REPORT OF THE WORKING GROUP ON ECOSYSTEM MONITORING AND MANAGEMENT

(San Diego, USA, 21 to 31 July 1997)

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INTRODUCTION

Opening of the Meeting

1.1 The third meeting of WG-EMM was held at the Hubbs-Sea World Research Institute, San Diego, USA, from 21 to 31 July 1997.

1.2 Dr M. Tillman, Director of the Southwest Fisheries Science Center, welcomed the participants to San Diego on behalf of the National Marine Fisheries Service. In opening the meeting, Dr Tillman outlined the history of the US Antarctic research program and recent advances in monitoring changes in populations of krill* and dependent species. Investigations on the impact of climate change on Antarctic marine living resources have led to greater needs for integrated physical and biological oceanography. The meetings of WG-EMM have served to pull these fields together and further contribute to the collaborative effort.

1.3 Dr Tillman thanked Mr D. Kent, Executive Director of Hubbs–Sea World Research Institute, and his staff, for making available the institute facilities for the meeting. He also thanked Sea World for their support during the meeting. Dr R. Holt (USA), the local organiser, thanked the US State Department and the National Science Foundation for their financial contributions to the meeting.

1.4 On behalf of the Working Group, the Convener, Dr I. Everson (UK), thanked Dr Tillman and the US Government for the invitation to hold the meeting in San Diego. Dr Everson expressed the Working Group's appreciation to Dr Holt and his team from the Southwest Fisheries Science Center for their substantial work in organising the meeting. He also thanked the staff of Hubbs–Sea World Research Institute for their involvement in the meeting. Dr Everson noted that the first meeting of the former WG-Krill was held in La Jolla in 1989, and had provided a sound foundation for the work of WG-EMM. In outlining the work ahead, Dr Everson welcomed the participants, the observers from two international organisations, Mr J. Cooper (IUCN) and Dr S. Reilly (IWC), and the new Data Manager, Dr D. Ramm, to the meeting.

Adoption of the Agenda and Organisation of the Meeting

1.5 A revised Provisional Agenda was introduced and discussed. The order of agenda items had been rearranged so as to provide a better coverage of the issues to be considered. The Agenda, as amended, was adopted (Appendix A).

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

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* For the purpose of this document, krill is *Euphausia superba* unless stated otherwise.

1.7 The report was prepared by Dr I. Boyd (UK), Prof. D. Butterworth (South Africa), Drs J. Croxall (UK), W. de la Mare (Australia), R. Hewitt and E. Hofmann (USA), G. Kirkwood (UK), K.-H. Kock (Germany), D. Miller (Chairman, Scientific Committee), E. Murphy (UK), S. Nicol (Australia), P. Penhale (USA), P. Trathan and J. Watkins (UK), P. Wilson (New Zealand) and the Secretariat.

Intersessional Activities

1.8 The Subgroup on Statistics met in La Jolla, USA, from 14 to 18 July 1997 and its report is attached as Appendix D.

1.9 The Workshop on International Coordination was also held in La Jolla from 14 to 18 July 1997 and its report submitted as WG-EMM-97/44. The executive summary of the workshop is attached as Appendix E.

FISHERIES INFORMATION

Harvesting Strategies

2.1 A summary of fine-scale data from the krill fisheries conducted during the 1995/96 season was presented by the Secretariat (WG-EMM-97/23). Krill catches were reported by four Members: India (6 tonnes in Subarea 58.4), Japan (60 546 tonnes mostly in Subarea 48.1), Poland (20 610 tonnes mostly in Subarea 48.1) and Ukraine (20 056 tonnes mostly in Subarea 48.3). In addition, Panama reported a catch of 496 tonnes in Subarea 48.3. No catches were reported from Area 88. The total krill catch reported was 101 714 tonnes.

2.2 Dr Boyd noted that large catches had been reported from fine-scale rectangles bordering the northern limit of the CCAMLR Convention Area. He inquired about the availability of information on krill fisheries in waters adjacent to the Convention Area. Dr Everson identified reports of catches along the northern boundary of Subarea 48.1 (e.g. November 1995). The Working Group requested that the Secretariat identify the nationality of vessels fishing in those areas, and seek information from those Members on any krill catches which may have been taken in adjacent waters.

2.3 The krill catches reported to the Secretariat by July 1997 indicated that four Members fished during the 1996/97 season: Japan (58 771 tonnes in Subareas 48.1 and 48.3), Poland (16 159 tonnes in Subareas 48.1 and 48.3), UK (308 tonnes in Subarea 48.1) and Ukraine (5 657 tonnes in Subareas 48.2 and 48.3). No catches were reported from Areas 58 or 88. The total catch of krill reported at the time of the meeting was 80 895 tonnes.

2.4 Members were asked about their plans to fish for krill during the 1997/98 season. Japan planned to continue fishing for krill at levels of catch and effort similar to those reported in 1996/97 (i.e. about 60 000 tonnes and four vessels). The Republic of Korea planned to deploy one trawler and take about 4 400 tonnes of krill. The UK indicated that detailed information was not yet available, but it anticipated that one vessel would fish for krill at catch levels similar to those in 1996/97 (i.e. about 500 tonnes). Chile and Russia reported that they did not plan to fish for krill. No information was available from Poland and Ukraine; these Members were not represented at the meeting.

2.5 Prof. Butterworth identified the potential for a rapid expansion of the krill fishery in response to major changes in the commercial viability of the fishery. He proposed that the economic history of the fishery be documented so that market trends and product developments can be identified. Dr Nicol informed the Working Group that a FAO report on worldwide trends in krill fisheries was due for release (FAO, in press).

2.6 Krill markets in 1996/97 were generally in decline. Mr M. Kigami (Japan) reported that the Japanese krill fleet supplied three types of markets: (i) aquaculture food, (ii) bait for recreational fisheries, and (iii) human consumption. The demand for aquaculture food has decreased in recent years, and the market for human consumption was small. Further, the Japanese market for bait was oversupplied, and Japan exported bait within Asia (e.g. Taiwan, Republic of Korea).

2.7 Mr Kigami said that the krill fishery was an important fishery to Japan, and he expected that this situation would be maintained in the future. In addition, the Working Group noted that other nations were gearing up for krill fishing within the Convention Area. Dr Miller reported that recent popular fishery articles indicated that China was preparing to enter the krill fishery. Dr E. Sabourenkov (Secretariat) reported on a proposal for a joint krill fishing venture between Ukraine and Canada using a supertrawler.

2.8 Dr B. Bergström (Sweden) questioned the ability for krill catches to rapidly increase and approach the precautionary catch limits set within the Convention Area. Dr Nicol suggested that this was unlikely to occur within the next one to two years. However, recent significant developments in krill-based pharmacology and biotechnology, which are closely guarded while pending patent, could change the nature of the fishery and lead to an increase in krill catches over the next five years. Consequently, the potential impact of these advances on the commercial viability of the krill fishery was difficult to evaluate.

2.9 Dr S. Kawaguchi (Japan) reported on the krill harvesting strategies used by Japanese vessels to avoid large catches of salps and 'green' krill (WG-EMM-97/37). Dr V. Sushin (Russia) reported on krill harvesting strategies used by Russian trawlers (WG-EMM-97/50). Drs Hewitt and Trathan outlined the importance of distinguishing between the behaviour of fishermen and environmental variability when interpreting variations in CPUE. Further, different fleets used different harvesting strategies: Japanese trawlers usually conduct short directed tows, while Russian and Polish vessels generally have longer tow durations.

2.10 Dr Everson stressed the importance of acquiring haul-by-haul data for the krill fishery. He urged Members to continue submitting this type of data to the Secretariat.

International Scheme of Scientific Observation

2.11 Dr Everson outlined the usefulness of the time budget data for krill fishery operations submitted by Ukraine in 1995. No further data have been submitted to date, and Members were reminded of the need to acquire and submit these data to the Secretariat (SC-CAMLR-XV, paragraph 4.11).

2.12 The method for collecting time budget data, and methods for collecting other observer data were revised during 1996/97. Early in 1997 the Secretariat produced an updated version of the *Scientific Observers Manual*. This manual has now been published and sent to all Members.

Other Information

2.13 No further information was presented.

HARVESTED SPECIES

Distribution and Standing Stock

3.1 A number of features of the distributional behaviour of krill were described which might affect the interpretation of the results from surveys.

Information from Scientific Surveys

3.2 The aggregation patterns of krill, detected acoustically, in the Elephant Island area (Subarea 48.1) differed from inshore where krill were in tight swarms, to offshore where they were found in layers (WG-EMM-97/28). The overall density inshore was about four times as high as that in the slope/offshore region. The swarms inshore exhibited diurnal vertical migrations whereas the layers offshore did not.

3.3 Acoustic records from this survey suggested that myctophid fish were absent from the inshore region but were common in the slope/offshore region. They formed large scattering layers which undertook diurnal vertical migrations from a daytime depth of greater than 150 m to the surface at night. The distributional and behavioural interactions of krill and myctophids were thought to affect their predation by fur seals and chinstrap penguins (see section 6).

3.4 In the Elephant Island area, scattering from krill during 1996/97 was generally in the upper 50 m, frequently near the thermocline and above water c. 0°C, and coincident with both the shelf break and a persistent but variable frontal zone (WG-EMM-97/44). Myctophids are thought to be associated with circumpolar deep water.

3.5 Revised results (WG-EMM-97/49) of the acoustic survey in Subarea 48.2 which was conducted by RV *Atlantida* in February/March 1996 (WG-EMM-96/36) were submitted. The total krill biomass in the surveyed area (19 200 n miles^2) was assessed as 2 million tonnes.

3.6 Vertical migration was seen as a source of bias in the conduct of this survey where a night-time drop in krill density was consistently observed and consequently the results had been corrected for this (WG-EMM-97/49). There was also a suggestion that because the survey was conducted late in the season it may have underestimated the maximum summer biomass.

3.7 Inshore–offshore and longitudinal differences in the distribution of krill from a 1996 survey of Division 58.4.1 were also reported (WG-EMM-97/59). Gravid females were only found in deep water north of the shelf break, with the remainder of the population found both north and south of the shelf break. The results of the survey and an analysis of historical data suggested that the 120–150°E region is an area where krill are perennially scarce and restricted to coastal region whereas krill in the 80–120°E region are more abundant and extend further offshore.

Information from the Fishery

3.8 Evidence from the krill fishery tends to support the scientific evidence of different patterns of distribution and behaviour of krill in inshore and offshore areas.

3.9 Krill fishing northeast of Livingston Island concentrated on the shelf and continental slope area (WG-EMM-97/36). Data from this fishery indicate that in summer larger krill are found in oceanic to continental slope area with small krill on the shelf, but that in late autumn only large krill occurred in slope and shelf areas.

3.10 CPUE data also show inshore–offshore differences in Area 48, with values for catch per towing time generally being higher in the shelf area and lower offshore (WG-EMM-97/22). The population size is generally larger on the shelf because of the presence of both adults and juveniles compared to offshore, where only adults are found, but there may be years when this is not observed. This may occur when krill are abundant and tend to spread out from the shelf area into the oceanic waters, or when the krill population lacks some of the juvenile size groups and the offshore adults contribute more to the overall biomass. The first possibility was not evident from the data presented, the second seems more likely.

Areal Distributions

3.11 Two surveys of Ross Sea – in ice cover (November/December 1994) and immediately following ice retreat (December 1989–January 1990) indicated higher biomass of krill in this area than had been previously envisaged (WG-EMM-97/53).

3.12 Seasonal differences in relative abundances of the two species of krill – *Euphausia superba* and *E. crystallorophias* – were determined by using two acoustic frequencies and by using net samples to verify the acoustic targets. *E. crystallorophias* was abundant in the south and near Ross Island in summer, whereas *E. superba* was found in a superswarm in an ice-free area in the pack-ice in front of Terra Nova Bay in spring but mainly further north later.

3.13 Analysis of haul-by-haul data from the Soviet fishing fleet in Subarea 48.2 provided information on the concentration of krill aggregations and their movement near Coronation Island (WG-EMM-97/50). One offshore krill aggregation persisted for 25 days and drifted to the northwest at a rate of 7.4 km/day and was fished throughout November 1989 until it dispersed. From December 1989 to April 1990, however, the fishing fleet remained to the northwest of Coronation Island and fished temporally and spatially sustained krill concentrations.

Trends in Krill Distribution and Standing Stock

Within-season Trends

3.14 In the South Shetland Islands, surveys were conducted during the spring and summer of 1996/97 (WG-EMM-97/16, 97/30, 97/33 and 97/44). Trends observed within the 1996/97 season included a prolonged spawning period with spawning peak late in the season and poor survival. The highest densities of krill were observed in the frontal zone parallel to the shelf break, which is consistent with previous years.

3.15 A survey conducted by the US in the Elephant Island area (Subarea 48.1) in February 1997 indicated an average year for krill abundance (WG-EMM-97/30), rather than the abundant year suggested by the *Polarstern* cruise conducted in December 1996 (WG-EMM-97/16). The seasonal maximum in krill abundance usually occurs in January, but this year it appears to have occurred earlier.

Between-season Trends

3.16 Acoustic biomass surveys of two areas in the South Georgia region in 1996/97 indicated that lower krill densities and larger krill were found northwest of South Georgia compared to those in the survey area to the northeast. These results were comparable to those from spring 1996 but differed from those obtained in 1994 when krill densities were substantially lower (WG-EMM-97/48).

3.17 Longer-term data from 11 cruises between 1980 and 1987 to the South Georgia region indicate that there were consistent differences in the sizes of krill caught in different areas around the island and that these differences may arise because the krill there originate in different water masses (WG-EMM-97/47). Larger krill encountered at the western end of South Georgia were associated with Bellingshausen Sea water, whereas smaller krill at the eastern end of the island were associated with Weddell Sea water.

3.18 Trends over the last 20 years detected from the results of net surveys conducted in Subarea 48.1 indicated that krill abundance and biomass are now at their highest levels since the mid-1980s, with standing stock in 1996/97 primarily composed of age 2+ krill recruited from spawning in 1994/95 (WG-EMM-97/29 and 97/33).

Indices of Abundance, Distribution and Recruitment

Indices of Local Distribution and Abundance

3.19 The Working Group recalled its request last year for information on indices of local krill availability (SC-CAMLR-XV, Annex 4, paragraphs 3.60 to 3.71), and noted that no progress had been reported in this area.

3.20 The Working Group reiterated the importance that it placed on the development of such indices and accordingly repeated the request that it had made last year (see paragraph 10.5).

Indices of Recruitment

Subarea 48.1

3.21 All available proportional recruitment data from Elephant Island since 1977 were analysed and a new 'absolute' recruitment index, in numbers per 1 000 m^3, was presented (WG-EMM-97/29). Compared to preceding years the absolute recruitment index had increased considerably over the past two years and it was suggested that krill stock size in this area should increase as a result. The 'absolute' krill recruitment index has increased over the last two years suggesting that the low levels of the last decade may be a result of variability rather than a downward shift in overall krill abundance.

3.22 Proportional recruitment estimates from the Elephant Island area indicate above-average reproductive success for krill spawning in 1994/95 and below-average reproductive success for krill spawning in 1995/96.

3.23 Spawning in the Elephant Island area in 1996/97 was delayed. Although spawning began in December 1996 it only peaked in March when there was a low level of abundance. This occurrence suggests that poor recruitment in this area next year is expected (WG-EMM-97/44).

3.24 Proportional recruitment indices calculated from commercial catches are broadly similar to those from scientific surveys (WG-EMM-97/22 and 97/35). The fishery, however, is selective – the nets select for the larger sizes of krill and the fishery concentrates in specific areas so the commercial data are biased. Proportional recruitment indices calculated from commercial fishery data may provide some useful information on recruitment. For example, because the commercial fishery targets large krill, the presence of large amounts of small krill in the catches may indicate very good recruitment that year.

Subarea 48.3

3.25 Off South Georgia, the only years when strong year classes of year-one krill were found were 1980/81 and 1994/95; these correspond with strong year classes off the Peninsula (WG-EMM-97/47 and 97/48). For example, the 34 mm size class found at South Georgia in 1996/97 can be linked to similar year classes in Subareas 48.1 and 48.2. However, because South Georgia experiences a mixture of waters it may be difficult to see year classes clearly and it is not possible to separate the water masses reliably on a simple east–west division (WG-EMM-97/47).

3.26 In length-frequency data from the commercial catch, only in one out of four years were the size frequencies from the commercial catch in Subarea 48.3 similar to those from Subarea 48.1 (WG-EMM-96/51).

Future Work on Recruitment

3.27 The Working Group recognised the recent progress in assessing krill recruitment from scientific surveys but noted that there was still much work to be done. A priority task was to develop a reliable predictor of krill recruitment and to determine its statistical properties so that it can be used in assessments.

3.28 There is continuing interest in knowing whether the recruitment and density data obtained for restricted areas reflect more global trends. Variability in krill recruitment and abundance will have to be apportioned between large-scale environmental processes and smaller-scale processes operating within the krill population.

3.29 Further analyses are required to determine how well the measures of abundance and proportional recruitment are matched by the output of the krill yield model (see also SC-CAMLR-XV, Annex 4, paragraph 6.23).

CPUE

3.30 Data from the commercial fishery in Area 48 provided an historical background to changes in CPUE (WG-EMM-97/22 and 97/35) and to the current levels of CPUE from the fishery operating in Subarea 48.1 (WG-EMM-97/36).

3.31 CPUE data for Area 48 for the period from 1975/76 to 1987/88 indicated that the highest CPUE occurred in 1980/81 and the lowest in 1977/78 which corresponds to scientific survey estimates of abundance for these years (WG-EMM-97/22). There was little apparent trend between years in the length-frequency distributions from the commercial catch.

3.32 The data from Subarea 48.1 indicated that there was a steady decrease in CPUE in the Livingston Island area and that this was most likely driven by the fishery concentrating more on higher-quality 'less-green' krill over time, although decreases in krill density could not be ruled out as a possible cause (WG-EMM-97/35). There were no apparent trends in the Elephant Island area, but this may have been because of the high variability in krill abundance and distribution noted there.

3.33 Annually-analysed CPUE data typically have very high variances. Surprisingly, given the greater degree of sampling, these are often greater than the variance estimates for scientific surveys in the same region. However, these estimates are not strictly comparable because the scientific survey results reflect only sampling variability and fail to take account of variations in catchability over time.

3.34 The CPUE variance may, in fact, swamp real differences in abundance that should correlate with other events. For example, at South Georgia, mass predator starvation was observed in 1977/78 which was associated with changes in measures of CPUE from the fishery in Subarea 48.3; however, because of the high variances, these observed correlations were not statistically significant.

3.35 The interpretation of CPUE data has some further problems. Observed decreases in CPUE in the Livingston Island area (WG-EMM-97/35) could be a result of krill abundance decreases or of changes in fishing operations – for example, the fleet avoiding 'green' krill. There are also differences in operational strategies of ships from different Members – Japan (and Chile) pursue a much more targeted fishery than Russia and Poland. Japanese CPUE probably reflects within-swarm density whereas Russian CPUE is probably more reflective of general density in the area. Differences in the tonnage of ships may also play a part.

3.36 CPUE provides a greater degree of sampling than scientific surveys and is relatively easily obtained from the commercial fleet but it has inherent biases. Catch/tow time gives some measure of within-swarm krill density but some measure of swarm distribution is also required to interpret these data (Mangel, 1988; Butterworth, 1988).

3.37 Search time has been suggested as a measure of interswarm distribution which could be obtained from the fishing fleet but it has proved difficult to obtain this regularly despite the advances reported at the last Working Group meeting using randomised time sheets by scientific observers (WG-EMM-96/26).

3.38 CPUE data are difficult to interpret because there are uncertainties, not only with regard to the operational strategies, but also because of lack of knowledge of the detailed distributional behaviour of krill and how this varies with abundance. Scientific surveys are essential to provide this type of information.

3.39 CPUE will only ultimately be of use if it can be factored into management advice. There have been major advances in understanding the behaviour of the krill fishery, and also in the data availability from the fishery over the last 10 years, for example, the availability of fine-scale data from the fishery. There is still, however, the problem that the fishery concentrates in a tiny fraction of the range of krill and any measure from the fishery is unlikely to provide an assessment of large-scale krill abundance in the near future.

3.40 The Working Group encouraged further attempts to incorporate CPUE with other operational information from the fishing fleets to work towards providing an index which could be used for assessment purposes.

Krill–Salp Interaction

3.41 New information was presented on the seasonal presence of salps (WG-EMM-97/30 and 97/73), the within-season appearance of salps (WG-EMM-97/33) and the geographic distribution of salps and their relationship to krill and ice (WG-EMM-97/59).

3.42 In the Elephant Island area, following below-average sea-ice coverage over winter, salps reached the second-highest recorded level of abundance despite being only moderately abundant early in the season (WG-EMM-97/30 and 97/33). Increasing salp abundance over the summer season was considered to be unusual and may be linked to the unusually high (4°C) surface water found in the area later in the season.

3.43 The late season salp abundance observed in the Elephant Island area was predicted to cause poor krill recruitment in 1997/98. Few krill larvae were seen late in the season which could have been caused by poor spawning success, by the larvae being eaten by salps, or by advection of the larvae out of the area.

3.44 A negative correlation was reported between the by-catch of salps in the commercial krill catch and the presence of 'green' krill, suggesting that when salps were abundant, krill were not feeding actively (WG-EMM-97/37). Salp blooms were generally detected later in the season (February/March) by the commercial fishery.

3.45 In Division 58.4.1 the presence of salps on transects of a scientific survey was negatively correlated with the average annual sea-ice cover (WG-EMM-97/59) whereas krill abundance was positively correlated with annual ice cover. This suggests that there may be a relationship between krill salps, and ice on a geographic as well as on a seasonal scale.

3.46 When dealing with the relationships between krill, salps and the environment and it is necessary to distinguish between hypothesis generating and hypotheses testing processes. A multivariate analysis of salp–krill recruitment/abundance/ice-cover data was suggested as an intersessional task that should be completed before definitive conclusions on these relationships could be reached.

DEPENDENT SPECIES

4.1 The Working Group reviewed papers concerned with the population sizes and demography of dependent species.

4.2 In response to a request from the Working Group, WG-EMM-97/39 described the population sizes of CEMP monitoring species at Marion Island in 1996. Overall, there had been a 22% decline in the breeding population size of gentoo penguins since the previous estimate made in 1994, but this was still an overall increase in numbers since a survey carried out in 1984. Estimates of the breeding population size of macaroni penguins gave the lowest level since surveys began in 1976. Since 1994, the size of the breeding population has declined by about 4% each year.

4.3 The Convener welcomed data resulting from the first year of occupation of the new CEMP site at Bouvet Island (WG-EMM-97/20). From a time series including seven counts of the study site dating back to 1958, the number of breeding chinstrap penguins increased by a factor of 10-times between 1958 and 1979 and has subsequently declined by a similar factor up to 1997. Macaroni penguins increased by a similar order of magnitude through to 1979 and have apparently decreased slowly in number since then. Cape petrels feed mainly on krill at Bouvet Island and showed highly variable breeding success due partly to predation in some parts of the population by sub-Antarctic skuas (WG-EMM-97/56). The population of Antarctic fur seals has increased substantially since 1990. The magnitude of the current rate of increase is such that it must be driven partly by immigration.

4.4 Up-to-date estimates of the breeding population sizes of fur seals and penguins at Cape Shirreff, Livingston Island (WG-EMM-97/62 and 97/63) showed that the long-term increase in fur seal numbers has continued at this site with an estimated average increase of 13% per annum. Although the total number of pups born at Cape Shirreff is still small compared with the numbers at South Georgia, the rate of increase is similar to that observed there in recent years.

4.5 At Cape Shirreff, the size of the breeding population of chinstrap penguins appears to have increased since surveys made over 40 years ago, while the numbers of breeding gentoo penguins have not changed (WG-EMM-97/62). However, Prof. D. Torres (Chile) and Dr W. Trivelpiece (USA) informed the Working Group that qualitative observations indicate that colonies of chinstrap penguins have declined in recent years. Analysis of population counts since 1990 are under review.

4.6 The Working Group noted the potential for changes in predator population sizes due to interactions between different groups of predators. Disturbance of penguins by some fur seals and the presence of penguins in the diets of fur seals has been described from Livingston Island (WG-EMM-97/62). The rapid increase in fur seal numbers generally has the potential to make some shore-breeding sites less attractive for penguins. Although it was acknowledged that this was a possibility, evidence from South Georgia did not support this view since gentoo penguins and fur seals appeared to co-exist at several sites. Furthermore, the declines in macaroni penguins at South Georgia and Marion Island had occurred mainly in areas and/or colonies which were inaccessible to fur seals.

ENVIRONMENT

5.1 The Convener noted that the report of the Workshop on International Coordination (WG-EMM-97/44) contained information relevant to environmental interests and asked Dr S. Kim (Republic of Korea), Convener of the workshop, to summarise the report.

5.2 Dr Kim introduced WG-EMM-97/44 by noting that a workshop was convened at the Southwest Fisheries Center in La Jolla, USA, during the week prior to the meeting of WG-EMM. Scientists from Japan, Republic of Korea, Germany, and the US participated in the workshop. Dr Kim asked Mr A. Amos (USA), who was the leader of the subgroup on the environment, to summarise this portion of the report.

5.3 Mr Amos said that three Members, Republic of Korea, Germany and the US, participated in the sequential occupation of a transect along 55°W during the 1996/97 field season to obtain information on seasonal environmental variability. All Members used the same instrumentation (e.g. CTD) and methodology, which minimised variability between datasets.

5.4 Mr Amos noted that the general water-mass structure seen in 1996/97 was the same as that seen in previous years. However, the surface temperatures in December 1996 were higher than those observed in previous years. Temperatures above 4°C were observed for the first time. The reason for the higher temperatures and the biological implications of this are unknown.

5.5 The Convener thanked Mr Amos for his summary and noted that the seasonal datasets from 55°W provide an example of what can be accomplished through cooperative, coordinated research.

5.6 WG-EMM-97/6, which provided further discussion of the German hydrographic dataset collected during December 1996 in the Elephant Island region, was introduced. Time series data presented in this paper show movement of the boundary between the Weddell Sea and southeast Pacific surface waters. This paper recommends a cooperative analysis of historical hydrographic data from the Elephant Island region.

5.7 WG-EMM-97/40 presented an analysis of hydrographic and sea-surface temperature data obtained during January and February 1994 around South Georgia. The primary focus of this analysis was on defining the position and character of the Polar Front and associated mesoscale features. The data and analysis indicate that the Polar Front is quite variable and it is suggested that this variability is likely of crucial importance to many of the predator species breeding at the northern end of South Georgia. Dr Trathan noted that this paper provides the first documentation of changes in the position of the Polar Front in this region.

5.8 Following from work begun at the Workshop on Evaluating Krill Flux Factors (WS-Flux) in Cape Town, South Africa in 1994, WG-EMM-97/65 provided revised calculations of krill flux in the South Georgia region. The fluxes were calculated using the circulation fields from the Fine Resolution Antarctic Model (FRAM) and hydroacoustic data. The computed krill fluxes were then compared to the estimated needs of predator populations in the South Georgia region. Dr Murphy said that further discussion of this paper would take place in the context of ecosystem interactions.

