ANNEX 4

REPORT OF THE WORKING GROUP ON ECOSYSTEM MONITORING AND MANAGEMENT

(Santa Cruz de Tenerife, Spain, 19 to 29 July 1999)

CONTENTS

REPORT OF THE WORKING GROUP ON ECOSYSTEM MONITORING AND MANAGEMENT
(Santa Cruz de Tenerife, Spain, 19 to 29 July 1999)

INTRODUCTION

Opening of the Meeting

1.1 The fifth meeting of WG-EMM was held at the Instituto Español de Oceanografía, Santa Cruz de Tenerife, Spain, from 19 to 29 July 1999.

1.2 The Assistant Director of the Instituto Español de Oceanografía, Dr E. López Jamar, opened the meeting and welcomed participants to the institute. In his opening remarks, Dr López Jamar outlined Spain's long-standing commitment to research in support of CCAMLR, and emphasised the importance of the Working Group's work in advising on the management of Antarctic marine living resources. Dr López Jamar thanked Dr E. Balguerías, Mr L. López Abellán and other staff at the institute for the local organisation of the meeting.

1.3 On behalf of the Working Group, the Convener, Dr I. Everson, thanked Dr López Jamar and the local organisers for hosting the meeting in Santa Cruz. He noted that some of the participants had attended the meeting of WG-CEMP held in the institute in 1991. He looked forward to a similarly productive meeting.

Adoption of the Agenda and Organisation of the Meeting

1.4 The Provisional Agenda was introduced and discussed. Two items were added to the agenda:

Item 6.4 'Environmental Interactions with Harvested and Dependent Species'; and

Item 10 'CCAMLR Website'.

With these changes, the agenda was adopted (Appendix A).

1.5 During the course of the meeting it became clear that some papers, although relevant to agenda items, did not fit well into the subitems. Accordingly, some modifications were made to the structure within agenda items as the meeting progressed.

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

1.7 The report was prepared by Prof. I. Boyd (UK), Dr A. Constable (Australia), Prof. J. Croxall (UK), Drs M. Goebel (USA), R. Hewitt (USA), D. Miller (South Africa), S. Nicol (Australia), D. Ramm (Data Manager), K. Reid (UK), E. Sabourenkov (Science Officer), V. Siegel (Germany), P. Trathan (UK), W. Trivelpiece (USA), J. Watkins (UK) and P. Wilson (New Zealand).

FISHERIES INFORMATION

Catches: Status and Trends

2.1 The distribution of catches from krill fisheries in the CCAMLR Convention Area during the split-year 1997/98 (July 1997 to June 1998) was presented in WG-EMM-99/9. A total of 80 178 tonnes of krill had been reported as fine-scale data, which represented 99% of the catches reported in the STATLANT data. Fishing took place in Subareas 48.1 (49 388 tonnes or 62% of the total catch), 48.2 (6 672 tonnes, 8%) and 48.3 (24 043 tonnes, 30%). In addition, catches totalling 75 tonnes of krill had been reported from waters adjacent to the Convention Area in Division 41.3.2 (Southern Patagonia). Fleets had fished for krill near the South Shetland Islands (Subarea 48.1) in all months except July to September 1997, and near South Georgia (Subarea 48.3) from July to September 1997 and May to June 1998. Vessels had also operated in the vicinity of the South Orkney Islands from December 1997 to March 1998 and May 1998. Catches exceeding 3 000 tonnes of krill per fine-scale rectangle and 10-day reporting period were reported off South Georgia for July 1997.

2.2 The Working Group discussed trends in catch per unit of effort (CPUE). CPUE has been reported in tonnes per hour (CEMP Index H1a) and tonnes per day (CEMP Index H1b) in WG-EMM-99/8. CPUE reported in Subareas 48.1, 48.2 and 48.3 over recent years were close to their long-term mean values, and no anomaly had been detected in any of the time series in 1997/98.

2.3 Haul-by-haul CPUE, estimated as catch per tow and catch per minute, and the size distribution of krill caught by the Japanese fleet in the 1997/98 season, were reported in WG-EMM-99/48 using data collected by fishing crews. Four Japanese trawlers targeted krill near the South Shetland Islands and Antarctic Peninsula from mid-December to mid-May. The fleet then divided, with two vessels continuing to fish near the South Shetland Islands, and two vessels fishing to the northeast of South Georgia from May until late June. CPUE, in catch per tow, ranged from 5 to 24 tonnes per tow, and increased as the season progressed. Measured in terms of catch per minute, CPUE showed marked variation between vessels, especially from late April to late June; differences in this measure of CPUE may be attributed to differences in the density and extent of krill aggregations. In addition, krill were distributed over a narrow size range on grounds near the Antarctic Peninsula and at South Georgia, with modal lengths of 50 mm and 37 to 39 mm respectively. Krill were found to be distributed over a wider size range near the South Orkney Islands where modal length varied over time.

2.4 The Working Group noted that only haul-by-haul CPUE was likely to be of use in answering key questions regarding krill population processes and in understanding the fishery, but that this was only available from the Japanese fishery. Submission of data from other nation’s fisheries was encouraged, as was the analysis of these data.

2.5 Visual and radar observations on the number of icebergs encountered by a Japanese trawler searching for krill in Subarea 48.1 in early May 1999 was presented in WG-EMM-99/54. Observations were made up to 24 n miles on either side of vessel, and indicated high densities of icebergs (>60–100 icebergs within 6 n miles of the vessel) along the inshore sector of the area surveyed, from Anvers Island northwards to Elephant Island. The high number of icebergs encountered by the Japanese trawler had prevented fishing and the vessel had moved to the South Orkney Islands. In contrast, Dr Trivelpiece reported that few icebergs had been sighted off Cape Shirreff during February 1999.

2.6 Information on the occurrence of icebergs was welcomed by the Working Group, and the potential effects of high densities of icebergs on the fishing operation and CPUE were briefly discussed. The Working Group agreed that a number of factors may influence trends in CPUE, including search time, fishing strategies, icebergs and trends in the krill market. These factors would need to be incorporated into any future analysis of CPUE aiming to understand trends in abundance of krill and fishing effort. The Working Group welcomed the analysis of CPUE on a vessel-by-vessel basis as reported in WG-EMM-99/48.

2.7 The krill catches for the 1998/99 season and reported to date to the Secretariat indicated that five Member countries had fished for krill in Area 48: Argentina (4 427 tonnes); Japan (55 879 tonnes); Republic of Korea (1 231 tonnes); Poland (16 285 tonnes) and Ukraine (5 694 tonnes). The Working Group noted that data for the past season were incomplete because the reports for June 1999 were not due until the end of July 1999. The Working Group was advised that Japanese vessels had caught approximately 15 000 tonnes of krill in June. The catch taken in June by the Japanese fleet represented approximately 15% of the total annual catch, and raised the annual catch taken by Japan to 71 022 tonnes. With this addition, the total catch within the Convention Area in 1998/99 would be at least 98 658 tonnes. No fishing was reported from Areas 58 and 88. In adjacent waters, Poland had reported a catch of 254 tonnes of krill in Subarea 47.4 (southeast Atlantic); no catch was reported from Division 41.3.2.

2.8 The Working Group discussed the types of conversion factors used to estimate the total catch of krill. The Japanese fleet has traditionally used a factor of 10 to raise the weight of fishmeal to the estimated fresh weight of the catch (i.e. fresh weight = 10 · fishmeal weight). A factor of 10 was also used to raise the weight of peeled krill to the estimated fresh weight of the catch. A factor of 1 was used to estimate fresh weight from the weight of frozen krill. The Working Group agreed that conversion factors used in the krill fishery should be documented, and that the approach used by WG-FSA to quantify conversion factors in the *Dissostichus* spp. fisheries was applicable to the krill fisheries. Members were encouraged to collect detailed data on fresh and processed weights, and submit this information to the Secretariat.

2.9 Members were asked about their plans to fish for krill during the split-year 1999/2000. The USA advised that two vessels were now licensed to fish for krill, and fishing was expected to start in August 1999 in Subareas 48.1, 48.2 and 48.3. Japan advised that it planned to continue fishing at the same level of about 50 000 to 70 000 tonnes of krill taken by four trawlers operating in Subareas 48.1, 48.2 and 48.3. Germany may issue a licence to one vessel, and fishing may begin in January 2000. India had no immediate plans to fish for krill. Australia had received several enquiries, but no licences had been issued. In the UK, one company had expressed interest in krill fishing but no licences had been issued. The Secretariat had received notice from Ukraine that two vessels would continue fishing in 1999/2000 at a level similar to that of the past season. The Secretariat was also aware of initial discussions in Chile for fishing using a non-Member flagged vessel; no further information was available. The Secretariat had sought information from Canada, China and Panama: Canada was evaluating a proposal; no response had been received from China; and Panama advised that it would not fish for krill in 1999/2000. Information at hand in the Secretariat at the time of adoption indicated that Poland had extended the licences of five vessels to the 1999/2000 season.

Harvesting Strategies

2.10 Last year the Working Group discussed the need for information on past and current market prices for krill. This information would provide further insight into the fishery, and is essential for the economic analysis of this fishery and development of management strategies (SC-CAMLR-XVII, Annex 4, paragraph 2.9). Some participants and the Secretariat had attempted to locate market information and prices via the Internet; no information had been found so far on market prices. The Working Group agreed that Members involved in krill fisheries should provide general information on krill prices and a breakdown of catches by product type. This information is essential to understand underlying market trends and to determine how reactive fishing operations were to market forces.

2.11 Japan confirmed that the key market features reported last year (SC-CAMLR-XVII, paragraph 2.5) had applied in 1999. That is, krill was harvested mostly as feed for the aquaculture industry and bait in recreational fisheries; a small proportion of the catches was also processed as food for human consumption. Also, Japanese trawlers had extended their fishing season to autumn and winter so as to avoid catching early-season green krill (low value), increase their catch of white krill (high value), and increase the length of the period when krill can be supplied to markets. The Working Group was concerned that the development of the winter fishery for krill in ice-free areas off South Georgia may place localised pressure on krill populations; management strategies should be reviewed in the light of year-round fishing.

2.12 Dr Nicol advised the Working Group that potential new markets for pharmaceutical products may only require small quantities of harvested krill as a base for enzyme production.

Observer Scheme

2.13 The Working Group noted that considerable data had been acquired by Japan in the past using national observers. In addition, in 1998/99 some observer data had been collected by Argentina and were to be submitted to the Secretariat, and the USA had considered deploying scientific observers aboard krill vessels. Despite these efforts, the Working Group noted that there remained a paucity of information on the operation of krill fisheries and by-catch. In particular, the Working Group recommended that observers be deployed regularly on krill vessels to collect and report data assigned high priority in CCAMLR's *Scientific Observers Manual* (section 1, part 2, paragraph 4). These are:

(i) observations on fishing activities;
(ii) gathering of haul-by-haul data on catch and effort;
(iii) representative length-frequency distributions;
(iv) representative distribution of sex and maturity stages;
(v) observations on feeding intensity;
(vi) observations on by-catch of juvenile finfish; and
(vii) observations on incidental mortality of predators (seabirds and seals).

2.14 In addition, the Working Group agreed that it may be desirable for observers to collect data on conversion factors used to convert the weight of various krill products to fresh weight. The availability of information on conversion factors is essential to ensuring that catches reported to CCAMLR have been reported in a consistent manner (see paragraph 2.8).

2.15 Members agreed that it is of high priority to have observers aboard commercial krill vessels during the execution of the CCAMLR 2000 Krill Synoptic Survey of Area 48 in January–February 2000 (hereafter referred to as 'the CCAMLR-2000 Survey'). Information provided by observers is likely to be important to the interpretation of survey results in relation to fishing operations taking place at the same time as the survey over various spatial scales.

2.16 In addition, the Working Group suggested that, as a matter of priority, information delineating the decision processes used by vessel masters to formulate fishing operation strategies was needed. For example, does the master formulate fishing strategy based on acoustic traces, catch parameters (green krill, krill size etc.) or other factors? The use of 'echolisteners' which provide scientific-quality output from echosounders on commercial vessels was considered an important component to provide information pertaining to fishing operations during the CCAMLR-2000 Survey.

2.17 It would be useful to develop standard survey questionnaires based on the list of activities identified by Butterworth (1988) to collect fishing strategy information.

HARVESTED SPECIES

Distribution and Standing Stock

Local Surveys

3.1 An acoustic krill biomass survey was conducted off the western end of South Georgia in 1986 using a radiating transect design specifically to examine the relationship between krill biomass and krill predators (WG-EMM-99/17). The data had been analysed in three depth strata: offshore (<2 000 m), slope and shelf. Krill biomass was highest on the slope (44.58 gm^{-2}), intermediate on the shelf (27.79 gm^{-2}) and lowest offshore (21.69 gm^{-2}), emphasising the importance of the shelf/slope area for krill.

3.2 Off South Georgia in 1998/99, biomass of krill in the two regularly sampled survey areas was low (11.1 gm^{-2} in the western box and 12.0 gm^{-2} in the eastern box) relative to other years in the BAS Core Programme (WG-EMM-99/20). The krill in both survey areas were large, with a mean size of 50.7 mm in the east and 52.9 mm in the west.

3.3 Based on recent trends, low krill densities are predicted in the South Georgia area in 1999/2000, unless there has been a major influx of krill into the area in the intervening period (WG-EMM-99/20).

3.4 Two small-scale acoustic surveys in the vicinity of the South Shetland Islands were conducted in 1998 (WG-EMM-99/55). In January 1998 a survey to the south of the South Shetlands yielded a biomass of 21.15 gm^{-2} in an area of 982 n $miles^2$. This biomass estimate was derived only from acoustic data collected between depths of 20 to 75–125 m because of noise problems outside that depth range. In December 1998 a larger (5 363 n $miles^2$) survey to the north of the South Shetlands yielded a mean krill biomass of 319.8 gm^{-2} with most of the krill (>75%) being found in layers between 115 and 320 m.

3.5 The reported high level of mean density in the December 1998 survey compared to other surveys in the region could have been a result of other species being included in the acoustic results. There was also some uncertainty over the target strength (TS) used to arrive at the biomass estimate. New calculations carried out during the Working Group meeting using the definition of krill TS at 120 kHz indicated a krill density of 151 gm^{-2} to the north of the South Shetland Islands.

3.6 The 1998/99 US AMLR surveys off the Elephant Island area reported the second lowest acoustically estimated density of krill (23 gm^{-2}) in the seven-year series (WG-EMM-99/47). This low density was also reflected in the net haul surveys. Krill in this area were concentrated in the shelf/slope area.

3.7 Krill in the area were dominated by larger size classes that had been actively spawning since mid- to late December, which contrasts to recent years when spawning has been reduced in intensity and occurred later in the season. The low biomass detected in the Elephant Island area in 1998/99 agrees with predictions, and even lower biomass levels are predicted for the 1999/2000 season.

3.8 Dr Constable suggested that changes in recruitment in this area, and other areas, could be related to changes in the rate at which krill are advected through the area. In this context, no direct measurements of changes in the rate of advection have been made, but changes in the value of M (see later sections) may indicate that the rate of advection is not constant.

Global Krill Abundance

3.9 Estimates of global krill abundance were presented, based on an estimate of the distributional range of krill from historical data and using modern estimates of acoustically estimated krill density from areas around the Antarctic (WG-EMM-99/22). The global krill biomass estimates ranged from 62 to 137 million tonnes which is low compared to earlier estimates based on a variety of methodologies.

3.10 Possible reasons for the difference between these and previous estimates include: underestimation of the range of krill, underestimates of krill density by acoustics and the overestimate of krill demand by predators. Further research is necessary to determine which of these factors contribute most to the uncertainties in krill biomass estimation.

3.11 Dr V. Sushin (Russia) noted that in a number of areas for which surveys gave low densities of krill, commercial fleets had high values of CPUE for seasons corresponding with surveys, for example in Subarea 48.2 (WG-EMM-99/8). He believes that this discrepancy has apparently resulted from areas of surveys and their duration being too small.

3.12 Although krill density figures can be varied and the results of the calculations would change, it was agreed that it would require unrealistic estimates of density throughout the distributional range to raise the estimates to levels approaching the figure of 500 million tonnes, which is often quoted as the global krill biomass (WG-EMM-99/22).

3.13 The calculations highlighted the need for research into krill distribution and abundance in large unsurveyed areas such as Subareas 48.6, 88.1 and 88.2 which had the potential to significantly alter the global figure. There is interest by New Zealand and Australia in surveying Subarea 88.1 – this initiative was encouraged by the Working Group.

3.14 Using the calculations in WG-EMM-99/22 it is evident that the CCAMLR-2000 Survey may result in a biomass estimate that could yield a large precautionary limit. The Working Group agreed that the development of mechanisms to subdivide the precautionary catch limit into smaller management areas could assume high priority since the fishery could concentrate all its effort within a relatively restricted area at one time.

Regional, Vertical and Seasonal Distribution of Krill

3.15 Discussion of the papers presented on krill distribution highlighted the need for further studies into the availability of krill in the surface layer which is likely to be of prime importance to predators yet which may be underestimated in acoustic surveys.

3.16 The Working Group agreed that acoustic surveys were the best method available to provide an estimate of krill biomass and that the planned CCAMLR-2000 Survey has been designed to minimise bias due to vertical migration by surveying only during the day.

3.17 It was recognised that studies into the distribution and abundance of krill in the surface layers have been carried out using techniques such as sideways or upward-looking echosounders and echosounders mounted in small boats. The Working Group encouraged the submission of reports on the results of such studies and the conduct of further studies of this nature. The issue of the relationship between krill density estimates derived from nets and from acoustics was also a topic highlighted for urgent study.

3.18 The relationship between the seasonal patterns of the fishery and the distribution of krill is important given that the fishery appears to be concentrating on Subarea 48.3 in winter. Little information, which could be used in developing strategies for managing the fishery in winter, is currently available on the winter distribution of krill and the foraging behaviour of krill predators in ice-covered or ice-free areas.

3.19 The Working Group noted that at least two studies on the winter distribution of krill and krill predators were planned; one at South Georgia in 2003 and the SO-GLOBEC study off the Antarctic Peninsula in 2001 (Marguerite Bay).

Population Structure, Recruitment, Growth and Production

3.20 The Working Group recognised that information on the mean sizes and length ranges of krill from various regions were available from a number of sources: RMT nets (WG-EMM-99/17 and 99/20), IKMT nets (WG-EMM-99/47), bongo nets (WG-EMM-99/55), commercial nets (WG-EMM-99/48) and predator diet samples (WG-EMM-99/37). The Working Group also recognised that regional comparisons between these different types of samples could be useful for the examination of krill population structure (see also BIOMASS, 1991), bearing in mind the limitations and biases particular to each type of sampling method.

3.21 The Working Group suggested that the development of general methodologies for the analysis and presentation of information on krill population structure, such as size ranges or length-density information from time-series studies, would be extremely useful to facilitate comparisons between areas. It was recognised that the formulation of data handling protocols from the CCAMLR-2000 Survey may go some way towards such standardisation.

3.22 The CCAMLR-2000 Survey and the continuing local-scale surveys in the same season may also provide an opportunity for the examination of the different scales of krill distribution and abundance, and how these relate to krill predator foraging behaviour. Consideration should be given to how the data from the regional surveys can be used in conjunction with the CCAMLR-2000 Survey.

Indices of Abundance, Distribution and Recruitment

3.23 A conceptual model of krill abundance and population structure, developed from krill lengths from predator diet samples at South Georgia from 1991 to 1997, allowed predictions to be made for the 1998 season (WG-EMM-99/37). It correctly predicted a serial change in krill population structure, low krill biomass and low predator reproductive performance.

3.24 The biomass of krill around South Georgia changed markedly during the 1997/98 season, being lowest in October and highest in January–February. The sizes of krill observed in fur seal and macaroni penguin diets also changed, reflecting an influx of krill from outside the area. Because of changes in the length-frequency composition over the season, the proportional index of recruitment could vary by two orders of magnitude between December and March.

3.25 The successful prediction by this conceptual model indicates that predator diet samples can reflect local processes in the krill population which may be under the influence of larger scale environmental processes.

3.26 The Working Group agreed that analyses of mean lengths of krill in the diet of predators need to take account of potential differences in the foraging area of different predator species and the size of krill eaten by each predator species. Examples of this were provided in WG-EMM-96/9 (Reid et al., 1996) and WS-Area48-98/15 (Reid et al., 1999). The Working Group indicated that it would be valuable to analyse the krill length-frequency data in WG-EMM-99/37 at the level of the individual seal. This will be the closest approximation to the length-density analyses comparing sizes of krill in trawl surveys and would be extremely useful for future comparisons. These analyses may help to distinguish between changes in krill abundance and changes in krill recruitment as assessed from analysis of predator diet samples.

3.27 A new per capita recruitment (PCR) model was developed to obviate some of the perceived ambiguities involved in using either proportional or absolute recruitment methods (WG-EMM-99/50; SC-CAMLR-XVII, Annex 4, paragraphs 9.6 to 9.12). The PCR is a proxy for recruits per spawner expressed as a function of R1 (the proportion of age-1 krill in the population).

3.28 The PCR model is based on four assumptions: post-recruit mortality does not vary over age or between years; 100% of age-1 animals spawn; a representative sample of the population is available; and the proportion of age-1 animals in the sample can be determined unambiguously.

3.29 A simple population model was constructed to test the sensitivity of the PCR to a relaxation of its underlying assumptions and to examine which of the input parameters it was most sensitive to. The PCR was found to be unbiased relative to recruits per spawner when mortality is constant over all age classes and all years, and when all age-1 animals spawn.

3.30 The results indicated that with age-specific declines in mortality and reducing proportion of age-1 spawners, the PCR is biased low. Introducing year-to-year random variability in both mortality and the proportion of age-1 spawners resulted in a broadening of the distribution, but did not appear to introduce additional bias. The PCR will underestimate recruits per spawner if reasonable assumptions are made regarding the variability of mortality and the proportion of age-1 spawners.

3.31 The Working Group recommended that simulation trials be conducted to examine whether correlation exists between recruits per spawner and the PCR described in WG-EMM-99/50.

3.32 The PCR is based on an approach that uses a minimum number of assumptions. In particular, the assumption that the spawners and recruits are found in the same general area. For example, in the Elephant Island area this assumption may hold true because year classes are observed to move through the population. This suggests that either the population in this area is stationary or that the population is representative of a larger area.

3.33 The Working Group noted that the CCAMLR-2000 Survey may determine whether the population sampled in the fine-scale surveys off the Elephant Island area is actually representative of a larger area. Additionally, fisheries data may be useful for obtaining information on wider areas than the smaller scale scientific surveys.

3.34 The Working Group agreed that the key use of such models is to provide information on the productivity of krill populations and that there were at least two linked processes involved in recruitment: spawning of adults and survival of larvae through year 1.

3.35 Producing an index of productivity in krill populations that is sensitive to factors that are known to be of importance and which is sensitive to factors such as local fisheries, was seen to be the ultimate aim of this process. However, caution was expressed concerning attempts to construct stock-recruitment relationships for krill as this approach had failed in many other fisheries where it had been applied.

3.36 Two models were put forward which correct for the proportion of age-1 krill in the krill density model proposed last year (SC-CAMLR-XVII, Annex 4, paragraphs 4.25 to 4.37), and both suggest that if reasonable mortality values are used (0.8 to 1.0), the potential proportional recruitment is larger than values actually observed (WG-EMM-99/51).

3.37 Although the two models were able to correct the uncertainties in the age-1 krill in the krill density model, they were unable to account for the variation in krill density in the Antarctic Peninsula area after the 1994/95 season. This suggests that the variation in krill density after the 1994/95 season may not be explained solely by recruitment and mortality.

3.38 Current estimates of mean recruitment rates suggest that the krill population is unsustainable as the recruitment rates are too low to maintain the estimated mortality rate. Two methods were put forward to tackle this problem (WG-EMM-99/56). In the first method mortality rates were estimated using bulk density estimates and linear regression methods. The second method used an age-structured population model.

3.39 Both models provided an instantaneous mortality rate of 0.6 (~43% per annum) for the first year class but this was poorly constrained between 0.3 and 1.0 (26–63% per annum) and long-term trajectories of density estimated by the models gave poor fits to the observed data. For the second year class the models produced higher mortality estimates, between 0.8 and 1.0 (59–63% per annum), and better fits to the observed density changes.

3.40 The exercise raised questions about the manner in which the recruitment data, particularly that for the first age group, could be interpreted. Mortality, density and recruitment are critically linked and estimates of these values should be internally consistent. It was suggested that changes in mortality rather than changes in recruitment could be responsible for the observed changes in density, and that changes in the rate of advection could affect estimates of all population variables. The Working Group encouraged further research on potential errors involved in sampling the krill population, including the non-random population structure of krill aggregations, flux into and out of the sampling areas, and the provision of independent estimates of mortality.

3.41 The Working Group reiterated the need for time-series data on krill demographic parameters from the Indian and Pacific sectors of the Antarctic to improve general understanding of krill population dynamics.

Future Work

3.42 Plans for surveys by Japan in the South Atlantic using the *Kaiyo Maru* in 1999/2000, include the CCAMLR-2000 Survey, an oceanographic survey and an investigation of krill flux through the krill fishing grounds (WG-EMM-99/49). This latter survey will be carried out by sampling close-spaced stations around the krill fishing grounds in the South Shetlands. A series of repeated surveys will also be carried out during December and January, with Korean and US surveys in other time periods as well.

3.43 A time series of surveys by Japan, USA and Republic of Korea between December 1999 and February 2000 was also noted. Some Peruvian scientists recently expressed their intention to join this coordination work. Peru's involvement is being considered by its National Commission of Antarctic Affairs. The Working Group also recalled that there had been earlier surveys by Peru in the Bransfield Strait and the Secretariat was requested to approach Peru for some details of the results of these surveys for next year's meeting.

DEPENDENT SPECIES

CEMP Indices

4.1 Dr Ramm submitted a summary report of trends and anomalies of CEMP indices (WG-EMM-99/8) supplemented by an appendix containing the complete datasets in the CEMP database.

4.2 The Working Group thanked Dr Ramm and his staff for this thorough report.

4.3 A number of queries were raised concerning specific data entries particularly relating to questionable dates and out-of-range values. A discussion followed on how to ensure quality control of the data. The Secretariat should review data after submission and flag 'out-of-range' values or dates and contact data holders as appropriate. Prof. Boyd proposed that data holders be required to confirm on each submission that the data were collected according to the standard method. It was reiterated that the data holders indicate the nature of and reason for, any departure from the standard method.

4.4 An ad hoc group was formed to review CEMP indices for possible errors in data and to make recommendations to the Secretariat on quality control of the data. The group assessed the indices and out of several thousand entries identified only about 34 with possible errors that needed to be checked with data holders (Table 1). Of these, however, only a few concerned the validity of the data entry, the rest likely involved transcription errors. It was noted that the number of potential errors detected was a very small percentage of the entire database.

4.5 The group made the following recommendations:

(i) updated CEMP indices should be posted on the CCAMLR website each year prior to WG-EMM and copies sent to attendees and data holders by email. Two hard copies of the data should be brought to each meeting by the Secretariat for reference;

(ii) data tables consisting of small, inactive summaries be archived after consultation with the respective data holders regarding the status of these data. A table summarising archived data should be included as an appendix to the report. This would reduce the bulk of the CEMP indices report by about 23 tables;

(iii) data should be submitted electronically in standard Excel formats to be developed by the Secretariat after consultation with current data holders;

(iv) the report of anomalies and trends should be presented in two ways: all variables by each site and all sites within subareas by each variable (where the variables are represented at every site); and

(v) each data holder should submit maps of sites and colonies where CEMP data are collected. These will be archived by the Secretariat.

4.6 Dr Trivelpiece advised the Working Group that the SCAR Working Group on Bird Biology held a workshop in Montana, USA, in May 1999 to review the status and population trends among Antarctic seabirds. The workshop participants analysed long-term datasets for several species of interest to WG-EMM. Models were used to statistically investigate trends in populations. The results of this workshop, including details of the methodologies used, will be available to WG-EMM at its next meeting. WG-EMM therefore agreed that substantive discussion of changes in status and trends of CEMP species be deferred until next year.

4.7 Inspection of the land-based predator indices for 1998/99 revealed that no major changes had occurred in predator performance indices in the Antarctic Peninsula (Scotia Sea regions) since the analyses conducted during the Workshop on Area 48 (WG-EMM-98/16).

4.8 Subareas 48.1, 48.2 and 48.3 showed coherence in predator indices. Penguin population estimates were stable or increasing throughout the region relative to 1997/98. Reproductive success, foraging trip duration and chick fledging weights were all average to good. This re-affirmed the findings of the Workshop on Area 48, that land-based predator indices in summer are generally coherent across Subareas 48.1, 48.2 and 48.3.

4.9 WG-EMM-99/25 examined foraging location data, trip duration, chick meal size, chick growth rates and reproductive success to determine the reasons for poor breeding success of

Adélie penguins at Béchervaise Island (Division 58.4.2) in 1998/99. It compared data for nine years, from 1990 to 1998. In 1998/99 adults spent more time at sea and males foraged greater distances (feeding at the shelf break with greater frequency than in ‘good’ years). Meal masses returned to chicks were considered normal, but adults made fewer trips to sea. The pattern in 1998/99, in part, was associated with late clearing of shore-fast ice from the area, but not entirely, as tidal cracks allowed access to local foraging grounds which appeared to be depleted in necessary food resources. The physical conditions causing late breakout of fast-ice may also have caused redistribution of prey resources.

4.10 Prof. Croxall remarked that a similarly poor year was reported for this site in 1994/95. In that year, poor reproductive success for Adélies at Béchervaise was apparently a localised event as colonies 100 km east and west had normal breeding seasons. No data were available for the other colonies in the region for 1998/99 to determine if the event was local or of a more regional nature.

4.11 WG-EMM-99/60 presented data from Edmonson Point (Subarea 88.1) on Adélie penguins for the 1994/95 to 1998/99 seasons. The 1998/99 season was characterised as normal. Few data were presented for 1997/98, but of the remaining four years, 1995/96 stood out as a year of poor reproductive success. No estimates of variance were presented, but there appeared to be no differences in foraging trip duration between 1994/95 and 1995/96. There were, however, apparent differences in diet (less krill in the diet in 1995/96 than in 1994/95) and meal masses were smaller. Data for foraging locations were not presented, but it was stated that birds foraged nearer the coastline in 1995/96 than in 1994/95 and 1998/99.

Studies on Distribution and Population Dynamics

4.12 WG-EMM-99/6 reported on 13 species of seabirds breeding on Marion Island. Censuses were conducted in varying years for different species to compare with censuses conducted in the early 1980s. Six species (northern giant petrel, grey-headed and wandering albatross, Salvin’s prion, blue and great-winged petrels) and possibly king penguins all showed increases in numbers of breeding animals. The southern giant petrel population was stable, while gentoo and rockhopper penguins, the Crozet shag, and possibly macaroni penguins, all decreased in numbers. In general, species with large foraging ranges increased whereas species foraging nearer to Marion Island showed decreases in numbers.

4.13 The Working Group noted that many of the species described in this paper were not CEMP species but that consideration of these trends will be discussed next year. There was a concern expressed by the members of the Working Group that techniques used in the censuses were not adequately described.

4.14 The Working Group noted that the discussion of trends in Antarctic seabird populations, including non-CEMP species, will be possible at next year’s meeting when the SCAR Working Group on Bird Biology will present its report (see paragraph 4.6). This consideration will include examination of the trends in seabird populations and the significance and potential causes of those trends.

4.15 WG-EMM-99/34 reported sightings of large whales from three independent sighting databases: a cruise of the *Abel-J* in 1997 from the Falkland/Malvinas Islands to South Georgia (Subarea 48.3), shore-based sightings from Bird Island (Subarea 48.3) between 1979 and 1998, and mariner sightings between 1992 and 1997. Southern right whales were the most common whale sighted. Two right whales from the South Georgia area were identified to have been observed at Peninsula Valdez. Blue and fin whales were less abundant. Areas where whales were sighted with the greatest frequency corresponded with traditional whaling areas, indicating that areas used by whales had not changed over time.

4.16 WG-EMM-99/16 reported an apparent 11% increase in pup production in 1998/99 at Cape Shirreff, Livingston Island. Pup production at the San Telmo Islands was estimated as researchers were unable to census there. Overall production for the SSSI (Cape Shirreff and San Telmo combined) appeared to be 10% greater in 1998/99 than in 1997/98. Pup production, however, appeared to be down the year before by 14%. The 1998/99 increase returned pup production to approximately the 1996/97 level.

4.17 The Working Group noted that limited access to the San Telmo Islands makes the estimation of overall population trends difficult. In addition, uncertainties in the estimates of the counts need to be presented. If the population at this SSSI continues to expand, a mark-recapture program may help facilitate improved estimates of demographic parameters.

