograms with moderate success. It was accepted that that method was very much dependent on operator skill and experience and was subject to considerable individual variation even between workers at the same institute. The workshop agreed that a processing algorithm would offer a better approach by providing a formalised and objective method for analysing the data.

3.23 Dr Watkins provided an overview of a method that he and his colleagues had developed (Watkins and Brierley, 2000). The method relies on the frequency dependence of the echostrength of acoustic targets. In the acoustic domain, the ratio of the echostrengths is given as the difference between the mean volume backscattering strength (ΔMVBS) at two frequencies. The chosen frequencies were 120 and 38 kHz and the method had been developed during studies over several seasons at South Georgia (Subarea 48.3).

3.24 Applying the method of Watkins and Brierley (2000), the ΔMVBS for krill fell within the general range 2–12 dB. Although other scatterers were present in the water these generally fell outside the ΔMVBS range for krill. It was accepted that some, such as other euphausiids (*Thysanoessa* and *Euphausia frigida*) and amphipods (*T. gaudichaudii*), might be included within the krill ΔMVBS. The ΔMVBS values determined from field studies fitted reasonably closely to those from theoretical models of krill TS and size.

3.25 This approach relies on the mean density averaged over the integration depth range and distance. Providing transducers are situated close together and the echosounders are synchronised, then a ping-by-ping comparison might provide a source of information for target delineation.

3.26 Dr Demer described an approach which sought to exploit the frequency dependence allied to differences in variance between individual pixels to address this problem. He had found that one component of the variance provided a good indication as to whether the echoes arose from biological scatterers or were due to noise, the seabed or some other non-biological source. Extending this analysis to include data from the three frequencies 38, 120 and 200 kHz provided a more rigorous approach to target identification. Modelling results had supported these conclusions from field observations and the frequency dependence at 38 and 120 kHz were in agreement with the Watkins and Brierley method outlined above.

3.27 The means to implement this procedure were still under development and at the time of the workshop the processing algorithms still required some development. The workshop felt that the approach had considerable merit and should be developed, however, it was felt that with the limited time available it would be appropriate to use the Watkins and Brierley method until such time as alternatives were available. Development of such methods was considered a high priority by the group.

Implementation of Echoview 2.00.62

3.28 The workshop discussed a stepwise approach to analysing the CCAMLR-2000 Survey data. It was agreed that the first group of processing activities should lead to the production of intermediate echogram datafiles which contained only those data deemed appropriate for echointegration.

3.29 The first step in this process involved the definition of the upper and lower depth ranges. Nominal surface layer exclusion depths to define the upper depth limit had been defined for each vessel. These are included in Table 7. The lower level was set according to one of two criteria. Where the bottom depth was <500 m, the lower level of integration was set as the bottom depth less 5 m. Where the bottom depth was >500 m, the lower level for integration was set to 500 m.

3.30 The second step involved the averaging of S_v into integration bins of 5 m depth by 100 s in time. These approximate to a horizontal distance of 0.5 km when the vessel is proceeding at 10 knots.

3.31 The third step was to calculate a time-varied noise S_v for each frequency on each vessel. Using the subtraction process, revised datasets of resampled 'noise-free' S_v values at each operating frequency were generated. The noise measurement results are set out in Table 7.

3.32 The fourth step was to generate a matrix of ΔMVBS values by subtracting the resampled noise-free 38kHz values from the resampled noise-free 120kHz values.

3.33 Although krill have previously been delineated by using a general ΔMVBS window of 2–12 dB, Watkins and Brierley (2000) showed that a substantial proportion of small krill sampled in a field study around South Georgia in 1996 and 1997 were not detected using this general window, but would be detected using a range of 2–16 dB. Given that krill in the eastern area of the Scotia Sea were relatively small, it was agreed that a ΔMVBS range of 2–16 dB should be used in the present analysis.

3.34 These steps were implemented as set out in Table 20.

Methods for Converting Integrated Krill Backscattering Area to Areal Krill Biomass Density

3.35 A factor for converting integrated backscattering area to areal krill biomass density can take the form:

$$\rho = S_A \, w/\sigma \qquad (1)$$

where ρ = areal krill biomass density
S_A = integrated backscattering area
w = krill mass
σ = acoustic cross-sectional area

where $$\sigma = 4 \pi r_0^2 \, 10^{TS/10} \qquad (2)$$

and $r_0 = 1$ m.

3.36 This factor can be considered as two components, the relationship of krill acoustic cross-sectional area to length and krill mass to length. These two can then be combined to provide a factor to convert S_A to areal krill biomass density.

3.37 The workshop used the generalised formula

$$w = aL^b \tag{3}$$

where w = total mass (mg) and L = total length (mm).

3.38 It was agreed that ideally the length to mass relationship to be used to analyse the CCAMLR-2000 Survey data should come from data collected during the survey. Length and mass data had been collected by the *Kaiyo Maru* when working in Subarea 48.3. No other length mass data from the survey were available to the workshop.

3.39 These data from the CCAMLR-2000 Survey were examined in relation to other published krill length to mass data from Area 48 which were thought to be compatible in terms of the season and krill maturity stage composition. The following length to mass relationships were considered.

a	b	L (mm)	Source
0.000925	3.550	-	FIBEX 1
0.00180	3.383	-	FIBEX 2
0.002236	3.314	30–48	This survey *Kaiyo Maru*
0.00385	3.20	26–59	Morris et al. (1988)
0.00205	3.325	23–60	Siegel (1992)

3.40 SC-CAMLR (SC-CAMLR-X, paragraph 3.34) adopted the following krill TS to length relationship at 120 kHz:

$$TS_{120} = -127.45 + 34.85 \log (L) \tag{4}$$

3.41 Applying the frequency dependent formula given by Greene et al. (1991) the following formulae for 38 and 200 kHz are obtained:

$$TS_{38} = -132.44 + 34.85 \log (L) \tag{5}$$

$$TS_{200} = -125.23 + 34.85 \log (L) \tag{6}$$

3.42 The workshop did not have sufficient time to examine *in situ* TS data from the survey. Consequently equations 4, 5 and 6 had been used to estimate the TS of the krill in the survey area. The workshop encouraged further work to compare the *in situ* results from the survey with those from the equations (see paragraph 6.7).

3.43 Substituting equation 3 along with equation 4, 5 and 6 as appropriate into equation 2, conversion factors were calculated to convert S_A (m^2/n $mile^2$) to areal biomass krill density (g/m^2).

3.44 The workshop agreed to use the conversion factor derived from the length and mass data obtained aboard the *Kaiyo Maru* because these data were collected during the CCAMLR-2000 Survey. The values fall within the range of the other estimates in Table 21.

Depth of Integration

3.45 The workshop had no prior reason for selecting any specific depth to set the lower level of integration. After some discussion it was agreed to integrate down to the deepest sampling depth and to describe the detection thresholds which will be a function of krill density and noise level (signal to noise ratios) for each frequency.

Examination of Echograms

3.46 The workshop considered ways by which the filtered resampled noise-free echograms (see paragraph 3.32) might be examined to identify outlying and erroneous values. This was tasked to four subgroups, one for each vessel. Noise subtraction was checked by inspection of raw echograms and filtered resampled noise-free echograms. Outlying and erroneous values were checked by integrating and inspecting the output by cell in Microsoft Excel.

3.47 In order to ensure consistency in the integration analysis a cross-checking process was included as follows:

Dataset	Analysed by
Kaiyo Maru	Drs S. Kasatkina and A. Malyshko (Russia)
Atlantida	Dr S. Kawaguchi and Mr Y. Takao (Japan)
James Clark Ross	Mrs J. Emery (USA)
Yuzhmorgeologiya	Drs J. Watkins and A. Brierley and Ms C. Goss (UK)

3.48 The integration analysis was undertaken according to the following schedule:

Step One: The 120 kHz echogram was examined and edited to ensure that near-surface swarms were included and bubbles arising from surface turbulence excluded. For this process the display threshold was set to -70 dB and depth grid turned 'off'. The resulting edited surface layer definition was saved.

Step Two: The S_v threshold was set to -100 dB and with this setting the noise level on NOISE 120 file was adjusted until the 'rainbow' was removed. The adjusted noise level was increased by 3 dB and the file resaved. All changes were recorded (Table 7).

Step Three: In the EV file menu properties the following variables were selected: S_v mean, S_A mean, S_v max, C height, C depth, Date M, Time M, Lat S, Lon S, Lat E, Lon E, Lat M, Lon M and EV file name. (The naming convention for these variables is M = mean, S = start, E = end). The filtered resampled noise-free echogram at 120 kHz was opened and the grid changed to a GPS distance of 1 n mile and 5 m depth. The echogram was then integrated by cell and the resultant integrated file saved according to the following filename convention: 'transect name' 'freq.' (eg SS03_120.csv). These files were saved to a folder for each ship.

Step Four: Each file was sorted by S_v max. This allowed the highest values to be identified by date, time and depth bin. These high values were then examined on the echogram to determine whether they were likely to have been due to biological scatterers such as krill or else due to noise, bottom integration or some other extraneous scattering. Scatterers thought not to be krill were labelled as 'bad data'. The corrected echogram was then re-integrated and saved as described in Step Three above.

3.49 The 38 and 200 kHz echograms were then analysed using the same process for noise subtraction and integration but excluding the 'bad data' regions and including near surface swarms identified at 120 kHz.

3.50 Conversion factors, CCAMLR-2000 from Table 21, were used to convert S_A along each transect to biomass using the appropriate clusters as indicated in Table 6.

3.51 For several reasons ships deviated from the planned transects. Such deviations included random effects caused by strong winds and ocean currents, and larger systematic deviations caused by avoidance of icebergs. To correct for these larger deviations, an expected change in latitude per nautical mile of transect, Δlat was calculated from the waypoints derived in WG-EMM-99/7. These values are listed in Table 22. Although the transects, on great circle courses, did not have a constant heading, using a constant Δlat as shown in Table 22 introduces a possible error of only 9 m in a N–S transect, and a possible error of only 25 m in a NE–SW transects. These errors are within the expected accuracy of the available navigation. An actual latitude made good, $\Delta l\hat{a}t$, was derived by differencing the latitudes of the 1 n mile Echoview output. An interval weighting W_I was calculated as:

$$W_{\mathrm{I}} = \frac{|\Delta lat| - |(\Delta lat - \Delta l\hat{a}t)|}{|\Delta lat|} \tag{7}$$

If the deviation from the standard track line for a particular interval was greater than 10% (i.e. if $W_I < 0.9$), then the 1 n mile integral was scaled by W_I, otherwise $W_I = 1$.

3.52 The sum of the interval weightings along each transect was used to weight the transect means to provide a stratum biomass.

3.53 The planned transect lengths within each subarea are set out in Table 23 and it was agreed that these should be used to estimate the proportion of survey effort in each subarea.

RESULTS

Estimated Standing Stock

4.1 Mean krill biomass densities along each transect and at each acoustic frequency were calculated according to the schedule set out in paragraphs 3.48 to 3.52. Biomass estimates were made according to the method of Jolly and Hampton (1990) as agreed in paragraph 3.1. The results are set out in Tables 24 to 26 and Figure 7.

4.2 With the results to hand, a series of checks was made to determine as far as possible that the analyses had been undertaken in the prescribed way.

4.3 In theory there should be the same number of distance intervals at each frequency for each transect. In some instances, however, there were differences, and in these instances files were checked and corrected.

4.4 As a first step to investigate the possibility of bias between ships, an analysis of variance was used to test whether there were significant differences between vessels. A rigorous test could only be undertaken for the Scotia Sea and Antarctic Peninsula regions where the survey tracks of the individual vessels, *James Clark Ross*, *Kaiyo Maru* and *Yuzhmorgeologiya*, were interleaved. The results from this analysis are set out in Table 27 and indicate there to be no significant difference between vessels. A second ANOVA which included the results from the *Atlantida*, the only vessel to sample in the South Sandwich Islands area, also indicated that there was no significant difference between any of the vessels (Table 28).

4.5 The distribution of the W_I (paragraph 3.51) was plotted on a map of the surveyed area to indicate whether any bias might exist in the sampling intensity. Although statistical analyses were not possible in the time available, a visual examination of the results suggested that the distribution was not likely to affect the estimates of krill density.

4.6. The distribution of the conversion factors along the transects of the krill length-frequency clusters was checked against the nominal distribution in Table 6. The distribution was confirmed to be correct over nearly all transects except within the region of the South Shetland Islands mesoscale survey on transects AP15 and AP16 where short portions of these two transects were assigned to Cluster 2 instead of Cluster 3. The workshop noted that the potential error to the standing stock estimate arising from this was likely to negligible. It was agreed that no further action was necessary at the workshop.

4.7 The krill standing stock, estimated using 120 kHz as agreed by the workshop, was 44.29 million tonnes (CV 11.38%). The standing stock estimates at the other two frequencies were 29.41 million tonnes (CV 9.25%) at 38 kHz and 44.82 million tonnes (CV 15.76%) at 200 kHz (see Tables 24 to 26; Figure 7).

4.8 The workshop accepted the estimate of krill standing stock at 120 kHz (44.29 million tonnes) as the best available for the CCAMLR-2000 Survey.

Considerations of Uncertainty

4.9 The workshop noted that the estimation of standing stock by the Jolly and Hampton method gave an associated sampling variance for the survey. This sampling variance provides an important component of the uncertainty. There are however other components of uncertainty which need to be identified so that they can be incorporated into the estimation of γ for the GYM.

4.10 During the meeting Dr Demer had undertaken a series of analyses to quantify the following components of uncertainty which might make a significant contribution to the overall uncertainty:

(i) TS: dependence on acoustic frequency and krill size and orientation;
(ii) detection probability: background noise, distribution of TS, krill by depth; and
(iii) efficiency of krill detection and delineation.

4.11 The following topics were thought to have a minimal effect on the overall uncertainty: variation in α and sound speed over the survey area in comparison to the agreed default values.

4.12 In order to provide an estimate of combined measurement and sampling uncertainty, it is necessary to undertake further analyses of the data and undertake simulation studies to determine the extent and relative importance of the key components. There was insufficient time at the workshop to undertake these studies. Dr Demer offered to develop this analysis and provide a paper for consideration at WG-EMM-2000.

ARCHIVE AND STORAGE OF DATA ANALYSED AT THE WORKSHOP

5.1 The analyses by the workshop were based on the three core datasets collected during the CCAMLR-2000 Survey (SC-CAMLR-XVIII, Annex 4, Appendix D, paragraph 19): acoustic data, micronekton net data, and CTD profiles. These data are to be transferred, together with documentation, to a new CCAMLR database for archiving. Dr D. Ramm (Data Manager) will present a report on the archiving process to WG EMM-2000.

5.2 Four types of acoustic data files were used: raw ping-by-ping data (EK5 files); Echoview data annotation files (EV files); S_A by transect and frequency, and total S_A by frequency (CSV files); and biomass by stratum (Excel files).

5.3 The raw ping-by-ping data files consist of EK500 telegrams, and these files are in a format specified by SonarData. Raw data were available from the *Atlantida* (3 414 files, 4.40 Gb); *James Clark Ross* (1 499 files, 5.88 Gb); *Kaiyo Maru* (936 files; 4.17 Gb); *Yuzhmorgeologiya* (1 445 files, 6.54 Gb). Dr Hewitt agreed to submit the EK500 data on CD-ROM (approximately 40 disks) to the Secretariat by the end of August 2000, together with a copy of the relevant documentation describing the data format used in these files.

5.4 The EV files specify the EK5 data, transect regions and acoustic parameters used in the analyses done in Echoview. These files are in Echoview format, and there is one EV file for each transect. The values of parameters are summarised in the tables of this report. The specifications held in each file are presently only accessible using Echoview, and the Secretariat does not have this software. Dr Hewitt agreed to submit the EV files to the Secretariat by the end of August 2000. In addition, the group agreed that a detailed listing of the data held in the EV files be developed by the Secretariat in consultation with Dr Hewitt and Mr Higginbottom.

5.5 The S_A files, in CSV format, and the biomass by stratum files, in Microsoft Excel, were developed at the workshop. Dr Hewitt agreed to submit the CSV files, Excel files and their descriptions to the Secretariat by the end of August 2000.