5.9 WG-EMM-97/67 used flow fields derived from historical wind, hydrographic, and circulation data to calculate transport patterns and transport times for particles released west of the Antarctic Peninsula and throughout the Scotia Sea. The simulated trajectories show that wind transport alone results in small displacements of particles from their initial location. Displacement due to the large-scale geostrophic flow transports particles from the Antarctic Peninsula to South Georgia in 120–160 days. A combination of wind and large-scale flow is needed to move particles from the northern Weddell Sea to South Georgia.

5.10 The hydrographic and circulation characteristics of the Antarctic continental shelf between 150°E and the Greenwich Meridian were described in WG-EMM-97/68. This analysis shows similarity in many of the water masses and water-mass structure over this region.

5.11 WG-EMM-97/66 gave examples of four marine fisheries that are affected by environmental variability. This paper was presented as an information item. The case histories indicate that management strategies for exploited fisheries must include the effects of environmental variability.

5.12 WG-EMM-97/69 presented an analysis of sea-ice data from the Antarctic Peninsula region obtained between 1978 and 1995. These data show a region of persistent open water off the tip of the Antarctic Peninsula. This feature was pronounced during 1987 and 1991, which were characterised by extensive sea-ice cover. Years of reduced sea-ice cover did not show the region of open water at the tip of the Antarctic Peninsula. A persistent region of open water may have considerable implications for biological production in this region.

5.13 Dr M. Naganobu (Japan) suggested that the region of open water may be a polynya produced by the westerly winds. Dr Kock said that the open water region observed at the tip of the Peninsula may not fit the accepted definition of a polynya. Dr Hewitt said that the important point made in WG-EMM-97/69 was that the region at the tip of the Antarctic Peninsula may be ice free in August and September when the ice extent is greatest. He also noted that the open water feature is more extensive in space and time than a simple lead in the ice.

ECOSYSTEM ANALYSIS

By-catch of Fish in the Krill Fishery

6.1 WG-EMM-97/72 provided information on the species composition and the amount of fish by-catch in krill catches of the trawler *Niitaka Maru* over the continental slope and in oceanic waters to the north of the South Shetland Islands from 1 to 23 February 1997. Sampling onboard followed the standardised manner as set out in the *Scientific Observers Manual*. Fish were encountered in 16 out of 80 hauls. With the exception of one specimen of the coastal icefish *Neopagetopsis ionah*, all fish belonged to oceanic mesopelagic species with the myctophid *Electrona antarctica* as the predominant species among them. Fish by-catches were primarily observed in hauls conducted in the late evening and at night when mesopelagic fish migrate to the upper part of the water column to feed.

6.2 The Working Group welcomed the continuous effort of Japanese scientists to provide information on the by-catch of juvenile fish in the krill fishery. The Working Group noted, however, that this study, as most previous studies, had been conducted in austral summer. It reiterated requests from previous years (e.g. SC-CAMLR-XV, Annex 4, paragraph 6.3) to extend these studies to other seasons to take into account spatial and seasonal differences in the occurrence of fish in krill catches in order to better assess when fish are most vulnerable to the krill fishery.

6.3 Following a recommendation of the Working Group from last year (SC-CAMLR-XV, Annex 4, paragraph 6.3), stomach contents of fish specimens incidentally taken by a Japanese krill fishing vessel in January–February 1995 are currently being studied in order to obtain a better understanding on the association of fish with krill aggregations. Results of this analysis will be submitted to the 1997 meeting of WG-FSA.

6.4 Following a request by WG-FSA in 1995, the Science Officer, Dr Sabourenkov, provided an interim report on the status of the comprehensive review on the by-catch of fish in the krill fishery which is currently being conducted under his coordination by a group of specialists in this field. The Working Group has agreed on a protocol for how the data should be analysed. The Secretariat has established a database which currently contains records from 1 018 commercial hauls taken in Subareas 48.1 and 48.2 and Divisions 58.4.1, 58.4.2 and 58.4.4. More information, primarily from the krill fishery in Subarea 48.1, is likely to be submitted by Japan and Chile in the near future. Information from other areas, for example Subarea 48.3, is also available. However, these data are often of limited value due to the lack of information on zero catches. The database is currently being extended to incorporate information from research vessels on the fish by-catch from macrozooplankton/nekton surveys which may assist in identifying areas where and when pelagic stages of Antarctic fish are abundant and likely to be taken during krill fishing. Pending the submission of outstanding datasets, it is envisaged that results from this review will become available at the 1997 meeting of WG-FSA.

Report of the Subgroup on Statistics

6.5 The Working Group considered the Report of the Subgroup on Statistics (Appendix D) which met in La Jolla, USA, immediately prior to the Working Group meeting. Aspects of the subgroup's report on indices of at-sea behaviour and survey design are discussed under other agenda items (paragraphs 8.69, 8.70 and 8.121).

Identification of 'Anomalies' in CEMP Indices

6.6 The subgroup recommended that an alternative term be found for 'anomaly' to describe noteworthy values in the CEMP indices. The term anomaly is commonly used to describe events that occur with low probability. However, events of interest may be fairly common, for example occurring once every four or five years. The important consideration may be whether the frequency of these events is changing over time. WG-EMM agreed that it would use the term 'Ecologically Important Value' (EIV), referred to by the Subgroup on Statistics as 'Value Outside the Generally Observed Norm' to describe a value in an index that is extreme relative to the distribution of values which are deemed to be unlikely to lead to substantial changes in the status of dependent, related and harvested species. The Working Group noted that the application of this definition requires not only further development of the statistical methods applied to the indices, but also further consideration on determining the range of values which would be deemed as unlikely to lead to substantial changes in the status of dependent, related and harvested species.

6.7 The Working Group noted the promising results obtained from illustrative examples of multivariate analyses of the CEMP indices including principal component analysis and a simple additive index. In particular, the Working Group endorsed the further development of multivariate analyses, including studies of combined indices that summarise a large number of indices into a smaller set which can be more easily examined. The Working Group also noted that comparing indices to distributions estimated from a set of baseline data provided for more reliable detection of extreme values.

6.8 The Working Group noted the importance of being able to detect not only extreme values in the indices, but also changes in variability, trends and shifts in the values, and changes in the frequency of extreme events.

6.9 Contributors to CEMP indices were requested to check the validity of data in WG-EMM-97/25 Rev. 1 and to inform the Secretariat of any changes which might be required.

Agnew–Phegan Model

6.10 The Subgroup on Statistics suggested modifications to the Agnew–Phegan model of overlap both in terms of adjustments to temporal aspects of the underlying model and changes in the form of the index calculated from it. The Working Group agreed that the Schroeder index proposed by the subgroup should be applied to Subarea 48.1 and requested the Secretariat to report the results to the next meeting. The Data Manager undertook, with assistance from Dr de la Mare, to examine revisions of the underlying model to improve its temporal aspects. The Working Group also noted that the Schroeder index gives a measure of the spatial overlap between the dependent species and the fishery in a given time period. It was agreed that an additional index is required to give some measure related to the possible impact on dependent species of the quantities of harvested species taken by a fishery.

Missing Values

6.11 The Working Group endorsed the advice of the Subgroup on Statistics that the causes of missing values in the database of CEMP indices need to be documented as part of the database. This is required so that if missing values need to be imputed for a particular type of analysis, the method of imputation can take into account those cases where the fact that data are missing is not independent of the expected values of the missing data. The Data Manager is preparing a circular seeking the information specified in paragraphs 5.3 to 5.6 of the subgroup's report (Appendix D). The Working Group also endorsed the advice of the subgroup given in paragraph 5.7 of Appendix D, and in particular that imputed values where all data for a particular year are missing should not be incorporated into the CCAMLR database.

Interactions between Ecosystem Components

Krill-centred Interactions

Harvested Species and the Environment

6.12 The Working Group discussed the ecological and fishery-based studies of the environment and harvested species interactions together. Initially mesoscale studies were considered with emphasis on the results from the last season, and aspects of importance for ecosystem analysis were noted. A number of the papers were discussed elsewhere in the agenda, so in this section only the main interaction effects relating to harvested species have been emphasised.

6.13 WG-EMM-97/6, 97/16, 97/30, 97/33 and 97/44 dealt with results from multidisciplinary surveys in the Elephant Island area during the 1996/97 field season. In particular WG-EMM-97/30 described the acoustically detected distribution of krill relative to hydrographic features measured during February 1997, and WG-EMM-97/33 provided a detailed description of salp population growth in February and March 1997. WG-EMM-97/44 presented results from the Workshop on International Coordination which provided an assessment of seasonal and between-year differences in (i) hydrographic conditions, (ii) phytoplankton biomass, composition and distribution and chlorophyll *a* concentrations, and (iii) krill and salp abundance and reproductive success in the Elephant Island area, from December 1996 to March 1997. Following conceptual ideas presented at earlier meetings the studies related krill and salp reproductive success to winter sea-ice conditions.

6.14 These data build on the long time series being generated for the Elephant Island region. The season 1996/97 showed a different pattern of development with the occurrence in the area of very warm surface water and the apparent rapid development of the salp population. The Working Group noted that this was not a direct effect of ice extent on krill recruitment but appeared to be a mid-season disruption of the krill population development. This emphasises that it is not only the potential sea-ice driven recruitment fluctuations which generate variability in this region. There may also be environmental events occurring at a range of scales which impact on the local krill population. Other details were also given with a detailed summary presented in WG-EMM-97/44 which is attached in Appendix E. The Working Group noted the paper also gave a series of recommendations relating to future integration of Elephant Island area studies. Some of these are of direct relevance to WG-EMM studies and attention was drawn to the list.

6.15 A number of papers gave information on the interactions occurring in other areas of the Southern Ocean. These highlighted the large-scale water mass effects, interactions with the seabed, contrasts between the shelf and off-shelf regions and considered the remote sources of krill in particular regions.

6.16 WG-EMM-97/28 described the different horizontal and vertical distributions of krill of different size and maturity stage and of myctophids occurring between inshore and slope/offshore areas adjacent to Seal Island. These regions provide different feeding environments for their predators. The distributional patterns of prey species were related to the strength and depth of the thermocline, which differs between inshore and offshore areas and the location of the shelf break front, which varies both seasonally and interannually.

6.17 Krill length-frequency distributions from the South Georgia region between 1980 and 1997 were analysed in WG-EMM-97/47 to consider regional variation. Distributions of krill representing different length categories were related to possible source areas and the transport from the Weddell Sea and Bellingshausen Sea. The larger krill occurred in the length-frequency distributions from the west of the island.

6.18 Data from the South Orkney Island area on water circulation and krill distribution were reported in WG-EMM-97/49. The aggregation of krill in relation to water circulation was related to the eddy activity in the shelf-break area north of Coronation Island in the South Orkney Island group.

6.19 WG-EMM-97/59 reported on the structure of krill populations in the 80–150°E area of the Southern Ocean during January and March 1996. The study emphasised the geographical variation of the krill populations, with lower krill densities in areas where salp abundance was high. The geographical relationship of krill and salps was discussed in relation to the sea-ice conditions, extending the temporal concept framed for the Antarctic Peninsula area to a larger scale. It was suggested that the southeast Indian Ocean area may be a particularly good area for examining these geographical aspects of the sea-ice, krill and salp relationships.

6.20 WG-EMM-97/53 presented data on the distribution of krill in sea-ice areas in the Ross Sea. The work indicated that densities of krill in the Ross Sea area can be similar to other high krill abundance regions of the Southern Ocean. Aspects of the krill aggregation characteristics in relation to sea-ice conditions were also presented. Krill aggregations were less frequent below the ice, with individual krill encountered in the surface ice floe areas. These interactions have important implications for the availability of prey to predators. The Working Group also discussed the potential effects of predators in modifying the prey distribution.

6.21 Although the relationship between krill and shelf break has been known for a long time, the haul-by-haul fishery data (WG-EMM-97/36, 97/41, 97/50 and 97/51) are providing larger-scale, longer-term indications of the position of exploitable concentrations of krill. The data are revealing aspects of the highly focused nature of the fishery and the importance of local bathymetric features in determining fishing grounds. The importance of the water circulation and seabed interactions in generating conditions for the concentration of krill was particularly emphasised in WG-EMM-97/50 and 97/51.

6.22 It was noted that the krill fishery does not target the whole Scotia Sea area and it was pointed out that the fishery, although focused, is almost certainly able to target the regular high concentration regions. As these traditional fishing grounds are in the vicinity of some of the largest predator colonies in the area, this highlights the usefulness of the fishery data in considering interactions between predators, prey and fisheries. As with all of the prey and predator datasets, the need for careful interpretation of such data was emphasised. The Working Group noted the value of analyses of individual trawl-based fishery data and encouraged further development of analyses of the fishing operation.

6.23 The Working Group discussed the integration of the information on krill–environment interactions and the factors determining the population dynamics. A number of papers addressed this topic bringing together a range of research and fishery-based information. In particular, WG-EMM-97/73 reported on the sea-ice, krill and salp interactions in the Elephant Island area.

6.24 Factors affecting krill population dynamics were further discussed in WG-EMM-97/29, in which the updated recruitment index series for the Elephant Island area was presented. In particular, the importance of the timing of spawning as well as the following winter sea-ice conditions in determining the recruitment success for a year class was noted.

6.25 Aspects of the integration of long-term information were addressed in WG-EMM-97/22 and 97/35, which developed analyses of krill fishery data to examine interannual variability. Both indicated the value of such analyses but also emphasised the problems in interpretation of the data. Links between recruitment indices and environmental changes were discussed in WG-EMM-97/35, but aspects of operational changes in the fishery were also noted.

6.26 The value of fishery-derived information in considering ecosystem interactions was again emphasised by WG-EMM-97/37 which presented data on the salp by-catch and condition of krill based on logbook data from fishing vessels. It was noted that the salp by-catch showed an inverse relationship with the occurrence of 'green' krill. The Working Group discussed ancillary data collected in association with the fishing operation and encouraged further analyses and reporting of such data.

6.27 Two papers (WG-EMM-97/67 and 97/65) addressed the concept of transport of krill with the ocean currents. WG-EMM-97/67 builds on work presented at WS-Flux in 1994 and emphasised the importance of the Southern Antarctic Circumpolar Current Front (SACCF) in the transport of krill across the Scotia Sea to the South Georgia area. The effect of Ekman drift is to entrain further particles in the SACCF and generates transport times from the Antarctic Peninsula to South Georgia of 140–160 days.

6.28 WG-EMM-97/65 also develops ideas presented at WS-Flux and combines physical model data and krill survey data to estimate krill flux and turnover times and related this to predator demand in the South Georgia area. Many of the concepts on which the approach is based are shown in the data and descriptions given in WG-EMM-97/49 and 97/50. WG-EMM-97/65 emphasised that there will be differential flux and turnover rates in such areas and that these will be important in determining the local availability of krill to predators. Further data are required to quantify krill flux and explore the development of krill aggregations in areas of complex hydrodynamics. The Working Group encouraged further analyses of the transport of krill and the factors determining the aggregation patterns.

6.29 There were detailed discussions of all the papers and the new information provided. It was noted that there was a range of hypotheses on the environmental and biological interactions determining the local krill population. These hypotheses included the factors of large-scale krill transport, water mass variations, biotic interactions within the area such as competition between salps and krill for the available primary production and the hypothesis of winter sea-ice conditions affecting the recruitment of krill and development of salp populations. It was noted that some of these factors were probably more important in some areas of the Southern Ocean than others.

6.30 The Working Group was reminded of the strategic modelling exercise for the management of the ecosystem derived at WG-EMM in 1995 and this was discussed using the conceptual framework shown in Figures 3 and 4 of the WG-EMM-95 report (SC-CAMLR-XV, Annex 4). It was suggested that the various hypotheses being proposed should be developed so that they could be tested using the indices being compiled by WG-EMM. This synthesis of ideas could then be used in guiding further refinements of the approach.

6.31 The discussions led to the generation of Figure 1 which characterises the main interactions occurring in a region based on the concepts derived from the Elephant Island area. The figure illustrates the environmental factors determining local krill abundance and distribution.

6.32 The concepts underlying the generation of Figure 1 are given in Table 1 with a brief comment on the potential form of the environmental interaction with the biological processes in the area. The final column of the table considers the requirements for the application of the ideas to a larger area.

6.33 The distinction between the krill population processes and the environmental factors influencing these was emphasised. For example, one of the population processes was immigration/emigration while the physical factor involved is characterised as advection. The Working Group agreed that the table and figure give a useful summary of the various hypotheses being discussed in relation to environment and harvested species interactions in the Elephant Island area.

6.34 There was some discussion about the possibility of generating a table which captured more generally ideas about the operation of the Southern Ocean ecosystem. However, it was noted that the hypothesised relationship between winter sea-ice conditions and krill recruitment may not have a circumpolar generality. It was suggested that the approach could be applied to other areas and Members were encouraged to develop such a view of the environmental factors and processes determining the local krill population in other Southern Ocean areas.

6.35 Various statistical and modelling approaches to examine the important interactions were discussed. The Working Group encouraged further multivariate analyses of the form recommended by the Subgroup on Statistics (Appendix D).

6.36 A paper which presented a more general view of the environmental variability effects on marine fisheries was discussed (WG-EMM-97/66). The review paper emphasised the environmental control of fisheries and highlighted the need for flexible management strategies.

6.37 The Working Group agreed that development should continue on methods which can allow for the incorporation of environmental information into management strategies.

6.38 As a final point the Working Group was reminded that at last year's meeting there was a prediction of a strong krill recruitment for the 1995/96 season in the Elephant Island area. WG-EMM-97/29 indicated that the proportional recruitment was low but the absolute recruitment was high as a result of a higher biomass of krill in the area. WG-EMM-97/44 predicted that, on the basis of a late krill spawning, below-average ice conditions and the high observed salp density, there will be a poor recruitment from the 1996/97 season.

Interactions between Krill and Dependent Species

Fur Seals

6.39 The Working Group reviewed papers concerning the interactions between krill and dependent species. Those that included information concerning the diet of predators, total consumption based on energy requirements, and the effects of changes in krill abundance on predator behaviour and production were considered by taxonomic group, i.e. seals, seabirds and minke whales. A further group of papers concerning the mechanisms of the interactions between dependent species and krill was considered separately.

6.40 WG-EMM-97/60 considered the diet of adult and subadult male Antarctic fur seals at Nelson Island, South Shetland Islands. Based on the analysis of scats, this study demonstrated that both krill and fish were important components of the diet and that myctophids were the dominant species group in the fish component of the diet. It was not known whether these seals were foraging in the Bransfield Strait region or elsewhere. Dr V. Siegel (Germany) suggested that such information might be useful because the composition of fish populations differs between Bransfield Strait and areas to the west of the South Shetland Islands.

6.41 In another study (WG-EMM-97/14) the diet of female Antarctic fur seals was examined using a new method involving the analysis of fatty acids in milk. This demonstrated that during 1991, a year of known low krill abundance, the krill component of the diet of female fur seals was reduced during the perinatal period compared with the remainder of lactation. It also showed that diet changed from mainly krill in the early and middle parts of lactation to one that contained a greater proportion of fish during the later stages of lactation, consistent with data from scat analysis. However, at this stage, it is not possible to distinguish between the different fish taxa involved.

6.42 Predator consumption rates have recently become a critical component of a proposed method for estimating the minimum krill standing stock biomass (WG-EMM-97/65) in Subarea 48.3. In WG-EMM-97/11 and 97/13, estimates were provided of the variation in the energy demand of Antarctic fur seal pups during the period of dependency on maternal resources. This will contribute to refining estimates of the consumption of krill by fur seals. These papers also demonstrated the magnitude of reduction in the total energy delivery to pups that resulted from the low level of krill abundance in 1991.

Seabirds

6.43 An important aspect of diet studies involving predators is the different degrees of specialisation on krill as a food source. A gradation of specialisation on krill among six species of predators at South Georgia was illustrated in WG-EMM-97/15. The paper also provided the length-frequency distributions of krill taken by each predator which showed differences between surface-feeding and diving species and small, but significant, biases towards larger individuals compared with net hauls. There was additional bias (in favour of mature females) in the maturity stage and sex of krill taken by predators in comparison with net hauls.

6.44 The two species of diving petrels at South Georgia have diets which are dominated by crustaceans. However, the South Georgia diving petrel has a greater dependency on krill than the common diving petrel in which copepods are the largest component of the diet (WG-EMM-97/10). This pattern of dependency on both krill and copepods was also demonstrated in a five-year study of the diet of Antarctic prions at South Georgia (WG-EMM-97/12). During years of low krill abundance, prions switched to feeding on copepods without reduction in reproductive success.

6.45 Cape petrels at Bouvet Island (Subarea 48.6) also have a diet that is dominated by krill (WG-EMM-97/56), consistent with data from Subareas 48.2 and 48.3 but different from the only study in Subarea 48.1, which indicated fish as the most important component of the diet. Diet samples from chinstrap and macaroni penguins from Bouvet Island also showed that these species are highly dependent on krill, although macaroni penguin diets also included myctophid fish (WG-EMM-97/20). Mr Cooper also informed the Working Group that southern fulmars at Bouvet Island appeared to take mainly krill.

6.46 Similarly, Antarctic petrels at Svarthamaren, Dronning Maud Land, feed krill to their chicks but birds sampled at sea in adjacent areas to the breeding colony were shown mainly to have a diet of fish (WG-EMM-97/58). It is therefore possible that the diet taken by adults foraging to provision their own needs differs from that supplied to the chicks. The Working Group also welcomed the calculations made of the total food consumption by Antarctic petrels at this site as a valuable addition to knowledge of the potential impact of these predators on krill.

6.47 WG-EMM-97/64 represented a comprehensive collaborative study between Australian and French scientists to compare the foraging ranges and diets of Adélie penguins in Division 58.4.1. This combined shore-based studies of foraging and diet with ship-based studies of prey in the regions. The trawl and penguin samples differed at the two sites. At Casey Station, where net samples contained both *E. crystallorophias* and *E. superba*, penguins took mainly *E. crystallorophias* and little *E. superba.* In contrast, at Dumont d'Urville, net samples contained only *E. crystallorophias* whereas penguins fed on both *E. crystallorophias* and *E. superba*.

6.48 The Working Group noted the insights into diet variation provided by these studies of seabirds and particularly the varying ability of species that are generally dependent upon krill to switch to other prey in the absence of krill. There is a continuum of species in terms of the extent to which fecundity, fledging/weaning mass and reduced survival of adults and young are affected by variations in krill abundance.

Minke Whales

6.49 Mr T. Ichii (Japan) reviewed the results of studies of minke whales which had been carried out by the Japanese Whale Research Program (WG-EMM-97/17 and 97/18) in Division 58.4.1 and Subarea 88.1. He concluded that minke whales are large consumers of krill in the Indian Ocean and the Ross Sea and that they may be an appropriate species for monitoring the status of krill stocks. This was based upon estimates of daily food consumption by minke whales which had been derived from a study of the diel variation in the mass of stomach contents. He estimated that the consumption of krill by minke whales in the Ross Sea region, around 3 million tonnes, was equivalent to the total standing stock biomass estimated for the region in late spring 1994 (WG-EMM-97/53).

6.50 The seasonal increase in the girth of minke whales was lowest in years of low krill abundance and, based on the analysis of the response of the girth of minke whales to changes in krill abundance, Mr Ichii proposed that girth could be used as a parameter to monitor the changing status of krill stocks.

6.51 Mr Ichii suggested that reduced body condition in minke whales is related to increased ice extent. This was because sea-ice covered the zone of the shelf slope which, therefore, made this rich region inaccessible to minke whales. Although this negative relationship between sea-ice and predator performance is similar to that observed in Subarea 48.2, it may differ from the current understanding of interactions between sea-ice, krill and predators in Subarea 48.1. However, further research is required to examine the differences and similarities between observations from each of these subareas. Mr Ichii also commented that the Ross Sea region had previously been considered an area of low food availability, which appeared paradoxical because this was an area of high minke whale density.

6.52 WG-EMM-97/17 provided information concerning the energetics and krill consumption by minke whales that had been requested previously. The Working Group agreed that it would be useful to have similar estimates for Area 48. Prof. M. Mangel (USA) suggested that past simulations used to model the krill fishery (Mangel, 1988) could be extended to predators such as the minke whale if the fishery was viewed to operate in a similar manner to a pelagic predator.

6.53 Unlike all the other CEMP monitoring species, with the exception of the crabeater seal, the minke whale is also the only species which is not a central-place forager which may mean that it could provide valuable insights into ecosystem variability which may not be available from the other monitoring species. Mr Ichii had proposed that changes in girth could be used as a monitoring parameter for minke whales. Although the Working Group supported the principle of developing standard methods for minke whales and acknowledged the importance of minke whales as predators of krill, it was felt that there remained sufficient uncertainty about the spatial and temporal scales represented by such a monitoring parameter that their reintroduction as a CEMP monitoring species could not be justified at this stage.

6.54 The Working Group also noted that to re-establish minke whales as a CEMP monitoring species would require methods capable of generating long-term data; non-invasive techniques, including photogrammetric measurements, should be investigated.

6.55 The Working Group noted that it would be useful to apply the estimates of minke whale food consumption given in WG-EMM-97/17 over a wide geographical range to quantify better the impact of minke whale predation on krill.

International Whaling Commission

6.56 Dr Reilly, the observer from IWC, explained that, having now completed its main task of developing a management procedure for whales, the focus of the interest of the IWC had shifted towards other topics, including the effects of the environment on whales. This was aimed at trying to incorporate predictions about climate variability, and about how this was likely to affect whales, into management advice. Dr Reilly drew the attention of the meeting to the report of its Workshop on Cetaceans and Climate Change held in Hawaii, USA, during April 1996. Several members of WG-EMM had been present at this meeting and Dr V. Marín (Chile) had represented SC-CAMLR on the steering group for the Hawaii Workshop.

6.57 The Working Group agreed to examine further the issue of areas of common interest to the IWC and WG-EMM. It was also recognised that the activities of WG-EMM had to a large degree ignored whales, despite their undoubted importance as krill predators, partly because whales were viewed as the preserve of the IWC. The research activities established by different national programs to address issues of importance to WG-EMM had begun to address fields of common interest to the IWC and there was perhaps potential to expand the scope of these activities by coordinating activities with the IWC. Further discussions are contained in paragraph 8.133.

Dependent–Harvested Species Interactions

6.58 The Working Group considered the mechanisms of predator–krill interactions separately from the empirical consequences of these interactions as they affect predator population dynamics in relation to a fishery.

6.59 WG-EMM-97/28 examined the mechanisms underlying the behaviour of chinstrap penguins and fur seals foraging from Seal Island. This paper had been revised in response to comments provided last year by the Working Group. It suggested that there were two distinct penguin foraging strategies involving daytime and overnight foraging trips and that these corresponded to trips made over the shelf and beyond the shelf break respectively. In contrast, fur seals always foraged beyond the shelf break.