Future Studies

4.18 WG-EMM-99/36 estimated field metabolic rates of Antarctic fur seals from variations in heart rate and reported results comparable to metabolic rates obtained from doubly labelled water studies. Heart rate exhibited a high degree of variability within and between animals. However, most of the variability was explained by the morphology of the animals. Estimates of metabolic rates suggested that there were no differences in the costs of being at sea or ashore and that the costs of being at sea were lower than previously estimated. A main advantage to this method is that it is not as restrictive as the doubly labelled water technique in the duration that metabolic rates can be measured over. The technique offers some promise in future studies of field metabolic rates in dependent species which are important for energetics calculation in prey consumption models.

ENVIRONMENT

Consideration of Studies on Key Environmental Variables

5.1 A number of papers were tabled which contained information on the environment. It was agreed that those papers which emphasised environmental interactions with harvested and dependent species (WG-EMM-99/15, 99/16 and 99/35) should be considered under relevant subitems of Agenda Item 6.

5.2 WG-EMM-99/47 provided a summary of field activities by the US AMLR Program in the 1998/99 season. It was noted that a long-term objective of this program was to describe functional relationships between krill, their predators and key environmental variables. Dr Hewitt noted that results from the program over the past 11 years had indicated the presence of an oceanic front to the northwest of Livingston Island and King George Island (Amos and Lavender, 1992) which was known to vary in its location by approximately 10 to 20 km. The Working Group encouraged the US AMLR Program to table a paper on the oceanographic environment in the AMLR area at its next meeting.

5.3 Following submissions in previous years (WG-EMM-97/69 and 98/31), WG-EMM-99/53 sets out preliminary work targeted at estimating the extent (area and number) of polynyas. Such work is in response to WG-EMM's request to standardise the investigation of polynya dynamics with a view to understanding better the influence of polynyas on biological productivity in winter and spring (SC-CAMLR-XVII, Annex 4, paragraphs 6.8 and 12.7). Further development of this work was encouraged.

5.4 WG-EMM-99/54 presented the distribution of icebergs detected by a fishing vessel during the course of fishing activities in Subarea 48.1 in May 1999. The implications of this paper are described in paragraphs 2.5 and 2.6.

5.5 WG-EMM-99/52 contained an assessment of large-scale environmental information that influences the variability of krill density and recruitment. Significant positive correlations were shown between krill recruitment in the Antarctic Peninsula region and the strength of westerly winds from 1982 to 1998. Years with strong westerlies during summer resulted in high krill recruitment in 1987/88, 1990/91 and 1994/95, while the years of weak westerlies resulted in low krill recruitment in 1982/83, 1988/89, 1992/93 and 1996/97. The strength of westerlies was significantly related to the recruitment of both one- and two-year-old krill. In addition, the strength of westerlies showed a strong correlation with chlorophyll-*a* and sea-ice cover at a lag period of one year.

5.6 A second result highlighted by WG-EMM-99/52 was a negative correlation between krill density in the vicinity of the Antarctic Peninsula and the extent of stratospheric ozone depletion between 1977 and 1997. The authors of WG-EMM-99/52 had suggested four hypotheses to explain the possible effects of ozone depletion on krill density (see also discussion in paragraph 5.10):

(i) UV-B has an adverse effect on phytoplankton, potentially reducing the krill stock size;

(ii) UV-B has an adverse direct effect on krill larvae, potentially affecting krill stock size;

(iii) ozone depletion in the stratosphere leads to atmospheric change, which potentially impacts certain oceanic phenomena that may affect krill habitat and krill stock size; and

(iv) spurious correlation exists owing to unknown causality.

5.7 WG-EMM-99/24 contained two published papers on the susceptibility of krill to ultraviolet radiation and on the susceptibility of krill DNA to damage by UV-B. It was agreed that these results offered important developments on a crucial topic, particularly in light of the discussion outlined in the previous paragraph. Future directed research on the potential impacts of ultraviolet radiation on krill was encouraged.

Indices of Key Environmental Variables

5.8 WG-EMM-99/8 (Figures 18 to 20) presented the index deviates for sea-ice cover, proportion of the year free of ice, sea-ice <100 km from CEMP sites and sea-surface temperature in various areas. The Working Group noted that while it was relatively simple to identify anomalous years from such presentations, the elaboration of trends was rather more difficult and required careful interpretation.

Future Work

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

5.10 It was also emphasised that directed research to understand the potential effects of ultraviolet radiation on key Antarctic biota should be encouraged. Ancillary to such research, modelling of key processes should be encouraged in order to develop a strategic appreciation of the potential effects of increased ultraviolet radiation on CEMP species in general and on krill in particular. Such modelling should serve to identify key parameters to be measured, define the likely extent of the effects of increased ultraviolet radiation on the important demographic properties (especially mortality) of key biota, and develop hypotheses to be tested.

ECOSYSTEM ANALYSIS

Analytical Procedures and Combinations of Indices

Multivariate Analysis of CEMP Indices

6.1 Last year the Working Group considered further work on the development of Composite Standardised Indices (CSIs) (SC-CAMLR-XVII, Annex 4, paragraphs 7.1 to 7.4), which provide a means of combining the many predator indices determined in CEMP into a single index. It requested that differences in approaches to estimating the covariance matrix underpinning the CSI be discussed intersessionally and presented at this meeting.

6.2 Dr Constable outlined the differences in the approaches presented last year and how these related to the original paper of Dr W. de la Mare (WG-EMM-STATS-97/7). The original formulation of the CSI in WG-EMM-STATS-97/7 intended that the covariance matrix be determined from pairwise correlations from all available pairwise combinations of the indices in the time series. This was the method used in WS-Area48-98/6. WG-EMM-98/45 presented a sensitivity analysis based on covariance matrices determined from pairwise correlations over the time series in years when all indices in the CSI were represented (i.e. a complete dataset where there were no missing values, and where the covariance matrix is identical to the correlation matrix). This was the same method used by the WG-EMM Subgroup on Statistics in 1997 (SC-CAMLR-XVI, Annex 4, Appendix D, paragraphs 2.7 to 2.18) in its initial appraisal of the method. A comparison of the robustness of these two different methods has been undertaken by Dr Constable but the results were not ready for presentation to this meeting.

6.3 An extension of this method for estimating CSIs was presented in WG-EMM-99/40. This extension was developed to provide a means of smoothing the covariance matrix when data were missing. This paper also outlined a possible method for determining confidence intervals around CSIs and a procedure for examining the relative influence of different predator indices to the trends indicated by the CSI. The paper used a single simulated dataset derived from a cyclical function as well as the Bird Island dataset used in previous workings of this method. This simulated dataset was then used to illustrate how well the new formulation may perform compared to the formulation presented in WG-EMM-98/45 given various combinations of numbers of missing values and numbers of vectors with missing values. In the specific case presented, the new formulation appeared more robust to missing data. Following this, the Bird Island dataset was re-analysed using the modified version of the CSI. This produced similar trends in predator performance to the original formulation discussed by the Subgroup on Statistics in 1997 and to other work describing changes in predator parameters in relation to known changes in krill abundance. The paper concluded by describing a possible positive non-linear correlation between the modified CSI and estimates of krill density in the region.

6.4 Dr Constable noted that the modifications to the CSI offered a potential enhancement of the method of combining indices. This modification, as with any other development, needs to be examined for its robustness in providing a high probability of correctly indicating the actual trends in the parameters of interest. To this end, Dr Constable also suggested that the performance of the modified CSI under various scenarios of missing values will need to be evaluated for scenarios when the different parameter vectors have varying degrees of relationship to a single function, such as the cyclical function, and for cases when some vectors are influenced by other functions. Examples of these tests are given in WG-EMM-98/45. This latter point is important because the later analyses in WG-EMM-99/40 indicate that some parameters in the Bird Island dataset may be influenced to varying degrees by other factors.

6.5 The Working Group thanked Prof. Boyd for his work in this area and agreed that further development would be welcomed. The Working Group reiterated the need to identify how CSIs can be used in a management context (SC-CAMLR-XVII, paragraph 6.5). The Working Group also noted that further development is required on how to formulate reference points for decision rules that incorporate CSIs or other information on predators.

6.6 The Working Group recalled its discussion on ecosystem assessments last year (SC-CAMLR-XVII, Annex 4, paragraphs 8.17 and 8.18), some of which related back to the early discussions of the Working Group in 1995. Most of the points raised in those paragraphs were regarded as remaining important to the development and use of CSIs. In addition, the Working Group raised the following questions for further consideration:

(i) What functional relationships can be developed relating CSIs to krill abundance (such as the one described in WG-EMM-99/40)?

(ii) How can CSIs be used for identifying a critical level of krill abundance (reference points) for use in estimating precautionary yields or for adjusting catch limits in the short term?

(iii) How sensitive are CSIs to changes in key environmental or other parameters compared to krill abundance?

(iv) What developments are required to facilitate the use of CSIs in feedback management processes or for evaluating the success of conservation measures?

(v) What analytical and assessment methods are required to test the utility of CSIs as a basis for management decisions?

6.7 The Working Group recognised that these questions need to be addressed as soon as possible.

Use of GYM for Krill Stock Assessments

6.8 Dr Ramm reported on progress to archive the krill yield model (SC-CAMLR-XVII, Annex 4, paragraphs 7.9 to 7.11). He has compiled all information available in the Secretariat and is ready to fully document the use of the model. Dr Constable agreed to assist in this documentation. Others involved in the development and application of the krill yield model will be approached to assist in this work during the intersessional period.

Other Approaches

6.9 Methods for estimating the overlap between fisheries and predator foraging areas have been considered since 1992 (see WG-EMM-99/11 for background; see also SC-CAMLR-XV, Annex 4, Appendix H, paragraphs 36 to 43 and SC-CAMLR-XVI, Annex 4, Appendix D, paragraphs 3.1 to 3.15). WG-EMM-99/11 presented a summary of how four different indices aimed at examining predator–fishery overlap compare for Adélie, gentoo, chinstrap and macaroni penguins in part of Subarea 48.1 since the early 1980s. The four indices are:

(i) catch in the Critical Period Distance (CPD) (where the CPD is up to 100 km from predator colonies);

(ii) Agnew–Phegan index (a measure of consumption of krill by predators compared to biomass of krill taken by fisheries in the same area);

(iii) Realised Potential Overlap (RPO) (modified Agnew–Phegan index to account for potential overlap); and

(iv) Schroeder Index (a measure of the relative proportions taken by predators and fishing in the foraging areas).

6.10 WG-EMM-99/11 also included revision to the Agnew–Phegan model and some refinements to the RPO index and to the fine-scale distribution of catches. The Agnew–Phegan and Schroeder indices were compared at nine levels of spatio-temporal resolution and using normal, exponential and uniform foraging distributions. The type of foraging distribution and level of spatio-temporal resolution produced only small differences in the values of both the Agnew–Phegan and Schroeder indices. However, it was noted that a more realistic distribution of foraging, for central place foragers such as penguins, was likely to be described by an inverse exponential function. The CPD and Agnew–Phegan indices produced similar temporal trends. The other two indices were similar to each other but differed in their trend from the former two indices. The RPO and Schroeder indices indicated a substantial increase in the level of overlap from 1995 to 1998. The catch in the CPD and the Agnew–Phegan indices were stable over this period. The analysis in WG-EMM-99/11 also showed that increasing the resolution of the model (especially spatially) results in lower values of overlap indices.

6.11 The Working Group thanked the Secretariat for presenting this work and agreed that further work was necessary to:

(i) determine overlap between predator foraging and fishing at times other than the summer breeding period, particularly in winter as this is when many krill fishing activities are becoming concentrated;

(ii) include more of the available empirical data on predator foraging areas;

(iii) extend the use of these indices to cover all areas where the krill fishery operates, particularly in Subareas 48.2 and 48.3;

(iv) improve the definition of what is required of the index and undertake additional work to develop the application of appropriate indices in this regard;

(v) estimate the confidence intervals for these indices; and

(vi) identify how these indices may be used in a management context.

6.12 The Working Group recalled the request of the Scientific Committee last year (SC-CAMLR-XVII, paragraph 6.11) to involve statistical experts in the development of these indices and encouraged Members to assist the Secretariat in this work.

6.13 Last year the Working Group considered other methods for assessing the status of ecosystems (SC-CAMLR-XVII, Annex 4, paragraph 8.19) including the use of Ecopath and Ecosim simulation software. The Secretariat reported on correspondence with Prof. T. Pitcher (University of British Columbia, Canada) who had approached CCAMLR for collaboration in developing an Ecosim model on the Antarctic marine ecosystem (WG-EMM-99/10). The Working Group endorsed the response of the Secretariat and the Chair of the Scientific Committee to Prof. Pitcher, which indicated that a full proposal would need to be submitted to the Scientific Committee before determining how such a request could be supported.

Krill-centred Interactions

6.14 The Working Group considered the format of this item and agreed that there were two components to the following discussion. The first component is to develop analyses that assist the Commission in understanding how krill predators may be influenced by krill at individual and population levels. In this context it was considered important to understand the importance of krill in predator diets and the degree to which predators are associated with krill and overlap in their foraging activities with the activities of krill fisheries.

6.15 The second component considered important is how krill and their predators fit into the ecosystem. To this end, the influence of environmental factors on krill and its predators is important. Also, interpretation of changes in the ecosystem may be facilitated by understanding the ecological processes, other than predation of krill, that may influence krill predators.

Diet of Krill Predators

6.16 WG-EMM-99/19 described the diet of gentoo penguins at Laurie Island, South Orkney Islands, in three autumn periods. The results indicated that, by mass, crustaceans were the most important in 1993 (krill was the dominant species) while benthic fish were most important in 1995 and 1996. The Working Group noted that at some sites gentoo penguins have a strong propensity to switch diet in seasons of reduced krill availability.

6.17 WG-EMM-99/28 detailed how time depth recorders with light sensors can be used to indicate the turbidity of water in which seals are diving by correlating light intensity with water depth. It showed that such information may provide indications of when the seals are diving in krill swarms. Prof. Boyd informed the Working Group that this paper is the first product of a project to deploy instruments on diving animals to record the characteristics of the physical environment.

6.18 WG-EMM-99/37 presented changes in length-frequency distribution of krill in the diet of fur seals and macaroni penguins at South Georgia. Years of increased mean lengths of krill in the diet of Antarctic fur seals, when adult krill dominate the population, follow periods of recruitment failure. This is discussed in more detail in paragraphs 3.23 to 3.25. The Working Group noted that such techniques may be useful in monitoring changes in the size structure and composition of both local and regional krill populations.

6.19 WG-EMM-99/44 examined the use of fatty acids in providing broad indications of seasonal and annual dietary shifts in seals as well as differences in diet between seals at South Georgia. The study showed that the diet of Antarctic fur seals was likely to be different from Elephant seals, the former consuming predominantly krill and krill-eating fish while the latter consumed fish-eating fish and squid.

6.20 WG-EMM-99/57 provided updated estimates of krill consumption by Adélie, chinstrap and gentoo penguins and female Antarctic fur seals in the South Shetland Islands. Total consumption of krill by all land-based predators on the South Shetland Islands was estimated at 8.3×10^5 tonnes. Sensitivity analyses showed that estimates of total prey consumption could be improved by better estimates of population size of predators, foraging ranges, prey consumption and the annual energy requirements of these species.

6.21 The Working Group welcomed these revised estimates of krill consumption, noting that the total consumption is 1.5 times higher than estimates currently used. It noted that the current estimates of krill density and demographic parameters do not provide sufficient krill for predators. Part of this problem may be uncertainty in the parameters used in the models as described in WG-EMM-99/57. These questions need to be addressed in the not too distant future.

Effect of Diet on Individual Predators

6.22 Foraging trip duration and time spent ashore by lactating female Antarctic fur seals at South Georgia are discussed in WG-EMM-99/32 and 99/35. The results indicated that, in times of low food supply over the last eight years when krill surveys have been undertaken, lactating female seals would increase both their foraging trip duration and time spent ashore. During long foraging trips, the feeding intensity would diminish. In high food years, these seals fed predominantly on krill during shorter foraging trips. In low food years, these seals still fed predominantly on krill but with more fish and squid in the diet.

6.23 The Working Group welcomed the development of an optimal foraging model for fur seals (WG-EMM-99/32). It encourages further development of functional feeding relationships and, in particular, models that endeavour to relate foraging areas of predators with the patchiness of prey at different scales.

6.24 WG-EMM-99/59 reported on a preliminary study examining the capacity of Adélie penguins and south polar skuas in the vicinity of Edmonson Point, Ross Sea to recover from oxidative stress. It was found that Adélie penguins recovered much more quickly than skuas, probably because of the need to sustain greater levels of diving activity. The Working Group noted that this type of research may be useful to assess stress in animals in the future. The Working Group looked forward to seeing results of comparisons with other penguins in the future.

Effect of Diet on Predator Populations

6.25 Trends in breeding success of Adélie penguins at the CEMP study site on Béchervaise Island, near Mawson in eastern Antarctica are reported in WG-EMM-99/25. The size of the colony has been stable since the start of the research program in 1990 and during most of these years the breeding success has been high, ranging from 0.7 to 1.1 chicks crèched per breeding pair for all but three seasons. In the 1994/95 season all chicks died of starvation. In the 1995/96 season only 0.35 chicks were crèched per nest and in the 1998/99 season 0.43 chicks were crèched per nest. Evidence is presented that increased foraging trip duration, as a result of poor food availability in foraging areas near the colony, contributed to lower growth rates, later fledging and higher mortality of chicks. Male foraging behaviour was different to female foraging behaviour, which was relatively normal. For males, more time was spent in feeding grounds further away than usual. This time away reduced the overall amount of food to chicks, even though the amount of food per trip was similar to good foraging years.

6.26 The Working Group noted that this was the second time that poor breeding success has occurred at this site. Dr Nicol informed the Working Group that current and future research aims to determine if there are differences in reproductive success between birds in the Mawson area with birds in other areas, such as near Casey and further east towards the Ross Sea.

6.27 Dr Nicol reported that Australia is planning to start regular sampling of krill off the coast of Béchervaise Island in a manner similar to the UK and USA programs around South Georgia and South Shetland Islands respectively.

6.28 The Working Group encouraged the continued monitoring of this site and suggested additional analyses for presentation at future meetings, such as the comparison of foraging trip duration between birds and an evaluation of different methods for summarising and analysing trip duration.

Distribution of Predators relative to Krill

6.29 WG-EMM-99/27 documented commercial operations of a Russian trawler targeting mackerel icefish (*Champsocephalus gunnari*) in the South Georgia and Shag Rocks areas in late February to March 1999. It presented observations consistent with surveys from approximately 10 years ago that aggregations of older *C. gunnari* are found in areas to the northwest of South Georgia where krill are typically found in high densities.

6.30 The Working Group noted that the locations of catches on aggregations in the northeast were consistent with one of the areas routinely surveyed for krill abundance by the UK in their annual fine-scale surveys around South Georgia.

6.31 WG-EMM-99/30 presented a positive relationship between whale sightings (numbers of whales per transect) and acoustic estimates of krill density on transects in the fine-scale krill survey at South Georgia in January to February 1998. This was consistent with the hypothesis that krill predators are associated with patches of high krill density. However, whale observations were not well correlated to krill abundance at fine-scale resolutions, indicating that whales are likely to be related to krill densities according to the distribution of swarms and other large-scale features rather than the density of krill *per se*. The paper also reports that most whales were observed to the east of South Georgia, which is consistent with previous reports on the locations of whales in the region.

6.32 Dr Nicol indicated that such studies are rare and that continued work on relating the distribution of whales to different characteristics of krill aggregations would be useful. A similar study from eastern Antarctica will soon be published.

6.33 The Working Group noted that the scale of association between predators and prey could well be modelled according to some optimal foraging model, which associates the scale of searching capacity (mobility) and the frequency of occurrence of prey. For ecosystem analyses generally, the development of predictive foraging models (e.g. those developed in WG-EMM-99/32) that endeavour to link the range of foraging areas with environmental parameters and prey distribution would be useful to the Working Group. This is because they may help predictions on how foraging areas may change between seasons and years, thereby improving our capacity to predict potential overlap with the krill fishery.

Overlap in Foraging of Predators with Fisheries

6.34 The overlap between predators and fisheries was examined in WG-EMM-99/11 and 99/57. The former paper has been discussed elsewhere (paragraphs 6.10 and 6.11). WG-EMM-99/57 was presented by authors not previously associated with CCAMLR activities. They used three different indices to assess potential overlap between foraging penguins and fisheries at the South Shetland Islands. They found, in contrast to Ichii et al. (1996) for the same area, that the overlap in foraging between penguins and the krill fishery was likely to be significant.

6.35 The Working Group noted that issues surrounding estimates of consumption of krill by predators as well as the methodologies used to estimate overlap had been discussed earlier (paragraphs 6.10, 6.20 and 6.21). The Working Group agreed that the use of the Schaeffer Ratio and the Evans Ratio as indices of overlap may be worth examining for their potential in the routine examination of overlap by the Working Group.

Ecological Processes and Interactions

6.36 WG-EMM-99/52 and 99/24 described the effects of environmental variables on krill populations. These are discussed in paragraphs 5.5 to 5.7.

6.37 WG-EMM-99/58 provided a review of the potential sensitivity of the marine ecosystem at the Antarctic Peninsula to global climate change. The authors discussed a number of models about the linkages between marine biota and the changes in the physical environment likely to ensue with a changing climate. In particular, the authors presented a conceptual model detailing how Adélie and chinstrap penguin populations may change as a result of these long-term changes to the environment.

6.38 The Working Group agreed that this paper provided an interesting and useful overview. However, some concerns were expressed in relation to the parts of the paper dealing with ice–prey–predator interactions in the light of previous Working Group discussions of this topic. Firstly, as the paper itself indicated, the models made no attempt to distinguish between changes in populations of dependent species directly caused by environmental change and those mediated by interactions with prey. Secondly, the conceptual model proposed that conditions of moderate ice cover are optimal for Adélie penguins and thereby responsible for decreases in populations at Anvers Island (ice cover and habitat quality decreasing) and increases in the Ross Sea (ice cover reducing and habitat quality increasing). This model may be insufficiently explicit generally and particularly so in respect of taking account of area-specific differences in population trends within Subareas 48.1 and 48.2, and in reflecting many current ideas on relationships between ice cover, krill spawning and survival, and prey availability to penguins.

6.39 The Working Group reiterated the need to develop appropriate ecosystem models for underpinning management decisions in CCAMLR. To that end, work to reduce uncertainties in these ecosystem models was encouraged. The Working Group also encouraged members who were attending the UK Workshop on Interannual Variability in the Physical Environment to pursue questions of relevance to CCAMLR and the development of these models. It noted that the Scientific Committee will be receiving a report from Drs J. Priddle and E. Murphy (UK) at its next meeting.

Fish and Squid-centred Interactions

6.40 WG-EMM-99/13 described the squid diet of southern elephant seals based on stomach lavage samples from 25 animals at King George Island, South Shetland Islands. It showed that the squid *Psychroteuthis glacialis* was the most common species in the samples obtained. However, the Working Group recognised the limitations with this type of study of diet in elephant seals. Stomach lavage samples may contain substantial biases. In comparison, WG-EMM-99/44 examined diet using fatty acid signatures in elephant seal milk, which is likely to provide a broader view of diet than stomach lavage. This showed that elephant seals did not feed on krill and that their most probable diet was fish or squid. There are limited reliable data concerning elephant seal diets.

6.41 WG-EMM-99/15 described a relationship between sea-surface temperatures in the southwest Atlantic and the activities of the vessels fishing for squid, *Illex argentinus*. The paper suggested that the southern area of the Falkland/Malvinas Current has been cooling in recent years and the eastern margin of the current fluctuated. The range of this species of squid varied with the movement of the boundary. This might have implications for Area 48 generally.

6.42 Dr Trathan informed the Working Group of a recent analysis of squid catches and sea-surface temperatures in the Falkland/Malvinas squid fishery that showed an inverse relationship between temperature in the area of spawning and catches in the following year.

ECOSYSTEM ASSESSMENT

7.1 The Working Group recollected the definition, from the first meeting of the Working Group in 1995 (SC-CAMLR-XIV, Annex 4, paragraph 2.13), of an ecosystem assessment:

(i) an analysis of the status of key biotic components of the ecosystem; and

(ii) a prediction of the likely consequences of alternative management actions on the future status of these components;

and noted the elaboration of the elements of this in SC-CAMLR-XIV, Annex 4, paragraphs 2.13 to 2.21. It noted that a conceptual framework of relevant components and interactions had been prepared (SC-CAMLR-XIV, Annex 4, Figure 1) in order to indicate the nature of the data and models that might be involved in comprehensive assessments.

7.2 Both at the 1995 meeting and subsequently, attempts were made to identify the nature and content of existing research, and to develop new initiatives as feasible, relevant to characterising or modelling the main interactions which might contribute to assessments.

7.3 Over recent years there has been considerable progress on a number of key initiatives. In many respects there are also now clearer ideas on the constraints imposed on assessments by limitations of data availability.

7.4 Encouraging progress has been made on characterising some of the main components essential to CCAMLR ecosystem assessment models, for example in improving the methods for estimating krill biomass and for combining indices of reproductive performance of dependent species. Areas of slower progress, however, have been in developing (or improving) indices of krill demography and indices of key environmental variables and processes at appropriate scales.

7.5 Although many substantial contributions have been made towards understanding interactions between components (or elements thereof), attempts to integrate these into models of potential relevance to generating management advice have essentially been confined to the topics of krill yield and functional relationships between krill and dependent species.

7.6 The krill yield model, despite limitations imposed by the difficulty of accurately characterising the mortality and recruitment variables, has allowed precautionary catch limits to be developed at a large (statistical area) scale. However, there still may be problems in applying this approach at smaller scales, including those of potentially greatest relevance to interactions between fisheries, dependent species and krill.

7.7 The relationships between prey availability and population dynamics of dependent species has been extensively explored using the best available data for the best-studied dependent species (Adélie penguin, black-browed albatross, Antarctic fur seal). Although some promising insights have been obtained, limitations in the data still preclude sufficiently accurate characterisation of the shape and dynamics of the functional relationships to develop clear advice on the magnitude of changes in prey availability that would produce specific changes in the population dynamics of dependent species.

7.8 Various conceptual models of potential interactions between environmental variables (e.g. sea-ice distribution and extent), krill reproduction and recruitment, and population changes in dependent species have been produced but quantification and testing of these are still at early stages.

7.9 It was recognised that almost all initiatives so far have focused on ecosystem interactions involving krill with little attention given to those involving fish and squid.

7.10 The Working Group noted that the Scientific Committee might wish to consider whether and in what form, action is necessary to improve assessment of ecosystem interactions involving fish and squid.

7.11 There was also a need to complement existing management advice for catch limits at large scales with advice on management at local scales.

7.12 Many tasks and initiatives have been developed as part of the Working Group's program over the last four years (SC-CAMLR-XIV, Annex 4, paragraph 8.2; SC-CAMLR-XV, Annex 4, paragraphs 7.58 and 7.59; WG-EMM-99/10). The current status of some of these is not always clear, particularly in respect of some of the earlier tasks. The Secretariat was requested to review the items listed under the agenda item on future work at and after the 1995 meeting and to provide some indication of the current status of these tasks. It was recognised that, in many cases, members of the Working Group would need to assist the Secretariat with this task.

7.13 The Working Group felt that it might also be appropriate to review the utility of some of the work (see paragraph 7.12) undertaken by WG-EMM in the context of the likelihood of developing timely management advice. It was agreed that this would best be carried out, if deemed appropriate, once the review of potential approaches to management involving precautionary principles (see paragraphs 7.43 to 7.62) had been completed.

Estimates of Potential Yield

7.14 In 1997 the Working Group recommended that revised estimates of potential yield of krill (and their use in calculations of precautionary catch limits) should be postponed until the results of the CCAMLR-2000 Survey became available (SC-CAMLR-XVI, Annex 4, paragraph 7.2). The Working Group reaffirmed this decision, noting that the survey was scheduled to take place in the forthcoming (1999/2000) season.

7.15 The Working Group recognised that advice needs to be given on a subdivision of the area-wide precautionary catch limit in order to identify the means by which the interaction between fisheries and predators remains at appropriate levels.

Precautionary Catch Limits

7.16 Precautionary catch limits for krill are currently enacted in Conservation Measures 32/X for Area 48, 45/XIV for Division 58.4.2 and 106/XV for Division 58.4.1. The Working Group recommended to the Scientific Committee that these conservation measures should remain in force as they stand, until the results of the CCAMLR-2000 Survey are available. The survey results will include revised estimates of stock biomass which will contribute to the revision of precautionary catch limits at least for Area 48. It was understood that unless relevant new data with which to revise γ are developed intersessionally, the only changes to the krill yield model will be the new estimates of stock biomass in Area 48.

Assessment of the Status of the Ecosystem

7.17 In developing its assessment of the status of the ecosystem at the present meeting, the Working Group relied primarily on the summaries of CEMP indices prepared by the Secretariat (WG-EMM-99/8) and on tabled papers presenting analyses of these and related data. As these latter papers were discussed extensively under earlier agenda items, only summaries of relevant conclusions are presented here.

7.18 It was noted that the presentation in WG-EMM-99/8 of the analysis of CEMP data was considerably enhanced since the 1998 compilation. The Secretariat and Data Manager were thanked for this and also for undertaking the substantial task of preparing this document so efficiently. The timely submission of data from Members is essential to this process and it was gratifying to note that almost all data for 1999 had been submitted for nearly all variables measured at all sites currently active.

7.19 The new format for summarising indices and anomalies was commended. However, it was noted that some additional consideration would need to be given to the presentation of the overall summary data in Figure 1 of WG-EMM-99/8 to take account of relationships between the number of variables monitored and the number of anomalies detected. Further work on identifying ecologically important values (EIVs) was still required, so the identification of anomalies throughout the figures in WG-EMM-99/8 should be regarded as very preliminary at this stage.

7.20 Given these considerations and that:

(i) an extensive review of these and related data had been presented to, and undertaken by, the Working Group in 1998 (particularly in the report of the Workshop on Area 48); and

(ii) detailed consideration of trends in populations of dependent species had been deferred until the WG-EMM meeting in 2000 when the SCAR report on status and trends of seabird populations would be available;

the Working Group agreed that the assessment this year should essentially be confined to observations relating to events in the current year (1999).

Area 48

7.21 In Subarea 48.1 the annual AMLR acoustic survey in the Elephant Island area produced an estimate of krill biomass that was the second lowest in the seven-year series. Krill were of older age classes and actively (and extensively) spawning early in the season. For this reason PCR is expected to be high in 2000, in contrast to the situation in the three preceding years. The low krill biomass in 1999 is consistent with predictions made last year (Brierley et al., 1999a) and enhances confidence in the prediction that values will be lower still in 2000.

7.22 Population sizes and breeding performance of penguins in Subarea 48.1 were indicative of an average year.

7.23 At South Georgia (Subarea 48.3) estimates of krill biomass from the annual survey were towards the lower end of values recorded in the last 20 years, albeit above the threshold (Brierley et al., 1999b) currently used to characterise years of abnormally low krill density. Krill were of large size and the absence of juveniles suggests that 2000 will also be a year of low krill density, consistent with predictions by Brierley et al. (1999a).

7.24 Krill-dependent penguins, albatrosses and fur seals at South Georgia showed population sizes and breeding performances characteristic of an average year.

7.25 The apparent paradox that, although krill biomass levels were relatively low in both Subareas 48.1 and 48.3 the performance of dependent species in these subareas was not worse than average, might be explained by some combination of:

(i) whereas krill abundance was relatively low in absolute terms, its availability was still adequate to sustain dependent species;

(ii) the krill available being large, providing predators with energy-dense prey and thereby enhancing their foraging efficiency;

(iii) functional relationships between prey availability and predator performance being unlikely to be linear;

(iv) lack of spatio-temporal congruence between krill surveys and foraging areas of dependent species from CEMP monitoring sites; and

(v) estimates of krill abundance from local surveys not fully representing krill availability to dependent species throughout their breeding season at relevant CEMP sites.

Division 58.4.2

7.26 At Béchervaise Island breeding success of Adélie penguins was significantly reduced compared to previous years (though nearly comparable to the year of breeding failure in 1995) and the duration and location of foraging supported suggestions that this was caused by reduced availability of krill. In 1994/95 the phenomenon was believed to be of local scale only but no data from adjacent areas were available for 1999.

Subarea 58.7

7.27 At Marion Island breeding population counts of gentoo and macaroni penguins indicated a normal year; breeding success for both species was the highest yet recorded in the five-year time series.

Subarea 88.1

7.28 Data from 1999 studies at Edmonson Point (WG-EMM-99/60) indicated that breeding population size and reproductive performance were typical of those over the last five years.