5.6 The micronekton net data were derived from samples collected using the RMT8. Raw data had been collated and analysed by Dr Siegel prior to the workshop (WG-EMM-00/6). Dr Siegel advised that these data required some further validation, and he agreed to do this shortly after the workshop. Once validated, Dr Siegel agreed to submit the micronekton net data, together with data documentation, to the Secretariat by early July 2000.

5.7 The CTD data were collected by all four ships. Data from the *James Clark Ross, Kaiyo Maru* and *Yuzhmorgeologiya* had been collated and analysed by Dr Brandon prior to the workshop. The data from the *Kaiyo Maru* required minor re-calibration, and Dr Naganobu agreed to undertake this task, and resubmit the data to Dr Brandon as soon as possible. In addition, Dr Kasatkina agreed to submit the CTD data from the *Atlantida* to Dr Brandon by early July 2000. Dr Brandon would then collate the CTD data, and submit these data, together with relevant documentation, to the Secretariat.

5.8 All acoustic data submitted to the Secretariat will initially be stored on CD-ROM. A catalogue of these data, together with the RMT8 and CTD data will be held in a Microsoft Access database. Once the structure of the new CCAMLR-2000 Survey database is established, data will be transferred to SQL Server format, in line with other data held by the Secretariat. Resources should be provided to the Secretariat so that the acoustic data can be transferred from CD-ROM to hard disk within the next 12 months. This will ensure that these data are backed up to magnetic tape regularly, and can be transferred, along with all other CCAMLR data, to any new, future system. All survey data submitted to CCAMLR will be subject to the rules of access and use of CCAMLR data.

FUTURE WORK

Archiving of Data and Access to Samples

6.1 All data considered by the workshop, together with detailed documentation of all data fields, are to be submitted to the CCAMLR Data Centre for archiving as specified in paragraphs 5.3 (EK5 files); 5.4 (EV files); 5.5 (S_A files), 5.6 (RMT8 data) and 5.7 (CTD data). A report on the archiving process will be presented to WG-EMM-2000 (paragraph 5.1).

6.2 The group noted that the archiving of the CCAMLR-2000 Survey data has a budgetary consideration: additional hard disk space and back-up capacity within the Secretariat will be required to ensure that all EK5 files can be transferred from CD-ROM format within the next 12 months (paragraph 5.8). To ensure complete archiving of the workshop data and analysis results, the Secretariat should hold a copy of Echoview 2.00.

6.3 All survey data submitted to CCAMLR will be subject to the rules of access and use of CCAMLR data (paragraph 5.8).

6.4 The group identified the need to develop a protocol and process for scientists wishing to access zooplankton and nekton samples collected using the RMT1 and RMT8 nets (Attachment C).

Publications and Future Symposia and Workshops

6.5 Much of the CCAMLR-2000 Survey data collected is yet to be analysed. It is expected that each major set of data would form the focus of future CCAMLR workshops. Data analysed at such workshops will need to be transferred to the CCAMLR Data Centre for archiving. All data submitted to the CCAMLR Data Centre for archiving should be fully documented with specific data formats being defined.

6.6 The following possibilities were identified for the future publication of the CCAMLR-2000 Survey results:

(i) prepare a short communication (in the order of 1 000 words) to a scientific journal with broad readership under the following conditions:

    (a) such communication will describe the survey, the participants, the methods of data collection and analysis and the estimate of B_0, but not necessarily the implications;

    (b) such communication will be authored by a team name such as 'CCAMLR-2000 Survey Team' with team members listed in alphabetical order in a footnote;

    (c) an initial draft will be prepared within the next four months by Dr Hewitt and circulated for comments via email.

(ii) develop a series of papers to describe the results of, and the protocols developed by, the workshop. This could include the development of a special issue of *CCAMLR Science*.

(iii) consolidate the protocols of the CCAMLR-2000 Survey into a CCAMLR manual on the execution of acoustic surveys of krill.

6.7 The CCAMLR-2000 Survey has produced a unique multinational dataset. It was agreed that to maximise the potential of these data, their collaborative analyses should be encouraged. Such analyses could be undertaken by future CCAMLR workshops, and/or through collaboration between individual data providers as well as between individual scientists. This requires that the intellectual property rights attached to the data are recognised and balanced with the need to maximise data use. Again, all data analysed at CCAMLR workshops will be subject to the CCAMLR data access rules. In responding to requests for other data, the SICs (or their alternates) should serve as a first contact point to manage data access and as a conduit to promote collaborative analyses. WG-EMM and the Scientific Committee were requested to consider this matter further.

6.8 Future analyses identified by the workshop include, *inter alia*:

(i) Sampling techniques:

(a) apply alternative analyses to the current survey data (e.g. using geostatistical techniques to estimate mean krill biomass density and its variance over the survey area);

(b) refine krill density and biomass estimates using conversion factors derived from data collected by all ships during the survey;

(c) develop refined methods for acoustic target delineation;

(d) identify targets larger than krill, especially myctophids;

(e) compare *in situ* TS estimates with those from SC-CAMLR equations;

(f) investigate *in situ* TS measurements with respect to the biological condition of krill;

(g) determine the pattern of ambient noise from 38 kHz in relation to water depth and weather;

(h) investigate net sampling survey design, net selection, catchability and selectivity with respect to krill; and

(i) develop protocols for the application of optimal temporal and spatial designs for future acoustic surveys of krill.

(ii) Multidisciplinary analyses:

(a) investigate the distribution of krill density and classification (length and maturity) in respect to water masses and in relation to the cluster boundaries identified by the workshop;

(b) investigate the distribution of acoustic scatterers and zooplankton other than krill;

(c) investigate the spatial distribution of krill biomass with respect to latitude, water masses and bathymetry;

(d) analyse combined oceanographic datasets;

(e) determine flow fields across the Scotia Sea and then calculate krill flux;

(f) compare acoustic data from mesoscale survey boxes with acoustic survey results from similar boxes over time;

(g) compare krill standing stock estimate to validate land-based dependent species population estimates; and

(h) integrate CCAMLR-2000 Survey data collected by CCAMLR and the IWC.

CLOSE OF WORKSHOP

7.1 The report of the workshop was adopted.

7.2 The Chairman of the Scientific Committee, Dr D. Miller, thanked Dr Hewitt for convening a very successful workshop and the US Government for facilitating the process. The workshop joined Dr Everson in thanking Mrs L. Bleathman and Dr Ramm for their participation and support. Dr Hewitt then thanked Dr Everson for his major input as rapporteur, and thanked contributors for their valued input to discussions and the report, and for working long hours to ensure the success of the workshop.

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Watkins, J.L. and A.S. Brierley. 2000. Verification of acoustic techniques used to identify Antarctic krill. *ICES J. Mar. Sci.*, (in press).

LIST OF DOCUMENTS

WG-EMM-00/06	Krill distribution patterns in the Atlantic sector of the Antarctic during the CCAMLR-2000 Survey V. Siegel, S. Kawaguchi, F. Litvinov, V. Loeb and J. Watkins

Table 1: Transect section from CCAMLR-2000 Survey large-scale transects which lie within mesoscale survey boxes. (See Table 4 for transect abbreviations).

Transect	From		To	
	Latitude (°S)	Longitude (°W)	Latitude (°S)	Longitude (°W)
South Georgia				
SS03	53.7099	35.2440	54.6058	35.1363
SS04	53.1002	37.1962	53.9972	37.1336
South Orkneys				
SS07	59.8292	43.4326	60.7249	43.5246
SS08	59.7697	45.2811	60.6639	45.4222
South Shetlands				
AP13	60.4858	55.4738	61.2918	54.6604
AP14	61.0372	57.9057	61.8577	57.1422
AP15	61.4720	60.2064	62.3050	59.4948
AP16	61.6936	61.8532	62.5341	61.0074
South Sandwich				
SSb	59.7557	25.3475	55.3544	27.0268
Overlap between AP and SS*				
SS10	61.9923	50.0037	discard data to the south	

* This portion of SS10 was discarded because of an overlap between AP and SS.

Table 2: System-specific echosounder settings by ship.

Transceiver	Menu	*Atlantida*	*James Clark Ross*	*Kaiyo Maru*	*Yuzhmorgeologiya*
1	Transducer type	ES38B	ES38B	ES38B	ES38-12
	Transducer depth (m)	5.0	5.70	5.8	7.0
	Two-way beam angle (dB)	-21.2	-20.8	-20.9	-15.9
	S_v transducer gain (dB)	23.32	25.49	27.06	22.95
	TS transducer gain (dB)	23.50	25.60	27.32	22.51
	Angle sens. along	21.9	21.9	21.9	12.5
	Angle sens. athw.	21.9	21.9	21.9	12.5
	3 dB beamw. along (°)	7.1	7.0	6.8	12.2
	3 dB beamw. athw. (°)	7.1	7.1	6.9	12.2
2	Transducer type	ES120-7	ES120	ES120-7	ES120-7
	Transducer depth (m)	5.0	5.70	5.8	7.0
	Two-way beam angle (dB)	-20.9	-18.4	-20.6	-20.4
	S_v transducer gain (dB)	24.49	2026	24.74	24.52
	TS transducer gain (dB)	24.66	20.26	24.83	24.13
	Angle sens. along	15.7	15.7	21.0	21.0
	Angle sens. athw.	15.7	15.7	21.0	21.0
	3 dB beamw. along (°)	7.3	9.3	7.1	7.3
	3 dB beamw. athw. (°)	7.3	9.3	7.1	7.3
3	Transducer type	200_28	200_28	200_28	200_28
	Transducer depth (m)	5.0	5.70	5.8	7.0
	Two-way beam angle (dB)	-20.3	-20.8	-20.5	-20.5
	S_v transducer gain (dB)	23.26	22.78	25.76	26.30
	TS transducer gain (dB)	23.47	23.07	25.78	26.30
	3 dB beamw. along (°)	7.1	6.9	7.1	7.1
	3 dB beamw. athw. (°)	7.1	7.1	7.1	7.1

Table 3: Survey echosounder settings defined in protocol.

Operation menu		Ping mode	Normal
		Ping auto start	Off
		Ping interval	2.0 Sec
		Transmit power	Normal
		Noise margin	0 dB
Transceiver menu	Transceiver-1 menu	Mode	Active
		Transd. Sequence	Off
		Absorption coef.	10 dB/km
		Pulse length	Medium
		Bandwidth	Wide
		Max. Power	2000 W
		Alongship offset	0.00°
		Athw.ship offset	0.00°
	Transceiver-2 menu	Mode	Active
		Transd. sequence	Off
		Absorption coef.	26 dB/km
		Pulse length	Long
		Bandwidth	Narrow
		Max. power	1000 W
		Alongship offset	0.00°
		Athw.ship offset	0.00°
	Transceiver-3 menu	Mode	Active
		Transd. sequence	Off
		Absorption coef.	40 dB/km
		Pulse length	Long
		Bandwidth	Narrow
		Max. power	1000 W
		Alongship offset	0.00°
		Athw.ship offset	0.00°
Bottom detection menu*	Bottom detection-1 menu	Min. depth	10.0 m
		Max. depth	500 m
		Min. depth alarm	0.0 m
		Max. depth alarm	0.0 m
		Bottom lost al.	0.0 m
		Min. level	-50 dB
	Bottom detection-2 menu	Min. depth	10.0 m
		Max. depth	500 m
		Min. depth alarm	0.0 m
		Max. depth alarm	0.0 m
		Bottom lost al.	0.0 m
		Min. level	-50 dB
	Bottom detection-3 menu	Min. depth	10.0 m
		Max. depth	500 m
		Min. depth alarm	0.0 m
		Max. depth alarm	0.0 m
		Bottom lost al.	0.0 m
		Min. level	-50 dB
Log menu		Mode	Speed
		Ping interval	20
		Time interval	20 s
		Dist. interval	1.0 n mile
		Pulse rate per n mile	200

* Initial settings, changed according to conditions.

continued

Table 3 (continued)

Layer menu		Super layer	Ship specific
	Layer-1 menu	Type	Ship specific
	Layer-2 menu	Type	Ship specific
	Layer-3 menu	Type	Ship specific
	Layer-4 menu	Type	Ship specific
	Layer-5 menu	Type	Ship specific
	Layer-6 menu	Type	Ship specific
	Layer-7 menu	Type	Ship specific
	Layer-8 menu	Type	Ship specific
	Layer-9 menu	Type	Ship specific
	Layer-10 menu	Type	Ship specific
TS detection menu	TS Detection-1 menu	Min. value	-90 dB
		Min. echo length	0.8
		Max. echo length	2.5
		Max. gain comp.	4.0 dB
		Max. phase dev.	2.0
	TS Detection-2 menu	Min. value	-90 dB
		Min. echo length	0.8
		Max. echo length	2.5
		Max. gain comp.	4.0 dB
		Max. phase dev.	2.0
	TS Detection-3 menu	Min. value	-90 dB
		Min. echo length	0.8
		Max. echo length	2.5
		Max. gain comp.	4.0 dB
		Max. phase dev.	2.0
Ethernet com. menu	Telegram menu	Remote control	On
		Sample range	0 m
		Status	On
		Parameter	On
		Annotation	Off
		Sound velocity	Off
		Navigation	On
		Motion sensor	Off
		Depth	1
		Depth nmea	Off
		Echogram	1&2&3
		Echo-trace	1&2&3
		S_v	Off
		Sample angle	Off
		Sample power	Off
		Sample S_v	Off
		Sample TS	Off
		Vessel-log	On
		Layer	On
		Integrator	Off
		Ts distribution	Off
		Towed fish	Off
	UDP port menu	Status	Ship specific
		Parameter	Ship specific
		Annotation	Ship specific
		Sound velocity	Ship specific
		Navigation	Ship specific
		Motion sensor	Ship specific

continued

Table 3 (continued)

Ethernet com. menu (continued)	UDP port menu	Depth	Ship specific
		Echogram	Ship specific
		Echo-trace	Ship specific
		S_v	Ship specific
		Sample angle	Ship specific
		Sample power	Ship specific
		Sample S_v	Ship specific
		Sample TS	Ship specific
		Vessel-log	Ship specific
		Layer	Ship specific
		Integrator	Ship specific
		TS distribution	Ship specific
		Towed fish	Ship specific
	Echogram-1 menu	Range	500 m
		Range start	0 m
		Auto range	Off
		Bottom range	0 m
		Botttom range start	10 m
		No. of main val.	700
		No. of bot. val.	0
		TVG	20 log r
	Echogram-2 menu	Range	500 m
		Range start	0 m
		Auto range	Off
		Bottom range	0 m
		Bottom range start	10 m
		No. of main val.	700
		No. of bot. val.	0
		TVG	20 log r
	Echogram-3 menu	Range	500 m
		Range start	0 m
		Auto range	Off
		Bottom range	0 m
		Bottom range start	10 m
		No. of main val.	700
		No. of bot. val.	0
		TVG	20 log r
Serial com. menu	Telegram menu	Format	ASCII
		Modem control	Off
		Remote control	On
		Status	Off
		Parameter	Off / on
		Annotation	Off / on
		Navigation	Off
		Sound velocity	Off
		Motion sensor	Off
		Depth	Off
		Depth nmea	Off
		Echogram	Off
		Echo-trace	Off
		S_v	Off
		Vessel-log	Off
		Layer	Off
		Integrator	Off

continued

Table 3 (continued)

Serial com. menu (continued)	Telegram menu	TS distribution	Off
		Towed fish	Off
	USART menu	Baudrate	9600
		Bits per char.	8
		Stop bits	1
		Parity	None
Motion sensor menu		Heave	Off
		Roll	Off
		Pitch	Off
Utility menu		Beeper	Off / On
		Status messages	On
		Rd display	Off
		Fifo output	Off
		External clock	Off
		Default setting	No
		Language	English

Table 4: Summary of activities undertaken by vessels during the CCAMLR-2000 Survey (January–February 2000), and data submitted to the B_0 Workshop. AP – Antarctic Peninsula; Sand – South Sandwich Islands; SG – South Georgia; SOI – South Orkney Islands; SS – Scotia Sea; SSI – South Shetland Islands.