6.60 Several different factors are likely to affect foraging behaviour including the distance to the prey, depth/dispersion of the prey, energy content of the prey, demand of the young and the necessity for parents to forage for themselves in addition to their dependent young. WG-EMM-97/28 demonstrated the possible effects of different depths/dispersions of prey, prey profitability and the distance which had to be travelled to find prey. Considering all of these variables, it should be possible to model the underlying mechanisms and trade-offs associated with this behaviour to begin to predict how behaviour might change in relation to changes in the underlying prey distribution. Prof. Mangel had provided an early version of such a model to the previous meeting of WG-EMM (Switzer and Mangel, 1996).

6.61 The Working Group noted the suggestion that the behaviour of penguins foraging to provision themselves may differ from that used when provisioning chicks. This could result in different diets as also suggested by the observations from Antarctic petrels (WG-EMM-97/58; paragraph 6.46). Chinstrap penguins at Admiralty Bay show no clear distinction in day and night foraging activities. This difference across sites further emphasises the need to understand how foraging behaviour is likely to vary as a result of different prey distributions. Differences between the foraging of penguins and fur seals might also be explained by taking life history variables into account within a mechanistic model.

6.62 WG-EMM-97/8 is a step towards an empirical assessment of how predators are likely to be influenced by variations in prey availability. This study examined the effects of an experimental reduction in the foraging capabilities of fur seals on the provisioning of pups. It showed that even though a significant reduction in swimming performance was achieved by the experimental manipulation, this did not affect the ability of these fur seals to provision their young. This illustrates that parameters of foraging and reproductive performance in these seals, some of which are used as CEMP indices, tend to be buffered against reduction in krill abundance.

6.63 This mechanistic approach to examining predator responses to variations in krill dispersion contrasts with the empirical approach outlined by WG-EMM-97/70. The Working Group welcomed further development of the predator–prey model presented at previous meetings of WG-EMM. In particular, it was noted that further simulations had been carried out taking into consideration comments from Drs Croxall and Boyd on the empirical estimates of survival rates in black-browed albatrosses and Antarctic fur seals. Their main conclusions were that the effect of a fishery on the depletion of a predator population was particularly sensitive to R^{max}, the maximum potential rate of increase. In the case of black-browed albatrosses, the sensitivity was such that a fishery of almost any level would cause the population to decline. Fur seals were less sensitive but Prof. Butterworth emphasised the importance of R^{max} even for this species. Therefore, in both cases, uncertainty about the value of R^{max} was likely to reduce the precision of the predicted effect of γ (krill fishing intensity) on the predator population size.

6.64 Dr Boyd considered that, in practice, the form of the functional relationship used in the model was probably more of a problem than the value of R^{max}. Whereas R^{max} can be estimated with reasonable precision, there are many factors that could affect the functional response. As illustrated in Figure 6 of WG-EMM-97/70, the functional relationship is between predator survival rate and krill availability. Krill availability, as seen by the predator, may not correspond well with krill availability defined by a synoptic survey mainly because predators may forage on different optimal densities/distributions of krill. It would be possible, for example, that the relationship between B (krill availability as defined in WG-EMM-97/70) and predator survival rate is not monotonic.

6.65 Prof. Butterworth pointed out that the form of the functional relationship had been recommended by the previous meeting and that uncertainty in the functional relationship is taken into account to some extent by *n* in Table 4 of WG-EMM-97/70. However, the functional relationship for the black-browed albatross, which is known to switch to alternative prey in years of low food availability, had taken this into account. The ability of species to prey-switch was seen by the Working Group as an important issue and this had been addressed by papers tabled at this meeting (see paragraphs 6.43 to 6.48). It was suggested that such an approach adopted to take prey switching into account for the albatross should also be extended to the fur seal.

6.66 It was also reported that little progress had been made with applying the model to Adélie penguins mainly because there were specific problems with the field data which had still to be resolved.

6.67 Dr Croxall raised the issue of the scales which were addressed by the model. Whereas the form of the functional relationship in the model may apply over a wide spatial and temporal scale, it is the effects of fishing at small scales that would seem to be of most importance.

6.68 Prof. Mangel questioned what was the effect of introducing variability into the relationship between krill fishing intensity and predator population depletion which is currently only represented as a deterministic relationship in WG-EMM-97/70. In response, Prof. Butterworth indicated that work was in progress to address this question.

6.69 Dr K. Shust (Russia) questioned the realism of the model because, on inspection, there appeared to be no relationship between predator survival rates and known periods of low krill abundance and that the variability in predator survival rates appeared to be small.

6.70 In response, Dr Boyd pointed out that, at least for fur seals, we might not expect to see a large response in survival rate if krill availability is such that most of the survival rates lie on the top plateau of the functional relationship.

6.71 Overall, the Working Group considered that there was much to be gained from a parallel approach to examining krill-predator interactions involving empirical and mechanistic models. At a broad scale, the empirical model described in WG-EMM-97/70, provides a useful foundation for the provision of management advice. The mechanistic modelling will provide the necessary link between prey abundance and distribution and predator behaviour, which is measured in the form of CEMP parameters. This can be used to better characterise the functional relationship between krill abundance and predator demographic parameters.

6.72 The Working Group encouraged the further development of the empirical model to ensure that in future there is a basis upon which management advice can be taken forward to the Scientific Committee. It also endorsed the mechanistic approach by inviting the submission of papers addressing this subject at future meetings.

Status and Trends of Dependent Species

6.73 The SCAR Bird Biology Subcommittee and the SCAR Group of Specialists on Seals had been requested by CCAMLR to provide guidance about the present status and trends of Antarctic seabird and seal populations. The report from the Bird Biology Subcommittee was tabled at the Scientific Committee last year. The report from the Group of Specialists on Seals arrived too late to be circulated at the present meeting. It was decided to defer consideration of both documents until the 1998 meeting of WG-EMM.

Interactions between Dependent Species

6.74 The issue of potential interactions between dependent species was raised because this was seen to be relevant to the Working Group's ability to discriminate between the effects of krill fishing and the effects of competition between predators.

6.75 This subject had been discussed previously (see also paragraph 4.6) and the Working Group considered that it is an issue that should be incorporated within assessments of the reasons underlying changes in predator abundance.

6.76 Dr Bergström noted that within WG-EMM consideration could be given to the possibility that one dependent species affects other dependent species to the extent that local species diversity may decline.

Fisheries–Dependent Species Overlap

6.77 New information on the potential overlap between the commercial fleet and predators in part of Subarea 48.2 was provided in WG-EMM-97/51. Dr Sushin noted that calculations of the proportion of local krill biomass on the entire fishing ground in Subarea 48.2 was less than 10% during the December–March critical period for krill predators. The paper also concluded that, for the area where the fleet worked most intensively, it took less than 14% per month of the local biomass. Given the regular recruitment of krill to this area from other areas, the authors of WG-EMM-97/51 believed that competition between the fishing fleet and the local predators was negligible.

6.78 The Working Group did not have time to evaluate the model used in WG-EMM-97/51 to estimate local krill biomass. Nevertheless even if the estimates of the proportion of local krill biomass removed by the fishery are correct, it does not follow that the impact on the large local breeding populations of krill predators is negligible. Dr Croxall noted that the situation described in WG-EMM-97/51 was one where the modelling approach described last year by Prof. Mangel (Switzer and Mangel, 1996; SC-CAMLR-XV, Annex 4, paragraphs 6.47 to 6.55) would give a much more realistic assessment of the nature, magnitude and potential consequences of the interactions between this fishery and local krill predators.

6.79 The Working Group noted that the distribution of the fishery at South Georgia was concentrated on the shelf break to the north of the island (WG-EMM-97/41). This is also a region targeted by krill predators. However, the fishery at South Georgia takes place in winter whereas the current understanding of predator dispersion is mainly from the summer. Therefore, the actual degree of overlap between predators and the fishery at South Georgia remains to be determined.

Predator Interactions with Fish and Squid

6.80 Predator interactions with fish or squid may have significance for decisions made concerning the management of developing squid and finfish fisheries in the Southern Ocean.

6.81 Accordingly, the UK tabled a list of published papers relevant to this subject (WG-EMM-97/7). In another paper, king penguins from the Crozet Islands were shown to feed mainly on myctophids but also took small quantities of squid (WG-EMM-97/9). The main species was *Moroteuthis*, an ammoniacal species which is currently of no commercial value. As indicated in WG-EMM-97/11 and 97/28, myctophids and other fish species can also form a small but important element in the diets of Antarctic fur seals.

6.82 As demonstrated in papers submitted to previous meetings of WG-EMM and in WG-EMM-97/61, Antarctic shags rely heavily on a range of inshore fish species. Many of these have been subject to historical heavy exploitation. The Working Group considered that, if a reliable method could be developed, it may be appropriate to adopt the Antarctic shag as a monitoring species. The Working Group then passed this question to the Subgroup on Monitoring Methods.

6.83 The Working Group also considered WG-FSA-96/20 (Rodhouse, in press) which had been referred to WG-EMM by the Scientific Committee. This paper examined the potential impact of a fishery for *Martialia hyadesi* on predators. The Working Group considered that there was generally insufficient information to conclude how the development of such a fishery was likely to influence predators. It appeared that most predators were taking small squid and there was little indication that they were feeding on spent squid. Moreover, the most accurate information about squid consumption came from the predator species which accounted for the smallest proportion of the estimated predation of squid in Area 48.

6.84 The Secretariat reported that a Korean fishing vessel had caught 28 tonnes of squid during four days of fishing in the last 10 days of June this year. A further 53 tonnes had been caught since then making a total of 81 tonnes so far this year in Subarea 48.3.

6.85 The Working Group noted that the Commission has set a precautionary catch limit at 1% of the estimated predator demand. The Working Group agreed that determining a more accurate rate for the precautionary yield would require more information on estimates of the natural mortality rate of squids from one to two years of age, on variability in recruitment and on the appropriate level of squid escapement after fishing to meet predator requirements.

6.86 Dr Kim pointed out that only limited information was available on the seasonal distribution and migratory movements of *M. hyadesi* and that more information could be obtained by spreading the fishing season over the entire year, thus allowing it to operate more flexibly in relation to changes in oceanographic conditions, especially around the Polar Frontal Zone.

6.87 Other members noted that the fishing season should be set to take into account the lack of sufficient data to assess how the development of a fishery for *M. hyadesi* would affect its dependent predators. At this stage, the Working Group supported the precautionary approach as set out in WG-FSA-96/20.

6.88 A report of a workshop to consider the management of exploitation in the Heard Island area was presented by the Australian delegation in WG-EMM-97/27. This multidisciplinary report considered a program of work and developed modelling approaches for the ecosystem. Detailed interactions had been considered and this had been distilled to more simple views of the ecosystem. As a general rule such a simplification attempts to account for the interactions which provide about 80% of the prey consumed by the predators.

6.89 WG-EMM-97/42 presented an analysis pertinent to the determination of the appropriate level for the median biomass after fishing (escapement) in the *Dissostichus eleginoides* fishery at Heard Island. The analysis took into account the age classes of *D. eleginoides* taken by elephant seals, based on seven otoliths from probably four *D. eleginoides* found in one of 65 sampled stomachs. The analysis indicated that the level of escapement in the age classes likely to be eaten by elephant seals was of the order of 87%, and the assessment developed by WG-FSA would not require adjustment to account for predator requirements of this species.

ECOSYSTEM ASSESSMENT

Estimates of Potential Yield

7.1 WG-EMM-97/45 detailed a method for correcting for a bias in the approach used in the krill yield model to compute the median krill spawning biomass in the absence of fishing on krill (i.e. the median pre-exploitation level). The bias was small for estimates of the median status of the spawning stock under fishing compared to this pre-exploitation level, but somewhat larger for estimates of the probability that the spawning stock be reduced below some critical level over a projection period.

7.2 It was noted that such improved computations would not greatly change the current value of γ used to calculate precautionary catch limits. Accordingly, the Working Group recommended that revised calculations of precautionary catch limits should be deferred until additional pertinent information (such as the results of the synoptic krill survey planned for Area 48) becomes available.

7.3 It was also noted that the GYM used by WG-FSA can duplicate results provided by the krill yield model, and is more readily extended to incorporate new features (such as the bias correction process referenced in paragraph 7.1 above). Noting also that the computer program implementing this GYM will shortly be validated by the Secretariat, the Working Group recommended that, once validated, it should replace the existing krill yield model for future krill-related computations, because a single rather than two standard programs would be easier for the Secretariat to maintain, though the existing krill program should be kept in its current form for cross-checking purposes.

Precautionary Catch Limits

7.4 At present, the precautionary catch limit for Area 48 has not been subdivided amongst subareas, in particular because the FIBEX survey estimate of krill biomass in Subarea 48.3 is considered to be unrepresentatively low as a result of incomplete areal coverage (SC-CAMLR-XIII, paragraph 5.35).

7.5 WG-EMM-97/65 presented a calculated biomass of krill for the vicinity of South Georgia based on an estimate of predator demand in that region, using the method of Everson and de la Mare (1996).

7.6 Drs Shust and Sushin expressed strong doubt about this calculated biomass (WG-EMM-97/65) and the possibility of using it as the basis for the calculation of a precautionary catch limit for Subarea 48.3.

7.7 The Working Group commented that should the Scientific Committee see an immediate need to recommend a subarea subdivision of the precautionary catch limit for Area 48, it might wish to take account of the information referenced in paragraph 7.5 for computations for Subarea 48.3. Nevertheless, as with other possible adjustments to such limits (see paragraph 7.2), it recommended that their consideration be deferred until the results from the planned synoptic survey in Area 48 become available (thus obviating any need to apply the approach of paragraph 7.5 in Subarea 48.3).

7.8 Two questions were raised in relation to utilisation of the Everson and de la Mare method referenced in paragraph 7.5 above:

(i) would this mean that the precautionary catch limit was decreased if the estimated predator demand in a subarea fell because of a reduction in predator numbers?

(ii) would the method be applied to subareas other than Subarea 48.3?

7.9 The Working Group noted that:

(i) these issues had not been discussed in detail but the method under consideration estimated demand averaged over a number of years; and

(ii) the method would be considered for application only in subareas where no adequate direct survey-based abundance estimate was available.

Assessment of the Status of the Ecosystem

7.10 In developing its assessment of the status of the ecosystem in 1996/97, the Working Group relied primarily on the summaries of CEMP indices prepared by the Secretariat (WG-EMM-97/25 Rev.1) 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.

7.11 The method used to identify anomalies in WG-EMM-97/25 was that agreed at last year's meeting of WG-EMM. It was noted that when it becomes possible to use revised methods for identifying EIVs along the lines recommended by the Subgroup on Statistics (WG-EMM-97/34; see also paragraph 6.6), additional years may be highlighted to those identified as anomalies in WG-EMM-97/25 Rev. 1. WG-EMM's ability to interpret the many series of indices will also be considerably enhanced when widespread use can be made of the multivariate methods for combining indices considered by the Subgroup on Statistics.

Subarea 48.1

7.12 Overall, in the Antarctic Peninsula region in 1996/97 absolute krill recruitment was close to historical averages.

7.13 Around Elephant Island, in 1996/97 there was a prolonged krill spawning season, a delayed spawning peak and a massive salp bloom. This followed below-average sea-ice conditions in winter 1996. Excellent recruitment success was observed for the 1994/95 year class, but lower recruitment success was observed for the 1995/96 year class. These observations confirm predictions made at last year's meeting (see paragraph 6.38) and support the hypothesised relationships between recruitment success and winter sea-ice conditions.

7.14 Low larval krill densities and high salp concentrations observed during this year suggest poor krill reproductive success. Poor recruitment of the 1996/97 krill year class is predicted.

7.15 Surface water temperatures off Elephant Island were unusually high throughout the spring and summer of 1996/97.

7.16 Although data for Adélie penguins at Palmer Station in 1996/97 are yet to be submitted to the CCAMLR database, WG-EMM-97/30 reported that there was a decrease in population size and breeding success of Adélie penguins, matching the predicted effects of a year with below-average sea-ice cover on over-winter survival of penguins and consistent with the krill recruitment index at Elephant Island.

7.17 At Cape Shirreff and San Telmo Islets, both pup production and total counts of fur seals were higher in 1996/97 than in the preceding five years (WG-EMM-97/63 and 97/77).

7.18 At Esperanza Station, Adélie penguin fledging success was slightly higher in 1996/97 than in the preceding two years, while penguin arrival weight and fledging weight were about average in 1996/97.

7.19 The Working Group noted that there appeared to be an encouraging degree of coherence in CEMP indices across sites within Subarea 48.1. Dr Trivelpiece noted that, on the basis of unpublished data being submitted to CCAMLR, this coherence was also present in data from Admiralty Bay.

Subarea 48.2

7.20 At Signy Island, breeding success of Adélie, chinstrap and gentoo penguins was at average to above-average levels in 1996/97. This suggests a degree of coherence in predator indices with those in Subarea 48.1 Breeding population size of Adélie penguins has now returned to 1994 levels, after the 24% decrease in 1995. In contrast chinstrap penguin populations have still not recovered from a similar decrease in the same year. Gentoo penguin populations continue to increase. At Laurie Island, Adélie penguin breeding success was higher than in 1996.

Subarea 48.3

7.21 Bird Island was the one CEMP site for which the Subgroup on Statistics had developed, as an illustrative example, a combined index for dependent species. The single index combined separate indices for fur seals, and for macaroni and gentoo penguins

(WG-EMM-97/34). As shown in Appendix D, Figure 1 (taken from WG-EMM-97/34) this index indicated that there has been a steady improvement in predator reproductive success since the last poor year in 1993/94, with 1996/97 being the best of the last four to five years. Note that the methods used to produce this figure are still under development.

7.22 Krill biomass densities off South Georgia in December 1996 were comparable with those in the previous year and were relatively high for this region. The summer sea-surface temperature in 1997 was within the range of previous values.

Subarea 48.6

7.23 The population of chinstrap penguins at the CEMP site at Bouvet Island has fallen sharply since the last visit to the site in 1989/90, while that of macaroni penguins has shown a more moderate decline (WG-EMM-97/20). The population of Antarctic fur seals has grown dramatically since the last visit.

7.24 It was noted that the fur seal foraging durations measured at Bouvet Island in 1996/97 were comparable to those observed at South Georgia during a normal krill year.

7.25 The Antarctic petrel colony at Svarthamaren, Dronning Maud Land has been monitored since 1991/92. Considerable variation has been observed in the numbers of petrel nests with egg or chick in the hatching period, but 1997 appears to have been quite a good year. Breeding frequencies and survival rates estimated at this colony are similar to values estimated at other Antarctic petrel colonies (WG-EMM-97/78).

Division 58.4.2

7.26 After two poor seasons, the breeding success of Adélie penguins at Béchervaise Island was high in 1996/97. The breeding population size has remained almost constant.

Subarea 58.7

7.27 At Marion Island, macaroni and gentoo penguins have been monitored for the past three seasons. The CEMP indices measured in 1996/97 were all within the ranges of previous values and there were no obvious EIVs.

Subarea 88.1

7.28 Though Adélie penguin breeding success was the highest of the three years for which data have been collected at Edmonson Point, no exceptional values of monitored CEMP indices were obtained in 1996/97. Data are not available as yet for Ross Island in 1996/97.

Format for the Presentation of Ecosystem Assessments

7.29 The Working Group agreed that it would be helpful if ecosystem assessments could be presented in a more standardised form. An illustrative example of a possible format for an ecosystem assessment summary for Subareas 48.1, 48.2 and 48.3 was proposed. This is given in Appendix F. The format was based on that used to present assessment summaries by WG-FSA.

7.30 The Working Group considered this to be a useful approach and agreed that this matter should be considered further at next year's meeting, with a view to presenting ecosystem assessment summaries in a standardised form in its 1998 report.

Consideration of Possible Management Measures

7.31 No new management measures are proposed.

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

Methods for Estimating Distribution, Standing Stock, Recruitment and Production of Harvested Species

Recruitment

8.1 WG-EMM-97/29 used the method outlined in de la Mare (1994a) to calculate an absolute recruitment index R_1 (number of one-year-old krill recruits per 1 000 m^3). The Working Group welcomed the use of this index. The relative merits of the different methods used to calculate confidence intervals for density estimates from net sampling surveys (de la Mare, 1994a, 1994b, 1994c) were also discussed. While the bootstrap method produced unbiased confidence intervals, these may not be as 'precise' as those produced by the assumption-dependent maximum likelihood technique. The Working Group agreed that at present it was advantageous to use both techniques. It was agreed that a draft standard method for this index should be developed.

Net Sampling

8.2 WG-EMM-97/21 examined net avoidance when sampling krill at night. The numerical density of krill in the net was similar to that estimated acoustically from a transducer mounted on the net, but significantly less than that estimated using a hull-mounted transducer, this effect decreasing with increasing depth. While such results could be influenced by depth-dependent transducer sensitivity, method of noise removal and most importantly instrument threshold settings, the suggestion that acoustic krill biomass might be underestimated due to vessel avoidance had implications for the design of future acoustic surveys. For instance night-time estimates of krill biomass would be more biased than daytime estimates if krill moved towards the surface at night.

8.3 WG-EMM-97/21 and 97/43 both considered the problem of net avoidance causing a bias in length-frequency distributions due to large krill avoiding the net better than small krill. Results from the first paper suggested that differential net avoidance was not a problem at night. A series of citations in the second paper concluded that there was no evidence of differential net avoidance for several euphausiid species both during the day and night.

8.4 WG-EMM-97/32 examined the problem of how many net samples were required to adequately assess and describe the krill and zooplankton assemblages in the Elephant Island area. The results indicated that considerable sampling effort was required to precisely estimate zooplankton and krill abundance, and krill population structure. The Working Group emphasised the importance of assessing the trade-off between sampling effort and sampling precision when designing and carrying out all net sampling programs.

8.5 WG-EMM-97/32 compared acoustic and net estimates of krill density during a survey in Division 58.4.1. Acoustic density estimates were up to several orders of magnitude larger than net density estimates. Excluding net estimates where the catch contained less than 90% krill reduced the variation by an order of magnitude but there was still no correlation between acoustic and net estimates. The Working Group agreed that the spatial scale over which such comparisons were made was very important and encouraged further analysis to improve the sample coincidence of the two methods.

Acoustic Target Identification and Echo Classification

8.6 WG-EMM-96 requested further work on multifrequency acoustic identification of krill. The Working Group was therefore pleased to receive a number of papers on multifrequency techniques (WG-EMM-97/24, 97/26, 97/28, 97/31, 97/44, 97/46, 97/53 and 97/54).

8.7 Net samples were used to validate acoustic delineation of krill echoes in paper WG-EMM-97/46. About 80% of acoustic targets thought to be krill on the basis of their appearance on echo charts were also identified as krill based upon a difference in mean volume backscattering strength (MVBS) at 120 and 38 kHz ($\Delta MVBS = MVBS_{120} - MVBS_{38}$) of between 2 and 12 dB. Biomass values estimated from krill identified using ΔMVBS were 94% of those estimated using echo-chart appearance. A simplified bent cylinder model was shown to be a better predictor of krill length than a fluid-filled sphere model.

8.8 The Working Group noted that similar findings were presented in paper WG-EMM-97/53 which also utilised ΔMVBS to delineate krill in the acoustic record. A mean ΔMVBS of 10.15 dB (sd = 1.6 dB) for krill of mean length 34.1 mm (average TS -74 dB) was obtained for aggregations of krill. The range of differences (6–14 dB) was attributable to both biological and behavioural factors.

8.9 WG-EMM-97/28 used backscatter at 120 and 50 kHz to differentiate between krill (assumed to backscatter at 120 kHz) and myctophid fish (assumed to backscatter at 50 kHz). In addition the different depth of occurrence and the different echo-chart appearance of krill and myctophids provided extra information to differentiate the targets. Volume backscattering strengths were reported to be lower for myctophids than for krill especially at 120 kHz. This was attributed to a lack of a swim bladder in the myctophids. However, an alternative explanation for the lower MVBS values may be lower densities of myctophids than krill. It was recognised that identification of echo traces attributed to myctophids still needs validation.

8.10 WG-EMM-97/44 also used the association of krill and myctophids with different water masses as an additional tool to distinguish between echo signals attributable to the two taxonomic groups.

8.11 WG-EMM-97/26 described acoustic signals thought to be characteristic of ommastrephid squid caught near to the Antarctic Polar Frontal Zone. The squid (average mantle length = 228.6 ± 21.8 mm) were linked with a strongly speckled layer on the echo chart with a ΔMVBS from -3 to 1 dB.

8.12 WG-EMM-97/24 demonstrated that exploiting frequency-dependent scattering and beam geometries improves single target discrimination and hence TS estimates. Differences in these TS values provided information about the constituents of mixed-species assemblages. The effectiveness of the method is sensitive to the combined uncertainties of the single-frequency measurements and variations in animal size, shape, orientation and acoustic impedance.

8.13 The Working Group noted that the power of multifrequency taxa delineation methods is increased by including biological and behavioural information (see for instance WG-Krill-94/12 which coupled TS measurements with length-frequency information and physics-based expectations).

8.14 WG-EMM-97/54 used multifrequency echo intensity data to discriminate a mixture of zooplankton taxa. Discriminate function analysis of differences between MVBS at 38, 120, and 200 kHz separated krill from four other species of zooplankton with an overall correct classification of 77%. The Working Group noted that differences in two- and three-frequency MVBS are linear and bi-linear approximations to non-linear scattering phenomenon (WG-Krill-94/13). Consequently, the efficiency of such methods is dependent upon distributions of animal length and orientation, the acoustic frequencies and pulse lengths, and the integration volume. Thus, echo-intensity data alone may be useful to separate even quite similar zooplankton species, but the techniques are much improved by including information on target distributions (horizontal and vertical) and length frequency.

8.15 The Working Group noted that another approach to the discrimination of acoustic targets was described in WG-EMM-97/31. Here, image analysis techniques were used to produce descriptional parameters of fish shoals which enabled species discrimination. Again, depth-dependent descriptors increased the discrimination success rate.

8.16 The Working Group reiterated the need for objective and repeatable techniques for delineating scattering taxa. It was recognised that multifrequency identification methods, in particular simple techniques which exploit the differences in scattering at two or more frequencies, are useful tools for delineating scattering taxa, especially when coupled with ancillary information such as animal length distributions.

8.17 The Working Group also recognised that image-recognition techniques, such as those being developed within the ICES community, are also potentially very useful as objective means for taxa delineation.

8.18 Most importantly, techniques such as those described in paragraphs 8.16 and 8.17 could be employed with equal precision by all investigators. Thus, Members were encouraged to continue studies on species discrimination techniques and to report their results in conjunction with theoretical expectations.

8.19 The Working Group recognised, however, that multifrequency acoustic techniques were not yet available to all nations undertaking biomass surveys, nor was there yet a recognised standard for such measurements. Therefore, the Working Group agreed that the recommendations from WG-EMM-96 were still valid. In particular, Members should always report biomass attributable to all biological scatterers prior to any allocation of biomass to krill and other taxa.

Acoustic Calibration

8.20 WG-EMM-97/52 described the effect of changes in transducer temperature on calibration. The authors concluded that 120 kHz S_v transducer gain was on average 1.4 dB less at South Georgia (sea temperature 2°C) than when calibration took place in waters with a temperature of 7.3°C. Such a difference would lead to a 50% underestimate of biomass. A similar trend was observed for 38 kHz. The Working Group recognised that such changes were significant and recommended most strongly that calibration should be conducted at water temperatures comparable to those found in the survey region.