Consideration of Information relevant to Ecosystem Assessment

7.29 Under this agenda item the Working Group felt that next year it might be useful to include consideration of information under five subitems, viz:

(i) status and trends of resources;
(ii) status and trends of dependent species;
(iii) status and trends of environmental variables;
(iv) status and trends of fisheries; and
(v) interactions between environment, resources, dependent species and fisheries.

Wherever possible, it would also be helpful to consider predictions based on the analysis of status, trends and interactions.

7.30 Although formal consideration of fishery-derived data has not previously been undertaken under this agenda item, the Working Group last year requested that fishery-dependent indices related to krill availability, such as CPUE, should be incorporated into these assessments (SC-CAMLR-XVII, Annex 4, paragraph 8.4). However, it was felt that some other indicators, including those relating to the economics of the fishery, might also be relevant (see also paragraphs 2.10, 7.66 and 7.67). Members were asked to consider intersessionally which indices might be relevant and to prepare suggestions and/or data on these to facilitate a detailed discussion at next year's meeting. It was noted that the recent review by

Nicol and Endo (1999) might be a useful source of relevant ideas, as might various papers to be published in the forthcoming proceedings of the 1995 Vancouver symposium (Pitcher and Chuenpagdee, 1995).

Use of CEMP Indices to provide Management Advice

7.31 The development of CSIs provides new opportunities for examining time-series data in the context of detecting trends, changes, patterns and relationships that may be relevant to the formulation of management advice (SC-CAMLR-XVI, Annex 4, paragraphs 6.6 to 6.8).

7.32 WG-EMM-99/40 provided recent examples relevant to two potential approaches. One approach (illustrated by reference to WG-EMM-99/40, Figure 3b) relates to the potential use of EIVs, defined by different probability levels, to provide information on trends or changes in frequency of such events (especially of years when low krill availability had clear negative effects on dependent species).

7.33 The other approach (illustrated by reference to WG-EMM-99/40, Figure 5a) involves relating the CSI to krill abundance. WG-EMM-99/40 noted that this has the potential of defining reference points and/or management targets for the system; purely illustrative examples of this could be keeping the CSI above zero or krill biomass above 20 gm^{-2} for the system.

7.34 Further development of these indices and relationships is required before they can be implemented fully. These indices could be related to krill abundance and used to adjust fishery catch levels in feedback management procedures. The development of such procedures will assist in ensuring that ecosystem values are protected from the effects of fishing in an expanding krill fishery.

7.35 The Working Group encouraged further development of these approaches, particularly in relation to feedback management procedures and reference points. It noted the importance of developing CSIs which would reflect system variability at other times of year (e.g. winter) and at longer temporal (and probably spatial) scales, for instance involving demographic variables, including population size.

7.36 Other areas of important future work could usefully include:

(i) investigation of the sensitivity of CSIs to the inclusion/exclusion of specific variables;

(ii) consequences for CSIs of incorporating variables with statistically significant trends across time (especially relevant to population size); and

(iii) refinement of the identification of EIVs and investigation of relationships between statistically and ecologically significant anomalies.

7.37 Dr Trivelpiece noted that predator variables and CSIs showed much greater interannual variation at South Georgia than at the South Shetland Islands, despite apparently similar magnitudes of fluctuation in krill abundance in the two areas. The basis for such area-specific effects needs investigation, particularly in respect of the size of predator populations in relation to both krill abundance and krill availability (including consideration of flux/replenishment rates).

7.38 The Working Group stressed the importance of comparing CSIs and estimates of krill abundance at equivalent spatio-temporal scales. Prof. Boyd indicated that this was indeed the case with the data used in WG-EMM-99/40.

7.39 The krill fishery is considered to be at a low level but may expand in the near future. Consequently, further elaboration of how to incorporate predator information in a management framework is required quickly in order that the effects of krill fishing on predators can be appropriately monitored. The Working Group noted that one option for achieving this work in the near future may be to arrange a consultancy with appropriate experts in this field. The Working Group agreed that such an option is not required at this stage but that it may be worth considering at the next meeting if insufficient work is undertaken in the interim.

Use of Models to provide Management Advice

7.40 The identification of potential cycles in abundance of krill in Area 48 (e.g. Brierley et al., 1999a; WG-EMM-99/37) might create an opportunity for adjustment of precautionary catch levels in respect of appropriate predictions of future patterns of abundance. A not dissimilar approach is already undertaken by WG-FSA in respect of using survey data for *C. gunnari* to set catch limits for the following two years. Such a procedure could also derive from the approaches discussed in paragraph 7.32.

7.41 The methods for adjusting catch limits in the short term need to be evaluated using the approaches developed by Butterworth, de la Mare and others in the late 1980s and synthesised at the joint WG-Krill and WG-CEMP meeting in Viña del Mar, Chile, in 1992 (SC-CAMLR-XI, Annex 8). The Working Group encouraged the further exploration, development and testing of models which offer the ability to ensure precautionary management approaches which are robust and effective.

7.42 Such work, however, is likely to be very time consuming and will need to be complemented in the interim by other approaches for developing effective feedback management, especially at local scales.

Considerations with respect to Precautionary Approaches

7.43 In considering precautionary approaches to management, Dr Miller drew attention to the Commission's expressed views on the relationship between management decisions and the nature and quality of scientific evidence and advice (CCAMLR-IX, paragraphs 7.6 and 7.7) and its view on the precautionary approach, specifically in relationship to the krill fishery (CCAMLR-X, paragraph 6.13).

7.44 In the first case the Commission noted that management decisions may be required when the Scientific Committee has been unable to formulate advice, even on the basis of the 'best scientific evidence available'. The Commission 'endorsed the principle that in the absence of essential data, very conservative catch limits should be set' (CCAMLR-IX, paragraph 7.7).

7.45 In the second case the Commission 'endorsed the advice of the Scientific Committee that reactive management … is not a viable long-term strategy for the krill fishery. Some form of feedback management … is preferred as a long-term strategy. In the interim, a precautionary approach is desirable and in particular a precautionary limit on annual catches should be considered' (CCAMLR-X, paragraph 6.13).

Uncertainty

7.46 Dr Constable gave a brief introduction to the krill yield model which had been developed specifically to take account of uncertainty with respect to decision rules for management.

7.47 The krill yield model is a simulation model that is used to find the proportion of a biomass estimate for setting precautionary catch limits. This proportion is known as γ and is chosen on the basis of the CCAMLR decision rules for precautionary catch limits, which are explained in SC-CAMLR-XIII, Annex 5, paragraph 4.98 and summarised in SC-CAMLR-XIV, Annex 4, paragraph 4.55. The model underpinning the simulations is an age-structured population model relying on functions of recruitment, natural mortality, growth and fishing mortality. The simulations generate many stock trajectories within the bounds of uncertainties associated with the four functions as well as uncertainties in the estimates of biomass. In the latter case, uncertainty as to whether the biomass is higher or lower than the pre-exploitation median is incorporated in the simulation. For a specific value of γ, the probability of the stock becoming depleted to a specified level is determined using these simulations. Similarly, the expected change in the median biomass in the long term is also determined. γ is reduced in cases when the stock is likely naturally to fall to levels lower than the level of critical depletion defined by the decision rule. Specific models of the different population functions, as well as the relationship of the biomass estimate to the pre-exploitation median, can be included in the simulations using the Generalised Yield Model (GYM).

7.48 The krill yield model as developed by 1995 had particular potential difficulty in dealing with estimating precautionary catch limits at smaller scales (SC-CAMLR-XIV, Annex 4, paragraph 7.40). The development of the GYM allows more flexibility in the input functions, such as recruitment and mortality. These functions can be specially written and incorporated within the general structure of the population model. Consequently, it may be possible to incorporate simple models of advection by adjusting the mortality function based on recent research that quantifies these parameters. In addition, there is the prospect of tuning estimates of B_0 using time-series data.

7.49 It was recognised that in the formulation of the GYM there were still significant opportunities for improving the model, particularly in sensitive areas such as the estimation of recruitment and mortality. It was agreed to re-investigate the potential for incorporating age-structured mortality based on approaches developed by WG-EMM between 1994 and 1996 (see SC-CAMLR-XIV, Annex 4, paragraphs 5.114 to 5.118). Prof. Boyd and Dr Constable agreed to correspond with Prof. D. Butterworth (South Africa) and to coordinate any further work, including the conduct of any simulations, as necessary or appropriate.

7.50 Applying the GYM to krill is only one of the management approaches that are being, or need to be, developed by the Working Group to contribute to the management objectives of the Commission. It does, however, have the advantage of taking explicit account of uncertainty and relating this to clearly defined decision rules.

7.51 Various other potential models were considered in paragraphs 7.31 to 7.41. In addition, the Working Group has tried to develop models based on estimation of krill consumption by dependent species, on the basis that surplus biomass, after meeting the requirements of dependent species, could be made available for harvesting. These initiatives were based on models suggested by Drs Everson and de la Mare in 1995 (SC-CAMLR-XIV, Annex 4, paragraphs 7.61 to 7.80 and Appendix H); a subgroup was established in 1995 to further develop this work.

7.52 The Working Group recommended that further consideration be given to this initiative, especially in collaboration with similar work being undertaken by Drs Constable and Nicol. A review of existing work and explicit proposals for new work should be solicited intersessionally; Prof. Boyd and Dr Everson, the coordinators of the original subgroup, would liaise with Dr Constable to achieve this.

7.53 It was re-emphasised that many of these models were complementary to the approach of the krill yield model/GYM but that significant progress on them would be unlikely to yield prospects of complementary management advice in the near future. There was still a need to identify mechanisms for providing proactive management advice, in timely fashion, in particular to deal with the scales at which fisheries, dependent species and krill overlapped.

7.54 Dr Miller introduced the topic of what levels of confidence should be considered in the formulation and testing of hypotheses relating to management advice and the concurrent assessment of risk. It was agreed that this was a complex topic, that levels of confidence should be attached to results wherever possible and that decisions on appropriate levels of confidence for decision rules and management advice would relate to the nature of the questions being asked and the potential consequences of error. A particular consideration would always be the application of the precautionary principle in respect of the risk of taking no management action when some action is required.

Ecosystem Variability

7.55 Various aspects of this topic, especially relating to predicting patterns of variability, were discussed in previous sections. One topic not so far explicitly addressed relates to the nature of temporal and spatial variability in the distribution of krill and dependent species and of the interactions between both of these with the krill fisheries.

7.56 Three key issues (themselves interlinked) were identified:

(i) the problems involved in scaling up (extrapolating) to larger scales using data collected at smaller scales;

(ii) the allocation of catch limits at scales smaller than statistical areas (i.e. how limits estimated at or for large areas are divided for application to smaller areas); and

(iii) avoidance of localised effects of krill fishing, especially in relation to potential adverse effects on dependent species.

7.57 This last issue has been a major topic of discussion for much of the last decade but although important reviews of potential management approaches (e.g. Watters and Hewitt, 1992) had been produced and various indices for measuring overlap developed (paragraph 6.9), little effective progress in translating these into precautionary management advice had been made.

7.58 Until approaches based on catch limits are developed to the point where management advice at all appropriate spatio-temporal scales can be produced, evaluated and implemented, other complementary approaches may be needed.

7.59 In this respect the Scientific Committee had recently (SC-CAMLR-XVII, paragraph 6.12) recommended further development of models involving fishery–predator–krill interrelationships (especially developing from models of Mangel and Switzer, 1998) and functional relationships (e.g. Butterworth and Thomson, 1995).

7.60 In addition, the Scientific Committee had recommended the continued investigation of the consequences of various types of conservation measure associated with precautionary approaches to management in local areas such as those described in paragraph 7.56(iii) (SC-CAMLR-XVII, paragraph 6.12). Potential measures to be considered would presumably include closed seasons and closed areas. Effective evaluation of these would require exploring with fishers and fishery managers the manner in which fishing practice could be modified in local areas important to predators (see SC-CAMLR-XII, paragraphs 6.65 to 6.69; CCAMLR-X, paragraphs 8.39 to 8.45).

7.61 As a precautionary approach it would be particularly important to identify potential changes to fishing areas and seasons that would impose no additional burden on fishing operations but which would yield clearly perceived conservation benefit for dependent species.

7.62 The Working Group agreed that this whole topic was a priority area for future work and for closer dialogue with Members involved in relevant fishing activities. The Working Group would monitor developments at both practical and theoretical levels in order to determine when it might be appropriate to undertake an in-depth evaluation and analysis of the nature, merits and feasibilities of the various potential approaches to providing interim advice on precautionary management at local scales.

Fishery Development Potential

7.63 The Commission desires to develop and maintain feedback management arrangements, including application of precautionary principles and proactive, rather than reactive, management. This includes the development of ways of preventing uncontrolled expansion and/or development of fisheries.

7.64 In the case of finfish fisheries, WG-FSA and the Scientific Committee have assisted the Commission in developing a suite of conservation measures governing the conduct of new and developing fisheries.

7.65 For krill, however, the conservation measures currently in force generally do not have measures to reduce risks of effects of fishing at the scale most critical to predator feeding. There are currently no mechanisms for preventing uncontrolled development of fishing at these scales, whether in terms of increased catches, or changes in intensity, whether by season or area.

7.66 Three approaches were identified which might assist in developing appropriate measures:

(i) consideration of the various potential changes in fishing practice which might need regulation and for which reference points might be developed in order to trigger appropriate management action;

(ii) acquisition and analysis of various economic indicators relating to the krill fishery and its products (e.g. trend analysis of product costs); and

(iii) better understanding of certain aspects of current krill fishing operations.

7.67 In relation to paragraph 7.66(i) and (ii), members were asked to provide any relevant information and/or ideas so that a more detailed discussion might take place at the next WG-EMM meeting (see also paragraph 7.30).

7.68 In respect of paragraph 7.66(iii), it was suggested that it might be timely to acquire some of the more important data (e.g. on fishing effort and search time) via scientific observers on krill fishing vessels.

7.69 Dr R. Holt (USA) recollected that Japan had provided considerable relevant data over many years and that a bilateral scientific observer arrangement between the USA and Japan had been particularly valuable in acquiring important insights. Nevertheless, the Working Group recognised that it had still proved difficult to obtain certain potentially sensitive information, including topics relating to fishing pattern and effort.

7.70 The Working Group reiterated its appreciation of the contributions by Japan and stressed that it hoped – and needed – to acquire data on fishing operations from all Members engaged in krill fishing. Particular opportunities were recognised in respect of Members newly participating in krill fishing.

7.71 The Working Group recommended to the Scientific Committee that the use of scientific observers on krill fishing vessels be encouraged and implemented as a matter of general importance.

7.72 The Working Group reiterated the considerable additional value from scientific observers collecting data on fishing operations at the same time as the CCAMLR-2000 Survey was being carried out (paragraph 2.15).

7.73 In view of the short time available before the start of the CCAMLR-2000 Survey, however, the Working Group encouraged Members to make appropriate bilateral arrangements as soon as possible. This would be facilitated by the ability to access the WG-EMM report rapidly via the CCAMLR website.

Globally Threatened Species

7.74 Prof. Croxall indicated that the next IUCN global review of threatened species would be published in about October 2000. In addition to being the most rigorous application yet of the new (1994) criteria (decision rules) for identifying and classifying threatened species, it is likely to be the first time that species (except for the wandering albatross) whose main populations lie within the Convention Area are included.

7.75 Several species are likely to be classified as globally threatened on the basis of criteria that include reference to substantial known or probable population decreases. Some of these species have demographies whereby these decreases are unlikely to be redressed over one or more decades.

7.76 Given that the CCAMLR Convention makes explicit reference to potential action in respect of changes which are unlikely to be reversible over 20 to 30 years (Article II, paragraph 3), the Commission may need to consider actions to improve (or avoid further jeopardy to) the conservation status of such species.

7.77 Members expressed interest in the details of the IUCN criteria and of the process leading to the publication of the new list. The Secretariat agreed to investigate this and notify Members as to how such information could be obtained.

7.78 It was noted that such information should also be relayed to WG-FSA, given that some Antarctic fish species might be candidates for globally threatened status under the new criteria.

Global Change

7.79 Discussion focused on the need to differentiate between the effects of fishing and the effects of environmental change on relevant resources, dependent species and interactions between them. The detection, evaluation and understanding of existing and potential environmental change is a complex but important topic, relating both to systematic change and to periodic fluctuations. In both cases it may be necessary to assess the potential effects of environmental change on marine system production and to revise or re-evaluate management approaches and measures.

7.80 The Working Group had discussed earlier three papers (WG-EMM-99/24, 99/52 and 99/58) that illustrate potential mechanisms by which environmental change could exert significant influence on the population dynamics of krill and dependent species (see paragraphs 5.5 to 5.7, 6.37 and 6.38).

7.81 The Working Group encouraged further research on methods that would help distinguish the effects of fishing from the effects of environmental change given the large degree of uncertainties in both these areas.

Concluding Remarks

7.82 No precautionary catch measures for krill have yet been agreed at anything other than the largest scales. Limited progress has been made in agreeing on precautionary approaches for management in respect of the spatio-temporal scales of greatest importance to regulating interactions between krill, dependent species and fisheries.

7.83 Using the approaches of the krill yield model (and other models as appropriate) to provide advice on precautionary catch limits, at least at the smaller scales, is an urgent priority.

7.84 Complementary approaches, involving all types of precautionary management measures potentially appropriate to the scales indicated in paragraph 7.82, need priority attention. These measures should be designed to help deliver precautionary management conferring potential benefits on krill stocks and on dependent species without undue restriction on the performance of krill fisheries.

METHODS AND PROGRAMS INVOLVING STUDIES ON HARVESTED AND DEPENDENT SPECIES AND THE ENVIRONMENT

Area 48 Synoptic Krill Survey (CCAMLR-2000 Survey)

Survey Design

8.1 The report of the CCAMLR Synoptic Survey Planning Meeting held at the British Antarctic Survey, Cambridge, UK, from 8 to 12 March 1999, is presented in WG-EMM-99/7 (attached to this report as Appendix D). The report provides detailed information on the following aspects of the survey:

(i) proposed survey design, including contingencies to cover losses due to bad weather;

(ii) principal participating nations plus those that have expressed an interest in the survey;

(iii) the development of primary protocols to cover acoustic, net and CTD sampling;

(iv) the development of secondary protocols to cover the collection of other multinational datasets; and

(v) implications for data analysis and archiving.

The Working Group endorsed the work of the planning meeting and the conclusions reached in Appendix D.

8.2 WG-EMM-99/39 (attached to this report as Appendix E) presented details of the rationale and procedures undertaken subsequent to the planning meeting to produce the final randomised, stratified transects and provisional sampling stations for the three principal participating nations. Figures within the paper provide details of the cruise tracks in relation to locations of the major fronts, commercial fishery and subarea boundaries and also the provisional locations of the net sampling stations.

8.3 The Working Group joined the Chairman of the Scientific Committee in thanking all those involved in the detailed and thorough planning of the CCAMLR-2000 Survey. In particular, a debt of gratitude was placed on record for the efforts of the principal scientists on the three vessels involved in the survey (Drs Hewitt, M. Naganobu (Japan) and Watkins), the producers of the survey plan (Drs Trathan, Watkins and Mr A. Murray (UK)) and Dr Watkins for convening the CCAMLR Synoptic Survey Planning Meeting in March 1999. It was recognised that the enthusiasm, dedication and hard work of such key participants had served to develop an excellent survey plan.

8.4 WG-EMM-99/43 presented details of a proposal by Russia to undertake a survey in Subarea 48.4 as an integral part of the CCAMLR-2000 Survey. It was reported that there is very little survey data available for this subarea, but commercial catches have been taken around the South Sandwich Islands in a number of years. Russia therefore proposed that a stratified survey of Subarea 48.4, based on the design principles outlined in WG-EMM-99/39, would be carried out in conjunction with a survey of the mesoscale stratum in Subarea 48.2.

8.5 The Working Group noted that a protocol for including any surveys in addition to those undertaken by the principal participating nations had been put forward at the planning meeting. It had been agreed that any such additional surveys should be replicates of the principal survey tracks and a suggested order for these replicates was provided in WG-EMM-99/39 (Appendix E) and posted on the CCAMLR-2000 Survey website.

8.6 Despite the above recommendation, the Working Group agreed that the Russian proposal would result in an enhanced survey of krill in Area 48 for the following reasons. Firstly, because commercial krill fishing had taken place in Subarea 48.4 and secondly, because this subarea could be considered as a direct extension of Subareas 48.2 and 48.3, so was likely to contain the same krill population. The Working Group therefore agreed that the Russian proposal be accepted, subject to the following conditions:

(i) Drs Trathan and Watkins and Mr Murray will produce a survey design to provide broad-area coverage in Subarea 48.4 and mesoscale coverage along the northeastern side of the South Sandwich Islands in a similar fashion to existing survey designs for Subareas 48.1, 48.2 and 48.3;

(ii) the mesoscale survey planned for the shelf area north of the South Orkney Islands be an exact replicate of the existing survey trackline for ship number 2;

(iii) acoustic sampling should be conducted with a Simrad EK500 echosounder operating at three frequencies (38, 120 and 200 kHz) and that data be collected using the SonarData EchoLog software;

(iv) ping-by-ping acoustic data shall be made available to the data analysis workshop to be held in May–June 2000 (paragraph 8.37). In addition, it would be preferable for one or more of the persons responsible for collecting the data to attend;

(v) net sampling for krill and other micro-nekton shall be accomplished with an RMT8 net and, if possible, zooplankton shall be sampled simultaneously with an RMT1 net;

(vi) all general protocols for core measurements (acoustic, net sampling, CTD protocols shown on the CCAMLR-2000 Survey website) should be followed; and

(vii) a progress report detailing the survey plan development and compliance with the above protocols should be submitted to the 1999 meeting of the Scientific Committee.

Sampling Protocols

Acoustic

8.7 In relation to the CCAMLR-2000 Survey, the data requirements of three TS estimation methods were considered: (i) the Greene et al. (1990) linear TS versus length relationship adopted by SC-CAMLR-X (GTS) (WG-Krill-90/29); (ii) the multiple-frequency method for *in situ* TS measurements (MFTS) (WG-EMM-99/38); and (iii) the distorted wave Born approximation model (DWBA) (WG-EMM-99/41). The GTS requires knowledge of krill lengths. The MFTS requires split-beam TS measurements at multiple frequencies and sufficiently dispersed krill to allow individual krill to be acoustically resolved. Application of the DWBA requires characterisation of krill densities, sound speeds, sizes, shapes, and orientations (or broadband measurements from which to infer orientation distributions) (WG-EMM-99/42). All three methods require a krill weight-to-length relationship for converting numerical abundance to density units (gm^{-3}). Although the DWBA explicitly accounts for the many variables primarily influencing acoustic backscattering from krill, their distributions are not easily characterised. Therefore the relatively minimal data requirements of the GTS and MFTS make them currently the most tractable methods for scaling the echo integration results of the CCAMLR-2000 Survey.

8.8 The MFTS improves the rejection of unresolvable and constructively interfering target multiples by combining synchronised signals from two or more adjacent split-beam transducers of different frequencies which are not integer multiples of each other. In WG-EMM-99/38 the method itself was improved by: (i) optimising the accuracy and precision of the angular and range measurements of the individual frequency detections; (ii) more precisely determining the relative three-dimensional locations (x, y, and z) and angular orientations (pan and tilt) of the transducers and thus the positional transformation; and (iii) increasing the range resolution of one or more of the frequencies. Tank tests indicated that such careful application of the MFTS method can reject all multiple targets while allowing 90% of the resolvable single targets to be measured.

8.9 Customised EK500 Control Processor EPROMs (firmware V5.3) have been created to allow 1.0 ms pulse durations at 200 kHz, equivalent to prescribed durations at both 38 and 120 kHz. Programmed and authorised by Mr Solli of Simrad, Norway, these EPROMs were duplicated by Mr Soule (South Africa) and distributed to Japan, UK and USA. Pending confirmation that RV *Atlantida* is outfitted with an EK500 configured to operate at 38, 120 and 200 kHz, an additional EPROM will be created and provided by Dr D. Demer (USA) to AtlantNIRO, Kaliningrad, Russia.

8.10 The Acoustic Protocols prescribe the usage of transducer beamwidths as characterised on the manufacturer's specification sheets and adjusted for the mean sound speed of Area 48 (see paragraph 8.11). Dr Demer will provide a conversion table for beam width versus sound speed which will be posted on the CCAMLR-2000 Survey website as Appendix D of the Acoustic Protocols.

8.11 The Acoustic Protocols prescribe the common usage of a mean sound-speed profile and mean absorption coefficients at 38, 120 and 200 kHz which are representative of Area 48 (Acoustic Protocols, Appendix E). To derive these mean values, Drs A. Brierley (UK) and Demer have been asked to gather, summarise and convert representative temperature and salinity versus depth data (0–500 m) from past surveys of the area. With this strategy, errors in the estimate of krill biomass resulting from estimates of the time-varying gain function can be most easily quantified and/or corrected after the survey.

8.12 Calibration spheres of 38.1 mm tungsten carbide with spark eroded holes and monofilament tethers, all manufactured with high precision from a single manufacturing lot, will be distributed by Dr Demer. Navigational and mooring information pertaining to the calibration sites at both Stromness Bay, South Georgia and Admiralty Bay, King George Island, will be provided by Drs Watkins and Hewitt. Local arrangements at South Georgia are to be organised by Dr Watkins.

8.13 Inter-ship comparisons of the acoustic system performance are to be conducted after both the initial and final standard sphere calibrations. The two short acoustic transects, located in the vicinity of Stromness Bay, South Georgia and Admiralty Bay, King George Island, will be defined by Drs Watkins and Hewitt and detailed in Appendix F of the Acoustic Protocols. The details of the shallow-water transect will include start and stop locations, ship speed and local navigational information.

8.14 Members have agreed to report any anticipated exceptions to the recommended and/or prescribed Acoustic Protocols to Dr Watkins who will tabulate them in Appendix G.

8.15 On completion of bench and field testing of the Acoustic Protocols by Drs Brierley, Demer and T. Pauly (Australia), the parameter lists for the survey (Acoustic Protocols, Appendix A), calibrations (Acoustic Protocols, Appendix B), and noise measurements (Acoustic Protocols, Appendix C) will be written to CD and copies will be distributed by Dr Demer. It was recognised that current testing of the parameters may identify the need to modify one or more of the parameters and any modifications would be reflected in the Acoustic Protocols on the website.

8.16 WG-EMM-99/18 highlighted the relationship of ambient noise perceived by the echosounder versus frequency, ship speed and ship type. Not mentioned are the appreciable effects of transducer deployment configuration (e.g. hull-mounting: flush, blister or retractable keel; or towed-body) and beam width.

8.17 It was agreed that the current prescription for characterising system noise in the Acoustic Protocols was sufficiently comprehensive. Measurements of ambient noise at each frequency are to be made at the conclusion of each day's acoustic survey effort under survey course and speed. Characterisation of system noise versus all vessel speeds was considered unnecessary, as appreciably slower speeds are impractical for completion of the current survey design in the allotted timeframe.

8.18 Concern was raised over the plan to perform daily data backup to writeable CDs concurrent with continuous data logging. To avoid any potential problems with such a data backup procedure, it was decided that the daily data backup would be conducted on workstation No. 2 and that data logging to workstation No. 2 would be temporarily halted during the backup procedures. Then, immediately upon completion of the backup procedures, logging on workstation No. 2 would be restarted and the data file(s) recorded during the backup procedure would be copied from workstation No. 1 to workstation No. 2.

Krill and Zooplankton

8.19 The Working Group discussed the net sampling protocols established during the CCAMLR Synoptic Survey Planning Meeting which had been made available on the CCAMLR-2000 Survey website for Members' consideration. The two objectives of the net sampling program were reiterated:

(i) to validate acoustic targets and obtain length-frequency data for TS estimation by target net hauls; and

(ii) to describe krill demography, large-scale distribution of size classes and regional recruitment indices from random double-oblique net hauls.

8.20 The Working Group re-examined the proposal for the use of different types of gear during the survey. It welcomed the effort that has been undertaken to equip every vessel participating in the survey with RMT8+1 nets and agreed that only this type of net shall be used as standard gear for target and random hauls. Alternative gear such as IKMT nets of a similar size to the RMT8 shall only be used when the RMT system is lost or damaged to a degree that no spare parts are available to effect repair. To date it has not been possible to clarify which net system will be used on the Russian survey vessel because the proposal (WG-EMM-99/43) does not specify the equipment precisely.

8.21 Some additional comments have to be included in the subsampling and preservation sections of the net sampling protocol, however, these are of minor explanatory nature and will not change the agreed substance of the protocol. These changes will be carried out by Drs Watkins and Siegel and included in the text on the website.

8.22 The protocols for random oblique and target hauls were reviewed. It was confirmed that random oblique tows shall be carried out during night time, while target hauls will be restricted to daytime. However, in contrast to the proposal put forward at the planning meeting in March, it was agreed that ships that do not have an opening and closing net shall carry out only day and night-time random oblique tows whereas those vessels that have an opening/closing net shall carry out random night tows and target daytime tows.

8.23 The Working Group noted the necessity to develop standardised data reporting formats to allow a minimum data collection by all participants. Dr Siegel will develop the required zooplankton and krill data sheets and send them to participating Members so that comments and changes can be made prior to the Scientific Committee meeting in October.

8.24 Participants in the survey were reminded that in case of delays during the CCAMLR-2000 Survey due to equipment failure or bad weather, the instructions that are clearly set out in WG-EMM-99/39 (page 7) should be followed.

Birds, Pinnipeds and Whales

8.25 The Working Group recognised the importance of the collaboration between CCAMLR and IWC, and agreed that priority be given to the collection of consistent marine mammal observations across participating vessels. Consistent methodology, and selection of observers, for cetacean observations will be coordinated by the IWC. IWC observers will collect data on all marine mammals.

8.26 The Working Group recommended that all bird observations should be made using one of the two primary methods available (i.e. vector correction or snapshot), and noted that these quantitative methods are to be used in preference to the BIOMASS protocol. It was recognised that the choice of methods would depend on the number and experience of the observers on each vessel.

8.27 The current situation with regard to proposed levels of participation was outlined.

> USA – six places consisting of six marine mammal observers with seabird observations to be conducted on an ad hoc basis.
>
> UK – six places consisting of four marine mammal observers and two dedicated seabird observers.
>
> Japan – three places consisting of two marine mammal observers (provisional) and one dedicated seabird observer.

8.28 IWC data collection methods dictate the need for a minimum of two dedicated observers on a vessel, as determined by the SOWER 2000 workshop and confirmed at the IWC Scientific Committee meeting in May 1999. Therefore, if only one place was available on any vessel, that place will not be taken up.

8.29 The IWC would welcome the opportunity to place a minimum of two observers on both the Japanese and Russian vessels. However, financial support for this has yet to be finalised and, if funding is limited, it may be more effective to concentrate IWC effort on just some of the four survey vessels now participating.

8.30 WG-EMM-99/33 presented a proposal to coordinate diet sampling of Antarctic fur seals at shore sites in Subareas 48.1, 48.2 and 48.3 to coincide with the areas of intensive sampling within the CCAMLR-2000 Survey. The aim of this diet study is to assess the level of concordance between krill sampled from predator diets and scientific nets at different locations, and to compare within-season trends in the local krill population with the regional population structure resulting from the CCAMLR-2000 Survey.

8.31 In recognising the importance of this study in relation to the CCAMLR-2000 Survey, the Working Group noted that data would also be available from diet samples from penguins across a similar range of sites.

Organisation of the CCAMLR-2000 Survey

8.32 Cruise leaders for Japan, UK and USA, along with other interested parties, met to discuss organisational details regarding the conduct of the CCAMLR-2000 Survey. Topics for discussion included timetables, invited participants and exchange of personnel between ships, coordination of the survey during its conduct, data analysis workshops, consideration of additional survey effort in the South Shetland Islands between December 1999 and March 2000, and publication of results.

8.33 With regard to timetables, it was noted that ship schedules currently published on the CCAMLR-2000 Survey website for the US survey vessel and in WG-EMM-99/43 for the Russian survey vessel, were subject to slight change pending ongoing developments in each country. It was noted however, that the current schedules call for both survey vessels to be conducting the mesoscale survey north of the South Orkney Islands at approximately the same time. It was also noted that the schedule for the Japanese survey vessel, currently posted on the website, needs to be updated to reflect current plans, and that the schedule for the UK survey vessel is set but may vary by one to two days in response to unexpected external factors.

8.34 It was re-emphasised that all planning and reporting times are expressed in GMT. Dr Watkins demonstrated the use of a spreadsheet listing transect waypoints and sampling stations for three of the survey vessels. Such a spreadsheet can be used to track progress and project actions that may be required to assure complete survey coverage. The spreadsheet may also be used to adjust schedules for changes in start dates, weather contingencies and other unexpected events. The spreadsheet was enthusiastically received by the cruise leaders and Dr Watkins was asked to distribute an updated version, including schedules for the Russian survey vessel.