	Vessel			
	Atlantida	*Kaiyo Maru*	*James Clark Ross*	*Yuzhmorgeologiya*
Synoptic survey				
Survey area	SS	AP SS	AP SS	AP SS
CCAMLR subareas	48.4	48.1 48.2 48.3	48.1 48.2 48.3	48.1 48.2 48.3
Start date	17 January	11 January	18 January	13 January
End date	1 February	2 February	10 February	4 February
Large-scale transects				
Number	3	6	7	6
Transect names	SSa SSb SSc	SS03 SS06 SS09 AP12 AP15 AP18	AP13 AP16 AP19 SS01 SS04 SS07 SS10	AP11 AP14 AP17 SS02 SS05 SS08
Mesoscale transects				
Number	10	8	0	8
Transect names	Sand01-10	SSI01-08		SG01-04 SOI01-04
Calibration				
Pre-survey				
Date	14 January	9 January	16 January	12 January
Location	Stromness Bay	Stromness Bay	Stromness Bay	Stromness Bay
Post-survey				
Date	5 February	4 February	11 February	7 March
Location	Stromness Bay	Admiralty Bay	Admiralty Bay	Admiralty Bay
Data submitted				
Acoustic data	√	√	√	√
Net data	√	√	√	√
CTD data		√	√	√

Table 5: Summary of data collected by vessels during the CCAMLR-2000 Survey. ADCP – acoustic Doppler current profiler; CPR – continuous plankton recorder; CTD – conductivity temperature depth probe; EPCS – electronic plankton counting system; EK500 – Simrad EK-500 echosounder (38, 120, 200 kHz) with SonarData Echoview software; IWC – IWC Observers; JNCC – Joint Nature Conservancy Council Seabirds-at-Sea; LADCP – lowered ADCP; MAPT – meteorological automatic picture transmission; NORPAC – North Pacific standard net; RMT1 – rectangular midwater trawl 1 m^2; RMT8 – rectangular midwatertrawl 8 m^2; SeaWIFS – sea-viewing wide field-of-view sensor; XBT – expendable bathythermograph; XCTD – expendable CTD.

Type of Data	Vessel			
	Atlantida	*Kaiyo Maru*	*James Clark Ross*	*Yuzhmorgeologiya*
Under-way Observations:				
Acoustic survey				
Acoustic profiles*	EK500	EK500	EK500	EK500
Bathymetry			EA500 (12kHz)	
Physical oceanography				
Meteorological data	Instruments	MAPT	Instruments	Instruments
Satellite images		NOAA		SeaWIFS
Current velocity and direction	ADCP		ADCP	
Water temperature and salinity		EPCS, XBT, XCTD	@6m	Thermosalinograph
Biological sampling				
Chlorophyll and zooplankton		EPCS		Flurometer
Chlorophyll calibration	Water samples	Water samples	Water samples	Water samples
Predator observations				
Seabirds and marine mammals	Observers	IWC, Observers	IWC, JNCC	IWC
On-Station Sampling:				
Physical oceanography				
Temperature and conductivity*	CTD	CTD	CTD	CTD
Dissolved oxygen	CTD	CTD		CTD
Current velocity and direction		LADCP	ADCP	
Water samples	to 1 000 m	to 1 000 m		to 1 000 m
Biological sampling				
Krill and other micronekton*	RMT8	RMT8	RMT8	RMT8
Zooplankton	RMT1	RMT1, NORPAC, CPR	RMT1, Bongo	RMT1
Chlorophyll-*a*		√		√
Nutrients		√		

* Core datasets

Table 6: Latitudinal position at which krill size clusters change along acoustic transects. (See Table 4 for transect abbreviations and Figure 4 for a description of the clusters).

Transect	Cluster	Position (latitude S) between Clusters
SS01	2	North of 54°30’
SS01	1	South of 54°30’
SS02	2	North of 52°54’
SS02	1	52°54’ to 58°18’
SS02	2	58°18’ to 60°
SS02	1	South of 60°
SS03	2	North of 53°
SS03	1	53° to 57°30’
SS03	2	57°30’ to 59°21’
SS03	1	South of 59°21’
SS04 to SS06	2	Entire transect
SS07	2	North of 60°
SS07	3	South of 60°
SS08	2	North of 60°
SS08	3	60° to 61°
SS08	2	South of 61°
SS09	2	South of 62°15’
SS09	3	North of 62°15’
SS10	2	South of 61°15’
SS10	3	North of 61°15’
AP11 to AP16*	2	South of 61°15’
AP11 to AP16*	3	North of 61°15’
AP17 to AP19	3	Entire transect
All SOI	3	Entire transect
SSI01	3	North of 61°20’
SSI01	2	South of 61°20’
SSI02 and 03	3	North of 61°30’
SSI02 and 03	2	South of 61°30’
SSI04 and 05	3	North of 61°45’
SSI04 and 05	2	South of 61°45’
SSI06 and 07	3	North of 62°
SSI06 and 07	2	South of 62°
SSI08	3	Entire transect
SG01 to 03	1	Entire transect
SG04	2	Entire transect
SSa 48.4 east	2	North of 58°45’
SSa 48.4 east	1	South of 58°45’
SSb 48.4 middle	2	North of 58°
SSb 48.4 middle	1	South of 58°
SSc 48.4 west	2	North of 56°33’
SSc 48.4 west	1	56°33’ to 58°
SSc 48.4 West	2	58° to 59°05’
SSc 48.4 West	1	South of 59°05’
Sand 01,02,03,06,07	2	Entire transect
Sand 04,05,08,09,10	1	Entire transect

* During the error checking phase (paragraph 4.6) it was noted that portions of AP15 and AP16 north of the mesoscale box in the SSI were incorrectly assigned to Cluster 2 and should have been assigned to Cluster 3.

Table 7: CCAMLR-2000 Survey noise measurements (dB) and surface exclusion. Atl – *Atlantida;* JCR – *James Clark Ross*; KyM – *Kaiyo Maru*; Yuz – *Yuzhmorgeologiya.* (See Table 4 for transect abbreviations).

Ship	Transect	Surface Layer (m)	Noise (S_v re 1 m)		
			38 kHz	120 kHz	200 kHz
Yuz	SG01	20	-123.00	-123.00	-123.00
Yuz	SG02	20	-124.00	-120.00	-121.00
Yuz	SG03	20	-125.00	-124.00	-124.00
Yuz	SG04	15	-137.00	-129.00	-124.00
Yuz	SS02	20	-137.00	-123.00	-124.00
Yuz	SS05	15	-135.00	-125.00	-123.00
Yuz	SS08	15	-131.00	-125.00	-123.00
Yuz	SOI01	15	-126.00	-120.00	-119.00
Yuz	SOI02	15	-126.00	-122.00	-123.00
Yuz	SOI03	15	-129.00	-122.00	-122.00
Yuz	SOI04	20	-135.00	-127.00	-122.00
Yuz	AP11	20	-129.00	-120.00	-123.00
Yuz	AP14	15	-129.00	-120.00	-125.00
Yuz	AP17	20	-121.00	-120.00	-117.00
Atl	Sand01	15	-127.00	-136.50	-135.00
Atl	Sand02	15	-127.00	-136.50	-135.00
Atl	Sand03	15	-127.00	-136.50	-135.00
Atl	Sand04	15	-127.00	-136.50	-135.00
Atl	Sand05	15	-127.00	-136.50	-135.00
Atl	Sand06	15	-127.00	-136.50	-135.00
Atl	Sand07	15	-127.00	-136.50	-135.00
Atl	Sand08	15	-127.00	-136.50	-135.00
Atl	Sand09	15	-127.00	-136.50	-135.00
Atl	Sand10	15	-127.00	-136.50	-135.00
Atl	SSa	15	-127.00	-136.50	-135.00
Atl	SSb	15	-127.00	-136.50	-135.00
Atl	SSc	15	-127.00	-136.50	-135.00
JCR	SS01	20	-150.00	-124.00	-110.00
JCR	SS04	15	-150.00	-124.00	-112.00
JCR	SS07	20	-150.00	-124.00	-112.00
JCR	SS10	20	-150.00	-124.00	-110.00
JCR	AP13	20	-150.00	-124.00	-110.00
JCR	AP16	20	-150.00	-124.00	-110.00
JCR	AP19	20	-152.00	-124.00	-110.00
KyM	SS03	20	-136.40	-136.40	-134.40
KyM	SS06	20	-147.40	-136.40	-138.10
KyM	SS09	20	-141.90	-136.80	-138.40
KyM	AP12	20	-147.00	-135.70	-135.10
KyM	AP15	20	-148.10	-136.20	-136.10
KyM	AP18	20	-147.40	-136.60	-136.80
KyM	SSI01	20	-140.90	-136.60	-134.40
KyM	SSI02	20	-138.90	-136.60	-133.40
KyM	SSI03	20	-144.90	-136.60	-133.40
KyM	SSI04	20	-141.90	-136.60	-135.40
KyM	SSI05	20	-144.90	-136.60	-134.40
KyM	SSI06	20	-146.90	-136.60	-135.40
KyM	SSI07	20	-149.90	-136.60	-135.40
KyM	SSI08	20	-152.90	-136.60	-135.40

Table 8: Calibration constants S_v gain (dB).

Frequency	Vessel	First Calibration	Second Calibration	Chosen Value
38 kHz	*Atlantida*	23.42	23.32	23.32
	James Clark Ross	25.49	25.53	25.51
	Kaiyo Maru	27.06	27.09	27.06
	Yuzhmorgeologiya	22.43	22.29	22.36
120 kHz	*Atlantida*	23.23	24.49	24.49
	James Clark Ross	20.26	20.15	20.20
	Kaiyo Maru	24.74	24.30	24.74
	Yuzhmorgeologiya	25.37	25.16	25.26
200 kHz	*Atlantida*	24.83	23.26	23.26
	James Clark Ross	22.78	23.04	22.91
	Kaiyo Maru	25.76	25.74	25.76
	Yuzhmorgeologiya	26.12	25.80	25.96

Table 9: Calibration constants TS gain (dB).

Frequency	Vessel	First Calibration	Second Calibration	Chosen Value
38 kHz	*Atlantida*	23.76	23.50	23.50
	James Clark Ross	25.60	25.60	25.60
	Kaiyo Maru	27.32	27.35	27.32
	Yuzhmorgeologiya	22.64	22.37	22.51
120 kHz	*Atlantida*	23.29	24.66	24.66
	James Clark Ross	20.26	20.09	20.18
	Kaiyo Maru	24.83	24.55	24.83
	Yuzhmorgeologiya	25.56	25.17	25.37
200 kHz	*Atlantida*	24.50	23.47	23.47
	James Clark Ross	23.07	23.16	23.12
	Kaiyo Maru	25.78	25.77	25.78
	Yuzhmorgeologiya	26.12	25.80	25.96

Table 10: CCAMLR-2000 Survey calibration settings.

Atlantida	38 kHz		120 kHz		200 kHz	
	Logging	Processing	Logging	Processing	Logging	Processing
Absorption coef. (dB/m)	0.010000	0.010000	0.026000	0.028000	0.040000	0.041000
Sound speed (m/s)	1449.00	1456.00	1449.00	1456.00	1449.00	1456.00
Transmitted power (W)	2000.00	2000.00	1000.00	1000.00	1000.00	1000.00
2-way beam angle (dB)	-21.30	-21.30	-21.00	-21.00	-20.30	-20.30
S_V gain (dB)	23.43	23.32	23.23	24.49	24.83	23.26
Wavelength (m)	0.03868	0.03844	0.01225	0.01223	0.00735	0.00728
Trans. pulse length (ms)	1.000	1.000	1.000	1.000	1.000	1.000
Frequency (kHz)		38.00		120.00		200.00
Draft correction (m)		0.00		0.00		0.00
Nominal angle (°)		7.10		7.30		7.10

James Clark Ross	38 kHz		120 kHz		200 kHz	
	Logging	Processing	Logging	Processing	Logging	Processing
Absorption coef. (dB/m)	0.010000	0.010000	0.026000	0.028000	0.040000	0.041000
Sound speed (m/s)	1449.00	1456.00	1449.00	1456.00	1449.00	1456.00
Transmitted power (W)	2000.00	2000.00	1000.00	1000.00	1000.00	1000.00
2-way beam angle (dB)	-20.80	-20.80	-18.40	-18.40	-20.80	-20.80
S_V gain (dB)	25.49	25.51	20.26	20.20	22.78	22.91
Wavelength (m)	0.03868	0.03844	0.01225	0.01223	0.00735	0.00728
Trans. pulse length (ms)	1.000	1.000	1.000	1.000	1.000	1.000
Frequency (kHz)		38.00		120.00		200.00
Draft correction (m)		0.00		0.00		0.00
Nominal angle (°)		7.10		9.30		7.10

Yuzhmorgeologiya	38 kHz		120 kHz		200 kHz	
	Logging	Processing	Logging	Processing	Logging	Processing
Absorption coef. (dB/m)	0.010000	0.010000	0.026000	0.028000	0.040000	0.041000
Sound speed (m/s)	1485.00	1456.00	1485.00	1456.00	1485.00	1456.00
Transmitted power (W)	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00
2-way beam angle (dB)	-15.90	-15.90	-20.40	-20.40	-20.50	-20.50
S_V gain (dB)	22.43	22.36	25.37	25.26	26.12	25.96
Wavelength (m)	0.03868	0.03844	0.01225	0.01223	0.00735	0.00728
Trans. pulse length (ms)	1.000	1.000	1.000	1.000	1.000	1.000
Frequency (kHz)		37.88		119.05		200.00
Draft correction (m)		0.00		0.00		0.00
Nominal angle (°)		12.20		7.10		7.10

Kaiyo Maru	38 kHz		120 kHz		200 kHz	
	Logging	Processing	Logging	Processing	Logging	Processing
Absorption coef. (dB/m)	0.010000	0.010000	0.026000	0.028000	0.040000	0.041000
Sound speed (m/s)	1449.00	1456.00	1449.00	1456.00	1449.00	1456.00
Transmitted power (W)	2000.00	2000.00	1000.00	1000.00	1000.00	1000.00
2-way beam angle (dB)	-20.90	-20.90	-20.60	-20.60	-20.50	-20.50
S_V gain (dB)	27.06	27.06	24.74	24.74	25.76	25.76
Wavelength (m)	0.03868	0.03844	0.01225	0.01223	0.00735	0.00728
Trans. pulse length (ms)		1.000		1.000		1.000
Frequency (kHz)		38.00		119.00		200.00
Draft correction (m)		0.00		0.00		0.00
Nominal angle (°)		7.10		7.10		7.10

Table 11: Calibration parameters for the *Atlantida*, *James Clark Ross*, *Kaiyo Maru* and *Yuzhmorgeologiya*.