8.21 WG-EMM-97/31 included a table summarising uncertainties in vertical echo sounding. The Working Group noticed in particular that some users of the Simrad EK500 had detected considerable variation in calibration values over several seasons.

8.22 WG-EMM-97/74 described the highly variable nature of acoustic background noise over a wide range of time scales. Three methods (of varying degrees of complexity) for the removal of background noise were described and compared. The method of noise removal has important implications for biomass estimation. In particular underestimation of noise can lead to substantial overestimation of biomass.

8.23 The Working Group recommended strongly that Members collecting data should not use any noise removal or thresholding techniques during the process of data collection and logging. Ideally raw ping-by-ping data should be stored and noise removal or thresholding should be undertaken as a separate stage during data processing.

8.24 The Working Group recognised that in the proposed synoptic survey it was most desirable to be able to use exactly the same noise estimation and removal techniques on all the datasets.

Target Strength (TS)

8.25 WG-EMM-97/24 demonstrated that the single target discrimination algorithm employed by the EK500 failed in 35 and 40% of cases for 38 and 120kHz, respectively. The effectiveness of combining the synchronised signals from two or more adjacent split-beam transducers of different frequencies improved the *in situ* single target discrimination giving correct results in 98.2 to 99.4% of cases. As noted in paragraph 8.12, such techniques also have considerable utility in describing the constituents in mixed-species assemblages.

8.26 WG-EMM-97/75 described a comprehensive series of TS estimations based on krill swimming free within a large volume tank. The Working Group was pleased to receive the final analysis of this work, noting that median TS values within the range -76.7 to -71.8 dB for krill with mean lengths between 29.6 and 36.2 mm complemented other TS data included in the interim TS relationship derived at WG-Krill-91.

8.27 The Working Group noted that characterisation of krill TS has advanced greatly since 1991. In particular, it has been repeatedly demonstrated through theory and experiment that krill TS is a highly non-linear function, depending primarily on animal length, orientation, shape, density and sound speed. Thus, the Working Group recommended that summaries and comparisons of TS data and models should account for the TS distributions, rather than focusing exclusively on values of central tendencies.

Biomass Estimates

8.28 The Working Group reviewed the extent and detail of methodological description within papers using acoustic techniques to estimate biomass. In particular the Working Group complimented the authors of WG-EMM-97/49 on the quality of the presentation and description of methodology.

8.29 While there was generally much more detail provided the Working Group reiterated the need to take account of the recommendations in Appendix G in the report of WG-EMM-96 (SC-CAMLR-XV, Annex 4).

8.30 The Working Group agreed that, given that much advice on net and acoustic sampling methods had been published in recent reports of WG-EMM and WG-Krill, the Secretariat should extract all relevant method advice from all the relevant reports and present them together (see also paragraph 8.122).

8.31 The Working Group agreed that standard methods for net and acoustic sampling, data storage and analysis for the planned synoptic survey of Area 48 should be specified and developed (see paragraph 8.122).

Survey Design

8.32 Various papers submitted to WG-EMM contained information relevant to the design, timing and placement of krill acoustic surveys.

8.33 WG-EMM-97/22, 97/28 and 97/36 highlighted differences in krill distribution/abundance between inshore and offshore areas within Area 48. The Working Group recognised that such differences were important for the allocation of survey effort inshore as opposed to offshore.

8.34 WG-EMM-97/49 emphasised that seasonal timing may impact on survey results and also indicated diel differences in krill density between day and night (see discussion in paragraph 8.2). The latter has some bearing on whether acoustic surveys are undertaken during both day and night; a topic previously discussed by WG-EMM (SC-CAMLR-XV, Annex 4, paragraph 3.75).

8.35 Acoustic target identification (see also paragraphs 8.15 and 8.16) and night-time estimation of krill biomass around South Georgia were reported in WG-EMM-97/48.

8.36 WG-EMM-97/53 followed a similar presentation to the Working Group's last meeting and outlined the results of an Italian survey in the Ross Sea during 1989/90 and 1994/95. The Working Group noted that due to the prevailing ice conditions, the survey had been based on a design and post stratification procedure which was somewhat different to that customarily used for the estimation of krill biomass and its associated variance. As such, survey effort was apportioned to pre-determined and geographically-defined boxes which were then treated as individual sampling units.

8.37 It was agreed that, given the ice conditions prevailing in the Ross Sea, the Italian approach offered a sensible and interesting way to implement krill surveys under such circumstances. Further consideration of the statistical assumptions underlying, and associated ramifications of, the approach is essential to its evaluation and to assessing its comparability with more routinely applied procedures. In particular, the Working Group noted that consideration still needs to be given to the efficacy of subdividing surveys into subsidiary sampling units which are considered as independent, and to which bootstrap variance estimation procedures can then be applied. Similarly, comparisons need to be made between survey variances estimated from data in ice-free areas using customarily applied analyses with those where the Italian approach is applied to the data as well as with the results from the survey described in paragraph 8.36 above.

Consideration of CEMP Sites

Management Plans

8.38 In accordance with Conservation Measure 18/XIII, which requires a review of CEMP management plans every five years in order determine whether revisions are required and whether continued protection is necessary, the Seal Islands CEMP site (Conservation Measure 62/XI) was discussed.

8.39 Dr Holt reminded Members that the US has reduced its research program at Seal Island, due to concerns raised during a safety review of the island (SC-CAMLR-XIV, Annex 4, paragraph 5.10). He stated that the US has begun a multi-year plan to remove all structures from the island. During this period, data on chinstrap penguin fledging weights and on penguin and seal tag sightings will be collected.

8.40 Dr Holt stated that the US intended to revise the Seal Islands Management Plan for consideration by the Scientific Committee and noted that continued site protection was required for at least the next five years. At the end of five years, the US will have made a decision whether or not to continue limited data collection at Seal Island.

8.41 The Working Group encouraged the US to revise the Seal Islands CEMP site management plan in time for consideration by the Scientific Committee. The Working Group recommended to the Scientific Committee that site protection be extended for five years, subject to approval of a revised management plan.

New CEMP Sites

8.42 Dr Penhale presented a summary of the discussion of the Ad Hoc Subgroup on the Protection of Sites (Dr K. Kerry (Australia), Dr Penhale and Prof. Torres) regarding Norway's request to the Commission for the designation of a CEMP site at Bouvet Island. The subgroup viewed very positively the extension of the CEMP research program to Subarea 48.6 (WG-EMM-97/19), due, in particular, to the increased interest in fishing in the area. The Working Group recommended to the Scientific Committee that this site be accepted as a CEMP site.

8.43 The Working Group complimented Norway on its thorough and well-documented Management Plan for the CEMP site at Bouvet Island (WG-EMM-97/19) and noted that site protection has been provided through national legislation in Norway; thus, site protection under Conservation Measure 18/XIII is not required.

Review of Existing CEMP Sites

8.44 The Working Group reviewed the status of work at existing CEMP sites to assess whether research programs at several sites were short-term efforts or long-term commitments.

8.45 As far as the Working Group could determine, sites where data on dependent species are being collected annually according to CEMP standard methods are as follows:

Subarea 48.1	Anvers Island, Esperanza Station, Cape Shirreff, Stranger Point, Admiralty Bay and Seal Island
Subarea 48.2	Signy Island and Laurie Island
Subarea 48.3	Bird Island
Subarea 48.6	Bouvet Island and Svarthamaren
Division 58.4.2	Béchervaise Island and Syowa Station
Subarea 58.6	Marion Island
Subarea 88.1	Edmonson Point and Ross Island.

Methods for Monitoring the Performance of Dependent Species

8.46 Last year the Subgroup on Monitoring Methods (SC-CAMLR-XV, Annex 4, Appendix I) proposed a variety of new standard methods, reviewed each of the existing standard methods and suggested areas where changes were required. Although these revisions and additions to *CEMP Standard Methods* are now complete, copies have not yet been circulated and were therefore unavailable to the members of the subgroup at the meeting.

8.47 The Working Group considered each method for which comments had been received in tabled papers or in the Report of the Subgroup on Statistics (Appendix D).

Existing Methods

A1 – Adult Weight on Arrival at Colony

8.48 The Subgroup on Statistics (Appendix D, paragraph 2.4(ii)) noted that for several standard methods adequate new data exist to evaluate whether the recommended sampling regimes and sample sizes are appropriate. Members with such data were encouraged to undertake evaluations and report the results to WG-EMM.

8.49 The Subgroup on Monitoring Methods noted this with particular reference to the five-day sampling period, which applies also to Methods A5, A7 and A9. Originally the five-day blocks were designed as an interim measure to extend sampling over the whole period of interest. However they are very demanding to execute in the field. Researchers are encouraged to analyse their data to see if the five-day period is still an appropriate basis for data collection.

A2 – Duration of First Incubation Shift

8.50 The Working Group expressed interest in the proposed Principal Component Analysis (PCA) of Béchervaise Island data by Australia, as it will greatly assist the review of the utility of this method.

A5 – Duration of Foraging Trips

8.51 The Working Group noted the concern raised in WG-EMM-97/71 about the effect of externally mounted instruments on penguins. They recommended the addition of Culik et al., 1994 and Croll et al., 1991 to the references for Method A5 and to the observation protocol (section 4) on the use of TDRs for collection of data on at-sea behaviour. The Working Group was, however, confident that recent advances in knowledge of attachment site to minimise hydrodynamic problems and reductions in size of instruments have significantly reduced this problem.

8.52 Other problems associated with Method A5 were discussed, for example, the need to standardise data reporting between years and to relate data to a standard biological reference point, such as mean creche date. The Data Manager should review the existing data, and revise the standard method appropriately, in consultation with the originators of the data. Once this had been done sample size appropriateness should be reviewed.

8.53 Dr F. Mehlum (Norway) outlined the problem Norway experienced on Bouvet Island with Method A5 and macaroni penguins. The method of only using males in the study reduces the chances of acquiring data because males stay at the nest for 10 days or more after chicks hatch before they commence foraging trips to sea. In order to get enough samples, transmitters were fitted to males and females. The Working Group encouraged Norwegian scientists to submit data for both sexes separately and to evaluate any differences.

A8 – Chick Diet

8.54 WG-EMM-97/71 discusses a potential bias in diet studies, whereby the fish component may be underestimated. The Working Group recommended that a paragraph on this topic be incorporated the next time standard methods are reviewed.

8.55 Mr Cooper reported that collection of diet samples from gentoo penguins at Marion Island has been stopped due to concerns that the disturbance results in reduced breeding success. He noted that gentoo penguins breeding at islands in the southern Indian Ocean are highly susceptible to disturbance. No obvious effects of this kind are known from studies of gentoos at South Georgia, South Orkney or South Shetland Islands.

A9 – Chronology

8.56 The Working Group welcomed the suggestions in WG-EMM-97/71 for reducing disturbance associated with the Method A9 protocol. It recommended that this topic should be addressed the next time that this standard method is reviewed.

B3 – Black-browed Albatross Demography

8.57 Dr Croxall advised the Working Group that the demographic data have been supplied to Prof. Butterworth for the modelling exercise, and can now be submitted to the CCAMLR database.

B4 – Petrel Diet

8.58 Diet data for Cape petrels at Bouvet Island (WG-EMM-97/56) and Antarctic petrels at Svarthamaren (WG-EMM-97/58) collected under this new standard method are now available. They should be submitted to the CCAMLR database as soon as possible.

B5 – Antarctic Petrel Population Size, Breeding Success

8.59 Dr S.-H. Lorentsen (Norway) indicated the intention to submit data from Svarthamaren (WG-EMM-97/78) to the CEMP database. Similar data for this species are held by Dutch and US scientists (e.g. Drs J. van Franeker and P. Hodum) working with Australia. The Data Manager should contact them to see whether some of their data would meet the criteria for submission to the CEMP database under this standard method.

C1 – Antarctic Fur Seal Foraging Trip Duration

8.60 The current standard method stipulates that individuals must have completed six foraging trips to be included in the calculation of the parameter in each year. Individuals which lose their pups during the first six trips are excluded from the analysis. This may lead to the creation of bias in the estimate of foraging trip duration.

8.61 The Working Group agreed that it is important for the biases created by inclusion/exclusion of individuals from the data to be investigated. Detailed datasets exist which would allow this to be done. Depending on the results, it may be necessary to reconsider how the index of foraging trip duration is both collected and calculated. Simulation of different sampling regimes could provide a guide to the most appropriate method for measuring foraging trip duration. However, considering the long time series that has already been collected for this parameter, it would be necessary to conduct monitoring of the parameter for an appropriate period using both the old and new methods simultaneously to ensure compatibility of all sections of the time series.

C2 – Antarctic Fur Seal Pup Growth

8.62 Biases exist in the measurement of pup growth in Antarctic fur seals (WG-EMM-97/34). This occurs because pups which die are lost from the sample so that, as pups age, there will be a tendency only to sample survivors which are also likely to be individuals with the greatest growth rates. A possible solution to this is to assess the growth of total population biomass. However, this modification would require the collection of data about population size and pup mortality rate in parallel with data about growth.

Observation Protocols and Techniques

Toxicology and Disease Studies

8.63 WG-EMM-97/39 summarises recent preliminary serological evidence for the presence of infectious bursal disease virus in Antarctic penguins. Undetected outbreaks of such diseases might have implications for interpreting CEMP data.

New Methods

A3B – Breeding Population Size

8.64 Dr Wilson introduced WG-EMM-97/57, a draft standard method for using aerial photography as an alternative method to ground counts of nests in entire colonies. The Working Group suggested changes to detail regarding camera format, film type and, via Dr Boyd, a formula for estimating the area of the photo footprint for each exposure. The method should apply initially only to Adélie penguins but may well be applicable to, and could be tested on, other species. Dr Wilson will submit a revised version next year.

C3 – Antarctic Fur Seal Adult Female Survival Rate and Pregnancy Rate

8.65 Preliminary draft methods for estimating survival and pregnancy rates in Antarctic fur seals (WG-EMM-97/4) were considered by the Working Group. A major problem with such methods is that they may require to be adapted to the specific circumstances concerning the study site. The two methods proposed for estimating survival rate involved the use of age structures and mark-recapture.

8.66 There are difficulties associated with using age structures to estimate survival rates, mainly because of the necessity to make assumptions about the rate of change in the population and because it would only ever be possible to sample relatively small numbers of individuals from each age class. The Working Group considered that it was not practical to use this as a standard method and recommended that the mark-recapture method should be developed. Specifically, attention should be given to developing a generalised method of randomly sampling individuals across the population of breeding females.

C4 – Antarctic Fur Seal Diet

8.67 Draft methods for the determination of diet in Antarctic fur seals using scats (WG-EMM-97/5) were considered by the Working Group. The methods as presented had been written specifically to address the question of the diet of adult females during lactation. The Working Group endorsed the proposal but suggested the inclusion of certain modifications. These were:

(i) the methods should be broadened to include diet sampling of adults and juveniles at breeding and non-breeding sites and other times of year;

(ii) the methods should include assessment of the section of the population which has been sampled by including a measure of the percent occurrence of different age/sex classes of individuals in the site from which samples are obtained;

(iii) attention needs to be given to the relative visibility of scats containing different types of prey; and

(iv) an assessment of the statistical power associated with different sample sizes of scats is required.

Potential Methods for Krill-dependent Species

Antarctic Fur Seal Breeding Success

8.68 A method for monitoring breeding success should be developed for Antarctic fur seals. However, this is closely associated with development of a method for measuring pregnancy rate using mark-recapture (paragraphs 8.65 and 8.66) and it would be appropriate to defer the development of this method until the method for measuring pregnancy rate has been resolved.

At-sea Behaviour

8.69 The Report of the Subgroup on Statistics (Appendix D) made specific recommendations about how to proceed with the development of analytical methods for measuring at-sea behaviour. A significant problem with setting up a standard method of analysis is that the understanding of at-sea behaviour is likely to develop with time and that summary parameters derived from these datasets may become outdated. To avoid this, the subgroup suggested that data should be submitted in both raw and analysed formats. Software to derive monitoring parameters from these data should be developed for use by the Secretariat and by the suppliers of the data. This will ensure that all data are analysed in the same way and will eliminate biases resulting from using slightly different analytical methods on each dataset. Although the datasets involved were potentially very large, the technology was now available to enable this approach to be taken.

8.70 This approach will also enable the inclusion of raw data on at-sea behaviour within the CEMP database in advance of firm decisions being made about how to analyse these datasets and about the monitoring parameters to be derived from them.

Minke Whales

8.71 The Working Group briefly reviewed the elements of WG-EMM-97/18 concerning body fat condition and stomach content mass of minke whales. While these indices are appropriate in concept, the spatial and temporal scales over which they integrate information are uncertain and hard to relate to those of land-based predators, and therefore the indices need further study. The Working Group lacked the expertise to review these methods further.

Crabeater Seals

8.72 The Working Group noted that the APIS Workshop on Survey Design held in Cambridge, UK, during July 1996 had made recommendations about the methods used to carry out surveys of seals in pack-ice. These methods could, with small modifications, form the basis for monitoring crabeater seal abundance within CEMP.

8.73 These methods had already been applied successfully by Australia for aerial and ship-based surveys and they were being tested by the UK for application to regular surveys using fixed-wing aircraft.

8.74 The SCAR Group of Specialists on Seals was requested to provide CCAMLR with a copy of the workshop report as soon as possible.

Potential Method for Non Krill-dependent Species

8.75 WG-EMM-97/61 describes the development of a project designed to provide data on the relative abundance of coastal fish populations (including those of several species formerly the targets of commercial fisheries in Subareas 48.1 and 48.2) through monitoring diet (from pellets) and reproductive performance of Antarctic shags. The paper also provides new data validating improvements to the draft standard methods proposed in a paper tabled in 1995. The Working Group welcomed this latest study. It felt that enough new information was now available to justify preparing a revised version of the draft standard method for consideration by WG-EMM and WG-FSA.

Use of CEMP-related Methods in ASI Project

8.76 WG-EMM-97/38 provides information on the Antarctic Site Inventory Project (ASIP), which includes making estimates of breeding population size at penguin colonies using counting methods similar to those of CEMP, but with the timing of counts not standardised within and between years. The results of this study might be of interest to CCAMLR but the consequences of the different method being used will need investigating. ASIP should be requested to provide WG-EMM with a list of its sites and, in due course, to submit a paper to CCAMLR when about five years of consecutive data are available from most sites.

Missing Values in Datasets

8.77 The Subgroup on Statistics had reviewed this problem, which is of particular relevance to CEMP data on dependent species, in detail (Appendix D, paragraphs 5.1 to 5.8). It defined various potential categories of missing data and made recommendations concerning the circumstances when techniques to impute missing values might reasonably be used.

8.78 Reasons why values are missing in the CEMP database could include:

(i) data collected but not submitted;

(ii) data not collected:

- (a) because of no intention to do so or because of logistic problems – i.e. values are missing completely at random;
- (b) because of adverse environmental conditions – i.e. values cannot be assumed to be missing completely at random;
- (c) because of biological circumstances (e.g. all chicks died before fledging weight values could be obtained) – i.e. value would clearly have been non-random and its absence potentially relevant to ecosystem status; and
- (d) data censored (see Appendix D, paragraph 5.3(iv)), non-random and requiring special treatment.

8.79 Data holders were requested to review (against WG-EMM-97/25 Rev. 1) all missing values in their data in terms of these criteria and to inform the Data Manager of the reasons why values are missing.

8.80 To assist in this process the Working Group undertook a brief review of the more obvious missing values.

Laurie Island (Argentina)	A3, A6a:	1995 – value missing because of logistics problem.
		1996 – value missing because data assigned to wrong colony denominator – i.e. present, but in wrong place in database.
Stranger Pt (Argentina)	A1:	1989 – reason uncertain.
	A3:	1995 – data missing as above.
		1996– present but wrong designations (as above).
Elephant Island (Brazil)	A7, A8:	1991 – no expedition took place.
Seal Island (USA)	A8:	1992, 1993 – chinstrap data missing. Dr Holt to investigate.
	C1:	1989 – missing year. Dr Holt to investigate.

8.81 In the case of Standard Methods A3 and A6 the data submitted appear to contain numerous examples of missing values for particular sub-colonies within a single year. There may also be circumstances where values within the submitted data have been imputed prior to submission. In the first case data holders should inform the Data Manager of the reason the values are missing. In the second case they should inform the Data Manager of the identity of the imputed missing values and how they were calculated. The Subgroup on Statistics has recommended further development of appropriate methods for imputing missing values in such datasets. The Working Group noted the advice of the Subgroup on Statistics that where all data for a particular year are missing no imputations should be carried out.

Other Business

8.82 Prof. Torres suggested that there was a need to coordinate the system of tagging Antarctic fur seals to ensure that replication of tag types and numbers deployed at different sites did not lead to confusion. The Working Group agreed that it was important to standardise tagging procedures for fur seals both to benefit from the experience in tagging methods and tag type of current researchers and to ensure compatibility across sites to avoid confusion of tags applied in different locations.

8.83 Dr Boyd described methods currently used for tagging Antarctic fur seals at Bird Island. This involved the use of Dalton Jumbo tags which have the advantages that they have an embossed number, their colours remained patent for the effective lifetime of the tag, they had been shown to last for more than 10 years and they were relatively inexpensive. They have the disadvantage that, in recent years, some batches of tags had split when applied.

8.84 Dr Boyd emphasised the importance of positioning the tag correctly both because of its relevance to the welfare of the animal and to help ensure that tags are not ripped out of the flipper.

8.85 The Working Group recommended that a standard method for tagging fur seals should be prepared and Dr Boyd agreed to undertake this task in time for the next meeting of the Working Group.

8.86 There was extensive discussion about how to coordinate tag number and colour sequences. This was complicated by the problem that many different tag colours and number combinations had already been applied over the years especially at Bird Island. Norway also planned to continue using the number sequences from their work on Arctic seals within their program at Bouvet Island. It was also considered to be important that tag numbers do not exceed four digits in order to ensure readability of the number at a distance. This meant there were fewer options available for tag colour/number combinations.

8.87 The Working Group agreed that the following colour combinations would be allocated for tagging of Antarctic fur seals under CEMP.

Location	Colour(s) of each Portion of the Tag Male/Female
Cape Shirreff	white / orange
Bouvet Island	white / yellow
Bird Island	white / light blue, yellow / light blue, green / orange
South Georgia	white / green
Elsewhere	white / black

8.88 These combinations will come into effect from 1999 at Bird Island and South Georgia and from 1998 elsewhere. They will permit researchers at each site to use whatever number sequences they desire while maintaining distinction between sites.

8.89 It was agreed that information on tagging would be submitted to the SCAR Antarctic Seals Tagging Database which is located at the National Marine Mammal Laboratory, Seattle, USA.

8.90 In relation to the Norwegian CEMP-related program at Bouvet Island (WG-EMM-97/20) it was recognised that due to the timing of arrival and departure of field workers, not all data could be collected exactly according to CEMP standard methods. Nevertheless continued standardised collection of such data from this site would be most valuable. Simulation studies, using CEMP data from other sites, to estimate the magnitude of biases in any of the Bouvet Island data, should be undertaken as soon as possible.

Methods for Monitoring Environmental Variables of Direct Importance in Ecosystem Assessment

8.91 No papers were submitted which directly considered CEMP environmental indices. However, the Working Group considered that it should focus upon the existing environmental indices as well as looking at ways of developing new indices which may be useful to CCAMLR.

CEMP Indices

8.92 As part of the CCAMLR Ecosystem Monitoring Program, the Secretariat currently produces four environmental indices (F2a–c and F5) which are considered to be relevant to the assessment of the dependent species indices (A1–8, B1a–b, C1–2). The dependent species indices are mainly site related and the current environmental indices reflect this situation. The existing indices are:

F2a Sea-ice percentage cover in a subarea in September;
F2b Sea-ice retreat past a CEMP site: number of ice free days;
F2c Sea-ice distance to a CEMP site: weeks sea-ice is within 100 km of site; and
F5 Summer sea-surface temperature adjacent to a CEMP site.

8.93 Further standard methodologies have been prepared by the Secretariat, however these are currently in draft format. These methodologies are also site related. The draft indices are:

F1 Sea-ice cover viewed from a CEMP site;
F3 Local weather at a CEMP site; and
F4 Snow cover at a CEMP site.

8.94 The Working Group reviewed each of the environmental indices in turn, including those which are currently active (F2a–c and F5) and those which are in draft format (F1, F3 and F4).

8.95 Using visual observations, index F1 aims to describe the amount of sea-ice cover in the vicinity of predator colonies. It was considered that such data are likely to reflect important ecological information and that they may be of importance in the analysis of predator indices. The Working Group felt that it would be useful to determine whether sea-ice data were already collected at CEMP sites and asked the Secretariat to request details of such information from Members. Standard methodologies are available for describing sea-ice cover, however it was not known whether these had been adopted. Therefore, before an appropriate index can be developed, or the draft method description updated, the Working Group felt it would be useful for the Data Manager to review the methodologies used by Members.

8.96 Using remotely-sensed data, index F2 aims to describe the percentage cover of sea-ice within a subarea (F2a), the number of ice-free days at a CEMP site (F2b), and the number of weeks when the ice-edge is within 100 km (F2c). The production of index F2 is carried out by the Secretariat using data obtained from the Joint Snow and Ice Data Center. The Data Manager agreed to document the methodology and to update the method descriptions. Methods for the analysis of remotely-sensed sea-ice data are continually improving and the Working Group emphasised the importance of Members developing collaborative links with experts in the subject. Areas of particular interest for the analysis of predator indices include sea-ice concentration, position and duration of polynyas, and sea-ice thickness. The Working Group noted that some Members already prepare their own indices from remotely-sensed sea-ice data, and felt that it would be useful if details of these methodologies were accessible to the Secretariat so that comparison may be made with index F2.

8.97 Index F3 aims to describe the local weather at a CEMP site, which the Working Group considered was likely to be of ecological importance. The Working Group felt that it would be useful to determine if weather records were collected at CEMP sites and asked that the Secretariat request details of such information from Members. The Working Group noted that weather records may not be available for individual field sites, however, records are likely to be available for most research stations and substituting data from such a nearby location may be appropriate in some situations. Weather data from Research Stations are collected using agreed protocols and are archived in meteorological data centres from where they are readily available. The Data Manager agreed to review the availability of meteorological data from CEMP sites and from research stations so that consideration of appropriate weather indices may proceed.

8.98 Using visual observations, index F4 aims to describe the local snow cover at a CEMP site. The Working Group felt that it would be useful to determine if snow cover records were collected at CEMP sites and asked that the Secretariat request details of such information from Members. Before an appropriate index can be developed, or the draft method description updated, the Working Group felt it would be useful for the Data Manager to review the methodologies used by Members.

8.99 Using remotely-sensed Advanced Very High Resolution Radiometry (AVHRR) data, index F5 aims to describe the sea-surface temperature adjacent to a CEMP site. The production of index F5 is currently carried out by the Secretariat using data obtained from the National Center for Atmospheric Research (NCAR). The Data Manager agreed to investigate and document the methodology used to prepare the index and to produce a method description. The Working Group considered that the NCAR sea-surface temperature dataset should also be further investigated in order to provide other indices which may be relevant to an integrated ecological analysis. Dr Trathan agreed to carry out further investigation of the dataset and to prepare a paper for a future meeting.