8.35 With regard to invited participants and exchange of personnel between survey ships, it was recognised that such exchanges would add considerably to the value of the survey as well as ensure that similar methods were employed in the data collection activities conducted aboard all of the survey vessels. Several possible participants and exchange opportunities were identified and tentative arrangements made. It was recommended that cruise leaders continue to actively pursue such opportunities.

8.36 With regard to coordination of the survey during its conduct, it was agreed that daily contact be maintained between the survey vessels. As a minimum, an evening radio schedule will be maintained by all participating ships; ancillary forms of communication include voice, facsimile and email via INMARSAT satellite links. It was agreed that vessel telephone numbers and email addresses would be exchanged between cruise leaders. It was further agreed that Dr Watkins would continue to act as survey coordinator during the conduct of the cruise, and that daily position reports would be forwarded to him so that he could track overall progress and recommend adjustments to each cruise leader if necessary.

8.37 The Working Group recommended that a two-week data analysis workshop be held in La Jolla, USA, sometime during May–June 2000 with the intention of estimating B_0 and its variance for Area 48 (hereafter referred to as the B_0 Workshop). The Working Group also recommended that all core datasets to be considered at this workshop be submitted to Dr Hewitt in electronic format no later than one month prior to the workshop so that they can be posted on a data server and linked to the CCAMLR-2000 Survey website with secure access. In this manner, all contributors will have access to the common datasets for the purposes of validation and cross-checking prior to the workshop. It was also recommended that ancillary datasets, which may assist in the interpretation of the core datasets, be submitted in summary form ahead of the workshop.

8.38 It was recognised that the B_0 Workshop will likely be the first of several workshops and collaborations making use of various datasets collected during the survey. It was again re-affirmed that the analysis of core datasets (acoustics, krill demographic samples and CTD data) shall be conducted in a cooperative and collaborative fashion.

8.39 With regard to additional surveys to be conducted along the mesoscale transects in the area north of the South Shetland Islands as part of the Subgroup on International Coordination (see paragraphs 3.42 and 3.43), it was agreed to treat these data as ancillary information rather than replicates as will be the case with the conduct of mesoscale survey transects north of the South Orkney Islands by the Russian and US survey vessels.

8.40 With regard to publishing various papers describing the survey plans and results, the Working Group recommended that consideration be given to a special issue of *CCAMLR Science* in 2001. This consideration should not preclude, however, the option of publishing a limited number of papers in the regular issue of *CCAMLR Science* or any other venue deemed appropriate by the survey participants.

Analytical Methods

8.41 The following analytical procedures were considered to be the key steps in the production of an estimate of B_0 from acoustic data:

(i) apportionment of volume backscattering strength (S_v) to that from krill ($S_{v\ krill}$) and all other biological scatterers;

(ii) conversion of $S_{v\ krill}$ to volumetric biomass density of krill;

(iii) summation of biomass density over the survey area; and

(iv) estimation of uncertainty.

8.42 It was further recognised that some analytical work could be conducted in advance of the B_0 Workshop. Such analyses would serve to refine the methods employed to accomplish the above procedures and could greatly contribute to the efficiency and productivity of the workshop.

8.43 With regard to the apportionment of volume backscattering strength it was recognised that at least two methods were available. Both methods take advantage of frequency-specific acoustic signatures of krill. The first method uses data collected at 38 and 120 kHz (Madureira et al., 1993) and the second method uses data collected at all three frequencies (Demer et al., 1999). Analytical work that could be accomplished in advance of the workshop includes the specific definition of multifrequency classifications, the definition of cell sizes (in both horizontal and vertical dimensions) over which volume backscattering data is to be averaged, and the development of software scripts required to accomplish this task for large datasets.

8.44 With regard to converting volume backscattering strength to volumetric krill biomass density, it was recognised that at least two methods were available. The first method uses a distribution of krill body lengths to estimate a distribution of target strengths which is then divided into volume backscattering strength in order to estimate density (Greene et al., 1991; Hewitt and Demer, 1993). The second method employs direct *in situ* measurements of volume backscattering strength (Demer et al., 1999). Both methods assume a krill length–weight relationship. Analytical work that could be accomplished in advance of the workshop includes the definition of strata over which to aggregate krill length frequencies or *in situ* TS measurements, specification of the appropriate krill length–weight relationship(s), and the development of software scripts required to accomplish this task for large datasets.

8.45 With regard to the summation of biomass density over the survey area it was recognised that at least two methods were available. The first method exploits the stratified random design of the survey (Jolly and Hampton, 1990) and the second employs geostatistical methods which are not dependent on randomisation of survey effort with respect to the population, but which exploit the spatial structure apparent in its dispersion (Foote, 1993; Petitgas, 1993). Analytical work that could be completed in advance of the workshop includes the development of spreadsheets, analytical tools and software scripts required to accomplish this task.

8.46 With regard to the estimation of uncertainty, it was recognised that both sampling (Jolly and Hampton, 1990) and measurement (Demer, 1995) errors should be included in the estimate of variance associated with B_0. Analytical work that could be accomplished in advance of the workshop includes definition of the major components of this variance, elaboration of methods for estimating their magnitude and techniques for combining these components.

8.47 In addition, it will be crucial for the participants to develop, formalise and submit appropriate analytical procedures in good time to ensure that the necessary computer routines are available during the workshop.

8.48 The Working Group agreed that in respect of advancing consideration of subareal divisions of the krill potential yield, the workshop should provide estimates of the total area surveyed as well as the proportions of that area which fall within specific statistical subareas (transect length in large-scale component of the survey in each statistical subarea (see paragraph 8.61)).

8.49 It was further agreed that all data to be considered at the workshop be submitted to Dr Hewitt in electronic form at least one month ahead of the workshop.

Interpretation of Results with respect to Estimation of Potential Yield

8.50 The Working Group agreed that there were a number of distinct processes that should be undertaken to obtain the estimate of potential yield:

(i) estimate B_0 for Area 48 (see paragraphs 8.41 to 8.49);

(ii) update γ to incorporate the variance estimate of the B_0 survey;

(iii) estimate sustainable potential yield (calculated from γ x B_0); and

(iv) derive the precautionary catch limit for Area 48 and subdivide this precautionary catch limit for smaller management areas as appropriate**.**

8.51 With respect to (ii) above, the Working Group recognised that it would be desirable to re-estimate γ with more realistic characterisation of possible variations in mortality and recruitment.

8.52 The Working Group discussed the relative merits of subdividing the estimate of B_0 versus subdividing the precautionary catch limit. The Working Group agreed that at present the most practicable way forward would be to subdivide the precautionary catch limit. However, in the future other options may be considered (see paragraph 8.63).

8.53 The Working Group examined methods for subdividing the estimated yield for Area 48 into smaller areas. It recalled that principles of such a subdivision had been discussed since the time of developing the first precautionary catch limit for krill in Area 48 (see SC-CAMLR-X, paragraphs 3.76 to 3.82; SC-CAMLR-XI, paragraph 2.72; SC-CAMLR-XI, Annex 4, paragraphs 4.86 to 4.88 and 6.6 to 6.10). These can be summarised as:

(i) to avoid localised depletion of krill (SC-CAMLR-X, paragraph 3.76); and

(ii) to reduce the potential impact of localised fishing within restricted predator ranges (SC-CAMLR-X, paragraph 3.80).

8.54 WG-Krill originally devised a method for partitioning the Area 48 precautionary catch limit (SC-CAMLR-XI, Annex 4, paragraph 6.9 and Table 5). However, WG-EMM recognised that these calculations were based on a survey that did not cover the whole of Area 48 and that fishing activities have changed since that time.

8.55 The Working Group examined various interim methods for subdividing the catch limits, and evaluated them in terms of their inherent biases and/or the uncertainties in data inputs or assumptions. The options for subdividing the yield estimate for Area 48 into yields per subarea included:

(i) dividing by the number of subareas to give equal catches between subareas;

(ii) prorating by the area of each statistical subarea;

(iii) prorating by the proportion of the CCAMLR-2000 Survey in each statistical subarea where the proportions are estimated from the lengths of survey tracks associated with the large-scale component of the survey;

(iv) prorating by the area of locations of importance in each statistical subarea where such locations may be defined as:

(a) mesoscale strata of expected high densities of krill;
(b) krill distribution;
(c) shelf area;
(d) water mass;
(e) foraging area; and

(v) prorating by the levels of historical fishing in the respective subareas.

8.56 The Working Group agreed that methods (i) and (ii) are likely to be biased because they do not relate to the proportions of areas where krill are available. Similarly, method (v) is not suitable because fishing locations and times have been changing in recent years. Method (iii) appears to be a tractable option this year as it directly relates the subdivision of yield to the areas in which krill were observed. This method may be slightly biased because of different levels of sampling in some of the strata in areas of known krill concentrations.

8.57 The Working Group discussed the different options for characterising local areas of importance to krill in method (iv). It considered that the stratification of areas by water masses or by predator foraging areas may be suitable in the future, but decided that work was required to develop the frameworks necessary for such subdivisions. For example, subdivisions by predator foraging areas would require assessment of these areas combined with an evaluation of predator consumption in these areas. Thus, the Working Group decided that neither of these approaches would be considered as high priority this year.

8.58 In considering the other three components of method (iv), the Working Group agreed that shelf area is incorporated into the definitions of mesoscale strata. In addition, shelf area would not give sufficient weight to Subarea 48.4. The Working Group agreed that both (iv)(a) and (iv)(b) could be determined in part from the results of the CCAMLR-2000 Survey or they could be determined from historical data.

8.59 For example, krill distribution in each area could be estimated from the boundaries of the CCAMLR-2000 Survey in which, say, 80% of krill biomass was found. These areas would then be used in the calculations of the subdivision. A problem with this approach is that such distributions may vary between years. Alternatively, historical data from the *Discovery* investigations would be used in place of such calculations as described in WG-EMM-99/22.

8.60 In the case of mesoscale strata, this approach may be problematic because no such strata have been defined for Subarea 48.4, the strata defined in Subareas 48.1, 48.2 and 48.3 have been defined subjectively at this stage and the abundance of krill is known to be low in Subarea 48.4.

8.61 The Working Group agreed to develop method (iii) and method (iv)(b) further for the workshop and for calculations of an interim subdivision at its next meeting. The Working Group requested that the relative proportions of track length in the large-scale survey be estimated at the workshop for each statistical subarea. Using method (iii), the Working Group noted that the subdivision of yield between Subareas 48.1, 48.2 and 48.3 (based on approximations from the current survey plan) would be approximately 28%, 31% and 41% respectively. If the method (iv)(b) is used as in WG-EMM-99/22, then the respective division of yield would be 37%, 15% and 48%. This is calculated from the spatial area of krill distribution in each of the subareas detailed in the *Discovery* reports.

8.62 The Working Group emphasised that these calculations were of an interim nature, but necessary to provide some guidance on how precautionary measures may be taken at smaller scales than the current management unit of whole statistical areas. It recommended that further work be undertaken to identify management units that relate directly to the ecology of krill and its predators, as well as examining other approaches to take account of the needs of predators.

8.63 The Working Group discussed a number of points to consider in the elaboration of measures in future to subdivide yield in Area 48, including:

(i) estimating B_0 in each location of importance (paragraph 8.55(iv));

(ii) the influence of flux on estimating yield in local areas based on either the krill yield model using a local estimate of B_0 or predator demand models; and

(iii) local variations in mortality, recruitment and growth.

8.64 The Working Group encouraged Members to develop such alternative methods and looked forward to reviewing presentations of the methods, how they address assumptions and how they will improve on the methods proposed to be used in the coming year.

8.65 The Working Group agreed that there is sufficient information on functional relationships between predators and krill abundances, as well as patterns in krill recruitment that would enable a re-examination of the reference points used in the current yield decision rule. The Working Group encouraged Members to consider the current reference points of the krill yield model.

Data Management and Archive Implications

8.66 The Working Group agreed that it was vital the CCAMLR Data Manager should attend the B_0 Workshop. In addition, given the expected high workload at the workshop, the Working Group considered that secretarial support from the Secretariat should also be provided.

8.67 The Working Group also agreed that the datasets arising from the CCAMLR-2000 Survey will be a very important resource and that long-term archive storage of these data should be undertaken by the CCAMLR Secretariat.

8.68 Each ship will store all acoustic data on CD-ROMs and copies should be provided to the Secretariat. Copies of the other core program datasets should also be held in the appropriate format by the Secretariat. The Working Group agreed that cruise leaders and the Data Manager will further refine the specification of these formats prior to the survey.

8.69 The Working Group discussed the status of data collected by IWC observers participating in the CCAMLR-2000 Survey and access by IWC to these data and to all other data collected during the survey.

8.70 Dr P. Hammond (IWC) indicated that data collected by IWC observers would not be governed by IWC rules for data availability because they would result from what were effectively platforms of opportunity. However, because the cetacean data would be collected by IWC observers, the IWC anticipated that these data would be freely available for analyses to be presented to its Scientific Committee.

8.71 The rules for access and use of CCAMLR data state, in essence, that such data may be used freely in the preparation of materials for CCAMLR working groups (and workshops), but that the publication of such data requires the authorisation of the data originator(s).

8.72 In the circumstances of the CCAMLR-2000 Survey, therefore, it was understood that all data collected during the survey would be freely available to IWC, for the purpose of submission of analyses in documents to be presented to its Scientific Committee. Publication of any data or results of these analyses, however, even if by IWC scientists and based on the cetacean data alone, would still be subject to the CCAMLR rules and therefore would require the permission of the appropriate authorities in respect of the scientists and vessel or vessels participating in the survey.

8.73 The analysis of data on interactions between environment, krill and marine mammals, which are of particular interest to both IWC and CCAMLR, will be planned and undertaken in appropriate collaborative fashion, with issues relating to publication being resolved on a case-by-case basis, but still within the rules for the use of CCAMLR data.

8.74 Dr Hammond indicated that the IWC would be willing to undertake responsibility for validating and archiving marine mammal data collected during the CCAMLR-2000 Survey, and to make such data available to the collaborative workshops undertaking interactive analyses. The Working Group welcomed this offer and agreed that this was a very important contribution.

Shore-based Studies

Consideration of Comments on Existing CEMP Methods

8.75 In WG-EMM-99/45 power analysis and bootstrap functions were used to estimate the sample size required to detect interannual differences in the foraging trip duration of lactating female Antarctic fur seals at Cape Shirreff. The current CEMP standard method (C1a) suggests a sample size of 40 animals. The results of this analysis indicate that at Cape Shirreff, significant differences between years can be detected with a smaller sample size and suggest that the CEMP method be amended to 25–40 animals.

8.76 Prof. Boyd expressed concern over the assumption of normality required for the power analysis. However, he believed that the non-linearity of the response of foraging trip duration to environmental variability increased the likelihood of detection of anomalous years.

8.77 It was agreed that the advice on reduced sample size for Method C1a should be incorporated into the next revision of the standard methods.

8.78 It was noted that the data on foraging trip duration that were involved in the original analysis to estimate appropriate sample size (WG-CEMP-89/6) were not held in the CEMP database. The Data Manager was requested to liaise with Dr Holt to determine the status and availability of these data.

8.79 Two papers presented the effects of different sampling protocols on the analysis of predator diets. In WG-EMM-99/29 the effects of sampling interval were examined by comparison of diet samples from gentoo penguin and Antarctic fur seals at South Georgia collected on three occasions over a 14-day period with an equivalent number of samples collected on a single sampling occasion. No differences were found in either the mass of samples or the characteristics of krill using either protocol.

8.80 Prof. Croxall commented that this study addressed the concerns raised by Marschoff and González (1989) and the results indicated that the current CEMP method for diet determination appears robust with respect to the sampling protocol recommended in the standard methods.

8.81 WG-EMM-99/46 presented a comparison of the meal masses of Adélie penguins at Anvers Island and Admiralty Bay. Mean meal mass at Admiralty Bay, where samples were only collected from breeding birds, was significantly higher than at Anvers Island where the breeding status of birds was not confirmed. This was attributed to the inclusion of non-breeding birds at Anvers Island that were not feeding chicks and were therefore carrying a reduced food load.

8.82 The Working Group agreed that:

(i) the CEMP Standard Method A8a requires clarification to emphasise the importance of determining the breeding status of sampled birds; and

(ii) the conclusions of WG-EMM-99/46, in respect of highlighting potential problems of interpretation arising from analysis of data of this CEMP parameter, both within and between sites, be flagged in the database.

Consideration of New Draft Methods

8.83 WG-EMM-99/12 presented new standard methods for indices of environmental parameters which have potential direct effect on predators. Methods and data collection forms were presented for three indices: F1 (sea-ice extent viewed from a CEMP site), F3 (local weather at a CEMP site) and F4 (snow cover at a CEMP site).

8.84 The absence of responses to requests from the Secretariat for intersessional comment on the further development of these standard methods was regretted.

8.85 The Working Group agreed that the text and data submission formats for Methods F1 and F4 seemed appropriate, but should be remitted to the Working Group's Subgroup on Methods for final consideration. The Working Group would expect to be able to adopt these standard methods in full at its next meeting.

8.86 For Method F3, the Working Group felt that it was not appropriate or necessary for Members to submit synoptic weather data to the CCAMLR database. In circumstances when unusual meteorological events had, in the opinion of the data holders, significantly influenced the data being submitted under CEMP protocols, this should be indicated at the time of submission and clearly flagged in the database.

8.87 The Secretariat would ask Members undertaking CEMP work at shore-based stations what meteorological data they collected on site or had ready access to from nearby stations.

Other Information relating to Shore-based Methods

8.88 WG-EMM-99/44 (discussed also in paragraph 6.19) described a method (fatty acid signature analysis) that could be useful in the characterisation of the diet of predators, particularly species difficult to sample in more conventional ways. An application of this method could be to classify such predators according to the general characteristics of their diet, i.e. krill-based predators, fish-based predators, squid-based predators and predators that have mixed diets.

8.89 The importance of diet determination in southern elephant seals was recognised, especially with respect to the contribution to the precautionary catch limit of squid, which is based to a large extent on estimates of predator demand. The Working Group encouraged the further use and development of this method, which members noted had applicability to a wide range of species.

8.90 WG-EMM-99/31 presented a discriminant function to determine the sex of krill based on simple length and width measurements of the removed carapace. Determination of the sex also allowed more accurate sex-specific regression models to be used to estimate total length of krill found in prey samples from predators.

8.91 This was considered a useful development and application of similar techniques to other taxa, particularly e.g. *Euphausia crystallorophias*, was encouraged.

8.92 WG-EMM-99/33 (see paragraphs 8.25 to 8.31) contained important developments relevant to the proposal of a standard method for the sampling of the diet of Antarctic fur seals (WG-EMM-97/5).

8.93 Prof. Croxall suggested that in future the detailed aspects of submissions relating to methods be considered in a subgroup, intersessionally by the Subgroup on Methods and/or by a subgroup at the Working Group meeting, and that a report be presented to the Working Group for discussion in plenary.

Consideration of CEMP Sites

8.94 No new CEMP sites have been proposed for consideration by the Working Group.

8.95 There was some concern expressed about the quality of the maps showing the location of monitored colonies of dependent species at CEMP sites, which had been provided for inclusion in the CEMP database. The CEMP Subgroup on Designation and Protection of CEMP Sites will work with the Secretariat intersessionally to address this matter.

8.96 Dr Holt reported that all structures have been removed from Seal Island and the site is now cleared. The Working Group was sorry that this CEMP site had to be closed, but noted with pleasure that the site had been cleared.

8.97 Dr Wilson introduced WG-EMM-99/21 and pointed out that an earlier draft of this management plan for the Balleny Islands' Specially Protected Area (SPA) had been submitted to the Committee on Environmental Protection at the recent XXIII ATCM in Lima, Peru. Under Annex V to the Protocol on Environmental Protection to the Antarctic Treaty, the ATCM is required to obtain CCAMLR's approval prior to establishing a protected area with a marine component. Although Annex V is not yet in force, New Zealand has tabled the Balleny SPA reserve proposal at WG-EMM for information, for discussion, and hopefully to have endorsement in principle of the concept of the proposed Balleny Island SPA as an ecological preserve.

8.98 The Working Group recognised that CCAMLR would have to deal with marine reserve proposals when Annex V to the Protocol on Environmental Protection to the Antarctic Treaty comes into force. The Working Group will circulate WG-EMM-99/21 to its Subgroup on the Designation and Protection of CEMP Sites for comment and as part of its work on the development of a methodology for the assessment of proposals for marine protected areas put forward by the ATCM within the Protocol for Environmental Protection.

8.99 The Working Group discussed New Zealand's Balleny Islands SPA plan, but noted that approval was beyond the remit of the Working Group. Drs Miller and Wilson noted that the key objective of the proposal was to preserve the integrity of the natural terrestrial and marine ecosystems in the Ross Sea at and around a site of outstanding biodiversity.

8.100 The Working Group felt that much clearer information and reasons on a scientific basis will be needed for the selection of a 500 m limit to the offshore restricted zone around Sabrina and Chinstrap Islands and for a 200 n mile limit for the marine reserve as a whole.

8.101 The Working Group also noted that the presentation of the maps and of the information contained therein would not meet the standards which CCAMLR currently applies to maps of CEMP sites.

8.102 Dr Wilson indicated that this version of the proposal is purely for information and discussion and that in later versions maps would be prepared to the standards required by CCAMLR and the ATCM.

8.103 The Working Group drew these comments to the attention of the Scientific Committee. Prof. Croxall noted that consideration of this proposal might be assisted by information on other marine protected areas, especially those adjacent to the Convention Area, including recent proposals by Australia for Macquarie Island.

THE ECOSYSTEM APPROACH AS APPLIED IN OTHER PARTS OF THE WORLD

9.1 The Working Group considered that it was important to take account of work with similar marine ecosystem management initiatives elsewhere in the world. There is value in examining the experiences of other groups that may have encountered similar management problems to those faced by CCAMLR. Two of the tabled papers were relevant to this issue.

9.2 WG-EMM-99/5 presented an executive summary of a scientific plan of the South African BENEFIT Program which focuses on the Benguela Current ecosystem. Fisheries in this region are in a depressed state partly as a result of mismanagement. The program objectives are to:

(i) develop the scientific capacity of marine fisheries science in the countries bordering the Benguela ecosystem;

(ii) develop a framework plan that would improve knowledge and understanding of the Benguela ecosystem; and

(iii) provide the enhanced science capability necessary for the optimal and sustainable utilisation of living resources in the Benguela ecosystem. The BENEFIT Program has been developed as a 10-year program in two phases, the first of which runs from 1997 to 2000.

9.3 Although the BENEFIT Program does not have an explicit ecosystem management component, it is an example of a large regional program that is likely to develop methods and expertise that would be of interest to CCAMLR. It was also noted that the BENEFIT Program complements a new regulatory convention which is proposed for fisheries management in the southeast Atlantic region and which contains many of the ecosystem-based sentiments of Article II of CCAMLR.

9.4 WG-EMM-99/26 reported on a SCOR/ICES symposium, held in Montpellier, France, during March 1999, on the ecosystem effects of fishing. The symposium aimed to:

(i) provide a global synthesis of the impacts of fishing on marine ecosystems;
(ii) report new methods for quantifying impacts at the ecosystem level; and
(iii) discuss how nature conservation objectives can be integrated in future fisheries management.

Discussion of the ecosystem perspective to management highlighted the general applicability of the principles in Article II of CCAMLR. Apart from those of CCAMLR, there are only a few examples of management procedures that included ecosystem monitoring. It was clear that the work of CCAMLR is well ahead of other management organisations in terms of developing a precautionary approach to the ecosystem management of fisheries.

9.5 The Working Group thanked Dr Constable for presenting the CCAMLR view of ecosystem-based fisheries management at the Montpellier meeting. Dr Constable noted that, while many of the participants at the meeting were ready to accept the principles of ecosystem management of fisheries, there were conceptual difficulties with the implementation of this approach which CCAMLR had begun to overcome through the development of the krill yield model and CEMP. Nevertheless, a difficulty that was identified by the meeting, and which is also likely to be a problem for CCAMLR, is development of an ability to adapt management tactics rapidly to changing circumstances.

9.6 The Montpellier meeting also identified several areas of marine conservation that have hitherto not featured strongly in the conservation strategies adopted by CCAMLR. These included the conservation of habitats and biodiversity. In this context, the Working Group considered that some aspects of the work of CCAMLR, especially in the areas of by-catch of elasmobranchs or the effects of trawling on the seabed, may merit greater attention in future by the Scientific Committee.

9.7 The Working Group also considered that the results of the Montpellier meeting would help to provide guidance about operational objectives and definitions for ecosystem management. Some of these, particularly in relation to the definitions of the precautionary approach to fisheries management, had been discussed and developed previously at a technical consultation meeting held by the Government of Sweden in conjunction with FAO at Lysekil, Sweden, in June 1995. The Working Group's attention was drawn to the report on that meeting given in SC-CAMLR-XIV, Annex 5, paragraphs 10.1 to 10.8.

9.8 The Working Group considered paragraph 6.20 of SC-CAMLR-XVII in which Mr R. Shotton (FAO) offered the cooperation and support of FAO to hold an international meeting on the ecosystem approach to management. The Working Group encouraged this initiative and recommended to the Scientific Committee that if CCAMLR is to participate then it should take a lead in developing the terms of reference of such a meeting and that it should ensure that it is strongly represented. The rationale for a strong CCAMLR involvement derives from the likelihood that CCAMLR can learn from experiences elsewhere, but also because there is a need to interest more experts within other management systems in contributing to the CCAMLR approach.

9.9 Dr S. Kim (Republic of Korea) informed the Working Group of a forthcoming PICES workshop on Pacific euphausiids and herring to be held in Vladivostok, Russia, during 8 and 9 October 1999. The objectives of this workshop will be to analyse the population dynamics of these species in relation to ecosystem variability.

CCAMLR WEBSITE

10.1 Dr Ramm advised on recent developments with the English sections of the CCAMLR website (http://www.ccamlr.org), and work underway for the implementation of the French, Russian and Spanish sections.

10.2 The Working Group reviewed this progress and discussed the usefulness of the website in support of its work. It noted that information on 'hit rates' and usage of the website was not yet available. The Secretariat had intended to monitor hit rates so as to quantify usage and fine-tune the structure of the website. However, the limited budget available to develop the website has precluded the implementation of this feature.

10.3 Participants who had accessed the CCAMLR website had generally found this site extremely useful, well presented and easy to use. The Working Group had appreciated the time and effort spent by the Secretariat in developing the website. The Working Group reviewed the advice it had provided last year (SC-CAMLR-XVII, Annex 4, paragraphs 13.14 to 13.16), considered new needs, and looked forward to future developments of the website.

10.4 Options for submitting meeting papers and documents destined for use on the website were re-examined. The Working Group agreed that papers and other material should be submitted, where possible, in Microsoft compatible formats to facilitate transfer to the website. Text and tables should be submitted in Word format (*.doc), figures in Excel (*.xls) or JPEG (*.jpg) formats, maps and photographs in JPEG (*.jpg) format. Graphics should be submitted in separate files (i.e. not embedded in text). Where necessary, large files may be zipped using WinZip (*.zip).

10.5 The Working Group noted that only a small number of the papers presented at the meeting had been submitted electronically and in time for loading onto the website. If all documents for circulation prior to the meeting had been submitted electronically, then the current system whereby photocopied documents are airmailed to participants prior to meetings could have been replaced by an email notification advising participants that documents were available on the website. This practice would lead to savings in paper and postage costs which may then be re-allocated to further development of the website. The Working Group encouraged participants to submit all documents electronically. However, it was recognised that the paperless distribution of meeting documents should be phased in, and that any document submitted by the deadline as a hard copy would still need to be copied and distributed via airmail.

10.6 The Working Group agreed that its request to scan meeting documents and place these on the website (SC-CAMLR-XVII, Annex 4, paragraph 13.14) was problematic and no longer practical. Documents scanned as images are usually large in size, leading to long download times. Documents scanned using character recognition software required additional proof reading to ensure that all characters were correctly assigned. The request to circulate meeting documents on CD-ROM prior to the meeting (SC-CAMLR-XVII, Annex 4, paragraph 13.15) was also agreed to be inappropriate for this purpose.

10.7 The Working Group agreed that information on papers and documents held in the CCAMLR bibliography, and related to the work of the Working Group, should be placed on the website. This would supplement the *CCAMLR Scientific Abstracts* which are now available via the website. The Working Group agreed that this part of the bibliography, containing information on authors, years, subjects and abstracts, should be loaded as a text file on an open-access section of the website; authors, years and titles of meeting papers were already in the public domain. Importantly, access to the content of the papers must continue to be governed by CCAMLR's policy on meeting papers.

10.8 The Working Group reiterated the usefulness of loading onto a password-protected webpage a collection of maps relating to CEMP sites and colonies. Potential uses of a web-based GIS were briefly considered, however the Working Group agreed that the low-cost alternative of scanning maps and displaying these in JPEG format would satisfy its needs in the near future.

10.9 The Working Group also considered making the STATLANT data available via the website; these data are public domain and published each year in the *StatisticalBulletin*. It was recommended that these data should be placed on an open-access section of the website. However, the Working Group's use of STATLANT data was limited, and it sought advice from WG-FSA and the Scientific Committee on the format used to present these data on the website. At this stage, the Working Group felt that these data may be best released as simple tables summarising main features published in the *StatisticalBulletin*. The use of a web-based query interface may be desirable in the long term. The Working Group supported Dr Ramm's proposal that STATLANT data provided on the website should be physically isolated from the primary databases held by the Secretariat so as to maintain the highest level of protection to the databases and data confidentiality.

10.10 During the course of the meeting, the Working Group considered three other features which should be included on the website:

(i) the CEMP Data Report, as presented in the appendix of WG-EMM-99/8, should be placed on a password-protected webpage and updated prior to each meeting;

(ii) an advance copy of the meeting report should be placed on a password-protected webpage immediately following each meeting, and remain accessible until the published version of the report is released under the publications section of the website; and

(iii) a link to the website of the CCAMLR-2000 Survey should be established as soon as possible.

Some participants also expressed interest in the development of electronic correspondence groups.

10.11 The Working Group was aware that development of the CCAMLR website was constrained by the human and financial resources available for this work. Importantly, the initial development of the website was proceeding in parallel with the established work procedures and methods of communication in use by the Secretariat. By necessity, the website would need to be evaluated and endorsed by all Members before it could replace some of the existing communication via paper copies and facsimile. Therefore the cost of developing the website could not be offset at present by savings in other operational areas. However, the Working Group recommended that cost-saving features of the website, such as the paperless distribution of documents in advance of meetings, should be introduced as soon as the procedures are operational.

10.12 The Working Group recognised that certain features it had discussed in relation to the website, such as a comprehensive assessment of hit rates and web-based software to support database queries and GIS, would require specific budget allocations if these were to be implemented in the foreseeable future.

ADVICE TO THE SCIENTIFIC COMMITTEE

Management Advice

Assessment

11.1 The Working Group reaffirmed its advice given in 1997 that revised estimates of potential yield of krill should be postponed until results of the CCAMLR-2000 Survey became available (paragraph 7.14). The Working Group agreed that the current conservation measures which establish precautionary catch limits for krill should remain in force as they stand (paragraph 7.16).

11.2 The Working Group reiterated the need for advice to be given on precautionary management measures for krill fisheries at spatio-temporal scales of greatest importance to regulating interactions between krill, dependent species and fisheries (paragraphs 7.15, 7.62 and 7.82 to 7.84). For example, some fisheries may be concentrating around South Georgia, particularly in winter (paragraph 2.11), whereas others are still concentrated around the South Shetland Islands especially during summer (paragraph 2.1). To that end, the Working Group considered methods for subdividing the estimate of yield that will arise out of the CCAMLR-2000 Survey and recommended two methodologies to be considered next year (paragraph 8.61) in the interim while developing more formal methodologies (paragraphs 8.62 and 8.63).

11.3 Preparation for the CCAMLR-2000 Survey is in its final stages with the addition of a fourth vessel from Russia. The Working Group has identified a considerable number of tasks as part of the ongoing planning process and tasks to be carried out after the survey. These tasks will be carried out, as appropriate, by the survey coordinator, the cruise leaders, the nominated experts and the Secretariat.

11.4 The Working Group recommended that a workshop to estimate krill biomass in Area 48 be held in May–June 2000 (paragraphs 8.37, 8.38 and 8.41 to 8.49). The workshop would require support of the Secretariat and, in particular, participation of the Data Manager. The Working Group recommended that the Secretariat archive a copy of the data from the survey. The Working Group also considered that a special issue of *CCAMLR Science* may be an appropriate place to publish the results of the survey. All of these activities have financial implications.

11.5 The Working Group requested that the Scientific Committee endorse the steps for providing an estimate of yield for Area 48 and for calculating an interim subdivision of this yield into statistical subareas at its meeting next year. These are detailed in paragraphs 8.50 and 8.61.

