ANNEX 4

REPORT OF THE WORKING GROUP ON ECOSYSTEM MONITORING AND MANAGEMENT

(Cambridge, UK, 18 to 29 August 2003)

CONTENTS

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INTRODUCTION

Opening of the Meeting

1.1 The ninth meeting of WG-EMM was held at Girton College, Cambridge, UK, from 18 to 29 August 2003. The meeting was convened by Dr R. Hewitt (USA).

1.2 Dr Hewitt welcomed participants and outlined the program for the meeting. This was the third meeting with a hybrid agenda consisting of plenary and subgroup sessions to discuss core topics, and a workshop (CEMP Review Workshop, Section 2).

Adoption of the Agenda and Organisation of the Meeting

1.3 The Provisional Agenda was discussed and adopted without change (Appendix A).

1.4 The list of participants is included in this report as Appendix B and the List of Documents submitted to the meeting as Appendix C.

1.5 The report was prepared by Drs A. Constable (Australia) and R. Crawford (South Africa), Prof. J. Croxall (UK), Drs I. Everson (UK), M. Goebel (USA), G. Kirkwood (UK), S. Nicol (Australia), D. Ramm (Secretariat), K. Reid (UK), V. Siegel (Germany), C. Southwell (Australia), P. Trathan (UK), W. Trivelpiece (USA) and P. Wilson (New Zealand).

CEMP REVIEW WORKSHOP

2.1 The Working Group discussed the report of the CEMP Review Workshop (WG-EMM-03/62). It endorsed its content and conclusions, subject to comments below, and agreed to include it as Appendix D of the WG-EMM report.

2.2 The Working Group thanked the Secretariat and Steering Committee for the intersessional work on data validation and analysis (Appendix D, paragraphs 130 and 132).

2.3 The Working Group noted the conclusions with regard to analyses of serial correlation and power (Appendix D, paragraph 131) that:

(i) in general, the amount of serial correlation in the biological indices was not greater than what might be expected by chance alone, but there was more serial correlation in the environmental and fisheries indices (Appendix D, paragraph 23);

(ii) it would be useful to obtain an improved understanding of the sources of variation in the CEMP indices, including spatial and temporal variability and the consequences of such variability on power to detect trends of varying magnitude, over varying lengths of time, at different numbers of monitoring sites, and under various levels of risk. An example of the type of work necessary to achieve this understanding was developed for indices on Adélie penguins (Appendix D, paragraphs 34 to 38);

(iii) extending the analysis of the sources of variation to the full suite of CEMP indices may lead to improvements in CEMP. It was recommended that such work should be conducted in the near future (Appendix D, paragraph 39).

2.4 The Working Group also noted the conclusions with regard to functional responses between indices of predator performance and measures of krill availability (Appendix D, paragraph 132) that:

(i) predator performance appears to be related to krill availability both at South Georgia and at the South Shetland Islands (WG-EMM-03/61) (Appendix D, paragraphs 46 to 48), but the form of the relationship differs between these two areas (Appendix D, paragraph 50);

(ii) at South Georgia, the relationship between predator performance and krill density was improved when multiple indices of predator performance were combined, but this was not the case for predators at the South Shetland Islands. The workshop identified a number of possible explanations for the different patterns of response by predator at these two locations (Appendix D, paragraphs 49 and 50);

(iii) differences in predator performance observed in the Mawson region of East Antarctica and at Edmonson Point in the Ross Sea during 2001 and 2003 were attributed to differences in krill biomass at Mawson and to environmental conditions at Edmonson Point (Appendix D, paragraphs 53 to 56);

(iv) the data requirements and analytical procedures required to evaluate the indices of krill availability derived from fisheries data should be defined (Appendix D, paragraphs 60 to 63);

(v) it may be possible to use the relationships between predator performance and krill availability for predicting krill availability and for developing a biological basis for the identification of years in which predator performance was anomalous (Appendix D, paragraphs 64 to 66 and Attachment 3);

(vi) the ability to relate CEMP indices (both singularly and combined) to the long-term demographics of predator populations and how these might respond to long-term trends in the krill resource are critical to future work (Appendix D, paragraph 66).

2.5 In considering the advice to WG-EMM on the terms of reference of the review of CEMP (Appendix D, paragraphs 130 to 136), the Working Group agreed that:

(i) the review is closely linked to the Working Group's workshops on the selection of appropriate predator–prey–fishery–environment models (2004) and on evaluation of management procedures, including objectives, decision rules and performance measures (2005) (Appendix D, paragraph 83);

(ii) many of the present replies to the questions posed should be viewed as interim responses based on work in progress (Appendix D, paragraph 84).

2.6 With regard to the first term of reference (Are the nature and use of the existing CEMP data still appropriate for addressing the original objectives[1]?), the Working Group agreed that:

(i) the CEMP data were appropriate for detecting and recording significant change in some critical components of the ecosystem, but further critical evaluation of the nature, magnitude and statistical significance of changes indicated by the data were necessary (Appendix D, paragraph 85);

(ii) it remains important to determine how representative the CEMP sites are of their local areas and regions (Appendix D, paragraph 86).

2.7 In particular, the Working Group noted the advice that:

(i) at current harvesting levels it was unlikely that the existing design of CEMP, with the data available to it, would be sufficient to distinguish between ecosystem changes due to harvesting of commercial species and changes due to environmental variability, whether physical or biological (Appendix D, paragraph 87);

(ii) with the existing design of CEMP, it may never be possible to distinguish between these different and potentially confounding causal factors and that the Scientific Committee should seek advice from the Commission on the extent to which further work should be directed towards this topic (Appendix D, paragraph 87);

(iii) without a real ability to separate the confounding effects of harvesting and environmental variation and in the context of uncertainty, the Scientific Committee should seek advice from the Commission about the policy of how management should proceed when a significant change was detected, but no single causal factor could be attributed (Appendix D, paragraph 88);

(iv) one possible method that may assist in the separation of confounding effects of harvesting and environmental variation would be the establishment of an experimental fishing regime whereby fishing would be concentrated in local areas in conjunction with an appropriate predator monitoring program (Appendix D, paragraphs 89 and 90).

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[1] The original objectives of CEMP (SC-CAMLR-IV, paragraph 7.2) were to:
(i) detect and record significant changes in critical components of the ecosystem to serve as a basis for the conservation of Antarctic marine living resources;
(ii) distinguish between changes due to the harvesting of commercial species and changes due to environmental variability, both physical and biological.

2.8 The Working Group noted that the CEMP review had summarised many examples of effects on predator populations, especially of breeding performance, that related principally (whether directly or indirectly) to environmental effects. These included the acute effects of years of exceptional ice cover, periodic effects ascribed to oceanographic influences, such as ENSO, and long-term changes that may reflect regional shifts in marine processes, potentially linked to climate change phenomena (Appendix D, paragraph 106; WG-EMM-03/53 and 03/59).

2.9 With regard to the second term of reference (Do these objectives remain appropriate and/or sufficient?), the Working Group agreed that the original objectives of CEMP remained appropriate, but that a third objective 'To develop management advice from CEMP and related data' should be added (Appendix D, paragraph 95).

2.10 With regard to the third term of reference (Are additional data available which should be incorporated in CEMP or be used in conjunction with CEMP data?), the Working Group agreed that:

(i) many time series of non-CEMP data contain information of considerable value in addressing the objectives of CEMP;

(ii) the Secretariat should maintain a register of the wide range of non-CEMP time-series data that were of use to this workshop and of potential utility to future workshops in support of the work of WG-EMM, including datasets derived from South African and French seabird and pinniped monitoring programs in the southern Indian Ocean (Appendix D, paragraphs 96 and 108; see also Appendix D, Table 9).

2.11 In particular:

(i) useful indices of krill availability to land-based krill predators could be derived from fishery-dependent data (Appendix D, paragraphs 91 and 92);

(ii) indices derived from mackerel icefish data may be of value in monitoring krill in certain regions; these indices should be subjected to the same analyses undertaken for CEMP data (Appendix D, paragraphs 98 to 100);

(iii) holders of other relevant time-series data are encouraged to undertake or collaborate in appropriate analyses (see Appendix D, paragraphs 31 to 42, 46 to 49, 64 to 66, 100 and 108) and report the results to the Working Group.

2.12 In addition, the Working Group agreed that indices derived from pellets regurgitated by Antarctic shags may be of value in monitoring the early life-history stages of coastal fish species, including several of commercial importance. It was recommended that WG-FSA consider how such indices may be useful to its stock assessment and management procedures (Appendix D, paragraphs 101 and 102).

2.13 With regard to the fourth term of reference (Can useful management advice be derived from CEMP?), the Working Group noted that good progress was being made with several promising modelling initiatives, particularly those relating to, or derived from, CSIs and functional relationships (Appendix D, paragraphs 109 and 110).

2.14 It particularly noted that the WG-EMM workshop next year on Plausible Ecosystem Models for Testing Approaches to Krill Management would be considering a variety of relevant approaches (Appendix D, paragraph 136), including:

(i) behavioural models based on interactions between the aspects of the environment, krill, krill predators and a krill fishery (Appendix D, paragraphs 111 to 115);

(ii) further work on functional responses linking predators to their prey field (Appendix D, paragraphs 116 to 119);

(iii) development of simulation studies to improve ability to detect anomalies (Appendix D, paragraphs 119 to 121 and Attachment 3);

(iv) further consideration of 'burden of proof' issues (Appendix D, paragraphs 122 and 123).

2.15 The Working Group noted the advice that, in respect of relationships between ISRs and SSMUs, it would be unlikely that the extensive monitoring and research programs developed within ISRs would be necessary for SSMUs (Appendix D, paragraph 127). It welcomed the provision of a summary of the nature of existing CEMP monitoring within each SSMU (Appendix D, paragraphs 128 and 129 and Table 8).

2.16 The Working Group endorsed the program of intersessional work concerning the development of aspects of the CEMP review (Appendix D, paragraph 138 and Table 9).

2.17 The Working Group requested that the report of the CEMP Review Workshop should include:

(i) a footnote to Table 8 to indicate the location of the source data, specifying the parameters monitored at each site (WG-EMM-03/24, Table 4);

(ii) in Figure 1, the location of all sites from where CEMP data are available (i.e. by adding Verner Island, Magnetic Island, Shirley Island, Svarthamaren and Bouvetoya);

(iii) in the legend to Figure 3, the units of krill density (g m^{-2}).

2.18 Dr Siegel noted that in the original Figure 4 (see also paragraph 57) of the CEMP Review Workshop report, the statistic 'proportion of krill in the diet' appeared to include data for *Euphausia* species other than *Euphausia superba* (e.g. for Subarea 58.7). At the Working Group's request, Figure 4 was subsequently revised and confined to data for *E. superba*.

2.19 The Working Group thanked the Co-conveners, Steering Committee and all workshop participants for ensuring such positive and constructive outcomes for the first phase of the review of CEMP.

Key Points for Consideration by the Scientific Committee

2.20 The Working Group advised the Scientific Committee of the outcome of the first phase of the CEMP review (paragraphs 2.1 to 2.18 and Appendix D). A plan of intersessional work (Appendix D, Table 9) had been developed to address some important tasks, particularly including:

(i) completion of the review of sources and magnitudes of variability in predator response parameters;

(ii) investigation of the utility of indices derived from haul-by-haul CPUE data as a proxy for direct measures of krill availability;

(iii) investigation of alternative methods for determining anomalies and predicting krill abundance using predator response curves.

STATUS AND TRENDS IN THE KRILL FISHERY

Fishing Activity

2001/02 Season

3.1 The provisional total krill catch in 2001/02 (125 987 tonnes) was 20% higher than the catch reported in 2000/01 (104 182 tonnes) (WG-EMM-03/28). The catch in 2001/02 was the highest catch since 1994/95 (135 686 tonnes). Available fine-scale data (10 x 10 n miles) for the 2001/02 season accounted for approximately 70% of the provisional total catch, and these data indicated that fishing in 2001/02 occurred mainly in Subareas 48.2 (64% of catch reported in fine-scale data) and 48.3 (24%). Relatively little fishing occurred in Subarea 48.1 (12%).

3.2 All Member countries fishing submitted monthly catch and effort reports for Area 48 as a whole, or in each of the subareas separately. Three Member countries (Poland, Ukraine and the USA) of the five Members that fished during the season have submitted complete sets of fine-scale data. One other Member (Japan) submitted data for the period December 2001 to June 2002 by the deadline (April 2003, Conservation Measure 23-03), and fine-scale data for the remaining period (July–November 2002) on 29 July 2003.

3.3 Two Member countries submitted STATLANT data covering the whole of the 2001/02 season, while three other Members submitted data for the year ending June 2002. 'Missing' STATLANT data for the period July–November 2003 were reconstructed using monthly catch and effort reports; this is a temporary solution to obtain a provisional total catch for the fishery.

3.4 Some Members experienced difficulties in submitting data in line with the new CCAMLR season, but efforts are being made by Members to overcome such problems and realign data submission with the deadline adopted in Conservation Measure 23-03. The total catch of krill reported in Area 48 from the three sources of data is:

- monthly reports – 122 778 tonnes
- fine-scale data – 86 348 tonnes
- STATLANT data – 125 987 tonnes (provisional).

2002/03 Season

3.5 Krill fishing has occurred only in Area 48 in 2002/03, with 74 053 tonnes of krill taken between December 2002 and June 2003. Eight trawlers have fished so far this season, and these are flagged to five Member countries: Japan (3 vessels), Republic of Korea (1 vessel), Poland (1 vessel), Ukraine (2 vessels) and the USA (1 vessel). Catch reported to date is similar to that reported at approximately the same time last year (WG-EMM-02/6), indicating that the current fishing season is following a pattern similar to that reported for the fishery in 2001/02.

Indications for 2003/04

3.6 The Working Group was informed that Japan intended to fish at approximately the same level in the forthcoming season as in the 2002/03 season with two vessels catching about 60 000 tonnes of krill. The US operation is also likely to maintain its current level of activity, although it may introduce a second vessel. No further information was available from other fishing nations.

3.7 The Working Group recalled that at its last meeting it indicated to the Scientific Committee the difficulty it had in understanding the trends in the krill fishery (SC-CAMLR-XXI, Annex 4, paragraphs 2.44 and 2.70) and it noted that representatives from only two of the fishing nations had attended the 2003 meeting of WG-EMM. Consequently, information available to the Working Group on future fishery plans was incomplete, and anecdotal, and was not sufficient to make any assessment of developments in the krill fishery.

3.8 The Scientific Committee was advised that if WG-EMM was expected to assess the status and trends in the krill fishery, then it needed annual submission of information on the detailed fishing plans of all Member nations which would include at a minimum: the number of vessels, the locations of planned fisheries and the expected catch levels.

Catch in SSMUs

3.9 WG-EMM-03/28 provided the first indications of catches in the newly defined SSMUs. The catch of krill in each SSMU over the past 10 fishing seasons indicates major shifts in fishing operations within and between SSMUs. Notably, fishing in the 2001/02 season targeted krill in the South Orkney West SSMU (SOW, Subarea 48.2) and South Georgia East SSMU (SGE, Subarea 48.3), with relatively little fishing reported to date in the Antarctic Peninsula SSMUs (Subareas 48.1 and 48.5). Over the past 10 years, the SOW SSMU has been fished intensely in the seasons 1994/95, 1998/99 and 2001/02. In South

Georgia, fishing has taken place mostly in the SGE SSMU in the seasons 1993/94 to 1997/98, 2000/01 and 2001/02. In the Antarctic Peninsula, catches of krill have been taken mostly in the Drake Passage SSMUs (APDPE and APDPW).

3.10 The Working Group agreed that examination of the krill catch by SSMU was a valuable exercise and that such analyses should continue in future because they would provide information regarding fishery behaviour and potential overlap with foraging land-based predators.

CPUE Analyses

3.11 Between 1977 and 1991 a number of different measures of CPUE were employed in the Soviet krill fishery: catch per fishing day (CFD), catch per extended fishing day (CEFD) and catch per hour (CH) (WG-EMM-03/35). The primary data for all the calculations were catch per haul and haul duration. CEFD represented the catch per day of fishing plus days with no actual catch due to stormy weather or because of the absence of appropriate krill aggregations. This parameter was introduced to evaluate the presence and availability of krill aggregations on the fishing grounds, and the weather conditions, but CEFD also included days spent waiting for fuel, delays because of catch overloading and other economic reasons, so it was difficult to use in fishery forecasting.

3.12 There was a good correlation between mean monthly values of CFD and CEFD, and CFD and CH. Correlation between daily values was poor, due to high fluctuations in haul duration caused by differing fishing strategies. Fishing strategies depended on whether the vessel was producing krill products for human consumption, krill meal or frozen krill. When different strategies were taken into account the mean daily CFD and CH are better correlated. Catch per hour has a different meaning when applied to short hauls and to longer hauls. Catches per hour in short single-swarm oriented krill hauls characterise krill single-swarm density, and in long hauls this parameter characterised krill abundance at a subarea level.

3.13 Depending on the fishing strategy, between 1 and 15 hauls were conducted per day and these ranged in duration from 0.1 to 16 hours; shorter hauls were utilised for higher final product quality, and shorter haul durations resulted in a larger number of hauls per day. Krill fishing vessels could be divided in three groups by their capacity for krill processing: those that could process up to 100–150 tonnes of raw krill per day, those that could process between 70 and 100 tonnes of raw krill per day and those that could only process 40–70 tonnes of raw krill per day.

3.14 The Working Group recognised that WG-EMM-03/35 provided valuable information on the utility of haul-by-haul data from the fishery, but also that it indicated the requirement for operational information from the fishery for the interpretation of CPUE indices and for the standardisation of fisheries-derived measures.

3.15 The Working Group reiterated its need for haul-by-haul data for its scientific work. Aggregated CPUE data lose considerable information and the assessment of the utility of aggregated CPUE for examining trends in krill distribution abundance becomes compromised unless the data are presented in haul-by-haul form over a number of years. Once such a dataset is available, it would then be possible to make an assessment of whether aggregated data could be used subsequently.

3.16 In addition to the need for haul-by-haul data, the Working Group stressed that there was a requirement for consistency in the reporting of CPUE data by fishing vessels from different nations. In line with the recommendations of SC-CAMLR's CPUE workshop in 1989 (SC-CAMLR-VIII, Annex 4) reporting of CPUE should include an assessment of search time as well as catch per tow. The Working Group also recommended that standardised methods such as GLMs be applied for the analysis of these data, and noted that such analyses would not be possible on aggregated data in the format currently submitted under Conservation Measure 23-06.

3.17 A subgroup was formed during the CEMP Review Workshop to evaluate fisheries-derived CEMP indices with respect to functional relationships of krill-dependent species with the following terms of reference:

(i) to define analytical procedures
(ii) to define the data required
(iii) to specify protocols on submission, curation and use of the data.

3.18 The subgroup was asked to submit its recommendations to WG-EMM under Agenda Item 3.2 (Appendix D, paragraph 63).

3.19 The task of assessing CPUE was divided into a number of categories and the subgroup addressed each of these issues:

Analytical procedures:

(i) determine sensitivity and power-analysis approaches required for the data validation;

(ii) identify covariates in GLM for assessing CPUE data (WG-FSA-03/40, paragraphs 2.18 to 2.21).

Data requirements:

(iii) define areas and seasons for which data are required, based on the existence of predator response data;

(iv) define scale of data required to conduct analytical procedures.

Submission protocols:

(v) timetable and delivery of outputs;
(vi) CCAMLR rules of data access.

3.20 The subgroup recognised that the statistical validation of fisheries-derived indices and the examination of the utility of these indices as proxies for krill availability to predators was a two-stage process. The first part of this process, the validation of the indices, defined the nature of the data required. The second part, evaluating the functional relationships, was based on the existence of CEMP time series of the performance of krill-dependent species, and these would define the spatial and temporal extent of the data required.

3.21 The subgroup also recognised that an important component of this work was to evaluate the relationship between the existing fisheries-derived CEMP parameter (H1) and CEMP-derived predator performance indices. This would require analyses of the relationships between the various fisheries-derived indices from the different fishing fleets. The subgroup recommended that the focus of the analysis should be in Area 48 as there were time series of predator performance from each of the three subareas where krill fishing has consistently occurred; Table 1 provides the location and duration of time series of these CEMP predator parameters for which complementary fisheries-derived indices would be desirable.

3.22 The subgroup recommended that the analysis of the sensitivity and power to detect trends in indices of krill fisheries performance (CPUE), as well as the evaluation of functional responses of dependent species to those indices, should follow the procedures and recommendations arising from the CEMP Review Workshop. In order to facilitate this validation process the following data are required for the analysis of CPUE data: vessel name, experience of the fishing master, vessel type, fishing location, fishing gear, date, time, catch per haul, haul duration and product type; this information should be provided on a haul-by-haul basis. It was recognised that not all these data would be available from all fishing operators in all areas and years.

3.23 The subgroup agreed that haul-by-haul data were necessary for this task and these would allow an assessment of the extent of data aggregation that might be appropriate for the future work of the subgroup. These data were required for the specified task and would be used in accordance with CCAMLR's rules of data access.

3.24 Dr M. Naganobu (Japan) recognised the scientific importance of the use of these data and indicated that the provision of haul-by-haul data from the Japanese fishery would require domestic consultation before the temporary submission of these data for the specified tasks.

3.25 The subgroup recommended that Dr S. Kawaguchi (Australia) should be an appropriate expert to carry out these analyses in cooperation with appropriate data holders and scientists, and he would be approached to conduct these analyses in the intersessional period and provide the results to the 2004 meeting of WG-EMM.

3.26 The Scientific Committee had indicated that haul-by-haul data will also be needed for the subdivision of the krill catch limits amongst SSMUs and the Working Group agreed that this is a further scientific justification for the collection and submission of krill fisheries data on the smallest scale possible.

Description of the Fishery

Fishery Economics

3.27 A recent search of the Internet by the Secretariat failed to locate relevant recent information regarding the market prices of krill. In 2002, WG-EMM asked the Secretariat to contact ICES for information about the number of vessels from North Atlantic fisheries that might potentially enter the krill fishery (SC-CAMLR-XXI, Annex 4, paragraph 2.50). The ICES Secretariat was contacted and agreed to forward WG-EMM's request for information to ICES members; no information had been forthcoming by the start of the meeting.

3.28 Also last year, WG-EMM asked the Secretariat to contact FAO for information on the demand for krill for aquaculture feeds and information on other krill fisheries (SC-CAMLR-XXI, Annex 4, paragraph 2.72). FAO was contacted and provided a copy of an FAO report entitled 'Use of fishmeal and fish oil in aquafeeds: further thoughts on the fishmeal trap' (Fisheries Circular No. 975, 2002).

3.29 The FAO circular reported that: 'The hope for increased fishmeal and oil supplies lies in the use of species that hitherto have not been used for fishmeal production. The two main sources are mesopelagic species and krill. Both species have been caught and used to produce high protein meals. The problem to date is a techno-economic one: with present fishing technologies, the harvesting, preservation and processing costs are in excess of those that fishmeal producers are prepared to pay' (WG-EMM-03/28).

3.30 The FAO circular further emphasised the importance of krill as an aquaculture feed: 'Krill is potentially an excellent nutrient source for feeding farmed fish and crustaceans. Besides providing protein, energy and palatability, it is also a source of essential amino acids, fatty acids and other nutrients. In addition, it has the potential to enhance the pigmentation of aquaculture products, thus increasing their visual quality'. Dr Nicol informed the Working Group that regulatory developments in the European Community will reduce the levels of permitted artificial colouration in farmed fish, and in the USA which will require labelling of artificially coloured farmed fish. These developments are likely to increase demand for krill which is a good source of natural red pigmentation.

3.31 The Working Group noted that some of the information in the FAO circular contained inaccuracies or misstatements (WG-EMM-03/28). These included the potential level of harvest of krill as well as the current level of harvesting. The FAO circular also contained no references to up-to-date publications on the krill fishery or the work of CCAMLR. The Secretariat was requested to contact FAO to address these points and report the outcome to the Scientific Committee and to the 2004 meeting of WG-EMM.

3.32 The Working Group recognised that there was information available on commercial websites that indicated that krill products were available from sources other than those for which CCAMLR regularly receives reports. The Secretariat was requested to contact companies listed on the Fish Information Service website (and any other websites where such information may be found) which were offering krill products for sale. Should any of these companies prove to be actively engaged in krill fisheries in the Convention Area, the countries where they are based should be informed that fishing for krill should be conducted in accordance with CCAMLR's conservation measures and that these included reporting requirements. The Scientific Committee should be informed of the results of these investigations.

Fishing Strategies

3.33 Acoustic assessments of krill density on the grounds fished by Soviet trawlers in Subareas 48.1, 48.2, 48.3 and 48.4 show that in the mid-1980s the fishery was conducted in areas where the mean krill density was greater than 100–110 g m^{-2} (WG-EMM-03/31). These acoustic observations correspond to estimated trawl density derived from haul-by-haul data from Soviet trawlers in 1987–1990, and Ukrainian vessels in 2001 and 2002. For these fisheries, a density of 100 g m^{-2} appears to be a threshold value of krill density for fishing operations and this value may apply to current fleet operations as well.

3.34 The Working Group recognised that this paper produced valuable information on the threshold density for krill fisheries and this information might be used to provide indicative maps of where krill fisheries might be expected to develop. Similar analyses of analogous datasets from the historical and current fisheries of other Members were requested and the Working Group acknowledged that this would require the standardisation of such analyses using the finest-scale fisheries information (haul-by-haul data).

Estimation of Krill Density from Commercial Trawls

3.35 WG-EMM-03/21 provided analyses from a combination of experimental and modelling approaches to examine the escapement of krill from trawls. Several factors affected krill escapement. Krill of different sizes escaped from different parts of the net and the degree of escapement probably is related to the design of the net and the behaviour of krill, so a simple assessment was not possible. The catchability of krill trawls appeared to be a stable characteristic for a particular trawl design regardless of the fishing area, but it also varied according to the time of day, swarm parameters and trawling conditions.

3.36 The differential catchability of krill caused by mechanical and behavioural factors affected estimates of krill density derived from simple calculations utilising merely the volume of water filtered. A mathematical model of catchability which takes into account the differences in effectiveness of the various parts of the net, as well as the biological characteristics of the krill, was developed. This provided an improved method for estimating krill density from commercial catches.

Questionnaire on Krill Fishing Strategies

3.37 Two Members submitted completed questionnaires: Poland 51 questionnaires and the USA 13 questionnaires. Most of these data were reported at WG-EMM-02, and all data (64 for 2001/02 and 4 for 2000/01) have been entered into a Secretariat database. No completed questionnaires on krill fishing strategies have been submitted to date for 2002/03.

Regulatory Issues

Scheme of International Scientific Observation

3.38 Five sets of scientific observer data were submitted for the 2001/02 season, collected by CCAMLR international scientific observers on board vessels from Japan, Ukraine and the USA. Currently, the CCAMLR database holds data collected by designated CCAMLR scientific observers from eight krill fishing voyages.

3.39 Several changes to the *Scientific Observers Manual* and electronic logbook (e-logbook) forms were recommended by WG-EMM-02 (SC-CAMLR-XXI, Annex 4, paragraph 2.62). These were related to observations on board krill fishing vessels.

3.40 An intersessional subgroup chaired by Dr Kawaguchi considered these recommendations and drafted the amendments required (WG-EMM-03/55) as follows:

Scientific Observer Manual –

(i) addition to existing guidelines for sampling of larvae fish by-catch in krill catches to include a section on sampling of fish larger than 7 cm;

(ii) data collection priorities and requirements for the collection of finfish by-catch (including larvae fish) and krill biological data;

e-logbook forms –

(i) revised form K4 'Krill Biological Data Collection' and K6 'Conversion Factors', with instructions;

(ii) new form K5b 'Finfish larvae by-catch' with instructions.

3.41 A task group comprising Drs J. Watkins (UK), V. Sushin (Russia), Hewitt and E. Sabourenkov (Secretariat) was established during the WG-EMM meeting to consider the amendments proposed. The task group recommended that WG-EMM approve the amendments proposed and forward them to WG-FSA for information/comments, and to the Scientific Committee for approval. It was agreed by WG-EMM.

3.42 In respect to the proposed addition of a new section to the manual with data collection priorities and sampling requirements for the collection of finfish by-catch in krill biological data, WG-EMM agreed that these should be incorporated into existing sections of the manual which already contain information on the same subject.

3.43 In respect to revision of the colour chart for krill feeding observations (SC-CAMLR-XXI, Annex 4, paragraph 2.62), WG-EMM noted that this had been postponed by the subgroup until 2004.

3.44 The task group also considered a number of general matters related to the production and use of the *Scientific Observers Manual* and e-logbooks. It advised WG-EMM that:

(i) e-logbooks have proved to be an indispensable tool for the collection and submission of data and their subsequent download to the Secretariat's database;

(ii) existing e-logbooks should be translated into all official languages of CCAMLR;

(iii) the use of e-logbooks should become standard for all scientific observations on board fishing vessels;

(iv) publication of printable versions of observer logbooks should be continued in order to provide backup means for recording and reporting data;

(v) the e-logbook for observations on board krill fishing vessels as prepared by the Secretariat and amended at this meeting, should be adopted as a standard and its printable version be included in the *Scientific Observers Manual*.

3.45 WG-EMM agreed with this advice and forwarded it for further consultation with and approval by WG-FSA and the Scientific Committee. In doing so, WG-EMM noted that translation of krill e-logbooks in other languages would need to be done during 2004, preferably by February–March, and that it would have financial implications for the Secretariat.

Krill Fishery Plan

3.46 The Working Group noted that the Secretariat had updated the plan for the krill fishery (WG-EMM-03/28).

Key Points for Consideration by the Scientific Committee

3.47 The Working Group recalled that at its last meeting it indicated to the Scientific Committee the difficulty that it had in understanding the trends in the krill fishery (SC-CAMLR-XXI, Annex 4, paragraphs 2.44 and 2.70) and it noted that representatives from only two of the fishing nations had attended the 2003 meeting of WG-EMM. Consequently, information available to the Working Group on future fisheries plans was incomplete, and anecdotal, and was not sufficient to make any assessment of developments in the krill fishery (paragraph 3.7).

3.48 The Scientific Committee was advised that if WG-EMM was expected to assess the status and trends in the krill fishery, then it needed annual submission of information on the detailed fishing plans of all Member nations which would include: the number of vessels, the locations of planned fisheries and the expected catch levels (paragraph 3.8).

3.49 The Working Group tasked Dr Kawaguchi with evaluating fisheries-derived CEMP indices with respect to functional relationships of krill-dependent species. This would require the temporary submission of time series of haul-by-haul data from the krill fisheries (paragraphs 3.17 to 3.26).

3.50 The Working Group requested analyses of historical and current fisheries datasets to determine threshold densities for krill fishery operations (paragraph 3.34).

3.51 The Working Group recommended that e-logbooks for scientific observation on board fishing vessels be translated into all official languages of CCAMLR (paragraph 3.45). This was referred to WG-FSA and the Scientific Committee for further consideration and would require allocation of appropriate funds.

STATUS AND TRENDS IN THE KRILL-CENTRIC ECOSYSTEM

Status of Predators, Krill Resource and Environmental Influences

CEMP Indices

4.1 Dr Ramm presented the annual report of trends and anomalies in CEMP indices (WG-EMM-03/24) provided by the Secretariat. The report included a summary of intersessional progress in data validation, a new measure of fishery overlap, and preparatory work for the CEMP Review Workshop.

4.2 The Fishing to Predation Index (FPI) defined by Everson (2002) was introduced as Index H3d. FPI is the ratio of the amount of krill taken by commercial fishing compared to the amount of krill required by predators. An increase in FPI indicates that fishing is taking a larger proportion of the available krill and consequently fishing is more likely to be having an impact on the dependent species.

4.3 Index H3a (standardised realised overlap based on the Agnew–Phegan model) was discontinued as a CEMP index following the recommendation of WG-EMM (SC-CAMLR-XXI, Annex 4, paragraph 3.40).

4.4 The Working Group recommended that the Secretariat investigate the feasibility of calculating overlap indices for each of the SSMUs and also recognised that there would be a need to review the utility of the different overlap indices again, including for purposes relevant to the management of SSMUs.

4.5 WG-EMM-03/24 suggested that in the context of 2003 there was little evidence of large-scale deviation from the long-term mean for most indices, however, there was evidence that indices of the performance of predators at Cape Shirreff were abnormally low (e.g. WG-EMM-03/54) and that unusual ice conditions in the Ross Sea continue to negatively impact on penguins in that region (Appendix D, paragraphs 54 and 132(iii); WG-EMM-03/59).

4.6 With regard to anomalies for 2003, it was noted that in the list of indices, which showed a positive anomaly for 2003, four (A5a Adélie penguin foraging trip duration at Béchervaise Island, C1 fur seal foraging trip duration at Cape Shirreff, Livingston Island, C2b fur seal pup growth rate at Cape Shirreff and A2 Adélie penguin incubation shift at Edmonson Point) should have been listed as negative anomalies. It was subsequently discovered that the 'trend correction' (see 'sign' in Table 2, WG-EMM-03/24) had not been applied to the anomalies, resulting in a misinterpretation of negative and positive anomalies in the indices for which a correction of –1 applies, including foraging trip duration and incubation shift.

4.7 A recommendation was made that data originators be asked to review the annual report of CEMP indices and anomalies, in order to identify any such transformation errors, some time prior to the compilation and submission of future reports to WG-EMM.

4.8 With regard to Index C2b, fur seal pup growth rate, a recommendation to use pup growth deviates based on Reid (2002) instead of growth rate was made. In the case of Cape Shirreff C2b 2003, if growth deviates were used instead of growth rates this index would be recorded as having a negative instead of a positive anomaly. It was recommended that further discussion of this topic be undertaken by the Subgroup on Methods.

4.9 Dr Kirkwood cautioned against undue emphasis on anomalies and the summing of anomalies to assign years to a qualitative category such as 'good' or 'bad' without due regard to the biological and statistical nature of these anomalies.

4.10 The Working Group recognised the need to provide an improved annual assessment of anomalies and trends of CEMP indices and tasked a subgroup on representation of CEMP indices (comprising Drs B. Bergström (Sweden), Goebel, Ramm, Reid and G. Watters (USA)). The terms of reference for the subgroup were to:

- examine the utility of the current approach to presenting anomalies in individual indices to provide assessment of the status of the ecosystem;

- define a process for the presentation and interpretation of CEMP indices to produce a status-of-the-ecosystem index each year with respect to long-term means/trends;

- define species as well as spatial and temporal framework in which to produce combined indices and to evaluate the use of CSIs in providing syntheses of CEMP indices.

4.11 Notwithstanding issues of the sign and magnitude of individual indices and the nature of the anomalies reported in WG-EMM-03/24, the subgroup considered that the current approach to presenting a balance of positive and negative anomalies was inappropriate and of limited utility to the future work of WG-EMM.