8.100 The Working Group noted that two environmental indices (F2c and F5) describe summer averages using the mean value over December, January and February; it was accepted that this period was originally chosen in order to cover the breeding period of many dependent species. However, it was considered that the use of a summer average should be reviewed, particularly as the remotely-sensed data for index F2c and index F5 are available throughout the year.

8.101 The Working Group recognised that short-lived events in the physical environment may lead to catastrophic breeding failure in some predator species, although such events may not be apparent in an annual environmental index. The Working Group therefore welcomed the recent changes to data forms which were designed to record comments on unusual events (SC-CAMLR-XV, Annex 4, paragraph 4.65). Matching the scale of physical and biological records was considered necessary and such physical data should be obtained at the resolution of the biological data, even if this required that an annual index integrated a number of physical records. The meeting also considered that year-round data were preferable to data which covered just the period around the breeding season of dependent species.

8.102 The Working Group noted that time series of physical data often showed serial correlation. This should be taken into account during further development of methods for highlighting EIVs. The Working Group noted that standard methodologies for time series analysis may be more appropriate for physical data.

8.103 The Working Group recognised that a review of the draft environmental indices (F1, F3 and F4) was necessary before formal data submission could proceed. In order to ensure that these indices were applicable to the analysis of predator data, this review should be made by individuals with knowledge of the biological indices, as well as individuals with knowledge of the environment. In preparation for such a review, the meeting asked that the Secretariat request information from Members regarding the draft indices (paragraphs 8.95, 8.97
and 8.98), and that this information should include methodological details for sea-ice cover (F1), meteorology (F3) and snow cover (F4) for those CEMP sites where such data were currently collected. The Working Group also considered that the two existing environmental

indices (F2c and F5) which are based on a summer average should also be reviewed (paragraph 8.100).

Future Directions

8.104 Further environmental parameters are desirable in order to fully characterise the physical environment adjacent to CEMP sites. A similar range of indices may also be appropriate to characterise fisheries locations. The Working Group accepted, however, that such indices would not be immediately available and that considerable effort would be required by Members in order to prepare new methods. The Working Group considered that characterising variability in the position of the southern Antarctic Circumpolar Current Front was of particular relevance, but that present techniques required the use of ships with hydrographic facilities. An examination of the sea-surface temperature at frontal positions may therefore prove to be useful.

8.105 Remotely-sensed ocean colour data may shortly become available with the proposed launch of the SeaSTAR satellite which carries a Sea-viewing Wide Field-of-view Sensor (SeaWiFS). The Working Group considered that such data should be examined as soon as available with the view to generating an environmental index.

8.106 The Working Group also considered that use of tidal models and mixed-layer models would be particularly profitable and that Members should be encouraged to develop applications. Oceanographic models require specific data to run or for ground truthing, and the Working Group noted that such data could be gained from a number of sources; these may include ships of opportunity and research cruises.

8.107 The feasibility of analysing data from predators tagged with oceanographic recording devices and relating such data to the environment was discussed. The Working Group felt that such methods may provide the possibility of generating oceanographic indices and that they should be encouraged.

8.108 The Working Group recognised that a number of new directions (paragraphs 8.104 to 8.107) were under development by Members and that these approaches may lead to the generation of novel ways of describing the environment. The Working Group therefore encouraged Members to develop these approaches and to present future results to WG-EMM.

Synoptic B_0 Survey

8.109 The meeting noted that the synoptic survey which was proposed for the determination of a new krill B_0 estimate also offered the opportunity to collect other valuable ecological data. It was agreed that the planning process for the survey should therefore include consideration of environmental and physical processes from the earliest stages.

Plans for the Area 48 Workshop

8.110 The Working Group's discussions of further plans for the Area 48 workshop included deliberations on the following issues:

(i) purpose, objectives and expected products of the workshop;
(ii) structure of the workshop; and
(iii) date, duration and venue of the workshop.

8.111 The Working Group re-confirmed the terms of reference for this workshop as listed in SC-CAMLR-XV, paragraph 5.25. These are:

(i) identify the extent of between-season and within-season variation in key indices of the environment, harvested species, and dependent species over past decades;

(ii) identify coherence in the indices between sites and clarify understanding of the linkages between Subareas 48.1, 48.2 and 48.3;

(iii) develop working hypotheses; and

(iv) provide a summary report for consideration of the 1998 meeting of WG-EMM.

8.112 The Working Group agreed that it would be useful to organise the workshop around the following hypothesis and its alternative:

(i) H_0: Subareas 48.1, 48.2 and 48.3 are discrete ecosystems and events observed in any one subarea do not reflect what is happening in other subareas; and

(ii) H_1: Area 48 is a homogenous ecosystem and events observed in any one subarea reflect the entire area.

8.113 It was recognised that neither of these hypotheses was likely to be correct. However, they represent the end points of the spectrum of possibilities and may thus serve a useful purpose for organising the workshop.

8.114 With regard to the structure of the workshop, it was agreed that:

(i) indices derived from datasets (not necessarily using standard methods) should be submitted prior to the meeting;

(ii) these indices would be loaded on a central server that could be accessed by a network of computers available to workshop participants;

(iii) working papers could be submitted that elucidated the details of sampling and data processing leading to the formulation of an index; and

(iv) additional working papers could be submitted which drew attention to apparent relationships between indices.

8.115 It was agreed that the primary purpose of the workshop was to explore coherence among processes occurring throughout Area 48. Workshop participants were requested to submit their full sets of data on indices (i.e. without combining similar indices). Participants were, however, encouraged to undertake analyses of their own data (e.g. investigating properties of indices, multivariate analysis, etc.) in advance of the workshop and to report their results to it.

8.116 Relevant ecosystem processes were divided into four categories and coordinators were assigned to facilitate submission of indices describing seasonal variation in these processes. Processes to be indexed and their coordinators are:

(i) Physical Environment (Mr Amos, Drs Trathan and Naganobu):
   (a) sea-ice;
   (b) circulation;
   (c) hydrography;
   (d) meteorology; and
   (e) sea-surface temperature.

(ii) Biotic Environment (Dr Loeb):
   (a) phytoplankton; and
   (b) zooplankton.

(iii) Dependent Species (Drs Croxall and Trivelpiece):
   (a) CEMP indices;
   (b) other indices; and
   (c) cetacean catches and sightings.

(iv) Krill (Drs Watkins and Siegel):
   (a) demographics;
   (b) recruitment;
   (c) abundance and distribution of post larval forms (as determined from net samples and acoustic surveys);
   (d) abundance and distribution of larvae; and
   (e) fishery-dependent data.

8.117 The Working Group invited the submission of any indices as long as they could be used to address the hypotheses outlined in paragraph 8.112. Contributors are encouraged to contact the appropriate coordinator.

8.118 The Working Group recommended that the workshop should be held at the Southwest Fisheries Science Center in La Jolla, USA, during the last two weeks of June 1998. It was noted that the venue could accommodate no more than 20 participants. Dr Hewitt agreed to convene the workshop and to organise communications between the coordinators listed above.

8.119 The Working Group recommended that the CCAMLR Data Manager should attend the workshop and that secretarial support from the CCAMLR Secretariat should also be requested. This recommendation is motivated by the nature and scope of the workshop, particularly since diverse sources of data will be used and data in the CCAMLR database are likely to be considered.

8.120 The Working Group recommended that the Convener formulate a request to the IWC for cetacean catch and sighting records for Area 48. The request should be forwarded by the Secretariat to the IWC.

Synoptic Survey in Area 48

8.121 WG-EMM noted the Subgroup on Statistics deliberations concerning the proposed synoptic survey of Area 48 (Appendix D, paragraphs 6.1 to 6.6). It agreed with the subgroup's view that the primary objective of such a survey would be to provide an updated estimate of krill biomass (B_0) and its variance for use in the krill yield model to estimate precautionary catch limits for the area.

8.122 Considering a timetable for the survey, the Working Group reviewed information presented at previous meetings (WG-EMM-95/71; SC-CAMLR-XI, Annex 5, Appendix H; Trathan and Everson, 1994; SC-CAMLR-XV, Annex 5, paragraphs 3.72 to 3.75) and made the following recommendations:

(i) the synoptic survey of Area 48 should be scheduled for the austral summer of 1999/2000. This timing is considered to offer the most suitable compromise which addresses the urgent need for the survey and allows sufficient time for logistical planning;

(ii) survey effort should be concentrated in Subareas 48.1, 48.2 and 48.3. However, consideration needs to be given to the allocation of survey effort north of Subarea 48.1 (FAO Area 41.0) and to the zone covered by the southwest Atlantic circulation within the western part of Subarea 48.4;

(iii) a series of task groups should be constituted to develop a survey work plan for consideration at WG-EMM's 1998 meeting. The following tasks and nominated scientists are proposed so as to provide a coordinated approach to the task at hand:

(a) delineation of survey boundaries and strata (Dr Everson). Particular note to be taken of allocating survey cover to the north of Subarea 48.1, to the east of Subarea 48.2 and around oceanic islands or other physical features in Subareas 48.1, 48.2, 48.3 and 48.4;

(b) identification of information impacting on survey implementation and analyses (Dr Murphy). An important consideration in this context would be to consider the implications of water circulation as this may affect the transport of krill (e.g. as outlined in WG-EMM-97/67);

(c) acoustic sampling protocols (Drs Demer, Hewitt, Pauly, Watkins and Madureira);

(d) net sampling protocols (Drs Siegel, Loeb and Watkins);

(e) survey design and simulation (Drs B. Manly (New Zealand), A. Murray (UK), Everson and de la Mare). The results of this study (see paragraphs 8.125 to 8.129 below) are considered crucial for the setting of limits (particularly in respect of time allocations) to the survey activities outlined in subparagraphs (c) and (d) above;

(f) oceanographics/environmental sampling protocols (Mr Amos, Drs Trathan and Naganobu). It was emphasised that focus should be given to the underway sampling of key environmental parameters and that the sampling of such parameters should not compromise the surveys synopticity or its primary objective of estimating B_0;

(g) ancillary information. To maximise ship survey time, it was acknowledged that some vessels may undertake activities (e.g. whale sighting) ancillary to the surveys main objectives. As with (f) above, it was emphasised that these activities should not detract from the survey's primary aim to estimate B_0; and

(iv) to facilitate the approach outlined in (iii) above, WG-EMM requested the Secretariat to compile a list of previous agreements (e.g. on acoustic survey standardisation) by CCAMLR and its subsidiary bodies relevant to synoptic survey design in general and the synoptic survey of Area 48 in particular (see also paragraphs 8.32 to 8.37).

8.123 The Working Group also recommended that the tasks outlined in the previous paragraph should be collated as a draft survey plan in time for consideration by a survey steering committee convened by Dr Holt and comprising Mr Amos, Drs Demer, Everson, Manly, Murphy, Naganobu, Phan van Ngan and Siegel. This committee could meet in conjunction with the planned Area 48 workshop in mid-1998 and prepare an outline survey plan to be considered at WG-EMM's 1998 meeting.

8.124 WG-EMM agreed with the Subgroup on Statistics' conclusion that the two key outstanding issues regarding the synoptic survey design for Area 48 are questions surrounding stratification and random versus systematic placement of survey transect lines.

8.125 The Working Group recommended that a simulation study be implemented so as to provide a quantitative comparison of the relative efficiencies of random as opposed to systematic transect placement in a synoptic survey for krill in Area 48. This study should be afforded high priority.

8.126 The Working Group therefore proposed that a small panel, comprising Drs Manly, de la Mare, Murray, Everson and other interested parties, should be tasked with defining realistic goals and boundaries for the simulation study (paragraph 8.122(iii)(e)). At a minimum this study should consider:

(i) the cost (in ship-hours) of alternative survey designs and transect placements (including the cost-benefit of various levels of randomisation in design);

(ii) the effects of and potential for survey biases introduced by diel vertical migration of krill (particularly with respect to the allocation of survey effort by day alone, as opposed to day and night together);

(iii) the effects of spatial coherence in krill distribution being different in different directions (including possible biases likely to arise from up- and downstream placements of survey transects and the relative costs of surveying a population which varies in time and space); and

(iv) whether there is a point at which the marginal utility of reducing the survey variance becomes small. This could be studied by considering when the results of the krill yield model become more sensitive to variability in krill recruitment than to uncertainty in krill biomass.

8.127 WG-EMM agreed that a number of other considerations should be taken into account in the setting up of the simulation. These would include:

(i) the optimal allocation of survey effort and transect placement, given the likely levels of ship commitment (i.e. available ship time) and the consequent expectation of optimal benefit in terms of minimising survey variance and maximising survey precision;

(ii) the trade off between allocation of survey effort and reduction in survey variance, especially when additional allocation of effort results in only marginal reduction in variance;

(iii) the range of krill spatial distributions likely to be encountered and how these may reflect transect placement. This will require examination of historic data, the simulation and sampling of various theoretical spatial distributions to take into account temporal variability arising from horizontal patchiness or diel vertical migration and to assess the likely range of impacts on estimates of survey variance; and

(iv) the use of historic datasets (e.g. FIBEX, data from the Discovery Investigations, commercial fisheries information) as well as regional scale (e.g. the Australian survey of Division 58.4.1) and local scale (e.g. the AMLR surveys around Elephant Island) data as an empirical basis for setting up the simulation as well as for tuning its results.

The Working Group noted that complete consideration of the items identified in subparagraphs (iii) and (iv) above constitute a substantial task within the planned time scale (one year) of the simulation.

8.128 WG-EMM agreed that the panel should formalise the simulation study terms of reference and develop an achievable (in the time available, i.e. one year) and realistic action plan prior to the Scientific Committee's 1997 meeting.

8.129 In the absence of a simulation study, WG-EMM noted the Working Group's conclusion that randomly-spaced parallel transects offer a conservative survey design since both design and model-based variance estimators can be used to analyse survey data. In this regard the Working Group acknowledged that randomly-spaced parallel transects offer a fall-back position which in no way reduces the urgency attached to the simulation study and that the former should not be seen as a desirable alternative. In this context, the Working Group recognised that consideration remains to be given to the apportionment of random as opposed to fixed transect allocation in a synoptic survey of krill in Area 48.

Other Activities in Support of Ecosystem Monitoring And Management

CCAMLR–IWC Collaboration

8.130 At its annual meeting in 1996, the IWC recommended that joint CCAMLR–IWC working groups be established to consider collaborative work in the Southern Ocean. As a consequence, SC-CAMLR invited IWC to send a representative to attend the 1997 Meeting of WG-EMM (SC-CAMLR-XV, paragraph 11.14). Dr Reilly, convener of the IWC Standing Working Group on the Effects of Environmental Change on Cetaceans, took part in the deliberations on behalf of the IWC (see paragraph 1.4).

8.131 The Working Group identified the study of the distribution of whales in relation to krill, oceanography and bathymetry as an area of common interest to CCAMLR and IWC. Therefore, it suggested the following ways in which closer collaboration could be developed:

(i) participation in existing and planned surveys which focus on either krill (or other prey) and environmental conditions or cetacean sightings;

(ii) joint analysis of recent and historical datasets containing information on whale distribution, whale catches and prey distribution and abundance; and

(iii) annual exchange of information which is of relevance to the other organisation.

Participation in Existing and Planned Surveys

8.132 The participation in existing and planned surveys of the other organisation would encompass various levels of involvement. The provision of advice by the IWC on CCAMLR-dedicated national and international surveys could range from the compilation of cetacean sighting protocols, information on minimum datasets required, skills of observers required to obtain reliable datasets, or the recruitment of suitable observers to the actual participation in those surveys. Examples where IWC protocols have been incorporated into krill surveys recently are the Australian krill survey in Division 58.4.1 in 1995/96, the German krill survey around Elephant Island in 1996/97 and various AMLR surveys over the last 10 years. Pending further investigation, cetacean sighting surveys might also become part of other CCAMLR-dedicated surveys, such as the UK predator/krill survey around South Georgia, and the CCAMLR international synoptic krill survey in Area 48 which is planned for 1999/2000. CCAMLR could provide advice to the IWC or IWC Members on surveys with the primary focus on cetaceans which include studies on the behaviour of whales in relation to prey distribution and abundance and/or the environment. As an example, CCAMLR has provided advice to the IWC on the planning of the Southern Ocean Whale and Ecosystem Research Cruises (SOWER) in 1995.

Coordination of CCAMLR and IWC Research Activities

8.133 Pending the experience from the collaborative work outlined in the previous paragraph, it could be envisaged that CCAMLR and the IWC would work together in some parts of the Southern Ocean to study the distribution and behaviour of whales in relation to prey distribution and the environment. The planned CCAMLR survey to estimate krill biomass in the western part of Area 48 (Subareas 48.1 to 48.4) in the 1999/2000 season (see paragraph 8.122) would offer the opportunity for such a joint effort if the IWC would be able to conduct one of its SOWER surveys in parallel with the CCAMLR survey.

Analysis of Historical and Recent Datasets

8.134 As more information on krill biology and population dynamics become available, it could be useful to revisit historical datasets, for example from the Discovery Investigations, which may now provide new insight into the behaviour of whales in relation to their prey and the environment, and the distribution and abundance of krill. Prerequisites for such investigations are:

(i) an inventory of existing historical datasets containing information on whale distribution, krill distribution and abundance and environmental parameters. This could be compiled in collaboration between the CCAMLR and IWC Secretariats;

(ii) the IWC database on catch records and biological information of whales taken in the Southern Ocean, as soon as it is completed; and

(iii) the specification of the objectives for which these datasets should be re-analysed. These need to be developed by CCAMLR in the intersessional period.

Prey surveys in the CCAMLR Convention Area have incorporated cetacean sightings without, however, following standard protocols such as those developed for line transect surveys. Advice about how such data might best be analysed, might be sought through the IWC.

Annual Exchange of Information

8.135 The exchange of information between the two organisations should be improved and could include lists of working papers a well as their abstracts. Working papers which are of relevance to both organisations should be submitted to meetings of both organisations either as working papers or as background documents, as has been the case for papers WG-EMM 97/17 and 97/18. Such papers need not be restricted to problems in the Southern Ocean, but might contain information on new methods which could be applied to studies in the Southern Ocean.

8.136 A closer collaboration between CCAMLR and the IWC could best be achieved by forming a small liaison group with IWC-SC which could work (mostly by correspondence) on matters outlined above. Members of this group should cover a wide range of expertise and should not be confined to those who attend meetings of both CCAMLR and the IWC.

8.137 Draft terms of reference for such a group will need to be developed by the Scientific Committee. WG-EMM suggested the following terms of reference:

(i) to facilitate communication between CCAMLR and the IWC on all scientific matters of mutual interest;

(ii) to advise the Scientific Committee on matters relevant to potential collaborative work, for example:

(a) exchange of information;
(b) the analysis of historical datasets;
(c) survey methods
(d) studies of interactions between whales, prey and the environment; and
(e) estimate prey consumption by whales.

GLOBEC Workshop

8.138 Following the meeting of WG-EMM there will be a workshop to plan the Southern Ocean Global Ocean Ecosystem Dynamics (SO-GLOBEC) effort. The SO-GLOBEC program will provide an opportunity to test hypotheses about environmental and biological interactions in the Antarctic marine ecosystem. Given the mutual scientific interests, it is hoped that collaborative research effects between CCAMLR and SO-GLOBEC will be developed.

ADVICE TO THE SCIENTIFIC COMMITTEE

9.1 The Secretariat should acquire data on krill catches in areas adjacent to Subarea 48.1 (paragraph 10.1).

9.2 Members should be encouraged to continue to submit the following data from their krill fisheries (paragraphs 10.2 to 10.4):

(i) haul-by-haul data;
(ii) time budget data; and
(iii) fish by-catch data.

9.3 Members should note the Working Group's advice on data collection and processing for zooplankton surveys using acoustic techniques (paragraph 10.11).

9.4 The Secretariat should compile into a single reference document all papers submitted to meetings of WG-EMM and WG-Krill relevant to surveys of krill distribution and abundance (paragraph 10.12).

9.5 The Working Group recommended that a synoptic survey of krill biomass in Area 48 be undertaken in the austral summer of 1999/2000 (paragraph 10.14).

9.6 The Working Group recommended that site protection at Seal Island under Conservation Measure 92/XI be extended for five years subject to approval of a revised management plan (paragraph 8.41).

9.7 The Working Group recommended that Bouvet Island be accepted as a CEMP monitoring site (paragraph 8.42).

9.8 The Secretariat should revise Tables 1 to 4 of the introduction of the standard methods and circulate the revised standard methods to all Members as soon as possible (paragraph 10.16).

9.9 The Data Manager should investigate the availability of data on Antarctic petrels potentially appropriate for the CEMP database (paragraph 10.18).

9.10 The Secretariat should request, from appropriate SCAR groups, the reports of workshops on survey design (APIS) and estimation of seabird distribution and abundance at sea (Bird Biology Subcommittee) (paragraphs 10.23 and 10.25).

9.11 The Secretariat should request ASIP to supply a list of its sites and to supply further information in due course (paragraph 10.26).

9.12 The Data Manager should request from Members specified information on environmental data (paragraph 10.27(i), (ii) and (iv)).

9.13 The Secretariat should request Members to check that their data in the CEMP database are correctly summarised in WG-EMM-97/25 Rev. 1 to ensure prompt submission to the Data Manager of CEMP data from current and recent seasons and outstanding historical data where available (paragraph 10.32) and to provide information on missing values (paragraph 10.33).

9.14 The Scientific Committee should note the advice from the Subgroup on Statistics concerning imputation of missing values (paragraph 6.11 and Appendix D, paragraph 5.7) and the request for development of imputation techniques when missing values have been identified.

9.15 The Scientific Committee should note the conclusions of the Subgroup on Statistics concerning evaluation of the Agnew–Phegan model for calculating potential overlap between fisheries and dependent species (Appendix D, paragraphs 3.1 to 3.15; paragraph 10.34).

9.16 The Scientific Committee should note the prediction of poor recruitment from krill spawning during 1996/97 in Subarea 48.1 (paragraph 6.38; also paragraph 3.43).

9.17 The Scientific Committee should note the recommendations contained in the executive summary of the report of the Workshop on International Coordination (Appendix E) as these apply to Members whose work is relevant to the topics considered by the workshop (paragraph 10.35).

9.18 The Scientific Committee should note comments on the possible re-establishment of minke whales as a CEMP monitoring species (paragraphs 6.53 and 6.54).

9.19 In response to the request of the Scientific Committee to evaluate aspects of WG-FSA-96/20, the Working Group noted the lack of sufficient data to assess how the development of a fishery in Subarea 48.3 for the squid *M. hyadesi* would affect its dependent predators. It supported the precautionary approach recommended in WG-FSA-96/20 (paragraphs 6.83 to 6.87).

9.20 The Working Group recommended that a workshop to consider the coherence of processes relating to environment, krill and dependent species between Subareas 48.1, 48.2 and 48.3 be held during the intersessional period with the terms of reference, arrangements and responsibilities as set out in paragraphs 8.111 to 8.119. This includes a request for the attendance of the Data Manager and for secretarial support (paragraph 8.119).

9.21 The Working Group recommended that revised calculations of precautionary limits be deferred until the results of the synoptic krill survey for Area 48 are available (paragraph 7.2).

9.22 The Working Group recommended that when the computer program implementing the GYM has been validated by the Secretariat it should replace the existing krill yield model for future krill-related computations (paragraph 7.3).

9.23 The Working Group recommended that subarea subdivision of the precautionary catch limit for krill in Area 48 be deferred until the results of the planned synoptic survey for Area 48 are available (paragraph 7.7).

9.24 The Scientific Committee should note the ecosystem assessment undertaken by the Working Group (paragraphs 7.12 to 7.28), in particular the preliminary use of new developments in methods to identify EIVs in data submitted to the CEMP database.

9.25 The Secretariat should request from the IWC:

(i) an inventory of the historical datasets on whale distribution and associated prey and environmental data and circulate the response to Members with the request for suggestions on analyses of such data which are relevant to CCAMLR (paragraphs 10.49 and 10.50);

(ii) cetacean catch and sightings records relevant to Area 48, in advance of the Area 48 workshop (paragraph 8.120).

9.26 The Working Group recommended that the Scientific Committee approve the establishment of a liaison group to facilitate collaboration between the Scientific Committees of the IWC and CCAMLR (paragraphs 8.136 and 8.137).

9.27 The Working Group recommended that the Scientific Committee review arrangements for meetings of WG-EMM, with particular attention to improving the availability and content of working group papers and the provision of the most appropriate Secretariat support at meetings (paragraphs 11.1 to 11.7).

FUTURE WORK

Fisheries Information

10.1 The Secretariat will seek information on krill catches which may have been taken in waters adjacent to those for which catches were reported along the northern boundary of Subarea 48.1 in recent years (paragraph 2.2).

10.2 Submission of haul-by-haul data from the krill fishery should continue to be encouraged (paragraph 2.10; SC-CAMLR-XV, Annex 4, paragraph 10.8(vii)).

10.3 Time budget data from krill fishing operations need to be acquired and submitted (paragraph 2.11).

10.4 Data on by-catch of fish in krill catches from seasons other than the austral summer are required (paragraph 6.2).

Harvested Species

General

10.5 Information and data on indices of local krill availability should be submitted to the next meeting of the Working Group (paragraphs 3.20, 6.77 and 6.78).

10.6 A reliable predictor of krill recruitment needs to be developed and its statistical properties assessed (paragraph 3.27).

10.7 The relationship between measures of abundance and proportional recruitment and the output of the krill yield model needs investigating (paragraph 3.29).

10.8 Further development of CPUE indices, incorporating additional operational information from the krill fishery, is encouraged (paragraph 3.40).

Methods

10.9 It was agreed to develop a draft standard method for the calculation of an absolute recruitment index for krill (paragraph 8.1).

10.10 Information and results relating to techniques for species-discrimination of zooplankton and nekton, in particular using image-recognition and multifrequency acoustic methods, should be submitted to the next meeting (paragraph 8.18).

10.11 Members collecting data from surveys of zooplankton distribution and abundance using acoustic techniques should note the Working Group's advice on data collection, logging and processing (paragraph 8.23).

10.12 Advice and information on methods and techniques relevant to the conduct of surveys of krill distribution and abundance which had been provided to current and previous meetings of WG-EMM and WG-Krill would be compiled into a single-reference source by the Secretariat (paragraphs 8.30 and 8.122(iv)).

10.13 Standard methods for net and acoustic sampling, data storage and analysis need to be developed prior to the synoptic survey of Area 48 (paragraph 8.31) by the task groups identified in paragraph 8.122(iii).

Biomass Survey

10.14 The Working Group recommended that work to prepare for a synoptic survey of krill biomass in Area 48 be undertaken with the arrangements and responsibilities described in paragraphs 8.121 to 8.129.

Dependent Species

Existing Standard Methods

10.15 The Working Group had not identified a need for any revision of the *CEMP Standard Methods* at this stage (except as in paragraph 10.13). When the *CEMP Standard Methods* is next revised, topics requiring further consideration, in addition to those listed in paragraphs 8.48 to 8.75, should include:

(i) potential biases in diet studies (paragraph 8.54);
(ii) reducing disturbance associated with Method A9 (paragraph 8.56).