Atlantida						
Date	13-Jan-00	05-Feb-00	13-Jan-00	05-Feb-00	13-Jan-00	05-Feb-00
Location	Stromness Bay	Stromness Bay	Stromness Bay	Stromness Bay	Stromness Bay	Stromness Bay
Transducer	ES38B	ES38B	ES120-7	ES120-7	200_28	200_28
Water depth (m)	56	53	54	53	54	53
Sound speed (m/s)	1 457	1 460	1 457	1 460	1 457	1 460
Alpha (dB/km)	10	10	28	28	41	41
Transmit power (watts)	2 000	2 000	1 000	1 000	1 000	1 000
Pulse duration (m/s)	1	1	1	1	1	1
Bandwidth (kHz)	3.8 (10%)	3.8 (10%)	1.2 (1%)	1.2 (1%)	2.0 (1%)	2.0 (1%)
2-way beam angle (dB)	-21.2	-21.2	-20.9	-20.9	-20.3	-20.3
Sphere type	60.0 mm CU	38.1 mm WC	23.0 mm CU	38.1 mm WC	13.7 mm CU	38.1 mm WC
Range to sphere (m)	17.1	14.5	15.0	15.9	14.7	15.5
Calibrated TS gain (dB)	23.76	23.50	23.29	24.66	24.50	23.47
Calibrated S_v gain (dB)	23.43	23.32	23.23	24.49	24.83	23.26

James Clark Ross						
Date	16-Jan-00	12-Feb-00	16-Jan-00	12-Feb-00	16-Jan-00	12-Feb-00
Location	Stromness Bay	Admiralty Bay	Stromness Bay	Admiralty Bay	Stromness Bay	Admiralty Bay
Transducer	ES38B	ES38B	ES120	ES120	200_28	200_28
Water depth (m)	54	264	54	264	54	264
Sound speed (m/s)	1 458	1 455	1 458	1 455	1 458	1 455
Alpha (dB/km)	10	10	27	27	41	41
Transmit power (watts)	2 000	2 000	1 000	1 000	1 000	1 000
Pulse duration (m/s)	1	1	1	1	1	1
Bandwidth (kHz)	3.8 (10%)	3.8 (10%)	1.2 (1%)	1.2 (1%)	2.0 (1%)	2.0 (1%)
2-way beam angle (dB)	-20.8	-20.8	-18.4	-18.4	-20.8	-20.8
Sphere type	38.1 mm WC	38.1 mm WC	38.1 mm WC	38.1 mm WC	38.1 mm WC	38.1 mm WC
Range to sphere (m)	27.7	29.9	28.2	29.73	28.2	28.7
Calibrated TS gain (dB)	25.60	25.60	20.26	20.15	23.07	23.16
Calibrated S_v gain (dB)	25.49	25.53	20.26	20.09	22.78	23.04

Kaiyo Maru						
Date	09-Jan-00	04-Feb-00	09-Jan-00	04-Feb-00	09-Jan-00	04-Feb-00
Location	Stromness Bay	Admiralty Bay	Stromness Bay	Admiralty Bay	Stromness Bay	Admiralty Bay
Transducer	ES38B	ES38B	ES120-7	ES120-7	200_28	200_28
Water depth (m)	80	58	80	58	80	58
Sound speed (m/s)	1 453	1 453	1 453	1 453	1 453	1 453
Alpha (dB/km)	10	10	28	27	41	40.5
Transmit power (watts)	2 000	2 000	1 000	1 000	1 000	1 000
Pulse duration (m/s)	1	1	1	1	1	1
Bandwidth (kHz)	3.8 (10%)	3.8 (10%)	1.2 (1%)	1.2 (1%)	2.0 (1%)	2.0 (1%)
2-way beam angle (dB)	-20.9	-20.9	-20.6	-20.6	-20.5	-20.5
Sphere type	38.1 mm WC	38.1 mm WC	38.1 mm WC	38.1 mm WC	38.1 mm WC	38.1 mm WC
Range to sphere (m)	30.6	30.0	30.0	29.9	30.5	30.1
Calibrated TS gain (dB)	27.32	27.35	24.83	24.55	25.78	25.77
Calibrated S_v gain (dB)	27.06	27.09	24.74	24.30	25.76	25.74

Yuzhmorgeologiya						
Date	12-Jan-00	07-Mar-00	12-Jan-00	07-Mar-00	12-Jan-00	07-Mar-00
Location	Stromness Bay	Admiralty Bay	Stromness Bay	Admiralty Bay	Stromness Bay	Admiralty Bay
Transducer	ES38-12	ES38-12	ES120-7	ES120-7	200_28	200_28
Water depth (m)	88	75	88	75	88	75
Sound speed (m/s)	1 450	1 450	1 450	1 450	1 450	1 450
Alpha (dB/km)	10	10	26	26	40	40
Transmit power (watts)	1 000	1 000	1 000	1 000	1 000	1 000
Pulse duration (m/s)	1	1	1	1	1	1
Bandwidth (kHz)	3.8 (10%)	3.8 (10%)	1.2 (1%)	1.2 (1%)	2.0 (1%)	2.0 (1%)
2-way beam angle (dB)	-15.9	-15.9	-20.4	-20.4	-20.5	-20.5
Sphere type	38.1 mm WC	38.1 mm WC	38.1 mm WC	38.1 mm WC	38.1 mm WC	38.1 mm WC
Range to sphere (m)	30.0	38.0	29.2	37.6	29.0	37.6
Calibrated TS gain (dB)	22.64	22.37	25.56	25.17	26.12	25.80
Calibrated S_v gain (dB)	22.36	22.29	25.37	25.16	22.78	25.80

Table 12: Equivalent two-way beam angle correction for sound speed for the four vessels.

Sound speed during Simrad calibration:	1 473 m/s
Sound speed during survey:	1 449 m/s
Sound speed ratio:	0.9837
Ratio squared:	0.9676
Ratio dB:	-0.1426

Transducer Frequency	Transducer Type	Simrad Specified Beam Angle (dB)	Corrected Beam Angle dB (= specified + dB ratio)
James Clark Ross			
38	ES38B	-20.7	-20.8
120	ES120	-18.3	-18.4
200	200_28	-20.7	-20.8
Kaiyo Maru			
38	ES38B	-20.9	*
120	ES120-7	-20.6	*
200	200_28	-20.5	*
Atlantida			
38	ES38B	-21.2	-21.3
120	ES120-7	-20.9	-21.0
200	200_28	-20.2	-20.3
Yuzhmorgeologiya			
38	ES38-12	-15.9	*
120	ES120-7	-20.4	*
200	200_28	-20.5	*

* Default values supplied by Simrad were used during the survey.

Table 13: *James Clark Ross* CCAMLR-2000 Survey transect times. (See Table 4 for transect abbreviations).

Transect	Begin		End		BAS ID	Comments
	Date	Time	Date	Time		
SS01	18-Jan	1737	18-Jan	2300	T10	
	19-Jan	0527	19-Jan	1359	T11	
	19-Jan	1637	19-Jan	2320	T12	
	20-Jan	0501	20-Jan	1204	T13	
	20-Jan	1505	20-Jan	2345	T14	
	21-Jan	0430	21-Jan	1400	T15	
	21-Jan	1624	21-Jan	1855	T16	
SS04						T17 transit from SS01 to SS04
	22-Jan	1324	22-Jan	1435	T18	
	22-Jan	1702	23-Jan	0015	T19	
	23-Jan	0505	23-Jan	0842	T20	
	23-Jan	0944	24-Jan	1430	T21	
	23-Jan	1611	23-Jan	2345	T22	
	24-Jan	0530	24-Jan	1432	T23	
	24-Jan	1658	24-Jan	2320	T24	
	25-Jan	1546	25-Jan	2321	T25	
SS07						T26 transit from SS04 to SS07
	26-Jan	2231	26-Jan	2320	T27	
	27-Jan	0634	27-Jan	1002	T28	
	27-Jan	1107	27-Jan	1451	T29	
	27-Jan	1609	27-Jan	2340	T30	
	28-Jan	0620	28-Jan	1433	T31	
	28-Jan	1716	29-Jan	0000	T32	
	29-Jan	0600	29-Jan	1356	T33	
	29-Jan	1629	30-Jan	0030	T34	
	30-Jan	0807	30-Jan	1116	T35	
	30-Jan	1214	30-Jan	1505	T36	
	30-Jan	1610	30-Jan	2020	T37	
SS10						T38 transit from SS07 to SS10
	2-Feb	0718	2-Feb	1225	T40	
	2-Feb	1541	3-Feb	0045	T41	
	3-Feb	0620	3-Feb	1524	T42	
AP13						T43 transit from SS10 to AP13
	4-Feb	0606	04-Feb	0748	T44	
	4-Feb	0854	4-Feb	1542	T45	
	4-Feb	1707	4-Feb	2127	T46	
	5-Feb	0635	5-Feb	1418	T48	
AP16						T49 transit from AP13 to AP16
	6-Feb	0900	6-Feb	1613	T50	
	6-Feb	1821	6-Feb	0055	T51	
AP19						T52 transit from AP16 to AP19
	8-Feb	0025	8-Feb	0153	T53	
	8-Feb	0756	8-Feb	1621	T54	
	8-Feb	1900	9-Feb	0205	T55	
	9-Feb	0722	9-Feb	1433	T56	
	9-Feb	1709	9-Feb	2020	T57	
AP16						T58 transit from AP19 back to AP16
	10-Feb	2308	11-Feb	0054	T59	Inner end AP16

Table 14: *Kaiyo Maru* CCAMLR-2000 Survey transect times. (See Table 4 for transect abbreviations).

Transect	Begin		End		Comments
	Date	Time	Date	Time	
SS03	10-Jan	2123	10-Jan	2325	
	11-Jan	0538	11-Jan	1321	
	11-Jan	1547	11-Jan	2345	
	12-Jan	0518	12-Jan	1323	
	12-Jan	1600	13-Jan	0015	
	13-Jan	0449	13-Jan	1323	
	13-Jan	1539	14-Jan	0056	
	14-Jan	0405	14-Jan	0600	
SS06	14-Jan	1830	15-Jan	0056	
	15-Jan	0449	15-Jan	1346	
	15-Jan	1555	16-Jan	0020	
	16-Jan	0527	16-Jan	1347	
	16-Jan	1554	16-Jan	2355	
	17-Jan	0549	17-Jan	1455	
	17-Jan	1710	17-Jan	2141	
SS09	19-Jan	0624	19-Jan	1414	
	19-Jan	1633	20-Jan	0043	
	20-Jan	0603	20-Jan	1415	
	20-Jan	1630	21-Jan	0122	
	21-Jan	0526	21-Jan	1428	
	21-Jan	1646	21-Jan	2024	
AP12	22-Jan	0018	22-Jan	0158	
	22-Jan	0524	22-Jan	1438	
	22-Jan	1655	23-Jan	0015	
	23-Jan	0553	23-Jan	1802	
AP15	24-Jan	1010	24-Jan	1511	
	24-Jan	1815	25-Jan	0215	
	25-Jan	0631	25-Jan	1340	
AP18	26-Jan	0910	26-Jan	1530	
	26-Jan	1751	27-Jan	0238	
	27-Jan	0643	27-Jan	1538	
	27-Jan	1755	28-Jan	0219	

Table 15: *Kaiyo Maru* CCAMLR-2000 Survey mesoscale transects. (See Table 4 for transect abbreviations).

Transect	Begin		End		Comments
	Date	Time	Date	Time	
SSI01	29-Jan	0703	29-Jan	1429	
	29-Jan	1646	29-Jan	1703	
SSI02	29-Jan	1910	29-Jan	2350	
SSI03	30-Jan	0701	30-Jan	1210	
SSI04	30-Jan	1552	30-Jan	1614	
	30-Jan	1805	30-Jan	2131	
SSI05	31-Jan	0701	31-Jan	1118	
SSI06	31-Jan	1614	31-Jan	1626	
	31-Jan	1803	31-Jan	2212	
SSI07	1-Feb	0723	1-Feb	1203	
SSI08	1-Feb	1956	2-Feb	0101	

Table 16: *Atlantida* CCAMLR-2000 Survey transect times. (See Table 4 for transect abbreviations).

Transect	Begin		End		Comments
	Date	Time	Date	Time	
SSa	22-Jan	0500	22-Jan	1322	
	22-Jan	1518	22-Jan	2235	
	23-Jan	0442	23-Jan	1330	
	23-Jan	1628	23-Jan	2301	
	24-Jan	0405	24-Jan	1239	
SSb	25-Jan	0413	25-Jan	1154	
	25-Jan	1458	25-Jan	2207	
	26-Jan	0455	26-Jan	1332	
	26-Jan	1842	26-Jan	2253	
	27-Jan	0513	27-Jan	1206	
	27-Jan	1454	27-Jan	2228	
	28-Jan	0528	28-Jan	1316	
SSc	29-Jan	0527	29-Jan	1314	
	29-Jan	1539	29-Jan	2211	
	30-Jan	0514	30-Jan	1238	
	30-Jan	1359	30-Jan	2246	
	31-Jan	0443	31-Jan	1235	
	31-Jan	1508	31-Jan	2253	
	1-Feb	0432	1-Feb	0822	

Table 17: *Atlantida* CCAMLR-2000 Survey mesoscale transects. (See Table 4 for transect abbreviations).

Transect	Begin		End		Comments
	Date	Time	Date	Time	
Sand01	17-Jan	1000	17-Jan	1324	
	17-Jan	1502	17-Jan	1752	
Sand02	17-Jan	1908	17-Jan	2146	
	18-Jan	0412	18-Jan	0544	
Sand03	18-Jan	0551	18-Jan	1104	
Sand04	18-Jan	1149	18-Jan	1255	
	18-Jan	1630	18-Jan	1742	
Sand05	18-Jan	1805	18-Jan	2323	
Sand06	19-Jan	0641	19-Jan	1119	
Sand07	19-Jan	1220	19-Jan	1321	
	19-Jan	1503	19-Jan	1731	
Sand08	19-Jan	1906	20-Jan	0017	
Sand09	20-Jan	0513	20-Jan	1118	
Sand10	20-Jan	1147	20-Jan	1302	
	20-Jan	1559	20-Jan	1833	

Table 18: *Yuzhmorgeologiya* CCAMLR-2000 Survey transects times. (See Table 4 for transect abbreviations).

Transect	Begin		End		Comments
	Date	Time	Date	Time	
SS02	16-Jan	0535	16-Jan	0809	
	16-Jan	1002	16-Jan	1417	
	16-Jan	1510	16-Jan	2323	
	17-Jan	0525	17-Jan	1243	
	17-Jan	1555	17-Jan	2046	
	18-Jan	0502	18-Jan	1420	
	18-Jan	1635	19-Jan	0019	
	19-Jan	0502	19-Jan	1420	
	19-Jan	1754	19-Jan	2042	
					Transit to SS05
SS05	20-Jan	1148	20-Jan	1442	
	20-Jan	1632	21-Jan	0035	
	21-Jan	0522	21-Jan	1148	
	21-Jan	1358	22-Jan	0003	
	22-Jan	0528	22-Jan	1445	
	22-Jan	1907	22-Jan	2352	
	23-Jan	0537	23-Jan	1438	
	23-Jan	1546	23-Jan	2335	
					Transit to SS08
SS08	25-Jan	1721	26-Jan	0013	
	26-Jan	0609	26-Jan	1324	
	26-Jan	1549	26-Jan	2139	
	27-Jan	0551	27-Jan	1520	
	28-Jan	0520	28-Jan	1503	
					Transit to AP11
AP11	31-Jan	0056	1-Feb	0052	
					Transit to AP14
AP14	1-Feb	2008	2-Feb	0134	
	2-Feb	0638	2-Feb	1610	
					Transit to AP17
AP17	3-Feb	0837	4-Feb	0208	
	4-Feb	0730	4-Feb	1642	
	4-Feb	1850	4-Feb	2019	

Table 19: *Yuzhmorgeologiya* CCAMLR-2000 Survey mesoscale transects. (See Table 4 for transect abbreviations).

Transect	Begin		End		Comments
	Date	Time	Date	Time	
SG04	13-Jan	1052	13-Jan	1437	
	13-Jan	1910	13-Jan	1936	
					Transit to SG03
SG03	13-Jan	2238	13-Jan	2339	
	14-Jan	0651	14-Jan	1105	
					Transit to SG02
SG02	14-Jan	1726	14-Jan	2255	
					Transit to SG01
SG01	15-Jan	0542	15-Jan	1044	
					Transit to SOI01
SOI01	29-Jan	0812	29-Jan	1315	
					Transit to SOI02
SOI02	29-Jan	1841	29-Jan	2255	
					Transit to SOI03
SOI03	30-Jan	0549	30-Jan	0957	
					Transit to SOI04
SOI04	30-Jan	1504	30-Jan	1830	

Table 20: Steps implemented in Echoview 2.00. Raw variables: Q1 – 38 kHz raw data; Q2 – 120 kHz raw data; Q3 – 200 kHz raw data.

Steps	Virtual Variables				
	Name	Operator	Operand1	Operand2	Other Settings Required
Define inclusions	Surf-bott	Line bitmap	Q1		Surface exclusion to integration stop line
	Good data	Region bitmap	Q1		Bad data regions, INVERT output
	Include	AND	Surf-bott	Good data	
Mask echograms	38-E	Mask	Q1	Include	DO check zero is no data
	120-E	Mask	Q2	Include	DO check zero is no data
	200-E	Mask	Q3	Include	DO check zero is no data
Resample masked echograms	38-S	Resample by time	38-E		100 seconds, 0–500 m, 100 samples
	120-S	Resample by time	120-E		100 seconds, 0–500 m, 100 samples
	200-S	Resample by time	200-E		100 seconds, 0–500 m, 100 samples
Generate noise	Noise 38	Data generator	38-S		Use noise(s_v)1 m from table; set α = 0.010
	Noise 120	Data generator	120-S		Use noise(s_v)1 m from table; set α = 0.028
	Noise 200	Data generator	200-S		Use noise(s_v)1 m from table; set α = 0.041
Subtract noise from resampled echograms	38-S-C	Linear minus	38-S	Noise 38	
	120-S-C	Linear minus	120-S	Noise 120	
	200-S-C	Linear minus	200-S	Noise 200	
Subtract (120-38)	Dif-S 120-38	Minus	120-S-C	38-S-C	Set display min s_v to 0
Define dB range	Range Dif-S	Range	Dif-S 120-38		Range 2–16
Mask resampled noise-free echograms	Mask 38-S-C	Mask	38-S-C	Range Dif-S	Do NOT check zero is no data, add grid
	Mask 120-S-C	Mask	120-S-C	Range Dif-S	Do NOT check zero is no data, add grid
	Mask 200-S-C	Mask	200-S-C	Range Dif-S	Do NOT check zero is no data, add grid
					Process tab: exclude above = surface exclusion; exclude below = integration stop.