4.12 The subgroup recommended that a distinction be made between the types of indices used in any approach such that indices with different properties (including the level of serial autocorrelation) were not compared directly. The combination of both predator-derived and physical indices from several areas of the CCAMLR Convention Area meant that only a very subjective interpretation of the state of the ecosystem was possible.

4.13 An approach which described the 'state' of the ecosystem relative to other years was recognised to be more desirable as it would have the potential to identify temporary shifts in the state of the ecosystem (i.e. anomalies), gradual changes (i.e. trends) or regime shifts. In particular, the subgroup recommended an approach that utilised all of the available data rather than being restricted to the presentation of statistical anomalies.

4.14 The subgroup proposed that an ordination approach be developed whereby the nature of the covariation in multivariate CEMP indices could be described and presented on an annual basis. This approach would serve to change from an emphasis of describing a year as 'good' or 'bad' to one in which the status of each year might be categorised with respect to other years in the time series.

4.15 Dr Watters provided a presentation to the Working Group of such an ordination approach using a hypothetical example of the results of an ordination approach where a time series of data is plotted for predator performance, physical indices (i.e. environmental conditions) and fishery performance (Figure 1). This example described the status of the current year and trends in indices, where the first two ordination axes described variability in indices that reflect 'winter' and 'summer' processes and these axes are used to describe a time series of predator performance indices (Figure 2). The subgroup suggested that this approach could be applied independently for each ISR.

4.16 In addition, there should be an emphasis on highlighting 'genuine' anomalies, e.g. the iceberg situation in the Ross Sea (Appendix D, paragraphs 54 and 132(iii)), rather than statistical anomalies that would be expected to occur by chance in each year.

4.17 There was recognition by the Working Group that the inclusion of non-CEMP time series (e.g. krill density estimates) may be important in this approach.

4.18 The Working Group thanked members of the subgroup for their efforts and endorsed the ordination approach to examining CEMP indices over a time frame that would allow the Secretariat to present the results to the next meeting of WG-EMM. However they recognised that this would be a process that might evolve over a longer time frame.

Krill

4.19 The Working Group considered documents describing results on biomass estimates from krill acoustic surveys in the Scotia Sea and the South Shetland Islands (WG-EMM-03/6, 03/30 and 03/31) and on krill demography from a net sampling survey around South Georgia (WG-EMM-03/40).

4.20 WG-EMM-03/6 analysed annual data from an 11-year time series of single- and multi-frequency acoustic surveys in the Elephant Island area conducted by the US AMLR Program. The reanalyses of the surveys improved accuracy by (i) characterising and deleting system noise, (ii) compensating for diel vertical migration, and (iii) employing a multi-frequency technique for delineating volume backscattering (S_v) due to krill.

4.21 Estimates of mean krill biomass density from the first and second surveys of each year (January and March) are generally not significantly different. Application of a filter using a dB difference between 38 and 120 kHz (where 4 < dB difference < 16) captured most aggregations of krill, but also included some identified as myctophids and smaller zooplankton. Application of a second filter using a difference between 120 and 200 KHz (where –4 < dB difference < 2) eliminated the non-krill targets while retaining most of the krill aggregations.

4.22 Estimated biomass density ranged from 1 to 60 g m^{-2}. From a mid-range level in 1992, biomass density decreased to a minimum in 1994, increased to a peak in 1998 and decreased again thereafter. The paper suggested that changes in density are consistent with changes in reproductive success. A truncated Fourier series fit to the acoustic estimates led to the conclusion that the majority of the variance was explained by three- and eight-year cycles. The model also predicted an increase in krill biomass density in 2003 and 2004, which is supported by the cycles in sea-ice extent and recruitment.

4.23 WG-EMM-03/31 examined former USSR and Russian acoustic survey data and compared the biomass density estimates with results obtained from commercial net samples from the fishing areas used by the former USSR, Russia and Ukraine in the Scotia Sea. The results indicated that vessels fishing where krill biomass was at least 100 to 120 g m^{-2} achieved a sustainable yield of 3 to 3.5 tonnes per hour. Below this threshold level vessels left the fishing grounds. The authors concluded that this commercially viable threshold level exceeded a critical minimum level of predator demand (24 g m^{-2} (Boyd, 2001)) and therefore the fishing fleet and dependent predators should have different density niches to exploit.

4.24 WG-EMM-03/30 gave results of an acoustic survey in the South Georgia area in February–March 2002. Survey transects were located within the 500 m isobath. Mean survey density was 45 g m^{-2}. Almost 50% of the survey area showed a biomass density of less than 6.9 g m^{-2}. Over 70% of the biomass was concentrated in the areas to the northeast and northwest of the island. In some locations near-bottom aggregations exceeded 100 g m^{-2}. Using a research vessel to fish for these aggregations with a commercial-sized midwater trawl yielded up to 1 tonne per half-hour trawling. Potential fishing locations were mapped using a threshold level of 100 g m^{-2}. Mean biomass density in these locations was 849 g m^{-2}.

4.25 The paper concluded that the biomass density in the western area was too low for a sustainable fishery, but in this area the krill density exceeded the critical minimum level of predator demand for krill-dependent predators. Thus the observed density was considered to meet the needs of predators feeding in this area during the critical period.

4.26 However, the Working Group could not agree with the conclusion of WG-EMM-03/31 that there is no overlap between predators and the fishery simply due to different threshold levels in their minimum density demand. Predators will certainly exploit krill concentrations above 100 g m^{-2} and therefore compete with a potential fishery operation.

4.27 The Working Group also felt it premature to agree in principal with the conclusion of WG-EMM-03/30 that the spatial segregation between predators and the fishery to the west of South Georgia is a commonly observed phenomenon. It was noted that predators concentrate in the western area during the breeding season, but at other times of the year the overlap with current fishing areas may be more important.

4.28 The Working Group welcomed the estimation of threshold levels for commercial operations as an important step forward in predicting where potential fishing could occur. Further work was encouraged firstly to compare the distribution of actual fishing with that predicted from distribution of threshold levels, and secondly, to compare predicted krill fishing areas in relation to distribution of predator demand in the area. The Working Group encouraged all Members with relevant data to undertake such analyses for all subareas of Area 48. When undertaking such comparisons the Working Group stressed that the temporal and spatial scales used for predator and fishery density estimates should be comparable.

4.29 WG-EMM-03/40 described the distribution of krill size classes north of South Georgia during summer 1988. Small krill (mode 33 mm) dominated the area 7 to 40 n miles offshore, while larger krill (mode 49 mm) occurred beyond this zone. An intermediate zone from 30 to 60 n miles offshore contained a mixture of small and large krill and this zone was considered to be the boundary between Weddell and ACC water masses.

4.30 The small-sized krill component contained two different spatially separated cohorts (means 32 and 35 mm). It was suggested that the larger cohort experienced a longer retention time in the area and thus a more prolonged growth period. During a second survey period in the same year the difference between these two cohorts increased to 6 mm.

4.31 The authors hypothesise that the ACC and Weddell current systems carry krill with different origin and different length frequencies into the area north of South Georgia. The currents may form quasi-stationary eddies which aggregate krill and increase retention times. These aggregations are then appropriate targets for the krill fishery.

4.32 Dr Watkins noted that UK surveys in the South Georgia region in other years usually showed an east–west split in size classes with large krill occurring at the western end. A marked onshore–offshore size distribution as seen in WG-EMM-03/40 had not been seen in other years.

4.33 Dr Reid explained that a similar pattern of bimodal size compositions of krill in January being replaced by a unimodal distribution in March has regularly been observed in predator diet samples from South Georgia, however, such changes did not appear to be associated with changes in the on-shelf/off-shelf foraging distribution.

4.34 The Working Group noted that although spatial variability in krill size composition around South Georgia may represent krill from different sources, ascribing the origin of these krill based on their size composition was not straightforward.

4.35 The Working Group noted more generally that there are a number of datasets describing aspects of krill demography and distribution that have not yet been presented to the Working Group. Members were encouraged to identify such datasets and submit synopses or analyses. It was recognised that compilation of such datasets into time series could provide valuable information on temporal and spatial variation in krill demography.

4.36 The Working Group recognised that it was particularly important to develop hypotheses on origin and transport of krill for use in management of krill. An understanding of the relative contribution of flux and local retention of krill within different regions may be very important for allocating precautionary catch limits to SSMUs. Similarly an understanding of the different origins of krill has implications for the use of the GYM, which currently assumes a single krill population.

Predator Trends

4.37 WG-EMM-03/29 compared data on stomach contents and food masses from approximately 1 200 Adélie, gentoo and chinstrap penguins breeding at Admiralty Bay, South Shetland Islands, during the chick-rearing period between the years 1981 and 2000. Krill accounted for 93–99% of all prey for each species by frequency of occurrence and by mass. There were significant differences in food-load masses within species among years, but a high degree of coherence among the three species as to the years of high versus low food loads. The paper noted significant differences in the percentage of digested contents in the stomach loads among the three species and found that the digested portion of individual stomach loads increased annually over the chick-rearing period in all species. The paper hypothesised that the digested food mass may represent approximately twice the energy value of a comparable mass of fresh krill in the same penguin's stomach. It further discussed the implications of this hypothesis to studies of penguin energetics, and suggested that estimates of energy requirements derived from using the double-labelled water technique may be biased by the absorption of dietary water from krill in the penguin's gut.

4.38 The Working Group noted that the digested portion of food loads in penguin stomachs would likely influence future estimates of predator consumption rates, particularly for Adélie and chinstrap penguins, which typically have approximately 50% of their stomach contents in a digested state. Further discussion established that the percentage of digested contents in penguins' stomachs did not vary between years with shorter versus longer foraging trips, but remained very consistent across years. This suggested that the digested contents were not a function of time spent at sea foraging, but rather species-specific adaptations to delivering energy to their respective chicks.

4.39 WG-EMM-03/37 recorded the foraging trip patterns and diving behaviour of chinstrap penguins breeding at Signy Island during January 2002. Foraging trip patterns were bimodal, with short diurnal trips of 7.8 hours constituting the majority (74%) of all trips and longer overnight trips averaging 19.9 hours the remainder. Diving depths of chinstrap penguins in this study were deeper than previously reported at this site in earlier years and deeper than dives reported elsewhere in the literature for this species. The paper reported a new pattern of dives typically associated with benthic foraging in marine animals, yet analysis of stomach contents from birds exhibiting this dive pattern showed that they fed almost exclusively on Antarctic krill. The results highlighted the potential importance of benthic feeding on Antarctic krill, a previously undescribed foraging strategy, thus providing new insights into predator–prey interactions within the Antarctic marine ecosystem.

4.40 The Working Group suggested that a benthic inshore distribution of krill could represent a potentially important source of error in krill biomass estimation in some regions. Further investigations into krill distributions in these habitats are required to determine the potential importance of these habitats to krill biomass estimates and predator–prey interactions.

4.41 WG-EMM-03/38 examined the at-sea distribution and critical foraging habitat of female Antarctic fur seals breeding at South Georgia. Breeding season foraging trips were largely constrained to within 100 km of the island and tended to be concentrated in similar areas at the Continental Shelf edge. Although bathymetry was suggested as the proximate cause explaining the observed foraging distributions, interannual variation in the characteristics and distribution of water masses, and differences in prey availability within these water masses, was suggested to be the ultimate cause explaining the fur seal foraging patterns. Energetic calculations of food demand by female fur seals during the breeding season suggested that they can potentially consume most of the krill present in some regions where they are foraging intensively. During winter, when female fur seals are no longer constrained by pup rearing, they disperse over a wide area, but are concentrated in two regions of known high productivity. Animals were tracked northwest to the Patagonian Continental Shelf, and south to the Antarctic pack-ice edge. It was suggested that these two different wintering areas may represent habitat preferences of individuals, but further studies are needed to test this hypothesis.

4.42 The Working Group noted that a proportion of the female Antarctic fur seal population spent the winter in the vicinity of the Patagonian Shelf, outside the CCAMLR Convention Area. It recollected that the pattern of widely dispersed wintering areas of individuals from the same breeding colony was also reported last year for Adélie and chinstrap penguins breeding in the South Shetland Islands (WG-EMM-02/55).

4.43 WG-EMM-03/39 measured heart rate, abdominal temperature and diving depth in female macaroni penguins during the 1998/99 breeding season at South Georgia. Analysis of these variables allowed estimation of the mass-specific rate of oxygen consumption while diving. In common with other diving birds, macaroni penguins exhibited significant changes in heart rate during dives and 95% of all dives recorded were within the calculated aerobic dive limit (cADL) for this species. This suggested that factors other than physiological ones are most important in determining diving behaviour. Such factors might include progressive effects of multiple dives during bouts and the location and density of krill patches on which animals feed. Thus, the ability to locate prey patches may be more important to the foraging behaviour of macaroni and other penguins than their ability to repeatedly dive to the depth of their prey.

4.44 The Working Group noted the potential utility of heart rate measures as a method for estimating metabolic rates and calculating aerobic dive limits (ADL) in penguins. It was further noted that estimates of ADL derived in the paper were in close agreement with earlier published data on Adélie penguins using O_2 consumption methods (Culik, 1994). This supported the suggestion that ADL rates derived from the doubly-labelled water method may contain important biases (WG-EMM-03/29).

4.45 WG-EMM-03/44 described interannual differences in Adélie penguin predator indices from Béchervaise Island during two seasons (2001 and 2003) of different krill abundance. Acoustic surveys from research cruises undertaken during the penguin breeding season reported approximately three times (see paragraph 4.46) as much krill within the survey region in 2001 compared to that found in 2003. Adélie penguins foraged farther from their breeding colony and had significantly longer mean foraging trips in 2003. In addition, adults returned with smaller food loads and had significantly more fish (mostly *Pleuragramma antarcticum*) in their diets in 2003. Breeding success was also significantly lower in 2003. The authors suggested that CEMP Indices A5 (foraging trip duration) and A8 (meal mass), respond significantly to interannual variations in krill biomass when measurements are at similar spatio–temporal scales.

4.46 Dr Nicol informed the Working Group that the krill biomass calculations for the 2003 season indicated a 20-fold decrease in the krill biomass estimate for the 2003 season, compared to the 2001 season (rather than the three-fold difference estimated in the paper). He also confirmed that the survey area was a 100 x 100 km grid (10 000 km^2, not 100 km^2 as stated in the paper).

4.47 WG-EMM-03/54 examined performance indices for Antarctic fur seals breeding at two sites in the South Shetland Islands. A total of five indices were derived from the two CEMP standard methods (C1 and C2b) currently reported as part of CEMP. An additional 10 measures of predator performance were summarised and data were presented in Table 2 of the paper. Pup growth rate (C2b) was recalculated for the 1997/98 to 2001/02 seasons at Cape Shirreff, to facilitate comparisons among sites. The 2002/03 season was characterised as one of poor reproductive performance for fur seals at Cape Shirreff; with longer foraging trips, lower frequency of krill in the diet, above-average pup mortality, and decreased female survival and natality. The Working Group noted that the paper offers substantial new information on possible future CEMP predator parameters that could be developed into standard methods for fur seal monitoring in the future.

4.48 WG-EMM-03/58 reported low concentrations of polychlorinated biphenyls (PCBs), hexachlorobenzene (HCB) and dichloro-diphenyl-trichloroethane (DDT) in the stomach contents of Adélie penguins breeding at Edmonson Point in the Ross Sea. Higher concentrations of these persistent organic pollutants (POPs) were found in stomachs with higher krill contents. The authors suggested that despite the low overall concentration of POPs in the samples, penguins should be periodically monitored since there is no information about toxicity threshold levels for penguins. This is particularly important as contaminant input through the diet is considerable. In addition, the authors pointed out that this method is non-invasive and samples can easily be collected as part of routine diet studies under CEMP Standard Method A8. The authors recommended updating the protocol for collecting samples for toxicological analysis (*CEMP Standard Methods*, Part IV, Section 5, paragraphs 1 to 3) in order to provide additional information for collecting samples utilising these new techniques.

4.49 The Working Group endorsed the suggestion that the toxicological methods be updated to add the new techniques outlined here and suggested that the new methods from WG-EMM-03/57 on blood and tissue sampling be included in the update. It was noted that the methodology was developed primarily to provide guidance in how to collect and preserve samples in response to acute events or outbreaks at study sites such that causal factors related to these events might be assessed subsequently.

4.50 WG-EMM-03/59 examined CEMP Standard Methods A2 (incubation shift durations), A6 (breeding success) and A9 (chronology) during the 2001 and 2003 seasons at Edmonson Point in the Ross Sea. The 2003 season was characterised by unusually heavy and persistent sea-ice throughout the breeding season and strong southerly winds with heavy snowfall in December. In that year foraging trips during the incubation period were significantly longer, breeding was delayed and breeding success was reduced due to heavy ice and snow. The authors attributed these results to a combination of environmental factors operating over the 2003 season; they highlighted the importance of collecting environmental data concurrent with predator data when monitoring for CEMP.

4.51 The Working Group noted that concurrent data on prey abundance was not available for this region in either year of the study, so this could not be assessed. The authors also indicated that data on foraging trip durations were available, but were as yet unanalysed.

Environmental Trends

Long-term Physical Data of Potential Use in Ecosystem Analyses

4.52 WG-EMM-03/20 reported that VNIRO continues to monitor sea-surface temperature in Subarea 48.3 (around South Georgia). The monthly SST maps (with resolution of 1° latitude by 1° longitude) have been constructed from GOES-E and Meteosat-7 daily satellite data that have incorporated real-time data from ships and buoys.

4.53 WG-EMM-03/46 reported on recent work to update the DPOI described by Naganobu et al. (1999). The index is now available from January 1952 to May 2003 and describes sea-level pressure differences across the Drake Passage between Rio Gallegos (51°32'S 69°17'W), Argentina and Base Esperanza (63°24'S 56°59'W), at the tip of the Antarctic Peninsula.

Ecosystem Analyses involving Long-term Physical Data

4.54 The authors of WG-EMM-03/53 highlighted the fact that the physical environment in the Southern Ocean is changing and that these recent changes have been most apparent during the later part of the 20th century. The authors particularly focused on the increasing air temperatures at various Southern Ocean locations and the increasing water temperatures in the ACC.

4.55 The authors related concurrent changes in the southern Indian Ocean populations of a number of high-trophic-level predators, including seals, penguins and flying seabirds, to the changes in the physical environment. They noted that warming influences from outside the area, particularly from the tropical Indian Ocean, may have contributed to these changes. The authors suggested that the increasing temperatures are related to profound functional changes in the southern Indian Ocean ecosystem, including impacts on primary and secondary production and impacts on the food resources used by the high-trophic-level predator populations.

4.56 The authors noted that for some species, the observed population changes have occurred with a time lag when compared with changes in temperature. The period of the time lag varied between sites for some species (e.g. wandering albatross) although generally time lags occurred over similar time scales. Of the species considered, only two have increased whilst most others have decreased. Based on this evidence, the authors suggested that a regime shift has occurred in the southern Indian Ocean ecosystem.

4.57 This paper highlighted two important issues for CCAMLR, that:

(i) responses to climate change are likely to be regional and will probably be site specific and depend on local productivity and foraging conditions;

(ii) for some species, interactions with fisheries may confound or complicate signals potentially ascribed to environmental change.

4.58 The Working Group recalled that there had been a complementary discussion in the CEMP Review Workshop (Appendix D, paragraphs 104 to 106) with respect to changes in the physical environment in the Indian Ocean and that there had been a number of papers presented to this Working Group in the past that indicated similar processes occurring in the Scotia Sea.

4.59 Given the number of indications of environmental change in the CCAMLR Convention Area, the Working Group considered that it may be appropriate to produce a coherent overview of environmentally induced variability in the Southern Ocean and consider potential change scenarios that might influence ecological relationships with implications for fisheries management.

Status and Trends of Seabirds and Seals in the Southwest Indian Ocean

4.60 Long-term population trends of land-breeding seals and seabirds were reported for several localities in the southern Indian Ocean. For particular species there was often consistency in trends across localities (WG-EMM-03/53). Several different trends were evident. For most species there was a decrease in numbers, sometimes followed by a recovery. However, a few species increased during the period of observation, notably king penguins at the Kerguelen, Crozet and possibly Prince Edward Islands, and sub-Antarctic fur seals at Amsterdam and the Prince Edward Islands (WG-EMM-03/53 and 03/18). These are species that feed mainly on myctophids in this region (WG-EMM-03/53). Antarctic fur seals have increased at Prince Edward Island (WG-EMM-03/18).

4.61 Most studied species, for which myctophids are not the primary diet component, decreased (WG-EMM-03/53). Amongst populations that showed a decrease and subsequent partial recovery were wandering albatrosses at the Kerguelen and Crozet Islands (WG-EMM-03/53) and Marion Island (WG-EMM-03/11), grey-headed albatrosses, northern giant petrels, southern giant petrels and white-chinned petrels at Marion Island (Nel et al., 2002), Adélie penguins at Syowa (WG-EMM-03/53) and black-browed albatrosses at Campbell Island, south of New Zealand in the western Pacific Ocean (WG-EMM-03/53). For the albatrosses and petrels at Marion Island, the trends corresponded with trends in pelagic longline fishing effort of tunas in the southern Indian Ocean and are thought to be related to mortality of birds in this fishery (Nel et al., 2002).

4.62 Female wandering albatrosses forage farther from Marion Island than males, come more often into contact with the pelagic longline fishery for tuna and have a lower survival rate (93% versus 96% per annum). Following mate loss, males take longer to replace a mate than females. The survival of adult wandering albatrosses at Marion Island is significantly related to that at the Crozet Islands (WG-EMM-03/11). At Marion Island, the proportion of mature wandering albatrosses that breed is positively related to the ENSO index. Following a decrease from the mid-1980s to the mid-1990s, breeding success has stabilised at Marion Island, possibly as a result of supplementary food being provided by discards and offal from the demersal longline fishery for toothfish there (WG-EMM-03/11). The trend in wandering albatrosses at Marion Island lagged behind those at the Kerguelen and Crozet Islands by about four years, similar to the later warming at Marion Island, suggesting some environmental modulation. As the trends in wandering albatross populations at all these localities followed the warming by several years, environment was thought to have influenced breeding or recruitment rather than survival (WG-EMM-03/53).

4.63 Several populations of birds that forage over wide areas have decreased with no apparent sign of recovery. These include both species of sooty albatross at Marion Island in the 1990s, possibly attributable to mortality in longline fisheries (WG-EMM-03/8), and yellow-nosed albatrosses at Amsterdam Island since the mid-1980s. Avian cholera played an important part in the latter through mortality of adults and especially chicks. It is also suspected to have caused mortality of Amsterdam albatrosses and sooty albatrosses at Amsterdam Island (WG-EMM-03/32).

4.64 Amongst seabirds that forage nearer to breeding colonies that have decreased, with no sign of recovery, are rockhopper penguins at Amsterdam Island (WG-EMM-03/53) and gentoo, rockhopper and macaroni penguins and Crozet shags at Marion Island (WG-EMM-03/16, 03/10, 03/15 and 03/17). At Marion Island, the decreases are most clear for species that feed near the island and are all thought to be at least partly attributable to inadequate reproduction. This is likely to have resulted from an altered availability of food, which (although there are no estimates of prey abundance) is suggested by a decrease in colony size of shags, a changed dominance in nototheniid prey in the diet of shags, a low mass at fledging of rockhopper penguins and a relationship between mass at fledging and contribution of fish to the diet of macaroni penguins.

4.65 At Marion Island, there have also been decreases in populations of two larids (sub-Antarctic skuas and kelp gulls), possibly associated with decreases in penguin populations (WG-EMM-03/8).

4.66 The climate in the southern Indian Ocean warmed between the mid-1960s and the mid-1980s. Because warming near Marion Island was later than at localities farther east, this may have resulted from intrusion of Indian Ocean water (WG-EMM-03/53). At Marion Island, mean surface air temperature increased by 1.2°C between 1969 and 1999 and annual precipitation decreased between the mid-1960s and the mid-1990s (Smith, 2002). SST increased by about 1.4°C between 1949 and 1998, compared with an increase of about 0.5°C at Gough Island (Melice et al., in press).

4.67 In 1997/98, coincident with the large El Niño of that period, there was unusually good or poor breeding by nine species of surface-nesting seabirds at Marion Island. Conditions favoured offshore feeders, whereas inshore feeders were generally adversely affected (WG-EMM-03/13). As has been suggested previously (e.g. Croxall, 1992), more widespread monitoring may elucidate how climatic perturbations influence seabirds and seals in the Southern Ocean. Climatic warming may increase the possibility of outbreaks of disease at subtropical and sub-Antarctic localities (WG-EMM-03/19 and 03/32).

4.68 For wandering albatrosses there is interchange of fledglings between the Crozet and Prince Edward Island breeding localities, indicating an advantage of considering management of these two sites at a metapopulation level (WG-EMM-03/41). Countering the adverse effects of climate change is likely to pose the greatest challenge to conservation of seabirds at the Prince Edward Islands (WG-EMM-03/14).

4.69 There was discussion on the increase of fur seals at several localities. It was noted that populations had increased both in areas where their main prey is krill and also in areas where myctophids and other zooplankton are their principal food. Rates and timing of fur seal population increase have been different in different areas and the South Georgia population may already have overshot pre-exploitation levels. There was also potential for interaction between fur seals and seabird species, e.g. through predation, displacement of breeding birds and competition for resources.

4.70 In respect of the data discussed in paragraph 4.66, it was noted that there was useful information not only in annual indices of temperature increases but in seasonal indices too, as had been reported for the Antarctic Peninsula.

4.71 Dr Constable indicated that a major biological survey of Heard Island would be undertaken in 2003/04, the results of which would be reported at the next meeting.

4.72 The Working Group agreed that information from the southern Indian Ocean had re-emphasised the importance for some seabirds of incidental mortality in fisheries, the periodic occurrence of extreme food shortage, the dynamic nature of Southern Ocean systems and the utility of comparing responses of predators in krill-based and non-krill systems (see also Appendix D, paragraphs 103 to 108).

Further Approaches to Ecosystem Assessment and Management

4.73 WG-EMM-03/33 and 03/34 presented behavioural models of the interactions between krill and their penguin predators and the effects of a krill fishery. WG-EMM-03/33 modelled habitat selection by krill, controlled by their diel vertical migration, and the foraging strategies of penguins, identifying stable strategies that maximised expected fitness. This model was then extended in WG-EMM-03/34 to investigate the effect of a krill fishery on this system. Increased fishing pressure offshore is predicted to decrease penguin food intake and thereby decrease their survival and reproduction. Incorporation of krill behavioural responses in the model leads to the effects of the krill fishery being stronger than would be expected simply from the absolute biomass removed by the fishery. Poorer environmental conditions are predicted to increase the effect of krill fishing on penguin success. It is also suggested that changes in penguin foraging behaviour can be used to assess the effect of local fishing on penguin reproductive success.

4.74 The Working Group recollected that these papers are the latest in a series of papers by these authors stemming from initiatives started in 1996 and 1997 to develop detailed models of the interactions between krill, land-based predators and the krill fishery (SC-CAMLR-XIV, Annex 4, paragraphs 7.23 and 7.24; SC-CAMLR-XV, Annex 4, paragraphs 6.47 to 6.55). It agreed that models described in the current papers represented a considerable refinement of those discussed in recent years (Alonzo and Mangel, 2001; Butterworth and Thomson, 1995; Butterworth et al., 1994, 1997; Mangel and Switzer, 1998; Switzer and Mangel, 1996).

4.75 WG-EMM-03/33 and 03/34 had been reviewed and discussed by the CEMP Review Workshop (Appendix D, paragraphs 111 to 115). In addition to the comments recorded there, the following points were made.

(i) Dr Sushin indicated that, while these papers were theoretically interesting, he felt they were currently unsuitable for practical use in management, because the structure and the assumptions of the models were unrealistic.

(ii) While the assumption that penguins species on which the model is based are obligate krill feeders during their reproductive period in the areas considered, this is not true of all penguin species in all areas, some of which may switch to alternative prey species when krill are sparse. In consequence, some modifications to the models may be necessary if they are to be fully applicable to all penguins at all times of year.

(iii) Given the better knowledge of penguin foraging behaviour now available, it may well be possible to identify the elements of foraging trip duration that are most relevant to prey capture success. In this case, the final suggestion in WG-EMM-03/34 that changes in penguin foraging behaviour might be used to assess the effect of local fishing on penguin reproductive success could well be currently practicable. If so, an examination by the Subgroup on Methods may be warranted.

4.76 The Working Group endorsed the conclusions of the workshop (Appendix D, paragraph 115) that individuals with relevant expertise should consider the formulation, assumption and parameterisation of these models carefully, with a view to the likely incorporation of such approaches into the WG-EMM workshop activities planned for 2004 and 2005.

Other Prey Species

Review of Tabled Papers

Mackerel Icefish

4.77 The mackerel icefish has a widespread distribution in the Atlantic and Indian Ocean sectors of the low-Antarctic region. It has been fished commercially since the 1970s and is currently fished around South Georgia (Subarea 48.3) and Heard Island (Division 58.5.2). In the Atlantic Ocean sector krill is a major prey item. Other prey species are taken in the Indian Ocean sector. Information provided to CCAMLR has been summarised into a 'Species Profile' as WG-FSA-03/4 and a list of published papers is set out in WG-FSA-03/5. These papers provide background information that will be updated annually by WG-FSA, from which ecosystem monitoring and management advice on mackerel icefish can be developed. WG-EMM-03/4, 03/7, 03/42 and 03/60 provided new information on biology and ecology of relevance in an ecosystem context.

4.78 Mackerel icefish are found over quite a wide geographical range within the CCAMLR Convention Area and are subject to subtle differences in their habitat. In WG-EMM-03/4, biological information is evaluated from which the following generalised latitudinal cline was developed. Fish living in the north:

- mature one year earlier than those in the south
- have a shorter life span relative to those further south
- possibly do not spawn more than two to three times
- produce more eggs per unit of body mass than those further south.

4.79 WG-EMM-03/4 noted that increases in fur seals in recent decades have probably increased predation pressure on mackerel icefish and may have a major effect reducing stock abundance.

4.80 Two papers, WG-EMM-03/7 and 03/60 considered age and growth of mackerel icefish in Subarea 48.3 using information from a number of seasons. Both papers demonstrated differences in growth rate that appear to be related to variation in the availability of krill, the preferred food of mackerel icefish in that region, as well as variation in environmental conditions such as temperature. WG-EMM-03/60 noted that the strong 1983/84 year class occurred at a time when fishing intensity was high. It noted that the one-year-old fish tend to be pelagic and are undersampled by the bottom trawls of research surveys and the wider mesh nets of the commercial fleets. The presence of strong year classes consequently does not become apparent until they are recruited to the commercial stock. They can be estimated using acoustics and this would provide valuable information for management of the stocks and also for ecosystem assessment.

4.81 Differences in size at age have also been noted in WG-EMM-03/7, with mean size at age being negatively correlated with sea-surface temperature from the preceding summer. It is suggested that this may be due to a change in the range of sea-surface temperatures over the South Georgia Shelf, whereby winters have become slightly cooler and summers slightly warmer over the period from 1960 to 1990. In addition to this trend, it was noted that there are consistent differences in recruitment and mortality rates and the time of hatching at Shag Rocks in comparison with South Georgia. It is suggested that a combination of signals in krill, fish and other krill predators indicates possible ecosystem changes in Subarea 48.3 between 1980 and 2002.

4.82 WG-EMM-03/42 outlined a series of indices that might provide insights into ecosystem interactions involving mackerel icefish. Information is taken largely from WG-FSA-03/4. The following indices were outlined:

(i) Standing stock:
The index is based on data from bottom trawl surveys by Argentina, Australia, Germany, Poland, Russia and the former USSR, UK and the USA. Although the results are available in the reports of WG-FSA it was noted that they should be re-evaluated by the current standard method and take account of the sampling region.

(ii) Cohort strength and recruitment:
This information is derived each year for the stock assessments undertaken by WG-FSA.

(iii) Natural mortality rate:
This is known to vary each year although precise annual estimators are not yet available. Currently it is thought to be at least twice the value in the 1960s.

(iv) Length of age classes 1 and 2:
This has been demonstrated to vary with environmental conditions and areas (see also WG-EMM-03/7 and 03/60).

(v) Condition:
This has been shown to have a functional relationship with observed krill abundance in Subarea 48.3.

(vi) Gonad maturation:
There are clear differences between seasons although some further work is needed to complete definitions of the most appropriate indices. This work should include a consideration of mature fish that fail to spawn.

(vii) Diet:
Information is available from research vessel surveys and observers on commercial vessels and has been presented as standardised indices.

4.83 The Working Group noted that these indices had been considered by the CEMP Review Workshop (Appendix D, paragraphs 98 to 100) and agreed with the proposals for future action in that report.

4.84 The Working Group also noted that extension of the estimation of standing stock to include acoustic estimates of juvenile icefish had been proposed in WG-EMM-03/60 and discussed by WG-FSA-SFA.

4.85 The Working Group noted that in order to investigate the interactions between icefish, krill and predators, information on distribution and vertical migration will be required.

Antarctic Shags

4.86 WG-EMM-03/5 provided a summary of monitoring research on Antarctic shags over the past five years. This work had been considered during the CEMP Review Workshop (Appendix D, paragraph 101) and by the Subgroup on Methods (paragraphs 4.93 to 4.96).

Myctophids and Squid

4.87 No papers were tabled on these species groups. The Working Group encouraged further research on these groups of relevance to understanding the krill-centred system.

Information on Status and Trends in the Krill-centred System Arising from Research on Other Species

4.88 The Working Group noted that although there was good evidence that indices from icefish could provide useful information on the status and trends of krill, further work was needed, as outlined in Appendix D, paragraph 100, before it could be incorporated into assessments. The Working Group encouraged work on this topic.

4.89 Several members reminded the Working Group that mackerel icefish was a harvested species, was dependent, at least in Area 48 on krill, and was preyed on by some of the CEMP species. This had been raised previously as a result of the Workshop on Assessment Methods for Icefish (SC-CAMLR-XX, Annex 5, Appendix D, paragraph 8.7) and supported by the Working Group (SC-CAMLR-XXI, Annex 4, paragraph 3.100).

4.90 In further discussion it was suggested that an appropriate way to improve assessments of ecosystem considerations relating to species other than krill and dependent species already covered with CEMP might be:

(i) to ensure that standard methods and/or indices were available, the appropriateness of which had been endorsed by relevant CCAMLR working groups;

(ii) to bring forward for consideration the results of analyses to investigate patterns of variation (including trends and anomalies) in such indices, including analyses in conjunction with indices relating to predators, prey and environment already adopted by CCAMLR.

4.91 It was recognised that this process would benefit from, if not require, closer collaboration between WG-EMM and WG-FSA. The Working Group recommended that this proposal be discussed further at the forthcoming meeting of WG-FSA.

4.92 In recognition of the potential importance of non-krill components of the ecosystem, the Working Group asked the Scientific Committee to provide advice on how the ecological relationships and trophic interactions involving non-krill-centric components of the Southern Ocean, including exploited stocks of finfish, should be included in the work of both WG-EMM and WG-FSA (see paragraph 4.90).