10.16 The Working Group recommended that before circulating to Members the *CEMP Standard Methods* as revised last year, Tables 1 to 4 of the introduction should be updated by the Secretariat, to take account of changes to sites and to Members' work as reported in SC-CAMLR-XV/BG/2. If possible, reference to two additional publications should be inserted in Method A5 and Section 4 of Observation Protocols and Techniques (see paragraph 8.51).

10.17 Members holding appropriate datasets were requested to evaluate sampling regimes and sample sizes for standard methods (paragraph 8.48), especially:

(i) in relation to five-day sampling periods for Methods A5, A7 and A9 (paragraph 8.49);

(ii) in conjunction with definition of a biological reference point for Method A5 (paragraph 8.52);

(iii) in relation to differences in foraging trip duration of macaroni penguins for Method A5 (paragraph 8.53);

(iv) investigating different approaches to analysis of data on Antarctic fur seal foraging trip duration (paragraphs 8.60 and 8.61); and

(v) reducing bias in methods estimating offspring growth rates (paragraph 8.62).

10.18 The Data Manager should investigate the availability of data potentially appropriate for CEMP on Antarctic petrel population size and breeding success (paragraph 8.59).

Potential Standard Methods

10.19 Revisions of the proposed new standard methods for penguin breeding population size (A3B), Antarctic fur seal adult female survival rate and pregnancy rate (C3), and Antarctic fur seal diet (C4) should be submitted to next year's meeting (paragraphs 8.64 to 8.67).

10.20 A draft standard method on tagging of Antarctic fur seals should be prepared by Dr Boyd (paragraph 8.85) and submitted to next year's meeting.

10.21 Members conducting research on fur seals should note the colour combinations for tags prescribed for the sites at Cape Shirreff, Bouvet Island, Bird Island, South Georgia and elsewhere (paragraph 8.87). Members tagging fur seals should ensure that data are submitted to the SCAR Antarctic Seals Tagging Database (paragraph 8.88).

10.22 The suggestion that data on at-sea behaviour, collected according to the standard method set out in Section 4 of Observation Protocols and Techniques should be submitted in both raw and analysed data format (paragraphs 8.69 and 8.70), requires the development of instructions for doing this which should be submitted to the Working Group as soon as possible, taking account of the methodological investigations recommended by the Subgroup on Statistics (Appendix D, paragraph 7.13).

10.23 The Secretariat should request from the SCAR Group of Specialists on Seals, the report of the APIS Workshop on Survey Design (paragraph 8.74), together with relevant details from Australian shipboard surveys and UK pilot studies with fixed-wing aircraft (see paragraph 8.73) in order to develop a standard method for monitoring crabeater seal abundance.

10.24 Dr R. Casaux (Argentina) and colleagues were encouraged to submit to the Working Group a new version of a draft standard method for collecting data on relative abundance of coastal fish species by monitoring the diet and reproductive success of Antarctic shags (paragraphs 6.82 and 8.75).

Other Matters

10.25 The Secretariat should request from the SCAR Subcommittee on Bird Biology, the report of the workshop dealing with standardising quantitative surveys of seabird abundance and distribution at sea (SC-CAMLR-XV, Annex 4, paragraph 4.92).

10.26 The Secretariat should request ASIP to provide a list of sites being monitored and, at a future time, a review of the data collected (paragraph 8.76).

Environment

10.27 The Working Group concluded that it was timely to review the nature of environmental data being collected to develop existing or potential CEMP standard methods. To assist in this:

(i) the Data Manager was requested to obtain information on data currently being collected under Methods F1, F3 and F4 (paragraphs 8.95, 8.97 and 8.98);

(ii) the Data Manager was requested to obtain indices of sea-ice cover and related measures currently being collected by Members in standard fashion (paragraph 8.95);

(iii) Dr Trathan was requested to investigate the dataset currently used to provide indices of sea-surface temperature under Method F5 to see if other indices could be developed (paragraph 8.99); and

(iv) the Data Manager would request Members to review the temporal scales at which data for Methods F2c and F5 should be collected (paragraph 8.100).

10.28 The Working Group agreed that it was desirable to obtain data on additional environmental parameters to characterise the physical environment adjacent to CEMP sites and within ISRs. Members were encouraged to investigate this intersessionally, particularly in relation to characterising frontal positions, investigating properties of oceanographic models and the potential use of instrumented predators to obtain relevant oceanographic information (paragraphs 8.104 to 8.108).

10.29 Cooperative analysis of historical hydrographic data from the Elephant Island region is encouraged (paragraph 5.6).

Ecosystem Analysis

10.30 Further work should be undertaken on multivariate analysis of CEMP indices, including studies of combined indices and the definition of baselines (paragraphs 6.7 and 6.35).

10.31 Members were requested to check the summary of the data held in the CEMP database as set out in WG-EMM-97/25, Rev. 1 and to inform the Data Manager of any errors or omissions (paragraph 6.9).

10.32 All Members were requested to ensure prompt submission to the CEMP database of (paragraph 9.13):

(i) outstanding data from the 1997 season;

(ii) outstanding historical data for all parameters currently covered by standard methods; and

(iii) data for the 1998 season, particularly for Area 48, to ensure that this is available in advance of the proposed workshop.

10.33 Information on missing values within data submitted to the CEMP database should be provided to the Data Manager as soon as possible (paragraph 6.11; see also paragraphs 8.79 and 8.81).

10.34 In respect of potential overlap between fisheries and dependent species, further work is required on (paragraph 6.10):

(i) revision of the Agnew–Phegan model, especially in respect of temporal aspects;

(ii) calculation of Schroeder indices; and

(iii) development of indices to assess possible impact of harvest on dependent species.

10.35 Members whose work is relevant to studies contributing to topics considered by the Workshop on International Coordination (WG-EMM-97/44) should take note of the recommendations in the executive summary of this report (Appendix E).

10.36 Analysis of trawl-based data from fishing operations to investigate the nature of potential interactions between predators, prey and fisheries is encouraged (paragraph 6.22).

10.37 Further analysis of ancillary data deriving from the krill fishery is encouraged (paragraph 6.26).

10.38 Further studies quantifying krill flux and exploring interactions between water transport and patterns of krill aggregation are required (paragraph 6.28).

10.39 Studies apportioning variability in krill recruitment and abundance between large-scale (environment) and small-scale (population) processes should be undertaken (paragraph 3.28).

10.40 Multivariate analyses of the relationships between salp abundance, krill recruitment, krill abundance and ice cover should be undertaken (paragraph 3.46).

10.41 Relationships between environmental factors and processes determining local krill population distribution and abundance should be developed for areas additional to Subarea 48.1 (paragraph 6.34).

10.42 Development of methods which assist incorporation of environmental information into management strategy are encouraged (paragraph 6.37).

10.43 Work to quantify the impact of minke whales on krill is encouraged (paragraphs 6.30 and 6.55).

10.44 Prof. Butterworth was encouraged to complete work on the existing model of functional relationships involving Antarctic fur seal and black-browed albatross (taking into account new information and advice provided in paragraphs 6.63 to 6.65, 6.68, 6.71 and 6.72) and to investigate the possibility of further progress with the sub-model involving Adélie penguin (paragraph 6.66).

10.45 The development of complementary approaches involving mechanistic modelling were encouraged (paragraphs 6.71 and 6.72).

10.46 The Working Group will consider the reviews by SCAR of the status and trends of dependent species at its next meeting (paragraph 6.73).

10.47 The Working Group will consider potential interactions between dependent species more explicitly at its next meeting (paragraph 6.74).

10.48 The Working Group recommended that a workshop to consider the coherence of processes relating to environment, krill and dependent species between Subareas 48.1, 48.2 and 48.3 be held during the intersessional period with the terms of reference, arrangements and responsibilities as set out in paragraphs 8.111 to 8.118.

Collaboration with the IWC

10.49 The Secretariat should request from IWC an inventory of the historical datasets on whale distribution and associated prey and environmental data (paragraph 8.134).

10.50 On the basis of this report the Secretariat will invite Members to suggest objectives, relevant to the work of the Working Group, for analysis of these datasets; these suggestions would be discussed at the next meeting (paragraph 8.134).

10.51 The Secretariat should request from IWC cetacean catch and sightings records relevant to Area 48, in advance of the Area 48 workshop (paragraph 8.120).

10.52 The Working Group identified responsibilities and priorities for all tasks listed in paragraphs 10.1 to 10.51 of the report and requested the Secretariat to summarise in a table format those needing to be carried out in the forthcoming year. This table would be distributed as a background paper at the forthcoming meeting of the Scientific Committee.

OTHER BUSINESS

Working Group Papers

11.1 The current rules require papers tabled at working group meetings to be lodged with the Secretariat by 0900 h on the first morning of the meeting. Participants bringing papers to meetings on the day of the meeting are asked to provide 40 copies. Papers received by the Secretariat in Hobart 30 days before the commencement of a working group meeting are circulated to participants prior to the meeting.

11.2 This year 20 out of 80 papers were received 30 days in advance of the WG-EMM meeting. The late arrival of the bulk of papers to be considered for discussion meant that important papers may not have received due attention. Indeed some papers were not available until the second day of the meeting. Participants therefore had great difficulty in reading all the papers and in adequately introducing them into the debate.

11.3 The Working Group agreed that the current situation as outlined above is unsatisfactory. It drew the Scientific Committee's attention to this important matter and made the following suggestions:

(i) the timely availability of working group papers should be improved. This could entail a mandatory closer submission deadline (e.g. two weeks before the beginning of a working group meeting), ensuring the availability of all papers to participants on registration. If the above cannot be met then participants must bring sufficient copies for all meeting participants (i.e. 75 copies) for distribution before 0900 h on the first day of the meeting.

(ii) the overall amount of material to be read by every participant should be reduced. This could be achieved by requesting the submission of informative abstracts of papers only and requiring the authors to indicate on the cover page that the papers are either for full consideration or contain background information only. Full papers could then be available on prior request;

(iii) photocopying and preparation of meeting papers at the beginning of the working group meeting should be minimised. Notwithstanding participants bringing their own papers to the meeting (see (i) above) participants should be requested to provide cover pages (including the CCAMLR approved disclaimer clause) to their papers. If at least the titles of papers were notified in advance of the meeting, that would enable the Secretariat to assign paper numbers which participants could include on their cover pages. Failing this, paper numbers would have to be inserted by hand; and

(iv) exploration of alternative methods to disseminate the information contained in papers should continue. This could entail the distribution of papers prior to the meeting by electronic means.

11.4 The Working Group agreed that there would be no point in implementing rules for the timely submission and distribution of papers if such rules were not strictly applied as this would defeat the purpose of the exercise.

Secretariat Support at WG-EMM Meetings

11.5 The Working Group expressed its thanks to the Secretariat for a difficult job well done in supporting its activities during meetings of the Working Group and its associated bodies. However, concern was expressed that certain aspects of this support could be improved in the interests of efficiency and in the deployment of adequate resources and skills to support WG-EMM's complicated function.

11.6 While acknowledging that the Commission had agreed to delay the publication of bound copies of the Commission and Scientific Committee's reports to spread the translation load, the Working Group requested that bound copies of the latter should be available in good time for WG-EMM meetings. This would allow Members easy access to past deliberations and associated material considered by the Scientific Committee.

11.7 To ensure the efficient deployment of limited Secretariat resources and given current budgetary constraints, WG-EMM requested the Scientific Committee to consider a process whereby the skill necessary for working group support should be more clearly defined. The purpose of such a review will be to ensure that the number and skills of Secretariat staff travelling to working group meetings is commensurate with the tasks likely to be required by the meeting concerned. As a general principle the Working Group agreed that the Scientific Committee is in the best position to define the Secretariat needs for meetings of its subsidiary working groups.

Krill Symposium

11.8 The Working Group examined a draft program for the second International Krill Symposium scheduled for 1999 and noted that the program will be presented to the Scientific Committee at its 1997 meeting (SC-CAMLR-XIV, paragraphs 4.23 and 4.24; SC-CAMLR-XV, paragraph 4.26).

ADOPTION OF THE REPORT

12.1 The report of the third meeting of WG-EMM was adopted.

CLOSE OF THE MEETING

13.1 In closing the meeting, the Convener, Dr Everson, expressed his sincere thanks to Dr Holt and his colleagues in San Diego for the substantial amount of work they had done to ensure that the meeting ran smoothly. He also thanked the participants for their contributions, and the rapporteurs for their work. Finally he thanked the Secretariat staff, and particularly Mrs G. Mackriell and Mrs R. Marazas for their support in preparing meeting papers and the report.

13.2 Dr Miller, on behalf of the Working Group, expressed his thanks to Dr Holt and his team for arranging the meeting, and his gratitude to Sea World and the Hubbs–Sea World Research Institute for providing excellent meeting facilities. He also thanked the Convener for conducting the meeting in an efficient and productive fashion.

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Table 1: Interactions between harvested species (krill) and the environment based on information derived from Elephant Island.

Environmental factors	Processes Determining Local Krill Population				Differential Effects on Local Versus Regional Populations
	Krill Production	Recruitment	Natural Mortality	Immigration and Emigration	
Primary production	Important Position, extent, timing and species composition of local blooms affects krill production – depends on physical environment.	Important	Important?	??	Important at all scales.
Biotic interactions (including salps and possibly other zooplankton).	Salps competing for primary production. Krill consumes zooplankton in winter.	Spring salp blooms inhibit early spawning. High summer salp populations consume eggs and larvae.	Salps eat eggs and larval krill.		Important at both local and regional scales.
Sea-ice	Winter and spring growth promoted by extensive sea-ice.	Extensive winter sea-ice promotes early spawning and improves survival of larvae. Poor sea-ice development promotes spring salp bloom.	Natural mortality over-winter reduced by extensive ice.	??	On local scales the relevant sea-ice effects occur upstream and in preceding years.
Changes in water temperature and circulation, including positions of fronts, depths of mixed layers, local advection	Direct effects on krill growth. Higher surface layer temperatures increase salp biomass. Local krill density affected by changes in local circulation – eddies.	Direct effects on krill spawning and survival. Higher surface layer temperatures increase salp biomass.	Higher surface layer temperatures increase incidence of parasites and disease. Influx of myctophids associated with circumpolar deepwater – increased predation.	Krill retention, distribution and transport affected?	Relative importance of effects depend on scale of interest i.e. regional or local.
Advection	Standing krill stock depends on transport. Salps advected with warm water masses.	Recruitment from advected krill may predominate at local scales. Recruitment exported to downstream localities.			Standing stock more dependent on transport at the local scale.

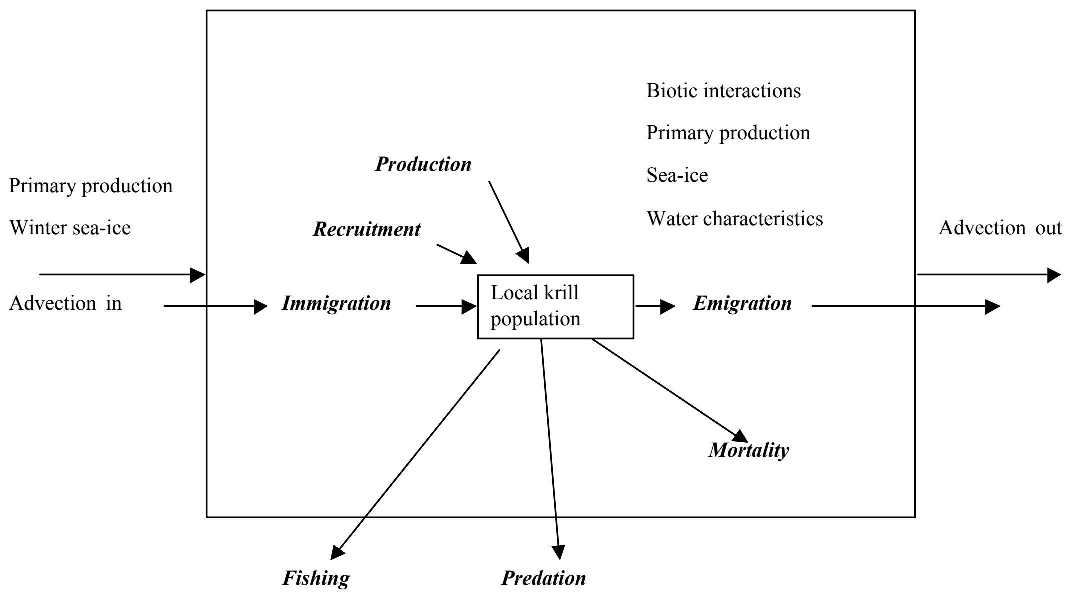

Figure 1: Environmental (biotic and abiotic) factors and processes determining local krill population distribution and abundance. The population processes are shown in bold italics. See Table 1 for further description of the possible effects of the environment on population processes.

APPENDIX A

AGENDA

Working Group on Ecosystem Monitoring and Management
(San Diego, USA, 21 to 31 July 1997)

1. Introduction

    (i) Opening of the Meeting
    (ii) Organisation of the Meeting and Adoption of the Agenda

2. Fisheries Information

    (i) Catches, Status and Trends
    (ii) Harvesting Strategies
    (iii) Observer Scheme
    (iv) Other Information

3. Harvested Species

    (i) Distribution and Standing Stock
    (ii) Recruitment and Production
    (iii) Indices of Abundance, Distribution and Recruitment
    (iv) Future Work

4. Dependent Species

    (i) Studies on Distribution and Population Dynamics
    (ii) Future Work

5. Environment

    (i) Consideration of Studies on Key Environmental Variables
    (ii) Indices of Key Environmental Variables
    (iii) Future Work

6. Ecosystem Analysis

    (i) By-catch of Fish in the Krill Fishery
    (ii) Report of the Subgroup on Statistics
    (iii) Interactions between Ecosystem Components
        (iii.i) Krill-centred Interactions
            (a) Harvested Species and the Environment
            (b) Harvested Species and Fisheries

(c) Dependent Species and the Environment
(d) Dependent Species and Harvested Species
(e) Fishery and Dependent Species Overlap
(iii.ii) Fish- and Squid-centred Interactions

7. Ecosystem Assessment

(i) Estimates of Potential Yield
(ii) Precautionary Catch Limits
(iii) Assessment of the Status of the Ecosystem
(iv) Consideration of Possible Management Measures
(v) Future Work

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

(i) Methods for Estimating Distribution, Standing Stock, Recruitment and Production of Harvested Species

(ii) Consideration of CEMP Sites
(a) Review Management Plan for the Seal Islands Site
(b) Consideration of New Requests for Site Protection

(iii) Methods for Monitoring the Performance of Dependent Species
(a) Consideration of Comments on Existing Methods
(b) Consideration of New Draft Methods for Fur Seal Diet and Demography

(iv) Methods for Monitoring Environmental Variables of Direct Importance in Ecosystem Assessment

(v) Plans for a Workshop Meeting to Consider Harvested and Dependent Species in Area 48

(vi) Plans for a Synoptic Krill Survey in Area 48

(vii) Other Activities in Support of Ecosystem Monitoring and Management

9. Advice to the Scientific Committee
(i) General Advice
(ii) Management Advice

10. Future Work

11. Other Business

12. Adoption of the Report

13. Close of the Meeting.

LIST OF PARTICIPANTS

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(San Diego, USA, 21 to 31 July 1997)

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LIST OF DOCUMENTS

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WG-EMM-97/1 Rev. 1	PROVISIONAL AGENDA AND PROVISIONAL ANNOTATED AGENDA FOR THE 1997 MEETING OF THE WORKING GROUP ON ECOSYSTEM MONITORING AND MANAGEMENT (WG-EMM)
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WG-EMM-97/4	DRAFT STANDARD METHOD FOR THE MEASUREMENT OF ANNUAL SURVIVAL RATE AND PREGNANCY RATE IN ADULT FEMALE ANTARCTIC FUR SEALS I.L. Boyd (UK)
WG-EMM-97/5	DRAFT STANDARD METHODS FOR MONITORING DIET IN ANTARCTIC FUR SEALS I.J. Staniland and K. Reid (UK)
WG-EMM-97/6	HYDROGRAPHIC CONDITIONS IN THE ELEPHANT ISLAND PLATEAU REGION DURING DECEMBER 1996 M. Stein (Germany)
WG-EMM-97/7	PREDATOR-PREY INTERACTIONS BETWEEN HIGHER PREDATORS AND FISH AND CEPHALOPODS IN THE SOUTHERN OCEAN I.L. Boyd, J.P. Croxall and P.A. Prince (UK)
WG-EMM-97/8	VARIATION IN FORAGING EFFORT BY LACTATING ANTARCTIC FUR SEALS: RESPONSE TO SIMULATED INCREASED FORAGING COSTS (*Behav. Ecol. Sociobiol.* (1997), 40: 135–144) I.L. Boyd, D.J. McCafferty and T.R. Walker (UK)
WG-EMM-97/9	FISH AND SQUID IN THE DIET OF KING PENGUIN CHICKS, *APTENODYTES PATAGONICUS*, DURING WINTER AT SUB-ANTARCTIC CROZET ISLANDS (*Marine Biology* (1996), 126: 559–570) Y. Cherel and V. Ridoux (France), P.G. Rodhouse (UK)
WG-EMM-97/10	DIET AND FEEDING ECOLOGY OF THE DIVING PETRELS *PELECANOIDES GEORGICUS* AND *P. URINATRIX* AT SOUTH GEORGIA (*Polar Biol.* (1997), 17: 17–24) K. Reid, J.P. Croxall, T.M. Edwards, H.J. Hill and P.A. Prince (UK)

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(*Can. J. Zool*. (1996), 74: 254–266)
J.P.Y. Arnould, I.L. Boyd and D.G. Socha (UK)

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(*EMU* (1997), 97: 00–00)
K. Reid, J.P. Croxall and T.M. Edwards (UK)

WG-EMM-97/13 LACTATION AND THE COST OF PUP-REARING IN ANTARCTIC FUR SEALS
(*Marine Mammal Science*, in press)
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(*Canadian Journal of Zoology*, in press)
S.J. Iverson (Canada), J.P.Y. Arnould and I.L. Boyd (UK)

WG-EMM-97/15 DIETARY SEGREGATION OF KRILL-EATING SOUTH GEORGIA SEABIRDS
(*J. Zool. Lond.* (1997), 242: 000–000)
J.P. Croxall, P.A. Prince and K. Reid (UK)

WG-EMM-97/16 DEVELOPMENT OF THE KRILL STOCK IN THE ELEPHANT ISLAND REGION DURING THE 1996/97 SEASON
V. Siegel (Germany)

WG-EMM-97/17 CONSUMPTION OF KRILL BY MINKE WHALES IN AREAS IV AND V OF THE ANTARCTIC
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WG-EMM-97/18 INTERANNUAL CHANGES IN BODY FAT CONDITION, STOMACH CONTENT MASS AND DISTRIBUTION OF MINKE WHALES IN ANTARCTIC AREAS IV AND V
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V. Loeb (USA)

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V. Loeb, D. Outram and K. Puglise (USA)

WG-EMM-97/34 REPORT OF THE SUBGROUP ON STATISTICS
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WG-EMM-97/65	HORIZONTAL FLUX OF SECONDARY PRODUCTION IN THE SOUTHERN OCEAN FOOD WEB: CURRENT VELOCITY DATA AND THE TRANSPORT OF KRILL IN THE SOUTH GEORGIA ECOSYSTEM E.J. Murphy, I.E. Everson and P.N. Trathan (UK)
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WG-EMM-97/68	HYDROGRAPHY AND CIRCULATION OF THE ANTARCTIC CONTINENTAL SHELF: 150°E EASTWARD TO THE GREENWICH MERIDIAN E.E. Hofmann and J.M. Klinck (USA)
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WG-EMM-97/70	FURTHER KRILL-PREDATOR MODEL CALCULATIONS R.B. Thomson and D.S. Butterworth (South Africa)
WG-EMM-97/71	AUSTRALIA'S CONTRIBUTION TO CEMP 1996/97: SUMMARY AND NOTES (Delegation of Australia)
WG-EMM-97/72	FISHES INCIDENTALLY CAUGHT BY JAPANESE ANTARCTIC KRILL COMMERCIAL FISHERY TO THE NORTH OF THE SOUTH SHETLAND ISLANDS IN FEBRUARY 1997 T. Iwami, M. Naganobu, T. Ichii and S. Kawaguchi (Japan)
WG-EMM-97/73	EFFECTS OF SEA-ICE EXTENT AND KRILL OR SALP DOMINANCE ON THE ANTARCTIC FOOD WEB (*Nature* (1997), 387: 897–900) V. Loeb (USA), V. Siegel (Germany), O. Holm-Hansen, R. Hewitt, W. Fraser, W. Trivelpiece and S. Trivelpiece (USA)

WG-EMM-97/74	ECHO INTEGRATION IN LOW SIGNAL TO NOISE REGIMES: METHODS OF NOISE ESTIMATION AND REMOVAL I. Higginbottom and T. Pauly (Australia)
WG-EMM-97/75	LABORATORY TARGET STRENGTH MEASUREMENTS OF FREE SWIMMING ANTARCTIC KRILL (*EUPHAUSIA SUPERBA*) T. Pauly and J.D. Penrose (Australia)
WG-EMM-97/76	WITHDRAWN
WG-EMM-97/77	SYNTHESIS OF THE ACTIVITIES CARRIED OUT AT SSSI NO. 32 AND CEMP SITE 'CAPE SHIRREFF AND SAN TELMO ISLETS' DURING THE ANTARCTIC SEASON 1996/97 D. Torres N. (Chile)
WG-EMM-97/78	SUMMARY OF MONITORING AND RESEARCH ACTIVITIES AT SVARTHAMAREN, DRONNING MAUD LAND N. Røv, S. Lorentsen and T. Tveraa (Norway)
WG-EMM-97/79	PROPOSAL FOR THE SECOND INTERNATIONAL SYMPOSIUM ON KRILL M. Mangel (USA), S. Nicol (Australia), J. Cuzin-Roudy (France), Y Endo (Japan), D. Miller (South Africa) and J. Watkins (UK)

OTHER DOCUMENTS

SC-CAMLR-XVI/BG/2	DRAFT CEMP TABLES 1 TO 3 Secretariat
WG-FSA-96/20	PRECAUTIONARY MEASURES FOR A NEW FISHERY ON *MARTIALIA HYADESI* (CEPHALOPODA, OMMASTREPHIDAE) IN THE SCOTIA SEA: AN ECOLOGICAL APPROACH (*CCAMLR Science* (1997), 4: 125–139) P.G. Rodhouse (UK)

APPENDIX D

REPORT OF THE SUBGROUP ON STATISTICS

(La Jolla, USA, 14 to 18 July 1997)

REPORT OF THE SUBGROUP ON STATISTICS
(La Jolla, USA, 14 to 18 July 1997)

INTRODUCTION

1.1 The 1997 meeting of the Subgroup on Statistics was held from 14 to 18 July 1997. The meeting was convened by Dr G. Watters (USA) and held at the Southwest Fisheries Science Center in La Jolla, USA.

1.2 A provisional agenda was introduced and discussed. It was agreed that an additional item, 'Synoptic Survey Design', be added to the agenda. The agenda (Attachment A) was adopted without further modification.

