ANNEX 4

REPORT OF THE WORKING GROUP ON ECOSYSTEM MONITORING AND MANAGEMENT

(Yokohama, Japan, 4 to 15 July 2005)

CONTENTS

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INTRODUCTION

Opening of the meeting

1.1 The eleventh meeting of WG-EMM was held at the National Research Institute of Fisheries Science (NRIFS), Yokohama, Japan, from 4 to 15 July 2005. The meeting was convened by Dr R. Hewitt (USA).

1.2 Dr Hewitt thanked Dr M. Naganobu and Mr A. Hachimine (Japan) and the NRIFS for hosting the meeting, and welcomed the participants.

1.3 Dr Hewitt outlined the program of work for the meeting which comprised two main elements:

- the Workshop on Management Procedures to Evaluate Options for Subdividing the Krill Catch Limit among Small-scale Management Units (SSMUs) which was conducted from 4 to 8 July 2005 (Section 2);

- the core business of the Working Group which was considered during the second week of the meeting.

1.4 Some of the core business was further developed by the:

- Advisory Subgroup on Protected Areas
- Subgroup on Methods
- Subgroup of the Steering Group for the 'CCAMLR-IPY-2008 Survey'
- Predator Survey Correspondence Subgroup.

Adoption of the Agenda and organisation of the meeting

1.5 The Provisional Agenda was discussed and adopted with the following changes (Appendix A):

- Subitems 4.2 and 6.2 were merged and renamed '6.2 Ecosystem models, assessments and approaches to management';

- Subitem 4.3 was deleted from the agenda because no new information had been submitted to the meeting. However, the Working Group agreed that this subitem should remain on the agenda for next year's meeting.

1.6 The meeting participants are listed in Appendix B. The documents submitted to the meeting are listed in Appendix C.

1.7 The report was prepared by Drs A. Constable (Australia), M. Goebel (USA), C. Jones (USA), S. Kawaguchi (Australia), G. Kirkwood (UK), P. Penhale (USA), D. Ramm (Data Manager), K. Reid (UK), H.-C. Shin (Republic of Korea), C. Southwell (Australia), P. Trathan (UK), W. Trivelpiece (USA), J. Watkins (UK) and G. Watters (USA).

WORKSHOP ON MANAGEMENT PROCEDURES

2.1 Following the past four workshops at WG-EMM in support of the development of a revised management procedure for krill, WG-EMM (SC-CAMLR-XXIII, Annex 4, paragraph 6.13) and the Scientific Committee (SC-CAMLR-XXIII, paragraphs 3.86 to 3.90) agreed that the first workshop to evaluate management procedures for the krill fishery should examine the six candidate methods for subdividing the krill catch. The agreed candidate methods to be evaluated were based on:

(i) the spatial distribution of catches by the krill fishery;

(ii) the spatial distribution of predator demand;

(iii) the spatial distribution of krill biomass;

(iv) the spatial distribution of krill biomass minus predator demand;

(v) spatially explicit indices of krill availability that may be monitored or estimated on a regular basis;

(vi) pulse-fishing strategies in which catches are rotated within and between SSMUs.

2.2 The Working Group agreed that, in order to provide information upon which management advice could be developed within the objectives of CCAMLR, performance measures were required to evaluate which options were robust or sensitive both to the initialisation data and conditions and to the alternative structural assumptions.

2.3 The Working Group agreed that the performance measures for krill that were based on the current operational decisions used by CCAMLR in the management of the krill fishery would be appropriate. For krill predators, two categories of potential performance measures were considered by the Working Group; these were based on rates of decline and recovery that are scaled to generation times, and the frequency with which these populations were below a reference 'depletion' level or above a reference 'recovery' level. In the case of the krill fishery, performance measures based on absolute catch, catch as proportion of allocation, probability of 'voluntary change' (where krill density falls below specified threshold) and the deviation of fishing patterns from historical patterns of spatial distribution were considered appropriate (Appendix D, paragraphs 4.1 and 4.6).

2.4 Three papers describing models relevant to the evaluation of options for the subdivision of the precautionary catch limit for krill amongst SSMUs in Area 48 were presented.

2.5 WG-EMM-05/13 described a krill–predator–fishery model (KPFM) developed specifically to address options for subdivision of the precautionary catch limit in Area 48 amongst SSMUs. The model is designed to investigate the performance of the identified options and their sensitivity to numerical and structural uncertainty. The model is spatially resolved to the level of SSMUs and surrounding oceanic areas, and it includes the transport of krill between these areas. Krill and predator population dynamics (of up to four predators in each SSMU, typically generic seal, whale, penguin and fish) are implemented with coupled delay-difference models, which are formulated to accommodate various assumptions about the recruitment and predation processes. The fishery is represented as a simultaneous and equal competitor with predators for available krill. Monte Carlo simulations can be used to integrate the effects of numerical uncertainty, and structural uncertainty can be assessed by comparing and merging results from multiple such simulations. A range of possible performance measures was also presented that can be used to evaluate catch-allocation procedures and assess trade-offs between predator and fishery performance. The paper provided basic instructions on running the model in S-Plus and illustrated its use. Although the model necessarily simplifies a complex system, it provides a flexible framework for investigating the roles of transport, production, predation and harvesting in the operation of the krill–predator–fishery system.