Methods

New Methods

4.93 WG-EMM-03/5 described a method for determining the qualitative composition of the fish diet of Antarctic shags (accepting that this method is suitable for all *Phalacrocorax* species in the CCAMLR region). The subgroup noted that this method had been presented in a tabled paper and previously considered by the Working Group, and that it had been through the peer-review process and evaluated with regard to its suitability for CCAMLR following the procedure described in SC-CAMLR-XXI, Annex 4, paragraph 3.114.

4.94 The Subgroup on Methods considered that this method had been thoroughly evaluated and was suitable for potential adoption as a CEMP standard method, and that future studies of the composition of the fish diet of Antarctic shags should follow this method.

4.95 In considering whether this method was appropriate for formal adoption as a CEMP standard method, the Working Group noted that this predator-derived index did not relate to the krill-centred system and questioned whether it had the potential to provide information of utility to the aims of CEMP.

4.96 The Working Group agreed that the index had the potential to provide information on ecological relationships and changes in populations of certain fish species and recommended that the method be referred to WG-FSA in order that it may provide advice on how the data gained using this standard method might be used in the work of that group.

Modifications to Current Methods

4.97 WG-EMM-03/45 described the data requirement for demographic studies of Adélie penguins in response to a request (SC-CAMLR-XXI, Annex 4, paragraphs 3.46 and 3.47) for standard methods for determining demographic parameters. The paper noted that CEMP Standard Method A4 is adequate until such time as the requirements for data are more closely defined.

4.98 The subgroup did not agree with the assertion in the paper that any form of demographic study requires individual birds to be marked as fledglings and that whatever marking system is used it must remain with the bird for its life span. The subgroup felt that information on adult survival may be gained from marking adult birds and recording the presence of these birds in subsequent years. The subgroup recognised that acquiring annual estimates of adult survival was of fundamental importance to the interpretation of long-term population time series.

4.99 In the context of penguin demography studies, the subgroup recognised that it was essential to appropriately evaluate the impact of band loss on demographic parameters. In addition, it recommended that existing estimates of band-induced mortality rates should be reviewed in respect of new developments in band design.

Developments

4.100 WG-EMM-03/57 and 03/58 outlined approaches to detecting chemical indicators of metabolic stress and pollutants in free-living penguins that have the potential to provide useful collateral information to aid interpretation of CEMP indices. The subgroup considered that these methods represented a potential change in emphasis from determining causes of lethal events to detecting sub-lethal effects that might influence other indices. The Working Group agreed with the suggested revision of *CEMP Standard Methods*, Part IV, Section 5 provided by Dr S. Corsolini (Italy) (see Appendix E).

4.101 WG-EMM-03/21 presented a model relating net mensuration and impact on catchability of krill, however the subgroup recognised that it did not have the relevant expertise to fully assess these methods and recommended that the analysis should be referred to WG-FSA for evaluation (see paragraphs 3.35 and 3.36).

4.102 WG-EMM-03/42 presented a series of indices from mackerel icefish that may be suitable as CEMP indices, or that may provide complementary data with which to interpret other CEMP indices. The subgroup noted that the discussion of these potential indices in the CEMP Review Workshop (Appendix D, paragraphs 97 to 100) had suggested that there was a need for thorough evaluation of the properties of such indices and that there was also a need to assess the likelihood of collection of icefish data on a regular/annual basis.

Consideration of Methods for Collecting Non-CEMP Parameters associated with Existing CEMP Parameters Arising from the CEMP Review Workshop

4.103 Analysis of CEMP Index C2b from South Georgia (Reid, 2002) and the South Shetland Islands, carried out during the CEMP Review Workshop, indicated that there was a problem with the representation of the rate of pup growth following the standard method such that in years of apparently poor foraging indices, pup growth rates appeared to be high. The problem was overcome at South Georgia (Reid, 2002) using a summed growth deviate to produce a biologically plausible index of the mass at age of fur seal pups. However, the subgroup recognised that this summed growth deviate may not be appropriate where the number of sampling dates varies between years (as is the case in the Cape Shirreff time series). An analysis of the mean growth deviate compared to the summed growth deviate indicated that the mean was an appropriate index and was not dependent on the number of sampling occasions.

4.104 The Working Group evaluated the existing data for Index C2b (fur seal pup growth rate) and recommended the following changes to the standard method in order to more appropriately represent the deviation from the mean mass at age:

An index of growth deviate (*gd*) in year *y* should be calculated as follows:

let N_y be the number of sampling occasions in year *y* such that I_y is the set of ages in days since the median pupping date on which sampling occurred in year *y*, e.g. $I_y = [30,60,90]$, $N_y = 3$;

for each *i* in the set I_y in year *y* calculate $m_{(y,i)}$, the mean mass of pups at age *i* in year *y*;

calculate the regression relationship $m_{(y,i)} = a + bi$ for all years *y* and ages *i*;

for each year calculate the growth deviate (gd_y) where:

$$gd_y = \frac{\sum_i \left(m_{(i,y)} - a - bi\right)}{N_y}$$

Future Surveys

4.105 There were no future surveys reported to the Working Group.

Key Points for Consideration by the Scientific Committee

4.106 The Working Group considered that the current approach to derive summaries based on the balance of positive and negative anomalies was inappropriate and of limited utility in providing an annual assessment of anomalies and trends of CEMP indices (paragraphs 4.9 to 4.11). It proposed that an ordination approach be developed whereby the nature of the covariation in multivariate CEMP indices could be described and presented on an annual basis. This approach would have the potential to characterise the state of the system in relation to other years and to identify temporary shifts (i.e. anomalies), gradual changes (e.g. trends) or regime shifts. This would utilise all of the available data rather than being restricted to statistical anomalies (paragraphs 4.13 to 4.18).

4.107 A comparison of acoustic survey data biomass density with estimates obtained from commercial net samples from the fishing areas in the Scotia Sea indicated that fishing vessels were only able to operate in areas where krill biomass was at least 100 to 120 g m^{-2}, achieving a sustained yield of 3 to 3.5 tonnes per hour. Further work was encouraged to:

(i) compare the distribution of fishing effort with that predicted from the distribution of threshold density levels;

(ii) compare predicted krill fishing areas in relation to distribution of predator demand in the area (paragraphs 4.24 and 4.26).

The Working Group encouraged all Members with relevant data to undertake such analyses for all subareas of Area 48.

4.108 The Working Group recognised that it was particularly important to determine the relative contribution of flux and local retention of krill within different regions as this may be very important for allocating precautionary catch limits to SSMUs and may have implications for the use of the GYM, which currently assumes a single krill population (paragraph 4.36).

4.109 Given numerous indications of environmental change in the CCAMLR Convention Area, the Working Group considered that it may be appropriate to obtain a coherent overview of environmentally induced variability in the Southern Ocean and to consider potential change scenarios that might influence ecological relationships with implications for fisheries management (paragraphs 4.59 and 4.60).

4.110 The Working Group evaluated the existing data for Index C2b (fur seal pup growth rate) and recommended the following changes to the standard method in order to more appropriately represent the deviation from the mean mass at age (paragraph 4.104):

An index of growth deviate (*gd*) in year *y* should be calculated as follows:

let N_y be the number of sampling occasions in year *y* such that I_y is the set of ages in days since the median pupping date on which sampling occurred in year *y*, e.g. $I_y = [30,60,90]$, $N_y = 3$;

for each *i* in the set I_y in year *y* calculate $m_{(y,i)}$, the mean mass of pups at age *i* in year *y*;

calculate the regression relationship $m_{(y,i)} = a + bi$ for all years *y* and ages *i*;

for each year calculate the growth deviate (gd_y) where:

$$gd_y = \frac{\sum_i \left(m_{(i,y)} - a - bi\right)}{N_y}$$

4.111 The Working Group recognised that improving the critical assessment of the ecological relationships and trophic interactions involving non-krill-centric components of the Southern Ocean, including exploited stocks of finfish, would require closer collaboration between WG-EMM and WG-FSA (paragraphs 4.90 and 4.91).

4.112 The Working Group asked the Scientific Committee to provide advice on how the ecological relationships and trophic interactions involving non-krill-centric components of the Southern Ocean, including exploited stocks of finfish, should be included in the work of both WG-EMM and WG-FSA (see paragraph 4.92).

STATUS OF MANAGEMENT ADVICE

Advisory Subgroup on Protected Areas

5.1 The Advisory Subgroup on Protected Areas met and considered tasks assigned to it. The tasks included:

(i) submission of revised maps for CEMP sites;

(ii) revision of guidelines for the production of maps of protected areas;

(iii) revision of the subgroup's terms of reference, based on CCAMLR decisions related to the evaluation of Antarctic Treaty management plans containing marine areas that are submitted to CCAMLR for approval;

(iv) review current membership of the group.

5.2 The subgroup noted that most of the required maps have been submitted. Members have access to these maps on the CEMP pages of the CCAMLR website. However, there were revised maps of three CEMP sites (Admiralty Bay, Anvers Island and Elephant Island) still to be submitted. The subgroup suggested that the USA and Brazil be requested to review the CEMP status at each of the remaining sites and provide maps if appropriate.

5.3 With regard to the existing guidelines for production of CEMP site maps, the subgroup took note of guidelines adopted by the ATCM at CEP-I for the production of maps of ASPAs and ASMAs. The subgroup recommended that the Secretariat be requested to review intersessionally the existing CEMP guidelines and prepare a draft of map production requirements for both terrestrial areas (i.e. CEMP sites) and marine protected areas (i.e. areas proposed in accordance with Article IX.2(g)). This should be done in consultation with members of the subgroup.

5.4 The subgroup noted that CEP had adopted revised 'Guidelines for consideration of new and revised draft ASPA and ASMA management plans' (CEP-VI, Annex IV). The guidelines contain a procedure for submitting plans to CCAMLR for consideration as required in accordance with the ATCM Environmental Protocol, Annex V, Article 6.

5.5 The subgroup decided not to review its membership in the absence of Dr P. Penhale (USA), but to ask Dr Penhale to review the group's membership intersessionally.

5.6 The subgroup noted that 'The science of marine reserves' was published in a special issue of *Ecological Applications*, 13 (1) in February 2003. The subgroup felt this publication would provide valuable background information for any future assessment of proposals for marine protected areas.

5.7 The Working Group reviewed WG-EMM-03/22. This paper summarised the terms of reference of the subgroup in a manner that properly places the tasks in the context of CCAMLR decisions (SC-CAMLR-XXI, paragraph 3.32; SC-CAMLR-XXI, Annex 4, paragraph 5.15).

5.8 The Working Group thanked Dr Sabourenkov for producing an excellent paper, which is a valuable document tracking the history of the evolution of the subgroup's terms of reference since the group was established in 1992.

5.9 The Working Group reviewed the following terms of reference for the Advisory Subgroup on Protected Areas and agreed to forward them for approval and adoption by the Scientific Committee:

(i) to review the details of proposals relating to designation and protection of CEMP monitoring sites and review of CEMP management plans as required in accordance with Conservation Measure 91-01;

(ii) to revise and keep under review, as appropriate, guidelines for the production of maps of protected areas relevant to CCAMLR;

(iii) to develop and keep under review, as appropriate, a methodology for assessment of proposals for marine protected areas forwarded in accordance with Article 6(2) of Annex V of the Protocol on Environmental Protection to the Antarctic Treaty;

(iv) to provide advice on marine protected areas that seek designation as an ASPA or an ASMA under the Antarctic Treaty;

(v) to provide advice on the implementation of marine protected areas that may be proposed in accordance with the provisions of Article IX.2(g) of the Convention, including 'the designation of the opening and closing of areas, regions or subregions for purposes of scientific study or conservation, including special areas for protection and scientific study'.

Harvesting Units

5.10 The ad hoc Subgroup on Harvesting Units examined the information that was available to it on krill and environmental data. It recognised that combining datasets from a range of sources would be useful for the determination of potential boundaries of harvesting units.

5.11 Krill distributions were available from SC-CAMLR-XX/BG/24, pages 1 to 11, and these were derived from the *Discovery Reports* (Mackintosh, 1973) and Voronina (1998); the position of frontal zones was available from Belkin and Gordon (1996) and Orsi et al. (1995); the surface layer (0–200 m) temperature from Naganobu and Komaki (1993); geostrophic flow from Gordon and Baker (1986) and Naganobu (1992, 1993, 1994); and additional satellite-derived information was available on ocean colour and sea-ice that might prove useful. These and other data would be utilised in assessing potential boundaries for harvesting units.

5.12 The Working Group agreed to correspond intersessionally and produce a document outlining new harvesting units of appropriate size for catch reporting of the krill fishery, concentrating principally on Subareas 48.6, 88.1, 88.2 and 88.3, and Divisions 58.4.1 and 58.4.2, for consideration at the 2004 meeting of WG-EMM.

Small-scale Management Units

5.13 In 2001, the Commission agreed on a precautionary catch limit for Antarctic krill of 4 million tonnes in Area 48. It further subdivided this catch limit among Subareas 48.1 (1.008 million tonnes), 48.2 (1.104 million tonnes), 48.3 (1.056 million tonnes) and 48.4

(0.832 million tonnes), in order to distribute fishing effort and thereby reduce the potential impact of fishing on land-based predators. Concern remained, however, that localised depletion of krill populations could still occur if all a subarea catch limit was taken within a small part of that subarea. Accordingly, the Commission further agreed that the total catch in Area 48 shall not exceed 620 000 tonnes until the precautionary catch limit had been subdivided amongst SSMUs (Conservation Measure 51-01). Specifications for SSMUs had been proposed by WG-EMM-02 and these were subsequently endorsed by the Scientific Committee and adopted by the Commission. The SSMUs are shown in Figure 3.

5.14 With the aim of stimulating discussion on possible means of subdividing the precautionary catch limit amongst SSMUs, WG-EMM-03/36 presented four possible options for performing the subdivision. Under each option, the catch limit for an SSMU is a specified proportion of the total precautionary catch limit. The options considered were:

1. The catch limit for an SSMU should be proportional to the combined estimated predator demand for krill in that SSMU. This option is predicated on the assumption that a high predator demand implies a high standing stock of krill and/or a high turnover rate.

2. The catch limit for an SSMU should be proportional to the estimated standing stock of krill in the SSMU. This is based on the assumption that in all areas where krill occur, emigration balances immigration and high krill biomass densities imply high availability.

3. The catch limit for an SSMU should be proportional to the estimated standing stock of krill in the SSMU, less the estimated annual predator demand. This is based on the premise that the amount of krill allocated to the fishery should be determined only after accounting for predator needs. Should the estimated standing stock of krill for an SSMU be less than the predator demand, the catch limit for that SSMU should be zero.

4. The catch limit for an SSMU should be calculated as an annually adjustable proportion of the catch limit specified by one of the static options 1 to 3, where the proportion would depend on the value of an ecosystem monitoring index or a combination of indices. This option may be particularly pertinent for SSMUs where there is a wide range of predator reproductive success associated with large changes in krill availability.

5.15 Reviewing the application of each of the options to the subdivision of the precautionary catch limit amongst SSMUs based on available estimates of predator demand and krill standing stock, WG-EMM-03/36 reached the following qualitative conclusions:

(i) Approximately 65% of total demand for krill by land-based predators in the Scotia Sea is in the vicinity of South Georgia. Under option 1, a correspondingly high proportion of the catch would also be concentrated in this area.

(ii) Option 2 leads to a more conservative allocation of catch limits among SSMUs with respect to land-based predators, with approximately 75% of the catch limit being allocated to the pelagic SSMUs.

(iii) Under option 3, the proportion of catches allocated to the pelagic SSMUs would increase to approximately 83% and no catch would be allowed in the South Georgia West SSMU.

(iv) Despite the increased allocation to pelagic SSMUs in options 2 and 3, annual variations in krill availability may still result in sufficient competition between land-based predators and the krill fishery for predator demand to exceed the krill standing stock in some SSMUs in some years. Option 4 was designed to take account of this, however for its implementation, improved indices for krill availability and/or transport into an SSMU may need to be developed.

5.16 The authors of WG-EMM-03/36 emphasised that other subdivision options could be devised and that the options presented could be further developed and improved. In particular, no preference was expressed amongst the options and it was not intended that a particular option should be selected from amongst them. Rather, the paper was intended to facilitate discussion and highlight the likely implications of different types of allocation schemes.

5.17 It was noted that there were two separate motivations for the establishment of SSMUs. The first is the need to address the Commission's specific request to spatially subdivide the catch limit such that a large proportion of the catch was not concentrated in a small portion of a subarea. The second is that SSMUs are likely to form the structural basis for long-term krill management strategies, the development of which is the basis for the two WG-EMM modelling workshops planned for 2004 and 2005. WG-EMM-03/36 was aimed at the first of these reasons.

5.18 It was further emphasised that, according to the Commission's decision last year, the need to implement a subdivision of the precautionary catch limit amongst SSMUs would only arise when the total krill catch in Area 48 approached a level of 620 000 tonnes. Current catches are a small fraction of that level.

5.19 Dr Watkins noted that Table 5 of WG-EMM-03/28 reveals that, over the past 10 years, three SSMUs (Antarctic Peninsula Drake Passage West, South Orkney West and South Georgia East) have accounted on average for 66% of the total krill catch in Area 48, and two others (Antarctic Peninsula Drake Passage East and Antarctic Peninsula Elephant Island) account for a further 20% of the total. Thus, at present, the vast majority of the krill catch is taken in just five SSMUs. In contrast, recorded catches in the last decade in the pelagic SSMUs have generally been very small, with the exception of isolated years in which the annual catch in pelagic SSMUs exceeded 6 000 tonnes (1995 and 1996 in Subarea 48.1 and 2000 in Subarea 48.3).

5.20 During the meeting, Dr Ramm was able to extend the time series of historic catches by SSMU back to 1988, and these data are shown in Table 2. Dr Ramm advised that for years prior to 1988, there were insufficient fine-scale krill catch data to allow reliable subdivision by SSMU. The most notable feature of the additional data in this table was that substantial catches (exceeding 7 000 tonnes) had been taken in the pelagic SSMU in Subarea 48.1 in each of the years from 1988 to 1992. Dr Ramm indicated that these were largely catches taken by the Japanese krill fleet. The Working Group agreed that these data were very useful and may provide a starting point for developing an alternative subdivision option incorporating information on historical catches.

5.21 Several members noted that a key implication of subdivision options 1 and 2 was a very substantial redirection of krill fishing effort to the pelagic SSMUs, and that this contrasts strongly with the present situation. If indeed the krill catch does increase substantially from its present level, in their view it would not be possible to continue to take the catch from a small number of SSMUs adjacent to predator colonies, either in terms of meeting the needs of the predators or of maintaining an economically viable fishery. In their view, redistributing krill fishing effort, particularly towards SSMUs not immediately adjacent to land-based predator colonies, was a desirable and necessary response to substantially increasing krill catches. It was noted, however, that a corollary of a shift to pelagic SSMUs was that fishing would be taking place in areas in which the fleet had not operated regularly in the past, and for which levels of monitoring were low.

5.22 Dr Sushin indicated that he had a number of specific objections to the options for allocation of precautionary catch limits described in WG-EMM-03/36, but before detailing them, he wished to make some more general comments:

(i) The basic hypothesis in the proposed precautionary catch limit allocations among SSMUs is the hypothesis that competition exists between the fishing vessels and krill predators for krill resources, and that it is assumed that the fishery always succeeds in that competition. However, this hypothesis has not been proved with scientific facts. Moreover, the results of some research provide evidence for the lack of any competition (e.g. WG-EMM-02/63 Rev.1 and 03/31). Any attempt to implement this hypothesis in practice is likely to result in displacement of the krill fishing fleet from the fishing grounds into the areas where a krill fishery is impossible in view of low krill concentrations. In addition, one of the Convention principles is violated, namely that conservation includes 'rational utilisation', since rational utilisation implies appropriate fishery efficiency.

(ii) The conservation principles defined in paragraph 3 of Article II of the Convention are actually replaced with the single principle, i.e. to ensure food demands of predators, taking into account their abundance for the recent years. At the same time the abundance of predators ensuring the ecosystem balance and conservation principles defined in paragraph 3 of Article II of the Convention remains unknown. In addition, the fact that the size of several populations has significantly increased in recent years (e.g. fur seals in Subarea 48.3) and could negatively affect other species is not taken into consideration. For example, the increase of fur seal abundance could result in a sharp increase of predator pressure on the icefish population, preventing the latter's stock restoration (e.g. WG-EMM-03/42 and paragraphs 4.77 to 4.85). First of all, it is necessary to determine appropriate biological reference points of predator population size in compliance with the conservation principles defined in paragraph 3 of Article II of the Convention. In future, predator food demand should be estimated on the basis of these biological reference points. Only when this has been done would it be possible to agree to precautionary catch limit allocations based on predator demands.

5.23 Prof. Croxall noted that:

(i) good circumstantial or inferential evidence exists for potential competition for krill between fishing vessels and krill predators, especially based on relative and absolute consumption rates in local areas and at particularly critical times of year for predators;

(ii) evidence to the contrary, even for selected areas of SSMUs with the greatest spatial and temporal differences between fishing operations and some of the critical areas/times for land-based krill predators (e.g. WG-EMM-02/63 Rev. 1 and 03/31) was at best inconclusive, as noted last year (SC-CAMLR-XXI, Annex 4, paragraph 3.38);

(iii) nevertheless, in seeking to implement management of krill fishing at the scale of SSMUs, he believed that WG-EMM was striving to find the appropriate balance between protecting the livelihood of krill-dependent species and avoiding unnecessary restriction to the operations of the fishery. He expressed disappointment at a situation whereby, after 10 years during which many Members had expressed serious concern over the potential effect on krill predators of existing krill fishing at local scales and critical periods, without achieving any regulation or management of the krill fishery at these scales, some Members now apparently saw no reason for some redistribution of krill fishing effort even if a fishery of thrice the current magnitude were to develop within SSMUs;

(iv) as a result of earlier discussions on how to manage spatio–temporal overlap between the krill fishery and predator foraging areas, in 1991 and 1992 the Scientific Committee requested information from those responsible for krill fishing, on the extent to which it is possible to fish commercially for krill outside these times and areas of particular overlap (SC-CAMLR-XI, paragraph 5.40; SC-CAMLR-XII, paragraphs 8.42 to 8.44). Unfortunately, no such information has yet been forthcoming and it would be very timely to recommence this dialogue.

5.24 In respect of the apparent assertion in paragraph 5.22 that competition between fishing vessels and krill predators needs to be proved before appropriate management action can proceed, several members disagreed and noted that an alternative requirement could be to demonstrate that the fishery had no impact on krill predators. They noted, however, that several earlier meetings of the Scientific Committee and its working groups had discussed how to deal with the uncertainties involved by means of changes in the distribution of fishing effort (including by closed areas and seasons) without requiring either type of proof.

5.25 While several members indicated that they disagreed with Dr Sushin's interpretation of Article II of the Convention, the Convener advised the Working Group that discussion of this topic was beyond the remit of WG-EMM and it should be deferred for consideration by the Scientific Committee. Rather, discussion of WG-EMM-03/36 during WG-EMM should be restricted to strictly scientific issues.

5.26 Dr Sushin then outlined his specific objections to the allocation options in WG-EMM-03/36 as follows:

(i) Option 1 is based on the hypothesis that the productivity of the prey population can be assessed through predator demand. This would be true only if the size of the predator population is controlled only by krill availability. However, this fact has not been proved. In different SSMUs, predator abundance can be limited by a variety of factors. In areas with rougher conditions (such as Subareas 48.1 and 48.2), factors such as the short summer season, lower mean annual temperatures, fewer areas suitable for reproduction etc. are essential. The fact that in subareas with high krill abundance (e.g. Subarea 48.2) relatively low predator abundance is observed, provides evidence that predator abundance is not proportional to krill abundance in all areas.

(ii) In option 2, the assumption is made that the results of a single acoustic survey provide adequate estimates of the standing stock of krill in each SSMU. However, biomass as assessed by one survey provides estimates proportional to standing stock only in areas comparable to the population distribution area (e.g. Area 48 as a whole). In small areas with strong water dynamics, the flux factor needs to be taken into consideration. In addition, to apply option 2 it is necessary to prove that krill biomass ratio among SSMUs estimated in the CCAMLR-2000 Survey remains unchanged for a sufficiently long period (at least comparable to the fishing season duration). However, this assumption is absolutely incredible in view of the current ideas about water dynamics, krill drift and mechanisms of formation of local krill aggregations.

(iii) Option 3 is also unacceptable as it includes all the problems mentioned for the first two options described above.

(iv) The fourth option can only be seriously discussed following assessment of the extent to which some CEMP indices (or their combination) used in 'predator performance' estimation and these estimates themselves comply with the principles defined in paragraph 3 of Article II of the Convention. WG-EMM-02/36 does not provide any explanation of this.

5.27 Given the problems associated with basing a subdivision of catches on the results of a single large-scale krill survey, the Working Group agreed that there was a need to develop an additional alternative subdivision option that takes account of both the survey data and information from historical krill catches.

5.28 The Working Group agreed that as it begins to address the issue of subdivision of catches amongst SSMUs, it is now essential that all available information on historical, current and possible future krill fishing activities be made available on a fine spatial and temporal scale.

5.29 One of the obvious attractions of the current major krill fishing grounds is that fishable concentrations of krill can reliably be found there each year. Results of the CCAMLR-2000 Survey did indicate that fishable concentrations of krill were found in pelagic areas within Area 48 (SC-CAMLR-XVII, Annex 4, Appendix D). However, these results represent a snapshot of krill densities at one point in a year. Dr Sushin noted that as a rule, such concentrations in open waters tended to exist in one place for only a short time (e.g. between several days and three weeks). The lack of predictability in locating fishable concentrations of krill in open waters meant that commercial fishing in such areas was unlikely to be viable.

5.30 Summarising the discussions on SSMUs, the Convener observed that WG-EMM-03/36 had definitely served its intended purpose – that of stimulating debate on how the precautionary catch limit in Area 48 could be subdivided. The debate had identified a need to refine options presented in that paper and the assumptions and calculations on which they were based. In order that further progress can be made on this topic, it was agreed that there is also a clear need to develop other alternative subdivision options, including ones that took account of historical fishing information. Members were urged to work on these topics intersessionally, with a view to presenting papers on revised or alternative subdivision options and making substantial further progress at the next WG-EMM meeting.

Analytical Models

5.31 Dr Constable reported on the first meeting of the WG-FSA Subgroup on Assessment Methods held at Imperial College, London, from 12 to 15 August 2003. This subgroup is of interest to WG-EMM because it reviews and evaluates analytical and assessment methods which are used to analyse surveys, estimate parameters or determine yields of fish stocks. It also has responsibility for determining what methods are appropriate to be used in the work of WG-FSA. Therefore, one of its primary tasks was to develop an agenda for the assessments at the coming meeting of WG-FSA. The following paragraphs provide a summary of the points of interest to WG-EMM.

5.32 CMIX is used by WG-EMM to determine the strengths of a single year class of krill as a proportion of the population based on length-density data arising from net samples (de la Mare, 1994). The subgroup discussed the use of CMIX and the potential difficulties of some kinds of data. It has recommended that CMIX continue to be used until further evaluation has been completed. Such evaluation is to include simulation testing to help compare the merits of different approaches to mixture analyses. In the meantime, the subgroup recommended that the diagnostic outputs provided from CMIX should be reviewed closely to help determine the reliability of the estimates of densities of fish in each year class from the haul-by-haul length-density data.

5.33 The Working Group noted that the Excel add-in for using CMIX from within Excel was still the main interface other than the development of text files. A manual is available for assisting in the use of CMIX, including details of the diagnostic outputs (de la Mare et al., 2002). The Australian Antarctic Division is currently developing a database version similar to the interface of the GYM.

5.34 The GYM is used by WG-EMM to undertake the assessments of precautionary yield of krill. The subgroup considered the advances in the development of the GYM in recent years, noting that the full manual and model specifications are now available. This year, the GYM has been extended to enable projections for a known age structure and/or biomass, which is required for the short-term assessment of yield in mackerel icefish. Such projections also enable simulations and assessments of population conservation and recovery, which may be of interest to WG-EMM. The new version, manual and specifications are available on the

Australian Antarctic Division website (www.antdiv.gov.au). A database with examples is also available. This database contains example validation routines that enable the user to validate for themselves the way the GYM works. It was also noted that the GYM has been translated into Java (Java GYM) to help validate the software. The subgroup had noted that the JGYM was slower in completing its trials but provided similar, but not identical, results to the GYM. It noted that the causes of differences between the JGYM and the GYM remain to be determined and a validation program has been proposed.

5.35 WG-EMM has an interest in standardising time series of CPUE in the krill fishery. At present, WG-FSA standardises the catch series in Patagonian toothfish fisheries using GLMs. The method for GLM standardisation was reviewed this year. There are some issues remaining on model construction and the appropriateness of some data used in these assessments. Nevertheless, GLMs may be a method that WG-EMM could consider in the analysis of CPUE. It was noted that the input data for GLMs needed to be haul-by-haul data in order that the importance of factors influencing CPUE can be adequately assessed (see paragraph 3.16).

5.36 WG-EMM primarily uses acoustics to estimate abundance of krill. The subgroup considered methods for integrating data from acoustic and trawl surveys for mackerel icefish. Some progress was made on the form of the assessment. However, the final assessment would be contingent on the outcomes of WG-FSA-SFA which met concurrently with WG-EMM.

5.37 WG-FSA will be required to revise its assessment on myctophid fish in the South Atlantic. In order to advance this revision, the subgroup requested assistance from WG-EMM in estimating the abundance of myctophid fish in this region using the results from the CCAMLR-2000 Survey. Dr Hewitt indicated that the USA is preparing a manuscript on the abundance of myctophids from that survey. Although the analysis does not differentiate between myctophid species, the Working Group noted that this may provide a basis for the work of WG-FSA and encouraged Dr Hewitt to have the manuscript submitted to WG-FSA for consideration.

5.38 In its future work, the subgroup is developing a framework to evaluate the different approaches to management, including the robustness of decisions to uncertainties arising from different kinds of monitoring data and assessment models. This is of interest to WG-EMM because of its work in developing a management procedure for krill.

5.39 The subgroup noted the advances in the development of Fish Heaven, a spatially-structured simulation model that can include multiple species (although not interacting at this stage), habitat quality maps for each species (which influence the movement of fish across the landscape), multiple fisheries (commercial and research activities) and a management structure for monitoring, assessing and specifying harvest activities. This model can be used as an operating model to test management procedures. As an example, Fish Heaven can interface directly with the GYM in determining catch limits each year within the simulation.

Existing Conservation Measures

5.40 No changes to existing CCAMLR conservation measures were proposed.

Key Points for Consideration by the Scientific Committee

5.41 The Working Group recommended that the Scientific Committee endorse the proposed revised terms of reference for the Advisory Subgroup on Protected Areas, as listed in paragraph 5.9.

5.42 The Working Group will correspond intersessionally and produce a document outlining new krill harvesting units of appropriate size for catch reporting of the krill fishery, for consideration at WG-EMM-04. Principal concentration will be on Subareas 48.6, 88.1, 88.2 and 88.3, and Divisions 58.4.1 and 58.4.2 (paragraphs 5.10 to 5.12).

5.43 A paper (WG-EMM-03/36) presenting possible ways in which precautionary catch limits in subareas of Area 48 could be subdivided amongst SSMUs provoked extensive discussions within the Working Group. Application of several of these options would lead to a substantial redirection of krill fishing to pelagic SSMUs, in contrast to the current situation in which fishing is concentrated in a small number of SSMUs adjacent to land-based predator colonies (paragraphs 5.13 to 5.21).

5.44 Discussion of the general principles of balancing predator demand and a krill fishery in or near predator foraging grounds raised issues relating to the interpretation of Article II of the Convention which were outside the remit of WG-EMM. These were referred to the Scientific Committee for further consideration (paragraphs 5.22 to 5.25).

5.45 It was agreed that there was a need to refine the subdivision options presented in WG-EMM-03/36. There is also a need to develop additional options, including ones taking account of both survey data and historical krill fishing information. Intersessional work on these topics is required in order that substantial further progress on precautionary catch limit subdivision can be made at the next WG-EMM meeting (paragraphs 5.26 to 5.30).

5.46 The attention of the Scientific Committee is drawn to the progress made in development of analytical models and software tools of relevance to WG-EMM during the recent meeting of the WG-FSA Subgroup on Assessment Methods (see paragraphs 5.31 to 5.39).

5.47 No changes to existing CCAMLR conservation measures were proposed (paragraph 5.40).

FUTURE WORK

Land-based Predator Surveys

6.1 In considering the feasibility of broad-scale surveys of land-based predators, the Working Group recognised four main groups of predators on the basis of the methods likely to be appropriate: colonial-breeding penguins, surface-nesting flying birds, burrow-nesting flying birds and colonial-breeding seals. The Working Group agreed that because colonial-breeding penguins were both the most tractable of these groups and a major consumer of krill, that initial efforts would best be focused on them.

6.2 With regard to surveys of colonial-breeding penguins, the Working Group considered it likely that the most feasible survey protocol would involve the initial use of satellite imagery, augmented by existing knowledge where possible, to locate colonies, followed by estimation of density within colonies from aerial photography.

6.3 Two sources of satellite imagery are possible. Firstly, there are numerous commercial companies that can provide satellite imagery of good quality, but the cost is likely to be substantial. WG-EMM-03/51 outlined some specifications and costs of such commercial satellite imagery. Coverage and resolution of commercial imagery is projected to improve in the future. Alternatively, it may be possible to obtain satellite images of superior quality from the US Government National Imagery and Mapping Agency (NIMA) at minimal cost, subject to security clearance and likely restrictions on publication of those images. Dr Goebel has made initial enquiries with the Civil Applications Committee, NIMA, about the availability of satellite images and will continue these discussions intersessionally. In particular, there was a need to know whether there was any substantial trade-off between the resolution of images and spatial coverage in images obtained from NIMA.

6.4 WG-EMM-03/51 reviewed previous attempts to ground truth the use of satellites for locating penguin colonies in East Antarctica, the Ross Sea and the Crozet Peninsula. Although the extent of ground truthing is very limited, the studies show that satellites have great potential for this purpose. However, the studies also allude to the need for further evaluation with respect to the spectral response of surrounding material, variability in the spectral response of guano due to environmental features, inadequate or ambiguous signal from guano, and spatial resolution of the technology and/or penguin breeding sites. Developments in satellite technology since the time of these studies will have alleviated some issues such as spatial resolution. The authors argue that consideration of survey design options may address some deficiencies in current satellite technology.