1.3 The list of participants is included as Attachment B, and the list of documents submitted to the meeting is included as Attachment C.

1.4 The report was prepared by Drs I. Boyd and J. Croxall (UK), B. Manly (New Zealand), W. de la Mare (Australia), A. Murray (UK), D. Ramm (Secretariat) and G. Watters (USA).

REVIEW OF UPDATED TIME SERIES OF CEMP INDICES

2.1 Dr Ramm introducted WG-EMM-97/25 which comprises the complete tabulation of all data submitted to CEMP (section 2), a selection of figures illustrating these data (section 3) and presentations relating to the identification of anomalies following the methods proposed by the subgroup last year (section 1).

2.2 Dr Ramm and the Secretariat were thanked for the considerable work involved in producing such a comprehensive set of documents.

2.3 In reviewing the compilation of incides the subgroup noted a small number of errors which were corrected in WG-EMM-97/25 Rev. 1.

2.4 The subgroup also made some specific comments:

(i) in the illustration of data collected under Method A1B (section 3, A1B, Figures 1 to 5) the different years should be more clearly demarcated; and,

(ii) for several of the standard methods adequate data were now available to evaluate whether the recommended sampling regimes and sample sizes are appropriate. Members with such data were encouraged to undertake evaluations and report the results to WG-EMM.

FURTHER REVIEW OF IDENTIFICATION
OF ANOMALIES IN CEMP INDICES

2.5 The subgroup recognised two particular issues with the identification of anomalies:

(i) identifying anomalies in data from non-normal distributions; and

(ii) some observations that are 'anomalies' from the biological point of view may not be statistically significant.

2.6 The paper by Drs Manly and MacKenzie (WG-EMM-Stats-97/6) was reviewed. The authors discussed the properties of a method for detecting anomalous years in CEMP indices, and extended the idea to situations where data contain a linear trend and autocorrelation, and where data are drawn from a constant distribution other than a normal distribution. In the case of non-normally distributed data, a Box-Cox transformation was applied prior to analysis. The method requires further investigation, but seems generally quite suitable for detecting single extreme values rather than, for example, a permanent change in the mean of a data series.

2.7 The paper by Dr de la Mare (WG-EMM-Stats-97/7) was also reviewed. This includes a proposal for combining CEMP variables to produce a smaller number of summary indices. It also notes that the currently used procedure for detecting anomalies lacks power when there are several extreme values, and that a permanent change in the mean and/or standard deviation in a series is better detected by calculating standardised residuals using the mean and standard deviation from a selected baseline derived from the series. From this point of view the detection of anomalies would include the following steps:

(i) define the classes of behaviour in a series to be detected (a change in the mean, a change in the variance, trend, etc.);

(ii) select a normalising transformation if necessary;

(iii) select a baseline derived from the series;

(iv) examine the statistical properties of the procedure taking into account possible serial correlation, missing values, etc.; and

(v) examine the power of the procedure to detect the phenomena of interest.

2.8 The need to take into account the uses for indices was discussed. It was noted that they are essentially meant to measure various aspects of the food available to predators, with integration over various spatial and temporal scales (Table 1). This emphasises the need to understand the relationship between indices through multivariate analyses, particularly if they are to be combined to produce summary indices of various kinds.

2.9 The use of the word 'anomalies' may be confusing because often what may need to be detected are extreme values that may be part of the natural variation in the system. To some extent these extreme values may just be the result of highly non-linear responses of the predators to environmental conditions. It is recommended that an alternative term be used such as VOGON (Value Outside the Generally Observed Norm). Here 'norm' is defined to be the conditions that are satisfactory for the predator populations.

2.10 Some illustrative calculations were carried out in order to demonstrate the potential value of multivariate analysis. For this purpose the data shown in Table 2 from Bird Island were used. A principal component analysis on the correlation matrix for the indices for the years 1990 to 1997 produced the output shown in Attachment D. It was found that the first component accounts for 53.0% of the variation in the data, while the second and third components account for 19.9% and 12.3%, respectively. Thus between them the first two components account for 72.9% of the variation, while the first three components account for 85.3% of the variation. Applying the analysis to transformed data gives very similar results.

2.11 The first component is essentially an average of the fur seal cow foraging duration (with a negative sign so that the least negative values represent good conditions), gentoo breeding success, macaroni fledging weight, the proportion of krill in the macaroni diet, the proportion of krill in the gentoo diet, the average of the last weighed fur seal pup mass for females, and the average of the last weighed fur seal mass for males. This component can be interpreted as the *overall biological state*. Component 2 mainly reflects the estimated fur seal pup growth rates for males and females, which may be biased because of high mortality in poor years. For this reason high values are not necessarily associated with good conditions. This can be named *fur seal pup growth*. Component 3 is mainly the *macaroni breeding success*. This may reflect the fact that these penguins are able to adapt their diet in poor years so that again it is not a good measure of overall biological conditions.

2.12 The subgroup considers that the results of this principal component analysis are helpful in clarifying the relationship between the various individual indices and the conditions in the different years and recommends that similar analyses are conducted for other sites and variables.

2.13 An initial exploration of the simple combination index suggested in WG-EMM-Stats-97/7 was prepared using CEMP dependent species data from fur seals and macaroni and gentoo penguins at South Georgia. The parameters selected for this illustration can be combined because they refer to similar temporal and spatial scales. The parameters included are listed in Table 2.

2.14 The simple index involves transforming and standardising the various parameters along the lines adopted by WG-EMM in 1996. Each parameter is transformed to have roughly a standard normal distribution. The parameter values are then added together and re-standardised using the estimated standard deviation for the sum using the covariance (correlation) matrix. The values are standardised also with respect to sign, for example, positive values indicating better than average conditions for the predator. For this reason, the sign of the transformed fur seal foraging trip duration was reversed. The simple index can be calculated for all years where some data exist.

2.15 The mean values and covariance matrix needed for the standardisation of the data series were calculated using the data for the period 1989 to 1997; the years when data were available for all the parameters. Prior to standardisation, the data were transformed using the currently accepted transforms for each parameter. This period has been used to provide the baseline mean and covariance matrix for the calculation of the index back to the beginning of the data series in 1977. The subgroup did not examine whether this particular period would form a suitable baseline; the results presented here are for illustrative purposes only. The resulting correlation matrix is shown in Table 3.

2.16 Figure 1 shows the simple index using all the available data. It clearly indicates the two known poor years in 1977 and 1984. The index also suggests poor years in 1987, 1988 and 1994, although the last does not appear as poor as the assessment arrived at by WG-CEMP in 1994. Because the fur seal pup growth parameters were not given a high loading in the first principal component from the principal components analysis (paragraph 2.11), the index was re-calculated without using these data. Excluding these data from the index (shown with a dashed line) results in a slight further depression of the point for 1994, but otherwise there are no changes of any substantial consequence. In light of the fact that 1994 was an extremely poor year for fur seals, the insensitivity of the index to the fur seal pup growth suggests that this parameter is not effectively indexing fur seal reproductive success. It was suggested that these parameters may require further refinement, e.g. by using growth rate of total pup biomass instead of individual pup growth rates.

2.17 Figure 2 shows the simple index calculated without fur seal pup growth rates (dashed line) compared with the simple index based on the breeding success of the two penguin species only (the only parameters represented in all years). The comparison shows that, at least in this instance, the index is not particularly sensitive to the absence of some of the parameters.

2.18 The subgroup considered that the results were encouraging and recommended that further studies should be undertaken to develop some form of combined simple indices at the appropriate regional and temporal scales. The subgroup also noted that the simple index may be more robust for identifying VOGONs than the separate parameter indices because the distribution of a sum of random variables approaches a normal distribution even when the random variables themselves are not normally distributed.

2.19 The subgroup noted previous concerns that the VOGON detection method does not always identify VOGONs when these events are known to be biologically significant (SC-CAMLR-XV, Annex 4, paragraph 4.72). The subgroup agreed that in instances where the distribution of an index (or its transformation) was not approximately normal, the 0.05 α-level might be too stringent to detect biologically significant VOGONs. It was also suggested that it may be useful to develop a procedure for identifying a VOGON in cases where a high proportion of the indices are close to, but not exceeding, their critical levels in the same year.

2.20 To provide two examples of where the 0.05 α-level could be too stringent, the subgroup estimated what α-level would be required to detect all of the biologically significant VOGONs in the Bird Island time series of gentoo penguin (Index A6a) and black-browed albatross (Index B1) breeding successes. Dr Croxall identified the biologically significant VOGONs in each time series.

2.21 For each example, the calculations were made in four steps:

- the index was transformed with the log-odds transformation;
- the least extreme, biologically significant VOGON was identified;
- a critical value (Z_C) for detecting the least extreme VOGON was calculated from

$$Z_c = \frac{\bar{x} - LEV}{s}$$

where $\bar{x}$ and s are the mean and standard deviation of the transformed index, and LEV is the value of the least extreme VOGON; and

- the α-level corresponding to Z_C was identified by simulating 1 000 20-year time series of standardised normal deviates, counting the number of instances where the absolute value of simulated deviate was $\geq Z_C$, and dividing this count by 20 000.

2.22 The results of the example calculations are provided in Table 4. An α = 0.22 would be required to detect all of the biologically significant VOGONs in the gentoo time series, and an α = 0.69 would be required for the albatross time series. An α = 0.05 would be too stringent in both cases.

2.23 Given the results of the example calculations, the subgroup agreed that the appropriate α-level for identifying VOGONs should be selected on an index-by-index basis after careful consideration of whether each index (or its transformation) is normally distributed. When the index (or its transformation) is not normal, α-levels between 0.2 and 0.3 may be appropriate.

CRITICAL EVALUATION OF THE ASSUMPTIONS AND PARAMETER VALUES OF THE AGNEW AND PHEGAN (1995) MODEL OF REALISED OVERLAP

3.1 Last year WG-EMM requested that the Subgroup on Statistics evaluate the assumptions and parameter values in the fine-scale model of the overlap between penguin foraging demands and the krill fishery in the South Shetland Islands and Antarctic Peninsula (Agnew and Phegan, 1995) (SC-CAMLR-XV, Annex 4, paragraph 6.80). This model calculates penguin foraging demand and is intended for the purposes of calculating an index of foraging–fishery overlap during the critical period December to March. Data from Subarea 48.1 on penguin foraging characteristics, energetic demands, and population numbers, and monthly krill catches by fine-scale grid are used as inputs to the model.

3.2 To assist in this process the Secretariat had requested (SC CIRC 97/2) data and analysis providing estimates of:

(i) monthly composition of diet (of penguins and fur seals);
(ii) maximum and mean/modal foraging distance;
(iii) mean foraging bearings; and
(iv) fine-scale data on foraging distributions.

3.3 Such data have been provided for gentoo and macaroni penguins and Antarctic fur seals for Bird Island South Georgia (Subarea 48.3) in WG-EMM-Stats-97/5. Data for chinstrap penguins at Seal Island had been submitted to the Secretariat for consideration by WG-EMM but were not available at the subgroup meeting. It was regretted that similar data have not yet been provided for other sites, particularly those in Subarea 48.1 where several extensive studies of diet and foraging have been carried out.

3.4 In reviewing the model the following main topics were considered:

(i) foraging distance;
(ii) foraging bearing;

(iii) predator consumption rates;
(iv) population counts; and
(v) model structure.

3.5 The model assumes that penguin foraging distances are normally distributed about a mean distance from the colonies. The values used in the model were: chinstrap penguin mean foraging distance of 20 km with a standard deviation of 8 km ~N(20,8); Adélie penguin ~N(38,15); gentoo penguin ~N(10,4); and macaroni penguin ~N(28,11). The maximum foraging distance was set to the mean + 2 standard deviations.

3.6 The model assumes that penguin foraging bearings are uniformly distributed about a line perpendicular to the coast on which the colony lies. Data on foraging bearings from colonies in Subarea 48.1 are limited to Seal Island. The values used in the model ranged generally 40° either side of a line perpendicular to the coast.

3.7 The foraging distance and bearing data used in the model were certainly appropriate for the Seal Island area. The group noted the paucity of available data to extend the model to include other regions within Subarea 48.1, and recommended that extrapolation to regions with no data should be made with caution.

3.8 The distribution of foraging distances is unlikely to be normal. *A priori* some kind of exponential distribution might be expected; available evidence from at-sea observations shows the pattern of distribution to be skewed. For foraging bearing there is no *a priori* reason, nor any observational evidence, to suggest that any assumption other than a uniform distribution is warranted. The distribution of both parameters should be re-examined in the light of new data, and literature on animal movements.

3.9 The model uses mean values for predator consumption rate which were the best estimates available from studies up to around 1984. There are quite extensive additional data on at-sea metabolic rate and energy requirements of penguins now available (see e.g. WG-EMM-96/19 and SC-CAMLR-XV, Annex 4, paragraph 6.41) which could improve the estimates used in the model.

3.10 The penguin population counts used in the model were derived from a long-term dataset on penguins counts, and were the best available in 1992. An updated dataset is now available (SC-CAMLR-XV/BG/29).

3.11 The subgroup examined the four steps involved in the model:

(i) estimating the total number of penguins from all colonies foraging within the area;
(ii) calculating the number of these expected to forage within each 10 x 10 n miles^2;
(iii) calculating the total consumption of krill by penguins; and
(iv) calculating the foraging–fishery overlap (FFO) index.

The subgroup agreed that the basic spatial modelling approach used was appropriate. However, it was not clear whether the temporal aspects of penguin foraging had been adequately captured in the model, and the subgroup agreed that this aspect should be developed further. The subgroup also found that the FFO index was not a direct measure of overlap, but rather was related to the total amount of krill removed from the foraging area during the critical period. The FFO index is the product [total krill consumption by penguins]∗[total krill catch in the fishery] with units of $(mass)^2$.

3.12 The subgroup proposed that a new standardised index be developed based on niche overlap theory (SC-CAMLR-XV, Annex 4, Appendix H), such as Schroeder's index

$$I_t = 1 - 0.5\sum\left|p_{i,t} - q_{i,t}\right|$$

where $p_{i,t}$ is the proportion of krill consumed by a predator(s) in grid square i during time period t and $q_{i,t}$ is the proportion of krill consumed by the fishery in grid square i during time period t. This type of index would range from $I_t = 0$, no spatial overlap between predator consumption and fishery consumption during period t to $I_t = 1$, complete overlap between predator consumption and fishery consumption during period t. At present, $p_{i,t}$ can be calculated along the lines of the structure in Agnew and Phegan (1995).

3.13 It was recommended that this new index should be applied first to Subarea 48.1, initially using the existing data from Seal Island. This should be undertaken by the Secretariat so that results can be presented to the meeting of the Scientific Committee in October.

3.14 The subgroup recommended that the next tasks relating to studies of realised overlap should include:

(i) examination of the sensitivity of the index I to the various assumptions made about penguin foraging effort and prey consumption;

(ii) incorporation of appropriate data on foraging effort and distribution from sites in Subarea 48.1 in addition to Seal Island. These data should be submitted as soon as possible using the forms prepared by the Secretariat (SC CIRC 97/2) as a guide but, where appropriate, providing data and analyses in ways analogous to those in WG-EMM-Stats-97/5; and

(iii) applying the model to Subarea 48.3. It was noted that the fishery currently operates there in winter providing little interaction with krill-dependent predators during the December to March critical period. Useful analyses, however, might still be made by using data from earlier years when the krill fishery operated in summer.

3.15 Future desirable developments would be to examine the overlap between penguin foraging demands and the krill fishery during other potentially critical periods. Of particular importance is the post-fledging period when large numbers of chicks begin foraging independently and adults are feeding intensively in preparation for their annual molt. Recent studies are also indicating that critical periods may exist during the winter. There are little or no empirical data for most of these periods. In terms of winter studies, the priority species for concurrent investigation of the distribution of predator foraging and the krill fishery are fur seal, macaroni penguin and chinstrap penguin.

DEVELOPMENT OF INDICES OF AT-SEA BEHAVIOUR AND METHODS OF DERIVING THEM VIA ANALYSIS OF SAMPLE DATASETS

4.1 Previous discussions of WG-EMM had identified a need for a coordinated approach to the analysis of data about the at-sea behaviour of diving predators such as penguins and fur seals. The main reason for this is to allow monitoring of the behaviour of diving predators at finer spatial and temporal scales than have been available using current CEMP indices. A further objective would be to provide input to the realised overlap index (paragraph 3.12). This will also utilise several existing datasets. Methods for measuring at-sea behaviour, and for the deployment of instruments used for measuring at-sea behaviour, have already been adopted (WG-EMM-96).

4.2 The subgroup was tasked with:

(i) reviewing appropriate temporal and spatial scales for developing indices of at-sea behaviour (SC-CAMLR-XV, Annex 4, paragraphs 3.61 to 3.65 and 7.58);

(ii) considering sample datasets and analyses (SC-CAMLR-XV, Annex 4, paragraphs 4.44 and 7.58);

(iii) developing indices and methods for the calculation via analysis of the sample datasets (SC-CAMLR-XV, paragraph 5.38(i)); and

(iv) providing advice on the most appropriate indices for inclusion in the CEMP database (SC-CAMLR-XV, Annex 4, paragraphs 4.44 and 7.58).

4.3 The subgroup examined several sample datasets from Antarctic fur seals. From a bivariate dataset involving time and depth (sampled at intervals from 5 to 15 seconds) it is possible to derive several subsidiary parameters such as dive depth, dive duration and the interval spent at the surface between dives. In turn, these can provide information about dive frequency, proportion of dives made at different times of day, and bouts of diving. Past studies have shown that these have the potential to provide information about variability in at-sea behaviour between years that reflects variation in food availability.

4.4 There is little consensus in the literature as to how comparisons of at-sea behaviour between individuals and across years should be made. As a general principle, the subgroup recommended that comparisons should be based on procedures that correctly take into account the variability in the data. In particular, attention was drawn to spectral analysis as a potentially useful approach. This would have the advantage of incorporating all of the data into a single analytical approach while minimising the need to make assumptions about how individual units of behaviour, such as dives or bouts of dives, should be defined.

4.5 A second approach, which also overcomes many of the assumptions with defining dives and bouts of dives, is to examine the cumulative time spent submerged during a foraging trip in relation to cumulative time spent at sea. The slope of this relationship could provide a single parameter that integrates most of the variability in at-sea behaviour within a single index.

4.6 Comparing at-sea behaviour across years is complicated by a potentially high degree of variability between individuals and because many of the parameters that are commonly used to measure at-sea behaviour often have highly-skewed distributions. Some may also show a degree of bimodality.

4.7 The subgroup recommended that the use of a randomisation test should be investigated to examine interannual variability in the indices. Dr Manly suggested that this could involve the following procedure:

(i) assume that the data consists of records for individual foraging trips and that these are from different animals;

(ii) for each pair of foraging trips measure the difference between them (e.g. a Kolmogorov-Smirnov measure of the difference between the index distribution). This gives a predator difference matrix for which $a(i, j)$, the element in row i and column j, is the difference for predators i and j;

(iii) generate a second matrix in which the elements are sample similarities as often recommended for the multi-response permutation procedure (Mielke et al., 1976). Thus the element $b(i, j)$ in row i and column j contains 0 from two cases in different years and $1/(n-1)$ for two cases in a year with a sample of size n;

(iv) test whether the correlation between $a(i, j)$ and $b(i, j)$ is significantly negative, by comparison with the distribution found by randomly permuting the sample labels for one of the matrices, i.e. do a Mantel (1967) matrix permutation test as described by Manly (1997); and

(v) the test can be done with any statistic measuring the difference between the behaviour of two predators.

4.8 The large size of the datasets and the need for detailed consideration of how these analytical techniques can be applied to measurements of at-sea behaviour meant that it was impractical for the subgroup to investigate these methods during the meeting. Drs Boyd and Murray agreed to undertake an example analysis to assess this method using multi-year data from Antarctic fur seals and to report the results to a future meeting of WG-EMM.

4.9 Scales of variability in at-sea behaviour may be defined most satisfactorily using spectral analysis. An example of such an analysis carried out by Dr Boyd showed several peaks in the spectrum that corresponded to the different scales of behaviour, namely, the dive, dive bouts and diel variability. Dr Murray suggested that alternatives to the assumptions of sine wave forms associated with Fourier transformations may provide an alternative spectrum with additional information. Drs Boyd and Murray also agreed to investigate this intersessionally.

4.10 The subgroup also considered the utility of including locational data from satellite tags as a variable describing at-sea behaviour. The precision of locational data is sufficient for input to the predator–fisheries realised overlap index (paragraph 3.12). However, at this stage, the precision of satellite locations is insufficient to allow assessments to be made of variability in foraging locations at the smallest spatial scales addressed by time–depth data.

4.11 The subgroup concluded that it was still too early to make firm recommendations about which indices of at-sea behaviour should be included within the CEMP database. Further consideration should be given to this subject once the various methods discussed by the subgroup had been tested.

METHODS FOR COPING WITH MISSING VALUES IN MULTIPLE DATASETS

5.1 Dr Murray presented his paper WG-EMM-Stats-97/8. The paper outlines three stages in analysis of incomplete datasets:

(i) understanding the mechanisms generating the missing values (were they random or not?);

(ii) deciding on the appropriate analysis of the data in order to support the required inferences (e.g. trend estimation, identification of unusual values); and

(iii) choosing and implementing an appropriate method of missing data imputation and subsequent data analysis.

The classes of missing value mechanisms and the broad categories of imputation methods were reviewed. For a value to be considered as 'missing at random' the probability of it being missing should be independent of the observed and missing values. Analysis of an example dataset of Chinstrap penguin colony counts from Signy Island was presented to illustrate four methods of imputation.

5.2 A method of evaluating the effect of imputing missing values on the analysis would be to take a complete dataset and try various patterns (random and non-random) and extents of data deletion. Imputed values could then be compared with the original values and analyses of completed datasets compared with the analysis of the full dataset. This would give a measure of the success of the imputation procedures. Many studies of this kind have been reported in the literature and for at least some the finding has been that, although individual values may not match the original data closely, statistics such as means may be close to the original values. For illustrative purposes, an exercise of this kind may be useful for an example CEMP dataset.

5.3 WG-EMM-Stats-97/8 drew attention to the importance of understanding the mechanisms leading to missing data and called for a discussion of these in the context of CEMP series. A number of possible reasons for missing data in CEMP indices were identified.

(i) <u>Data were not collected either because there was no intention to collect or because logistic considerations</u> such as lack of means of access or equipment failure prevented collection. Such data could be considered to be missing completely at random.

(ii) <u>Data were not collected because of adverse environmental conditions</u>, such as sea-ice preventing access to a site or bad weather making completion of field work impossible. Depending on the nature of the variable in question, such reasons might not be regarded as random. For instance, for some biological parameters such as arrival time, the presence of sea ice might have an important influence so that the same reason leading to the data being missing might also affect the value. Such data could not be regarded as missing at random.

(iii) <u>Data were not collected due to biological circumstances</u>, for example the animals in question died during the course of the season (e.g. death of chicks before fledging as occurs in some years). This seems unlikely to occur at random and may, in itself, be an important biological indicator of the ecosystem status in that year.

(iv) Data were not recorded although they are known to exceed a given threshold (e.g. where data exceed storage capacity of the recording instrument). This is called censoring and is common in observations of time duration where the event, such as return from a foraging trip, is not observed before the end of the period available for observation. The reasons might be either biological in the case of extended or incomplete foraging trips in poor seasons or non-biological in the case of equipment failure or exceeding instrument data storage capacity. The former could certainly not be regarded as random although the latter might in some circumstances be so regarded. Standard statistical methods are available for estimating parameters of distributions (such as means) where observations for some units in the sample are censored. It was felt that it would be worth reviewing the standard method for foraging trip duration of fur seals (method C1) to see whether adoption of this analysis methodology would allow more complete datasets of this index to be produced.

(v) Data were not reported where in fact they were actually null values, for example certain prey items were absent from stomach contents. Such values should be identified and replaced with zeroes in the data base.

5.4 The subgroup agreed that it was important to assess the CEMP series to determine the reasons for the missing data before proceeding to formal analysis. Such an assessment should be done as soon as possible. The originators of the data should be encouraged to supply the necessary information and it was felt that such a request could be phrased in the form of a multiple choice along the lines in paragraph 5.3.

5.5 There are two levels at which missing data may arise in the CEMP series. The first is at the level of the samples which go to make up the calculated value which is submitted; the second at the level of the calculated CEMP indices.

5.6 It is important to discover if any missing value techniques have been applied to sample data in the calculation of values which have been already submitted to CCAMLR. In certain cases, for example a colony count is missing from a set of colony counts at a site, missing value imputation could be used to calculate a site value. The subgroup recommended that where such cases can be identified the raw data should be submitted so that appropriate statistical techniques can be examined and applied.

5.7 Missing values in time series incorporated into the CEMP database should only be imputed in the course of analyses for particular purposes. The methods used should take into account the reasons for the missing data supplied by the originators of the data and the intent of the analysis. Such imputed data should not be stored in the CCAMLR database. The imputed values should not be used as if they are real data. They serve solely to allow the analysis of values which do exist and, indeed, different values may be imputed in the context of different analyses. It is important to ensure that the imputation methods which are used serve to allow the use of all observed data without adding artificial effects to the data. That is, the imputed values should be as far as possible 'neutral' in their effect on estimates of means, correlations, trends, etc.

5.8 Imputation should be as realistic as possible with consideration being given to the appropriate biological, spatial and temporal factors in deciding which data to use in multivariate imputation techniques. For example, imputation might be 'cross-sectional' based on using values for the same variable or related variable(s) at different colonies or sites in the same year, or 'longitudinal' using values from adjacent years, or a combination of both.

SYNOPTIC SURVEY DESIGN

6.1 The subgroup reiterated the view that the primary objective of the synoptic survey is to provide an estimate of krill biomass and its variability for use in the krill yield model. Other objectives (e.g. to study the spatial structure of krill aggregations) are secondary. The subgroup noted that there are two key issues with regard to the design of the synoptic survey: stratification, and random versus systematic placement of transect lines.

6.2 The subgroup agreed with WG-EMM's previous opinion (SC-CAMLR-XV, Annex 4, paragraph 3.75(v)) that the survey should be stratified according to large-scale spatial differences in krill density. The subgroup noted that there are many historical datasets (e.g. FIBEX, AMLR, LTER) that can be used to estimate how sampling effort should be allocated between strata.

6.3 The subgroup initiated the discussion on transect placement by noting that random placement should facilitate both design-based (e.g. Jolly and Hampton estimators) and model-based (e.g. geostatistics) estimates of variance in krill biomass. Systematic transect placement requires model-based variance estimation. Model-based variance estimators can be more efficient than design-based estimators, but such estimators are conditional on the adequacy of the model. A simulation study is needed to compare the relative efficiencies of random and systematic transect placement in a synoptic survey for krill. Such a study is the only quantitative way of comparing the two survey designs.

6.4 The subgroup agreed that a simulation study should receive high priority; it would be best if the work could be completed within about one year. A small panel of interested parties should be convened as soon as possible to define some realistic goals and boundaries for the simulation study. The subgroup did note that the simulation should, at a minimum, consider the following points:

(i) the cost (e.g. in ship-hours) of alternative designs (including the cost of various degrees of randomisation);

(ii) the biases introduced by the diel vertical migrations of krill; and,

(iii) the effects of the spatial coherence of the krill distributions being different in different directions.