Fishing Activities

11.6 The Working Group recommended that scientific observers on board krill fishing vessels should be used to collect information as described in the *Scientific Observers Manual* and further amended by the Working Group (paragraphs 2.8, 2.13, 2.14, 7.30, 7.66(iii), 7.68 and 7.71).

11.7 The Working Group recommended that more information be obtained on fishing operation strategies for its assessments (paragraph 2.10).

11.8 The Working Group recommended that a special effort be made to place observers on board krill fishing vessels which will conduct fishing within Area 48 at the same time as the CCAMLR-2000 Survey (paragraphs 2.15 and 7.73) and that the use of echo-listener data loggers on echosounders may be useful in this regard (paragraph 2.16).

11.9 The Working Group also recommended the collection and submission of data to the Secretariat on krill products, conversion rates used in the krill fishery, a breakdown of krill catches by product type and general information on krill prices (paragraphs 2.8, 2.10 and 7.66(ii)).

11.10 The Working Group requested that consideration be given to identifying potential changes to fishing areas and seasons that would impose no additional burden on fishing operations, but which would yield conservation benefit for dependent species (paragraphs 7.60 and 7.61).

11.11 The Working Group noted that there are currently no mechanisms for preventing uncontrolled development of krill fishing at scales most critical to predator foraging and recommended that a procedure be developed to ensure measures can be taken to safeguard predators as the krill fishery expands (paragraphs 7.63 to 7.66).

Other

11.12 The Working Group recommended that greater attention be given to research into by-catch of elasmobranchs and the effect of trawling on the seabed (paragraph 9.6).

11.13 At its next meeting the Working Group expected to have further information on the IUCN global review of threatened species to be published in 2000, which would include species whose main populations lie within the Convention Area. The Working Group advised that the Commission may need to consider actions to improve the conservation status of such species (paragraph 7.76).

11.14 The Working Group noted that the Scientific Committee might wish to consider whether, and in what form, action is necessary to improve assessment of ecosystem interactions involving fish and squid (paragraph 7.10).

11.15 The Working Group drew the attention of the Scientific Committee to issues related to proposals for marine protected areas that may arise from Annex V to the Protocol on Environmental Protection to the Antarctic Treaty when the Annex comes into force (paragraphs 8.97 to 8.103).

11.16 The Working Group recommended the continued collaboration with IWC, and in particular, observing marine mammals during the CCAMLR-2000 Survey (paragraph 8.28), developing access rules for data collected by IWC observers during the survey (paragraph 8.69) and the proposal by IWC to undertake validation and archiving of marine mammal observations during the survey (paragraph 8.74).

11.17 The Working Group identified a number of tasks for the 1999/2000 intersessional period and research priorities for future work which had been identified at the meeting. These are summarised below under Item 12 'Future Work' (paragraphs 12.1 to 12.6).

11.18 The Working Group recommended that its next meeting be held in 2000 at approximately the same time as WG-EMM/99. The Working Group welcomed an offer from Italy for the meeting to be held in Sicily and noted that a formal invitation would be submitted to CCAMLR-XVIII.

11.19 The Working Group recommended that the Scientific Committee consider Dr Hewitt as the new Convener of WG-EMM (paragraph 15.3).

FUTURE WORK

12.1 The Working Group identified a number of tasks to be carried out by WG-EMM participants and the Secretariat during the 1999/2000 intersessional period. The tasks are summarised below. References are given to paragraphs in the report which contain these tasks.

12.2 The following tasks were identified in the work on harvested and dependent species:

Secretariat tasks:

(i) Amend scientific observation logbook forms for krill fisheries in order to include records of information on conversion rates for krill products and urge Members to submit this information (paragraphs 2.7, 2.14 and 7.66).

(ii) In cooperation with Members, develop standard survey questionnaires to collect information on krill fishing strategies (paragraph 2.17).

(iii) In cooperation with Members, continue work on the estimation of the overlap between fisheries and predator foraging areas (paragraphs 6.11, 6.12 and 6.35).

(iv) Request Peru to submit to the next meeting of WG-EMM results of their krill surveys conducted in Subarea 48.1 (paragraph 3.43).

(v) Contact IUCN in order to obtain details on the criteria used and the process applied in the preparation for publication in 2000 of a new list of globally threatened species; relay this information to WG-FSA (paragraphs 7.77 and 7.78).

(vi) Prepare documentation on the use of krill yield model in cooperation with Dr Constable (paragraph 6.8).

Working Group activities:

(vii) Submit fine-scale CPUE data and their analysis for national krill fisheries in addition to data already submitted by Japan – Members (paragraph 2.4).

(viii) Re-investigate the potential for incorporating age-structured krill mortality into the GYM – Prof. Boyd, Dr Constable and Prof. Butterworth (paragraph 7.49).

(ix) Review existing work and new proposals on potential krill yield models based on estimation of krill consumption by dependent species – Prof. Boyd and Drs Everson, Constable and Nicol (paragraphs 7.51 and 7.52).

(x) Provide any information and/or ideas relevant to the development of ways of preventing uncontrolled expansion and/or development of krill fisheries (paragraphs 7.66 and 7.67).

12.3 The following tasks were identified in the work on environmental variables:

Working Group activities:

(i) Table a paper on the oceanographic environment in the South Shetland Islands area at the next meeting of WG-EMM – Dr Holt (paragraph 5.2).

12.4 The following tasks were identified in the work on ecosystem analysis and assessment:

Secretariat tasks:

(i) Implement recommendations of the Working Group on handling CEMP data (paragraphs 4.3 and 4.5).

(ii) Review, in cooperation with members of WG-EMM, the status of tasks and initiatives undertaken by the Working Group since its meeting in 1995 (paragraph 7.12).

(iii) To the extent that new data are available from Members or statistical experts, continue to develop indices and models of overlap between predator foraging and fishing (paragraphs 6.11, 6.12, 6.33 and 6.35).

Working Group activities:

(iv) Consider which indices derived from fishery-related data might be relevant to ecosystem assessment (paragraph 7.30).

12.5 The following tasks were identified in the work on CEMP sites, existing and new standard methods:

Secretariat tasks:

(i) Resolve the status of all queries listed in Table 1 (paragraph 4.4).

(ii) Flag, in the database, potential problems of interpretation arising from analysis of parameters of the Method A8a (paragraph 8.82).

(iii) Request Members undertaking CEMP work at shore-based stations to specify what meteorological data they collect on site or had ready access to from nearby stations (paragraph 8.87).

Working Group activities:

Subgroup on Designation and Protection of CEMP Sites –

(iv) In cooperation with the Secretariat, upgrade the quality of maps for CEMP sites (paragraph 8.95).

(v) Consider the draft management plan prepared by New Zealand for the Balleny Islands SPA (WG-EMM-99/21) (paragraph 8.98).

Subgroup on Standard Methods –

(vi) Prepare advice on reduced sample size for Method C1a which should be incorporated into the next revision of the CCAMLR standard methods (paragraph 8.77).

(vii) Consider drafts of Methods F1 and F4 for their adoption at the next meeting of WG-EMM (paragraph 8.85).

12.6 The following tasks were identified in the work on the CCAMLR-2000 Survey:

Secretariat tasks:

(i) Archive data submitted to the Secretariat from the CCAMLR-2000 Survey (paragraph 8.67).

Working Group activities:

(ii) Investigate how the data from regional krill surveys can be used in conjunction with the CCAMLR-2000 Survey (paragraph 3.22).

(iii) A considerable number of tasks have been identified as part of the ongoing planning process for the CCAMLR-2000 Survey. These tasks, detailed in paragraphs 8.1 to 8.40, will be carried out as appropriate by the survey coordinator, cruise leaders, nominated experts and the Data Manager.

(iv) Tasks to be carried out after the CCAMLR-2000 Survey, but prior to the B_0 Workshop in May–June 2000, are outlined in paragraphs 8.41 to 8.49 and will be carried out as appropriate by the survey coordinator, cruise leaders, nominated experts and the Data Manager.

12.7 The following tasks were identified in the work on the CCAMLR website:

Secretariat tasks:

(i) Place the report of WG-EMM on the website as soon as possible after the end of the meeting (paragraph 7.73).

(ii) The following features should be added to the CCAMLR website as password-protected pages:

(a) the CEMP Data Report (paragraph 10.10);
(b) a collection of maps showing CEMP sites and colonies (paragraph 10.8);
(c) an advance copy of the meeting reports (paragraph 10.10); and
(d) a link to the website of the CCAMLR-2000 Survey (paragraph 10.10).

(iii) The following features should be added as open-access pages:

(a) text file containing information (authors, dates, titles and abstracts) on papers and documents held in the CCAMLR bibliography, and related to the work of the Working Group (paragraph 10.7); and

(b) text files summarising STATLANT data (paragraph 10.9).

(iv) Wherever possible, the current system whereby photocopied documents are airmailed to participants prior to meetings should be replaced by an email notification advising participants that documents are available on the website (paragraph 10.5).

Working Group activities:

(v) Members to submit via email all documents intended for circulation prior to meetings and other information for use on the web, using formats specified in paragraph 10.4.

12.8 In addition, the Working Group identified a number of research priorities for future work. These research priorities are summarised below. References are given to paragraphs in the report which identify research requirements.

Development of precautionary management measures for krill fisheries:

(i) Further exploration, development and testing of models of precautionary management approaches to krill fisheries (paragraph 7.41).

(ii) Development of precautionary management measures, including interim measures, which are potentially appropriate to spatio-temporal scales of greatest importance for regulating interactions between krill, dependent species and fisheries (paragraphs 3.14, 7.15, 7.55 to 7.62 and 7.82 to 7.84).

(iii) Development of proactive and feedback management approaches to krill fisheries, especially at local scales (paragraphs 7.40, 7.42 and 7.53).

(iv) Consider a variety of factors which may influence trends in krill CPUE (paragraph 2.6).

(v) Investigate consequences of various types of conservation measures associated with precautionary approaches to management in local areas (paragraphs 7.60 and 7.61).

(vi) Investigate alternative methods for subdividing krill yield in Area 48 into smaller management units (paragraph 8.64).

(vii) Consider the current biological reference points of the krill yield model (paragraph 8.65).

Research on harvested and dependent species, and environment:

(viii) Research into krill distribution and abundance in large unsurveyed areas such as Subareas 48.6, 88.1 and 88.2 (paragraph 3.13).

(ix) Collect time-series data on krill demographic parameters from the Indian and Pacific sectors of the Antarctic (paragraph 3.41).

(x) Conduct simulation trials to examine whether correlation exists between krill recruits per spawner and per capita as described in WG-EMM-99/50 (paragraph 3.31).

(xi) Conduct regional comparisons of data on the mean sizes and length ranges of krill obtained using different types of sampling techniques (paragraph 3.20).

(xii) Study the relationship between krill density estimates derived from net and acoustic sampling (paragraph 3.17).

(xiii) Determine factors responsible for differences between estimates of global krill abundance based on historical data and on recent acoustics surveys (paragraph 3.10).

(xiv) Study the availability and distribution of krill in the surface layer, in particular, using techniques as side-looking and up-looking echosounders and echosounders mounted in small boats (paragraphs 3.15 and 3.17).

(xv) Investigation of errors involved in sampling the krill population, flux into and out of the sampling areas and the provision of independent estimates of krill mortality (paragraph 3.40).

(xvi) Development of general methodologies for the analysis and presentation of information on krill population structure (paragraph 3.21).

(xvii) Estimation of krill consumption by predators, including analysis of mean length of krill in their diets, and effect of diet on individual predators and predator populations (paragraphs 3.26, 6.21, 6.24 and 6.28).

(xviii) Continued work on relating the distribution of whales to different characteristics of krill aggregations (paragraph 6.32).

(xix) Directed research on, and modelling of the potential impacts of, ultraviolet radiation on krill (paragraphs 5.7 and 5.10).

(xx) Further development of methods of determining diets in elephant seals and other species of seals (paragraph 8.89).

(xxi) Further work on discriminant functions to determine the sex of euphausiids based on simple length and width measurements of the removed carapace (paragraph 8.90).

Research on ecosystem assessment and modelling:

(xxii) Further work on identifying EIVs for CEMP (paragraph 7.19).

(xxiii) Development of combined standardised indices (paragraphs 6.6, 6.7 and 7.31 to 7.36).

(xxiv) Development of ecosystem models underpinning management decisions in CCAMLR (paragraphs 6.39 and 7.49 to 7.52).

(xxv) Development of methods to distinguish the effects of fishing from the effects of environmental changes (paragraph 7.81).

OTHER BUSINESS

13.1 The Working Group noted with great pleasure the imminent Second International Krill Symposium being held at the University of California, Santa Cruz, USA, from 23 to 27 August 1999 (WG-EMM-99/23), of which CCAMLR is a co-sponsor.

13.2 Over 40 papers and 29 posters will be presented, including 32 presentations on Antarctic krill. A number of papers submitted to the symposium will be published as a supplement to the *Canadian Journal of Fisheries and Aquatic Sciences.*

ADOPTION OF THE REPORT

14.1 The report of the fifth meeting of WG-EMM was adopted.

CLOSE OF THE MEETING

15.1 In closing the meeting, the Convener, Dr Everson, on behalf of the Working Group, thanked the Director of the institute, Dr Balguerías, Mr López Abellán and other staff for hosting the meeting and for providing excellent facilities. This had greatly contributed to the smooth running of the meeting. Dr Everson also thanked Mrs L. Bleathman, Mrs R. Marazas and Drs Ramm and Sabourenkov of the Secretariat for their dedicated efforts, and other staff back in Hobart for their work in support of the Working Group, such as the compilation of the CEMP indices.

15.2 Dr Everson had indicated earlier that this meeting of the Working Group was to be his last as Convener. He recalled the difficult task which had been undertaken at the first meeting of this Working Group in Siena, Italy, in 1995 when the work of WG-Krill and WG-CEMP had been brought together. A new agenda had been developed and this had provided a successful framework for future meetings and the work of WG-EMM. The outcome of this work is evident today with new developments in ecosystem assessments and the forthcoming CCAMLR-2000 Survey. Dr Everson thanked all participants for their enthusiasm in conducting this work, and he felt confident that this collaborative spirit would continue under the stewardship of the new Convener.

15.3 Dr Siegel, Vice-Chair of the Scientific Committee, advised that informal discussions during the meeting had identified a candidate to replace Dr Everson. The Working Group recommended that the Scientific Committee consider Dr Hewitt as the new Convener of WG-EMM.

15.4 Prof. Croxall, on behalf of the Working Group, thanked Dr Everson for his outstanding leadership during the first five meetings of the Working Group. Prof. Croxall joined with Dr Miller who, earlier in the meeting and on behalf of participants and the Scientific Committee, had thanked Dr Everson for convening yet another successful meeting. Dr Everson's leadership had greatly advanced CCAMLR's work in ecosystem monitoring and management. The Working Group joined in expressing their appreciation and looked forward to Dr Everson's continued participation in the work of WG-EMM.

REFERENCES

Amos, A. and M.K. Lavender. 1992. AMLR Program: water masses in the vicinity of Elephant Island. *Antarctic J. US*, 26 (5): 210–213.

BIOMASS. 1991. Non-acoustic Krill Data Analysis Workshop (Cambridge, UK, 29 May to 5 June). *BIOMASS Rep. Ser.*, 66: 1–59.

Brierley, A.S., D.A. Demer, R.P. Hewitt and J.L. Watkins. 1999a. Concordance of interannual fluctuations in densities of krill around South Georgia and Elephant Islands: biological evidence of same-year teleconnections across the Scotia Sea. *Mar. Biol.*, in press.

Brierley, A.S., J.L. Watkins, C. Goss, M.T. Wilkinson and I. Everson. 1999b. Acoustic estimates of krill density at South Georgia, 1981 to 1998. *CCAMLR Science*, 6: 47–57.

Butterworth, D.S. 1988. Some aspects of the relationship between Antarctic krill abundance and CPUE measures in the Japanese krill fishery. In: *Selected Scientific Papers, 1988 (SC-CAMLR-SSP/5)*, Part I. CCAMLR, Hobart, Australia: 109–125.

Butterworth, D.S. and R.B. Thomson. 1995. Possible effects of different levels of krill fishing on predators – some initial modelling attempts. *CCAMLR Science*, 2: 79–97.

Demer, D.A., M.A. Soule and R.P. Hewitt. 1999. A multiple-frequency method for potentially improving the accuracy and precision of *in situ* target strength measurements. *J. Acoust. Soc. Am.*, 105 (4): 2359–2376

Demer, D.A. 1995. Uncertainty in acoustic surveys of Antarctic krill. Document *WG-EMM-95/72*. CCAMLR, Hobart, Australia.

Foote, K.G. 1993. Abundance estimation of herring hibernating in a fjord. *ICES CM* 1993/D:45: 12 pp.

Greene, C.H., P.H. Wiebe, S. McClatchie and T.K. Stanton. 1991. Acoustic estimates of Antarctic krill. *Nature*, 349: 110 pp.

Hewitt, R.P. and D.A. Demer. 1993. Dispersion and abundance of krill in the vicinity of Elephant Island in the 1992 austral summer. *Mar. Ecol. Prog. Ser.*, 99: 29–39.

Ichii, T., M. Naganobu and T. Ogishima. 1996. Competition between the krill fishery and penguins in the South Shetland Islands. *Polar Biol.*, 16 (1): 63–70.

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

Madureira, L.S.P., I. Everson and E.J. Murphy. 1993. Interpretation of acoustic data at two frequencies to discriminate between Antarctic krill and other scatterers. *J. Plankton. Res.*, 15: 787–802.

Mangel, M. and P.V. Switzer. 1998. A model at the level of the foraging trip for the indirect effects of krill (*Euphausia superba*) fisheries on krill predators. *EcologicalModelling*, 105: 235–256.

Marschoff, E. and B. González. 1989. The use of analysis of penguin stomach contents in simultaneous study of prey and predator parameters. In: *Selected Scientific Papers, 1989 (SC-CAMLR-SSP/6)*. CCAMLR, Hobart, Australia: 367–375.

Nicol, S. and Y. Endo. 1999. Krill fisheries: development, management and ecosystem implications. *Aquat. Living Resour*., 12 (2): 105–120.

Petitgas, P. 1993. Geostatistics for fish stock assessments: a review and an acoustic application. *ICES J. Mar. Sci.*, 50: 285–298.

Pitcher, T. and R. Chuenpagdee (Eds). 1995. Harvesting krill: ecological impact, assessment, products and markets. *Fisheries Centre Research Reports*, 3 (3).

Reid, K., P.N. Trathan, J.P. Croxall and H.J. Hill. 1996. Krill caught by predators and nets: differences between species and techniques. *Mar. Ecol. Prog. Ser.*, 140: 13–20.

Reid, K., J. Watkins, J. Croxall and E. Murphy. 1999. Krill population dynamics at South Georgia 1991–1997, based on data from predators and nets. *Mar. Ecol. Prog. Ser.*, 117: 103–114.

Watters, G. and R.P. Hewitt. 1992. Alternative methods for determining subarea or local area catch limits for krill in Statistical Area 48. In: *Selected Scientific Papers, 1992 (SC-CAMLR-SSP/9)*. CCAMLR, Hobart, Australia: 237–249.

Table 1: List of actions with respect to the CEMP data and the calculation of indices.

Responsibility	Table	Split-year(s)	Task	Comment
Argentina	1.05, mixed	1989	Check date of first period	
	3.08	1995	Check dates	
	9.07*	All years	Check data (total <100%)	
Australia	1.07, all	1993	Check procedure	
	4.05	All years	Why do data differ from those reported in WG-EMM-99/25?	
		1996 onwards	Are data available (see Table 1.07)?	
	7.08	1995	Check dates	
	8.08	1996	Check data	
	9.09*	1999	Check data (total <100%)	
Italy	3.16	1996	Check dates	
	5.10	All years	Why do data differ from those reported in WG-EMM-99/60?	
	9.10*	1999	Check data (total <100%)	
Japan	3.13	1991, 1996	Check dates	
New Zealand	3.17	1993	Check dates	
South Africa	3.04	1995	Check date of last period	
	3.27	All years	Why do data differ from those reported in WG-EMM-99/6?	
	7.04	1995, 1999	Check data (sd, se)	
		1997, 1998	Check dates	
	7.16	Most years	Check dates	
		1997, 1999	Check data (sd, se)	
	8.04	1996, 1997, 1999	Check data	
	9.04*	1999	Check data (total <100%)	
UK	1.01, female	1996, 1999	Check dates	
	1.01, male	1996	Check dates	
	1.08, mixed	1998–1999	Check data	
	3.21	1999	Check data	
	5.06	1996	Are data available?	
	5.12	1993	Check number of colonies for A6	
		1999	Are data available?	
	5.15	All years	Check number of nests and chicks	
	7.03	1996	Check data (sd, se)	
	8.02	1999	Check data (mean)	
	9.02*	1998, 1999	Check data (total <100%)	
	9.18*	1999	Check data (total <100%)	
	14.03	Most years	Provide dates	
USA	3.05	Most years	Check date of last period (>24 November)	
	6.03	Most years	Check data	
	7.12	1997	Check dates	
	14.01	1999	Check data	Corrected dates
	14.02	1987, 1989	Check data because some data are reported in WG-CEMP-89/6	
Secretariat	1.08, all	1998	Add missing value (reason b)	
	1.08, mixed	1998–1999	Check data	
	3.05	1999	Add missing value (reason b)	
	3.10	1996	Check date of first period	
	3.21	1998	Add missing value (reason b)	

Table 1 (continued)

Responsibility	Table	Split-year(s)	Task	Comment
Secretariat (continued)	3.25	Most years	Check calculation	
		1998	Add missing value (reason b)	
	3.26	1981	Add missing value (reason a)	
	5.06	1998	Add missing value (reason b)	
	5.09	1996	Check number of colonies for A6	
	5.12	1998	Add missing value (reason b)	
	5.15	All years	Check number of nests and chicks	
	7.03	1999	Check date for last period	
	8.05	1996	Check date last period	
	8.17	1999	Add missing value (reason a)	
	14, all		Transform deviate by (-1)	
	15.01	1994, 1995	Flag last date as early	
	General		Use summary provided by researchers in absence of CEMP data	
	General		Develop flag for data which do not Conform with CEMP standard methods	
	General		Flag time series collected using >1 procedure	
	General		Filter data, in consultation with researchers, to exclude short time series and discontinued research	

* Will also affect calculation of Index A8c

APPENDIX A

AGENDA

Working Group on Ecosystem Monitoring and Management
(Santa Cruz de Tenerife, Spain, 19 to 29 July 1999)

1. Introduction

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

2. Fisheries Information

    2.1 Catches: Status and Trends
    2.2 Harvesting Strategies
    2.3 Observer Scheme
    2.4 Other Information

3. Harvested Species

    3.1 Distribution and Standing Stock
    3.2 Population Structure, Recruitment, Growth and Production
    3.3 Indices of Abundance, Distribution and Recruitment
    3.4 Future Work

4. Dependent Species

    4.1 CEMP Indices
    4.2 Studies on Distribution and Population Dynamics
    4.3 Future Work

5. Environment

    5.1 Consideration of Studies on Key Environmental Variables
    5.2 Indices of Key Environmental Variables
    5.3 Future Work

6. Ecosystem Analysis

    6.1 Analytical Procedures and Combination of Indices
        (i) Multivariate Analysis of CEMP Indices
        (ii) Use of GYM for Krill Stock Assessments
        (iii) Other Approaches
    6.2 Krill-centred Interactions
    6.3 Fish and Squid-centred Interactions
    6.4 Environmental Interactions with Harvested and Dependent Species

7. Ecosystem Assessment

    7.1 Estimates of Potential Yield
    7.2 Assessment of the Status of the Ecosystem
        (i) Current Trends by Areas and Species
        (ii) Presentation of Assessments in Summary Form
    7.3 Consideration of Possible Management Measures
    7.4 Further Approaches to Ecosystem Assessment

8. Methods and Programs involving Studies on Harvested and Dependent Species and the Environment

   8.1 Area 48 Synoptic Krill Survey
      (i) Survey Design
      (ii) Sampling Protocols
         (a) Acoustic
         (b) Krill and Zooplankton
         (c) Oceanographic
         (d) Birds, Pinnipeds and Whales
         (e) New CEMP Methods for At-sea Studies
      (iii) Organisation of Synoptic Survey
      (iv) Analytical Methods
      (v) Interpretation of Results with respect to Estimation of Potential Yield
      (vi) Data Management and Archive Implications
   8.2 Shore-based Studies
      (i) Consideration of Comments on Existing CEMP Methods
      (ii) Consideration of New Draft Methods
   8.3 Consideration of CEMP Sites

9. The Ecosystem Approach as Applied in Other Parts of the World

10. CCAMLR Website

11. Advice to the Scientific Committee

12. Future Work

13. Other Business

14. Adoption of the Report

15. Close of the Meeting.

APPENDIX B

LIST OF PARTICIPANTS

Working Group on Ecosystem Monitoring and Management
(Santa Cruz de Tenerife, Spain, 19 to 29 July 1999)

BALGUERÍAS, Eduardo (Dr)	Centro Oceanográfico de Canarias Instituto Español de Oceanografía Apartado de Correos 1373 España ebg@ieo.rcanaria.es
BERGSTRÖM, Bo (Dr)	Kristinebergs Marine Research Station S-450 34 Fiskebäckskil Sweden b.bergstrom@kmf.gu.se
BOYD, Ian (Prof.)	British Antarctic Survey High Cross, Madingley Road Cambridge CB3 0ET United Kingdom I.Boyd@bas.ac.uk
CONSTABLE, Andrew (Dr)	Australian Antarctic Division Channel Highway Kingston Tasmania 7050 Australia andrew_con@antdiv.gov.au
CORSOLINI, Simonetta (Dr)	Dipartimento di Biologia Ambientale Università di Siena Via delle Cerchia, 3 I-53100 Siena Italy corsolini@unisi.it
CROXALL, John (Prof.)	British Antarctic Survey High Cross, Madingley Road Cambridge CB3 0ET United Kingdom j.croxall@bas.ac.uk
DEMER, David (Dr)	US AMLR Program Southwest Fisheries Science Center PO Box 271 La Jolla, Ca. 92038 USA ddemer@ucsd.edu
EVERSON, Inigo (Dr)	British Antarctic Survey High Cross, Madingley Road Cambridge CB3 0ET United Kingdom iev@pcmail.nerc-bas.ac.uk

FERNHOLM, Bo (Prof.)	Swedish Museum of Natural History S-104 05 Stockholm Sweden ve-bo@nrm.se
GOEBEL, Michael (Mr)	US AMLR Program Southwest Fisheries Science Center PO Box 271 La Jolla, Ca. 92038 USA megoebel@ucsd.edu
HAMMOND, Philip (Dr)	Sea Mammal Research Unit Gatty Marine Laboratory University of St Andrews St Andrews Fife KY16 8LB United Kingdom psh2@st-andrews.ac.uk
HEWITT, Roger (Dr)	US AMLR Program Southwest Fisheries Science Center PO Box 271 La Jolla, Ca. 92038 USA rhewitt@ucsd.edu
HOLT, Rennie (Dr)	US AMLR Program Southwest Fisheries Science Center PO Box 271 La Jolla, Ca. 92038 USA rholt@ucsd.edu
KAWAGUCHI, So (Dr)	National Research Institute of Far Seas Fisheries Orido 5-7-1, Shimizu Shizuoka 424 Japan kawaso@enyo.affrc.go.jp
KIGAMI, Masashi (Mr)	Japan Deep Sea Trawlers Association Ogawacho-Yasuda Building 6 Kanda-Ogawacho 3-Chome Chiyoda-ku Tokyo 101 Japan
KIM, Suam (Dr)	Korea Ocean Research and Development Institute Ansan PO Box 29 Seoul 425-600 Republic of Korea suamkim@sari.kordi.re.kr

LÓPEZ ABELLÁN, Luis Jose (Mr)	Centro Oceanográfico de Canarias Instituto Español de Oceanografia Apartado de Correos 1373 Santa Cruz de Tenerife España lla@ieo.rcanaria.es
MILLER, Denzil (Dr)	Chairman, Scientific Committee Sea Fisheries Research Institute Private Bag X2 Roggebaai 8012 South Africa dmiller@sfri.sfri.ac.za
NAGANOBU, Mikio (Dr)	National Research Institute of Far Seas Fisheries Orido 5-7-1, Shimizu Shizuoka 424 Japan naganobu@enyo.affrc.go.jp
NICOL, Steve (Dr.)	Australian Antarctic Division Channel Highway Kingston Tasmania 7050 stephe_nic@antdiv.gov.au
OLMASTRONI, Silvia (Ms)	Dipartimento di Biologia Ambientale Università di Siena Via delle Cerchia, 3 I-53100 Siena Italy olmastroni@unisi.it
REID, Keith (Mr)	British Antarctic Survey High Cross, Madingley Road Cambridge CB3 0ET United Kingdom kre@pcmail.nerc-bas.ac.uk
RYDZY, Jerzy (Prof.)	Ministry of Foreign Affairs Direzione Generale delle Relazioni Culturali – Uff. VII ENEA Progetto Antartide Rome
SANJEEVAN, V.N. (Dr)	Department of Ocean Development Government of India Sagar Sampada Cell Church Landing Road Kochi 682 016 India dodchn@ker.nic.in

SHUST, Konstantin (Dr)	VNIRO 17a V. Krasnoselskaya Moscow 107140 Russia frol@vniro.msk.su
SIEGEL, Volker (Dr)	Bundesforschungsanstalt für Fischerei Institut für Seefischerei Palmaille 9 D-22767 Hamburg Germany siegel.ish@bfa.fisch.de
SOH, Sung Kown (Dr)	Korea Ocean Research and Development Institute Ansan PO Box 29 Seoul 425-600 Republic of Korea sksoh@kordi.re.kr
SUSHIN, Viatcheslav (Dr)	AtlantNIRO 5 Dmitry Donskoy Str. Kaliningrad 236000 Russia sushin@atlant.caltnet.ru
TRATHAN, Philip (Dr)	British Antarctic Survey High Cross, Madingley Road Cambridge CB3 0ET United Kingdom pnt@mail.nerc-bas.ac.uk
TRIVELPIECE, Wayne (Dr)	US AMLR Program Southwest Fisheries Science Center PO Box 271 La Jolla, Ca. 92038 USA wtrivelpiece@ucsd.edu
VANYUSHIN, George (Dr)	VNIRO 17a V. Krasnoselskaya Moscow 107140 Russia
WATKINS, Jon (Dr)	British Antarctic Survey High Cross, Madingley Road Cambridge CB3 0ET United Kingdom j.watkins@pcmail.nerc-bas.ac.uk
WILSON, Peter (Dr)	Manaaki Whenua – Landcare Research Private Bag 6 Nelson New Zealand wilsonpr@landcare.cri.nz

CCAMLR SECRETARIAT:

Esteban DE SALAS (Executive Secretary)	CCAMLR
Eugene SABOURENKOV (Science Officer)	PO Box 213
David RAMM (Data Manager)	North Hobart 7002
Rosalie MARAZAS (Information Resource Administrator)	Tasmania Australia
Leanne BLEATHMAN (Coordinator, Executive Resources)	ccamlr@ccamlr.org

APPENDIX C

LIST OF DOCUMENTS

Working Group on Ecosystem Monitoring and Management
(Santa Cruz de Tenerife, Spain, 19 to 29 July 1999)

WG-EMM-99/1	Provisional Agenda and Provisional Annotated Agenda for the 1999 Meeting of the Working Group on Ecosystem Monitoring and Management (WG-EMM)
WG-EMM-99/2	List of participants
WG-EMM-99/3	List of documents
WG-EMM-99/4	Withdrawn
WG-EMM-99/5	BENEFIT – Benguela Environment Fisheries Interaction and Training: Science Plan Delegation of South Africa
WG-EMM-99/6	Population size and trends of some seabirds at Marion Island R.J.M. Crawford, O.A.W. Huyser, D.C. Nel, J. Cooper, J. Hurford and M. Greyling (South Africa)
WG-EMM-99/7	Report of the CCAMLR Synoptic Survey Planning Meeting (British Antarctic Survey, UK, 8 to 12 March 1999)
WG-EMM-99/8	CEMP indices 1999: analysis of anomalies and trends Secretariat
WG-EMM-99/9	Fine-scale data from the krill fisheries in 1997/98 Secretariat
WG-EMM-99/10	Secretariat work in support of WG-EMM Secretariat
WG-EMM-99/11	Estimation of the fishery–krill–predator overlap Secretariat
WG-EMM-99/12	Draft standard methods for environmental indices F1, F3 and F4 Secretariat
WG-EMM-99/13	Cephalopod diet of the southern elephant seal (*Mirounga leonina*) at King George Island, South Shetland Islands G.A. Daneri, A.R. Carlini (Argentina) and P.G.K. Rodhouse (United Kingdom) (*Antarctic Science*, submitted)
WG-EMM-99/14	SCAR Bird Biology Subcommittee ad hoc Working Group on Seabirds at-sea Methodology – Synopsis of Workshop Activities and Recommendations SCAR Bird Biology Subcommittee