6.5 The Working Group considered that further evaluation or ground truthing would best be undertaken in an experimental framework and should, where possible, be undertaken in collaboration with existing field work. In this regard, the correspondence group agreed to work intersessionally to (i) identify those factors most likely to confound our ability to identify penguin colonies from satellite imagery at a regional level, such that these factors could form the basis of an experimental program, and (ii) compile current and planned future field work by various investigators within and outside CEMP to assist in assessing the feasibility of undertaking experimental evaluation in collaboration with existing field research.

6.6 Once the location of colonies has been determined over large scales, a second stage of survey will require estimation of penguin or nest density within colonies. The Working Group agreed that aerial photography is likely to be the most successful method for this purpose.

6.7 The Working Group discussed the feasibility of using unmanned aircraft as a platform for aerial photography, of which there are many types and designs on the market. WG-EMM-03/50 reviewed the advantages and disadvantages of one such type named the 'Aerosonde'. The British Antarctic Survey has also been investigating unmanned aircraft for this purpose. Although superficially attractive, the Working Group considered there were numerous disadvantages that were evident with this platform. Most unmanned aircraft are designed as high-speed data collection platforms, which may not be appropriate for aerial photography. Performance was likely to be adversely affected by strong wind and/or icing, and navigation in mountainous terrain is likely to be difficult. Currently the Aerosonde would be no cheaper to operate than conventional aircraft.

6.8 Infra-red photography is a possible alternative to conventional aerial photography for counting penguins. Although the Working Group considered infra-red photography to be of limited utility, it was agreed that further assessment would be given to this option before ruling it out.

6.9 It was recognised that any broad-scale survey would need to take into account the breeding biology of the target species, in that the actual number of breeding and non-breeding birds varies throughout the breeding season and at different locations. Existing data on nest attendance and breeding chronology would be particularly valuable in identifying optimal time windows for survey work and/or forming the basis of corrections for counts outside the optimal time period. It would be particularly important to incorporate any uncertainties into any such corrections. The CEMP database may be one source for such data for penguins, but the Working Group recommended enquiring elsewhere for additional relevant data. Additionally or alternatively, it may be necessary to conduct 'calibration' counts through the breeding season in conjunction with broad-scale surveys.

6.10 The Working Group recognised that it would not be possible to undertake a census or total count of colonial-breeding penguins over broad-scale regions, and hence considered that some form of sample survey would be required. Careful consideration of an optimal sampling design would be important. The possibility of undertaking simulation studies of various candidate sampling designs using real data was discussed with the view to identifying an optimal design prior to a survey being conducted. The results of several regional surveys that have been published in papers or reports indicated that mapping colony boundaries at relatively fine detail, might form the basis of such an investigation. Using a GIS, it might be possible to overlay various sampling designs, such as selection of whole islands, selection of transects across colonies, plots within colonies, or colonies, and examine the bias and precision in relation to sampling effort and design. This approach might be extended further to simulate location of colonies by satellites with varying degrees of spatial resolution and classification error. The Working Group considered this avenue of investigation worthy of further development.

6.11 Rather than attempting surveys at circumpolar scale at the first instance, the Working Group considered that a more prudent approach would be to select a few regions for pilot studies to evaluate methodologies and designs, followed by broader-scale application of evaluated methods depending on the results of such pilot studies. In this regard, it was agreed that regions in East Antarctica and the lower latitudes of West Antarctica would provide contrasting complexities and therefore may present differing feasibilities.

6.12 Given the above staged approach, the Working Group agreed that preparation of a prospectus and detailed background document, as recommended in last year's advice to the Scientific Committee (SC-CAMLR-XXI, Annex 4, paragraphs 6.26 and 6.51) in the context of surveys at circumpolar scale and for all predator groups, was unnecessary at this stage of investigation, but may be useful at a later date.

Workshop on Management Models

6.13 WG-EMM noted the discussion at its last meeting regarding the development of ecosystem models (SC-CAMLR-XXI, Annex 4, paragraphs 6.27 to 6.31). It also noted that this will be the topic for the workshop at WG-EMM next year as part of its program of work (SC-CAMLR-XXI, Annex 4, Table 3). As identified in that work plan, a workshop on developing management procedures for krill will be held in 2005. The aim of the workshop associated with WG-EMM-04 is to develop plausible 'operating' models of the Antarctic marine ecosystem that will facilitate the evaluation of management procedures as part of the workshop in 2005. To that end, the working group recalled the conceptual framework for the development of a management procedure illustrated in Figure 4.

6.14 A management procedure includes the operational objectives related to Article II and the consequent field collection of data (such as data on catch, target species and predators through CEMP), the analyses and assessment methods, and the decision rules that influence the fisheries interaction with the natural world. Decision rules are framed in terms of what is required to meet the operational objectives given the results of the assessment model. The Working Group agreed that the evaluation of management procedures would be undertaken by simulating how well the management procedure would perform under different plausible scenarios, of how the natural world worked and how the fishery interacted with the natural world. In this way, the robustness of the management procedure in meeting the objectives of the Convention, despite the uncertainties in our understanding of the natural world and in the data collection and assessment processes, can be evaluated. The plausible scenarios are often called 'operating models', i.e. alternative models of the natural world and how the fishery interacts with it (the left side of Figure 1).

6.15 In preparation for the workshop next year, a steering committee was formed to consider the organisation of the workshop, its terms of reference and a work plan for the coming year.

6.16 It was agreed that the steering committee would comprise Drs Constable (Coordinator) and C. Davies (Australia), P. Gasiukov (Russia) and S. Hill (UK), Prof. E. Hofmann, Drs Kirkwood, E. Murphy (UK), Naganobu, Ramm, Reid, Southwell, Trathan and Watters. Drs Hewitt (Convener, WG-EMM) and R. Holt (Chair, Scientific Committee) will be *ex officio* members of the steering committee.

6.17 The Working Group agreed that the workshop would be titled 'Workshop on Plausible Ecosystem Models for Testing Approaches to Krill Management'. The terms of reference for the workshop were agreed to be:

(i) to review approaches used to model marine ecosystems, including:

  (a) the theory and concepts used to model food-web dynamics, the influence of physical factors on those dynamics, and the operations of fishing fleets;

  (b) the degree to which approximations could be used to form 'minimally realistic' models[2];

  (c) the types of software or computer simulation environments used to implement ecosystem models;

(ii) to consider plausible operating models for the Antarctic marine ecosystem, including:

  (a) models of the physical environment;

  (b) food-web linkages and their relative importance;

  (c) dynamics of the krill fishing fleet;

  (d) spatial and temporal characteristics of models and their potential limitations in space and time;

  (e) bounding parameters used in the models;

(iii) to advance a program of work to develop and implement operating models that can be used to investigate the robustness of different management approaches to underlying uncertainties in the ecological, fishery, monitoring and assessment systems, including:

  (a) the development and/or testing of software;

  (b) specification of requirements of software, including diagnostic features, ability to test the efficacy of observation programs, such as different kinds of monitoring of predators, prey and the fishery;

  (c) consideration of spatial and temporal characterisation of the physical environment (ice, oceanography) that could be used to parameterise the models.

6.18 The Working Group noted that term of reference (iii)(c) could also be used to help with the design of the spatial and temporal monitoring of the physical environment, as well as other aspects associated with CEMP.

6.19 In reviewing existing modelling approaches and considering future approaches for use by the Working Group, it was agreed that other bodies involved in similar modelling evaluations, such as the JGOFS Regional Testbed Program, should be consulted. The Working Group agreed that it would be useful to invite one or two experts with experience

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2 A minimally realistic model of an ecosystem is one that includes just sufficient components and interactions to enable the key dynamics of the system to be realistically portrayed.

across a variety of modelling approaches, such as from the JGOFS or other programs. It also noted that expertise from the WG-FSA Subgroup on Assessment Methods might be useful in this workshop. The Working Group also requested that Members consider bringing additional modelling experts, if possible, to contribute to the work at the workshop.

6.20 The steering committee was tasked with specifying an intersessional program of work to prepare for the workshop prior to the Scientific Committee meeting this year, including:

(i) advising the Scientific Committee of proposals for contributions from invited experts either during the intersessional period or at the workshop;

(ii) developing a review of the available literature on development of ecosystem models;

(iii) identifying the availability of software and other simulation environments;

(iv) preliminary consideration of the requirements for datasets, estimates of parameters and other aspects related to the second term of reference.

6.21 The Working Group agreed that intersessional work in preparation for the workshop should aim to address the first term of reference and, as far as practicable, the second term of reference in time for discussion at the workshop. In particular, it agreed that sensitivity tests of the available models would be valuable to identify how the outputs might vary between models based on the same input parameters.

6.22 An interim progress report of the steering committee will be circulated at the Scientific Committee meeting. The steering committee members facilitating this work are indicated in parentheses. It is intended that this report will provide, *inter alia*:

(i) advice on the potential contributions from experts in preparation for the workshop and in participating in the development of models at the workshop (Drs Hill and Southwell);

(ii) a first attempt at drawing together relevant literature and information on the development of ecosystem models elsewhere as per the first term of reference (Prof. Hofmann and Dr Murphy);

(iii) a catalogue of available software and other simulation environments for ecosystem modelling (Drs Ramm, Watters and Gasiukov);

(iv) preliminary consideration of the requirements for datasets, estimates of parameters and other aspects related to the second term of reference (Drs Trathan, Reid and Naganobu);

(v) preliminary outline of the aims and specifications for ecosystem modelling as it relates to the development of management procedures for krill (Drs Constable, Davies and Kirkwood).

6.23 The steering committee has noted that the areas of expertise that could be brought to this work include:

(i) development of operating models for the purpose of evaluating management procedures;

(ii) development of models that take account of biological and physical coupling;

(iii) different approaches in food-web modelling;

(iv) development of spatially structured food-web models;

(v) development of foraging models in large-scale systems which may include optimal foraging models.

6.24 The Working Group felt that additional expertise in relation to term of reference (ii)(c), dynamics of the krill fishing fleet, would be desirable. Dr Sushin suggested that Dr S. Kasatkina (Russia) could make a valuable contribution on this issue, and Dr D. Miller (Secretariat) noted that a representative of the Secretariat would also be helpful. The Working Group recommended that the Scientific Committee give consideration to additional expertise in relation to specific issues that would benefit the workshop.

Workshop on Management Procedures

6.25 The Working Group noted that initial planning for the Workshop on Management Procedures in 2005 was under way. In this regard, Dr Hewitt suggested that the workshop be co-convened by Drs Reid and Watters. The Working Group agreed with Dr Hewitt's suggestion.

Long-term Work Plan

2003/04 Intersessional Work

6.26 Tasks identified by the Working Group for the 2003/04 intersessional period are listed in Table 3.

6.27 The Working Group welcomed the invitation from Italy to host the 2004 meeting in Siena, Italy, within the period from 5 July to 10 August. It was noted that specific dates for WG-EMM-04 will need to be determined at the Scientific Committee meeting, and should take into account, where possible, a concurrent SCAR conference in Bremen, Germany, from 26 to 28 July, and the need to coordinate with the Subgroup on Assessment Methods of WG-FSA.

Historical Record of Work Undertaken by WG-EMM

6.28 The Working Group thanked the Secretariat for preparing WG-EMM-03/23, which outlined in tabular form the historical development of tasks put forward and completed by WG-EMM since 2001. The Working Group endorsed the utility and format of the paper and encouraged the Secretariat to undertake similar summaries in the future.

Long-term Work Plan

6.29 The long-term work plan of the Working Group (SC-CAMLR-XXI, Annex 4, Table 3) was revised to reflect recent progress and the need for future work. A revised work plan is outlined in Table 4.

6.30 The Working Group welcomed initial proposals for the subdivision of the precautionary catch limit in Area 48 at this meeting (paragraphs 5.14 to 5.16) and encouraged the submission of additional proposals in 2004. The Working Group noted that it had indicated to the Scientific Committee that it would forward a recommendation on this topic in 2004. Most participants agreed that this was possible. However, some participants felt that additional time may be needed to achieve a consensus recommendation.

6.31 Following the review of CEMP (paragraphs 2.1 to 2.18), further analytical work has been identified to occur intersessionally before the 2004 meeting (Appendix D, Table 9).

6.32 Following the establishment of a steering committee, terms of reference and an initial intersessional work plan at this meeting, preliminary work is on target for the workshop on predator–prey–fishery–environment models in 2004 (paragraphs 6.15 to 6.22).

6.33 In considering the work plan for the evaluation of management procedures, Dr Sushin indicated that there is a need to elaborate the scientific basis for the setting of reference points for predator population size as a basis for management.

6.34 Dr Hewitt noted that evaluation of management procedures will require the definition of specific operational objectives to reflect the intent of Article II of the Convention, and recalled the long-standing request for operational definitions of Article II at WG-EMM. Dr Hewitt indicated that the Working Group would welcome such submissions at any of its future meetings prior to the 2005 workshop.

6.35 A planning session for the 2005 Workshop on Management Procedures is scheduled to occur at the 2004 meeting of WG-EMM.

6.36 The Working Group noted the comment by the Scientific Committee that the current reporting requirements from the krill fishery (Conservation Measure 23-06) should be considered as interim requirements, and that haul-by-haul data reported by 10-day periods will be required once the precautionary catch limit is subdivided among SSMUs (SC-CAMLR-XXI, paragraphs 4.25 to 4.27). In addition, when adopting the SSMUs in Area 48, the Commission noted that the submission of haul-by-haul data is necessary for future assessments of activities in these units (CCAMLR-XXI, paragraph 4.9(iii)).

6.37 The Working Group recognised that, following the CEMP review (paragraphs 2.1 to 2.18) and the proposed development of management procedures at the 2005 workshop, CEMP will undergo a process of refinement and refocusing in the future as management procedures and objectives are clarified.

6.38 The Working Group noted the progress report provided by the ad hoc Subgroup on Harvesting Units at this meeting (paragraphs 5.10 and 5.11) and also noted that further recommendations for Subareas 48.6, 88.1, 88.2 and 88.3, and Divisions 58.4.1 and 58.4.2 would be provided at the 2004 meeting of WG-EMM (paragraph 5.12).

6.39 Work on the assessment of predator demand will move from the present discussion stage to the consideration of pilot studies in 2004 and 2005 (paragraph 6.11).

6.40 The Working Group noted that the initial 2002–2005 work plan outlined in SC-CAMLR-XXI, Annex 4, Table 3, has been very useful in guiding progress towards its long-term goal of developing a feedback approach to manage the krill fishery. However, the Working Group recognised that as the end of that time frame approaches, attention needs to be given to planning beyond 2005.

6.41 The Working Group recalled the workshop in 2001 that resulted in the present work plan, and considered that a similar workshop to revise the current plan may be necessary at some time in the future. A planning session for such a possible workshop is scheduled in the revised plan for 2005 under the subtitle ‘Strategic Planning’.

6.42 The Working Group discussed whether the scope of its work should expand from its current krill-centric focus to include other species and systems. The consensus of the Working Group was to remain focused on the krill-centric system for the immediate future, but that the issue could be addressed in a future strategic review of the work plan. In that context, it was thought that the workshop on predator–prey–fishery–environment models in 2004 might point to other elements of the system in need of attention. Paragraph 4.90 discusses a way to improve assessments of ecosystem considerations relating to species other than krill and dependent species.

Key Points for Consideration by the Scientific Committee

Predator Surveys

6.43 Following further discussion by the correspondence group on land-based predator surveys, the Working Group agreed that work should initially focus on colonial-breeding penguins, which as a group are both the most tractable of the land-based predators for broad-scale survey and major consumers of krill (paragraph 6.1).

6.44 The Working Group also agreed that rather than attempting surveys at circumpolar scale at the first instance, a more prudent approach would be to select a few regions for pilot studies to evaluate methodologies, followed by broader-scale application of evaluated methods depending on the results of such pilot studies. The Working Group agreed that pilot studies would best focus on regions in East Antarctica and the lower latitudes of West Antarctica, which provide contrasting complexities for surveys and therefore likely differing feasibilities (paragraph 6.11).

6.45 Given the above staged approach, the Working Group agreed that preparation of a prospectus and detailed background document, as recommended in last year's advice to the Scientific Committee in the context of surveys at circumpolar scale and for all predator species (SC-CAMLR-XXI, Annex 4, paragraphs 6.26 and 6.51), was unnecessary at this stage of investigation, but may be useful at a later date (paragraph 6.12). The Working Group requested the correspondence group to continue intersessional work to further progress on the land-based predator survey initiative.

Workshop on Management Models

6.46 In preparation for a workshop next year on ecosystem models (titled 'Workshop on Plausible Ecosystem Models for Testing Approaches to Krill Management'), a steering committee was established to consider terms of reference and an intersessional work plan for the coming year. The Working Group endorsed and accepted the work of the steering committee. An interim progress report of the steering committee will be circulated at the Scientific Committee meeting (paragraph 6.22).

6.47 The Working Group endorsed the principle of inviting one or two experts with experience across a variety of modelling approaches (paragraph 6.23), and noted that this would have budgetary implications for the Scientific Committee. The Working Group also recommended that the Scientific Committee give consideration to additional expertise in relation to specific issues that would benefit the workshop (paragraph 6.24).

Workshop on Management Procedures

6.48 The Working Group recommended that the Workshop on Management Procedures planned for 2005 be co-convened by Drs Reid and Watters (paragraph 6.25).

Long-term Work Plan

6.49 The Working Group reviewed progress towards its long-term goal of developing a feedback approach to manage the krill fishery. The revised work plan is summarised in Table 4. Work identified by the Working Group for the 2003/04 intersessional period is listed in Table 3. Tasks identified by the Working Group for the steering committee for the Workshop on Plausible Ecosystem Models for Testing Approaches to Krill Management are noted in paragraphs 6.20 to 6.22.

Next Meeting of WG-EMM

6.50 The Working Group welcomed the invitation from Italy to host the 2004 meeting in Siena, Italy, within the period from 5 July to 10 August. It was noted that specific dates for WG-EMM-04 will need to be determined at the Scientific Committee meeting, and should take into account, where possible, a concurrent SCAR conference in Bremen, Germany, from 26 to 28 July, and the need to coordinate with the Subgroup on Assessment Methods of WG-FSA (paragraph 6.27).

OTHER BUSINESS

Krill Workshop

7.1 An international workshop on understanding living krill for improved management and stock assessment was held at Port of Nagoya Public Aquarium, Nagoya, Japan, from 1 to 4 October 2002 (WG-EMM-03/56). The workshop included presentations and discussions of research on live krill. Twelve papers from the meeting will be published in a special volume of the journal *Marine and Freshwater Behaviour and Physiology* in late 2003. WG-EMM thanked the conveners of the meeting (Dr Kawaguchi and Mr Y. Hirano) and the sponsors (Fisheries Research Agency, Fisheries Agency, Port of Nagoya Public Aquarium) for supporting this important meeting.

Krill Survey Methodology

7.2 Dr Bergström advised that he had submitted a proposal to the European Union Program for funding for a series of four courses and a symposium on micronekton and krill survey methodology. This series is to be known as 'Krill Survey Methodology (KrillSUME)' and the proposal was developed with the assistance of Drs Everson, Siegel, Hewitt and D. Demer (USA).

7.3 Each course will introduce up to 15 young scientists to internationally accepted acoustic- and net-sampling protocols used by CCAMLR Members. The courses will be based at the Kristineberg Marine Research Station (Sweden) and will use Nordic krill (*Meganyctiphanes norvegica*) in Gullmarsfjorden as a proxy for Antarctic krill in the Southern Ocean. The courses will be held in the spring and autumn of 2004 and 2005, with a concluding symposium scheduled at the end of the two-year period.

7.4 The Working Group thanked Dr Bergström for his efforts in developing the proposal, and hoped that funding can be secured for this important series of courses.

Informal Ross Sea Research Meeting

7.5 Dr Wilson advised that an informal meeting had been held in Cambridge, UK, on 20 August 2003, between various CCAMLR Members involved in research in the Ross Sea. The meeting was attended by Drs S. Corsolini and S. Olmastroni (Italy), E. Fanta (Brazil), S. Hanchet, K. Sullivan and P. Wilson (New Zealand).

7.6 The aim of the meeting was to informally investigate how the various groups conducting research in the Ross Sea might best aid and assist each other by collaboration where appropriate and by data and hardware/logistics sharing. Issues such as ecosystem modelling, toothfish ecology, the currently running latitudinal-gradient study, krill studies and biodiversity work were briefly discussed. One suggestion for the future was to hold another Ross Sea workshop in New Zealand in 2006. The focus could be on modelling the Ross Sea marine ecosystem. Models developed at the next WG-EMM meeting could form the basis of such a study.

7.7 The Working Group welcomed these plans for enhanced collaboration and encouraged further developments and reports to CCAMLR.

IWC

7.8 In the report of the CCAMLR Observer, Dr K.-H. Kock (Germany), at the 55th Meeting of the IWC Scientific Committee held in Berlin, Germany, from 26 May to 6 June 2003 (SC-CAMLR-XXII/BG/2), it was noted that the IWC is planning work on defining the edge of the Antarctic sea-ice. The findings of such work may be of interest to WG-EMM in the context of the current sea-ice definitions used in generating CEMP Indices F2a (sea-ice cover in September), F2b (proportion of the year which is free of ice) and F2c (weeks when sea-ice is within 100 km of a site). The Secretariat was requested to ensure that CCAMLR was kept in touch with relevant developments from this work.

Modelling Antarctic Ecosystems

7.9 WG-EMM noted that a workshop on modelling Antarctic Ecosystems was held at the University of British Columbia, Vancouver, Canada, in April 2003. The workshop aimed to capture the critical features of Antarctic ecology in ECOPATH/ECOSIM-based models and forecast the impacts of fisheries and climate change on Antarctic ecosystems. The edited proceedings from the workshop will be published as a Fisheries Centre Research Report. Dr Hill attended the workshop and agreed to arrange for a copy of the proceedings to be lodged with the Secretariat.

SO GLOBEC

7.10 WG-EMM noted the information on SO GLOBEC which Prof. Hoffman reported at the CEMP Review Workshop (Appendix D, paragraphs 69 to 76). In addition, Dr Nicol advised that the marine science survey conducted by Australia off the Mawson Coast in East Antarctica in 2003 was held under the auspices of SO GLOBEC.

Fourth World Fisheries Congress

7.11 Last year, the Scientific Committee endorsed the proposal by WG-EMM and WG-FSA for the involvement of the conveners of these working groups in the planning of a session on the Southern Ocean at the Fourth World Fisheries Congress, 2 to 6 May 2004, Vancouver, Canada (SC-CAMLR-XXI, paragraph 9.33). This is an important opportunity to present CCAMLR science and resource management in a global context.

7.12 WG-EMM noted that Drs Everson and Hewitt had prepared and submitted an abstract describing case studies on CCAMLR's management of krill, icefish and toothfish fisheries. In addition, the Secretariat had prepared complementary abstracts on the management of by-catch and a comparison between CCAMLR's management efforts and those of other regional management organisations. Participation by the Secretariat at the congress will be discussed at SC-CAMLR-XXII.

Deep Sea 2003 Conference

7.13 The Working Group noted that planning for the Deep Sea 2003 Conference, which is being co-sponsored by CCAMLR, is well under way. Drs Miller and Sabourenkov are members of the Steering Committee and Program Committee respectively. The meeting will be held in Queenstown, New Zealand, from 1 to 5 December 2003 and will focus on the governance and management of deep-sea fisheries. Related workshops are planned for the week immediately prior to the conference. Information and registration is available from www.deepsea.govt.nz.

Collaborative Project

7.14 Prof. Croxall had been informed of a collaborative program by Ukraine and Bulgaria on research into gentoo penguin breeding biology at Vernadsky Station, Antarctic Peninsula (Ukraine) and Livingston Island, South Shetland Islands (Bulgaria). The Working Group noted that this research may be relevant to CCAMLR and could potentially contribute to CEMP if sites and methods were (or could be) selected and applied in accordance with CEMP standard methods. The Secretariat was requested to contact Ukraine and Bulgaria, seek further information on the scope of this research and report to the meeting of the Scientific Committee.

Revision of the Rules for Access and Use of CCAMLR Data

7.15 Last year, the Commission tasked the Secretariat with consulting Members to develop a draft set of rules for access to CCAMLR data based on advice provided by the Scientific Committee (CCAMLR-XXI, paragraphs 4.67 and 4.68; SC-CAMLR-XXI, Annex 6).

7.16 In developing a draft set of rules, the Secretariat built on, and revised, the current Rules for Access and Use of CCAMLR Data (CCAMLR-XXII/8). The key principles being addressed and underlying CCAMLR data access are (i) data submission and access to be facilitated in respect of CCAMLR endorsed work; (ii) data security protected on submission and archiving; (iii) Secretariat to serve as secure data archive; (iv) data access governed by specified guidelines; (v) any data use to be specifically defined; (vi) distinction between data for CCAMLR work endorsed by the Commission and/or Scientific Committee and individual requests by Members (and/or others) not explicitly related to CCAMLR work program; (vii) guidelines required for specifying data and accompanying levels of security on release, particularly in terms of requests as per the latter part of (vi) above; and (viii) Secretariat to administer data guidelines.

7.17 The Working Group noted the draft set of rules and thanked the Secretariat for this work.

Publication of Results from the CCAMLR-2000 Survey

7.18 Dr Watkins informed the Working Group of the status of the special issue of *Deep-Sea Research* for the CCAMLR-2000 Survey. Papers had now been reviewed and 16 papers revised in accordance with the reviewers recommendations. These papers have been sent to a technical editor who was editing the papers to ensure consistency of terminology and language. Final author approval of the technical editing had been received for five papers and was awaited for another six papers. The remaining six papers were currently undergoing technical editing and would be sent out to authors for approval soon.

7.19 To ensure that papers were ready to be submitted to *Deep-Sea Research* as soon as possible, authors would be asked to return any comments on the final edits within two weeks of receiving them. The editor and technical editor would assume that after this period all changes would be taken as approved by authors. Dr Watkins will liaise with the editor of *Deep-Sea Research* to ensure that the money allocated from this year's CCAMLR budget for publication of the papers can be utilised within the present financial year.

7.20 Dr Watkins further informed the Working Group that he had made a presentation entitled 'The CCAMLR-2000 Synoptic Survey: a synthesis of an interdisciplinary, multi-ship international biological oceanography cruise in the Southern Ocean' on behalf of co-authors (Drs Grant, Sushin, Hewitt, Naganobu, Brandon, Murphy and Siegel) at the biennial UK Marine Science Symposium in September 2002.

ADOPTION OF THE REPORT AND CLOSE OF THE MEETING

8.1 The report of the ninth meeting of WG-EMM was adopted.

8.2 In closing the meeting, Dr Hewitt thanked all participants for contributing to the meeting and the workshop. The Working Group had completed another key stage in its five-year work plan.

8.3 Dr Hewitt also thanked the local organisers of the meeting, led by Prof. Croxall and Dr Reid, for hosting the meeting in the historic setting of Girton College and for providing excellent support.

8.4 Dr Hewitt thanked the Secretariat for their work in support of WG-EMM, both at the meeting and during the intersessional period.

8.5 Prof. Croxall, on behalf of the Working Group, thanked Dr Hewitt for leading the Working Group through another successful meeting.

8.6 The meeting was closed.

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Table 1: Location and duration of time series of CEMP predator parameters in Area 48.

Subarea	CEMP Predator Parameter	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
48.1	A1 arrival weight (g)																			X	X	X	X	X			X		
	A2 incubation shift (day)							X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	A3 breeding pairs				X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	A5a foraging duration (h)													X	X	X	X	X	X	X	X	X	X	X	X				
	A6a chicks fledged per egg laid																			X	X	X	X	X	X	X	X	X	X
	A6c chicks fledged per chicks hatched													X	X	X	X	X	X	X	X	X	X	X	X				
	A7 fledging weight (g)							X	X					X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	A8 stomach contents weight (g)			X				X	X					X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	A8b proportion item in diet			X				X	X					X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	A8c occurrence item in diet			X				X	X					X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	C1 foraging duration (h)													X		X	X	X	X	X	X			X	X	X	X	X	X
	C2b pup growth rate (kg/month)													X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
48.2	A1 arrival weight (g)													X	X	X							X		X	X	X	X	X
	A3 breeding pairs																X	X	X	X	X	X	X	X	X	X	X	X	X
	A6a chicks fledged per egg laid															X	X	X	X	X	X	X	X	X	X	X	X	X	X
	A7 fledging weight (g)																						X	X	X	X	X	X	X
	A8 stomach contents weight (g)																						X	X	X	X	X	X	X
	A8b proportion item in diet																						X	X	X	X	X	X	X
	A8c occurrence item in diet																						X	X	X	X	X	X	X
48.3	A1 arrival weight (g)														X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	A3 breeding pairs			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	A6a chicks fledged per egg laid		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	A7 fledging weight (g)														X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	A8 stomach contents weight (g)														X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	A8b proportion item in diet														X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	A8c occurrence item in diet														X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	B1a breeding pairs		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	B1b breeding success	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	C1 foraging duration (h)															X	X	X	X	X	X	X	X	X	X	X	X	X	X
	C2b pup growth rate (kg/month)															X	X	X	X	X	X	X	X	X	X	X	X	X	X

Table 2: Annual and 5-year catch (tonnes) of krill by subarea and SSMU for the past 15 fishing seasons. Antarctic Peninsula SSMUs: Pelagic Area (APPA); Bransfield Strait East (APBSE); Bransfield Strait West (APBSW); Drake Passage East (APDPE); Drake Passage West (APDPW); Antarctic Peninsula West (APW); Antarctic Peninsula East (APE); Elephant Island (APEI). South Orkney Islands SSMUs: Pelagic Area (SOPA); North East (SONE); South East (SOSE); West (SOW). South Georgia SSMUs: Pelagic Area (SGPA); East (SGE); West (SGW). Data Source: fine-scale data weighed to STATLANT data (FS%: percent of catch in STATLANT data reported in the fine-scale data).

Subarea	SSMU	CCAMLR Season (e.g. 1993: 1 December 1992–30 November 1993)														
		1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
48.1	APPA	9376	8474	6090	7069	7363	62	11	8873	6287	1721	4031	2961	1472	6	47
48.1	APBSE	0	0	106	1078	35	0	0	0	0	13	102	908	4028	763	139
48.1	APBSW	0	17	0	6	5	49	108	190	503	87	677	19	5350	4071	419
48.1	APDPE	32020	37612	13832	17266	23689	1059	1077	3102	5714	17474	18775	10651	22771	20592	2127
48.1	APDPW	9711	17158	691	16149	44554	34084	26517	12393	36323	20370	24105	11285	32515	27426	6857
48.1	APE	0	0	0	0	0	0	0	0	25	0	0	0	0	0	0
48.1	APEI	22818	42046	23975	30949	6948	2708	17847	15955	12485	9136	5783	8908	11534	5175	6037
48.1	APW	28	33	8		17	0	5	0	0	0	2867	3883	109	539	0
48.2	SOPA	4703	72936	81821	5497	39434	1433	4	29	41	0	631	1004	3185	2	77
48.2	SONE	4394	14	12659	13378	2967	4703	81	1351	3	91	305	3448	1145	1522	3734
48.2	SOSE	19601	0	0	0	0	0	1317	25	0	0	0	12576	1511	2823	1293
48.2	SOW	71199	15370	129087	148673	52971	8357	18062	50434	2105	8	6066	46315	11265	1252	75089
48.3	SGPA	107307	1411	11351	7485	410	132	385	432	15	0	53	0	6375	408	44
48.3	SGE	107666	157200	89571	79005	60872	3712	20118	42604	24973	26647	23284	0	11465	28380	28719
48.3	SGW	24	0	6908	4763	18344	11890	11	297	2685	106	3419	0	1705	11223	1405
Other		106	0	0	0	55	38	0	0	0	0	0	0	0	0	0
Total		388953	352271	376099	331318	257663	68227	85544	135686	91156	75653	90098	101957	114430	104182	125987
FS%		98	100	100	96	91	98	100	95	100	100	99	100	99	89	69

Subarea	SSMU	Total Catch (tonnes)			Percent Catch		
		1988–1992	1993–1997	1998–2002	1988–1992	1993–1997	1998–2002
48.1	APPA	38371	16863	8513	2	4	2
48.1	APBSE	1218	13	5939	0	0	1
48.1	APBSW	29	929	10534	0	0	2
48.1	APDPE	124419	28270	74899	7	6	14
48.1	APDPW	88263	125573	102168	5	28	19
48.1	APE	0	25	0	0	0	0
48.1	APEI	126735	57497	37433	7	13	7
48.1	APW	86	5	7395	0	0	1
48.2	SOPA	204391	1349	4899	12	0	1
48.2	SONE	33412	5703	10153	2	1	2
48.2	SOSE	19601	1328	18203	1	0	3
48.2	SOW	417299	77393	139981	24	17	26
48.3	SGPA	127964	943	6879	7	0	1
48.3	SGE	494314	117040	91830	29	26	17
48.3	SGW	30040	13687	17749	2	3	3
Other		160	33	0	0	0	0
Total		1706304	446650	536575	100	100	100

Table 3: List of tasks identified by WG-EMM for the 2003/04 intersessional period. The paragraph numbers (Ref.) refer to this report unless stated otherwise. √ – general request, √√ – high priority.