Table 21: Conversion factor, integrated volume backscattering (S_A, m^2/n miles^2) to areal krill biomass density (g/m^2).

	Cluster 1	Cluster 2	Cluster 3	Clusters 2+3	Clusters 1+2+3
120 kHZ					
FIBEX 1	0.1481	0.1523	0.1536	0.1526	0.1508
FIBEX 2	0.1656	0.1583	0.1557	0.1576	0.1609
CCAMLR-2000	0.1636	0.1517	0.1477	0.1506	0.1560
Morris et al. (1988)	0.1931	0.1703	0.1630	0.1684	0.1785
Siegel (1992)	0.1556	0.1449	0.1414	0.1440	0.1487
38 kHz					
FIBEX 1	0.4672	0.4805	0.4847	0.4815	0.4757
FIBEX 2	0.5224	0.4993	0.4913	0.4971	0.5075
CCAMLR-2000	0.5163	0.4786	0.4661	0.4753	0.4921
Morris et al. (1988)	0.6092	0.5372	0.5142	0.5311	0.5630
Siegel (1992)	0.4909	0.4573	0.4461	0.4543	0.4693
200 kHz					
FIBEX 1	0.0888	0.0914	0.0921	0.0915	0.0904
FIBEX 2	0.0993	0.0949	0.0934	0.0945	0.0964
CCAMLR-2000	0.0982	0.0910	0.0886	0.0904	0.0936
Morris et al. (1988)	0.1158	0.1021	0.0977	0.1010	0.1070
Siegel (1992)	0.0933	0.0869	0.0848	0.0864	0.0892

Table 22: Expected change in latitude (Δlat) per nautical mile of transect. (See Table 4 for transect abbreviations).

Transect	Δlat	Transect	Δlat	Transect	Δlat
SS01	0.01649	SSI01	0.01496	Sand01	0.01635
SS02	0.01657	SSI02	0.01507	Sand02	0.01632
SS03	0.01662	SSI03	0.01519	Sand03	0.01630
SS04	0.01665	SSI04	0.01532	Sand04	0.01629
SS05	0.01666	SSI05	0.01539	Sand05	0.01628
SS06	0.01667	SSI06	0.01554	Sand06	0.01639
SS07	0.01665	SSI07	0.01559	Sand07	0.01637
SS08	0.01662	SSI08	0.01574	Sand08	0.01637
SS09	0.01656	S0I1	0.01665	Sand09	0.01635
SS10	0.01650	S0I2	0.01664	Sand10	0.01632
SSa	0.01625	S0I3	0.01662		
SSb	0.01635	S0I4	0.01660		
SSc	0.01643	SG01	0.01662		
AP11	0.01451	SG02	0.01663		
AP12	0.01463	SG03	0.01665		
AP13	0.01487	SG04	0.01666		
AP14	0.01521				
AP15	0.01546				
AP16	0.01561				
AP17	0.01590				
AP18	0.01599				
AP19	0.01613				

Table 23: Planned transect length (km) sampled within each subarea.

Subarea	Large-scale	Mesoscale	Total	% in each Subarea
48.1	3 818	800	4 618	25.6
48.2	4 413	400	4 813	26.6
48.3	4 219	400	4 619	25.6
48.4	2 993	1 000	3 993	22.1

Table 24a: Mean krill density and associated variance by transect and stratum estimated from acoustic data collected at 38 kHz. (See Table 4 for transect abbreviations and Attachment D for description of calculations).

Transect						Stratum Krill Density		
Name	Length (n miles)	Weighting Factor	Krill Density: Measured (g/m²)	Krill Density: Weighted (g/m²)	Variance Component	Mean (g/m²)	Variance	CV (%)
AP11	95.99	0.67	5.02	3.36	13.10	10.42	6.46	24.38
AP12	194.66	1.36	18.18	24.70	111.15			
AP13	133.00	0.93	10.30	9.56	0.01			
AP14	76.59	0.53	13.77	7.36	3.20			
AP15	108.14	0.75	25.29	19.09	125.96			
AP16	90.29	0.63	13.41	8.45	3.55			
AP17	156.60	1.09	8.77	9.59	3.26			
AP18	228.75	1.60	5.33	8.51	66.08			
AP19	205.40	1.43	2.22	3.18	138.48			
SS01	431.22	1.23	9.29	11.46	42.77	14.60	2.68	11.21
SS02	416.33	1.19	15.16	18.06	0.46			
SS03	364.24	1.04	14.33	14.92	0.08			
SS04	312.13	0.89	18.44	16.46	11.78			
SS05	397.78	1.14	14.07	16.00	0.36			
SS06	402.61	1.15	11.25	12.95	14.87			
SS07	379.43	1.09	25.92	28.13	150.99			
SS08	271.53	0.78	15.85	12.31	0.94			
SS09	346.36	0.99	11.19	11.09	11.37			
SS10	175.13	0.50	9.18	4.60	7.36			
SSa	327.02	1.07	5.66	6.06	7.95	8.29	13.38	44.13
SSb	199.88	0.66	1.51	0.99	19.70			
SSc	388.56	1.27	13.99	17.81	52.67			
SSI01	37.87	1.09	58.10	63.39	15.53	54.49	105.20	18.82
SSI02	35.11	1.01	28.57	28.90	687.32			
SSI03	38.34	1.10	78.25	86.44	688.95			
SSI04	28.67	0.83	45.71	37.75	52.63			
SSI05	31.56	0.91	30.65	27.86	469.78			
SSI06	32.88	0.95	42.78	40.52	122.99			
SSI07	35.14	1.01	111.84	113.21	3 369.89			
SSI08	38.13	1.10	34.46	37.85	484.16			
SOI01	38.71	1.22	6.52	7.98	7 222.60	75.93	1678.90	53.96
SOI02	32.65	1.03	100.27	103.54	631.75			
SOI03	29.61	0.94	185.27	173.50	10 483.16			
SOI04	25.51	0.81	23.20	18.71	1 809.31			
SG01	38.47	1.03	17.68	18.23	53.02	10.62	9.78	29.45
SG02	39.48	1.06	3.38	3.57	58.60			
SG03	39.07	1.05	12.40	12.98	3.48			
SG04	32.26	0.86	8.89	7.69	2.22			
Sand01	42.27	1.13	23.32	26.32	125.01	13.41	4.49	15.79
Sand02	38.89	1.04	16.77	17.41	12.15			
Sand03	38.35	1.02	15.56	15.94	4.85			
Sand04	36.60	0.98	11.10	10.84	5.13			
Sand05	39.33	1.05	7.13	7.49	43.55			
Sand06	36.28	0.97	21.71	21.03	64.64			
Sand07	27.21	0.73	15.12	10.99	1.54			
Sand08	37.09	0.99	5.06	5.01	68.41			
Sand09	39.57	1.06	5.02	5.30	78.64			
Sand10	38.96	1.04	13.27	13.80	0.02			

Table 24b: Mean krill density and standing stock, and associated variances, by stratum and for the entire survey, estimated from acoustic data collected at 38 kHz. (See Table 4 for transect abbreviations and Attachment D for description of calculations).

Stratum	Nominal Area (km^2)	Mean Density (g/m^2)	Area*Density (million tonnes)	Variance Component
AP (11–19)	473 318	10.42	4 933 506.55	1 446 231 977 393.93
SS (01–10)	1 109 789	14.60	16 199 493.48	3 297 868 733 235.00
SS (a–c)	321 800	8.29	2 667 686.01	1 386 065 333 392.42
SSI (01–08)	48 654	54.49	2 651 158.06	249 033 424 971.57
SOI (01–04)	24 409	75.93	1 853 439.54	1 000 288 115 684.75
SG (01–04)	25 000	10.62	265 399.27	6 110 386 467.47
Sand (01–10)	62 274	13.41	835 277.60	17 405 436 721.73
Total	206 5244		29 405 960.52	7 403 003 407 866.88
Survey				
Mean density	14.24	g/m^2		
Variance	1.74	$(g/m^2)^2$		
CV	9.25	%		
Krill standing stock	29.41	million tonnes		
Variance	7 403 003.41	million $tonnes^2$		
CV	9.25	%		

Table 25a: Mean krill density and associated variance by transect and stratum estimated from acoustic data collected at 120 kHz. (See Table 4 for transect abbreviations and Attachment D for description of calculations).

Transect						Stratum Krill Density		
Name	Length (n miles)	Weighting Factor	Krill Density Measured (g/m^2)	Krill Density Weighted (g/m^2)	Variance Component	Mean (g/m^2)	Variance	CV (%)
AP11	95.99	0.67	12.83	8.59	1.13	11.24	4.70	19.29
AP12	194.66	1.36	15.58	21.17	34.79			
AP13	133.00	0.93	11.79	10.94	0.26			
AP14	76.59	0.53	18.06	9.65	13.29			
AP15	108.14	0.75	22.88	17.27	77.18			
AP16	90.29	0.63	13.22	8.33	1.56			
AP17	156.60	1.09	10.57	11.55	0.54			
AP18	228.75	1.60	5.30	8.46	89.92			
AP19	205.40	1.43	3.61	5.18	119.59			
SS01	431.22	1.23	20.38	25.14	26.28	24.54	14.07	15.28
SS02	416.33	1.19	47.53	56.60	749.40			
SS03	364.24	1.04	26.11	27.19	2.66			
SS04	312.13	0.89	30.94	27.62	32.67			
SS05	397.78	1.14	25.49	29.00	1.17			
SS06	402.48	1.15	13.93	16.03	149.20			
SS07	379.43	1.09	30.16	32.73	37.17			
SS08	271.53	0.78	21.40	16.62	5.96			
SS09	346.36	0.99	10.43	10.33	195.34			
SS10	175.13	0.50	8.29	4.15	66.27			
SSa	326.60	1.07	8.18	8.75	11.29	11.32	23.10	42.46
SSb	199.88	0.65	1.97	1.29	37.44			
SSc	389.24	1.28	18.75	23.91	89.85			
SSI01	37.87	1.09	17.73	19.35	476.09	37.73	97.94	26.23
SSI02	35.11	1.01	27.65	27.96	103.96			
SSI03	38.34	1.10	61.30	67.71	677.62			
SSI04	28.67	0.83	14.48	11.96	368.57			
SSI05	31.56	0.91	25.83	23.48	117.00			
SSI06	32.88	0.95	29.89	28.32	55.08			
SSI07	35.14	1.01	95.76	96.94	3 451.40			
SSI08	38.13	1.10	23.78	26.12	234.93			
SOI01	38.71	1.22	12.20	14.93	28 615.52	150.37	6966.86	55.51
SOI02	32.65	1.03	221.61	228.84	5 412.21			
SOI03	29.61	0.94	361.59	338.62	39 127.21			
SOI04	25.51	0.81	23.65	19.08	10 447.39			
SG01	38.47	1.03	70.75	72.94	1 051.46	39.30	146.24	30.77
SG02	39.48	1.06	17.34	18.34	539.47			
SG03	39.07	1.05	42.35	44.34	10.24			
SG04	32.26	0.86	24.95	21.57	153.74			
Sand01	42.27	1.13	27.69	31.25	4.77	25.76	46.15	26.37
Sand02	38.89	1.04	20.88	21.69	25.60			
Sand03	38.35	1.02	20.89	21.39	24.83			
Sand04	36.60	0.98	22.11	21.60	12.72			
Sand05	39.33	1.05	18.09	19.00	64.81			
Sand06	36.28	0.97	85.63	82.94	3 363.21			
Sand07	27.21	0.73	28.11	20.42	2.93			
Sand08	37.09	0.99	10.47	10.37	229.21			
Sand09	39.57	1.06	6.86	7.24	398.80			
Sand10	38.96	1.04	20.83	21.67	26.23			

Table 25b: Mean krill density and standing stock, and associated variances, by stratum and for the entire survey, estimated from acoustic data collected at 120 kHz. (See Table 4 for transect abbreviations and Attachment D for description of calculations).

Stratum	Nominal Area (km^2)	Mean Density (g/m^2)	Area*Density (million tonnes)	Variance Component
AP (11–19)	473 318	11.24	5 319 647.98	1 052 496 388 913.78
SS (01–10)	1 109 789	24.54	27 234 964.55	17 326 537 058 061.60
SS (a–c)	321 800	11.32	3 642 035.01	2 391 655 734 991.07
SSI (01–08)	48 654	37.73	1 835 720.49	231 845 632 004.71
SOI (01–04)	24 409	150.37	3 670 294.56	4 150 849 848 119.59
SG (01–04)	25 000	39.30	982 423.23	91 401 915 350.65
Sand (01–10)	62 274	25.76	1 603 985.17	178 954 989 453.98
Total	2 065 244		44 289 070.99	25 423 741 566 895.40

Survey		
Mean density	21.44	g/m^2
Variance	5.96	$(g/m^2)^2$
CV	11.38	%
Krill standing stock	44.29	million tonnes
Variance	25 423 741.57	million $tonnes^2$
CV	11.38	%

Table 26a: Mean krill density and associated variance by transect and stratum estimated from acoustic data collected at 200 kHz. (See Table 4 for transect abbreviations and Attachment D for description of calculations).

Transect						Stratum Krill Density		
Name	Length (n miles)	Weighting Factor	Krill Density Measured (g/m^2)	Krill Density Weighted (g/m^2)	Variance Component	Mean (g/m^2)	Variance	CV (%)
AP11	95.99	0.67	19.81	13.27	67.62	7.54	3.03	23.09
AP12	194.66	1.36	10.18	13.83	12.88			
AP13	133.00	0.93	7.15	6.63	0.13			
AP14	76.59	0.53	12.56	6.71	7.20			
AP15	108.14	0.75	12.01	9.07	11.42			
AP16	90.29	0.63	7.87	4.96	0.04			
AP17	156.60	1.09	4.83	5.28	8.77			
AP18	228.75	1.60	3.38	5.40	43.97			
AP19	205.40	1.43	1.87	2.68	66.03			
SS01	431.22	1.23	26.39	32.54	46.99	20.83	22.83	22.94
SS02	416.33	1.19	52.90	62.98	1 457.89			
SS03	364.24	1.04	15.56	16.21	30.11			
SS04	312.13	0.89	26.90	24.02	29.43			
SS05	397.78	1.14	18.49	21.04	7.04			
SS06	402.61	1.15	8.05	9.27	216.26			
SS07	379.43	1.09	18.65	20.23	5.59			
SS08	271.53	0.78	14.85	11.53	21.57			
SS09	346.36	0.99	6.68	6.62	196.38			
SS10	175.13	0.50	7.66	3.84	43.46			
SSa	327.04	1.07	23.00	24.65	112.13	32.88	182.73	41.11
SSb	199.88	0.65	8.08	5.29	264.00			
SSc	388.56	1.27	53.96	68.71	720.24			
SSI01	37.87	1.09	24.11	26.31	0.10	23.82	16.84	17.23
SSI02	35.11	1.01	13.91	14.07	100.53			
SSI03	38.34	1.10	32.50	35.90	91.92			
SSI04	28.67	0.83	26.64	22.00	5.42			
SSI05	31.56	0.91	14.51	13.19	71.76			
SSI06	32.88	0.95	18.76	17.77	23.04			
SSI07	35.14	1.01	46.24	46.81	515.18			
SSI08	38.13	1.10	13.24	14.54	135.24			
SOI01	38.71	1.22	10.23	12.52	11 072.17	96.17	2612.93	53.15
SOI02	32.65	1.03	154.86	159.91	3 672.22			
SOI03	29.61	0.94	214.35	200.73	12 248.51			
SOI04	25.51	0.81	14.29	11.53	4 362.27			
SG01	38.47	1.03	94.32	97.25	2 694.41	43.98	307.82	39.90
SG02	39.48	1.06	22.44	23.74	518.79			
SG03	39.07	1.05	35.13	36.78	85.76			
SG04	32.26	0.86	20.99	18.14	394.82			
Sand01	42.27	1.15	51.73	59.49	25.54	47.34	105.62	21.71
Sand02	38.89	1.06	39.51	41.81	68.58			
Sand03	38.35	1.04	52.34	54.61	27.22			
Sand04	36.60	1.00	2.17	2.16	2 022.03			
Sand05	32.33	0.88	60.97	53.62	143.73			
Sand06	36.28	0.99	65.19	64.35	310.63			
Sand07	27.21	0.74	136.64	101.15	4 370.60			
Sand08	37.09	1.01	61.26	61.82	197.45			
Sand09	39.57	1.08	23.18	24.96	676.45			
Sand10	38.96	1.06	8.85	9.38	1 663.85			

Table 26b: Mean krill density and standing stock, and associated variances, by stratum and for the entire survey, estimated from acoustic data collected at 200 kHz. (See Table 4 for transect abbreviations and Attachment D for description of calculations).