WG-EMM-99/15	Effects of the Antarctic Circumpolar Current on fishing for squid (*Illex Argentinus*) in the Atlantic sector of the Southern Ocean G.P. Vanyushin and T.B. Barkanova (Russia)
WG-EMM-99/16	Trends of Antarctic fur seal population at SSSI No. 32, Livingston Island, South Shetlands, Antarctica R. Hucke-Gaete, D. Torres, A. Aguayo, J. Acevedo and V. Vallejos (Chile)
WG-EMM-99/17	Estimation of krill biomass from an acoustic survey carried out in 1986, during a study of predator–prey interactions around the western end of South Georgia C. Goss and S. Grant (United Kingdom)
WG-EMM-99/18	Underwater noises produced by research vessels (some comments on acoustic sampling protocol for the Area 48 synoptic survey S. Kasatkina (Russia)
WG-EMM-99/19	Interannual variation in the autumn diet of the gentoo penguin *Pygoscelis papua* at Laurie Island, Antarctica N. Coria, M. Libertelli, R. Casaux and C. Darrieu (Argentina)
WG-EMM-99/20	Acoustic estimates of krill density at South Georgia, December/January 1998/99 A.S. Brierley and C. Goss (United Kingdom)
WG-EMM-99/21	Draft management plan for Specially Protected Area (SPA) No. 4: Balleny Islands northern Ross Sea, Antarctica New Zealand
WG-EMM-99/22	Estimates of global krill abundance based on recent acoustic density measurements and their implications for the calculation of precautionary catch limits and the designation of management areas S. Nicol, A. Constable and T. Pauly (Australia)
WG-EMM-99/23	The Second International Krill Symposium S. Nicol (Australia) and M. Mangel (USA)
WG-EMM-99/24	Potential effects of UV-B on krill – experimental and genetic studies S. Newman, S. Jarman, S. Nicol, D. Ritz, H. Marchant, N. Elliot and A. McMinn (Australia) (*Polar Biol.*, 22: 50–55, 1992)
WG-EMM-99/25	Poor breeding success of the Adélie penguin at Béchervaise Island in the 1998/99 season L. Irvine, J.R. Clarke and K.R. Kerry (Australia)
WG-EMM-99/26	Report on the SCOR/ICES Symposium on the Ecosystem Effects of Fishing, March 1999 A. Constable (Australia)

WG-EMM-99/27	Correlation between krill and *Champsocephalusgunnari* stocks in the South Georgia Area 48.3 K.V. Shust, V.L. Senioukov, P.N. Kochkin and N.A. Petrukhina (Russia)
WG-EMM-99/28	Light levels experienced by foraging Antarctic fur seals, *Arctocephalus gazella* D.J. McCafferty, I.L. Boyd and T.R. Walker (United Kingdom)
WG-EMM-99/29	Influence of sampling protocol on diet determination of gentoo penguins, *Pygoscelis papua* and Antarctic fur seals, *Arctocephalus gazella* S.D. Berrow, R.I. Taylor and A. Murray (United Kingdom) (*Polar Biol.,* in press)
WG-EMM-99/30	Relationships between the distribution of whales and Antarctic krill *Euphausia superba* at South Georgia K. Reid, A.S. Brierley (United Kingdom) and G.A. Nevitt (USA) (*J. Cetacean Res. Management*, in press)
WG-EMM-99/31	Determining the sex of Antarctic krill *Euphausiasuperba* using carapace measurements K. Reid and J. Measures (United Kingdom) (*Polar Biol.*, 19: 145–147, 1998)
WG-EMM-99/32	Foraging and provisioning in Antarctic fur seals: interannual variability in time-energy budgets I.L. Boyd (United Kingdom) (*Behav. Ecol*., 10 (2): 198–208)
WG-EMM-99/33	A proposal for large scale sampling of krill in the diet of predators across Area 48 to coincide with the CCAMLR synoptic survey K. Reid (United Kingdom)
WG-EMM-99/34	Relative abundance of large whales around South Georgia M.J. Moore (USA), S.D. Berrow (UK), B.A. Jensen (USA), P. Carr (UK), R. Sears (Canada) and V.J. Rowntree, R. Payne and P.K. Hamilton (USA) (*Marine Mammal Science,* in press)
WG-EMM-99/35	Foraging response of Antarctic fur seals to changes in the marine environment D.J. McCafferty, I.L. Boyd, T.R. Walker and R.I. Taylor (United Kingdom) (*Mar. Ecol. Prog. Ser.*, 166: 285–99, 1998)
WG-EMM-99/36	Heart rate and behaviour of fur seals: implications for measurement of field energetics I.L. Boyd, R.M. Bevan, A.J. Woakes and P.J. Butler (United Kingdom) (*Am. J. Physiol.,* 276 (*Heart Circ. Physiol*., 45): H844–H857, 1999)

WG-EMM-99/37	Predicting changes in the Antarctic krill *Euphausia superba* population at South Georgia K. Reid, K.E. Barlow, J.P. Croxall and R.I. Taylor (United Kingdom) (*Marine Biology*, in press)
WG-EMM-99/38	Improvements to the multiple-frequency method for *in situ* target strength measurements D.A. Demer (USA) and M.A. Soule (South Africa)
WG-EMM-99/39	The CCAMLR 2000 Krill Synoptic Survey: a description of the rationale and design
WG-EMM-99/40	Combining data vectors from CEMP indices I.L. Boyd and A.W.A. Murray (United Kingdom)
WG-EMM-99/41	Effect of orientation on broadband acoustic scattering of Antarctic krill *Euphausia superba*: implications for inverting zooplankton spectral acoustic signatures for angle of orientation L.V. Martin Traykovski (USA), R.L. O'Driscoll (New Zealand) and D.E. McGehee (USA) (*J. Acoust. Soc. Am.*, 104 (4), 1998)
WG-EMM-99/42	Effects of orientation on acoustic scattering from Antarctic krill at 120 kHz D.E. McGehee (USA), R.L. O'Driscoll (New Zealand) and L.V. Martin Traykovski (USA) (*Deep-Sea Research*, II, 45: 1273–1294, 1998)
WG-EMM-99/43	Supplement to the krill synoptic survey design in Area 48 (with participation of a Russian scientific research vessel) V.A. Sushin, S.M. Kasatkina and F.F. Litvinov (Russia)
WG-EMM-99/44	Fatty acid signature analysis from the milk of Antarctic fur seals and southern elephant seals from South Georgia: implications for diet determination D.J. Brown, I.L. Boyd, G.C. Cripps and P.J. Butler (United Kingdom) (*Mar. Ecol. Prog. Ser.*, for submission)
WG-EMM-99/45	An examination of variance and sample size for female Antarctic fur seal trip durations M.E. Goebel (USA)
WG-EMM-99/46	The effect of different methodologies used in penguin diet studies at three US AMLR predator research sites: Admiralty Bay, Palmer Station and Cape Shirreff W. Trivelpiece, S. Trivelpiece (USA) and K. Salwicka (Poland)
WG-EMM-99/47	AMLR 1998/99 Field Season Report: objectives, accomplishments and tentative conclusions US Delegation

WG-EMM-99/48	CPUEs and body length of Antarctic krill density during the 1997/98 season in Area 48 S. Kawaguchi (Japan)
WG-EMM-99/49	Plan for 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-99/50	An index of per capita recruitment R. Hewitt (USA)
WG-EMM-99/51	An idea to incorporate potential recruitments in the krill density model S. Kawaguchi and M. Naganobu (Japan)
WG-EMM-99/52	Relationship between Antarctic krill (*Euphausia superba*) variability and westerly fluctuations and ozone depletion in the Antarctic Peninsula area M. Naganobu, K. Kutsuwada, Y. Sasai and T. Taguchi (Japan) and V. Siegel (Germany) (*Journal of Geophysical Research*, in press)
WG-EMM-99/53	Note: time series of polynyas extent in the Antarctic ocean K. Segawa and M. Naganobu (Japan)
WG-EMM-99/54	Observations on a large number of icebergs in the krill fishing ground (Subarea 48.1) in May 1999 Japan Deep Sea Trawlers Association
WG-EMM-99/55	Distribution and abundance of Antarctic krill (*Euphausia superba*) around the South Shetland Islands, Antarctic Ocean D. Kang, D. Hwang and S. Kim (Republic of Korea)
WG-EMM-99/56	Modelling the dynamics of krill populations in the Antarctic Peninsula region E.J. Murphy (United Kingdom), A. Constable (Australia) and D. Agnew (United Kingdom)
WG-EMM-99/57	Penguins, fur seals, and fishing: prey requirements and potential competition in the South Shetland Islands, Antarctica D.A. Croll and B.R. Tershy (USA) (*Polar Biol.*, 19: 365–74, 1998)
WG-EMM-99/58	Marine ecosystem sensitivity to climate change R.C. Smith, D. Ainley, K. Baker, E. Domack, S. Emslie, B. Fraser, J. Kennett, A. Leventer, E. Mosley-Thompson, S. Stammerjohn and M. Vernet (*BioScience*, 49 (5))
WG-EMM-99/59	Susceptibility to oxidative stress in different species of Antarctic birds: preliminary results S. Corsolini, F. Regoli, S. Olmastroni, M. Nigro and S. Focardi (Italy)

WG-EMM-99/60	Breeding biology of Adélie penguin (*Pygoscelis adeliae*) at Edmonson Point CEMP site (Ross Sea, Antarctica): report of the first five years S. Olmastroni, S. Corsolini, F. Pezzo, S. Focardi (Italy) and K. Kerry (Australia)

Other Documents

SC-CAMLR-XVIII/BG/3	Observer's report from the 51st Meeting of the Scientific Committee of the International Whaling Commission, Grenada, 3–15 May 1999 CCAMLR Observer (K.-H. Kock, Germany)

APPENDIX D

CCAMLR SYNOPTIC SURVEY PLANNING MEETING
(Cambridge, UK, 8 to 12 March 1999)

CCAMLR SYNOPTIC SURVEY PLANNING MEETING
(Cambridge, UK, 8 to 12 March 1999)

A planning meeting for the CCAMLR-sponsored multinational, multi-ship, near-synoptic acoustic survey for krill biomass in Area 48 to be conducted in January 2000 (hereafter referred to as CCAMLR-2000) was convened by Dr J. Watkins (UK) and held at the British Antarctic Survey (BAS), Cambridge, UK, from 8 to 12 March 1999. The List of Participants is included in this report as Attachment A, the Agenda as Attachment B and a List of Actions resulting from the meeting as Attachment C.

2. Ms S. Hedley, representing the IWC, expressed her gratitude for the opportunity to explain the IWC's broad objectives with regard to the study of cetaceans and their habitat, and to present the IWC request to participate in CCAMLR-2000. She also expressed the hope for fruitful collaboration between IWC and CCAMLR scientists as well as a closer relationship between the two organisations.

SURVEY DESIGN

3. The group reaffirmed that the principal participants conducting the survey will be Japan, UK and USA. The time period of the survey would be early January to mid-February with specific start and stop dates dictated by the necessities of national programs. Each country would contribute 30 days of ship time for the conduct of CCAMLR-2000. Specific ship schedules are listed under Itinerary[1].

4. Dr S. Kim (Republic of Korea) noted that the CCAMLR Subgroup on International Coordination intends to encourage several countries who plan to have field programs in the vicinity of the South Shetland Islands during the austral summer of 1999/2000 to repeat the CCAMLR-2000 transects in this area. The close-spaced CCAMLR-2000 transects on the north side of the South Shetland Islands are likely to be surveyed four times (one by the Republic of Korea in late-December, one by Japan in late-December, one by the CCAMLR-2000 survey vessel in late January–early February, and one by the USA in late February–early March).

5. It was understood that Brazil, Russia and Ukraine are also interested in participating, but that each of these countries is not in a position to make firm commitments at this time to CCAMLR-2000. It was further reported that Ukraine will be conducting field work in the vicinity of the South Orkney Islands during the 1999/2000 austral summer and that their ship will be equipped with an echosounder other than a Simrad EK500; that Russia may have a research vessel available during the survey period and that it will be equipped with a Simrad EK500 echosounder; and that Brazil has a research vessel equipped with an EK500, but that the availability of this ship during the survey period is less certain. Accordingly, it was decided that the Ukrainians would be encouraged to conduct an acoustic survey with a calibrated system in the vicinity of the South Orkney Islands and that this information could be used to complement the planned survey coverage and as an aid in the interpretation of survey results. It was also decided that if Russia were able to participate they would be encouraged to conduct a replicate of one of the three planned survey tracklines with a calibrated EK500 system.

6. It was recognised that the extent of sea-ice may affect the degree to which the southward extent of planned transect lines may be conducted. It was agreed, therefore, to examine recent trends in the annual extent of sea-ice and if a reasonable probability existed that the planned transect lines could not be completed, then the survey design would be adjusted so as to achieve a more efficient use of time.

---

[1] Underlined words refer to links to the CCAMLR-2000 website.

7. During a discussion of the survey design it was noted that the proposed transects run along meridians were not parallel, converging as they approach the pole. Considerable discussion ensued weighing the advantages of design simplicity against the disadvantages of over-sampling the higher latitudes relative to the lower ones (transect spacing at the highest latitudes would be approximately 65% of the transect spacing at the lowest latitudes). Ultimately, it was decided to use transects that were parallel on the earth's surface. In order to orient these transects as closely as possible along the prevailing topographic gradient the area was divided into two grids. The first grid includes Subareas 48.2 and 48.3 and was aligned N–S along the 40°W meridian. The second was aligned along a bearing of 330° at 50°W in order to take account of the topography in Subarea 48.1. These grids were used to describe the nominal survey design, which would yield the maximum survey coverage using the available ship time. A randomisation scheme will now be applied to all possible parallel transects on this grid to achieve the final survey design. Every third transect will then be assigned to each ship and cruise tracks will be laid out. Each transect will have a unique number. In addition, the nominal noon and midnight stations will be laid out for each transect and be assigned a unique number. Mr A. Murray (UK) agreed to undertake these tasks with the understanding that his work is critical to the success of CCAMLR-2000 and should be thoroughly checked.

8. Weather contingencies were discussed and it was agreed that the following guidelines would be adopted by each cruise leader in the event that weather and/or equipment failure caused introduced delays such that the survey could not be completed within the allotted time. Noon and midnight stations will be placed along each transect (the actual time of the station will vary according to the net-sampling rules laid out in paragraph 10 below and adjustment for local apparent time). The cruise leader on each survey vessel will check progress against the expected time at the station and make adjustments if necessary according to the following hierarchical scheme:

(i) lengthen daytime acoustic survey operations by beginning and ending acoustic transects at the local apparent time of civil twilight; else

(ii) increase vessel speed without sacrificing quality of acoustic data (see Acoustic Sampling Protocol for guidance); else

(iii) delete daytime net sampling and CTD cast.

In addition, the cruise leader will check progress against the expected time at the approximate mid-point of each major transect (seven for each ship) and make adjustments if necessary according to the following hierarchical scheme:

(i) break survey work on current line and redirect the survey vessel toward the beginning of the next transect; else

(ii) break survey work on current line and redirect the survey vessel toward the most adjacent point on the next transect; else

(iii) delete an entire transect according to a randomly determined transect ranking order (see Random).

PRIMARY PROTOCOLS

9. During a discussion of acoustic sampling protocols it was reaffirmed that acoustic data should be collected at all times. The costs of data storage were considered to be relatively cheap when compared to the cost of missing data collection that may prove useful for future analysis. This principle pertains to time periods while calibrating, to noisy conditions during rough seas,

to station times, and to transits between sampling transects. The directive, in essence, is to turn on the echosounder and record data from the time the ship leaves the pier to the time it returns again. It was also noted that additional specifications regarding the characterisation of noise and operational guidelines as to its acceptable level should be developed; that guidelines should be developed for simultaneous use of echosounders and ADCPs; that lists of instrument settings for calibration and underway data collection should be developed and distributed among survey participants; and that during calibration only TS gain and Sv gain be adjusted while keeping axis offset angles (in the case of split-beam transducers) set to zero and the beam angles set to the manufacturer's description, adjusted for sound speed, for the specific transducer. In light of the fact that the acoustic data are critical to the success of CCAMLR-2000, it was also emphasised that data should be recorded redundantly and equipment spares should be aboard each ship. These and other issues are to be addressed in an updated Acoustic Sampling Protocol.

10. During a discussion of net sampling protocols it was noted that some directed net sampling effort would be necessary to reduce the uncertainty associated with the delineation of krill in the acoustic data record. This sampling would be directed at a variety of 'acoustic morphs', some presumed to be krill and some presumed not to be krill, and, as such, would not be appropriate for the primary purpose of the net sampling as stated at the 1998 WG-EMM meeting; that is, the description of krill population demography. Nonetheless, it was noted by the group that the primary purpose of CCAMLR-2000 is to provide an estimate of B_0 from an acoustic survey and some directed sampling is necessary to achieve this end. Discussion further ensued as to whether the net sampling effort should be increased by reducing the number and/or length of acoustic transects or whether the currently planned net sampling effort (one tow at midnight and another at midday) should be reallocated with some tows used for directed sampling and others as standard oblique tows at predetermined locations. Again, the primary purpose of CCAMLR-2000 was invoked as a rationale for reallocating net sampling effort rather than reducing acoustic sampling effort. The following fishing strategy was adopted:

(i) At local apparent midnight, conduct a standard oblique tow in conjunction with a CTD cast.

(ii) From the time of local apparent sunrise to local apparent noon, conduct a directed tow if an acoustic morph of interest was detected and a reasonable chance of sampling it existed.

(iii) If a directed tow was conducted between local apparent sunrise and three hours before local apparent noon, delay the CTD cast until local apparent noon.

(iv) If a directed tow was conducted after three hours before local apparent noon, conduct the CTD cast at the same locale.

(v) If no suitable acoustic morphs were detected by local apparent noon, conduct a standard oblique tow in conjunction with a CTD cast.

Additional issues were raised during discussion of the net sampling protocol including the desire to standardise nets among all participants, the treatment of 'other zooplankton', and the use of additional nets for sampling smaller zooplankton. These issues were addressed in the revised Net Sampling Protocols. It was noted that Japan does not currently have access to an RMT8 net and that this may be addressed by inviting the participation of an outside expert who has an RMT8 net, on the Japanese survey vessel.

11. During a discussion of the CTD protocols, it was noted that both the general flow pattern across the Scotia Sea as well as the position of fronts were important determinates of the dispersion of krill and that describing these should be the objectives of the oceanographic sampling protocol. It was further noted that CTD sampling to the depth of a particular

oceanographic feature (e.g. a vertical boundary of the CDW) may be more rational than sampling to an arbitrary depth of 1 000 m. This could be considered a plane of no motion for geostrophic calculations as it relates to the structuring of krill habitat. Discussion ensued as to whether this would add to the time required to conduct the CTD casts, but without a detailed analysis of climatic atlases this question could not be readily answered. It was also noted that the UK intends to collect ADCP measurements to approximately 400 m depth with hull-mounted transducers and that Japan intends to collect LADCP measurements over the full extent of the CTD cast; only the USA does not expect to make ADCP measurements. These measurements of absolute currents may be used to interpret CTD data. It was therefore decided that the current protocol (CTD casts to 1 000 m depth (or to the bottom if shallower)) should stand pending investigation of the climatological depth of UCDW. It was further noted that the position of fronts along the transects could be more accurately described with the use of towed and/or expendable sensors. Issues relating to CTD measurements are addressed in the revised CTD Protocols.

Secondary Sampling

12. Ms Hedley presented an overview of the IWC's objectives, sampling methods, and personnel requirements for its participation in CCAMLR-2000. Discussion ensued as to the value of relative versus absolute estimates of cetacean abundance. The IWC's short-term objective with regard to CCAMLR-2000 is to relate the spatial distribution of baleen whales to krill and other environmental covariates; in this regard relative abundance may be adequate. There is some debate, however, within the IWC scientific community on this point. On the other hand, the IWC's long-range objective is to evaluate the impact of baleen whale consumption on the krill resource (presumably this is of direct interest to CCAMLR as well); in this regard absolute estimates of whale abundance are more appropriate. For CCAMLR-2000 the IWC would like to achieve 100% coverage of all transects using the double-platform method which will generate absolute estimates of whale abundance. This would require two teams of four observers (eight berths) on each survey vessel. Tradeoffs between transect coverage and the proportion of the survey that could be conducted using the double-platform method were described if fewer berths were available. It was noted that firm commitments needed to be passed by the CCAMLR-2000 coordinator to Dr G. Donovan at IWC in time for the annual meeting in May. The final protocols for pelagic krill predator observations may differ between ships and will be determined in consultation with the IWC and published on the CCAMLR-2000 website.

13. The extraordinary opportunity offered by CCAMLR-2000 to sample zooplankton across the Scotia Sea was discussed. Sampling may be accomplished without jeopardising the primary sampling operations by adding a set of 1 m^2 333 micron mesh nets to the RMT8 sampler which will be used to sample krill and other micronekton. Specific protocols were not developed except to note the value to all participants of a common zooplankton database, which could be accessed via the CCAMLR-2000 website. Phytoplankton sampling was also discussed and it was determined that all three survey vessels will have fluorometers mounted on their flow-through systems as well as CTD instrument packages and will also make chlorophyll extractions from water samples. Additional measurements will vary among vessels and it was agreed that observation protocols would be posted on the website as they are developed. It was further noted that water samples could be preserved in a Lugol's solution for subsequent analysis, but that the shelf life of such samples was only two years.

14. Underway observation systems will be maintained by all three survey vessels. Measurements will include wind speed and direction, air pressure, humidity, photosynthetically available radiation, sea-surface temperature, salinity, turbidity and fluorescence. In addition, Japan will collect continuous measurements of particle volumes (as a proxy for zooplankton) and dissolved oxygen. The UK will also tow an undulating oceanographic recorder which will contain an optical plankton recorder and make additional measurements of photosynthetically

available radiance, fluorescence, turbidity, salinity and temperature. It was noted that it would be advisable to standardise averaging intervals among the three vessels. Japan has an ADCP that could be operated continuously, however, current plans call for it to be secured during underway operations and an LADCP used instead in conjunction with CTD casts. The UK will operate an underway ADCP, but the USA has no current plans to do so.

15. The potential value of satellite imagery was discussed and it was agreed that Dr Watkins would investigate the various products that would be appropriate complements to CCAMLR-2000. In this regard it may be necessary to request SeaWiFS ground stations at Palmer and/or Rothera to archive specific imagery.

DATA COLLECTION AND ARCHIVING

16. With regard to the conduct of acoustic transects, it was agreed that after the completion of station observations each survey vessel would relocate to the closest point along the intended transect before proceeding to the next station.

17. The utility of maintaining an underway log was emphasised. Such a log would contain notes regarding the start and end times of acoustic transects, comments on weather conditions and sea state as they affect the acoustic records, unusual features noted in the acoustic data, and any other details that may be of use when interpreting the acoustic data after the survey is finished. Similar notes obtained in conjunction with net sampling and CTD operations would clearly be useful as well. Discussion ensued regarding routine logs and the various numbering systems for activities and stations employed by different national programs. It was agreed that, as a minimum, the start and end times and positions of all operations should be recorded in an electronic format such that a list could be made up and queried for all activities conducted at a given set of stations or, alternatively, all locations where a given set of activities was conducted.

18. With regard to computer problems associated with the year 2000 (Y2K), all vessel cruise leaders were encouraged to check the GPS receivers on their ships that will be in use during CCAMLR-2000. These receivers will be the primary source for time stamping the acoustic date set and must be compatible with the millennium change. It is highly desirable that all data collections on a survey vessel are referenced to the same time standard and thus redundant Y2K compliant GPS receivers are critical. Vessel coordinators were also encouraged to check with Simrad and SonarData for assurances that their equipment and software has been tested for Y2K compliance.

DATA ANALYSIS

19. The group reaffirmed and strongly endorsed the decisions made at the last planning session for CCAMLR-2000 held during the WG-EMM meeting in 1998 at Kochi, India, that (i) the collection of acoustic data, micronekton samples from RMT8 nets, and CTD profiles would form the core datasets, and that (ii) the analyses and interpretation of these core datasets and the reporting of results would be conducted in a collaborative fashion. The core datasets refer to those collected according to the survey design described in paragraph 7.

20. It was agreed that because an estimate of B_0 derived from the acoustic data is expected to be tabled at the meeting of WG-EMM in July 2000, a data workshop should be held sometime during May–June 2000. It was tentatively agreed that the workshop would be held over a one- to two-week period in La Jolla, USA, where computational facilities and other logistic support are readily available. It was emphasised that results from the directed net sampling for identification of acoustic morphs, the oblique net sampling for the determination of krill demographic structure and the oceanographic sampling would be of value in interpreting the

acoustic records. As such, it will be highly desirable to include these elements in the workshop. It was also recognised that summary statistics from the regional surveys conducted at South Georgia and the South Shetland Islands would be valuable in the interpretation of the results.

21. With regard to analysis of the acoustic data it was noted that two of the most important tasks will be target strength estimation and the apportionment of backscattered energy to krill and other scatterers of lesser interest. It is anticipated that several methods of accomplishing these tasks will be applied to the dataset and results compared as part of the final report to WG-EMM. Accordingly, it was suggested that working papers on various techniques to estimate TS and to delineate taxa in the acoustic dataset be invited for the upcoming meeting of WG-EMM in July 1999, that time be requested at that meeting for survey participants to discuss these methods and to select the most promising methods, and that individual scientists be commissioned to develop the computer code required to implement the selected methods on a production basis. This code could then be brought to the workshop and applied to the datasets at hand with the potential of saving a substantial amount of time that would otherwise be spent at the workshop accomplishing these preliminary tasks. The group agreed to this idea in principle.

22. It was also emphasised that the May–June 2000 workshop would be only the first of many workshops and collaborative analyses that may be expected in the aftermath of CCAMLR-2000.

OTHER ISSUES

23. Dr Watkins reported to the group that Drs D. Miller (South Africa) and V. Siegel (Germany) had expressed interest in participating in CCAMLR-2000. It was agreed that their participation was very desirable and that recommendations as to how to best deploy additional experts should be made after all expressions of interest are received and a better idea of how they could contribute is in hand. Exchange of personnel between ships was also discussed and it was decided that such agreements would be first explored between national programs and ultimately coordinated by the CCAMLR-2000 coordinator (Dr Watkins). Dr M. Naganobu (Japan) noted that Japan would not be able to send any personnel to other ships but would welcome experts in the field of acoustics and net sampling, particularly if the latter were able to bring an RMT8 net.

24. The importance of maintaining liaison with other institutions and groups conducting field programs in this sector of the Southern Ocean was recognised. In particular, it was recognised that substantial benefits could accrue by making these groups aware of the developing plans for CCAMLR-2000 and inviting their comments and suggestions. It was recognised that there could be several collaborative opportunities of which we are currently unaware and that individual scientists should actively engage colleagues outside the CCAMLR community regarding planned operations and the existence of the website. In particular, the group agreed that the coordinators for SO-GLOBEC (Drs Kim and E. Hofmann (USA)) should be contacted.

25. Dr Naganobu presented a plan to conduct a series of deep CTD casts across the Drake Passage (following the standard WOCE transect) with the intention of describing the flow field. The group recognised the potential value of such a set of observations and enthusiastically endorsed the plan.

ATTACHMENT A

LIST OF PARTICIPANTS
CCAMLR Synoptic Survey Planning Meeting
(Cambridge, UK, 8 to 12 March 1999)

BRIERLEY, Andrew (Dr)	British Antarctic Survey High Cross, Madingley Road Cambridge CB3 0ET United Kingdom a.brierley@bas.ac.uk
DEMER, David (Dr)	Antarctic Ecosystem Research Group Southwest Fisheries Science Center PO Box 271 La Jolla, Ca. 92038 USA ddemer@ucsd.edu
EVERSON, Inigo (Dr)	British Antarctic Survey High Cross, Madingley Road Cambridge CB3 0ET United Kingdom i.everson@bas.ac.uk
GOSS, Cathy (Ms)	British Antarctic Survey High Cross, Madingley Road Cambridge CB3 0ET United Kingdom c.goss@bas.ac.uk
HEDLEY, Sharon (Ms)	Research Unit for Wildlife Population Assessment Mathematical Institute North Haugh St Andrews Fife KY16 9SS Scotland sharon@mcs.st-andrews.ac.uk
HEWITT, Roger (Dr)	Antarctic Ecosystem Research Group Southwest Fisheries Science Center PO Box 271 La Jolla, Ca. 92038 USA rhewitt@ucsd.edu
KAWAGUCHI, So (Dr)	National Research Institute of Far Seas Fisheries 5-7-1 Orido, Shimizu Shizuoka 424 Japan kawaso@enyo.affrc.go.jp
KIM, Suam (Dr)	Korea Ocean Research and Development Institute

	Ansan PO Box 29 Seoul 425-600 Republic of Korea suamkim@kordi.re.kr
MURRAY, Alistair (Mr)	British Antarctic Survey High Cross, Madingley Road Cambridge CB3 0ET United Kingdom a.murray@bas.ac.uk
NAGANOBU, Mikio (Dr)	National Research Institute of Far Sea Fisheries 5-7-1 Orido, Shimizu Shizuoka 424 Japan naganobu@enyo.affrc.go.jp
PAULY, Tim (Dr)	Australian Antarctic Division Channel Highway Kingston Tasmania 7050 Australia tim_pau@antdiv.gov.au
PRIDDLE, Julian (Dr)	British Antarctic Survey High Cross, Madingley Road Cambridge CB3 0ET United Kingdom j.priddle@bas.ac.uk
REID, Keith (Mr)	British Antarctic Survey High Cross, Madingley Road Cambridge CB3 0ET United Kingdom k.reid@bas.ac.uk
TRATHAN, Philip (Dr)	British Antarctic Survey High Cross, Madingley Road Cambridge, CB3 0ET United Kingdom p.trathan@bas.ac.uk
WARD, Peter (Mr)	British Antarctic Survey High Cross, Madingley Road Cambridge CB3 0ET United Kingdom p.ward@bas.ac.uk
WATKINS, Jon (Dr)	British Antarctic Survey High Cross, Madingley Road Cambridge CB3 0ET United Kingdom j.watkins@bas.ac.uk

ATTACHMENT B

AGENDA
CCAMLR Synoptic Survey Planning Meeting
(Cambridge, UK, 8 to 12 March 1999)

1. Introduction
   1.1 Welcome
   1.2 Meeting arrangements
2. Adoption of agenda
3. Survey design
   3.1 Timing (time available, start times)
   3.2 Assessment of survey coverage in relation to physical and biological variables
   3.3 Randomisation of surveys (explanation of techniques)
   3.4 Boundaries and sampling intensity of second stratum
   3.5 Intercalibration
   3.6 Integration of national regional surveys
   3.7 Contingency plans (bad weather etc.)
   3.8 Additional survey tracks for new participants
4. Primary protocols
   4.1 Acoustics including calibration
   4.2 Net sampling for population structure and target strength
   4.3 CTDs and station ADCP
5. Opportunities for secondary sampling
   5.1 Predator observations (IWC collaboration)
   5.2 Larval krill/zooplankton/macrozooplankton
   5.3 Krill feeding, growth
   5.4 Physical environment – towed undulator
   5.5 Others
6. Secondary protocols
   6.1 Predator observations
   6.2 Sea-surface samples
   6.3 Underway ADCP
   6.4 Chlorophyll, nutrient, dissolved oxygen measurements
   6.5 Others
7. Data entry, maintenance and archive requirements for cruise
8. Data analysis
   8.1 Timetable
   8.2 Workshop
   8.3 Methods
   8.4 Publication strategy
9. International experts
   9.1 Allocation of additional experts
   9.2 Intership exchanges
   9.3 Collaboration with other programs

10. Preparation of report
    10.1 Report of meeting to WG-EMM
    10.2 Preparation of protocols
    10.3 Dissemination on website
11. Additional discussion groups
    11.1 Beyond the EK500 (acousticians)
    11.2 RMT8 and associated equipment.