	Task	Ref.	Priority	Action Required	
				Members	Secretariat
	CEMP Review Workshop				
1.	Accomplish tasks identified by the workshop as listed in Appendix D, Table 9, particularly key tasks.	2.16, 2.20	√ √√	Members identified (tasks 1 to 6)	Secretariat (tasks 1 and 7)
	Status and trends in krill fisheries				
2.	Request Members to include in their krill fishing plans, as a minimum, information specified by WG-EMM.	3.8, 3.48	√√	Members	Remind
3.	Request Members to maintain consistency in the reporting of CPUE data which should include, in particular, search time as well as catch per tow.	3.16	√	Members	Remind
4.	Carry out analyses of the sensitivity and power to detect trends in indices of krill fisheries performance (CPUE) and the evaluation of functional responses of dependent species to those indices.	3.22–3.25, 3.49	√√	Dr Kawaguchi in cooperation with data holders	Assist and participate as required
5.	Reiterate the need for haul-by-haul data for WG-EMM scientific work.	3.14	√√	Members	Advise
6.	Contact companies offering krill for sale on the Internet, identify companies actively engaged in krill fishing in the Convention Area, contact base countries of such companies and request compliance with CCAMLR conservation measures.	3.32	√		Implement
	Scientific Observers Manual				
7.	Revise the manual to incorporate new krill data collection and sampling requirements, and guidelines for sampling by-catch fish larger than 7 cm.	3.40–3.42	√	WG-FSA be advised	Implement
8.	Translate existing e-logbooks into all official languages of CCAMLR.	3.44(ii)	√	WG-FSA be advised	Implement
9.	Include krill observation logbook in the standard set of logbooks published in the manual.	3.44(v)	√		Implement
10.	Revise krill colour chart for its subsequent inclusion in the manual.	3.43	√	Dr Kawaguchi	Remind
	Status of the krill-centric ecosystem				
11.	Request data owners to review the annual report of CEMP indices and anomalies (WG-EMM-03/24) prior to the compilation and submission of future reports to WG-EMM.	4.7	√	Data owners	Implement
12.	Start implementing the ordination approach to examining CEMP indices.	4.18	√√	WG-EMM	Implement

	Task	Ref.	Priority	Action Required	
				Members	Secretariat
13.	Investigate the feasibility of calculating fishery–predator overlap indices for each of the SSMUs.	4.4	√		Implement
14.	Identify the existence of datasets describing aspects of krill demography and distribution, and submit their synopses or analyses.	4.35	√	Members	Encourage
15.	Update protocols for collecting samples for toxicological analysis for inclusion in the *CEMP Standard Methods*, Part IV, Section 5.	4.48, 4,49	√		Implement
16.	Refer Method T1 to WG-FSA in order that it may provide advice on how the data obtained by this method might be used in the work of that group.	4.94–4.96	√	WG-FSA	Forward a request
17.	Amend Index C2b as decided by WG-EMM.	4.104	√		Implement
18.	Request WG-FSA to consider how to improve the assessment of ecosystem considerations relating to species other than krill.	4.90, 4.91	√		
	Status of management advice				
19.	Request Members to review the status of CEMP sites for which updated maps have not yet been submitted and provide maps, if appropriate.	5.2	√	Brazil, USA	Remind
20.	Prepare draft of updated guidelines for production of maps for both CEMP sites and marine protected areas to be proposed in accordance with Article IX.2(g) of the Convention.	5.3	√		Implement
21.	Review membership of the Advisory Subgroup on Protected Areas.	5.5	√	Subgroup Convener	Implement
22.	Produce an outline of new harvesting units of appropriate size for krill catch reporting for Subareas 48.6, 88.1, 88.2 and 88.3, Divisions 58.4.1 and 58.4.2.	5.12	√√	Members	Remind
23.	Develop additional options for subdivision of krill precautionary catch limits, including options that takes account of historical fishing information; prepare proposals for WG-EMM.	5.27, 5.28, 5.30	√√	Members	Remind
	Future work of WG-EMM				
24.	Prepare for the Workshop on Plausible Ecosystem Models for Testing Approaches to Krill Management as required in accordance with the adopted plan of intersessional work.	4.76, 6.19–6.24	√√	Implement (Steering Committee and identified scientists)	Implement specific tasks identified
25.	Develop an experimental framework for ground truthing satellite imagery for locating penguin colonies.	6.5	√	Correspondence group	Remind

	Task	Ref.	Priority	Action Required	
				Members	Secretariat
26.	Continue evaluation of sources for obtaining satellite imagery.	6.3	√	Correspondence group	
27.	Enquire about availability of data, other than in CEMP database, on penguin nest attendance and breeding chronology.	6.9	√	Correspondence group	Implement
28.	Keep under review the IWC work on defining the edge of the Antarctic sea-ice.	7.8	√	CCAMLR Observers at IWC	Implement
29.	Obtain information on collaborative research on gentoo penguins by Bulgaria and Ukraine.	7.14	√	Ukraine, Bulgaria	Implement
	Other considerations				
30.	Continue analyses of krill catch by SSMU.	3.10	√	Secretariat	Remind
31.	Conduct analyses of threshold krill density for krill fisheries using the finest-scale fisheries information.	3.34, 3.50, 4.107	√√	Members	Remind
32.	Carry out work to compare the distribution of actual fishing with that predicted from distribution of threshold levels for Subareas 48.1 and 48.3.	4.28	√	Members	Remind
33.	Develop hypotheses on origin and transport of krill for use in management of krill.	4.36	√	Members	Remind
34.	Conduct investigations into krill distribution in inshore habitats.	4.40	√	Members	Remind
35.	Consider obtaining a coherent overview of environmentally induced variability in the Southern Ocean and consider potential change scenarios that might influence ecological relationships with implication to fisheries management.	4.59	√	Members	Remind
36.	Carry out work on the evaluation of icefish indices which are of relevance to studies of the krill-centred ecosystem.	4.88	√	Members	Remind
37.	Investigate designs for surveying abundance of colonial-breeding penguins over broad-scale regions.	6.10	√	Members	Remind

Table 4: Revised plan of work scheduled between 2002 and 2005.

Issue	2002	2003	2004	2005
Subdivide Precautionary Catch Limit	Discussion	Initial proposals	Additional proposals Recommendation	
Revised Krill Management Procedure				
Delineation of small-scale management units in Area 48	Workshop (SC-CAMLR-XXI, Annex 4, Appendix D)			
CEMP review	Planning session	Workshop (SC-CAMLR-XXII, Annex 4, Appendix D)	Consideration of further analytical work (SC-CAMLR-XXII, Annex 4, Appendix D, Table 9)	
Selection of appropriate predator–prey–fishery–environment models	Discussion	Planning session	Workshop	
Evaluation of management procedures including objectives, decision rules, performance measures	Discussion	Discussion	Planning session	Workshop
Reporting requirements from fishery	Discussion	Interim requirements adopted by Commission	Consideration of revised requirements	Recommendation
Monitoring requirements from CEMP	Discussion	Discussion	Initial specifications	Revised specifications
Assessment of Predator Demand				
Large-scale surveys of land-based predators	Discussion	Discussion	Consideration of pilot studies	Consideration of pilot studies
Subdivision of Large FAO Statistical Areas				
Establishment of harvesting units	Discussion	Discussion	Proposals for 48.6, 88.1, 88.2, 88.3, 58.4.1 and 58.4.2 Recommendation	
Strategic Planning	Discussion	Discussion	Discussion	Planning session for possible workshop

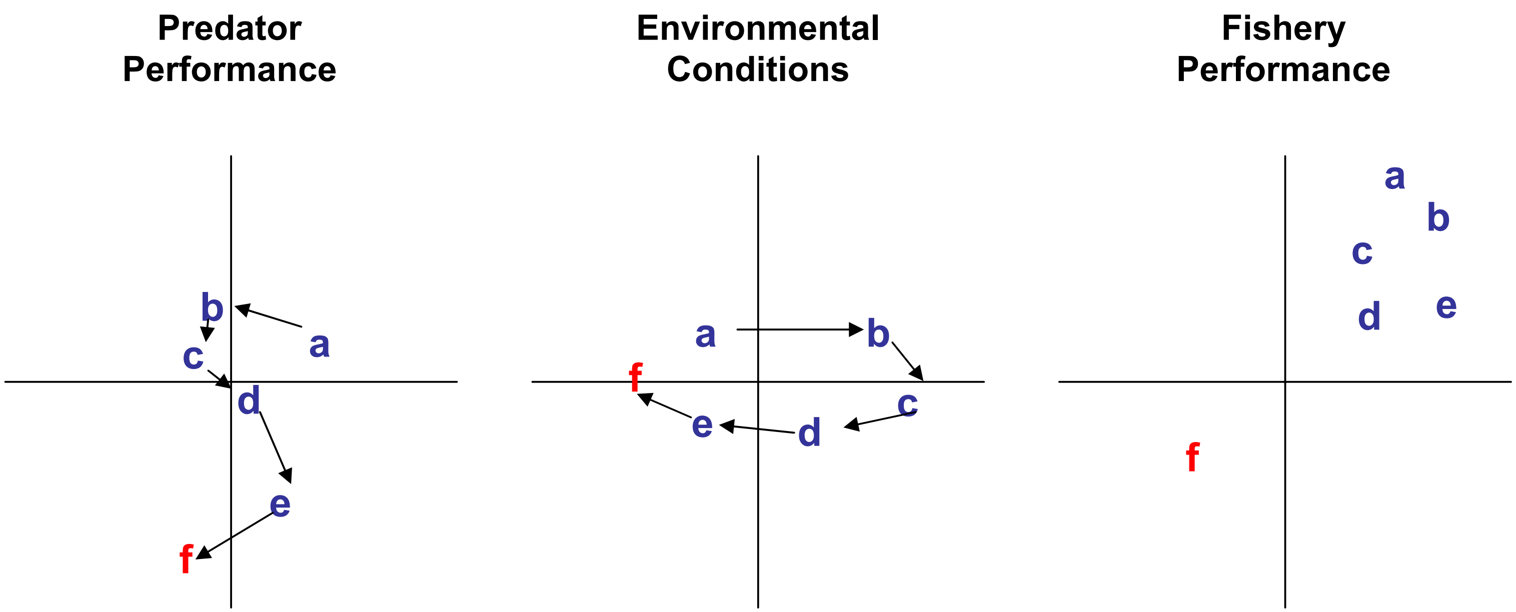

Figure 1: A hypothetical example of possible results of an ordination approach where a time series of data (a–f, where a–f denote years) are plotted for predator performance, physical indices (i.e. environmental conditions) and fishery performance. The three examples identify scenarios showing a trend in predator performance, a cyclical process in environmental conditions and an anomaly in year f in fisheries performance.

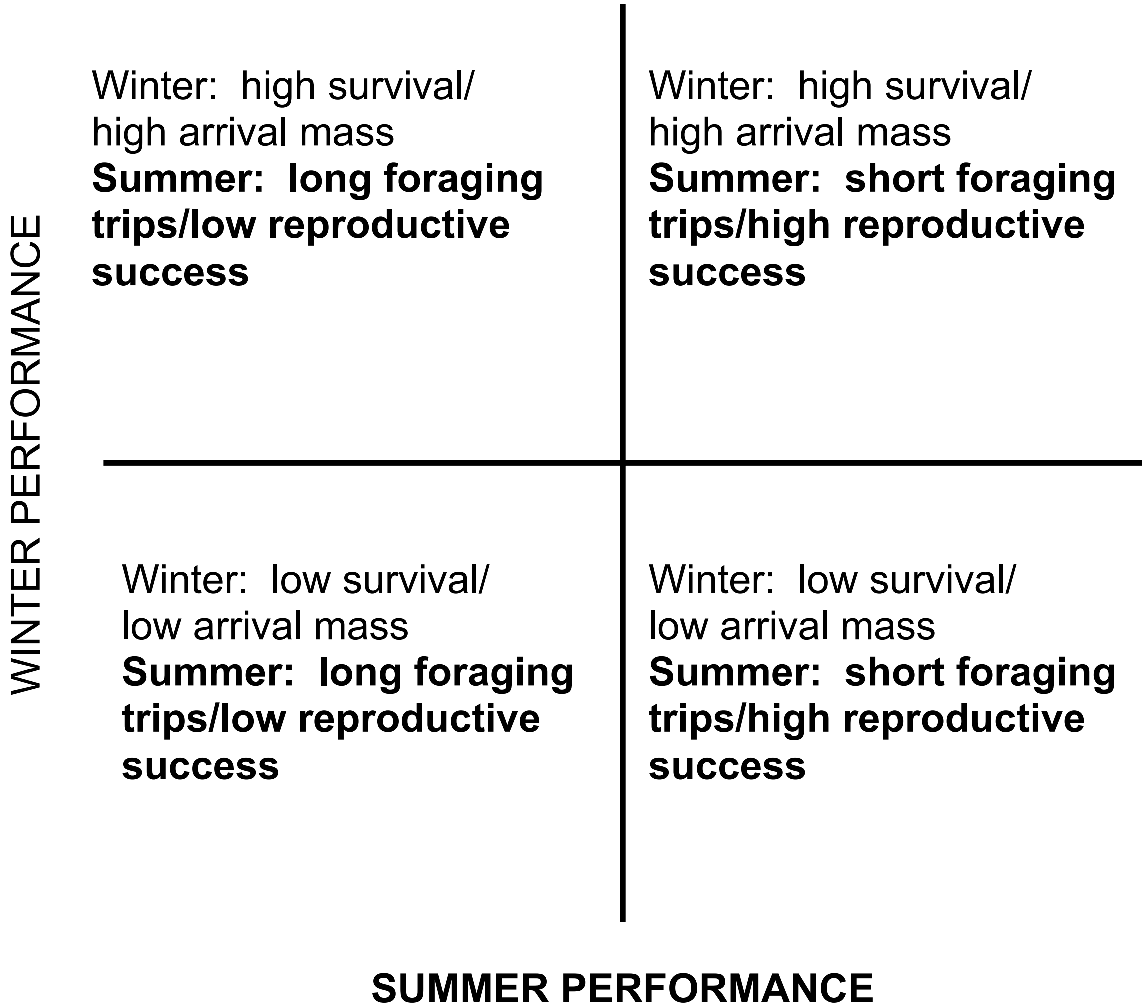

Figure 2: An interpretive example of predator performance indices where the first two ordination axes describe variability in indices that reflect 'winter' and 'summer' processes that might be used for a time series of CEMP indices for any given ISR.

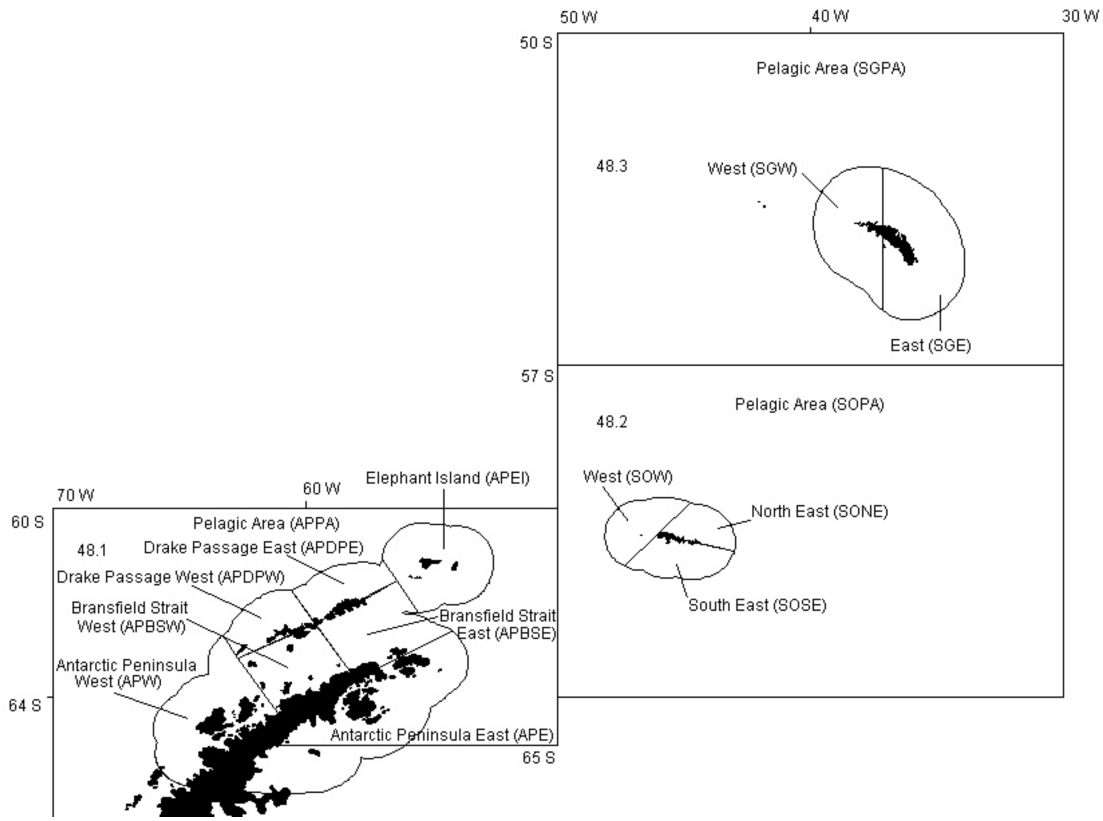

Figure 3: Location of small-scale management units.

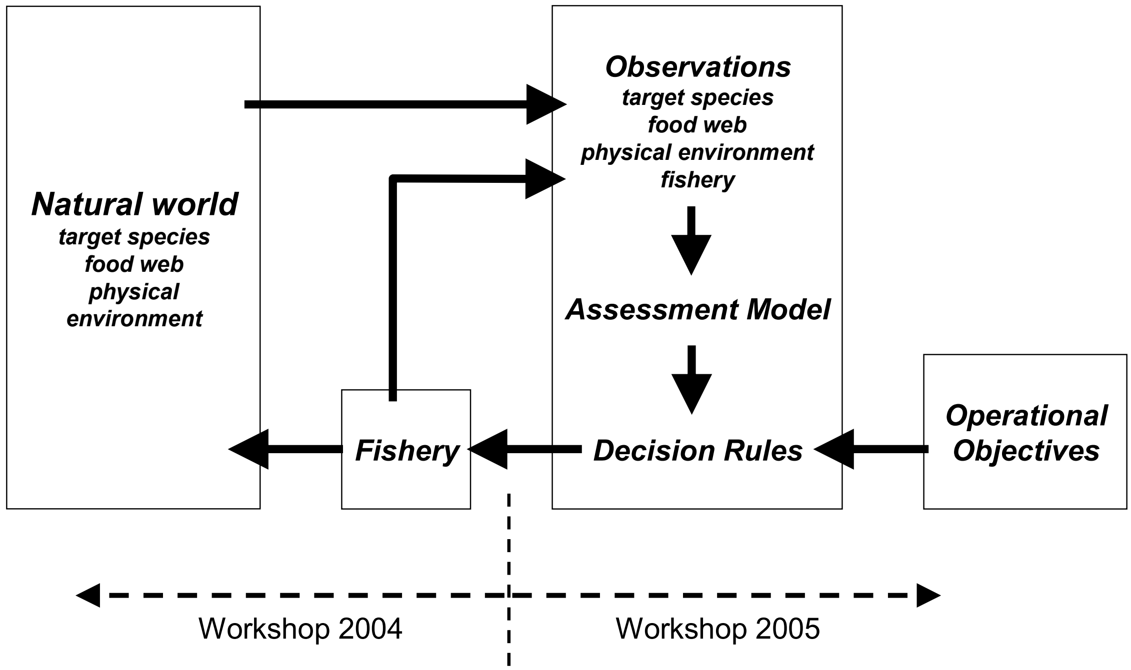

Figure 4: Conceptual framework for the development of a management procedure. The management procedure includes the operational objectives and the consequent field collection of data, the analyses and assessment methods and the decision rules that influence the fisheries interaction with the natural world. Decision rules are framed in terms of what is required to meet the operational objectives given the results of the assessment model. *Operating models capture the range of plausible scenarios of the natural world and how a fishery interacts with that world.*

APPENDIX A

AGENDA

Working Group on Ecosystem Monitoring and Management
(Cambridge, UK, 18 to 29 August 2003)

1. Introduction
    1.1 Opening of the meeting
    1.2 Adoption of the agenda and organisation of the meeting

2. CEMP Review Workshop

3. Status and trends in the krill fishery
    3.1 Fishing activity
    3.2 Description of the fishery
    3.3 Regulatory issues
    3.4 Key points for consideration by the Scientific Committee

4. Status and trends in the krill-centric ecosystem
    4.1 Status of predators, krill resource and environmental influences
    4.2 Further approaches to ecosystem assessment and management
    4.3 Other prey species
    4.4 Methods
    4.5 Future surveys
    4.6 Key points for consideration by the Scientific Committee

5. Status of management advice
    5.1 Designation of protected areas
    5.2 Harvesting units
    5.3 Small-scale management units
    5.4 Analytical models
    5.5 Existing conservation measures
    5.6 Key points for consideration by the Scientific Committee

6. Future work
    6.1 Predator surveys
    6.2 Workshop on Management Models
    6.3 Long-term work plan
    6.4 Key points for consideration by the Scientific Committee

7. Other business

8. Adoption of report and close of meeting.

APPENDIX B

LIST OF PARTICIPANTS

Working Group on Ecosystem Monitoring and Management
(Cambridge, UK, 18 to 29 August 2003)

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APPENDIX C

LIST OF DOCUMENTS

Working Group on Ecosystem Monitoring and Management
(Cambridge, UK, 18 to 29 August 2003)

WG-EMM-03/1	Provisional Agenda and Provisional Annotated Agenda for the 2003 Meeting of the Working Group on Ecosystem Monitoring and Management (WG-EMM)
WG-EMM-03/2	List of participants
WG-EMM-03/3	List of documents
WG-EMM-03/4	Shedding new light on the life cycle of mackerel icefish in the Southern Ocean K.-H. Kock (Germany) and I. Everson (United Kingdom) (*Journal of Fish Biology*, in press)
WG-EMM-03/5	The use of Antarctic shags to monitor coastal fish populations: evaluation and proposals after five years of test of a standard method R. Casaux and E. Barrera-Oro (Argentina) (*CCAMLR Science*, submitted)
WG-EMM-03/6	An 8-year cycle in krill biomass density inferred from acoustic surveys conducted in the vicinity of the South Shetland Islands during the austral summers of 1991/1992 through 2001/2002 R.P. Hewitt, D.A. Demer and J.H. Emery (USA) (*Aquatic Living Resources*, in press)
WG-EMM-03/7	Mackerel icefish size and age at South Georgia and Shag Rocks A.W. North (United Kingdom)
WG-EMM-03/8	Populations of surface-nesting seabirds at Marion Island, 1994/95 to 2002/03 R.J.M. Crawford, J. Cooper, B.M. Dyer, M.D. Greyling, N.T.W. Klages, P.G. Ryan, S.L. Petersen, L.G. Underhill, L. Upfold, W. Wilkinson, M.S. de Villiers, S. du Plessis, M. du Toit, T.M. Leshoro, A.B. Makhado, M.S. Mason, D. Merkle, D. Tshingana, V.L. Ward and P.A. Whittington (South Africa) (*African Journal of Marine Science*, 25, in press (2003))

WG-EMM-03/9	Counts of surface-nesting seabirds breeding at Prince Edward Island, summer 2001/02 P.G. Ryan, J. Cooper, B.M. Dyer, L.G. Underhill, R.J.M. Crawford and M.N Bester (South Africa) (*African Journal of Marine Science*, 25, in press (2003))
WG-EMM-03/10	Decrease in numbers of the eastern rockhopper penguins *Eudyptes chrysocome filholi* at Marion Island, 1994/95 to 2002/03 R.J.M. Crawford, J. Cooper, B.M. Dyer, M.D. Greyling, N.T.W. Klages, D.C. Nel, J.L. Nel, S.L. Petersen and A.C. Wolfaardt (South Africa) (*African Journal of Marine Science*, 25, in press (2003))
WG-EMM-03/11	Population dynamics of the wandering albatross *Diomedea exulans* at Marion Island: long-line fishing and environmental influences D.C. Nel, F. Taylor, P.G. Ryan and J. Cooper (South Africa) (*African Journal of Marine Science*, 25, in press (2003))
WG-EMM-03/12	The oldest known banded wandering albatross *Diomedea exulans* at the Prince Edward Islands J. Cooper (South Africa), H. Battam, C. Loves, P. J. Milburn and L.E. Smith (Australia) (*African Journal of Marine Science*, 25, in press (2003))
WG-EMM-03/13	Unusual breeding by seabirds at Marion Island during 1997/98 R.J.M. Crawford, C.M. Duncombe Rae, D.C. Nel and J. Cooper (South Africa) (*African Journal of Marine Science*, 25, in press (2003))
WG-EMM-03/14	Conserving surface-nesting seabirds at the Prince Edward Islands: the roles of research, monitoring and legislation R.J.M. Crawford and J. Cooper (South Africa) (*African Journal of Marine Science*, 25, in press (2003))
WG-EMM-03/15	Population of macaroni penguins *Eudyptes chrysolophus* at Marion Island, 1994/95 to 2002/03, with information on breeding and diet R.J.M. Crawford, J. Cooper and B.M. Dyer (South Africa) (*African Journal of Marine Science*, 25, in press (2003))
WG-EMM-03/16	Population and breeding of the gentoo penguin *Pygoscelis papua* at Marion Island, 1994/95 to 2002/03 R.J.M. Crawford, J. Cooper, M. du Toit, M.D. Greyling, B. Hanise, C.L. Holness, D.G. Keith, J.L. Nel, S.L. Petersen, K. Spencer, D. Tshingana and A.C. Wolfaardt (South Africa) (*African Journal of Marine Science*, 25, in press (2003))

WG-EMM-03/17	Population, breeding, diet and conservation of Crozet shag *Phalacrocorax [atriceps] melanogenis* at Marion Island, 1994/95 to 2002/03 R.J.M. Crawford, J. Cooper, B.M. Dyer, A.C. Wolfaardt, D. Tshingana, K. Spencer, S.L. Petersen, J.L. Nel, D.G. Keith, C.L. Holness, B. Hanise, M.D. Greyling and M. du Toit (South Africa) (*African Journal of Marine Science*, 25, in press (2003))
WG-EMM-03/18	Population numbers of fur seals at Prince Edward Island, Southern Ocean M.N. Bester, P.G. Ryan and B.M. Dyer (South Africa) (*African Journal of Marine Science*, 25, in press (2003))
WG-EMM-03/19	Absence of haematozoa in breeding macaroni *Eudyptes chrysolophus* and rockhopper *E. chrysocome* penguins at Marion Island A. Schultz and S.L. Petersen (South Africa) (*African Journal of Marine Science*, 25, in press (2003))
WG-EMM-03/20	Modern mean monthly SST and SST anomalies off South Georgia during recent years (based on satellite data) G.P. Vanyushin (Russia)
WG-EMM-03/21	Differentiated catchability of trawls as a method for a more precise estimate of density of krill swarms and its biomass V. Akishin (Russia)
WG-EMM-03/22	WG-EMM Subgroup on Protected Sites: Terms of Reference – summary of CCAMLR decisions Secretariat
WG-EMM-03/23	History of development and completion of tasks put forward by WG-EMM (2001/02) Secretariat
WG-EMM-03/24	CEMP Indices 2003: analysis of anomalies and trends CCAMLR Secretariat
WG-EMM-03/25	General information about CEMP CCAMLR Secretariat
WG-EMM-03/26	Preliminary analyses in support of the CEMP Review Workshop: power analyses CCAMLR Secretariat

WG-EMM-03/27	Preliminary analyses in support of the CEMP Review Workshop: serial correlations CCAMLR Secretariat
WG-EMM-03/28	Krill fishery information CCAMLR Secretariat
WG-EMM-03/29	Diets of sympatrically breeding Adélie, gentoo and chinstrap penguins from Admiralty Bay, South Shetland Islands, Antarctica, 1981 to 2000 W.Z. Trivelpiece (USA), K. Salwicka (Poland) and S.G. Trivelpiece (USA)
WG-EMM-03/30	Krill biomass and density distribution in February–March 2002 in Subarea 48.3 S.M. Kasatkina and A.P. Malyshko (Russia)
WG-EMM-03/31	On commercial significance of krill aggregations S.M. Kasatkina (Russia) (*CCAMLR Science*, submitted)
WG-EMM-03/32	Diseases outbreak threatens Southern Ocean albatrosses H. Weimerskirch (France) (*Biological Conservation*, submitted)
WG-EMM-03/33	Ecological games in space and time: the distribution and abundance of Antarctic krill and penguins S.H. Alonzo, P.V. Switzer and M. Mangel (USA) (*Ecology*, 84 (6): 1598–1607 (2003))
WG-EMM-03/34	An ecosystem-based approach to management: using individual behaviour to predict the indirect effects of Antarctic krill fisheries on penguin foraging S.H. Alonzo, P.V. Switzer and M. Mangel (USA) (*Journal of Applied Ecology*, 40: 692–702 (2003))
WG-EMM-03/35	Different CPUE types in Soviet krill fishery statistics in 1977–1992 F.F. Litvinov, A.Z. Sundakov and V. Arkhipov (Russia) (*CCAMLR Science*, submitted)
WG-EMM-03/36	Options for allocating the precautionary catch limit of krill among small-scale management units in the Scotia Sea R.P. Hewitt, G. Watters (USA) and P.N. Trathan (United Kingdom) (*CCAMLR Science*, submitted)

WG-EMM-03/37	Foraging strategies of chinstrap penguins at Signy Island, Antarctica: importance of benthic feeding on Antarctic krill A. Takahashi (Japan), M.J. Dunn, P.N. Trathan (United Kingdom), K. Sato, Y. Naito (Japan), J.P. Croxall (United Kingdom) (*Marine Ecology Progress Series*, 250: 279–289 (2003))
WG-EMM-03/38	Distribution of foraging by female Antarctic fur seals I.L. Boyd, I.J. Staniland and A.R. Martin (United Kingdom) (*Marine Ecology Progress Series*, 242: 285–294 (2002))
WG-EMM-03/39	Energetics of diving in macaroni penguins J.A. Green, P.J. Butler, A.J. Woakes and I.L. Boyd (United Kingdom) (*The Journal of Experimental Biology*, 206: 43–57 (2003))
WG-EMM-03/40	Krill length frequency distribution in Subarea 48.3 in January–April 1988 in relation to sources of its origin F.F. Litvinov, V.N. Shnar, A.V. Zimin and V.V. Lidvanov (Russia)
WG-EMM-03/41	Exchange of wandering albatrosses *Diomedea exulans* between the Prince Edward and Crozet Islands: implications for conservation J. Cooper (South Africa) and H. Weimerskirch (France) (*African Journal of Marine Science*, 25, in press (2003))
WG-EMM-03/42	Mackerel icefish ecological indices I. Everson (United Kingdom), K.-H. Kock (Germany) and A.W. North (United Kingdom)
WG-EMM-03/43	Ecosystem indicators: factors affecting the choice of predator performance indices for use in monitoring programmes K. Reid (United Kingdom)
WG-EMM-03/44	Adélie penguin foraging behaviour and breeding success in seasons of contrasting krill availability (Mawson Coast, Antarctica) J. Clarke, M. Tierney, S. Candy, S. Nicol, L. Irvine and K. Kerry (Australia)
WG-EMM-03/45	Demographic studies for CEMP K.R. Kerry, J.R. Clarke and L.M. Emmerson (Australia)
WG-EMM-03/46	Short note: time series of Drake Passage Oscillation Index (DPOI) from 1952 to 2003, Antarctica M. Naganobu and K. Kutsuwada (Japan)

WG-EMM-03/47	Spatial variability and power to detect regional-scale trends C. Southwell and L. Emmerson (Australia)
WG-EMM-03/48	Sources of variability associated with Adélie penguin CEMP parameters measured at Béchervaise Island, East Antarctica L.M. Emmerson, C. Southwell, J. Clarke and K. Kerry (Australia) (*CCAMLR Science*, submitted)
WG-EMM-03/49	The effect of temporal variability on power analysis predictions for Adélie penguin CEMP parameters at Béchervaise Island L.M. Emmerson and C. Southwell (Australia) (*CCAMLR Science*, submitted)
WG-EMM-03/50	An unmanned aerial vehicle as a platform for aerial photography of land-based predator populations in Antarctica: specifications and suitability of the Aerosonde Mark III L. Irvine and C. Southwell (Australia)
WG-EMM-03/51	The utility of satellite remote sensing for identifying the location and size of penguin breeding sites in Antarctica: a review of previous work and specifications of some current satellite sensors C. Southwell and L. Meyer (Australia)
WG-EMM-03/52	Power analyses of CEMP indices for penguins at Admiralty Bay and fur seals at Cape Shirreff and Seal Island G.M. Watters, R.P. Hewitt, W.Z. Trivelpiece and M.E. Goebel (USA)
WG-EMM-03/53	Trends in bird and seal populations as indicators of a system shift in the Southern Ocean H. Weimerskirch, P. Inchausti, C. Guinet and C. Barbraud (France) (*Antarctic Science*, 15 (2): 249–256 (2003))
WG-EMM-03/54	Antarctic fur seal predator performance indices for the South Shetland Islands 1987/88–2002/03 M.E. Goebel (USA)
WG-EMM-03/55	Suggestions on revision of *CCAMLR Scientific Observers Manual* S. Kawaguchi, R. Williams (Australia) and E. Appleyard (CCAMLR Secretariat)
WG-EMM-03/56	Report of the international workshop on understanding living krill for improved management and stock assessment S. Kawaguchi (Australia) and M. Naganobu (Japan)

WG-EMM-03/57	Developing a non-lethal approach for assessing endocrine disruptors in Antarctic seabirds S. Corsolini (Italy), W.Z. Trivelpiece (USA) and S. Focardi (Italy)
WG-EMM-03/58	Persistent organic pollutants in stomach contents of Adélie penguins from Edmonson Point (Victoria Land, Antarctica) S. Corsolini, S. Olmastroni, N. Ademollo, G. Minucci and S. Focardi (Italy) (*Antarctic Biology in a Global Context*: 296–300 (2003))
WG-EMM-03/59	Observations of Adélie penguins in two seasons with contrasting weather and sea-ice conditions – a brief report S. Olmastroni, F. Pezzo, V. Volpi and S. Focardi (Italy) (*CCAMLR Science*, submitted)
WG-EMM-03/60	Growth of mackerel icefish (*Champsocephalus gunnari*) and age-size composition of populations in subarea of South Georgia K.V. Shust and E.N. Kuznetsova (Russia)
WG-EMM-03/61	Synopsis of CEMP and non-CEMP predator parameters from Admiralty Bay and Cape Shirreff, South Shetland Islands, Antarctica: their relationships to krill abundance and ice cover, 1978–2003 W.Z. Trivelpiece (USA), K. Salwicka (Poland) and S.G. Trivelpiece (USA)
WG-EMM-03/62	Report of the CEMP Review Workshop (Cambridge, UK, 18 to 22 August 2003)

Other Documents

CCAMLR-XXII/8	Draft Rules of Access to and Use of CCAMLR Data Secretariat
SC-CAMLR-XXII/BG/2	Observer's Report from the 55th Meeting of the Scientific Committee of the International Whaling Commission, Berlin, Germany, 26 May–6 June 2003 CCAMLR Observer (K.-H. Kock, Germany)
WG-FSA-03/4	Species profile: mackerel icefish I. Everson (United Kingdom)
WG-FSA-03/5	Bibliography on mackerel icefish K.-H. Kock (Germany) and I. Everson (United Kingdom)
	Ecosystem approach to fisheries: some developments in the FAO Submitted by the Secretariat

APPENDIX D

CEMP REVIEW WORKSHOP
(Cambridge, UK, 18 to 22 August 2003)

CONTENTS

REPORT OF THE CEMP REVIEW WORKSHOP
(Cambridge, UK, 18 to 22 August 2003)

INTRODUCTION

Background

In 2001 the Scientific Committee agreed, as part of its scheduled plan of work, to commence a review of the CCAMLR Ecosystem Monitoring Program (CEMP) at the 2003 meeting of WG-EMM. The Scientific Committee established the following terms of reference for this review (SC-CAMLR-XX, Annex 4, paragraphs 5.16 and 5.17):

(i) Are the nature and use of the existing CEMP data still appropriate for addressing the original objectives[1]?

(ii) Do these objectives remain appropriate and/or sufficient?

(iii) Are additional data available which should be incorporated in CEMP or be used in conjunction with CEMP data?

(iv) Can useful management advice be derived from CEMP or be used in conjunction with CEMP data?