Stratum	Nominal Area (km^2)	Mean Density (g/m^2)	Area*Density (million tonnes)	Variance Component
AP (11–19)	473 318	7.54	3 567 466.33	678 506 608 166.80
SS (01–10)	1 109 789	20.83	23 113 322.60	28 118 640 024 444.60
SS (a–c)	321 800	32.88	10 581 899.97	18 922 484 846 099.70
SSI (01–08)	48 654	23.82	1 159 090.11	39 869 126 927.20
SOI (01–04)	24 409	96.17	2 347 454.90	1 556 782 525 132.16
SG (01–04)	25 000	43.98	1 099 399.53	192 384 609 178.69
Sand (01–10)	62 274	47.34	2 947 763.77	409 612 070 977.53
Total	2 065 244		44 816 397.21	49 918 279 810 926.70
Survey				
Mean density	21.70	g/m^2		
Variance	11.70	$(g/m^2)^2$		
CV	15.76	%		
Krill standing stock	44.82	million tonnes		
Variance	49 918 279.81	million $tonnes^2$		
CV	15.76	%		

Table 27: Results of a single-factor ANOVA testing for differences in krill densities (g/m^2 at 120 kHz) measured by the *James Clark Ross*, *Kaiyo Maru* and *Yuzhmorgeologiya* running interleaved transects in the Scotia Sea (SS) and Antarctic Peninsula (AP) regions. Minor changes to transect means resulting from error checking (paragraph 4.3) are not included. The inclusion of these changes is not expected to alter the conclusions drawn from this table.

Krill density (g/m^2)						
Ship/transect means	SS01,02,03	SS04,05,06	SS07,08,09	AP13,12,11	AP16,15,14	AP19,18,17
James Clark Ross	20.38	30.94	30.16	11.74	13.22	3.61
Kaiyo Maru	26.11	13.93	10.43	15.58	22.88	5.30
Yuhzmorgeologiya	47.53	25.49	21.40	12.83	18.06	10.57
Summary						
Groups	Count	Sum	Average	Variance		
James Clark Ross	6	110.05	18.34	117.90		
Kaiyo Maru	6	94.22	15.70	59.77		
Yuhzmorgeologiya	6	135.87	22.65	178.46		
ANOVA						
Source of variation	SS	df	MS	F	P-value	F crit
Between groups	147.34	2	73.67	0.62	0.55	3.68
Within groups	1 780.66	15	118.71			
Total	1 927.99	17				

Table 28: Results of a single-factor ANOVA testing for differences in krill densities (g/m^2 at 120 kHz) measured by all four research vessels in the Scotia Sea (SS) and Antarctic Peninsula (AP) regions. Minor changes to transect means resulting from error checking (paragraph 4.3) are not included. The inclusion of these changes is not expected to alter the conclusions drawn from this table.

Krill density (g/m^2)							
Ship/transect means	SS01,02,03	SS04,05,06	SS07,08,09	AP13,12,11	AP16,15,14	AP19,18,17	SS10
James Clark Ross	20.38	30.94	30.16	11.74	13.22	3.61	7.39
Kaiyo Maru	26.11	13.93	10.43	15.58	22.88	5.30	
Yuhzmorgeologiya	47.53	25.49	21.40	12.83	18.06	10.57	
Atlantida	8.18	1.97	18.75				
Summary							
Groups	Count	Sum	Average	Variance			
James Clark Ross	7	117.45	16.78	115.38			
Kaiyo Maru	6	94.22	15.70	59.77			
Yuhzmorgeologiya	6	135.87	22.65	178.46			
Atlantida	3	28.90	9.63	71.96			
ANOVA							
Source of variation	SS	df	MS	F	P-value	F crit	
Between groups	364.17	3	121.39	1.08	0.38	3.16	
Within groups	2 027.34	18	112.63				
Total	2 391.51	21					

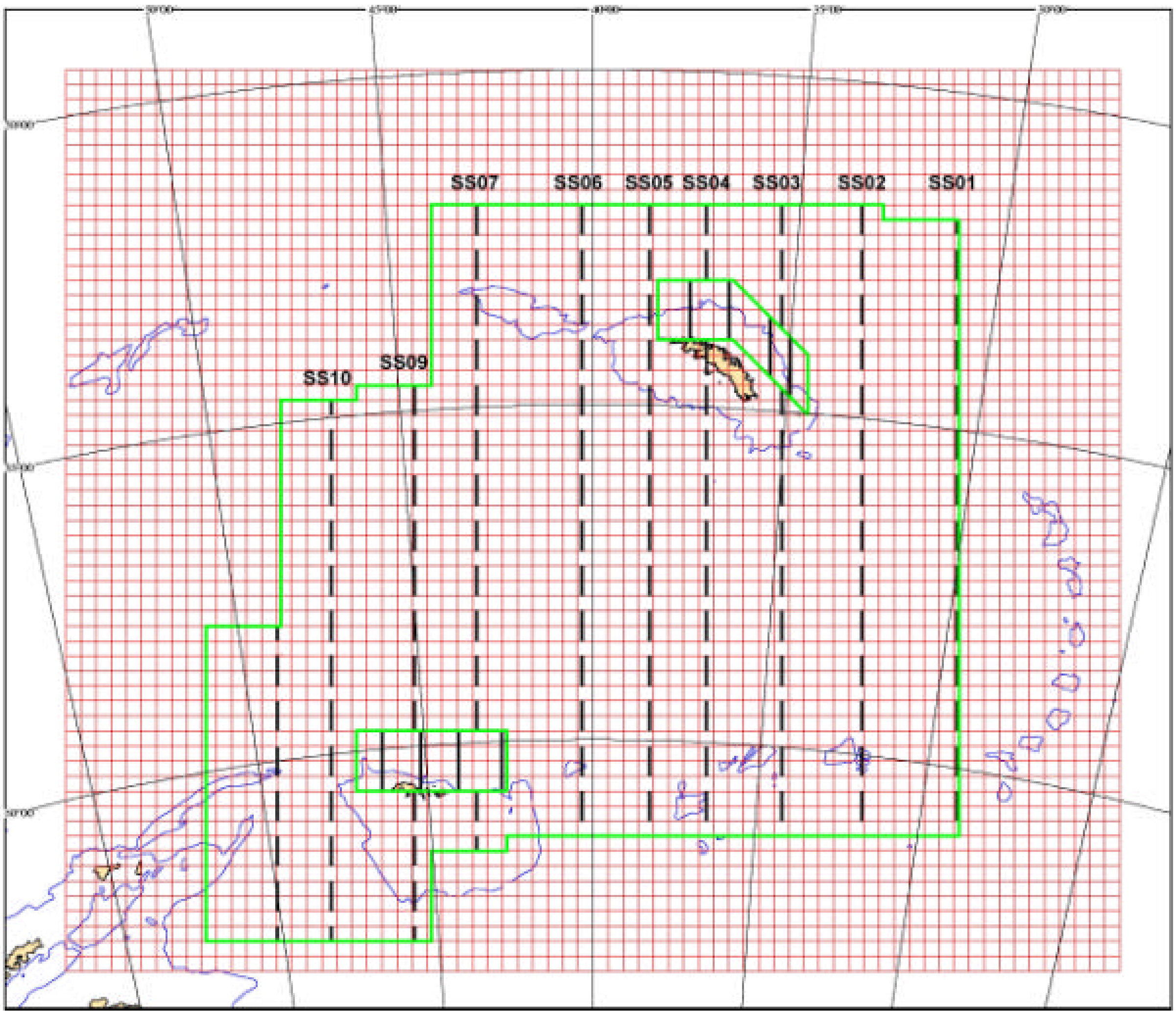

Figure 1a: CCAMLR-2000 Survey strata in the Scotia Sea. The large-scale stratum extends across the region, and two mesoscale survey boxes were located adjacent to South Georgia and the South Orkney Islands. Large-scale transects (SS01-SS10, dashed lines) and mesoscale transects (SG01-SG04 and SOI01-SOI04, solid lines) are shown. The grid squares are 25 x 25 km.

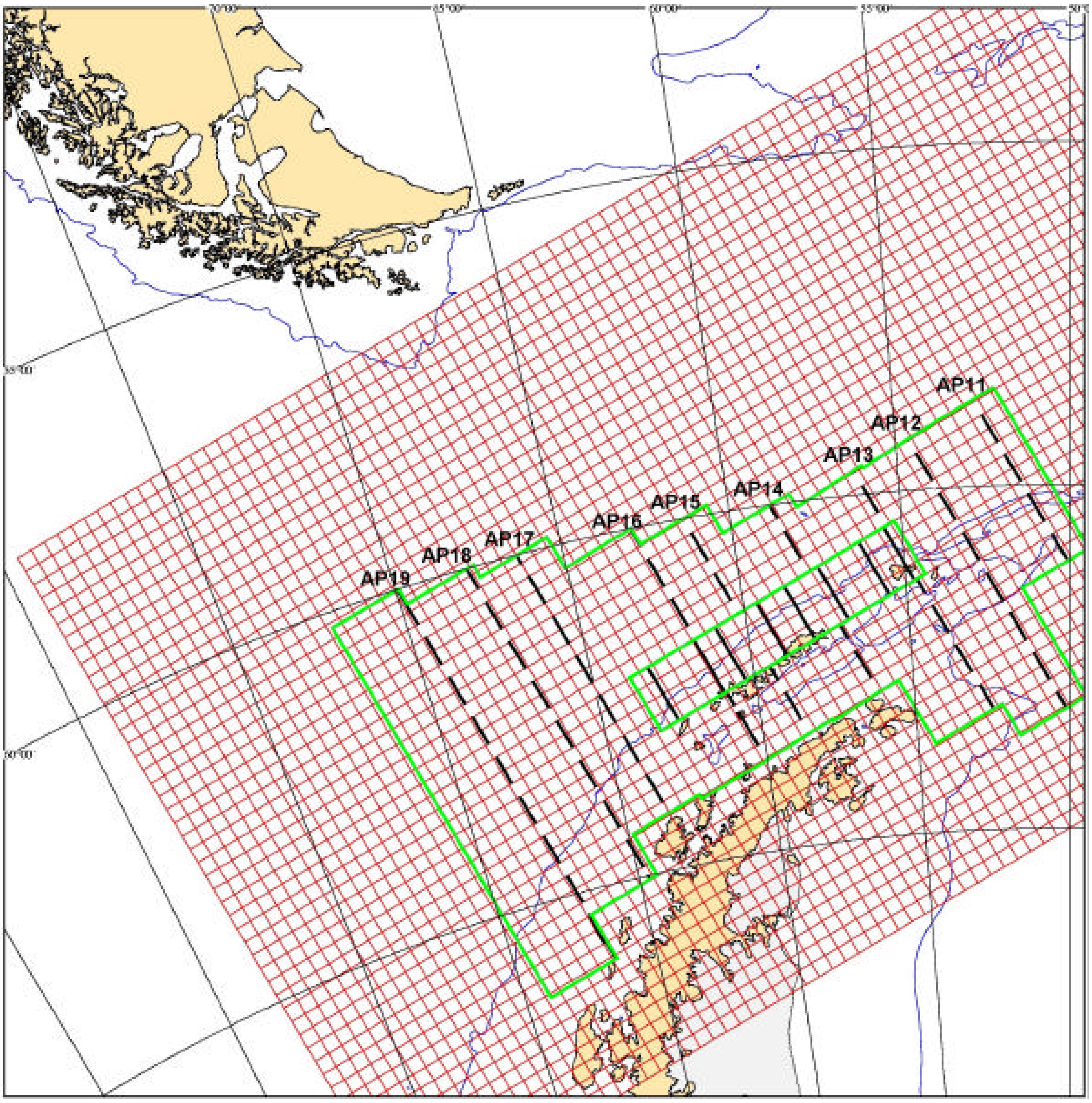

Figure 1b: CCAMLR-2000 Survey strata in the Antarctic Peninsula region. The large-scale stratum extends across the region, and the mesoscale survey box was located adjacent to the South Shetland Islands. Large-scale transects (AP11-AP19, dashed lines) and mesoscale transects (SSI01-08, solid lines) are shown. The grid squares are 25 x 25 km.

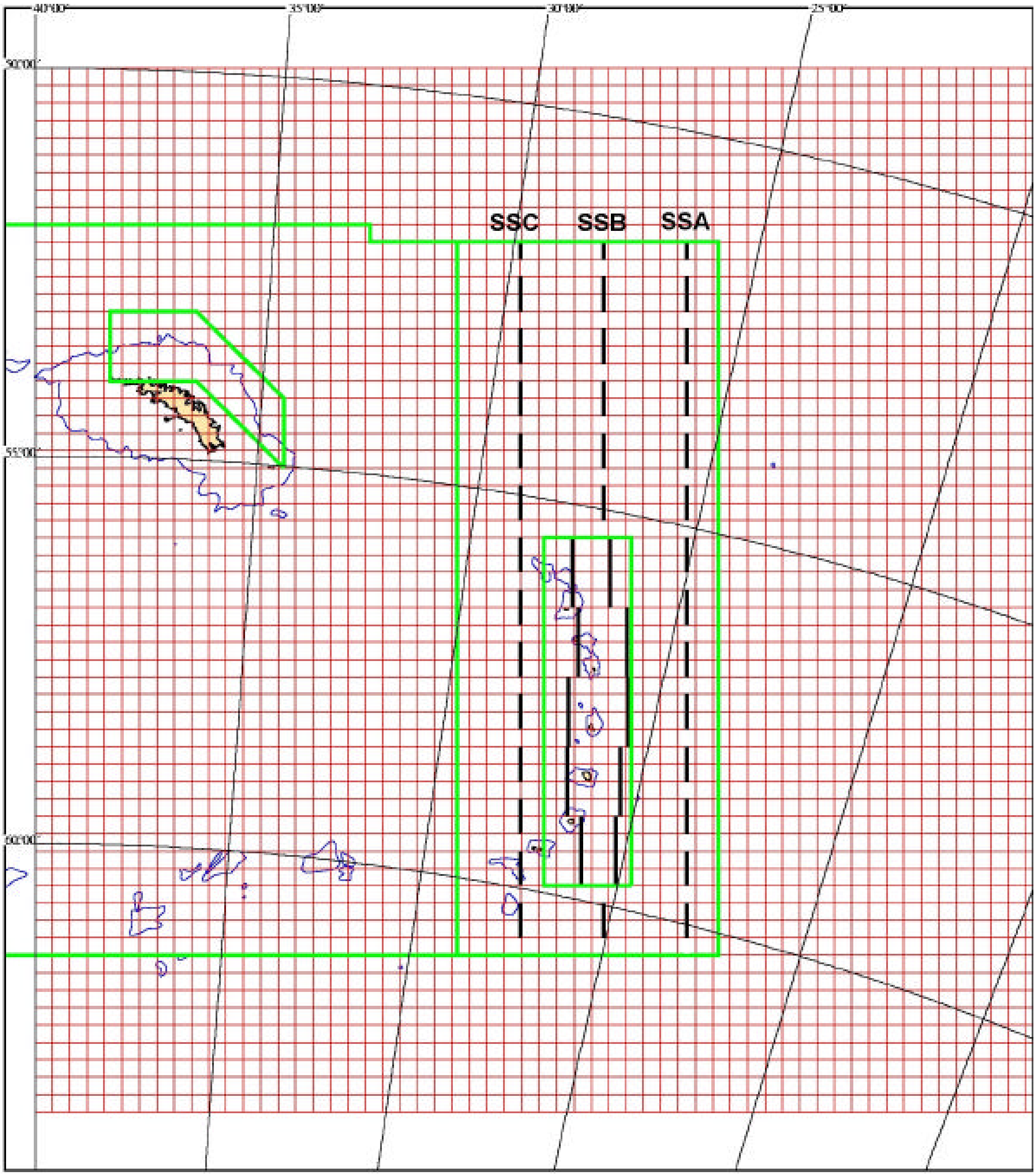

Figure 1c: CCAMLR-2000 Survey strata in the East Scotia Sea. The large-scale stratum extends across the region, and the mesoscale survey box was located adjacent to the South Sandwich Islands. Large-scale transects (SSA-SSC, dashed lines) and mesoscale transects (Sand01-10, solid lines) are shown. The grid squares are 25 x 25 km.