ATTACHMENT C

LIST OF ACTIONS RESULTING FROM CCAMLR SYNOPTIC SURVEY PLANNING MEETING
(Cambridge, UK, 8 to 12 March 1999)

Task	Reference	Responsible
Update ship schedules	paragraph 3	Dr Watkins
Inform Russia, Ukraine and Brazil of latest plans	paragraph 5	Dr Watkins
Examine recent trends in sea-ice extent	paragraph 6	Dr Hewitt
Finalise survey design • determine exact transect alignment • randomise transects • produce final survey plot • check calculations • produce station plots • produce grid of day length for different dates and latitude/longitude	paragraph 7	Drs Murray, Trathan and Watkins
Develop acoustic protocols further • noise measurement protocols • guidelines for concurrent operation of ADCP and EK500	paragraph 9	Drs Demer, Brierley and Pauly
Develop net sampling protocols further	paragraph 10	Drs Watkins, Siegel and Kawaguchi
Develop CTD protocols further • explore climatological depth of UCDW	paragraph 11	Drs Amos, Naganobu and Trathan
Inform IWC of berths available on each ship	paragraph 12	Dr Watkins
Produce guidelines for zooplankton sampling	paragraph 13	Drs Watkins, Siegel and Kawaguchi
Produce guidelines for surface monitoring	paragraph 14	Drs Priddle, Watkins and others
Investigate availability of satellite imagery	paragraph 15	Drs Watkins and Trathan
Contact SO-GLOBEC coordinators	paragraph 24	Dr Watkins

APPENDIX E

CCAMLR 2000 KRILL SYNOPTIC SURVEY:
A DESCRIPTION OF THE RATIONALE AND DESIGN

THE CCAMLR 2000 KRILL SYNOPTIC SURVEY: A DESCRIPTION OF THE RATIONALE AND DESIGN

PREAMBLE

The aim of this document is to describe the rationale behind the CCAMLR 2000 Krill Synoptic Survey of Area 48 (hereafter referred to as CCAMLR-2000), and to document in one place the details underlying the survey design. Such a document will be necessary in the future, particularly during the analysis and interpretation of the survey results. Furthermore, detailed descriptions of survey design are relatively rare in the published literature, therefore this document provides an opportunity for CCAMLR to establish a lead in this topic.

2. At present the CCAMLR-2000 survey design and data protocols have not received final ratification by either WG-EMM or the Scientific Committee. Therefore the status of this document should be seen as provisional; it is inevitable that it will evolve following future discussions. This document draws heavily from previous planning documents and meetings, and work carried out at the CCAMLR Synoptic Survey Planning Meeting held in Cambridge, UK, from 8 to 12 March 1999. The planning meeting report is contained in Appendix D.

INTRODUCTION

3. Antarctic krill (*Euphausiasuperba*), are considered to be one of the key species in the Antarctic marine food web, being prey to a wide variety of dependent species. In addition to consumption by natural predators, krill are also harvested commercially. Commercial exploitation of krill is managed under the direction of CCAMLR and is regulated in accordance with a sustainable ecosystem rationale. Such management principles are still developing, however, they require fundamental knowledge about the abundance and distribution of krill.

4. The CCAMLR methodology for the management of krill relies heavily on results derived from the CCAMLR generalised yield model (Constable and de la Mare, 1996) and the krill yield model (Butterworth et al., 1991, 1994). This model is used to estimate the long-term annual yield of krill in Area 48 and the precautionary catch limit for the fishery (Conservation Measure 32/X; SC-CAMLR-X). To run the krill yield model, a number of parameters are required, including an estimate of the pre-exploitation biomass of krill (B_0) together with an estimate of the associated variance. The current estimate of B_0 used in the model is derived from the FIBEX synoptic survey which took place from January to March 1981.

5. Over recent years it has been increasingly recognised by the CCAMLR community that a more up-to-date estimate of krill biomass is required for B_0 (SC-CAMLR-XII paragraphs 2.38 to 2.43). For example, in 1996 the Scientific Committee recognised the urgent need for a synoptic survey in Area 48 and noted that management advice for Area 48 could not be updated until such a survey had been conducted (SC-CAMLR-XV, paragraph 4.28). Since then, plans to carry out a CCAMLR krill synoptic survey have progressed steadily (SC-CAMLR-XVI, paragraphs 5.13 to 5.19) and there is now a firm commitment to carry out a survey in the summer of 2000 (between January and February). The primary objective of this survey will be to improve the CCAMLR estimate of B_0 (SC-CAMLR-XII, paragraphs 2.39 and 2.41 to 2.47); additional survey objectives have been formulated, but these are considered secondary to the estimate of B_0.

6. The synoptic survey is a community project that will concentrate effort in Subareas 48.1, 48.2 and 48.3. The survey will involve the participation of three (or more) research vessels from different CCAMLR nations. The composition of the scientific parties

aboard these vessels will also be multinational and will include relevant experts from outside the CCAMLR community. The planning effort for this multi-ship survey is considerable and complex, therefore it is crucial that all stages of the process are documented. Thus, the primary purpose of this paper is to describe in detail the procedures used to design the synoptic survey.

SAMPLING STRATEGY

7. The synoptic survey design was a culmination of numerous decisions. These are reported in a number of separate working documents and reports, and are reproduced here in order to provide a single ready source. The major design strategy decisions were:

(i) whether pre-planned transects positions or adaptive transects positions should be used;

(ii) whether transect separation should be regular and systematic or random;

(iii) whether the design should be stratified or unstratified; and

(iv) the definition of survey limits.

Pre-planned or Adaptive Transect Positions

8. An adaptive survey design would generally offer an increased understanding of the structure of the ecosystem, and improve the CV of the biomass estimate. However, the advantages of a more detailed description of the distribution of krill within high-density areas may be out-weighed by the increased complexity in terms of survey design, execution and subsequent analysis. In the light of these concerns, a more conservative approach of utilising a pre-planned survey has been adopted as the preferred approach. Such an approach had been widely used in the past (for instance FIBEX–BIOMASS, 1980) and is statistically robust and defensible.

Systematic or Random Transect Positions

9. The main objective of the survey is to improve the estimate of B_0 used in the krill yield model. Although an improved estimate could be based on a wide variety of survey designs, the chosen survey design must be statistically defensible. Modern methods of statistical analysis are continually evolving and are providing new opportunities for improved analysis. However, at present no overall consensus exists with regard to some of the model-based geostatistical methodologies. In the future, an agreed methodology using model-based methods may become available, but until that time the CCAMLR community has agreed that a randomised design coupled to a design-based analysis should produce the most statistically defensible result (CCAMLR, 1998a; 1998b Appendix 1; see also conclusions from Miller, 1994).

10. To achieve this the survey will follow a design based on randomised parallel transects. The advantage of using such a design will be that it will be possible to use classical design-based statistical methods (Jolly and Hampton, 1990) without precluding model-based geostatistical methods (e.g. Petitgas, 1993; Murray, 1996) during the survey analysis. In contrast, the use of regular systematic transects would preclude the use of classical design-based statistical methods.

Stratified or Unstratified Design

11. There is still considerable uncertainty within the CCAMLR community regarding the relative abundance of krill in the open ocean compared to that over the continental shelf areas around the Antarctic Peninsula and the islands in Area 48. Although the distribution is complex (illustrated by a variety of datasets and published papers, e.g. Ichii et al., 1998; Sushin and Shulgovsky, 1998), it is important that the B_0 estimate is based on a survey that samples all areas where biomass is important. The FIBEX survey was based on the premise that the majority of krill biomass was close to, or over, shelf areas. However, if krill are also distributed in similar quantities in the open ocean, a design that gives a uniform density of sampling across the whole region should be used. In contrast, if krill are concentrated in particular predictable areas, an appropriate stratified sample design is likely to produce a lower overall CV. Though appropriate stratification may improve the overall CV, it will not change the expected estimate of mean biomass.

12. In view of the debate over the relative importance of shelf and oceanic areas, a compromise survey design was considered appropriate. Thus, the design will allocate extra effort to areas of expected krill concentration.

Definition of Survey Boundaries

13. Given the complexity of the marine ecosystem (cf. Ichii et al., 1998; Sushin and Shulgovsky, 1998), natural limits to the survey area are difficult to define. In establishing appropriate boundaries a variety of factors have to be considered. These include the known historical distribution of krill, the oceanographic structure within the region, the distribution of the commercial fishery, and the distribution of the summer pack-ice. However, these ecological boundaries do not necessarily equate to the artificial limits of the subareas that define the management boundaries.

14. As estimates of krill biomass may be required for strata that have been defined using either ecological or management-based criteria (for example, the Scotia Sea cf. Subarea 48.1), survey boundaries must be based on a compromise between ecological and management boundaries.

OUTLINE OF SELECTED SURVEY DESIGN

15. Considering the factors outlined in the previous section (sampling strategy) the following survey design has been agreed. The ships will undertake a series of randomised transects located within two large-scale strata that cover the Scotia Sea and the area to the north of the Antarctic Peninsula. The first of these strata will cover much of Subareas 48.2 and 48.3, whereas the second will cover most of Subarea 48.1. In order to lie orthogonal to the main axis of the regional bathymetry, the two strata will be oriented in different directions. Within these large-scale strata, three regions are known to have a high abundance of krill and to be of importance to commercial fishing fleets. In these areas additional mesoscale transects will be steamed in order to reduce the CV of the biomass estimate. The first of the mesoscale strata will be to the north of South Georgia, the second will be to the north of the South Orkney Islands, and the third will be to the north of the South Shetland Islands. In the mesoscale strata, the transects will be double the transect density of the large-scale strata. The boundaries of the mesoscale strata will be coincident with the boundaries of selected large-scale sampling units in order to ensure that the survey area is uniformly covered by primary sampling units (transects) for the purposes of randomisation. Details of these cruise tracks are shown in Figures 1, 2 and 3.

METHOD OF RANDOMISATION

16. Within each stratum, transects are randomised. The basic requirement for a truly randomised parallel-transect survey is that all potential transect lines in the survey area should have an equal probability of being sampled. However, one problem arising from a simple randomisation procedure is that there is a possibility of transects being very close together; this can result in an inefficient use of available effort. To overcome this we have used a two-stage randomisation process (see also Brierley et al., 1997). First, the survey area was divided into a series of parallel zones of equal width separated by alternating parallel inter-zones of the same width. A survey transect was then randomly placed within each of the zones. The inter-zones contain no transects and act to keep the transects a minimum distance apart. To comply with the requirement that any transect has an equal probability of being chosen, the location of the entire survey grid was then moved by a random distance equal to, or less than, the inter-zone width. Thus, using the two-stage process, all sampling units have equal probability of being chosen; this gives the necessary condition for the validity of the design-based estimators.

IMPLEMENTATION OF SURVEY DESIGN

17. The computer software package used to carry out the survey design was Arc/Info Version 7.1.1 (ESRI). The final design was checked in Arc/Info and then validated using a separate software package (Proj4). The survey design was undertaken in five strata:

(i) the Scotia Sea large-scale stratum (SS);
(ii) the Antarctic Peninsula large-scale stratum (AP);
(iii) the South Georgia Island mesoscale stratum (SGI);
(iv) the South Orkney Islands mesoscale stratum (SOI); and
(v) the South Shetland Islands mesoscale stratum (SSI).

18. The implementation of the two-stage randomisation process was carried out in seven steps:

(i) generate a regular 25 x 25 km base grid extending beyond the limits of the survey area;

(ii) for each stratum, identify the sampling zones and inter-zones on the appropriate base grid;

(iii) for each transect, identify the random shift within each sampling zone;

(iv) for each stratum, identify the random grid shift for the sampling zones and inter-zones;

(v) for each transect, identify the northern and southern limits of sampling;

(vi) for each transect, identify waypoints at 25 km spacing; and

(vii) for each transect, project the waypoints into geographic coordinates.

Generate Regular 25 x 25 km Base Grids

19. Two regular 25 x 25 km grids that extended beyond the limits of the anticipated survey area were generated, one for the Scotia Sea and one for the Antarctic Peninsula. Each grid was oriented orthogonal to the general axis of the regional bathymetry. Thus, the base grid for the Scotia Sea was designed to lie parallel to the 40°W meridian, whereas the grid for the Antarctic Peninsula was designed to lie at 330° to the 50°W meridian; this second grid was therefore located parallel to the line between 65°00.0’S, 50°00.0’W and 60°00.0’S, 55°46.4’W. The limits of the regular base grids are shown in Table 1.

20. The two base grids were generated using a Lambert Conformal Conic Projection with standard parallels placed approximately 25% from the top and bottom of the anticipated survey areas; with these parallels, scale errors should be approximately 1%. The parameters used for the generation of the grids are shown in Table 2.

Identify the Survey Sampling Zones and Inter-zones

21. Following the criteria outlined above, transect sampling zones were generated on the two base grids. The zones were located at equal distances across the anticipated survey area and were separated by inter-zones of the same width. The parameters for setting up the sampling zones are shown in Table 3.

Identify the Random Transect Positions within the Sampling Zones

22. In order to assign random transect positions, each sampling zone was subdivided into 125 potential positions, giving a sampling resolution of 0.5 km for the large-scale transects and 0.25 km for the mesoscale transects. Within each sampling zone the actual transect position was determined by randomly selecting one of the potential transect positions. The random shift for each transect within each sampling zone is shown in Table 4.

Identify the Random Grid Shift

23. The second level of survey randomisation was carried out by subdividing the grid shift inter-zone into 125 potential grid positions, giving a sampling resolution of 0.5 km. The grid shift was chosen by picking one of these potential grid positions at random. The same grid shift was used for both base grids. This provided the second level of randomisation for both the large-scale transects and the mesoscale transects and ensured that even sampling probability was maintained. The random shifts for the grids are shown in Table 4.

Identify the Northern and Southern Limits for Each Transect

24. After randomly assigning transect positions on the X-axis of the base grid, Y-axis coordinates for the northern and southern end points of each transect were determined by extending the transects to the limits of the survey strata. The southern transect limits were identified with reference to nearby coastlines and the anticipated northern extent of the summer pack-ice, while the northern limits were identified with reference to the boundaries of Subareas 48.1, 48.2 and 48.3, the existence of krill in Area 41, and the frontal structure of the Antarctic Circumpolar Current (see Figures 4, 5 and 6).

Identify Waypoints along each Transect

25. As survey transects are parallel and do not follow meridians, transect orientation continually changes. Therefore to aid navigation during the survey, waypoints were created at regular intervals along each transect. These waypoints were generated from north to south at 25 km spacing.

Project the Transects into Geographic Coordinates

26. The transect waypoints on the base grid were projected from the Lambert Conformal Conic Projection to geographic coordinates using the parameters shown in Table 5.

IMPLICATIONS FOR THE ANALYSIS OF SURVEY STRATA

27. The different orientations of the large-scale grids lead to an overlap of some primary sampling units and a change to the sampling probability to the east of the Antarctic Peninsula. Therefore when estimating B_0 for the southwest Atlantic, it is important that an *a priori* selection of sampling units is made in the region of overlap. Thus, it is recommended that data collected south of 59° on transect 10 should be omitted to avoid problems in data analysis.

28. When preparing an estimate of B_0 for the FAO subareas, other parts of the transects outside the FAO areas will need to be omitted. For these estimates there is no ambiguity about which transect sections to discard.

ALLOCATION OF SURVEY EFFORT TO PARTICIPATING VESSELS

29. Three Member nations within the CCAMLR community have arranged to support the synoptic survey with approximately 30 days each of ship time. These nations are Japan, UK and USA. Other nations may be able to contribute effort, but at the moment they are not in a position to confirm their commitment.

30. The transects within the Scotia Sea (SS) and Antarctic Peninsula (AP) large-scale strata were allocated to the three vessels as follows:

Ship 1 (UK): transects SS-1, SS-4, SS-7, SS-10, AP-13, AP-16 and AP-19;
Ship 2 (USA): transects SS-2, SS-5, SS-8, AP-11, AP-14 and AP-17; and
Ship 3 (Japan): transects SS-3, SS-6, SS-9, AP-12, AP-15 and AP-18.

31. The transects within the mesoscale strata were allocated as follows:

Ship 2 (USA): transects SGI-1, SGI-2, SGI-3 and SGI-4;
Ship 2 (USA): transects SOI-1, SOI-2, SOI-3 and SOI-4; and
Ship 3 (Japan): transects SSI-1, SSI-2, SSI-3, SSI-4, SSI-5, SSI-6, SSI-7 and SSI-8.

32. The UK vessel (Ship 1) was not allocated any mesoscale sampling effort as it has a larger commitment to contribute effort at the large scale.

ADDITIONAL SURVEY EFFORT

33. The synoptic survey design allows for three survey vessels operating within a restricted period of time. However, it is possible that additional survey effort from other CCAMLR Member nations will become available in the future. If this occurs, plans will be required to efficiently utilise the additional effort without compromising the validity of the basic survey design. For example, adding additional transects interleaved between existing transects would result in uneven sampling probabilities, which would be unacceptable. However, two feasible options are available, these are:

(i) to replicate one (or more) of the mesoscale survey areas; and
(ii) to replicate one (or more) of the large-scale survey areas.

34. Choosing between these options depends on the amount of additional effort that becomes available. If a limited amount of effort was to become available (for example five or six days), it would be most useful if it was used to replicate one of the mesoscale strata. Conversely, if a longer period was available (for example 11 to 15 days), it would be most useful if it was used to replicate one of the large-scale strata.

35. It is likely that logistic constraints will dictate which strata will be sampled. However if time were unconstrained, additional effort would be used most efficiently if it were used to repeat the complete itinerary of one (or more) vessel. Following a random selection, the vessel itinerary to repeat should be that of Ship 1, followed by that of Ship 2, and then that of Ship 3.

REDUCTION OF SURVEY EFFORT DUE TO LOST TIME

36. In the southwest Atlantic it is highly likely that some survey time will be lost due to bad weather; contingency plans for lost time are therefore absolutely necessary. The following guidelines are provided in the event that weather and/or equipment failure causes serious delays. It is suggested that each vessel should check progress against the expected time at each station and make adjustments if necessary according to the following hierarchical scheme:

- increase vessel speed without sacrificing quality of acoustic data; or
- delete daytime net sampling and CTD casts.

37. In addition, a check should be made against the expected time at the approximate mid-point of each major transect (six or seven for each ship) and adjustments made according to the following hierarchical scheme:

- curtail the current transect and recommence surveying at the start of the next; else

- curtail the current transect and recommence surveying at the most adjacent point on the next; or

- omit an entire transect according to the randomly determined ranking given in Table 6.

DETERMINATION OF STATION POSITIONS ON TRANSECTS

38. In addition to undertaking a series of acoustic transects, it was agreed that each ship should undertake a series of net hauls to collect krill and zooplankton, and a series of CTD casts to characterise water masses. The initial plans were based on the following assumptions:

- that acoustic transects would be run during daylight so that acoustic biomass estimates would not be biased by night-time migrations of krill to the surface (where they would not be sampled by echosounders);

- that 18 hours per day would be spent conducting acoustic transects; and
- that the remaining six hours per day would be used to sample two stations. One station would be sampled around local midnight, the other around local midday. At each station a CTD cast to 1 000 m and a net haul between 0 m and 200 m would be undertaken.

39. The major implication of such a sampling regime is that station positions are not fixed locations but rather will depend on the start time of each ship, the time and duration of the dark period and the actual progress the ship makes along each transect.

40. The provisional position of the stations has been determined in a series of stages:

(i) determine the approximate dates when each ship will steam each transect;

(ii) calculate the times of local dawn and dusk for the given dates for set positions on each transect; and

(iii) establish the station positions and the cruise plan based on the calculated steaming times.

41. To facilitate cruise planning we have used a PC-based spreadsheet to calculate steaming times around the survey grid. It is hoped that this spreadsheet can be made available to all cruise leaders to help monitor expected progress around the survey transects.

Provisional Start Date for each Vessel

42. Provisional sampling positions have been calculated assuming that the first transect to be steamed by each ship will be started at the times shown in Table 7.

Times of Dawn and Dusk for each Vessel on each Transect

43. The times of civil twilight (where the sun is more than 6° below the horizon) are shown for each vessel respectively in Tables 8, 9 and 10. Selected positions for each transect are shown in order to provide an estimate of local conditions at different latitudes and longitudes. These set positions were selected at the northern and southern extremity of each transect and close to the middle of each transect. Three positions were considered adequate for initial planning purposes as it was recognised that station times would vary according to weather and equipment failures. The final station positions will need to be recalculated by each cruise leader as each cruise progresses.

44. Inspection of the twilight times for each position on each transect reveals that many parts of the survey are in areas where the sun is more than 6° below the horizon for between 4 and 6 hours. This means that the nominal 3 hours allocated for a night-time station is unrealistic. Several compromises will therefore be required to ensure that the survey transects can be covered in the time available. These compromises are:

- transecting starts at local civil dawn and extends until local civil twilight;
- only 2 hours are allowed for the daytime net and CTD; and
- the ships steam at 10.5 knots along transects and at 12 knots between transects.

45. If these conditions cannot be met, then the survey will take longer than originally anticipated, or the transects will have to be shortened according to the hierarchy discussed in the sampling protocols. Assuming that the compromise conditions will be met, provisional station positions have been calculated.

Provisional Station Sampling Positions

46. Based on the available transecting time between local civil dawn and local civil twilight, station positions were calculated. The provisional positions for each of the ships are shown in Tables 11, 12 and 13.

REGIONAL SUPPORT AND CONTEXT FOR THE SYNOPTIC SURVEY

47. The results derived from CCAMLR-2000 will allow a new estimate of B_0 to be produced. However, the magnitude of this new estimate is likely to differ from that of the existing B_0 estimate derived from the FIBEX results (Trathan et al., 1992). If the difference between these two values is marked, considerable debate is likely to ensue and subsequent synoptic surveys may be required. Given the financial and logistic complexity of multi-ship operations, such future surveys cannot be relied upon.

48. However, CCAMLR-2000 should be seen in the context of smaller-scale regional surveys that have been undertaken previously or which may be undertaken in the future. Of particular importance will be those smaller-scale surveys that are undertaken close to the time of the synoptic survey; especially those surveys that form part of long-term time series (such as the US AMLR survey (USA), the BAS Core Programme (UK) and the cruises fostered by the CCAMLR Subgroup on International Coordination). If these regular regional surveys can be linked to the large-scale synoptic survey in time and space, it may be possible to interpret temporal variations observed in the regional surveys, with respect to the larger area. If this proves feasible, it may then become possible to use smaller-scale regional surveys to monitor long-term trends in krill biomass. At present, prior to CCAMLR-2000, any relationship between the regional surveys and the biomass across Area 48 remains undefined.

REFERENCES

BIOMASS. 1980. FIBEX acoustic survey design. *BIOMASS Rep. Ser.*, 14: 15 pp.

Brierley, A.S., J.L. Watkins and A.W.A. Murray. 1997. Interannual variability in krill abundance at South Georgia. *Mar. Ecol. Prog. Ser.*, 150: 87–98.

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

Butterworth, D.S., G.R. Gluckman, R.B. Thomson, S. Chalis, K. Hiramatsu and D.J. Agnew. 1994. Further computations of the consequences of setting the annual krill catch limit to a fixed fraction of the estimate of krill biomass from a survey. *CCAMLR Science*, 1: 81–106.

CCAMLR. 1997. *Statistical Bulletin,* Vol. 9 (1987–1996). CCAMLR, Hobart, Australia.

CCAMLR. 1998a. Hydroacoustic and net krill sampling methods – Area 48 survey.

Document *WG-EMM-98/24*. CCAMLR, Hobart, Australia.

CCAMLR. 1998b. Report from the Steering Committee for the synoptic survey of Area 48. Document *WG-EMM-98/25*. CCAMLR, Hobart, Australia.

Constable, A. and W.K. de la Mare. 1996. A generalised model for evaluating yield and the long-term status of fish stocks under conditions of uncertainty. *CCAMLR Science,* 3: 31–54.

Ichii, T., K. Katayama, N. Obitsu, H. Ishii, and M. Naganobu. 1998. Occurrence of Antarctic krill (*Euphausia superba*) concentrations in the vicinity of the South Shetland Islands: relationships to environmental parameters. Document *WG-EMM-98/18*. CCAMLR, Hobart, Australia.

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

Miller, D.G.M. 1994. Suggested outline for the design and implementation of future near-synoptic krill surveys. Document *WG-Krill-94/20*. CCAMLR, Hobart, Australia.

Murray, A.W.A. 1996. Comparison of geostatistical and random sample survey analyses of Antarctic krill acoustic data. *ICES J. Mar. Sci.*, 53: 415–421.

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

Petitgas, P. 1993. Geostatistics for fish stock assessments: a review and an acoustic application. *ICES J. Mar. Sci.*, 50: 285–298.

Sushin, V.A. and K.E. Shulgovsky. 1999. Krill distribution in the western Atlantic sector of the Southern Ocean during 1983/84, 1984/85 and 1987/88 based on the results of Soviet mesoscale surveys conducted using an Isaacs-Kidd midwater trawl. *CCAMLR Science,* 6: 59–70.

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

Trathan, P.N., M.A. Brandon and E.J. Murphy. 1997. Characterisation of the Antarctic Polar Frontal Zone to the north of South Georgia in summer 1994. *J. Geophys. Res.*, 102: 10483–10497.

Table 1: Limits of the 25 x 25 km base grids used as the foundation for the survey design.

Stratum	Grid		Limit			
	Origin	Rotation	Northern	Southern	Eastern	Western
Scotia Sea	62°S, 40°W	0°	49°S	62°S	23°W	56°W
Antarctic Peninsula	65°S, 50°W	330°	52°S	68°S	40°W	79°W

Table 2: Parameters used for the Lambert Conformal Conic Projections.

Stratum	Spheroid	Units	Standard Parallel 1	Standard Parallel 2	Central Meridian	Origin of Projection	X,Y Shift
Scotia Sea	WGS84	Metres	54°30’S	59°30’S	40°W	62°W	0, 0
Antarctic Peninsula	WGS84	Metres	59°30’S	64°30’S	50°W	65°W	0, 0

Table 3: Parameters used for determining the transect sampling zones.

Stratum	Start Position on Base Grid* (grid column)	Width of Grid Shift Inter-zone (km)	Number of Transects	Width of Transect Sampling Zone (km)	Width of Transect Sampling Inter-zone (km)
Scotia Sea	11	62.50	10	62.50	62.50
Antarctic Peninsula	15	62.50	9	62.50	62.50
South Georgia	21	62.50	4	31.25	31.25
South Orkney Islands	41	62.50	4	31.25	31.25
South Shetland Islands	25	62.50	8	31.25	31.25

* The position with row = 1, column = 1 is at the northeast corner of the grid.

Table 4: Random offsets for transects within the sampling zones and for the grid shift.

Stratum	Random Shift within Transect Sampling Zones (km)										Random Shift for Grid (km)
	T01	T02	T03	T04	T05	T06	T07	T08	T09	T10	
Scotia Sea*	3.00	36.00	43.50	44.50	13.50	0.50	50.00	29.00	41.50	6.50	17.50
Antarctic Peninsula*	40.00	38.50	16.00	37.00	44.50	1.50	57.00	13.00	2.00		17.50
South Georgia+	29.25	0.75	6.50	9.25							17.50
South Orkney Islands+	7.75	18.25	18.50	19.25							17.50
South Shetland Islands+	20.50	5.00	20.25	20.75	11.00	26.75	4.25	29.25			17.50

* Randomisation was carried out with potential transect sampling units separated by 0.50 km.
\+ Randomisation was carried out with potential transect sampling units separated by 0.25 km.

Table 5: Parameters used for the Geographic Projection.

Stratum	Spheroid	Units	X,Y Shift
Scotia Sea	WGS84	Decimal degrees	0, 0
Antarctic Peninsula	WGS84	Decimal degrees	0, 0

Table 6: Priority for omitting transects following periods of lost time; if a transect has already been surveyed, then the next highest priority transect should be omitted.

Vessel	Priority for Omission

	1	2	3	4	5	6	7	8
Ship 1 (large scale)	SS-7	AP-13	SS-10	AP-16	SS-1	SS-4	AP-19	
Ship 2 (large scale)	SS-5	SS-8	AP-14	AP-11	SS-2	AP-17		
Ship 3 (large scale)	AP-12	SS-3	SS-6	SS-9	AP-15	AP-18		
Ship 2 (mesoscale)	SGI-4	SGI-2	SGI-3	SGI-1				
Ship 2 (mesoscale)	SOI-2	SOI-4	SOI-1	SOI-3				
Ship 3 (mesoscale)	SSI-7	SSI-5	SSI-8	SSI-6	SSI-2	SSI-1	SSI-4	SSI-3

Table 7: Start times for each vessel.

Vessel ID	Nation	Start Date and Time
Ship 1	UK	20 Jan 2000 14:00
Ship 2	USA	14 Jan 2000 06:00
Ship 3	Japan	14 Jan 2000 11:00

Table 8: Times of civil dawn and civil dusk for each transect undertaken by Ship 1. Times are GMT.

Transect	Position	Longitude	Latitude	Date	Civil Dawn	Civil Dusk
SS01	North	-31.22	-51.89	20/01/00	05:40	22:52
SS01	Middle	-30.13	-56.56	22/01/00	04:58	23:24
SS01	South	-28.80	-61.00	24/01/00	04:08	00:06
SS04	North	-37.27	-51.98	24/01/00	06:05	23:16
SS04	Middle	-36.93	-56.69	26/01/00	05:35	23:43
SS04	South	-36.49	-61.40	27/01/00	04:46	00:32
SS07	North	-42.79	-51.98	28/01/00	06:36	23:31
SS07	Middle	-43.16	-56.91	30/01/00	06:10	00:03
SS07	South	-43.62	-61.62	31/01/00	05:29	00:48
SS10	North	-48.89	-57.99	01/02/00	06:30	00:29
SS10	Middle	-49.54	-60.44	02/02/00	06:14	00:50
SS10	South	-50.22	-62.66	03/02/00	05:55	01:15
AP13	North	-56.25	-59.68	04/02/00	06:55	01:04
AP13	Middle	-54.45	-61.49	04/02/00	06:30	01:14
AP13	South	-52.47	-63.25	05/02/00	06:05	01:23
AP16	North	-62.93	-60.00	06/02/00	07:26	01:27
AP16	Middle	-61.52	-61.90	06/02/00	07:02	01:39
AP16	South	-60.03	-63.67	07/02/00	06:40	01:50
AP19	North	-69.94	-60.00	08/02/00	08:01	01:48
AP19	Middle	-68.38	-63.05	09/02/00	07:30	02:07
AP19	South	-66.47	-66.06	10/02/00	06:47	02:35

Table 9: Times of civil dawn and civil dusk for each transect undertaken by Ship 2. Times are GMT.

Transect	Position	Longitude	Latitude	Date	Civil Dawn	Civil Dusk
SS02	North	-33.53	-51.82	16/01/00	05:35	23:11
SS02	Middle	-32.73	-56.15	18/01/00	05:02	23:46
SS02	South	-31.69	-61.20	19/01/00	03:54	00:40
SS05	North	-38.63	-52.01	20/01/00	06:02	23:27
SS05	Middle	-38.46	-56.72	21/01/00	05:28	00:03
SS05	South	-38.24	-61.43	23/01/00	04:35	00:55
SS08	North	-44.59	-54.62	24/01/00	06:17	00:04
SS08	Middle	-45.15	-58.87	25/01/00	05:45	00:41
SS08	South	-45.81	-62.89	27/01/00	04:59	01:34
AP11	North	-52.74	-58.73	30/01/00	06:33	00:56
AP11	Middle	-51.25	-60.11	30/01/00	06:13	01:04
AP11	South	-50.08	-61.11	31/01/00	06:12	00:56
AP14	North	-58.81	-60.01	31/01/00	06:48	01:30
AP14	Middle	-57.53	-61.45	01/02/00	06:31	01:37
AP14	South	-56.13	-62.88	01/02/00	06:06	01:51
AP17	North	-66.33	-60.01	02/02/00	07:25	01:53
AP17	Middle	-64.98	-62.16	03/02/00	07:01	02:08
AP17	South	-63.53	-64.17	04/02/00	06:31	02:25
SGI01	South	-34.89	-54.78	15/01/00	05:16	23:40
SGI04	North	-37.60	-53.11	14/01/00	05:38	23:39
SOI01	South	-42.75	-60.74	28/01/00	05:24	00:44
SOI04	North	-46.22	-59.73	29/01/00	05:53	00:43

Table 10: Times of civil dawn and civil dusk for each transect undertaken by Ship 3. Times are GMT.