2. An interim steering committee, convened by Prof. J. Croxall (UK), met during the WG-EMM 2002 meeting and prepared a report and plan of intersessional work that was subsequently adopted by WG-EMM and the Scientific Committee (SC-CAMLR-XXI, Annex 4, Appendix E; SC-CAMLR-XXI, paragraphs 6.1 to 6.16).

3. The Scientific Committee agreed that the inauguration of CEMP (in 1987) and its subsequent development and implementation represented an outstanding achievement of CCAMLR. It noted that major new programs of monitoring and directed research in support of CEMP had been initiated by Australia, Japan, South Africa, UK and the USA, together with significant additional contributions by Argentina, Chile, Germany, New Zealand and the former USSR. The value of these programs and of the time series of data collected in consistent fashion as part of CEMP was recognised worldwide.

4. Nonetheless, it endorsed the timeliness of reviewing CEMP, especially to assess the strengths and weaknesses of the existing program and the limitations these might impose for meeting the original objectives, and potential additions and improvements to the existing program.

5. The Steering Committee for the Review of CEMP (members indicated on the list of participants (Attachment 1)) was co-convened by Prof. Croxall and Dr C. Southwell (Australia). Meetings were held to discuss and further develop the implementation of the

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[1] The original objectives of CEMP (SC-CAMLR-IV, paragraph 7.2) were to:
(i) detect and record significant changes in critical components of the ecosystem to serve as a basis for the conservation of Antarctic marine living resources;
(ii) distinguish between changes due to the harvesting of commercial species and changes due to environmental variability, both physical and biological.

intersessional work plan (SC-CAMLR-XXI, Annex 4, Appendix E, Attachment 4) on 3 August 2002 at Big Sky, Montana, USA (Interim Steering Committee), and on 24 October 2002 at Hobart, Australia. Various subgroups were established to coordinate and undertake intersessional work.

6. The reports of the above meetings, details of the revised intersessional work plan, the coordinators of the subgroups on data analysis, krill and environmental data, and references to appropriate background literature were all made available on the CCAMLR website from early December 2002.

Opening of the Meeting

7. The Co-conveners welcomed participants (Attachment 1) and thanked the UK hosts and the local organising committee for their assistance with the arrangements for the meeting, and the CCAMLR Secretariat for support during intersessional planning and at the meeting itself.

8. The Preliminary Agenda was adopted with minor changes (Attachment 2).

9. The report was prepared by Prof. Croxall, Drs M. Goebel (USA), R. Hewitt (USA), G. Kirkwood (UK), E. Murphy (UK), S. Nicol (Australia), D. Ramm (Secretariat), K. Reid (UK), Southwell, P. Trathan (UK), W. Trivelpiece (USA) and G. Watters (USA).

GENERAL REVIEW OF DATA, SUPPORTING PAPERS AND OTHER MATERIALS AVAILABLE

10. CEMP data available to the workshop are listed in detail in WG-EMM-03/24 and are summarised in terms of sites (for locations see Figure 1) and the number of years for which data for each parameter of each species are available (Table 1).

11. In preparing the CEMP data for the workshop, a process of validation and logic testing was prescribed by the Steering Committee and carried out by the CCAMLR Data Manager and his staff. Data were checked logically using database queries; data owners were contacted where appropriate to clarify or resubmit any data which failed these tests. It was noted that CEMP data submission for some sites was limited to the essential data defined in the CEMP standard methods.

12. These data had been analysed in terms of anomalies and trends (WG-EMM-03/24) as well as for their power to detect change (WG-EMM-03/26 and 03/27; see paragraphs 22, 23, 31, 85 and 109).

13. The Steering Committee had emphasised the importance of acquiring and analysing non-CEMP time-series data which had been collected in a standardised fashion as an adjunct to the time series of CEMP data. The Secretariat noted, however, that despite requests for such sets of non-CEMP data, only one had been submitted prior to the workshop and was therefore the only one available for analysis during the meeting. However, a number of papers submitted to the meeting contained summaries of non-CEMP data (Table 2).

14. The workshop noted that there were notable time series of non-CEMP data, particularly for physical variables over a wide geographic range. These data included information on: DPOI (WG-EMM-03/46), satellite imagery of sea-ice, sea-surface temperature (e.g. WG-EMM-03/20) and meteorological data. There was also information available from other scientific programs such as SO GLOBEC and the Italian Antarctic Program. These datasets could be used to augment data from the CEMP database and can be used to set up future analyses.

15. The Steering Committee had indicated the kinds of non-CEMP data that would be relevant and desirable for its analyses (Table 3). Notable absences of non-CEMP data available to the workshop included time series of krill abundance and distribution from areas other than Elephant Island, time series for pelagic predators (whales and crabeater seals) and time series of fisheries information from sources other than the former USSR.

UPDATE ON INTERSESSIONAL WORK

Data Availability and Validation

16. Validation and logic testing on all CEMP data were undertaken by the Secretariat during the intersessional period and is now completed for data submitted to June 2003. This validation process is ongoing and will continue to be applied to all data submissions.

17. Validations were carried out with special attention paid to the tasks set by the Interim Steering Committee (SC-CAMLR-XXI, Annex 4, paragraph 6.12 and Appendix E, Attachment 4). Data were checked logically using database queries; data owners were contacted where appropriate to clarify or resubmit any data which failed these tests.

18. CEMP data available at the workshop were reported in WG-EMM-03/24 and 03/25 (see data matrix) and summarised in Table 1. CCAMLR fishery data available at the workshop were reported in WG-EMM-03/28.

19. Non-CEMP data available at the workshop were reported in Table 2. Only one set of data had been submitted in advance of the workshop and was therefore available for analysis.

SENSITIVITY ANALYSES

20. The Interim Steering Committee for the CEMP Review established a correspondence group that was tasked with undertaking preliminary intersessional discussion and analyses on the sensitivity and power to detect trends in CEMP indices. The correspondence group consisted of Drs Hewitt, Watters and Southwell.

21. The correspondence group reviewed available power analysis software programs at the commencement of their work and, after some consideration of various programs' respective strengths and weaknesses, suggested the DOS program MONITOR for exploratory analyses (see also paragraph 24). During the course of intersessional work, several limitations and constraints became evident in this software. Nevertheless, the process of intersessional

discussion and analysis using MONITOR was valuable in exploring concepts, assessing the magnitude of variability both temporally and spatially where possible, and exploring the implications of this variability on power to detect trends.

22. The correspondence group completed a number of exploratory analyses during the intersessional period, and these analyses were presented to the workshop in WG-EMM-03/26, 03/27, 03/47 to 03/49 and 03/52. The analyses considered sources and estimates of spatial and temporal variability and their consequences on power to detect trends of varying magnitude, in relation to monitoring program parameters such as duration of monitoring, number of sites monitored, Type I error levels and one- or two-sided tests.

23. Serial correlation in CEMP indices, which may affect predictions of power, was examined by the Secretariat during the intersessional period. Results of this work were presented as WG-EMM-03/27. Autocorrelation functions were estimated for 157 of the 198 biological time series and 64 of the 80 environmental and fishery time series in the CEMP database. The remaining time series could not be analysed due to insufficient or invariant data. Serial correlation occurred in 4, 10 and 33% of the biological time series at alpha levels of 0.05, 0.10 and 0.20 respectively (i.e. not more frequently than would be expected by chance alone). Generally, serial correlation was more prevalent in time series of population size, CEMP Indices A3 and B1a. Serial correlation occurred in 23, 38 and 55% of the environmental and fishery time series at alpha levels of 0.05, 0.10 and 0.20 respectively. Generally, serial correlation appeared more prevalent in time series of CEMP Indices H3b and F2c.

24. The documents submitted by members of the correspondence group (archived at the Secretariat and available on request) contained a variety of related results, and the workshop decided to review these results by deliberating on three topic areas:

(i) outlining issues and problems identified during the work of the correspondence group (paragraphs 25 to 30);

(ii) providing a synopsis of the analytical results prepared by the correspondence group (paragraphs 31 to 39);

(iii) discussing alternative approaches to power analysis (paragraphs 40 to 43).

Issues and Problems Identified by the Correspondence Group

25. The workshop acknowledged that only some of the CEMP parameters might be expected to show a sustained, gradual change in relation to changing krill availability and hence be suitable for trend analysis as undertaken by MONITOR, and that alternative methods of detecting change would be required for parameters that exhibited a sudden change. The nature of expected change would reflect the shape of the predator response relationship with krill availability, which was being investigated in parallel prior to and at the workshop by separate correspondence group and subgroup.

26. The workshop recognised that it was important to identify appropriate sources of variability for input to power analyses. There was some intersessional discussion regarding process and measurement error, and the workshop paid particular attention to this issue during the CEMP review (paragraphs 33 to 39).

27. The workshop discussed the issue of one- and two-tailed tests in the context of a traditional hypothesis-testing approach and alternative approaches such as Bayesian methods. With regard to hypothesis-testing approaches, three alternatives were discussed: (i) a one-tailed test initially at pre-impact when only a uni-directional change was required to be detected, then subsequently a two-tailed test after detection of a detrimental effect to determine whether the effect has been reversed or not; (ii) use of a two-tailed test at all stages of monitoring; and (iii) the use of 'asymmetrical' one-tailed tests as a compromise between (i) and (ii). The appropriate choice from these and possibly other options would need to be considered in relation to specific management objectives and decision rules yet to be established.

28. The workshop noted that in undertaking power analyses it was critical to specify the effect size that is required to be detected. This would also need to be considered in conjunction with the establishment of specific management objectives and decision rules, and may need to take account of the demographic characteristics of the species.

29. Two types of error may be expected when trying to detect an environmental impact. A Type I error is the probability of falsely concluding an effect has occurred, and a Type II error the probability of failing to detect a real effect. Power is the inverse of a Type II error, or the probability of successfully detecting a real effect. The traditional hypothesis-testing approach has tended to consider only Type I errors and by convention has used Type I error levels of 0.05. Use of this error level in management would mean that management action would be taken unnecessarily one in 20 times. Since the probability of one type of error occurring varies inversely with the other, this approach places a low priority on Type II errors and leads to reduced power. However, in assessing environmental impacts it may be preferable to take a precautionary approach by giving higher priority to Type II errors, since the cost of management action in response to occasional false reports of change may be considered an acceptable trade-off to waiting for definitive change, at which time there may be fewer management options. Consequently in undertaking preliminary power analyses, the correspondence group considered a range of Type I error levels from the traditional level of 0.05 to higher levels of 0.10 and 0.20.

30. The workshop discussed the need to consider power analysis within the context of the management framework within which a monitoring program is operating. There is a need to distinguish between power in a statistical context and power in a management context. In a management context for CCAMLR, power would need to take into consideration the time lag due to delayed effects of demographics as well as the time lag for statistical detection, such that detection and recovery would be possible within two to three decades of an impact occurring.

Synopsis of the Analytical Results prepared by the Correspondence Group

31. In attempting to summarise the analytical results presented in WG-EMM-03/26, 03/47 to 03/49 and 03/52, the workshop noted both the exploratory nature of the analyses (paragraphs 21 and 22) that were conducted and the variety of difficulties that the correspondence group had with identifying appropriate inputs to the power analysis software (paragraphs 25 to 30). In view of these points, the workshop agreed that the objectives of the CEMP review might best be accomplished by gaining an improved understanding of the nature of variation in the CEMP indices rather than by studying specific results from these documents.

32. Identifying the source of variability in CEMP indices is useful for at least two reasons. First, it would be useful to separate measurement variance (uncertainty arising from the observation of a phenomenon and summarising observations in the form of an index) from process variance (uncertainty arising from environmental forcing, variability in demographic parameters etc.). Such separation would facilitate identification of those indices for which increased sample size or alternative observation protocols could reduce uncertainty. Ultimately, reductions in uncertainty may increase power to detect trends. The workshop recognised, however, that first it is not always feasible to increase precision in a CEMP index because of fiscal and logistic constraints, and, second, that reducing measurement uncertainty will not guarantee an increase in power to detect trends if the total amount of variation in the index remains large.

33. A second, useful reason to identify the source of variability in CEMP indices relates to the level at which data are summarised in the development of such indices. It is possible that summarised data contain too many levels of variation to be useful indices. For example, foraging trip duration is dependent on the immediate energetic requirements of an individual animal. If individual variability in foraging trip duration is not preserved, it is possible that an index which is developed from combined data would have limited utility for detecting trends. This could occur if the between-individual variability is greater than the interannual variability in foraging trip duration. In general, identifying the sources of variability in CEMP indices can illustrate whether improvements can be made by alternative levels of data aggregation.

34. The workshop attempted to identify sources of variation (process variation and measurement variation) in CEMP Indices A3 (breeding population size), A5a (mean foraging trip duration) and A6c (breeding success) for Adélie penguins at a number of CEMP sites. An upper limit for measurement variance in Index A3 was assumed to be determined by the guidelines specified in the standard method for that index (i.e. that replicate counts should be made until such time as those counts are within 10% of each other). Measurement variance in Index A5a was estimated by computing the standard error of the index from numbers of foraging trips recorded in the CEMP database. Measurement variance in Index A6c was estimated from the properties of the binomial distribution. Empirical estimates of process variation in all three indices were developed directly from the time-series data in the CEMP database.

35. Measurement variance in Indices A3 and A6a for Adélie penguins may be relatively small (Tables 4 and 5 respectively). This result has two possible implications: (i) sample sizes for these indices have likely been sufficient; (ii) uncertainty in these indices may not have stemmed from the ways in which these data were collected and summarised in the

CEMP database. The workshop noted, however, that it is possible that assuming replicate counts are within 10% of each other may both overestimate the level of measurement variance in Index A3 for small colonies and underestimate this level for large colonies. It was recognised that the only way to resolve this issue would be to analyse the replicate counts used to develop Index A3 at two or three of the largest and smallest colonies. The workshop agreed that these counts should be compiled and analysed as part of its future work.

36. The workshop also noted that Standard Method A3a may predispose Members to monitor relatively small colonies. This could lead to bias because animals in large colonies may respond to changes in krill availability differently than animals in small colonies. It was noted that Standard Method A3b does describe methods for counting animals from aerial photographs, and these are appropriate for use on large colonies.

37. Finally, with respect to Index A3, the workshop recalled the generally high degree of serial correlation in indices of population size and noted that such serial correlation is likely an important component of the process variation in these indices. Thus, in the future, it might be desirable to compute the power of non-linear models to detect trend in Index A3.

38. In contrast to Indices A3 and A6c, measurement variance in Index A5a for Adélie penguins appears to be relatively large (Table 6). This suggests that it may be possible to reduce uncertainty in this index by either collecting additional data or summarising the foraging trip data in an alternative way. The workshop noted that variation in foraging trip duration is determined by individually and temporally specific energetic requirements (paragraph 33), and agreed that a first attempt to reduce uncertainty in Index A5a should be to account for this variability in the index. Such an approach might lead to a revised standard method or to the submission of additional data. The workshop further emphasised that Index A5a is a potentially valuable index for evaluating changes in krill availability, and, given the complexity of variation in foraging trip duration, work on this index should be a priority.

39. The workshop agreed that the exploratory analysis of variation in the CEMP indices for Adélie penguins was informative, and future work to extend this analysis to include other CEMP indices, species and sites may lead to improvements in CEMP. Such work might best be accomplished by convening a small subgroup comprising individuals familiar with the collection and summarisation of CEMP data and with statistical knowledge.

Alternative Approaches to Power Analysis

40. The subgroup considered that any future consideration of power should be undertaken within the framework of a monitoring program designed to meet explicit and specific management objectives. Therefore, explicit and specific statements of management objectives are a priority.

41. Bayesian or maximum likelihood approaches, in which different candidate models are fitted to data in an attempt to better understand those that best explain the observed patterns, were recommended as possible alternatives to the traditional hypothesis-testing approach. Simulation and data-assimilative approaches could also be used to investigate optimal designs for proposed monitoring programs within the context of fixed sampling constraints.

Data-assimilative models minimise the degree of misfit between data and observations, thereby giving simulations that are accurate to the level allowed by the dynamical model and the input datasets. Data-assimilative models allow exploration of the type and frequency of data that are needed, the structure of the dynamical model, and the degree of accuracy that is needed in the observations that are input to the model. The CEMP time series, which extend for more than 20 years for some sites, would be more than adequate for development and testing of data-assimilative models. This approach has been used in the development of meteorological monitoring networks for weather prediction, the implementation of oceanographic sampling programs, and for analyses of historical multi-disciplinary oceanographic datasets.

42. The workshop recognised that a monitoring program that aimed to detect an effect at scales appropriate to management may require a different design to a monitoring program that aims to attribute causality, given fixed sampling constraints. Such contrasting designs may need to be applied within differing spatial contexts and measure different sets of parameters.

43. In a later plenary session, it was suggested that another alternative was to test for the absence of an undesirable change, as opposed to the usual test for the absence of any change (paragraphs 122 and 123).

PREDATOR PARAMETERS AS INDICATORS OF KRILL AVAILABILITY

44. A subgroup was convened to consider the relationship between the response of krill-dependent predators to krill abundance. The Terms of the Reference for that group were to:

(i) update the intersessional comparisons of the response of krill-dependent predators to krill in Subareas 48.1 and 48.3;

(ii) examine different functional response models and to identify sources of data with which to investigate models;

(iii) investigate the options for predicting krill abundance based on the functional response of krill predators.

Update of the Intersessional Comparisons of the Response of Krill-dependent Predators to Krill in Subareas 48.1 and 48.3

45. The subgroup recognised that whereas there are no CEMP data on prey abundance, there are long time series of krill abundance estimates from Subareas 48.1 (WG-EMM-03/06, 03/54, 03/61) and 48.3 (WG-EMM-03/43) and that these are the areas from which there are the longest time series of predator performance parameter; hence these regions formed the focus of the data analysis conducted in the intersessional period and during the workshop.

46. Using indices of predator performance from four species of krill-eating predator together with independent ship-based acoustic estimates of krill abundance from South Georgia (Subarea 48.3), WG-EMM-03/43 examined the relationship between a range of

indices of predator performance and krill abundance. Predator parameters that reflected processes occurring during the summer showed the closest relationship with krill abundance, especially those for species with foraging ranges similar to the spatial scales at which krill surveys were undertaken. Using combinations of indices that reflect processes at the same temporal scale to produce CSIs, showed an increased fit to the krill abundance data compared to any of the individual parameters. Population size parameters showed no such functional response relationship with annual krill abundance estimates.

47. This analysis emphasised the importance of identifying the spatial, and especially the temporal scales, over which indices of krill-dependent species operate (Figure 2) and the importance of this in identifying those indices, either individually or combined, that show the closest relationship with krill abundance.

48. WG-EMM-03/61 presented analyses of a suite of CEMP and non-CEMP predator performance indices collected at Admiralty Bay and Cape Shirreff, South Shetland Islands (Subarea 48.1), to assess the characteristics of the individual parameters and their relationships to krill abundance indices. The analysis of these parameters indicated that body mass and egg size/mass measurements have low overall CVs (<10%), whereas breeding success, population change and foraging trip duration have relative high (25–50%) CVs. The results of linear regression analyses of individual predator indices and krill biomass density for the South Shetland Islands indicated that Adélie penguin incubation shift durations, gentoo penguin population size changes, and gentoo penguin egg masses were significantly correlated with krill biomass density.

49. The analysis presented in WG-EMM-03/43 suggests that combining variables into standardised indices has the advantage of not only reducing the dimensionality of the data to a form in which it is readily interpretable but also, by encapsulating the variability inherent in the suite of parameters, provides a better fit of the functional response of predators to changes in krill abundance. Following this approach, CSIs were calculated using those parameters that reflect 'summer' variables for Adélie, chinstrap and gentoo penguins from Admiralty Bay and Cape Shirreff (WG-EMM-03/61) and from Antarctic fur seals at Cape Shirreff (WG-EMM-03/54) in order to investigate the form of the relationship with the krill data presented in WG-EMM-03/36 for the Elephant Island region.

50. It was noted that the apparent relationships between predator performance and krill biomass density from data collected in the vicinity of the South Shetland Islands was not of the same form as that from data collected at South Georgia (Figure 3). In considering potential reasons why the predator–prey functional relationships at Admiralty Bay and Cape Shirreff did not appear to follow the same Holling Type II relationships that were found for predators at South Georgia, the subgroup discussed the following:

(i) The krill biomass data used in the South Shetland Islands analyses were derived from a series of surveys conducted on a survey grid centred on Elephant Island (WG-EMM-03/6), whereas estimates of krill biomass derived for monitored predator foraging areas near Admiralty Bay and Cape Shirreff may be more appropriate. Accordingly, a times series of krill biomass densities for these areas was generated by: (a) noting the strong correlation between density estimates in the Elephant Island stratum and the South stratum (encompassing the foraging area of predators monitored at Admiralty Bay) and the West stratum (encompassing the foraging area of predators monitored at Cape Shirreff) of recent US AMLR Program surveys (r^2 = 0.91, n = 5, and r^2 = 0.89, n = 6 respectively); and (b) generating a longer times series for the South and West strata based on results from the Elephant Island strata. However, the spatial refinement of the krill biomass density estimates did not substantially change the relationships between krill and CSIs of predator performance.

(ii) The difference in length of data time series at different sites is considerable and this may be a particularly important consideration for Cape Shirreff where most data exist only from 1998.

(iii) The South Georgia time series includes two years, 1991 and 1994, when predator performance and krill density estimates were exceptionally low. Although lower krill densities than those measured for South Georgia have been recorded in the South Shetland Islands, these have not been associated with the same level of reduced reproductive performance in predators.

(iv) The amplitude of variability of krill biomass densities may be greater at South Georgia than at the South Shetland Islands, arising from differences in krill demographic parameters (WG-EMM-02/16), thereby producing a greater range of predator response values.

(v) Krill biomass densities, although apparently suitable for defining functional relationships for predators foraging from South Georgia, may not be the best parameter for defining functional relationships for predators in general or at other sites. In past working group deliberations other parameters have been considered, for example, mean distance of prey from predator colonies, mean depth of prey, persistence of prey over time (Hewitt et al., 1997). These, as well as other potential parameters (e.g. intensity, density and/or size of patches) may warrant further exploration. In essence, this highlights the need to better understand the relationship between the measures of the abundance of krill and the availability of that krill to predators.

51. Whilst the CSI approach is able to accommodate missing values, the subgroup recognised that, where there were systematic biases in the reasons for the absence of data, this posed a particular problem in reflecting krill abundance.

52. In particular, the subgroup considered the importance of identifying those indices that may not be available for measurement under certain conditions, e.g. during situations of complete breeding failure where it is not possible to measure indices such as foraging trip duration when none of the study birds return to the colony. Where such methodological biases exist these monitoring parameters may be of limited utility to CEMP.

53. WG-EMM-03/44 described the relationship between krill availability and predator performance in the Mawson region of East Antarctica. Shipboard acoustic surveys of krill indicated that more than three times as much krill was present during the survey period in 2001 than in 2003 and this was reflected in the reproductive performance of Adélie penguins at Béchervaise Island. Penguins travelled further to forage in 2003 than 2001, remained at sea for longer, brought back smaller meals and achieved lower breeding success. Fish (mostly *Pleuragramma antarcticum*) contributed significantly to the diet in 2003 but was only a minor component in 2001.

54. In welcoming this integrated analysis of predator performance and prey availability, the workshop noted that WG-EMM-03/59 reported a similar contrast in the reproductive performance for Adélie penguins between 2001 and 2003 at Edmonson Point in the Ross Sea, however, the reasons for the latter had been attributed to unusual sea-ice and weather conditions during critical periods of the breeding season.

55. Dr Nicol informed the workshop that meteorological data from Béchervaise Island from both 2001 and 2003 did not indicate any anomalous events that might have contributed to the differences in breeding success.

56. Dr S. Olmastroni (Italy) informed the workshop that there were no measurements of krill abundance in the vicinity of the Edmonson Point colony. In considering the potential for such confounding problems in the interpretation of CEMP data, the subgroup recognised the importance of collecting data for a suite of parameters of predator performance and environmental conditions.

Indicator Species

57. The workshop recognised that the extent to which predators are dependent on krill may have a large influence on their potential utility as indicator species. This level of dependence should be reflected in the proportion of krill (by mass) in the diet. An analysis of the diet parameters (A8) in the CEMP database indicates that there are considerable intra-specific regional differences with the dietary dominance of krill being greatest in Area 48 in all species, especially for chinstrap penguins (Figure 4). The variability in dietary dominance of krill may reflect differences in alternative prey resources as well as the extent to which species are obligate krill feeders in different locations.

58. However, the workshop noted that although krill comprised 50% of the diet of gentoo penguins in Subarea 48.3, this species had the best fit to the functional response between predator-specific CSI and krill abundance of the range of CEMP species at South Georgia (r^2 = 0.6; WG-EMM-03/43).

Sources of Available Data with which to Examine Functional Responses

59. Drs K. Shust and V. Sushin (Russia) reminded the workshop that it was difficult to assess the distribution, density, aggregation structure and biomass of krill from small-scale surveys that have been undertaken in locally restricted areas and within relatively restricted time periods. When oceanographic flux and advection of krill are taken into account, there are potential impacts both on the assessment of the stock and the amount of krill available to predators.

60. They suggested that information from the commercial fishery could therefore be extremely useful in augmenting predator–prey analyses as they may reflect the distribution and density of krill concentrations. They further suggested that CPUE indices derived from the commercial fishing fleet could provide useful information that could be included in analyses of CEMP indices, krill distribution, predator consumption and the potential impact on predators of catches made by the fishing fleet.

61. The workshop considered the utility of using fishery-based indices as a proxy for krill density when examining the functional response of predators to availability of their prey (krill). It noted that such proxies could be extremely valuable in a variety of contexts; thus, they could help inform those studies where information on predators and krill have been collected on an annual basis for some years (e.g. South Georgia and South Shetland Islands), as well as other areas where regular krill surveys have not been conducted annually (e.g. South Orkney Islands).

62. Dr Sushin reminded the workshop that there was an index of the krill fishery performance in the CEMP database (CEMP Index H1) although there were no analyses of these indices presented at this workshop. The workshop agreed that in order to fully evaluate these indices of fishery performance, these data should be subjected to the same evaluation procedures as other CEMP indices. The workshop recommended that such an analysis of the sensitivity and power to detect trends in indices of krill fisheries performance and the evaluation of functional responses of dependent species to those indices should follow the procedures and recommendations arising from this workshop.

63. The workshop established a subgroup (comprising Drs Hewitt (Convener), M. Naganobu (Japan), Nicol, Reid and Sushin) on the evaluation of fisheries-derived CEMP indices with respect to functional relationships of krill-dependent species with the following terms of reference:

(i) to define analytical procedures
(ii) to define the data required
(iii) to specify protocols for the submission, curation and use of the data.

This subgroup was asked to submit their recommendations to WG-EMM-03 under Agenda Item 3.2.

Predicting Krill Abundance Based on the Functional Response of Krill Predators

64. Drs A. Constable (Australia) and Murphy investigated approaches to predicting krill abundance based on the functional response of krill predators. This involved the development of a simulation framework to evaluate the influence of the choice of functional response model and the CV associated with the estimates of predator performance. The inclusion of the error associated with the estimation of krill density estimates will have a large impact on the utility of predator response functions to predict krill abundance (details are presented in Attachment 3).

65. Dr R. Crawford (South Africa) indicated that it was important to recognise the importance of these predator response functions both in terms of predicting krill abundance and in their intrinsic value in understanding the potential consequences of changes in krill abundance on krill dependent predators.

66. The workshop recognised that the ability to relate concurrent indicators of predator performance to changes in krill when measured at appropriate scale was an important

advance. However, it further recognised that the ability to relate these indices to the long-term demographics of predator populations and how these might respond to long-term trends in the krill resource is critical to future work on this topic.

ENVIRONMENTAL PARAMETERS

Relevance of Non-CEMP Data to the CEMP Review

67. WG-EMM-03/20 reported that VNIRO have been monitoring sea-surface temperature in Subarea 48.3 (around South Georgia) since December 1989. The monthly SST maps (with resolution of 1° latitude by 1° longitude) have been constructed from GOES-E and Meteosat-7 daily satellite data that have incorporated real-time data from vessels and buoys. The workshop recognised the utility of such data and the potential to extract indices that could be included in analyses of CEMP data, other predator data and fishery data.

68. WG-EMM-03/46 reported on recent work to update the DPOI described by Naganobu et al. (1999). The index is now available from January 1952 to May 2003 and describes sea-level pressure differences across the Drake Passage between Rio Gallegos (51°32'S 69°17'W), Argentina, and Base Esperanza (63°24'S 56°59'W), at the tip of the Antarctic Peninsula. The workshop recognised the potential utility of the DPOI to the work of CEMP.

Relevance of Southern Ocean GLOBEC

69. Prof. E. Hofmann (Invited Expert) informed the workshop about the success of the recent field studies carried out by the SO GLOBEC multinational science program. The primary objective of SO GLOBEC is to understand the physical and biological processes that control the abundance, distribution and population variability of Antarctic krill (*Euphausia superba*). Addressing this objective requires concurrent studies of the habitat, predators and competitors of Antarctic krill. The SO GLOBEC program is focused on understanding winter processes, especially those that contribute to overwinter survival of Antarctic krill.

70. The west Antarctic Peninsula was chosen as one of the regions for SO GLOBEC field programs because this area is known to include large populations of Antarctic krill and predators, such as Adélie penguins and seals, and dependable winter sea-ice. The region of the west Antarctic Peninsula studied during the SO GLOBEC field effort was centred around Marguerite Bay and extended across the continental shelf to the seaward side of the southern boundary of the ACC. The US and German Antarctic programs undertook large SO GLOBEC field efforts in the west Antarctic Peninsula region.

71. The US SO GLOBEC field effort consisted of four process cruises, four survey cruises and three current meter mooring deployment and/or recovery cruises which took place during the austral autumn and winter of 2001 and 2002. Data collected during these cruises consisted of measurements of hydrographic distributions, sea-ice properties and distribution, hydroacoustic and net-derived zooplankton distributions, phytoplankton pigment distributions and rates of primary production, ecology and physiology of Antarctic krill and zooplankton, fish abundance and distribution, seabird abundance and distribution, penguin abundance and distribution and diet sampling, seal abundance and distribution and physiology, penguin and

seal tagging and cetacean abundance and distribution. These data are now undergoing analyses and some of these results are presented in a special issue of *Deep-Sea Research* devoted to SO GLOBEC, which will be published in early 2004.

72. One of the results emerging from analyses of the US SO GLOBEC datasets is the importance of CDW to the physical and biological processes on the west Antarctic Peninsula continental shelf. CDW is a large water mass that is transported by the ACC and is identified by its relatively warm (1.5°C to 2.0°C) and salty (34.65‰ to 34.72‰) characteristics. This water mass also contains high concentrations of macronutrients and also micronutrients, such as iron. Along the west Antarctic Peninsula the ACC is located along the outer continental shelf edge, which puts CDW at depths of 200 to 500 m. In regions of topographic variability, CDW intrudes onto the continental shelf and floods the shelf below 150 m. Areas where CDW intrudes onto the west Antarctic Peninsula continental shelf are characterised by variable topography and deep trenches that extend from the outer to inner shelf. In particular, the Marguerite Trough provides a conduit for the movement of CDW from the outer shelf to the innermost part of Marguerite Bay. Thus, the regions of CDW intrusion and upwelling are persistent over time.

73. Once on the continental shelf, CDW upwells via a range of processes that introduce heat, salt and nutrients into the upper water column. The introduction of heat to the upper ocean affects sea-ice thickness and concentration as shelf surface waters remain above freezing in winter, producing reduced sea-ice thickness and concentration. Thus, CDW is an integral part of the heat and sea-ice budgets developed for west Antarctic Peninsula continental shelf waters.

74. Diatom-dominated phytoplankton blooms characterise the areas where CDW upwells. This is believed to result from the high silica and possibly iron concentrations associated with CDW. These upwelling areas provide a dependable supply of food for grazers, such as Antarctic krill. As such, these regions may represent preferred sites for biological production along the west Antarctic Peninsula continental shelf. Dr P. Wilson (New Zealand) reported that in the Ross Sea an analogous scenario seems to be operating in relation to increased primary productivity and penetration of CDW. Thus, where diatom-dominated blooms occur, penetration of CDW also occurs. Prof. Hofmann confirmed that where blooms of *Phaeocystis* occur, penetration of CDW is likely to be minimal or absent. Dr Nicol noted that the deep waters around Heard Island are not iron rich; Prof. Hofmann suggested that there existed a shelf-slope front around the island and that this potentially prevented the iron-rich CDW from flooding the shelf.

75. Prof. Hofmann reported how the emerging results from SO GLOBEC could be of use to CEMP. Firstly, she indicated that the results showed that the physical and biological structure of Antarctic continental shelf waters are largely controlled by one particular water mass, CDW. Secondly, that the distribution of this water results in regions of consistent and dependable enhanced biological production, which is reflected in the overall food web. Thus, the effects of this physical and biological structure may influence CEMP indices, especially those indices collected from predator colonies that are in close proximity to areas where CDW upwells. Knowledge of where these areas occur may therefore be an important part of analyses for some of the CEMP data.

76. Prof. Hofmann reported how it may be possible to include information about CDW distribution in the predator-based measurements that are being made by CEMP. Recent work,

undertaken by Dr D. Costa (University of California, Santa Cruz, USA) as part of SO GLOBEC, showed the feasibility of instrumenting crabeater seals with PTTs that also contain temperature and salinity sensors. Preliminary analyses of the temperature and salinity data from these tags show that it is possible to use these data to characterise the thermohaline properties of the portion of the water column sampled by the seals. In many instances, the depth to which the seals dive is sufficient to encounter CDW. Thus, incorporation of this technology into CEMP measurements would allow sampling of the oceanographic conditions within the predator foraging area. The inclusion of temperature and salinity sensors in predator tags is becoming a proven technology and the experiences from SO GLOBEC provide a basis from which additional uses and analyses of these data can be developed.

General Conclusions

77. Following Prof. Hofmann's presentation about SO GLOBEC, the workshop considered various issues related to the krill fishery in the light of the information presented.

78. Prof. Hofmann suggested that the strongest correlations between krill and hydrography occurred with modified CDW rather than with CDW *per se*; indeed recently upwelled or recently modified CDW often show poor relationships with krill. In Marguerite Bay, relationships between secondary production and modified CDW are strong, thus the workshop expressed some surprise that the krill fishery had not developed in this area. Dr Naganobu agreed and further emphasised that variability in Antarctic Surface Water was also important for the krill fishing fleet.

79. Dr Naganobu noted that there was considerable variability in water mass structure in the fishing grounds to the north of the South Shetland Islands. Prof. Hofmann suggested that in this region the ACC did not always occur in close proximity to either the shelf or the land boundaries. This large-scale movement of the ACC potentially has a number of consequences at both small and medium scales. For example, when the ACC moved offshore from the land, waters from Bransfield Strait and from the Weddell Sea can move into the region. Prof. Hofmann indicated that understanding such movement of the ACC was critical to understanding the ecosystem. She suggested that the role of atmospheric forcing may be crucial in this process at a local scale.