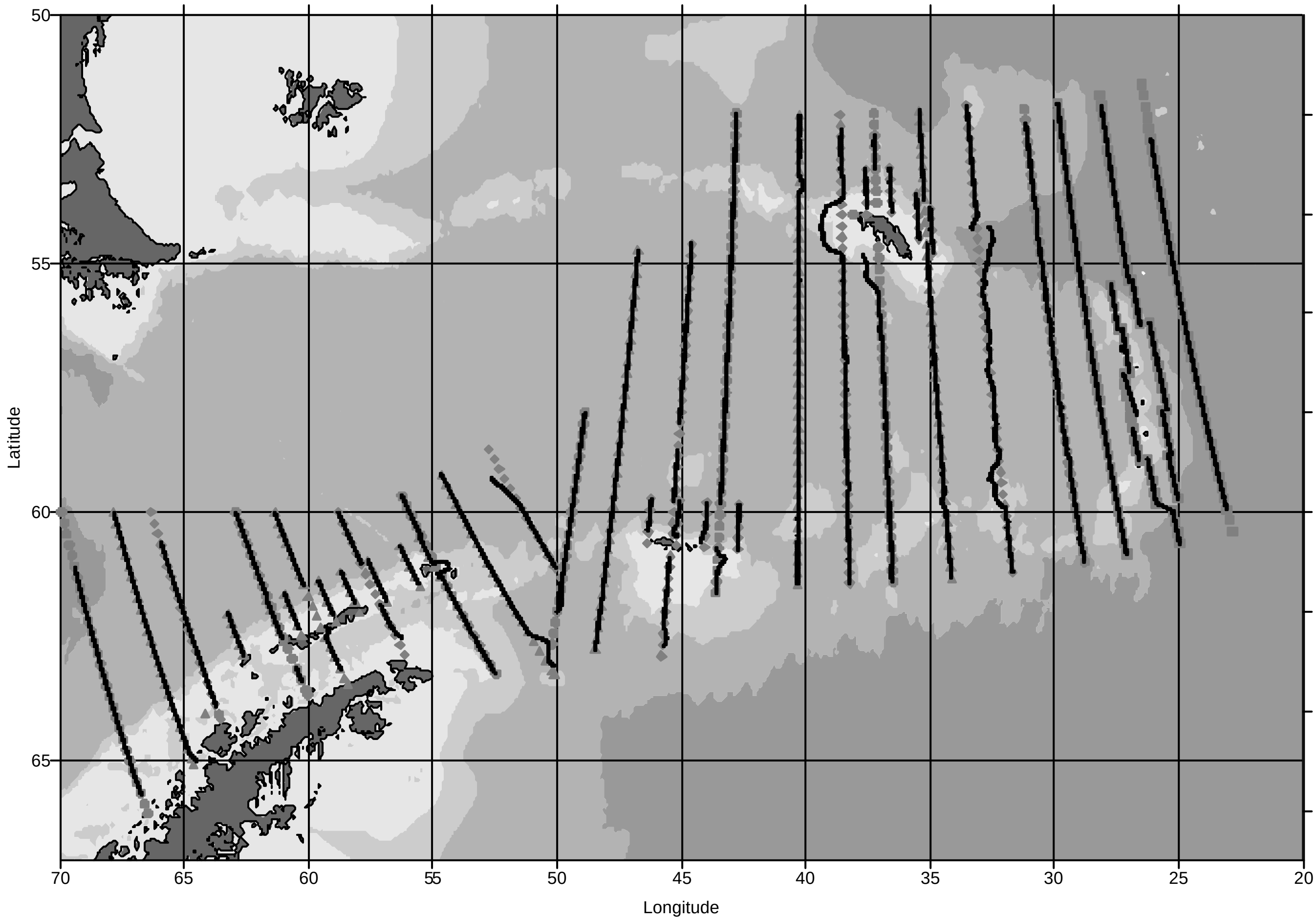

Figure 2: Planned way points for the *Atlantida* (¦), *Kaiyo Maru* (?), *James Clark Ross* (?) and *Yuzhmorgeologiya* (?) and actual transects (solid lines) conducted during the CCAMLR-2000 Survey.

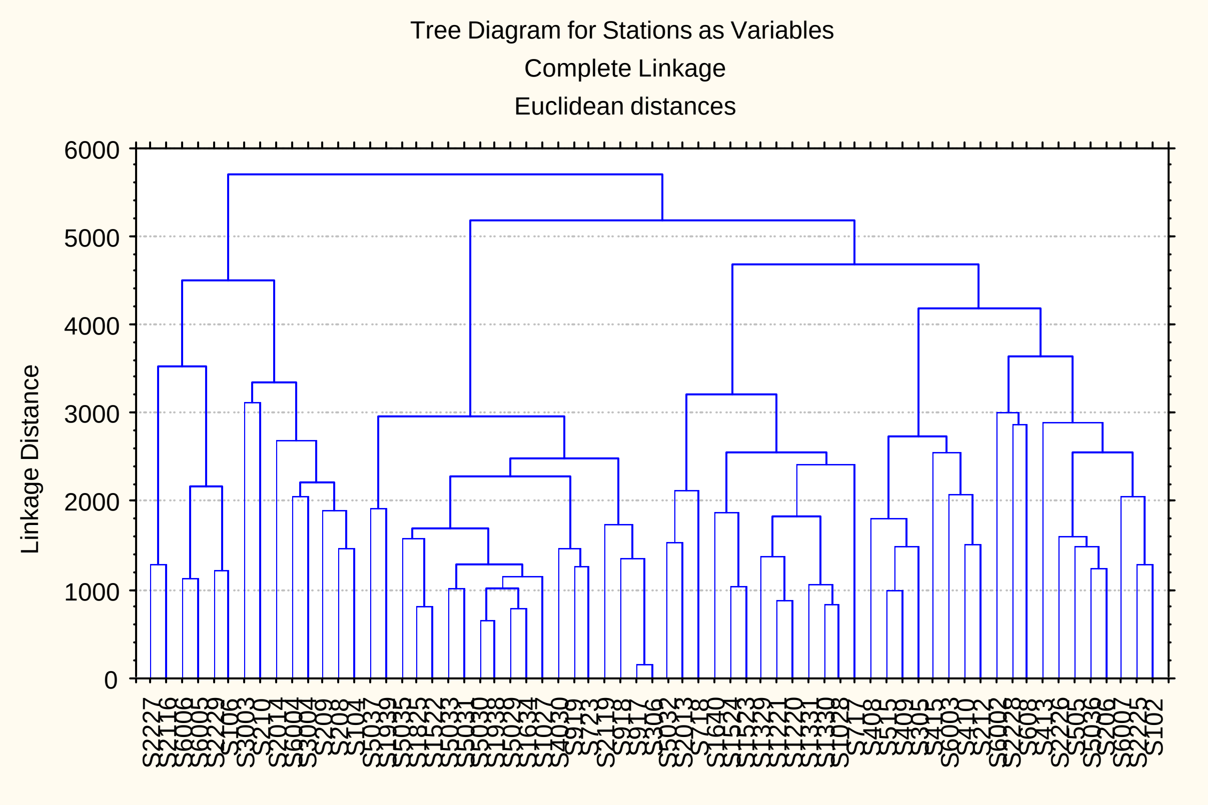

Figure 3: Dendrogram showing the clustering of length-frequency distributions of krill, from RMT8 samples, using the Complete Linkage Method.

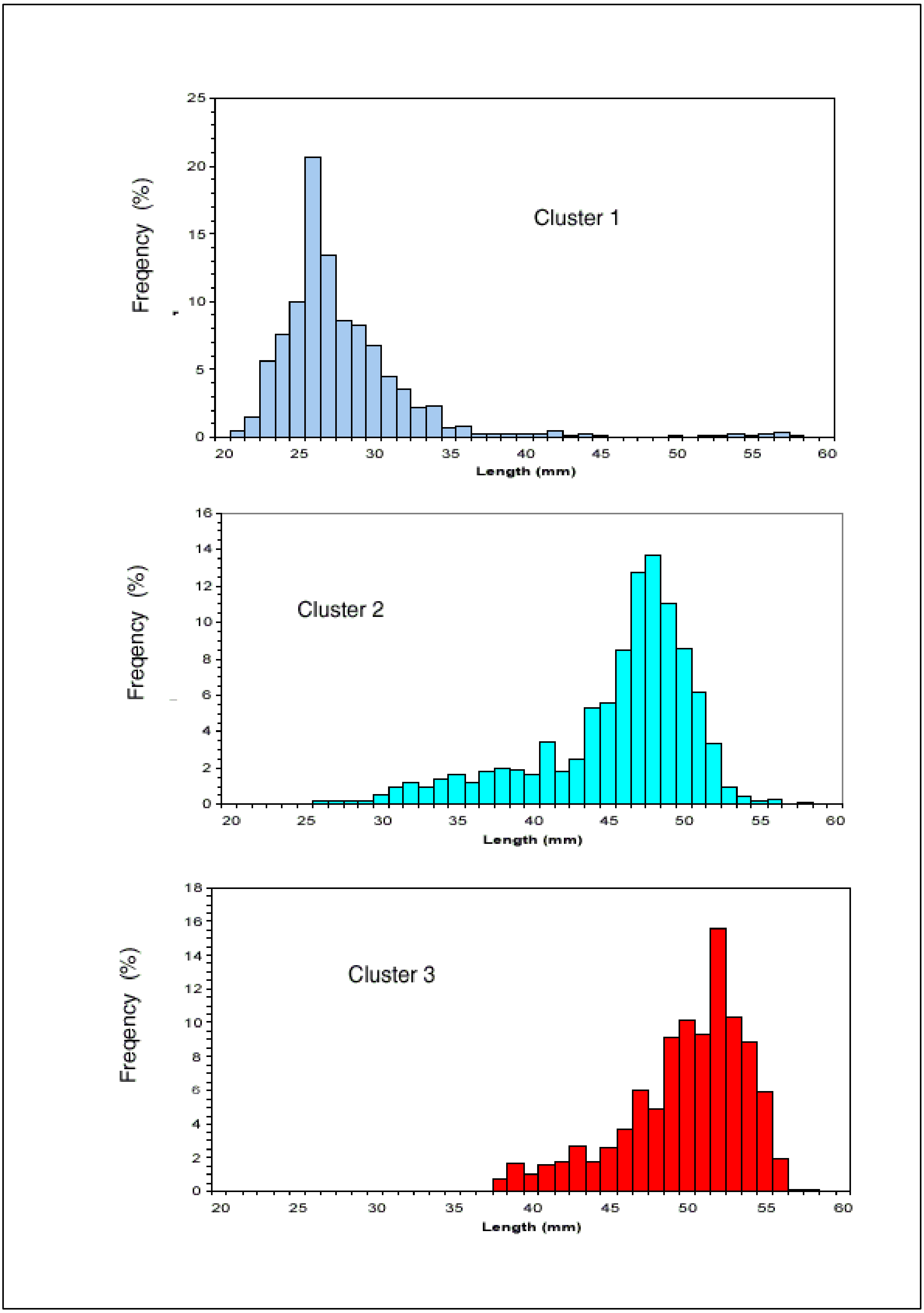

Figure 4: Aggregated length-frequency distributions of krill, from RMT8 samples, for the three clusters shown in Figure 3.

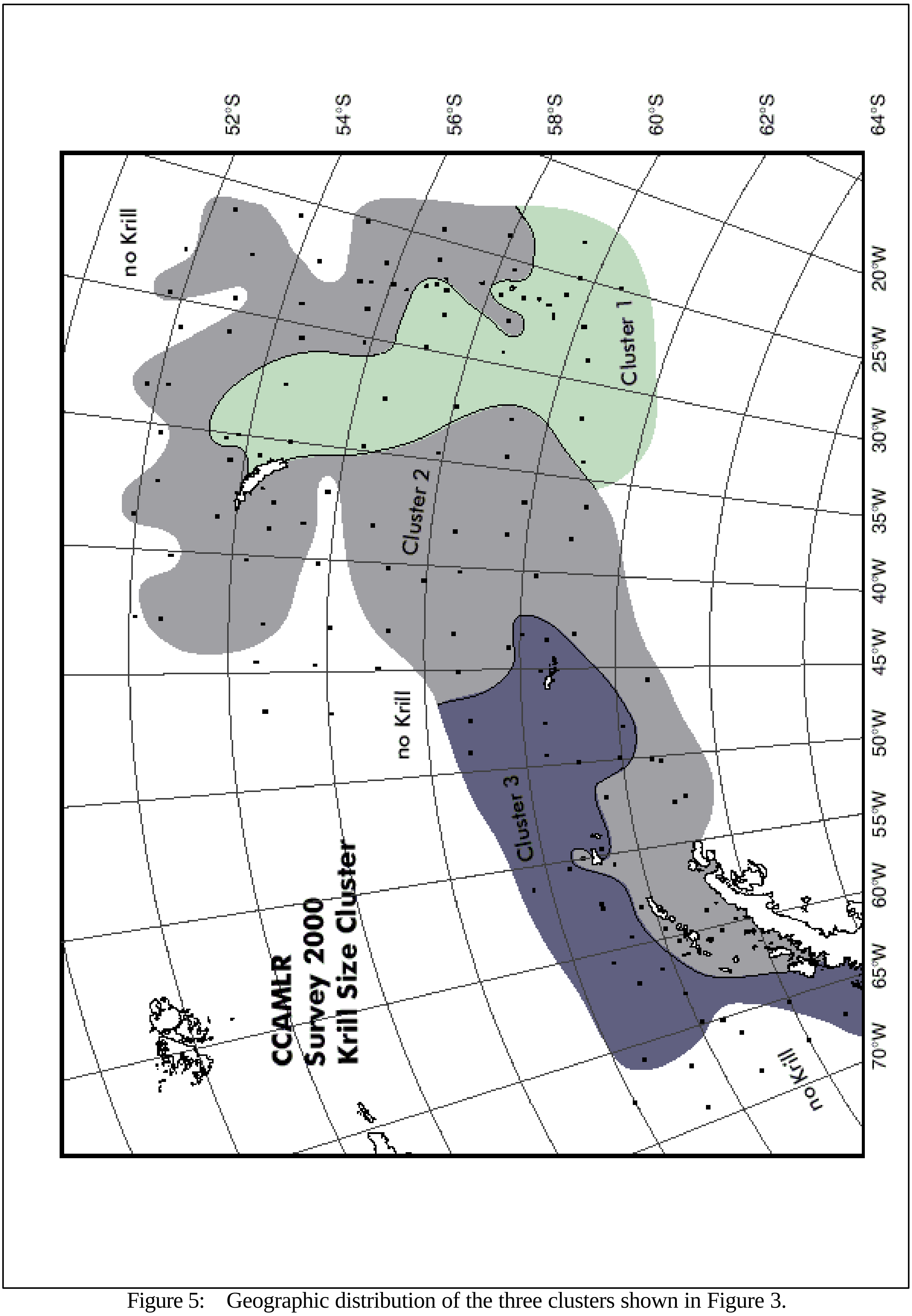

Figure 5: Geographic distribution of the three clusters shown in Figure 3.