It might also be valuable to consider whether there is a point at which the marginal utility of reducing the variance becomes small. This could be studied by considering when the results of the krill yield model become more sensitive to variability in krill recruitment rather than to uncertainty in krill biomass.

6.5 Drs Manly and Murray stated that they would be willing to develop the simulation study in collaboration with a colleague from New Zealand who specialises in geostatistics. Drs Manly and Murray also noted that they would be grateful for input from other interested parties, especially those with historical krill survey datasets. Dr de la Mare undertook, in conjunction with the Secretariat, to examine the marginal utility of reducing the variance in biomass estimates.

6.6 In the absence of a simulation study, the subgroup agreed that randomly-spaced parallel transects would be a conservative design because both design- and model-based variance estimators could be used to analyse the data.

ADVICE TO WG-EMM

7.1 The subgroup summarised its recommendations.

Agenda Item 2

7.2 The term VOGON (Value Outside the Generally Observed Norm) should be used in place of anomaly (paragraph 2.9).

7.3 Principal components analysis should be carried out for appropriate sites and indices (paragraph 2.12).

7.4 The fur seal pup growth index (C2b) may not be an effective measure of reproductive success and should be examined for further refinement (paragraph 2.16).

7.5 Further studies should be undertaken to develop combinations of CEMP indices at appropriate regional and temporal scales that may be more robust for identifying VOGONs than individual indices (paragraph 2.18).

7.6 Consideration should be given to the development of a procedure for identifying situations where a high proportion of indices give near VOGONs (paragraph 2.19).

7.7 Appropriate α-levels for identifying VOGONs should be done on an index-by-index basis, with levels higher than 0.05 being considered for non-normal data (paragraph 2.23).

Agenda Item 3

7.8 Modify the Agnew and Phegan (1995) model to improve temporal aspects (paragraph 3.11).

7.9 A new index of niche overlap, such as Schroeder's Index, should be applied to Subarea 48.1 (paragraph 3.12).

7.10 Further work on the study of realised overlap, including sensitivity analyses, incorporation of new data from Subarea 48.1, and application to Subarea 48.3 should be undertaken (paragraph 3.14).

7.11 Future developments of a realised overlap index should examine penguin–fishery interactions during other potentially critical periods (paragraph 3.15).

7.12 Additional data should be submitted so that the work outlined above can progress (paragraph 3.3).

Agenda Item 4

7.13 Methods of comparing at-sea behaviour indices between sites and across years should be developed with randomisation tests (paragraphs 4.7 and 4.8).

7.14 Indices that summarise at-sea behaviour, including the use of satellite data (paragraph 4.10), should be developed and the properties of these indices should be investigated (paragraph 4.9).

7.15 Items in paragraphs 7.13 and 7.14 need to be dealt with before a decision can be made about which indices can be incorporated into the CEMP database.

Agenda Item 5

7.16 Various missing value scenarios should be explored with a complete CEMP dataset (paragraph 5.2).

7.17 Information on the reasons for missing values in CEMP data should be collected, as soon as possible, along the lines suggested in paragraph 5.3 (paragraph 5.4).

7.18 Work should be undertaken to identify series and methods whereby missing sample data can be imputed in order to provide a value for a parameter which would otherwise be missing from the CEMP series (paragraph 5.6).

7.19 Work should be undertaken to explore the methodology for analyses of multivariate series with missing values so that such analyses can be performed in the future (paragraphs 5.7 and 5.8).

Agenda Item 6

7.20 A simulation study should be conducted to compare random versus systematic transect spacing for the synoptic krill survey, and a panel should be convened to define realistic goals and boundaries for the study (paragraph 6.4).

7.21 Work should be undertaken to use the krill yield model to examine the marginal utility of reducing uncertainty in the krill biomass estimate (paragraph 6.5).

7.22 Random transect spacing should be used in the synoptic survey if a simulation study is not completed (paragraph 6.6).

CLOSE OF THE MEETING

8.1 The report was adopted. In closing the meeting the Convener thanked the Southwest Fisheries Science Center and Dr R. Holt for hosting the meeting. The Convener also thanked all the meeting participants.

REFERENCES

Agnew, D.J. and G. Phegan. 1995. Development of a fine-scale model of land-based predator foraging demands in the Antarctic. *CCAMLR Science*, 2: 99–110.

Manly, B.F.J. 1997. *Randomisation, Bootstrap and Monte Carlo Methods in Biology*, 2nd Edition. Chapman and Hall, London.

Mantel, N. 1967. The detection of disease clustering and a generalized regression approach. *Cancer Research*, 27: 209–220.

Mielkle, P.W., K. J. Berry and E.S. Johnson. 1976. Multi-response permutation procedures for *a priori* classifications. *Communications in Statistics*, A5: 1409–1424.

Table 1: Temporal scales of integration of variables monitored for predators.

2 – 10 years	1 Year	0.5 – 2 Years	About 6 Months (winter)	1 – 6 Months (summer)
Juvenile survival	Adult survival	Population size	Adult mass at arrival	Foraging trip duration Pup growth rate Weaning/fledging mass Breeding success Diet composition Meal mass

Table 2: Data from Bird Island used for illustrative purposes for multivariate analysis and the production of summary indices. The sign of the fur seal foraging duration is given a negative sign in order that the least negative values represent good conditions.

Year	C1 Fur Seal Cow Foraging Duration * (-1)	C2b Fur Seal Pup Growth Female	C2b Fur Seal Pup Growth Male	A6a Macaroni Breeding Success	A6a Gentoo Breeding Success	A7 Macaroni Fledging Weight	A7 Gentoo Fledging Weight	A8 Macaroni Proportion Krill in Diet	A8 Gentoo Proportion Krill in Diet	Fur Seal Last Weighed Mass Female	Fur Seal Last Weighed Mass Male
1977				0.476	0.598						
1978				0.250	0.006						
1979				0.473	0.294						
1980				0.602	0.577						
1981				0.527							
1982				0.509	0.048						
1983				0.491	0.506						
1984				0.092	0.285						
1985				0.477	0.428						
1986				0.504	0.418						
1987				0.361	0.427						
1988				0.364	0.468						
1989				0.608	0.457	3450	5464				
1990	-80	1.89	2.38	0.592	0.356	3237	5800	0.998	0.594	11.24	13.07
1991	-203	2.77	3.26	0.583	0.010	3112	5043	0.694	0.191	11.48	12.73
1992	-94	2.14	2.58	0.408	0.631	3507	5791	0.988	0.499	12.84	14.81
1993	-123	2.67	3.69	0.553	0.894	3318	5482	0.833	0.845	12.45	15.02
1994	-469	2.48	2.66	0.456	0.040	2913	5065	0.112	0.129	10.66	11.89
1995	-103	2.12	3.31	0.505	0.583	3025	5239	0.536	0.544	11.21	13.92
1996	-90	2.25	2.78	0.445	0.789	3179	5502	0.999	0.243	11.84	14.31
1997	-97	2.25	2.95	0.484	0.500	3300	5960	0.986	0.362	11.93	14.95

Table 3: Correlation matrix for CEMP parameters of dependent species during the breeding season at South Georgia for the years 1989 to 1997.

Variable	Fur Seal Foraging Trip Duration	Fur Seal Pup Growth Females	Fur Seal Pup Growth Males	Macaron i Breeding Success	Gentoo Breeding Success	Macaroni Fledging Weight	Gentoo Fledging Weight	Macaroni Krill Proportion in Diet	Gentoo Krill Proportion in Diet	Fur Seal Female Pup Mass at Weaning	Fur Seal Male Pup Mass at Weaning
Fur seal foraging trip duration	1.000	0.611	0.069	0.047	0.710	0.665	0.743	0.808	0.590	0.552	0.730
Fur seal pup growth females		1.000	0.672	-0.160	0.367	0.225	0.607	0.571	0.197	-0.051	0.132
Fur seal pup growth males			1.000	-0.307	-0.139	0.109	0.389	0.451	-0.347	-0.185	-0.311
Macaroni breeding success				1.000	-0.272	-0.168	-0.166	-0.073	0.310	-0.283	-0.270
Gentoo breeding success					1.000	0.549	0.590	0.506	0.717	0.607	0.835
Macaroni fledging weight						1.000	0.784	0.630	0.546	0.919	0.766
Gentoo fledging weight							1.000	0.769	0.432	0.560	0.663
Macaroni krill proportion in diet								1.000	0.213	0.454	0.491
Gentoo krill proportion in diet									1.000	0.528	0.624
Fur seal female pup mass at weaning										1.000	0.851
Fur seal male pup mass at weaning											1.000

Table 4: Determination of α-levels that are required for detecting biologically identified VOGONs.

	Gentoo	Albatross
Years with biologically significant VOGONs	1978, 1982, 1991, 1994	1980, 1984, 1987, 1991, 1994
Years excluded from analysis – reason for exclusion	1981 – no data	1988, 1995 – adverse environmental conditions identified as main cause of breeding failure
Adjusted time series length	20 years	20 years
Year with least extreme VOGON	1982	1987
Mean of transformed index	-0.7210	-1.4650
Standard deviation of transformed index	1.8508	2.1379
Level of least extreme VOGON	-2.9874	-2.3259
Critical value required to detect least extreme VOGON	1.2245	0.4027
α-level for critical value	0.22	0.69

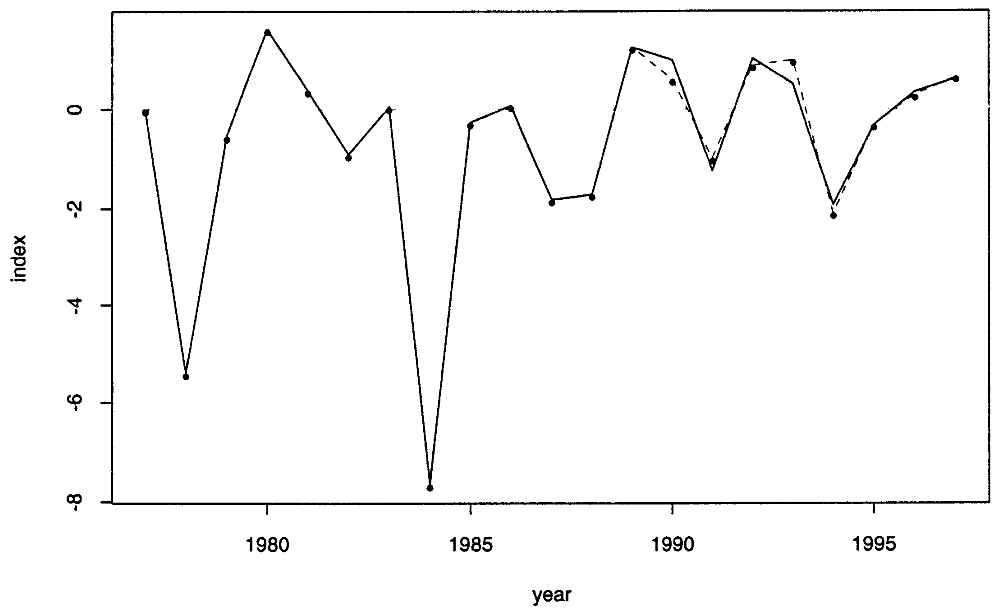

Figure 1: Illustration of the simple index for dependent species at South Georgia which combines fur seal and penguin data relevant to the breeding season. The full line is the index using all the data values, the dashed line shows the effect of deleting the fur seal pup growth data.

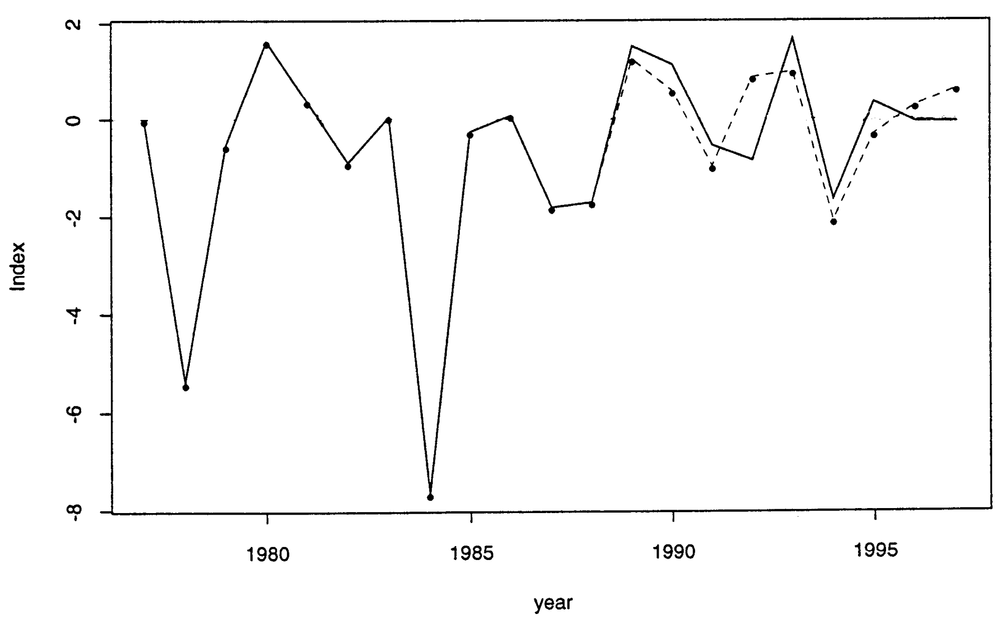

Figure 2: Illustration of the simple index for dependent species at South Georgia which combines fur seal and penguin data relevant to the breeding season. The full line is the index using only the penguin breeding success data, the dashed line shows the effect of including all the other data, apart from the fur seal pup growth data.

ATTACHMENT A

AGENDA

Subgroup on Statistics
(La Jolla, USA, 14 to 18 July 1997)

1. Introduction

   (i) Opening of the Meeting
   (ii) Organisation of the Meeting and Adoption of the Agenda

2. Further Review of Identification of Anomalies in CEMP Indices

   (i) Review updated time series of CEMP indices

   (ii) Summarise recent problems with/suggestions for identifying anomalies (various problems and suggestions can be found in SC-CAMLR-XV, Annex 4, paragraphs 4.58 to 4.61, 4.70, 4.72, 4.75 and 7.1)

   (iii) Discuss and develop methods to deal with problems/take up suggestions in identifying anomalies (SC-CAMLR-XV, paragraph 5.38(ii))

3. Critical Evaluation of the Assumptions and Parameter Values of the Agnew and Phegan (1995) Model of Realised Overlap

   (i) Review and summarise data and analyses submitted in response to SC CIRC 97/2 ('WG-EMM Subgroup on Statistics – Request for Data and Analyses')

   (ii) Evaluate assumptions and parameter values used in the Agnew and Phegan model (SC-CAMLR-XV, paragraph 5.38(iv))

   (iii) Determine whether the data submitted in response to SC CIRC 97/2 could be used to refine the Agnew and Phegan model or develop an alternative index of realised overlap

4. Development of Indices of At-sea Behaviour and Methods of Deriving them via Analysis of Sample Datasets

   (i) Review appropriate temporal and spatial scales for developing useful indices (background information on this topic is presented in SC-CAMLR-XV, Annex 4, paragraphs 3.61 to 3.65 and 7.58)

   (ii) Consider sample datasets and analyses (SC-CAMLR-XV, Annex 4, paragraphs 4.44 and 7.58)

   (iii) Develop indices and methods for their calculation via analysis of the sample datasets (SC-CAMLR-XV, paragraph 5.38(i))

(iv) Provide advice on the most appropriate indices for inclusion in the CEMP database (SC-CAMLR-XV, Annex 4, paragraphs 4.44 and 7.58)

5. Methods for Coping with Missing Values in Multiple Datasets

(i) Examine methods for interpolating missing data in matrices of time series of CEMP indices collected from a group of predator colonies (SC-CAMLR-XV, paragraph 5.38(iii) and Annex 4, paragraph 4.63)

6. Synoptic Survey Design

7. Advice to WG-EMM

8. Close of the Meeting.

ATTACHMENT B

LIST OF PARTICIPANTS

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(La Jolla, USA, 14 to 18 July 1997)

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LIST OF DOCUMENTS

Subgroup on Statistics
(La Jolla, USA, 14 to 18 July 1997)

WG-EMM-Stats-97/1	PROVISIONAL AND ANNOTATED PROVISIONAL AGENDA FOR THE 1997 MEETING OF THE WG-EMM SUBGOUP ON STATISTICS
WG-EMM-Stats-97/2	LIST OF PARTICIPANTS
WG-EMM-Stats-97/3	LIST OF DOCUMENTS
WG-EMM-Stats-97/4	DEVELOPMENT OF INDICES OF AT-SEA BEHAVIOUR I.L. Boyd (UK)
WG-EMM-Stats-97/5	DIET AND FORAGING RANGE OF PENGUINS AND FUR SEALS AT SOUTH GEORGIA J.P. Croxall, I.L. Boyd, K. Reid and P.N. Trathan (UK)
WG-EMM-Stats-97/6	TESTS FOR ANOMALOUS YEARS IN THE CCAMLR INDEX SERIES (DRAFT) B.F. Manly and D. MacKenzie (New Zealand)
WG-EMM-Stats-97/7	SOME CONSIDERATIONS FOR THE FURTHER DEVELOPMENT OF STATISTICAL SUMMARIES OF CEMP INDICES W.K. de la Mare (Australia)
WG-EMM-Stats-97/8	TREATMENT OF MISSING VALUES IN CEMP DATA SETS A. Murray (UK)

OTHER DOCUMENTS

WG-EMM-97/25	CEMP INDICES 1997: SECTIONS 1 TO 3 Secretariat

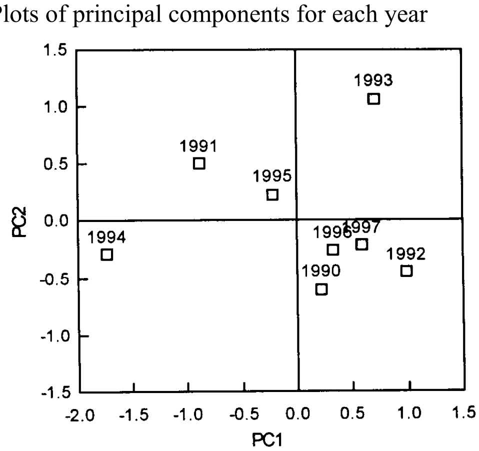
RESULTS OF A PRINCIPAL COMPONENTS ANALYSIS ON BIRD ISLAND DATA 1990–97

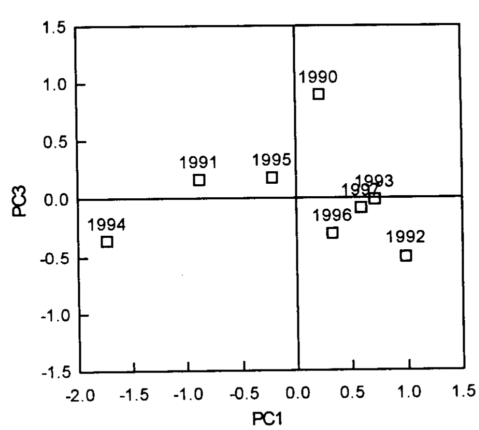
The variables are in the order shown in Table 2, with obvious abbreviations for names.

Bird Island data (all untransformed)

PCA axis	1	2	3	4	5	6	7
Eigenvalue	5.83	2.19	1.36	0.82	0.47	0.20	0.13
% of Total	53.02	19.92	12.32	7.46	4.27	1.78	1.22
Cumulative %	53.02	72.94	85.26	92.72	96.99	98.78	100.00
Eigenvectors (component loadings)							
SEALFD (C1)	0.36	0.02	0.27	-0.02	-0.49	0.26	-0.33
SEALPG-F (C2b)	-0.16	0.51	-0.28	0.45	0.03	-0.12	0.35
SEALPG-M (C2b)	0.02	0.65	-0.04	-0.13	-0.20	-0.25	-0.35
MACBS (A6a)	-0.06	0.29	0.73	0.26	0.04	-0.06	0.17
GENBS (A6a)	0.34	0.15	-0.16	-0.47	-0.13	0.13	0.65
MACFW (A7)	0.37	-0.05	-0.10	0.37	0.34	0.16	-0.17
GENFW (A7)	0.34	-0.29	0.10	0.10	0.17	-0.74	0.08
MACPK (A8)	0.36	-0.09	0.17	0.34	-0.34	0.09	0.33
GENPK (A8)	0.27	0.27	0.31	-0.36	0.61	0.13	-0.02
SEALWT-F	0.35	0.14	-0.31	0.28	0.19	0.31	-0.12
SEALW-M	0.38	0.14	-0.21	-0.12	-0.16	-0.38	-0.17
Principal component scores							
1990	0.22	-0.60	0.90	0.03	0.15	0.04	0.08
1991	-0.88	0.50	0.17	0.60	-0.19	0.10	-0.08
1992	0.99	-0.44	-0.50	0.16	0.24	0.18	-0.13
1993	0.71	1.07	-0.00	-0.09	0.26	-0.03	0.12
1994	-1.74	-0.29	-0.36	-0.14	0.26	-0.07	0.07
1995	-0.21	0.23	0.18	-0.61	-0.17	0.05	-0.19
1996	0.32	-0.25	-0.30	-0.10	-0.42	0.10	0.21
1997	0.59	-0.21	-0.08	0.16	-0.12	-0.37	-0.07

Plots of principal components for each year





APPENDIX E

EXECUTIVE SUMMARY
WORKSHOP ON INTERNATIONAL COORDINATION

(La Jolla, USA, 14 to 18 July 1997)

EXECUTIVE SUMMARY
WORKSHOP ON INTERNATIONAL COORDINATION
(La Jolla, USA, 14 to 18 July 1997)

The 1997 Workshop on International Coordination was convened by Suam Kim (Republic of Korea) at 0900 on 14 July 1997 at the Southwest Fisheries Science Center, La Jolla, USA. In attendance were Sung-Ho Kang (Republic of Korea), Hyungmoh Yih (Republic of Korea), Mikio Naganobu, So Kawaguchi (Japan), Volker Siegel (Germany), Anthony Amos, David Demer, Christopher Hewes, Roger Hewitt, Osmund Holm-Hansen and Valerie Loeb (USA). Attendees and addresses are listed in Table 1.1 of WG-EMM-97/44.

2. During the 1996/97 field season Germany, Republic of Korea and USA conducted surveys in the Elephant Island area. It was agreed during a planning session at the 1996 meeting of WG-EMM to conduct observations at a common set of stations along the 55°W meridian north and south of Elephant Island. These stations correspond to stations 60–67 on the US AMLR grid which has been occupied twice each austral summer since 1991. Table 1.2 of WG-EMM-97/44 lists the cruise dates, the dates that the common stations along 55°W were occupied, the survey areas, the types of observations conducted and the equipment used by each Member country.

3. Of particular note were the following conclusions:

(i) surface waters were extremely warm throughout the spring and summer of 1996/97 with surface temperatures exceeding 4°C in February 1997;

(ii) as the season progressed the upper mixed layer deepened, the thermocline intensified, the cold winter water layer diminished, Bransfield Strait waters warmed, and the intrusion of the Circumpolar Deep Water varied. Freshening of surface waters due to the processes of ice melting, precipitation and advection was also noted;

(iii) a dramatic change in the biomass and geographic distribution of phytoplankton was observed at the five stations north of Elephant Island through December to February time period. However, the chlorophyll-*a* (Chl) concentrations at the three stations to the south of Elephant Island did not change dramatically with time from late spring 1996 (German data), through early summer 1996 (Korean data), to late summer 1997 (USA data);

(iv) diversity of the phytoplankton species was low. Only seven species accounted for more than 84% of the total phytoplankton carbon biomass. The increased Chl and phytoplankton carbon were mainly due to the dominance of an autotrophic nanoflagellate (*Cryptomonas* spp., <10 micrometer in length);

(v) on average, 81% of the integrated Chl (0–100 m) was dominated by nanoplankton (<20 micrometer), which compares to the previous surveys;

(vi) a prolonged krill spawning season and delayed spawning peak and massive salp population bloom in 1997 followed below average sea-ice conditions in winter 1996. Low larval krill densities observed during this year suggest poor reproductive success and poor recruitment of the 1996/97 year class is to be expected;

(vii) conditions during 1996/97 contrasted strongly with 1994/95 when high larval krill densities and low salp densities occurred after above average sea-ice conditions;

(viii) dominant acoustic scattering in the Elephant Island area generally followed a band, just north of the archipelago, extending from the southwest to the northeast. This feature is coincident with both the shelf break and a persistent but variable frontal zone;

(ix) krill tended to reside in the upper 50 m, frequently near the thermocline and above water ~ 0°C; and

(x) myctophids may be associated with circumpolar deep water and their residence in the Elephant Island area may be influenced by the advance and retreat of the warm-water dome.

4. In addition the group made the following recommendations:

(i) all cooperating national research programs should standardise, or at least inter-calibrate, the methodologies used in their analyses;

(ii) closer spaced CTD casts extending to the ocean bottom are necessary to resolve the frontal boundary north of Elephant Island;

(iii) CTD stations should extend to the ice edge early in the season in order to investigate the thermohaline properties of water near the ice edge;

(iv) moored current meters and Acoustic Doppler Current Profiler (ADCP) instruments should be deployed to investigate water transport relative to krill movement along the north side of the South Shetland Islands;

(v) shipboard ADCP should be used to provide continuous data on current structure and scattering layer velocities. The use of shipboard ADCP data to evaluate geostrophic calculations of circulation patterns should be investigated;

(vi) collection of underway environmental data, including meteorological measurements, along transects between stations is encouraged;

(vii) seasonally extensive temporal sampling of microbial plankton is necessary to assess variability of food sources for krill and salps;

(viii) future phytoplankton work should incorporate increased size-fraction ranges for measurement of particles and methodologies for differentiation of phytoplankton sub-populations;

(ix) substantially greater spatial sampling effort than a single transect across the Elephant Island area is necessary in order to obtain a more representative sample of krill length/maturity stages and abundance in the Antarctic Peninsula area;

(x) seasonally extensive temporal sampling coverage is necessary to assess the timing and success of krill and salp reproduction. This information, along with winter sea-ice data, is essential for the prediction of krill year class success;

(xi) improved net sampling techniques should be used for validation of sound scatterer identification, especially regarding mesopelagic fish; and

(xii) enhanced multifrequency acoustic methods should be used for remotely identifying and delineating species of sound scatterers.

EXAMPLE FORMAT FOR ECOSYSTEM ASSESSMENT SUMMARY

Ecosystem Assessment Summary: Krill-centred System in Subareas 48.1, 48.2 and 48.3.

Component	Subarea		
	48.1	48.2	48.3
Krill			
Reported catch (tonnes)			
1991/92	78 385	123 186	101 310
1992/93	37 716	12 670	30 040
1993/94	45 085	19 259	18 648
1994/95	35 025	48 833	33 590
1995/96	62 384	2 734	36 590
Largest reported annual catch (tonnes)			
Standing stock			
Recruitment			
Status of CEMP dependent species			
Conservation measures in force			