80. The workshop recognised that our understanding about large-scale environmental affects and their impact on small- and medium-scale processes continued to increase with the advent of new and sophisticated modelling studies. Indeed, the confidence in modern global circulation models (GCMs) is such that they now potentially offer valuable insights into how the physical environment can be monitored in a way that provides useful information for management. Studies about the levels of spatial and temporal variability present in such GCMs could help identify the necessary scales for a field-based, or satellite-based, environmental monitoring program.

81. Such an approach could potentially lead to the collation of new and relevant environmental data (at a range of scales) that may eventually prove to be of value as covariates when examining predator–prey functional response relationships. Such data would also help identify the degree to which sites were likely to be representative of their local and/or regional area.

82. The workshop recognised that a number of environmental parameters are potentially important covariates in analyses of predator–prey interactions. It therefore considered that it would be valuable to produce a matrix of environmental parameters that potentially confound the analysis of predator–prey functional response relationships. The workshop acknowledged that producing such a matrix was beyond the scope of the current CEMP Review Workshop, but recommended that work continue intersessionally to develop such a matrix. Table 1 outlines a pro-forma layout that the workshop considered appropriate; it recognised that for some species for some areas the content of the matrix would be sparse.

RESPONSES TO THE TERMS OF REFERENCE FOR THE CEMP REVIEW

83. The workshop noted that the review of CEMP is a key element in the work plan of WG-EMM, being closely linked to its main workshop activities planned for 2004/05, (SC-CAMLR-XXI, Table 1) viz:

(i) selection of appropriate predator–prey–fishery–environment models (2004);

(ii) evaluation of management procedures, including objectives, decision rules and performance measures (2005).

84. The workshop also noted that the present meeting represents only the commencement of a review of CEMP. Therefore replies to the questions posed by means of the terms of reference should be seen, in many cases, as interim responses based on work in progress.

Are the Nature and Use of the Existing CEMP Data still Appropriate for Addressing the Original Objectives?

85. Previous discussions (SC-CAMLR-XXI, Annex 4, Appendix E, paragraph 11) by the Interim Steering Committee had concluded that CEMP data were likely to be appropriate for detecting and recording significant change in some critical components of the ecosystem. The workshop endorsed this conclusion, but also emphasised that critical evaluation of the nature, magnitude and statistical significance of changes indicated by CEMP data was necessary. The work on power analysis and sensitivity undertaken by the workshop (see also WG-EMM-03/26, 03/27, 03/47 to 03/49 and 03/52) was crucial in this respect for identifying the sources and magnitude of variation in CEMP data.

86. During previous discussions (SC-CAMLR-XXI, Annex 4, Appendix E, paragraph 12), the Interim Steering Committee had considered that the design of CEMP should be evaluated in order to determine whether the construction of the monitoring program was adequate to assess changes before and after potential environmental perturbation at the scales appropriate to management decisions. However, in considering this issue, the workshop now recognised that CEMP had not been designed *per se*, rather it had been formed by the incorporation or development of research within national programs. It remains important therefore, to determine how representative these sites are of their local areas and regions.

87. The workshop further recalled (SC-CAMLR-XXI, Annex 4, Appendix E, paragraph 13) that at current harvesting levels it was unlikely that the existing design of

CEMP, with the data available to it, would be sufficient to distinguish between ecosystem changes due to harvesting of commercial species and changes due to environmental variability, whether physical or biological. The workshop reiterated this conclusion and further noted that with the existing design of CEMP it may never be possible to distinguish between these different and potentially confounding causal factors. As a result, the workshop felt that the Scientific Committee should seek advice from the Commission on the extent to which further work should be directed towards this topic.

88. Within any ecosystem monitoring program, there will always remain a level of uncertainty when assessing predator–prey interactions; a direct consequence of this is that there will always be associated levels of uncertainty in management advice. Without a real ability to separate the confounding effects of harvesting and environmental variation and in the context of uncertainty, the workshop felt that the Scientific Committee should seek advice from the Commission about the policy of how management should proceed when a significant change was detected, but no causal factor could be attributed.

89. The workshop considered that one possible method that could potentially lead to a separation between the confounding effects of harvesting and environmental variation was to initiate a structured fishing experiment that concentrated fishing effort in the vicinity of specifically selected predator colonies. If the Commission determined that it was desirable to initiate such an experiment with the power to distinguish between these confounding effects, an appropriate structured monitoring program would also be required. This would be necessary as it is unlikely that the existing design of CEMP would be sufficient.

90. Dr Sushin suggested that a structured fishing experiment may have economic consequences for the commercial fishery. Prof. Croxall agreed but noted that:

(i) the nature of these consequences, if any, would depend on the design and location of the experiment;

(ii) until the concept and detail of any such experiment was approved, consideration of fishery economics might be premature.

91. The workshop recognised that the number of indices that describe harvested components remains small. It therefore welcomed the suggestion of Dr Shust that future analyses should take into account fishery-derived information describing the distribution and biomass of krill. Dr Shust emphasised that the marine ecosystem is dynamic and that the potential overlap between dependent species and the commercial fishery probably varies. Given the dynamic nature of the system, the workshop agreed that further details from the commercial fleet were essential.

92. The workshop recommended the prompt evaluation and production of appropriate indices. However, it was recognised as critical to have the involvement of experienced ecologists and fisheries scientists in order to establish which indices would adequately describe the relevant operations of the fishery. The workshop proposed that intersessional work be undertaken to develop suitable indices based on fisheries data.

93. The workshop recognised that Antarctic krill and those species that were dependent on it were central to CEMP. Other data describing the krill-centric system were also available, but were not a component of CEMP. Further data were also available that described the

non-krill-centric system (see Tables 1 to 3). Most CEMP data originate from the west Antarctic Peninsula and the Scotia Sea, though considerable data holdings are also available from the East Antarctic. Data holdings from the Ross Sea and the Indian Ocean are still relatively sparse. Incorporating data from other locations will be important as it is now recognised that the Southern Ocean contains a number of regional components that may differ from each other in important ways.

94. The workshop recognised that the existing CEMP has many strengths. Thus, the program has provided an extremely valuable description of the Southern Ocean that was not previously available; it has provided exceptional time series of data relating to key components in the ecosystem; and it has documented a number of events where environmental variability has been positively attributed as the reason for decreases in predator breeding performance. Such events include extensive sea-ice around colonies or colonies blocked by icebergs; other such events have occurred in localities where no fishery has been operating. The workshop agreed that the existing CEMP continues to have considerable management utility.

Do these Objectives remain Appropriate and Sufficient?

95. Previous discussions (SC-CAMLR-XXI, Annex 4, Appendix E, paragraph 15) by the Interim Steering Committee had concluded that the existing objectives of CEMP remain appropriate. The workshop reiterated this conclusion, and agreed that an additional objective was now necessary. This was, that 'Appropriate management advice should be developed from CEMP and related data'.

Are Additional Data Available which should be Incorporated in CEMP or be Used in Conjunction with CEMP Data?

96. The workshop has found valuable a number of datasets that are not part of the standard CEMP, particularly those that have been collected for a number of years using standardised procedures. Given the wide variety of non-CEMP datasets that have been of use to this workshop and the potential number that could be of use to the 2004 Workshop on Plausible Ecosystem Models for Testing Approaches to Krill Management, the workshop recognised that it would be inappropriate to incorporate all these data into the CEMP databases. Therefore, it recommended that:

(i) the Secretariat should maintain a register of non-CEMP time-series data of potential utility for the work program of WG-EMM and its subgroups and workshops;

(ii) conveners of WG-EMM workshops and subgroups should, in relation to their terms of reference and objectives, determine which of these data (and other appropriate data) would be useful for their work, especially in relation to the development of management advice.

97. Details about two time series of non-CEMP data were presented: WG-EMM-03/42 and 03/05. The first of these described potential monitoring information from mackerel icefish, the second from Antarctic shags.

98. Dr I. Everson (UK) explained that icefish are potentially a very useful species for monitoring krill, being an important predator of krill over the shelf at a number of Antarctic and sub-Antarctic islands. Dr Shust agreed and reminded the workshop that icefish diet had a greater proportion of other euphausiids as well as *Themisto* at some locations, particularly in the Indian Ocean.

99. WG-EMM-03/42 described several possible indices that may have application to the work of CEMP. Dr Everson emphasised that these were not currently proposed as standard CEMP indices, rather these indices reflected the data currently available. He considered that three indices, in particular standing stock, condition and diet, may have some utility to CEMP; the others (cohort strength and recruitment, natural mortality, gonad maturation and size of age 1 and age 2 fish), may be useful in the future, pending further study.

100. The workshop recommended that the data owners/originators carry out any necessary work to refine these icefish indices. They should then subject the indices to the same analyses as undertaken for CEMP indices. This should include comparison with other CEMP and non-CEMP indices from similar locations and reflect krill availability over similar temporal and spatial scales.

101. Prof. Croxall introduced WG-EMM-03/05, reporting research on Antarctic shags carried out by Argentinean colleagues over a number of years, including the results of a five-year evaluation of the methods and results of a pilot study. WG-EMM-03/05 described the way in which the standardised analysis of pellets can be used for estimating qualitatively and quantitatively the diet of shags and how this can reflect differences in fish availability between seasons and areas. The workshop thanked its Argentinean colleagues for their careful work.

102. Dr Hewitt reminded the workshop that it had previously agreed that a detailed analysis of the non-krill-centric component of the ecosystem would be beyond the scope of the current CEMP Review Workshop (SC-CAMLR-XXI, Annex 4, Appendix E, paragraph 17). However, the workshop recognised that this work on shags had potential utility to both WG-EMM and WG-FSA as it provided information about potentially important ecosystem interactions. The workshop agreed that WG-EMM-03/05 demonstrated that an appropriate method now existed for monitoring aspects of the abundance of young life-history stages of coastal fish species, including those of commercial importance which were subject to CCAMLR conservation measures. It requested WG-FSA to evaluate ways in which such data could be useful to its stock assessment and management procedures.

103. The workshop noted that the papers for the WG-EMM meeting included a wealth of material on the status and trends of seabird and seal populations for the southwest Indian Ocean (WG-EMM-03/8 to 03/19, 03/22 and 03/53). These papers would be more fully discussed in WG-EMM Agenda Item 4.1.5, but the content of several papers contained matters of relevance to the CEMP Review Workshop.

104. First, many papers summarised time-series data on dependent species (WG-EMM-03/8, 03/10, 03/11, 03/15 to 03/18, 03/32 and 03/53), in many cases substantially

updating data and interpretations most recently reviewed by Woehler et al. (2001) and considered by WG-EMM at its 2000 meeting. In addition, several of the species reported on are CEMP indicator species (WG-EMM-03/8, 03/15, 03/16, 03/18 and 03/53). It was recognised that such data from a region where krill is not the main prey of any of the species involved, form a valuable resource for comparison with CEMP data for the same species in areas where krill is the main diet.

105. Second, several of the papers made convincing cases that some trends in dependent species populations may relate to causes other than changes in prey availability (e.g. by-catch mortality in longline fisheries; WG-EMM-03/8, 03/11 and 03/14) or local disease effects (WG-EMM-03/32).

106. Third, several papers described effects likely due to changes in prey availability at different spatial and temporal scales, ranging from the temporary acute effects on breeding performance due to ENSO-type effects (WG-EMM-03/13 and 03/17) to potential shifts in climatic and oceanographic regimes in the sub-Antarctic Southern Ocean (WG-EMM-03/17 and 03/53). In addition, some papers suggested that interactions between different dependent species may be influencing population trajectories and reproductive performance (WG-EMM-03/17 and 03/18).

107. The workshop recognised that the valuable information and ideas contained in these papers complemented earlier reviews of analogous processes of krill-centric systems, particularly in the Atlantic sector (e.g. Area 48 Workshop (SC-CAMLR-XVII, Annex 4, Appendix D)).

108. Many features of the long-term data on population trends and dynamics, arising from studies by South African and French scientists in the Indian Ocean are of considerable relevance to the work of CCAMLR, including CEMP, and it was hoped that the data in these papers (and updates thereof) could continue to be made available for work related to the review of CEMP.

Can Useful Management Advice be Derived from CEMP or be Used in Conjunction with CEMP Data?

109. Previous discussions (SC-CAMLR-XXI, Annex 4, Appendix E, paragraphs 22 to 24) by the Interim Steering Committee had concluded that intersessional work to develop models that would contribute to appropriate management advice was necessary. It recognised that valuable progress had been made (and will continue to be made), particularly work relating to the development of CSIs and functional responses (WG-EMM-03/43), and work relating to power analyses and sensitivity (WG-EMM-03/26, 03/27, 03/47, 03/49 and 03/52). The workshop recognised that such work had the potential to contribute to appropriate management advice.

110. The workshop further considered two different modelling approaches. The first approach (WG-EMM-03/33 and 03/34) allows the consideration of a spatial, dynamic ecological interaction between predators and their prey using a life-history perspective. The

second method relates indices of upper-trophic level species to indices of independent ship-based acoustic estimates of krill abundance through functional responses (WG-EMM-03/43).

Behavioural Models

111. Dr Hewitt informed the workshop that the behavioural models developed by the authors of WG-EMM-03/33 and 03/34 had considered the vertical movement of krill, aspects of penguin foraging behaviour and interactions with the krill fishery. These papers suggest that changes in species' abundance and distribution caused by human disturbances can have indirect effects on other species in a community. However, a fuller understanding of how individual behaviour determines interactions within and between species is required if such effects are to be incorporated into ecosystem approaches to management. The behavioural model predicts that increased fishing pressure offshore will lead to behavioural responses of krill and reduced penguin food intake. Given the documented links between krill and penguins, this also leads to a prediction of decreased penguin survival and reproduction. Krill behaviour is predicted to cause stronger effects from krill fisheries than those explained solely by the percentage of biomass removed. Environmental conditions that decrease krill growth rates or cause krill to spend time in deeper water are also predicted to increase the magnitude of the effect of fishing on penguin reproductive success. The authors show that changes in penguin foraging behaviour can be used to assess the impact of local fisheries on penguin reproductive success.

112. Results from WG-EMM-03/33 and 03/34 demonstrate that an understanding of predator–prey interactions, indirect effects between species, and individual behaviour, is important to our ability to manage populations, particularly if, as suggested by WG-EMM-03/34, the population dynamics of these species may respond to changes in the abundance of their prey at time scales that are too long to be used in a management context. The workshop asked Dr Hewitt to convey its thanks to Drs S. Alonzo and P. Switzer (USA) and Prof. M. Mangel (USA) for their useful contribution.

113. Dr Southwell reported that concurrent predator–prey studies at Béchervaise Island have indicated that foraging trip duration may be a sensitive indicator of krill availability (see paragraph 33). Further field studies and modelling work targeting the interactions between foraging behaviour and krill diel vertical migration may therefore prove useful for the future WG-EMM Workshop on Plausible Ecosystem Models for Testing Approaches to Krill Management.

114. Dr Sushin noted that WG-EMM-03/34 described a theoretical modelling scenario, and that as a consequence the potential utility of the model to provide advice was untested. It was agreed that the parameterisation of such models was critical and that careful validation with field observations was important.

115. The workshop therefore suggested that individuals with relevant expertise consider the model carefully with a view to providing advice, given the likely incorporation of such approaches into the WG-EMM workshop activities planned for 2004 and 2005.

Functional Responses

116. The workshop agreed that there had been significant developments in work on functional responses during the intersessional period, as described in WG-EMM-03/43 and 03/61. It was noted that a range of factors could affect the ability to fit such functions to the available krill and predator data. These included: spatial and temporal scale mismatches in the predator and prey datasets, and the fact that predators may not be obligate krill feeders and therefore the relationships may be affected by prey switching. The workshop discussion highlighted that such effects may require changes in the mathematical functions used to characterise the relationships.

117. The question of whether it is possible to estimate changes in krill abundance using predator performance indices was raised. It was noted that there is considerably more information available about predator performance than there are direct measures of local krill availability. If so, it may be possible to use the information from the predator indices to predict krill availability.

118. The workshop noted that a more explicit examination of the assumptions on which the response curve fitting is undertaken would be valuable. It was noted that it would be possible to simulate some of the effects of including estimated error distributions in the estimates of krill abundance and predator performance. It should then be possible to examine the implications for fitting predator response curves and the ability to detect changes in krill abundance.

119. Preliminary simulation studies undertaken by workshop members are reported in Attachment 3. The simulations indicated that the nature of the variability observed had significant implications for our capacity to characterise and quantify underlying predator response curves. The initial results highlighted that the current methods for determining anomalies could be improved by taking account of the nature of the variability of the krill abundance and predator performance estimates. These preliminary studies indicate that there would also be implications for how the analyses of data on krill abundance might be developed to improve the capacity to detect anomalies.

120. The workshop considered that an important aspect of the approach was that it could provide the potential for determining unusual events based on biologically significant criteria rather than just statistical significance.

121. The workshop noted that the time for developing and considering the simulations reported in Attachment 3 was severely constrained. The information presented in the appendix, although very provisional, did indicate the approach should be further developed and reported in detail. This should include further simulation work to determine the robustness of the approaches for detecting anomalies and changes in krill abundance. The workshop considered that this development was an important and novel outcome from the meeting and requested the workshop members involved (Drs Constable and Murphy) to develop the simulation studies and present a detailed account for the forthcoming Scientific Committee meeting.

Burden of Proof

122. Given the goal of precautionary management, Dr T. Gerrodette (Invited Expert) suggested that the CEMP indices could be interpreted in a different way to that currently adopted. At present, an anomalous value of an index is one that is outside the normal range, as identified by a test of statistical or biological significance. This is equivalent to testing the null hypothesis of no change. A more appropriate test in the context of precautionary management may be of the null hypothesis that an undesirable change, as identified by the management objectives, has not occurred. This alteration in the 'burden of proof' is a common component of other precautionary management regimes.

123. The workshop considered this to be a useful suggestion and recommended that it be considered further at the Workshop on Plausible Ecosystem Models for Testing Approaches to Krill Management.

OTHER MATTERS

Relationships between ISRs and SSMUs

124. Last year WG-EMM requested that the review of CEMP consider the utility of ISRs and whether the proposed SSMUs might provide a suitable alternative structure for future work on the relationships between krill, predators and fisheries (SC-CAMLR-XXI, Annex 4, paragraph 5.31).

125. It was recollected that the original formulation of CEMP distinguished two categories of operations: ISRs and network sites. The former were delimited regions (in Subarea 48.3 (South Georgia), Subarea 48.1 (Antarctic Peninsula) and Division 58.4.2 (Prydz Bay)), within which a wide range of monitoring studies, together with associated directed research, would be undertaken in order to provide insights into the nature and dynamics of prey–krill–environment interactions, including those in relation to fisheries.

126. Network sites were envisaged as locations providing as wide as possible geographic distribution of monitoring activities, albeit with a restricted range of variables being monitored at each site.

127. Although the nature of activities within SSMUs is still under discussion, it was felt unlikely that the extensive monitoring and research programs developed within ISRs would be necessary for each SSMU.

128. However, the envisaged subdivision of precautionary catch limits into SSMUs might need to be accompanied by monitoring of appropriate indicators to assess the efficacy of the management process and objectives. Initial ideas on the scope and nature of such monitoring should be sought once the nature of the precautionary catch limits and associated management operations and objectives were clarified.

129. The nature of existing CEMP monitoring within each ISR, SSMU and subarea/division is summarised in Table 8.

ADVICE TO WG-EMM

Preparatory Work

130. CEMP data were comprehensively validated prior to the workshop. Summaries of available CEMP data and fishery data were prepared by the Secretariat (paragraphs 10, 11, 16 to 18). Although only one non-CEMP dataset was submitted to the Secretariat prior to the workshop, many such datasets were made available in background documents (paragraphs 13 and 14). Notable absences of non-CEMP data included information on krill abundance and distribution from areas other than Elephant Island and South Georgia, and fisheries information from sources other than the former USSR (paragraph 15). Analyses undertaken related to: (i) serial correlation and power of the CEMP predator indices; and (ii) functional responses between these indices and measures of krill availability.

Results of Analyses

131. With regard to analyses of serial correlation and power, the workshop concluded that:

(i) in general, the amount of serial correlation in the biological indices was not greater than what might be expected by chance alone, but there was more serial correlation in the environmental and fisheries indices (paragraph 23);

(ii) it would be useful to obtain an improved understanding of the sources of variation in the CEMP indices, including spatial and temporal variability and the consequences of such variability on power to detect trends of varying magnitude, over varying lengths of time, at different numbers of monitoring sites, and under various levels of risk. An example of the type of work necessary to achieve this understanding was developed for indices on Adélie penguins (paragraphs 34 to 38);

(iii) extending the analysis of the sources of variation to the full suite of CEMP indices may lead to improvements in CEMP. It is recommended that such work should be conducted in the near future (paragraph 39).

132. With regard to functional responses between indices of predator performance and measures of krill availability, the workshop concluded that:

(i) predator performance appears to be related to krill availability both at South Georgia and at the South Shetland Islands (WG-EMM-03/61) (paragraphs 46 to 48), but the form of the relationship differs between these two areas (paragraph 50);

(ii) at South Georgia, the relationship between predator performance and krill density was improved when multiple indices of predator performance were combined, but this was not the case for predators at the South Shetland Islands. The workshop identified a number of possible explanations for the different patterns of response by predators at these two locations (paragraphs 49 and 50);

(iii) differences in predator performance during 2001 and 2003 were also observed in the Mawson region of East Antarctica and at Edmonson Point in the Ross Sea (paragraphs 53 to 56). In the former case, this difference was attributed to differences in krill biomass, and in the latter case it was attributed to environmental conditions;

(iv) the data requirements and analytical procedures required to evaluate the indices of krill availability derived from fisheries data should be defined. A subgroup was formed to do this and to report its recommendations to WG-EMM-03 (paragraphs 60 to 63);

(v) it may be possible to use the relationships between predator performance and krill availability for predicting krill availability and for developing a biological basis for the identification of years in which predator performance was anomalous (paragraphs 64 to 66 and Attachment 3);

(vi) the ability to relate CEMP indices (both singularly and combined) to the long-term demographics of predator populations and how these might respond to long-term trends in the krill resource are critical to future work (paragraph 66).

Responses to Terms of Reference

133. With regard to the first term of reference (Are the nature and use of the existing CEMP data still appropriate for addressing the original objectives?), the workshop concluded that:

(i) the CEMP data were appropriate for detecting and recording significant change in some critical components of the ecosystem, but also emphasised that critical evaluation of the nature, magnitude and statistical significance of changes indicated by the data were necessary (paragraph 85);

(ii) it was not possible to distinguish between ecosystem changes due to harvesting of commercial species and changes due to environmental variability. It was recommended that the Scientific Committee seek advice from the Commission about the policy of how management should proceed when a significant change was detected but no causal factor could be attributed (paragraphs 87 and 88);

(iii) one possible method that may assist in the separation of confounding effects of harvesting and environmental variation would be the establishment of an experimental fishing regime whereby fishing would be concentrated in local areas in conjunction with an appropriate predator monitoring program (paragraphs 89 and 90);

(iv) useful indices of krill availability to land-based krill predators could be derived from fishery-dependent data. Intersessional work was established to address this (paragraphs 91 and 92).

134. With regard to the second term of reference (Do these objectives remain appropriate and/or sufficient?), the workshop concluded that the original objectives of CEMP remained appropriate. However, a third objective should be added 'To develop management advice from CEMP and related data' (paragraph 95).

135. With regard to the third term of reference (Are additional data available which should be incorporated in CEMP or be used in conjunction with CEMP data?), the workshop concluded that:

(i) the Secretariat should maintain a register of the wide range of non-CEMP time-series data that were of use to this workshop and of potential utility to future workshops in support of the work of WG-EMM, including datasets derived from South African and French seabird and pinniped monitoring programs in the southern Indian Ocean (paragraphs 96 and 108);

(ii) indices derived from mackerel icefish data may be of value in monitoring krill in certain regions; these indices should be subjected to the same analyses undertaken for CEMP data (paragraphs 98 to 100);

(iii) indices derived from pellets regurgitated by Antarctic shags may be of value in monitoring the early life-history stages of coastal fish species, including several of commercial importance. It was recommended that WG-FSA consider how such indices may be useful to its stock assessment and management procedures (paragraphs 101 and 102).

136. With regard to the fourth term of reference (Can useful management advice be derived from CEMP?), the workshop concluded that:

(i) behavioural models based on interactions between the aspects of the environment, krill, krill predators and a krill fishery may be of utility in a management context, although correct parameterisation and validation of such models was critical to their use (paragraphs 111 to 115);

(ii) functional responses linking predators to their prey field may also be of utility in a management context, although several confounding factors were identified requiring further work (paragraphs 116 to 119);

(iii) simulation studies conducted during the workshop indicated that accounting for the nature of the variability of estimates of krill availability and predator performance could result in improved ability to detect anomalies (paragraphs 119 to 121 and Attachment 3);

(iv) further consideration of 'burden of proof' issues might be timely (paragraphs 122 and 123);

(v) all the above topics might appropriately be considered at the WG-EMM Workshop on Plausible Ecosystem Models for Testing Approaches to Krill Management.

137. The workshop considered the relationship between ISRs and SSMUs, and concluded that it would be unlikely that the extensive monitoring and research programs developed

within ISRs would be necessary for SSMUs (paragraph 127). Nevertheless, monitoring within SSMUs might need to be extensive and the workshop summarised the nature of existing CEMP monitoring within each SSMU (paragraphs 128 and 129 and Table 8).

Future Work

138. A program of future work was defined and is summarised in Table 9.

ADOPTION OF REPORT AND CLOSE OF WORKSHOP

139. The report, with figures, tables and attachment, was adopted.

140. The Convener of WG-EMM, Dr Hewitt, thanked the Co-conveners for their hard work in coordinating and organising the workshop and their guidance throughout in ensuring its success.

141. The Co-conveners thanked all the participants, particularly the members of the CEMP Review Steering Committee and of the intersessional and workshop subgroups. They thanked the invited experts for their valuable contributions, all the owners and originators of submitted data, without which the review could not have taken place, and the Secretariat for their unfailing support both intersessionally and at the workshop.

142. The workshop closed on 22 August 2003.

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Woehler, E., J. Cooper, J.P. Croxall, W.R. Fraser, G.L. Kooyman, G.D. Miller, D.C. Nel, D.L. Patterson, H.-U. Peter, C.A. Ribic, K. Salwicka, W.Z. Trivelpiece and H. Weimerskirch. 2001. *A Statistical Assessment of the Status and Trends of Antarctic and SubAntarctic Seabirds*. SCAR, Cambridge.

Table 1: Summary data matrix for CEMP biological indices currently held in the CEMP database. Number of years for which data are available. A1: weight of adult penguin on arrival; A2: duration of penguin incubation shift; A3: penguin breeding population size; A5a: duration of penguin foraging; A6: penguin breeding success (a: chicks fledged per egg laid; b: % potential chicks; c: chicks fledged per chicks hatched); A7: penguin chick weight at fledging; A8: weight of stomach contents of adult penguins; A8: diet composition of adult penguin (b: proportion; c: occurrence); B1a: albatross breeding population size; B1b: albatross breeding success; B5c: petrel breeding population size; C1: duration of fur seal cow foraging; C2b: growth rate of fur seal pups.

Species	Site	Biological Index														
		A1	A2	A3	A5a	A6a	A6c	A7	A8	A8b	A8c	B1a	B1b	B5c	C1	C2b
Arctocephalus gazella (SEA)	Bird Island (BIG)														14	14
	Bouvetoya (Bouvet Island) (BOI)														2	2
	Cape Shirreff (CSS)														6	10
	Seal Island (SES)														7	8
Diomedea melanophrys (DIM)	Bird Island (BIG)											28	28			
Eudyptes chrysolophus (EUC)	Bird Island (BIG)	15		28		27		15	15	15	15					
	Bouvetoya (Bouvet Island) (BOI)			2	2	2			2	2	2					
	Elephant Island (Stinker Point) (EIS)			1		1		1	2	2	2					
	Marion Island (MAR)	9		9			9	9	9	9	9					
	Seal Island (SES)				1		7	1								
Pygoscelis adeliae (PYD)	Admiralty Bay (ADB)		21	26		3		18	18	18	18					
	Anvers Island (Antarctic Peninsula) (AIP)			8	10		10	10	10	10	10					
	Béchervaise Island (BEE)	12	13	13	11	12	12	12	11	11	11					
	Edmonson Point (EDP)	2	5	9	1	7	6	3	5	5	5					
	Esperanza Station (Hope Bay) (ESP)	6	8	9		9		8								
	Laurie Island (LAO)	3		8		7			6	6	6					
	Magnetic Island (Prydz Bay) (MAD)		1	1			1	1								
	Ross Island (ROS)			21												
	Shirley Island (Casey Station) (SHI)			1	1	1	1		1	1	1					
	Signy Island (SIO)			13		13		7	7	7	7					
	Stranger Point (King George Island) (SPS)	2		9		8			2	2	2					
	Syowa Station (SYO)			22												
	Verner Island (Mawson Station) (VIM)	1		6												

(continued)

Table 1 (continued)

Species	Site	Biological Index														
		A1	A2	A3	A5a	A6a	A6c	A7	A8	A8b	A8c	B1a	B1b	B5c	C1	C2b
Pygoscelis antarctica (PYN)	Admiralty Bay (ADB)		13	25		2		8	18	18	18					
	Bouvetoya (Bouvet Island) (BOI)			2	2	2			2	2	2					
	Cape Shirreff (CSS)			6		4		7	6	6	6					
	Elephant Island (Stinker Point) (EIS)			1		1		2	2	2	2					
	Laurie Island (LAO)								6	6	6					
	Seal Island (SES)				7		8	10	7	7	7					
	Signy Island (SIO)	6		13		13		7	7	7	7					
Pygoscelis papua (PYP)	Admiralty Bay (ADB)			25		2		6	16	16	16					
	Bird Island (BIG)			27		26		14	15	15	15					
	Cape Shirreff (CSS)			6				4	6	6	6					
	Marion Island (MAR)			9		6	3	9	3	3	3					
	Signy Island (SIO)			13		13			5	5	5					
Thalassoica antarctica (TAA)	Svarthamaren (SVA)													6		

Table 2: Non-CEMP data available at the workshop.

Type of Data	Years	Availability
BIOLOGICAL DATA		
Antarctic and sub-Antarctic seabirds and seals		
Status and trends of seabirds	Various times, areas	Woehler et al., 2001
Predators at South Georgia		
Black-browed albatross peak mass	1989–2003	Submitted to Secretariat
Fur seal median pupping date	1984–2003	Submitted to Secretariat
Fur seal pup production	1979–2003	Submitted to Secretariat
Fur seal birth mass	1984–2003	Submitted to Secretariat
Fur seal frequency of fish in diet	1999–2003	Submitted to Secretariat
Fur seal pup survival	1979–2003	Submitted to Secretariat
Fur seal growth deviate	1989–2003	Submitted to Secretariat
Predators at South Shetland Islands		
Predator parameters	1978–2003	WG-EMM-03/61
Penguin population parameters	1981–2000	WG-EMM-03/29
Fur seal performance indices	1987–2003	WG-EMM-03/54
Predators in Indian Ocean		
Seabird population parameters	2001–2002	WG-EMM-03/9
Seabird population parameters, diet	1980s, 1994–2003	WG-EMM-03/8, 10, 11, 13, 15, 16, 17
Seabird population parameters	1950s–2000	WG-EMM-03/53
Fur seal population parameters	2001	WG-EMM-03/18
Predators in Eastern Antarctica		
Penguin population parameters	2000–2003	WG-EMM-03/59
Penguin foraging and breeding	2001–2003	WG-EMM-03/44
Icefish		
Standing stock	Various times, areas	WG-EMM-03/42
Cohort strength, recruitment	Various times, areas	WG-EMM-03/42
Natural mortality	Various times, areas	WG-EMM-03/42
Length at age 1+ and 2+ years	Various times, areas	WG-EMM-03/42
Condition	Various times, areas	WG-EMM-03/42
Gonad maturity	Various times, areas	WG-EMM-03/42
Diet	Various times, areas	WG-EMM-03/42
Size and age	1987–2002	WG-EMM-03/7
Age and growth	Various times	WG-EMM-03/60
Species profile	Various times	WG-FSA-03/4
Coastal fish populations		
Shag diet	Various years	WG-EMM-03/5
Krill		
CPUE	1977–1992	WG-EMM-03/35
Krill at South Georgia		
Length index	1991–2003	Submitted to Secretariat
Density	1981–2003	Submitted to Secretariat
Biomass and density	2002	WG-EMM-03/30
Size	1988	WG-EMM-03/40
Krill at South Shetland Islands		
Biomass and density	1991–2002	WG-EMM-03/6
Abundance	1978–2003	WG-EMM-03/61
Krill in Eastern Antarctica		
Biomass and density	2001–2003	WG-EMM-03/44
SO GLOBEC		
Plankton, krill and predators	2001–2002	globec.whoi.edu/globec

(continued)

Table 2 (continued)

Type of Data	Years	Availability
ENVIRONMENTAL DATA		
DPOI	1952–2003	WG-EMM-03/46
SST adjacent to South Georgia	1989–2003	WG-EMM-03/20
Air temperature Indian Ocean	1950s–2000	WG-EMM-03/53
Sea-ice at South Shetland Islands	1978–2003	WG-EMM-03/61
SO GLOBEC Southwest Atlantic		
Hydrography, sea-ice, currents, bathymetry, meteorology	2001–2002	globec.whoi.edu/globec
Ross Sea		
Automatic weather stations	1987–1999	meteo.pnra.it
Air temperature data	1984–2003	meteo.pnra.it
Synoptic data	1994–2003	meteo.pnra.it
Satellite images	1998–2003	meteo.pnra.it

Table 3: Types of data of known or potential utility in relation to CEMP (SC-CAMLR-XXI, Annex 4, Appendix E, Table 1).

KRILL	METEOROLOGY AT CEMP SITE
Abundance	Precipitation
Distribution	Air temperature
Demographics	
Condition	PREDATOR PARAMETERS (non-CEMP)
Fisheries performance	Demographics
	Diet composition
PELAGIC PREDATORS	
Whales	DATA FROM OTHER BODIES/PROGRAMS
Crabeater seals	IWC
Icefish	SCAR
	France
BIOLOGICAL ENVIRONMENT	LTER
Primary productivity	
Other prey species	DATA FROM ‘NON-KRILL’ FISHERIES
Salps	IMAF
	Icefish
PHYSICAL ENVIRONMENT	Squid
Sea-ice	Myctophids
Frontal positions	
ENSO	
DPOI	
SST	
Surface-layer temperature	

Table 4: Sources of variation in CEMP index A3 (breeding population size) for Adélie penguins at a variety of CEMP sites. Proportions represent the proportion of the total variation in a time series from the CEMP database.