Transect	Position	Longitude	Latitude	Date	Civil Dawn	Civil Dusk
SS03	North	-35.45	-51.92	14/01/00	05:38	23:22
SS03	Middle	-34.88	-56.62	15/01/00	04:58	23:57
SS03	South	-34.14	-61.32	17/01/00	03:52	01:01
SS06	North	-40.26	-52.01	18/01/00	06:05	23:37
SS06	Middle	-40.29	-56.73	19/01/00	05:29	00:14
SS06	South	-40.34	-61.44	21/01/00	04:34	01:11
SS09	North	-46.75	-54.74	22/01/00	06:20	00:17
SS09	Middle	-47.52	-58.76	23/01/00	05:49	00:55
SS09	South	-48.48	-62.77	24/01/00	04:55	01:57
AP12	North	-54.65	-59.24	25/01/00	06:19	01:23
AP12	Middle	-52.34	-61.43	25/01/00	05:41	01:43
AP12	South	-50.12	-63.25	26/01/00	05:03	02:04
AP15	North	-61.36	-60.01	27/01/00	06:44	01:53
AP15	Middle	-60.03	-61.68	27/01/00	06:16	02:10
AP15	South	-58.43	-63.46	28/01/00	05:44	02:30
AP18	North	-67.84	-60.00	29/01/00	07:17	02:12
AP18	Middle	-66.33	-62.60	30/01/00	06:42	02:36
AP18	South	-64.63	-65.06	31/01/00	05:51	03:13
SSI01	North	-55.55	-60.50	01/02/00	06:34	01:19
SSI08	South	-62.61	-62.88	05/02/00	06:51	01:59

Table 11: Provisional positions for net and CTD sampling stations for Ship 1. Times are GMT.

Station	Station ID	Transect	Longitude	Latitude	Date and Time
1	SS0101	SS01	-30.8837	-53.4453	20 Jan 23:32
2	SS0102	SS01	-30.5734	-54.7801	21 Jan 13:33
3	SS0103	SS01	-30.2413	-56.1149	21 Jan 23:12
4	SS0104	SS01	-29.8852	-57.4489	22 Jan 12:33
5	SS0105	SS01	-29.4357	-59.0032	22 Jan 23:29
6	SS0106	SS01	-28.9448	-60.5540	23 Jan 13:08
7	SS0401	SS04	-36.5109	-61.1745	24 Jan 13:29
8	SS0402	SS04	-36.6692	-59.6071	25 Jan 00:24
9	SS0403	SS04	-36.8137	-58.0372	25 Jan 14:11
10	SS0404	SS04	-36.9280	-56.6905	25 Jan 23:51
11	SS0405	SS04	-37.0344	-55.3436	26 Jan 13:23
12	SS0406	SS04	-37.1495	-53.7729	27 Jan 02:36
13	SS0407	SS04	-37.2114	-52.8761	27 Jan 14:09
14	SS0701	SS07	-42.8095	-52.2023	28 Jan 15:26
15	SS0702	SS07	-42.8866	-53.3227	28 Jan 23:49
16	SS0703	SS07	-42.9849	-54.6685	29 Jan 14:25
17	SS0704	SS07	-43.0900	-56.0152	30 Jan 00:04
18	SS0705	SS07	-43.2029	-57.3620	30 Jan 14:04
19	SS0706	SS07	-43.3242	-58.7083	30 Jan 23:43
20	SS0707	SS07	-43.4780	-60.2772	31 Jan 14:13
21	SS0708	SS07	-43.6216	-61.6195	31 Jan 23:51
22	SS1001	SS10	-49.8668	-61.5496	02 Feb 00:22
23	SS1002	SS10	-49.4155	-59.9966	02 Feb 14:19
24	SS1003	SS10	-49.0601	-58.6623	02 Feb 23:58
25	AP1301	AP13	-53.5832	-62.2921	05 Feb 00:53
26	AP1302	AP13	-55.0723	-60.8894	05 Feb 14:50
27	AP1601	AP16	-62.0074	-61.2721	07 Feb 00:54
28	AP1602	AP16	-60.8325	-62.7437	07 Feb 15:25
29	AP1603	AP16	-60.0261	-63.6703	07 Feb 23:05
30	AP1901	AP19	-66.7579	-65.6520	09 Feb 00:47
31	AP1902	AP19	-67.8720	-63.9227	09 Feb 15:20
32	AP1903	AP19	-68.6227	-62.6191	10 Feb 01:00
33	AP1904	AP19	-69.4196	-61.0931	10 Feb 15:26
34	AP1905	AP19	-69.9429	-60.0005	10 Feb 23:48

Table 12: Provisional positions for net and CTD sampling stations for Ship 2. Times are GMT.

Station	Station ID	Transect	Longitude	Latitude	Date and Time
1	SGI0301	SGI03	-36.5551	-53.9814	14 Jan 19:17
2	SGI0201	SGI02	-35.5553	-53.6031	15 Jan 04:46
3	SGI0101	SGI01	-35.0060	-53.8866	15 Jan 17:07
4	SGI0102	SGI01	-34.8924	-54.7824	16 Jan 03:35
5	SS0201	SS02	-33.4295	-52.4934	16 Jan 22:40
6	SS0202	SS02	-33.1729	-54.0565	17 Jan 13:50
7	SS0203	SS02	-32.9365	-55.3972	17 Jan 23:29
8	SS0204	SS02	-32.6393	-56.9614	18 Jan 13:58
9	SS0205	SS02	-32.3639	-58.3014	18 Jan 23:38
10	SS0206	SS02	-32.0155	-59.8625	19 Jan 13:03
11	SS0207	SS02	-31.6907	-61.1978	19 Jan 22:42
12	SS0501	SS05	-38.3117	-60.0865	21 Jan 01:15
13	SS0502	SS05	-38.3860	-58.5159	21 Jan 14:20
14	SS0503	SS05	-38.4446	-57.1683	22 Jan 00:00
15	SS0504	SS05	-38.5079	-55.5957	22 Jan 14:11
16	SS0505	SS05	-38.5581	-54.2482	22 Jan 23:51
17	SS0506	SS05	-38.6051	-52.9019	23 Jan 13:32
18	SS0801	SS08	-44.6999	-55.5132	24 Jan 23:41
19	SS0802	SS08	-44.8985	-57.0823	25 Jan 14:36
20	SS0803	SS08	-45.0826	-58.4267	26 Jan 00:16
21	SS0804	SS08	-45.3157	-59.9933	26 Jan 14:23
22	SS0805	SS08	-45.4587	-60.8873	27 Jan 00:11
23	SS0806	SS08	-45.7690	-62.6711	27 Jan 14:36
24	SOI0201	SOI02	-44.0864	-60.7096	28 Jan 20:02
25	SOI0301	SOI03	-45.0948	-59.7768	29 Jan 01:18
26	SOI0401	SOI04	-46.2158	-59.7299	29 Jan 19:29
27	SOI0402	SOI04	-46.3817	-60.6231	29 Jan 23:57
28	AP1101	AP11	-50.3436	-60.8879	30 Jan 15:40
29	AP1102	AP11	-51.6909	-59.7185	31 Jan 00:22
30	AP1103	AP11	-52.7420	-58.7345	31 Jan 11:23
31	AP1401	AP14	-58.8057	-60.0060	01 Feb 05:59
32	AP1402	AP14	-57.7186	-61.2427	01 Feb 14:41
33	AP1403	AP14	-56.3368	-62.6736	02 Feb 00:30
34	AP1701	AP17	-63.6028	-64.0762	03 Feb 00:08
35	AP1702	AP17	-65.1266	-61.9409	03 Feb 15:28
36	AP1703	AP17	-65.9425	-60.6521	04 Feb 00:10

Table 13: Provisional positions for net and CTD sampling stations for Ship 3. Times are GMT.

Station	Station ID	Transect	Longitude	Latitude	Date and Time
1	SS0301	SS03	-35.3969	-52.3671	14 Jan 13:46
2	SS0302	SS03	-35.2440	-53.7099	14 Jan 23:25
3	SS0303	SS03	-35.0806	-55.0539	15 Jan 12:52
4	SS0304	SS03	-34.8753	-56.6226	15 Jan 23:49
5	SS0305	SS03	-34.6521	-58.1907	16 Jan 13:46
6	SS0306	SS03	-34.4086	-59.7572	17 Jan 00:42
7	SS0307	SS03	-34.1419	-61.3207	17 Jan 13:11
8	SS0601	SS06	-40.3234	-60.0965	18 Jan 13:35
9	SS0602	SS06	-40.3091	-58.5255	19 Jan 00:31
10	SS0603	SS06	-40.2961	-56.9529	19 Jan 14:00
11	SS0604	SS06	-40.2858	-55.6046	19 Jan 23:40
12	SS0605	SS06	-40.2746	-54.0323	20 Jan 14:08
13	SS0606	SS06	-40.2657	-52.6859	20 Jan 23:47
14	SS0901	SS09	-46.9069	-55.6322	22 Jan 14:32
15	SS0902	SS09	-47.1562	-56.9734	23 Jan 00:12
16	SS0903	SS09	-47.4706	-58.5370	23 Jan 14:33
17	SS0904	SS09	-47.7629	-59.8754	24 Jan 00:12
18	SS0905	SS09	-48.1900	-61.6558	24 Jan 14:45
19	AP1201	AP12	-50.1248	-63.2510	25 Jan 03:32
20	AP1202	AP12	-51.6568	-62.0233	25 Jan 14:34
21	AP1203	AP12	-53.0033	-60.8403	26 Jan 00:13
22	AP1204	AP12	-54.6487	-59.2442	26 Jan 14:39
23	AP1501	AP15	-60.7156	-60.8449	27 Jan 15:03
24	AP1502	AP15	-59.6764	-62.0971	28 Jan 00:42
25	AP1801	AP18	-65.6257	-63.6743	29 Jan 15:18
26	AP1802	AP18	-66.4672	-62.3828	30 Jan 00:57
27	AP1803	AP18	-67.4827	-60.6532	30 Jan 15:20
28	SSI0201	SSI02	-56.3241	-60.6831	01 Feb 20:11
29	SSI0301	SSI03	-56.8563	-61.7915	02 Feb 08:51
30	SSI0401	SSI04	-57.9514	-62.0227	02 Feb 21:52
31	SSI0501	SSI05	-59.6069	-61.3797	03 Feb 09:54
32	SSI0601	SSI06	-60.9750	-61.6381	03 Feb 23:36
33	SSI0701	SSI07	-61.0057	-62.6053	04 Feb 11:25
34	SSI0801	SSI08	-62.6133	-62.8770	05 Feb 01:31
35	SSI0802	SSI08	-63.2521	-62.0290	05 Feb 12:59

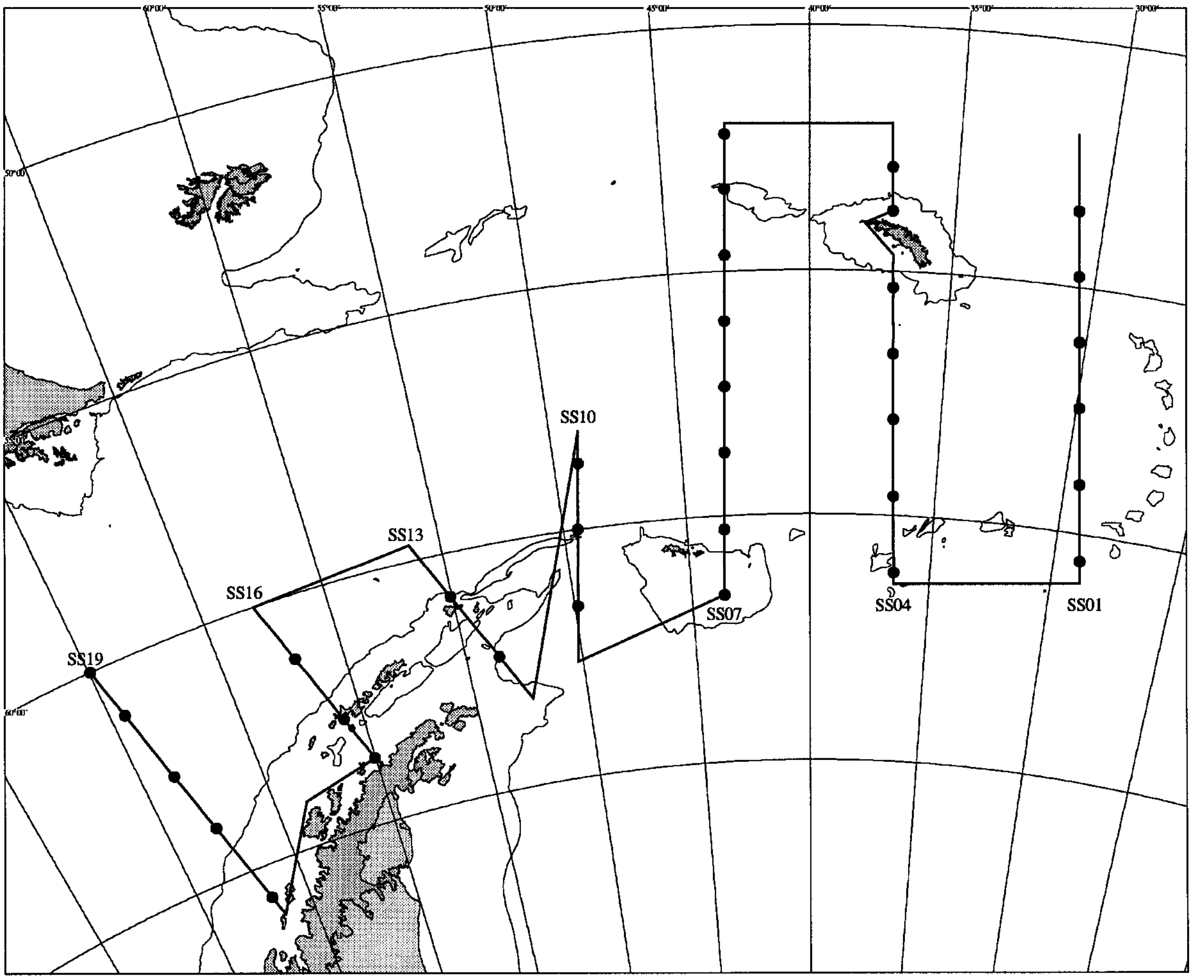

Figure 1: CCAMLR-2000 cruise track for Ship 1 (UK vessel).

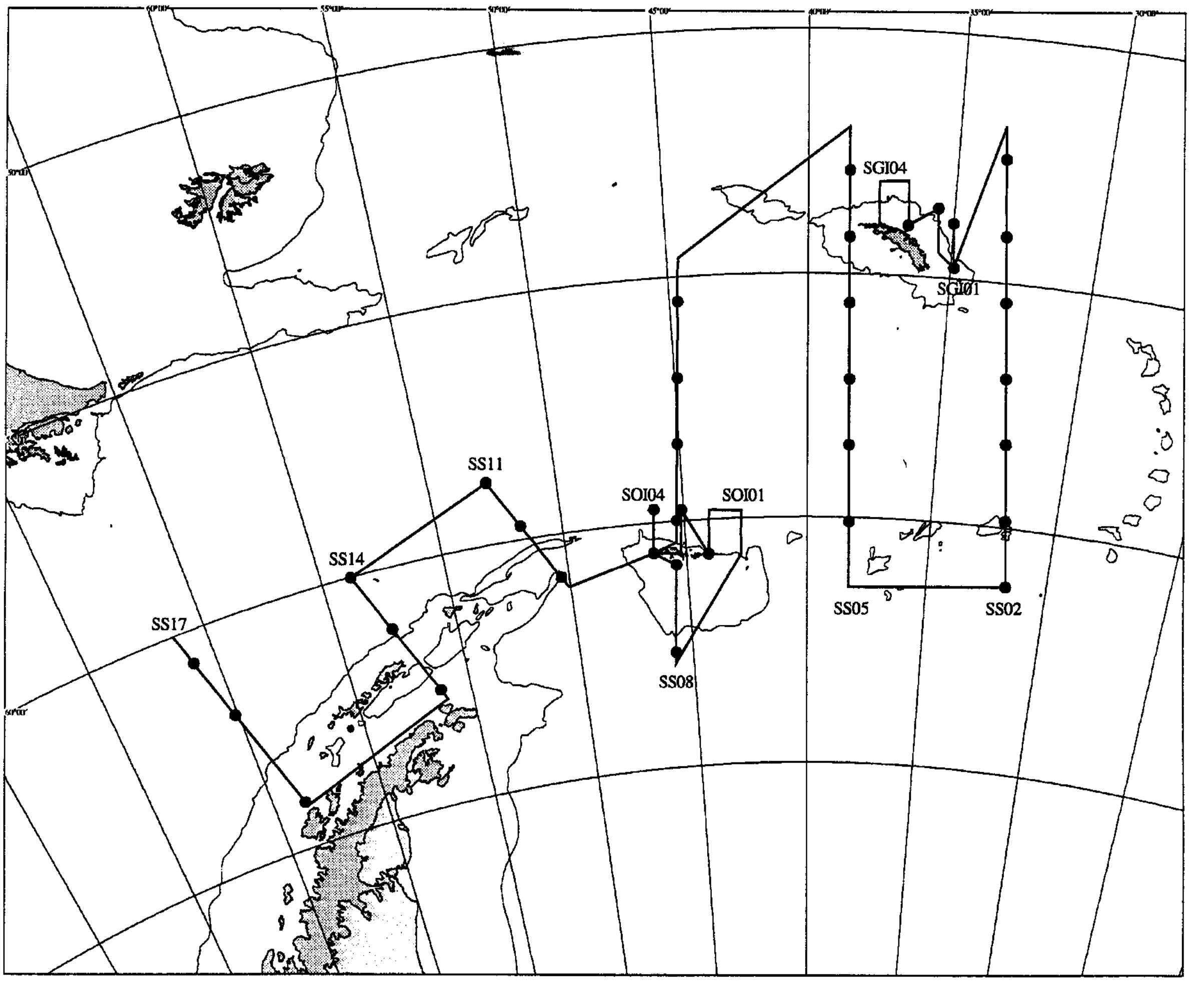

Figure 2: CCAMLR-2000 cruise track for Ship 2 (USA vessel).

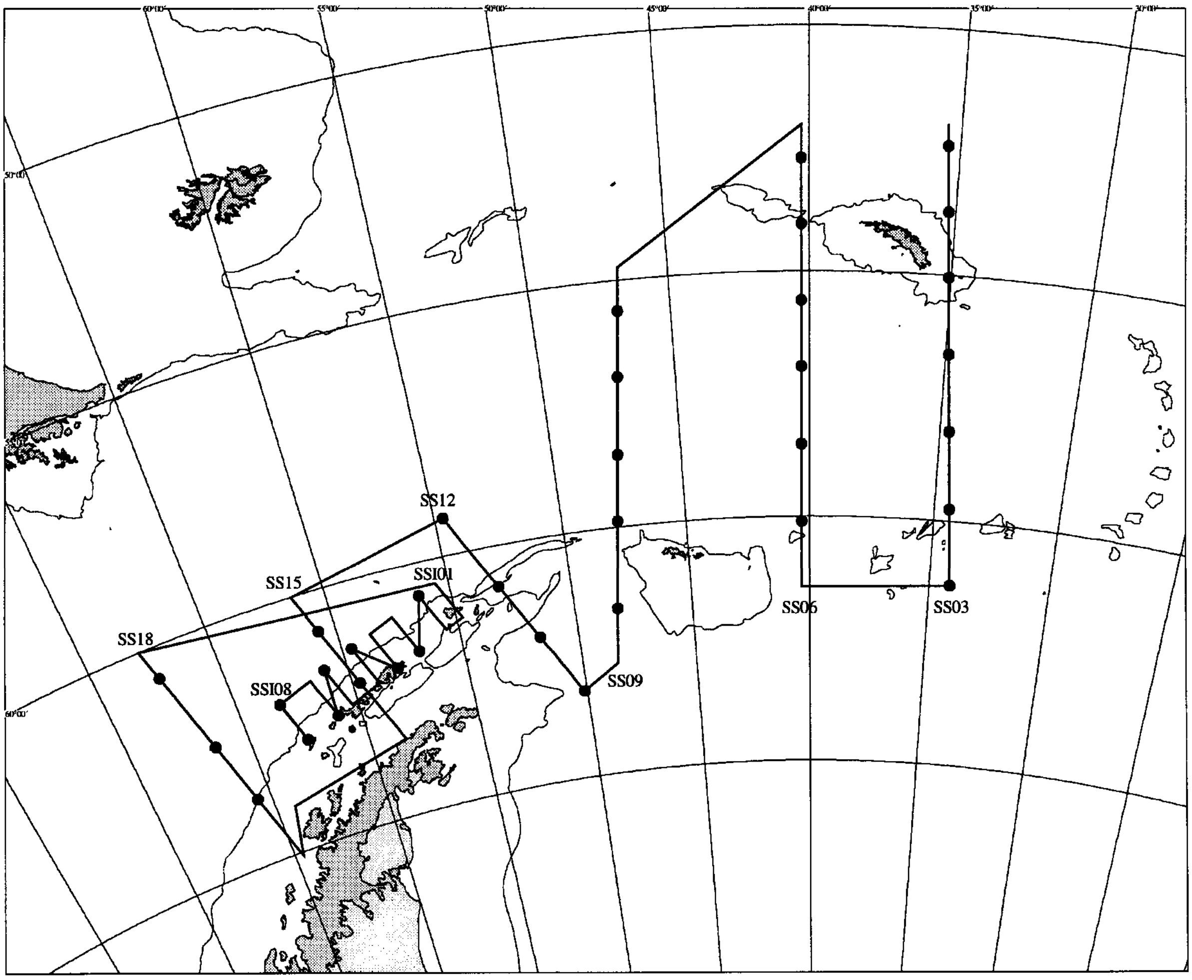

Figure 3: CCAMLR-2000 cruise track for Ship 3 (Japanese vessel).

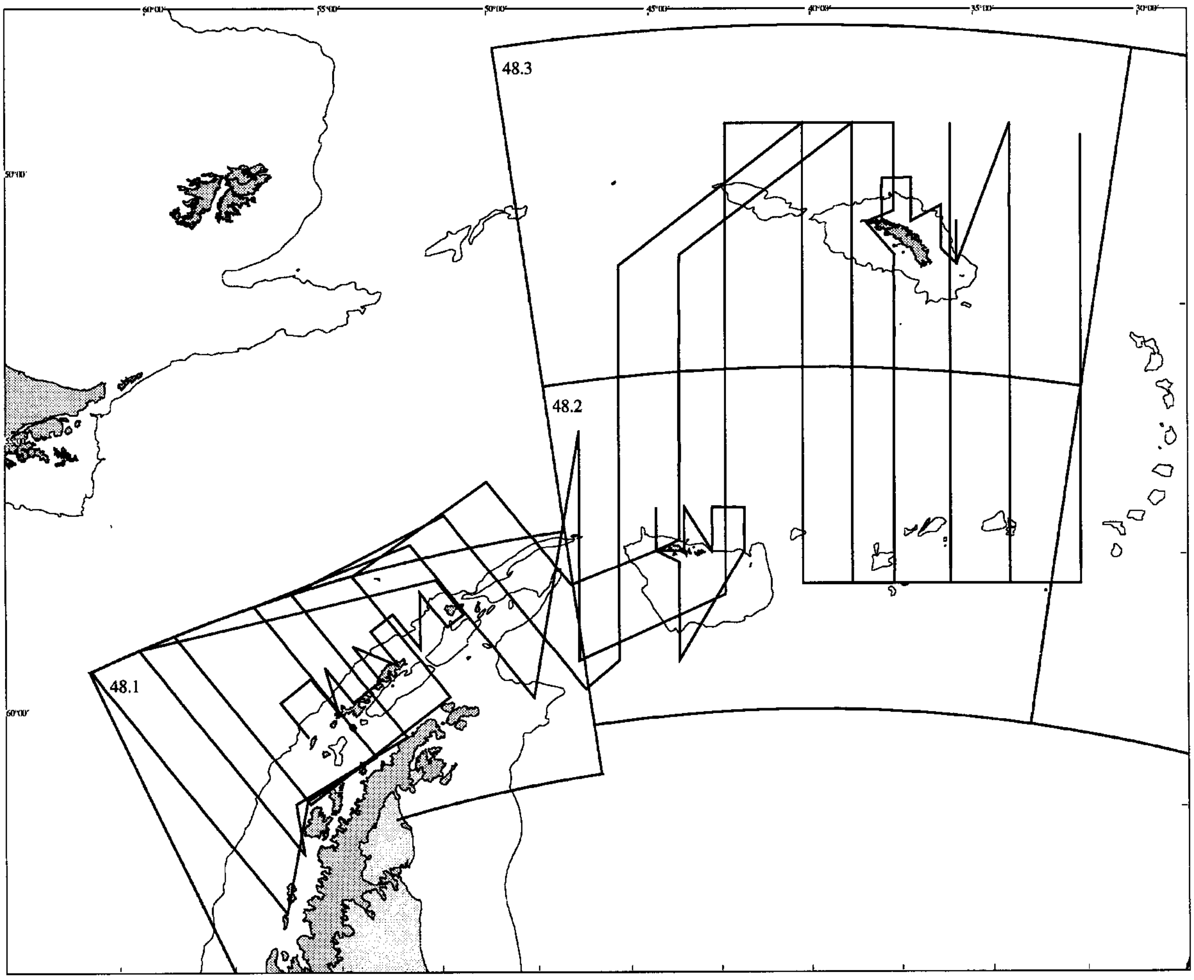

Figure 4: CCAMLR-2000 cruise tracks with the boundaries shown for Subareas 48.1, 48.2 and 48.3.

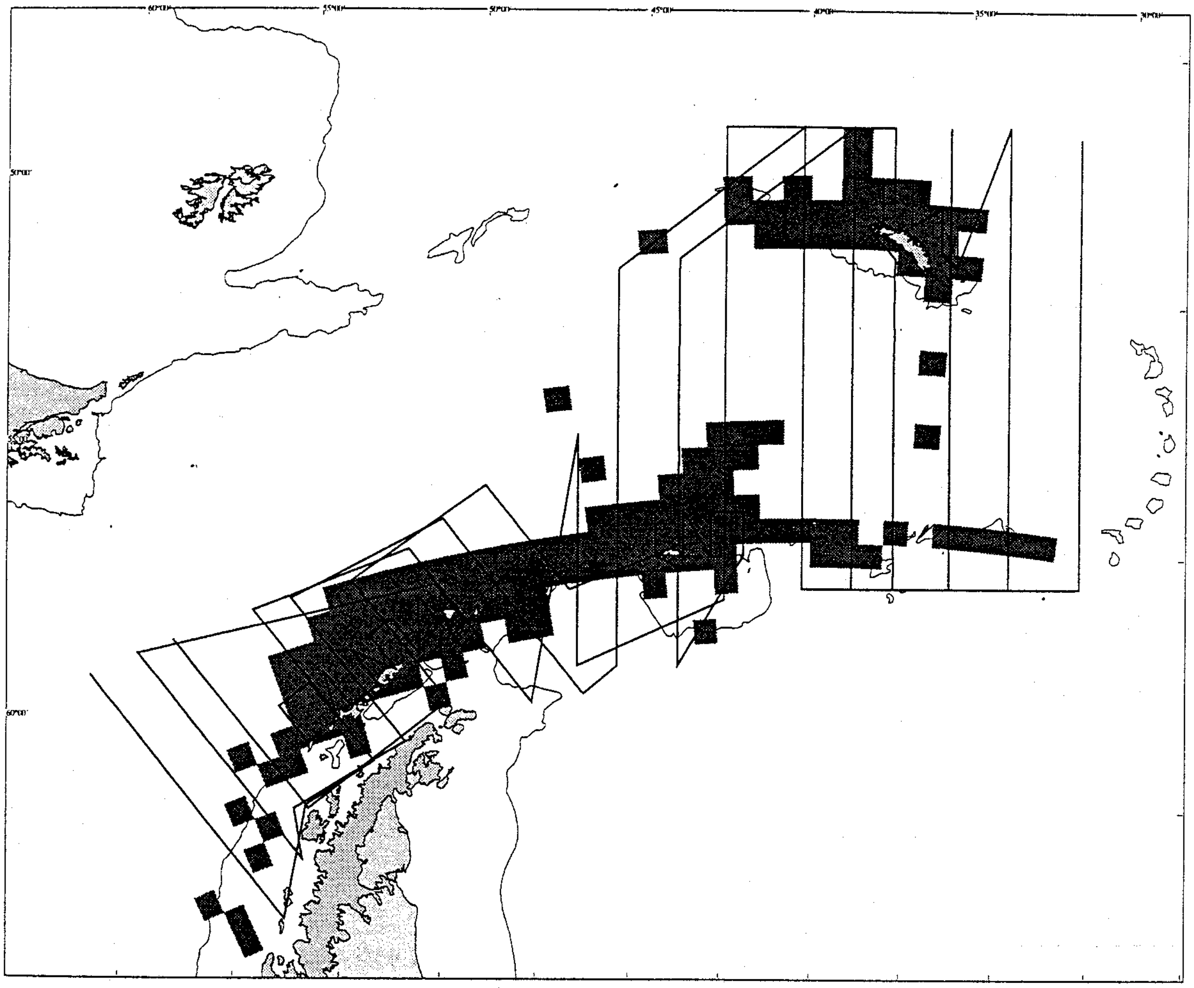

Figure 5: CCAMLR-2000 cruise tracks with positions where krill catches have been reported during the period 1986 to 1992 (CCAMLR, 1997).

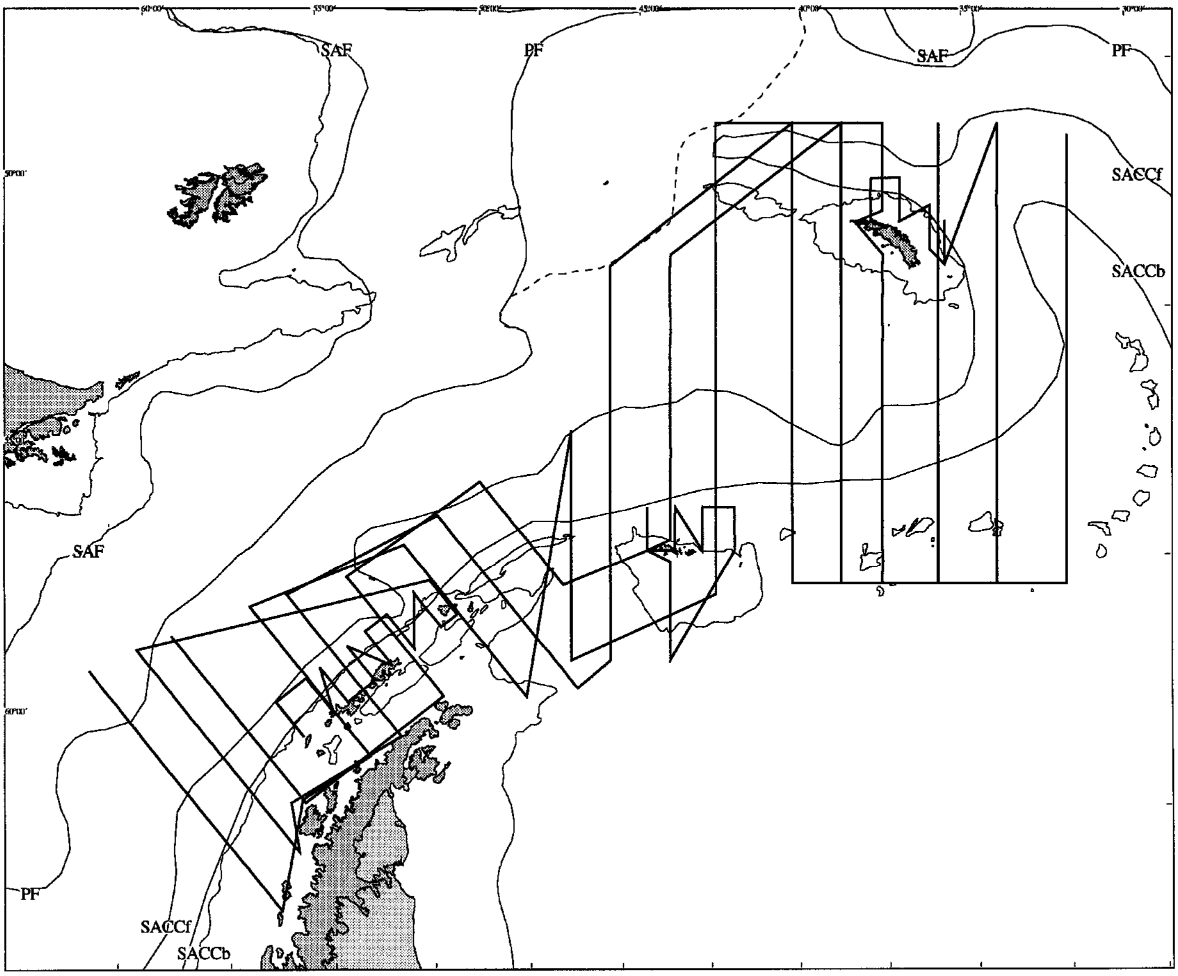

Figure 6: CCAMLR-2000 cruise tracks with climatic positions of the major fronts in the Antarctic Circumpolar Current. SAF – Sub-Antarctic Front; PF – Polar Front; SACCf – Southern ACC Front; SACCb – Southern ACC boundary. Positions of fronts after Orsi et al. (1995), with the Polar Front modified after Trathan et al. (1997).