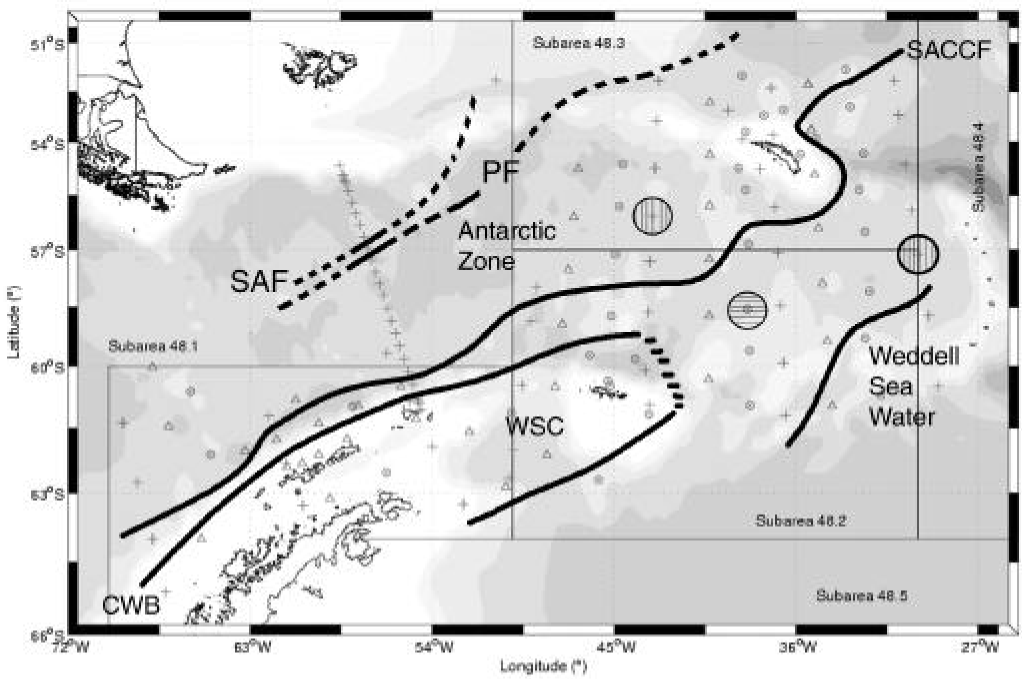

Figure 6: General distribution of water masses in the Scotia Sea and Antarctic Peninsula region during the CCAMLR-2000 Survey, based on CTD data collected by the *James Clark Ross* (+), *Yuzhmorgeologiya* (?) and *Kaiyo Maru* (?). Circles with vertical hatching represent eddies of warm water, horizontal hatched circles eddies of cold water. CWB: Continental Water Boundary; PF: Antarctic Polar Front; SACCF: Southern Antarctic Circumpolar Current Front; SAF: Sub-Antarctic Front; WSC: Weddell-Scotia Confluence.

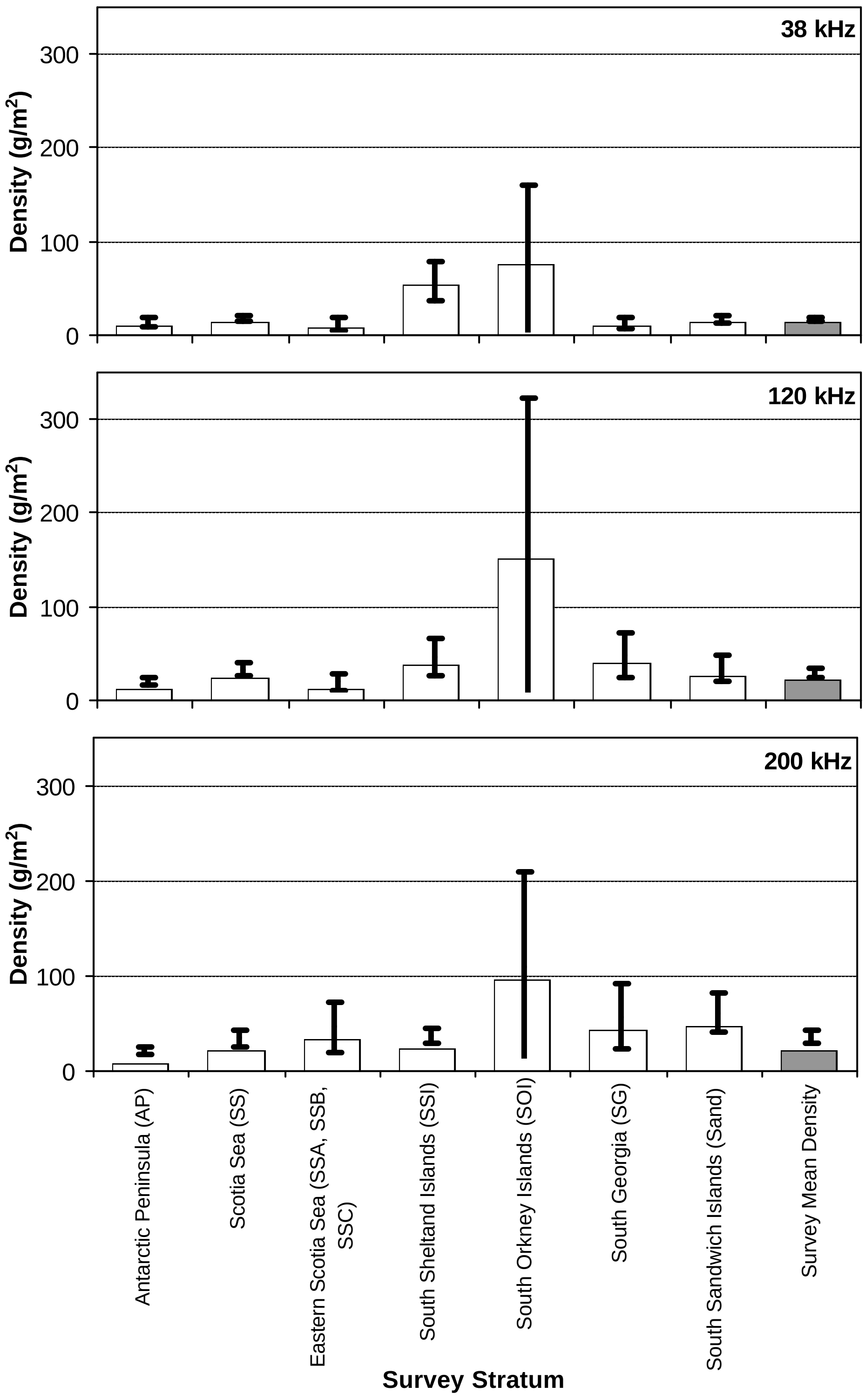

Figure 7: Mean krill density (g/m^2) by stratum, and for the entire survey area, estimated from acoustic data collected at 38, 120 and 200 kHz. Error bars represent the 95% confidence intervals.

ATTACHMENT A

LIST OF PARTICIPANTS

B_0 Workshop
(La Jolla, USA, 30 May to 9 June 2000)

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ATTACHMENT B

AGENDA

B_0 Workshop
(La Jolla, USA, 30 May to 9 June 2000)

1. Introduction (Day 1)

   1.1 Discussion of, and agreement to, the terms of reference, the specific tasks to be conducted, timetable, and output of workshop.
   1.2 Description of local facilities and infrastructure for accessing datasets and using analytical tools.
   1.3 Description of data preparations.

2. Abstracts of Survey Results (Day 1)

   2.1 Overviews of CCAMLR-2000 Survey by coordinators from Japan, UK, Russia and USA.
   2.2 Brief overviews of national surveys conducted in 1999/2000 over portions of the CCAMLR-2000 Survey area.
   2.3 Overviews of krill length frequency and water mass boundaries observed during CCAMLR-2000 Survey.

3. Methodology (Day 2)

   3.1 Presentation and discussion of methods for delineating krill volume backscattering from all other.
   3.2 Presentation and discussion of methods for converting krill volume backscattering to krill biomass density.
   3.3 Presentation and discussion of methods for estimating krill biomass over entire survey area.
   3.4 Presentation and discussion of methods for estimating variance of krill biomass estimate.
   3.5 Overview of Echoview 2.00.

4. Work Organisation (Day 2)

   4.1 List of specific tasks, designation of subgroups and assignment of responsibilities.
   4.2 Appointment of subgroup coordinators and rapporteurs.
   4.3 Outline format and content of report.
   4.4 Delegate work for writing sections and generating graphs.

5. Periodic Presentation and Discussion of Results from the Subgroups (Day 3 to Day 7).

6. Assemble Report (Day 8)

   6.1 Outline format and content of report.
   6.2 Delegate work for writing sections and generating graphs.
   6.3 Write report.

7. Adopt Report (Day 9).

CCAMLR B_0 ANALYSIS WORKSHOP SUBGROUP ON NET SAMPLING

Drs S. Kawaguchi (Japan), V. Siegel (Germany) and J. Watkins (UK) met to discuss the planned analysis of the RMT samples collected during the CCAMLR-2000 Survey.

2. Dr Watkins reported that all the RMT8+1 samples collected on board the *Yuzhmorgeologiya*, *James Clark Ross*, *Atlantida* and *Kaiyo Maru* had just returned to Cambridge, UK, on British Antarctic Survey ships. Basic sorting of RMT1 samples had been carried out on board the *Yuzhmorgeologiya*, but only sample volume had been determined on board the other ships. However, there had been no time to inspect the sample boxes prior to this workshop. Mr P. Ward (UK) will start the basic analysis of the unsorted RMT1 samples this summer and he estimates that this task will take around nine months. The data will then be made available to the CCAMLR participants, possibly through a future data analysis workshop.

3. It was re-emphasised that the zooplankton and krill samples collected during the CCAMLR-2000 Survey were extremely valuable, representing the largest single set of samples collected since the days of the Discovery Expeditions (1920–1930). It was therefore very important that the integrity of this dataset should be maintained while at the same time maximising the research that could be carried out on such samples.

4. It was recognised that the basic sorting of the RMT1 samples would separate the main species or groups of zooplankton but that there would be scope for more detailed analyses of individual taxa. Therefore it was likely that experts either within or outside the CCAMLR community will request access to the actual samples to undertake such work. For instance, interest in krill larvae (Dr Siegel) and salps (Dr Kawaguchi) had already been expressed. While such work should be welcomed it was important that this should take place within an agreed framework that protected the integrity of the samples and also the rights of the data originators. The latter was probably taken care of with the rules for access and use of CCAMLR data but the integrity of samples should be addressed through a set of 'conditions of access'.

5. A draft set of conditions of access was produced:

(i) Samples would only be released for further analysis if data originators from each country agreed.

(ii) Priority for analysis should be given to data originators, then other members of the CCAMLR community and finally requests originating outside of CCAMLR.

(iii) Persons requesting samples would have to guarantee return of entire samples to the archive within the agreed time.

(iv) All data from such analysis would have to be copied to the CCAMLR Data Centre and each data originator.

(v) All further analyses and publications would need approval of data originators.

6. In respect of the above, a general condition of access to samples should be to the account of the party wishing such access. As a consequence all costs associated with accessing the samples, processing the samples, and ensuring that their safety or integrity is not compromised will be borne by the accessing party. This will require that CCAMLR formalise the status of the samples and delineate a process for their use.

7. It was recognised that at present there were no firm plans to analyse the RMT8 samples further. However, a request had already been received from outside the CCAMLR community to look at the taxonomy and feeding ecology of myctophid fish. Any requests would need to take into account the stipulations of the draft conditions of access.

8. The particular case of samples of krill collected for genetic analyses was discussed. The collection of such samples had been agreed as part of the zooplankton sampling protocols. It was therefore thought appropriate that the idea of holding such samples centrally and sending subsamples for analysis to various groups should be considered. In the light of this discussion it was thought appropriate that clarification should be sought from the data originator (Dr B. Bergström, Sweden) about the status of genetic samples collected by the *Yuzhmorgeologiya*.

ATTACHMENT D

DESCRIPTORS FOR SUMMARY TABLES CONTAINING BIOMASS ESTIMATES

The following descriptors relate to labels contained in Tables 24 to 26. It should be noted that the various descriptor functions are based on those given in Jolly and Hampton (1990). In the formulae below *i* is used to index intervals along a transect, *j* is used to index transects within a stratum, and *k* is used to index strata.

Transect Label	Formula /Descriptor
Length	Transect length defined as the sum of all interval weightings (as defined in paragraph 3.51) $L_j = \sum_{i=1}^{N_j} (W_I)_i$ where L_j is the length of the *j*th transect, $(W_I)_i$ is the interval weighting of the *i*th interval, and N_j is the number of intervals in the *j*th transect.
Weighting factor	Normalised transect length $w_j = \frac{L_j}{\frac{1}{N_k}\sum_{j=1}^{N_k} L_j}$ such that $\sum_{j=1}^{N_k} w_j = N_k$ where w_j is the weighting factor for the *j*th transect, and N_k is the number of transects in a stratum.
Krill density measured	Mean areal krill biomass density over all intervals on each transect $\bar{\rho}_j = \frac{1}{L_j}\sum_{i=1}^{N_j} S_{Ai} f_i (W_I)_i$ where $\bar{\rho}_j$ is the mean areal krill biomass density on the *j*th transect, S_{Ai} is the integrated backscattering area for the *i*th interval and f_i is the conversion factor for the *i*th interval (see paragraphs 3.28 to 3.52).
Krill density weighted	Mean areal krill biomass density times the weighting factor $\bar{\rho}_{wj} = w_j \bar{\rho}_j$ where $\bar{\rho}_{wj}$ is the mean weighted areal krill biomass density on the *j*th transect.
Variance component	$VarComp_j = w_j^2 \left(\bar{\rho}_j - \bar{\rho}_k\right)^2$ where $VarComp_j$ is the weighted contribution of the *j*th transect to the stratum variance.

Stratum Label	Formula/Descriptor
Mean	Stratum mean areal krill biomass density $\bar{\rho}_k = \frac{1}{N_k}\sum_{j=1}^{N_k} w_j \bar{\rho}_j$ where $\bar{\rho}_k$ is the mean areal krill biomass density in the kth stratum (after equation 1, Jolly and Hampton, 1990).
Variance	Stratum variance $Var(\bar{\rho}_k) = \frac{N_k}{N_k - 1} \frac{\sum_{j=1}^{N_k} w_j^2 (\bar{\rho}_j - \bar{\rho}_k)^2}{\left(\sum_{j=1}^{N_k} w_j\right)^2} = \frac{\sum_{j=1}^{N_k} w_j^2 (\bar{\rho}_j - \bar{\rho}_k)^2}{N_k (N_k - 1)}$ where $Var(\bar{\rho}_k)$ is the variance of the mean areal krill biomass density in the kth stratum.
CV (%)	Coefficient of variation $CV_k = 100 \frac{(Var(\bar{\rho}_k))^{0.5}}{\bar{\rho}_k}$ where CV_k is the coefficient of variation for the kth stratum.

Survey Label	Formula/Descriptor
Nominal area	Area of kth stratum (A_k) estimated at the time of survey design (see paragraphs 2.2 and 2.3).
Mean density	Mean areal krill biomass density of the kth stratum, $\bar{\rho}_k$.
Area*density	$A_k \bar{\rho}_k$
Variance component	$VarComp_k = A_K^2 Var(\bar{\rho}_k)$ where $VarComp_k$ is the contribution of the kth stratum to the overall survey variance of B_0.
Mean density	Overall survey mean areal krill biomass density $\bar{\rho} = \frac{\sum_{k=1}^{N} A_k \bar{\rho}_k}{\sum_{k=1}^{N} A_k}$ where N is the number of survey strata (after equation 2, Jolly and Hampton, 1990).

Survey Label (continued)	Formula/Descriptor
Variance	Overall survey variance of the mean areal krill biomass density $Var(\bar{\rho}) = \frac{\sum_{k=1}^{N} A_k^2 Var(\bar{\rho}_k)}{\left(\sum_{k=1}^{N} A_k\right)^2} = \frac{\sum_{k=1}^{N} VarComp_k}{\left(\sum_{k=1}^{N} A_k\right)^2}$ (after equation 3, Jolly and Hampton, 1990).
CV	Overall coefficient of variation of the mean areal krill biomass density $CV_{\bar{\rho}} = 100 \frac{\left(Var(\bar{\rho})\right)^{0.5}}{\bar{\rho}}$
Krill standing stock	$B_0 = \sum_{k=1}^{N} A_k \bar{\rho}_k$
Variance	Overall survey variance of B_0 $Var(B_0) = \sum_{k=1}^{N} VarComp_k$
CV	Overall coefficient of variation of B_0 $CV_{B_0} = 100 \frac{\left(Var(B_0)\right)^{0.5}}{B_0}$