CEMP Site	Proportion Representing Process Variation	Proportion Representing Measurement Variation
Admiralty Bay (ADB)	0.9880	0.0120
Béchervaise Island (BEE)	0.9355	0.0645
Ross Island (ROS)	0.9983	0.0017
Anvers Island (AIP)	0.9238	0.0762
Edmonson Point (EDP)	0.9937	0.0063
Esperanza Station (ESP)	0.9879	0.0121
Laurie Island (LAO)	0.8068	0.1932
Signy Island (SIO)	0.9587	0.0413
Stranger Point (SPS)	0.9599	0.0401
Syowa Station (SYO)	0.9925	0.0075
Verner Island (VIM*)	–2.6463	3.6463

* The estimate of measurement variation at this site was greater than the total amount of variation empirically estimated from the CEMP database, suggesting that the assumption used to develop an estimate of the measurement error was positively biased in this case.

Table 5: Sources of variation in CEMP index A5a (mean foraging trip duration) for Adélie penguins at three CEMP sites. Proportions represent the proportion of the total variation in a time series from the CEMP database.

CEMP Site	Proportion Representing Process Variation	Proportion Representing Measurement Variation
Admiralty Bay (ADB*)	–0.3470	1.3470
Béchervaise Island (BEE)	0.3389	0.6611
Anvers Island (AIP)	0.6758	0.3242

* The estimate of measurement variation at this site was greater than the total amount of variation empirically estimated from the CEMP database, suggesting that variation in foraging-trip duration among individuals and among trips is a large source of variation that data in the CEMP database cannot account for.

Table 6: Sources of variation in CEMP index A6c (breeding success) for Adélie penguins at three CEMP sites. Proportions represent the proportion of the total variation in a time series from the CEMP database.

CEMP Site	Proportion Representing Process Variation	Proportion Representing Measurement Variation
Admiralty Bay (ADB)	0.9957	0.0043
Béchervaise Island (BEE)	0.9911	0.0089

Table 7: Examples of environmental covariates, potentially important in relationships between krill predators and their prey. Numbers indicate the relative ranking between regions (1 = minimal influence, 2 = moderate influence, 3 = major influence).

	Sea-Ice	Fast-ice and Icebergs	Total Sum of Ranking
Scotia Sea			
South Georgia	1	1	2
South Orkney Islands	3	2	5
South Shetland Islands	3	2	5
Ross Sea	3	3	6
East Antarctica	3	3	6

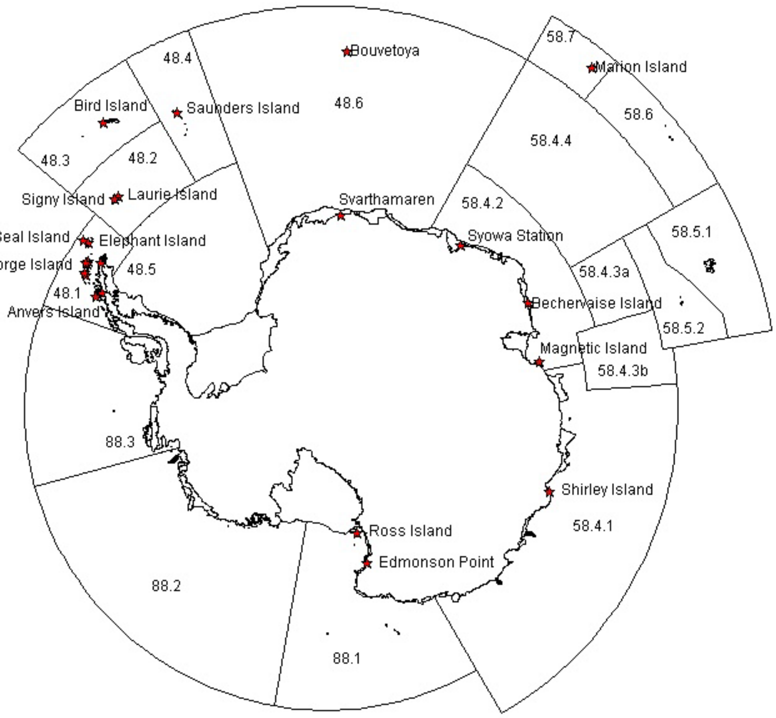
Table 8: Summary of CEMP data (number of annual index values) by ISR and SSMU. Details of the specific parameters measured at each site can be found in WG-EMM-03/24, Table 4. AP: Antarctic Peninsula (BSE Bransfield Strait East; DPW: Drake Passage West; EI: Elephant Island; W: Western); SO: South Orkney Islands (NE: North East); SG: South Georgia (W: West); *: in part.

Subarea/ Division	ISR	SSMU	CEMP Site/Area	CEMP Indices								
				Penguins				Fur Seal	Black-browed Albatross	Antarctic Petrel	Krill Fishery	Sea-ice and SST
				Macaroni	Adélie	Chinstrap	Gentoo					
48.1	AP	APBSE	Admiralty Bay (ADB)		175	131	106					
	AP	APW	Anvers Island (AIP)		96							67
	AP	APDPW	Cape Shirreff (CSS)			46	39	26				21
	AP	APEI	Elephant Island (EIS)									21
	AP	APBSE	Esperanza Station (ESP)		44							21
	AP	APEI	Seal Island (SES)	7		65		23				67
	AP	APBSE	Stranger Point (SPS)		25							67
	AP*	AP*	Subarea 48.1								188	24
48.2	-	SONE	Laurie Island (LAO)		45	30						21
	-	SONE	Signy Island (SIO)		66	76	48					67
		SO*	Subarea 48.2								134	24
48.3	SG	SGW	Bird Island (BIG)	173			139	42	84			21
	SG*	SG*	Subarea 48.3								158	24
48.6	-	-	Svarthamaren (SVA)							4		
58.4.1	-	-	Division 58.4.1								34	
58.4.2	Prydz Bay	-	Magnetic Island (MAD)									21
	Prydz Bay	-	Béchervaise Island (BEE)		199							52
	Prydz Bay	-	Verner Island (VIM)		5							
	Prydz Bay	-	Prydz Bay									24
	Prydz Bay*	-	Division 58.4.2								31	
	-	-	Syowa Station (SYO)		21							21
58.4.4	-	-	Division 58.4.4								6	
58.7	-	-	Marion Island (MAR)	89			39					
88.1	-	-	Subarea 88.1								20	
	-	-	Edmonson Point (EDP)		64							21
	-	-	Ross Island (ROS)		14							
88.3	AP*	-	Subarea 88.3								8	

Table 9: Future work for the 2003/04 intersessional period.

	Task/Topic	Paragraphs of Report	Responsibility	Comments
1.	Further examine the sources and magnitudes of variability in predator response parameters.	39	Data Manager, UK, USA, Southwell	Hold an analysis meeting during the 2003/04 intersessional period.
2.	Further work on defining the relationship between estimates of krill abundance and availability to dependent species.	50(v)	UK, USA	
3.	Within the CSI approach, identify indices where systematic biases might be inherent in missing data.	51 and 52	UK, Australia	
4.	Investigate the utility of haul-by-haul CPUE data as a proxy for direct measures of krill availability, with a view to further analyses of functional relationships for research purposes.	59 to 63	Hewitt, Naganobu, Nicol, Reid, Sushin	Terms of Reference are in paragraph 63. Interim report to 2003 meeting of WG-EMM.
5.	Investigate alternate methods for determining anomalies by using predator response curves for a predator parameter or composite index.	64 to 66, 119 to 121 and Attachment 3	Constable, Murphy	Interim report to the 2003 meeting of the Scientific Committee.
6.	Develop a matrix of environmental parameters that are potentially important covariates in the analyses of predator–prey interactions.	82 and Table 7	Trathan, Wilson, Southwell	
7.	Maintain a register of non-CEMP time-series data of potential utility for future CEMP work.	96	Secretariat	Commence with data listed in Table 2. Review and incorporate other datasets/sources after discussion with members of the CEMP Review Steering Committee and/or conveners of Scientific Committee working groups.

(a)



(b)

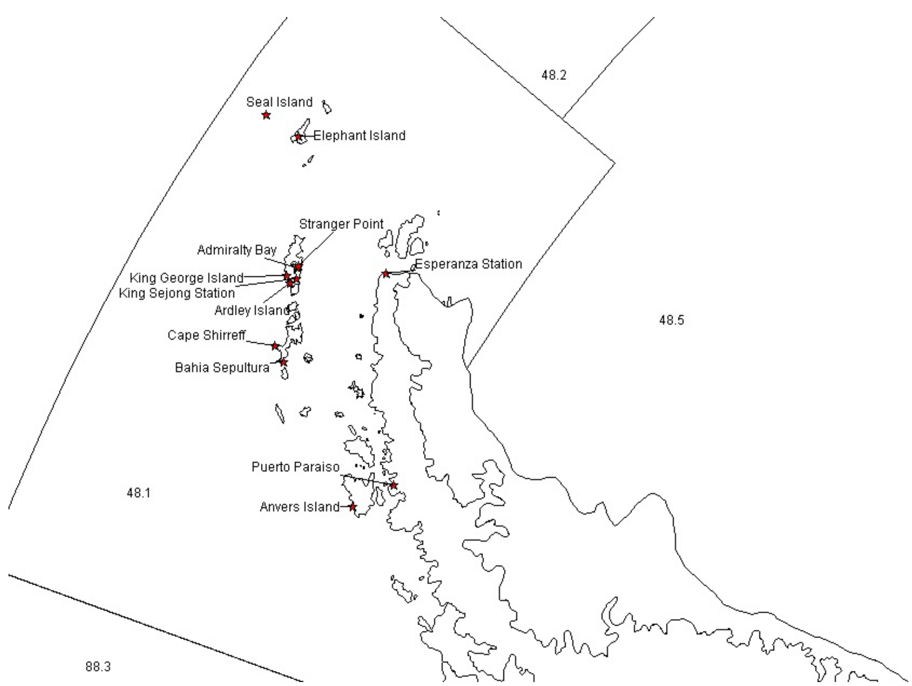


Figure 1: Location of CEMP sites (star). General view (a) and Antarctic Peninsula (b).

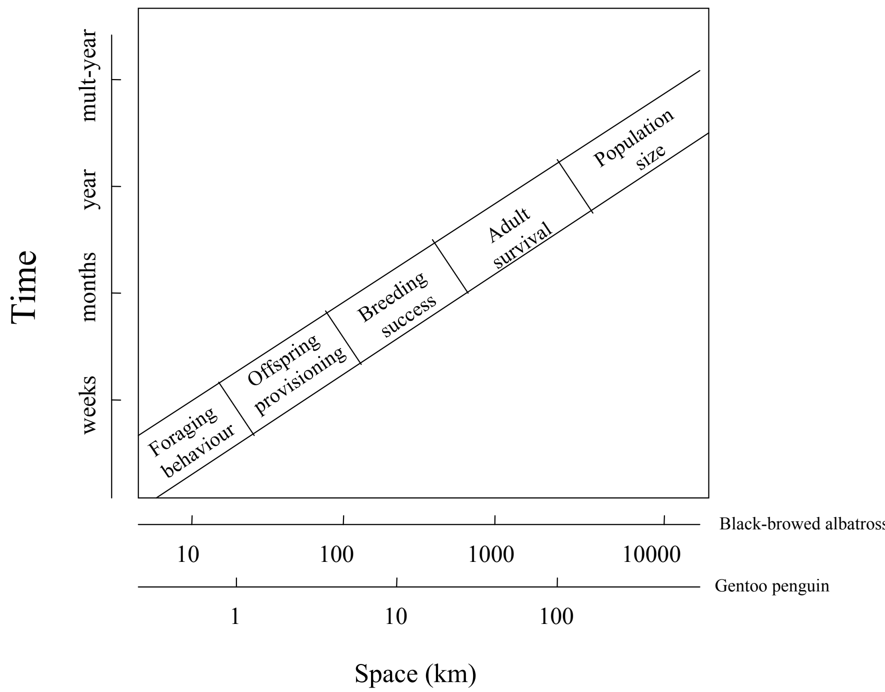


Figure 2: The spatial and temporal scales over which indices of predator performance reflect ecosystem processes. The x-axes scales reflect the two extremes within the group of predators in the CEMP database (from WG-EMM-03/43).

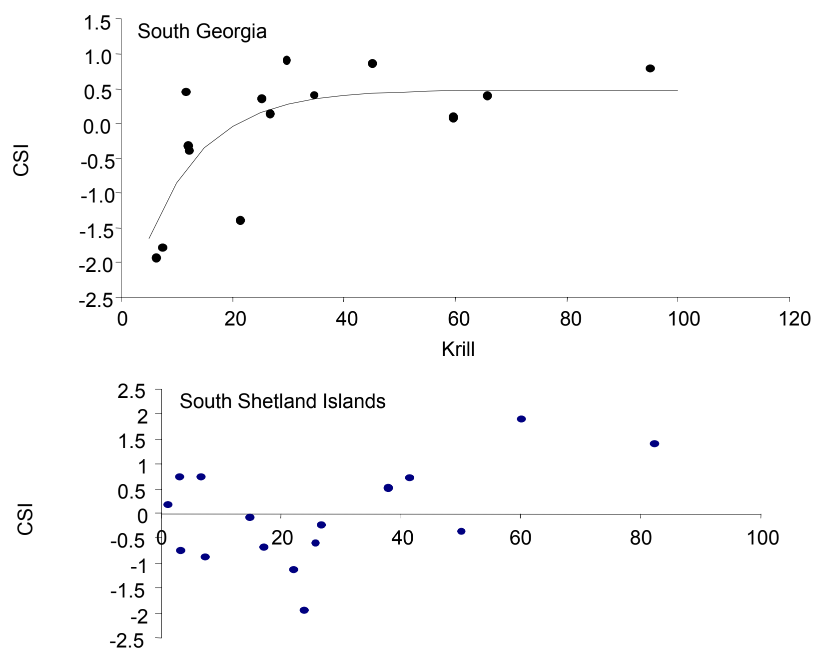


Figure 3: The relationship between krill density (g m^{-2}) and CSI of predator performance at South Georgia and South Shetland Islands.

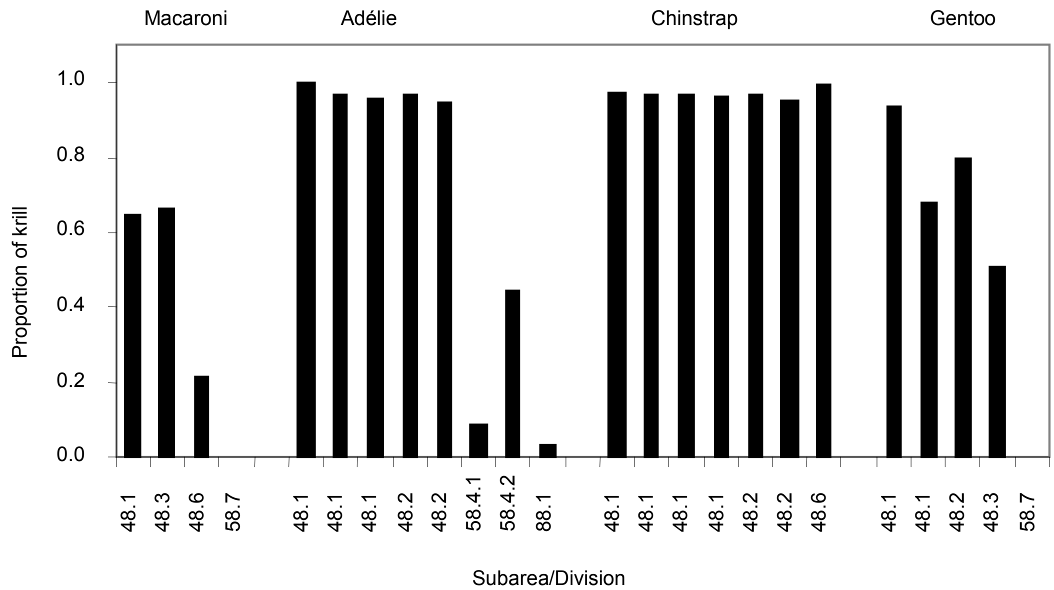


Figure 4: The mean proportion by mass of krill (*Euphausia superba*) in the diet of penguins. Data from the CEMP database.

ATTACHMENT 1

LIST OF PARTICIPANTS

CEMP Review Workshop
(Cambridge, UK, 18 to 22 August 2003)

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ATTACHMENT 2

AGENDA

CEMP Review Workshop
(Cambridge, UK, 18 to 22 August 2003)

1. Introduction

    1.1 Adoption of agenda and work plan
    1.2 Operational issues and appointment of rapporteurs

2. General review of planning and preparatory work

3. General review of data, supporting papers and other materials available

4. CEMP Review Workshop

    4.1 Defining those indices which, either singly or in combination, are the most informative biologically

        4.1.1 Update on intersessional work
            (i) Data availability and validation
                (a) CEMP data: spatial and temporal availability, by species and parameter (data matrices)
                (b) Non-CEMP data: spatial and temporal availability, by species and parameter (data matrices)
            (ii) Sensitivity analyses
                (a) Spatial and temporal correlation issues and solutions
                (b) Type I and type II error level considerations
                (c) Effect size and form of change considerations
                (d) Progress on analysis of western Antarctic data
                (e) Progress on analysis of eastern Antarctic data
            (iii) Issues related to predator parameters as indicators of krill availability

        4.1.2 Predator parameters as indicators of krill availability
            (i) Prey parameters
                (a) Availability of predator/krill data
                (b) Proxies to krill data
            (ii) Functional relationships
                (a) Availability of predator/krill or proxy data
                (b) Modelling relationships

(iii) Composite indices
(iv) Indicator species
(v) Responsiveness

4.1.3 Environmental parameters

4.1.4 Sensitivity analyses
(i) Time required to detect a trend
(ii) Frequency of monitoring
(iii) Number of monitoring sites
(iv) Interactions and trade-offs between monitoring progam parameters

4.1.5 Appropriateness of parameters to monitoring at different scales and for different purposes

4.2 Implementation considerations

4.3 Management advice considerations

4.4 Further work on the workshop theme program

5. Responses to the Terms of Reference for the CEMP Review

5.1 Are the nature and use of the existing CEMP data still appropriate for addressing the original objectives?

5.2 Do these objectives remain appropriate and/or sufficient?

5.3 Are additional data available which should be incorporated in CEMP or be used in conjunction with CEMP data?

5.4 Can useful management advice be derived from CEMP or be used in conjunction with CEMP data?

6. Other matters

6.1 Potential links between ISRs and SSMUs

7. Further work

8. Advice to WG-EMM.

USING PREDATOR RESPONSE CURVES TO DECIDE ON THE STATUS OF KRILL AVAILABILITY: UPDATING THE DEFINITION OF ANOMALIES IN PREDATOR CONDITION – PRELIMINARY ANALYSES

By A. Constable[1] and E. Murphy[2]
[1] Australian Antarctic Division
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A number of predator parameters monitored in CEMP have been shown, using non-linear regression, to be correlated to krill availability. These relationships will be termed 'predator response' curves in this note. The aim of this note is to consider the use of predator response curves in helping make decisions about the status of krill availability in a given year, based on the magnitude of the predator parameter or composite index for that year. In doing so, the note will consider the types of data available, the uncertainties associated with the analysis and consideration about how decisions on krill availability might be made.

BACKGROUND

2. Currently, the determination of extreme years for predators is through a two-tailed test of anomalies. This test determines whether the value of a predator parameter or a composite index is outside the generally observed norm, i.e. less than the lower 2.5 percentile or above the 97.5 percentile of the baseline series. This identifies very good or very poor years, whichever sign they may be assigned.

3. Over the last five years, data have been used for estimating predator response curves, using non-linear regression techniques. These data comprise:

(i) individual predator parameters estimated for a year
(ii) relative estimates of krill abundance for a given year.

4. The predator parameters may be combined into CSIs, first presented to WG-EMM in 1997 (de la Mare, 1997) and later elaborated in de la Mare and Constable (2000) and Boyd and Murray (2001).

5. Difficulties arise with these datasets when data may not be available for some years (de la Mare and Constable, 2000). This is critical if they are more likely to be the low krill years.

COMPARING PREDATOR RESPONSE CURVES TO FUNCTIONAL FEEDING RELATIONSHIPS

6. Functional relationships are often considered in the form of functional feeding relationships which relate the consumption rate of a predator to prey (krill) abundance. In this

case, the relationship will begin at the origin and increase in some form, usually to an asymptote. Two types of relationship are usually considered – Holling Type II and Holling Type III. These are illustrated in Figure 1.

7. The formulation of the relationship is

$$f\left(k_d, k_{0.5}, q\right) = \frac{k^{q+1}}{k_{0.5} + k^{q+1}} \tag{1}$$

where k_d is krill density, $k_{0.5}$ is the krill density when the function equals half the range and q is a shape parameter such that the function is a Holling Type II when $q = 0$ and Holling Type III when $q > 0$.

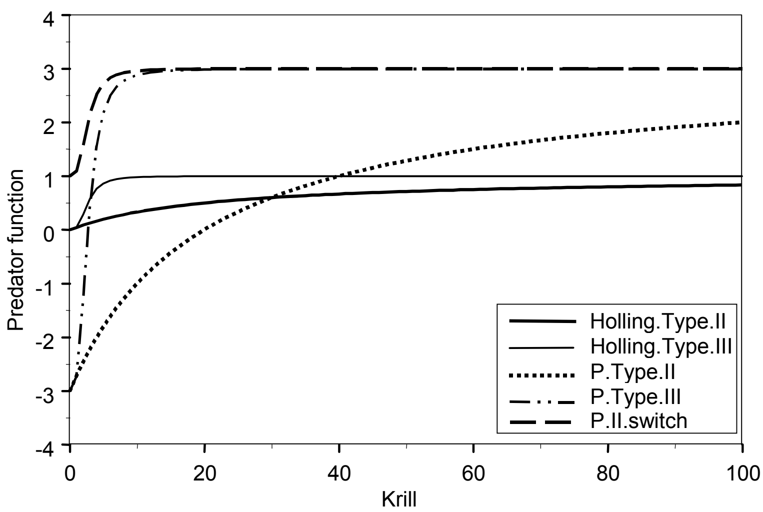

Figure 1: Predator functions in response to hypothetical levels of krill availability. The Holling Type II and Type III functions are functional feeding relationships. The P.Type II and Type III functions are predator response curves based on the respective functional feeding relationships but not restricted to the origin. The P.II.switch curve illustrates the potential effect of prey switching on the predator response, such that the predator remains relatively unaffected when krill are absent.

8. The predator response curves considered by WG-EMM differ from the feeding relationships in four main ways:

(i) estimate a response (parameter/s) of predator performance relative to <u>availability</u> of the prey (krill) species;

(ii) prey switching or other factors may result in relationship not beginning at the origin;

(iii) the shape function may be influenced by many factors other than the prey;

(iv) combined indices potentially range from $-\infty$ to $+\infty$.

9. The formulation of the predator response curve is based on the equation above, such that

$$P\left(P_{range}, k_d, k_{0.5}, q\right) = P_{range}\left[\frac{k^{q+1}}{k_{0.5} + k^{q+1}}\right] + P_0 \tag{2}$$

where P_{range} is the range of the predator response from P_0, which is the value of the predator response when krill availability is zero, and the upper asymptote.

10. Examples of predator responses based on the Holling Type II and III formulations as well as the effect of prey switching are shown in Figure 1.

UTILITY OF PREDATOR RESPONSE CURVES

11. Predator response curves have been proposed to be used to facilitate decisions on when krill abundance is seriously affecting predators (Boyd, 2002). Alternatively, in the absence of estimates of krill availability, these curves might be used to help estimate from predator parameters what the status of the krill availability is for a given year. A question is whether such an approach might also be useful for areas where predator parameters may be monitored but little information is available on krill availability.

12. A number of uncertainties may influence the utility of this approach.

(i) The correlation between the predator response variable and krill availability may be poor and may not appropriately match the spatial and temporal scales or locations of the krill time series.

(ii) Predators may not be obligate krill feeders and therefore the relationship may be influenced by prey switching or other factors.

(iii) The abundance of krill is highly variable, approximating a lognormal distribution, which means that the chances of sampling at the lower end of krill availability will be low and potentially problematic in short time series of data, such that the ability to estimate the curvature in the relationship may be poor.

(iv) The probability of sampling at the lower end may also be reduced further by autocorrelation in the time series of krill abundance, which could also lead to autocorrelation in the predator response.

(v) The estimates of krill availability have uncertainty as well with errors considered to be lognormally distributed.

(vi) Uncertainties in the underlying model of predator response to krill availability, e.g. difference between Type II and Type III approaches.

(vii) The error function for the predator response may not be correctly modelled with a Gaussian or lognormal.

13. The results of some of these uncertainties are illustrated in Figure 2 which shows a predator response curve that then is sampled according to error functions on both krill availability and the predator response. This set of samples is then used to illustrate the issues below.

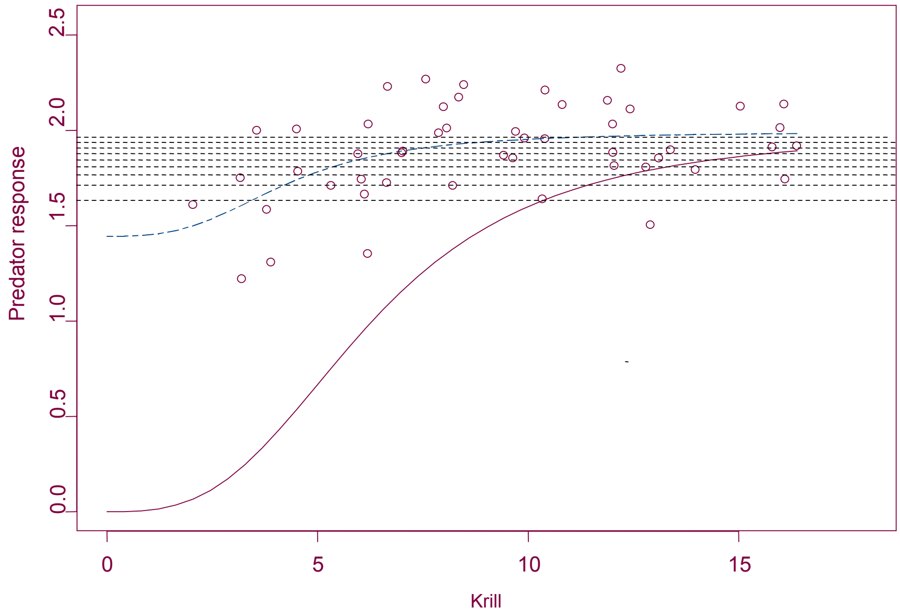

Figure 2: Predator response related to theoretical krill availability. Points are estimates of the predator response to estimates of krill abundance. The solid line shows the Type III relationship. The dashed line shows the fitted relationship using non-linear regression estimating P_{range}, P_0 and $K_{0.5}$. Horizontal dashed lines show the 0.05 percentile intervals starting at the lower 0.05 percentile and increasing to the 0.5 percentile. The shift of the points to the left of the true predator response curve is because of the lognormal error function in the krill estimates (based on the range of CVs observed at the Antarctic Peninsula).

14. The parameters in equation 2 (except for q in this simulation) were estimated using a non-linear regression (see Figure 2). The percentiles for the asymptote were estimated based on the residuals of the fit and the estimate of P_{range} plus P_0.

DECIDING ON STATUS OF KRILL AVAILABILITY

15. In order to decide on the status of krill availability based on the estimate of predator response, the relationship needs to be viewed as krill availability as predicted by a function of predator response. Figure 2 has been replotted in Figure 3 to reflect this change of view.

16. Figure 3 illustrates how there is little or no information above the lower 0.05 percentile of the predator response for estimating the availability of krill. Therefore, the first step is to determine an appropriate percentile of predator response, above which the data would be excluded from an assessment of krill availability under the assumption that the krill availability is likely to be sufficient for predators. The area of interest would then be below that percentile.

17. Figure 3 also provides the current approach to estimating anomalies where the lower 0.025 percentile and upper 0.975 percentile are shown. It also shows a one-tailed test of anomalies such as the lower 0.1 percentile illustrated.

18. In this example, it would appear that the estimation of the predator response asymptote and its variance provides an opportunity to revise the view of anomaly such that an anomaly would be any value of the predator response falling below the critical percentile.

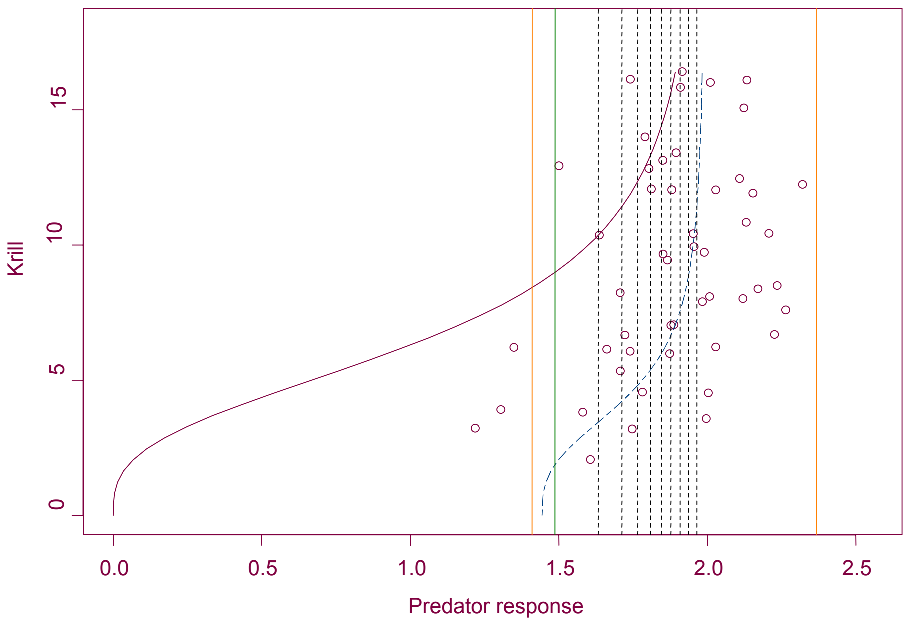

Figure 3: The inverted predator response curve to consider the estimation of krill availability from the predator response. Lines are as indicated in Figure 2. The vertical solid lines indicate from left to right – lower 0.025 anomaly, lower 0.1 anomaly and upper 0.975 anomaly as formulated for the predator response by WG-EMM in 1997.

CONCLUSIONS

19. This short note provides some possibilities for the future work of WG-EMM:

(i) it is apparent that the current method for determining anomalies could be improved for some parameters based on appropriate predator response estimates;

(ii) the ability to decide on krill availability will be contingent on the CV of the predator response in the upper part of the range of krill availability;

(iii) it seems most likely that the asymptote of the predator response curve will be reasonably estimated while the lower tail may be difficult to estimate in short time series. This would favour an approach based on anomalies rather than estimation of krill availability;

(iv) the lognormal errors in the krill estimates will cause some problems with this procedure and will need to be incorporated explicitly in the approach in the future.

20. Given the uncertainties surrounding these responses and the importance of identifying a critical level below which the predator response is likely to be reduced, it would seem reasonable to conclude that the lower percentile anomaly test should be a one-tailed test and probably at a higher percentile than the current 0.025.

21. The use of predator response curves provides an opportunity to base the anomaly criterion on biological rather than statistical parameters. It is a way of screening out the lower tail of predator responses in defining a more biologically oriented criterion.

22. Further simulation work is needed to determine the robustness of the method to the uncertainties in the approach described above. In that respect, simulations to identify the length of time series required to undertake this assessment would be very helpful.

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APPENDIX E

**PROPOSED REVISION OF *CEMP STANDARD METHODS*,
PART IV, SECTION 5**

PROPOSED REVISION OF *CEMP STANDARD METHODS*, PART IV, SECTION 5

OBSERVATION PROTOCOLS AND TECHNIQUES: PROTOCOLS FOR COLLECTING SAMPLES FOR TOXICOLOGICAL ANALYSES

The following procedure describes the methods for collecting and storing samples of animal tissues in the event that pollutants or toxic substances are suspected in species being monitored as part of CEMP.

Samples should be collected and analysed for organochlorine compounds such as polychlorinated biphenyls (PCBs), dichloro-diphenyl-trichloroethane (DDTs), lindane, polycyclic aromatic hydrocarbons (PAHs) and heavy metals (cadmium, mercury, lead, zinc and copper). It should also be appreciated that chemical content in seabirds may be related to diet and lifestyle and is naturally occurring.

It is recommended that all field teams conducting CEMP programs maintain stocks of sampling equipment at their monitoring site to allow adequate collection, storage and transport of samples for the following laboratory analyses.

The analyses of samples for contaminants involve sophisticated and expensive techniques and therefore require support from appropriate specialised centres.

SAMPLING GUIDELINES

Chlorinated Hydrocarbons

The body burden of chlorinated hydrocarbons can be evaluated from muscle and/or fatty tissue, skin biopsies, unhatched eggs, blood, preen gland oil and stomach contents. Collect a minimum of 2 g of tissue or skin and a few microlitres of preen gland oil. If the animal is dead, collect in addition liver, muscle and brain. Post-mortem sampling should be carried out on recently-dead individuals, with records of biometric parameters and times of death and sampling attached.

Heavy Metals

Ante-mortem collection of feathers, faeces and skin biopsies is suitable. Post-mortem sampling of recently-dead animals can also include liver and kidney.

Biochemicals

The modification of specific biochemical responses (i.e. enzymes and metabolites) may indicate the presence of pollutants in seabirds. These analyses can be correlated with those carried out on samples collected as described above. The following table summarises the biological samples suitable for specific biochemical tests.

Test	Sample
Porphyrin (COPRO-URO-PROTO)	Faeces, feathers, liver, blood (whole)
Mixed-function oxidases: Ethoxyresorufin-O-deethylase (EROD) Penthoxyresorufin-O-deethylase (PROD) Benzyloxyresorufin-O-deethylase (BROD)	Liver, skin biopsies
Benzopyrene-monooxygenase (BPMO) CYT-P450-reductase	
Esterases: Acetylcholinesterase (AChE) Butyrylcholinesterase (BChE)	Brain, blood (whole for mammals, and serum or plasma for birds and fish)

COLLECTION AND STORAGE OF SAMPLES

All samples should be collected into glass containers or tubes which can be sealed so they do not dehydrate in storage.

Samples for heavy metals and chlorinated hydrocarbon analyses should be stored as soon as possible at –20°C. Care should be taken to prevent contamination of samples – in the case of heavy metals, by metallic compounds in the sampling tubes (e.g. metal tops) and in the case of hydrocarbons, by plastics (e.g. plastic wrapping material).

Samples for biochemical analyses should be stored promptly in liquid nitrogen; it is very important for further successful laboratory analyses to freeze the samples immediately.

All samples should be labelled to provide details of sample, the identity of the individual animal and date of collection. It is important to ensure that tissue from the same animal may be matched in the laboratory. A detailed logbook should be maintained and forwarded with the samples.