2.6 WG-EMM-05/14 outlined a proposed spatial modelling framework that could be used to quantify the flux of krill past islands in the Antarctic Peninsula region, in an attempt to quantify what level and localisation of the fishing effort might impact the land-based predators negatively. The approach described represents work in progress as the focus thus far has been on first developing a model of the possible impact of pelagic fishing on seal and penguin colonies on the South African west coast. The latter ecosystem shares a number of common features with the Antarctic Peninsula ecosystem in that there is a substantial advective flux of either pelagic fish or krill, with both species serving as dominant prey items for colonies of land-based predators in the region concerned. Subject to the availability of data from both predator studies and krill surveys, the South African west coast model methodology could potentially be adapted to the Antarctic Peninsula region. This would permit the evaluation of a wide range of management options taking into account the needs of other species when setting precautionary krill catch limits at an appropriate spatial scale.

2.7 WG-EMM-05/33 described an ecosystem, productivity, ocean, climate (EPOC) model that has been developed in the R statistical language to help explore topical issues on Antarctic marine ecosystems, including impacts of climate change, consequences of over-exploitation, conservation requirements of recovery and interacting species, and the need to evaluate whether harvest strategies are ecologically sustainable. EPOC has been designed as an object-oriented framework, with the main modules on biota, environment, human activities and management. Each element within a module (e.g. a species in the biota module) is an object carrying all its own functions and data. EPOC is designed to be a fully flexible plug-and-play modelling framework. This is because of the need to easily explore the consequences of uncertainty in model structures but, more importantly, to enable ecosystem modelling to proceed despite widely varying knowledge on different parts of the ecosystem and avoiding the need to guess model parameters for which no information exists. The author noted that EPOC provides these opportunities as well as examining the sensitivity of outcomes to changes in model structures. It can also be used to develop alternative ways of modelling different taxa such that, within the same simulation, different species can be modelled at different spatial and temporal scales as well as with different biological and ecological complexity (Appendix D, paragraphs 5.4 and 5.5).

2.8 During the workshop there was agreement that, given the limited time available, it would concentrate its review on the KPFM. The Working Group noted that the KPFM, with its extensive documentation, graphic outputs and diagnostics, had successfully engaged participants from a wide range of backgrounds, including those with and without sophisticated modelling skills (Appendix D, paragraphs 5.7 and 8.2).

2.9 The Working Group recognised that there was a range of possible formats for the presentation of information for making decisions. Graphical presentation was thought to convey important properties of performance measures. Overall, the Working Group indicated that it preferred graphical presentation over tabular presentation, particularly with respect to what might be considered to be robust performance, where large amounts of data were to be summarised (Appendix D, paragraphs 4.7 and 4.8).

2.10 The Working Group agreed that considerable progress had been made this year sufficient for it to believe that a further year's work should allow the delivery of appropriate advice on the evaluation of options for the subdivision of the precautionary catch limit for krill in Area 48.

2.11 In order to achieve this, however, it was essential that appropriate benchmarks be established. It was agreed that it would be necessary to present to WG-EMM next year sets of results that demonstrated the sensitivity of results and performance measures to plausible ranges of model parameters and structural hypotheses and robustness to uncertainties. The Working Group agreed that at least three key aspects should be given further attention in the models and their implementation (Appendix D, paragraphs 5.8 to 5.10, 5.18 and 5.19):

(i) incorporation of shorter time steps and/or seasonality
(ii) incorporation of alternative movement hypotheses
(iii) incorporation of a threshold krill density below which a fishery will not operate.

STATUS AND TRENDS IN THE KRILL FISHERY

Fishing activity

3.1 The Secretariat advised that 10 vessels had been licensed to fish for krill in Area 48 in the 2004/05 season. At the time of preparing WG-EMM-05/5, nine vessels had harvested krill, and the total catch of krill reported so far this season was 62 049 tonnes. This total did not include the catch taken by Vanuatu in April, as the monthly report was overdue. Most of the catch was taken in Subarea 48.2 between January and May. So far, the Republic of Korea has reported the largest catch of krill (19 675 tonnes), followed by Vanuatu (17 087 tonnes), Japan (11 653 tonnes), Ukraine (8 929 tonnes), Poland (3 633 tonnes) and the USA (1 072 tonnes) (WG-EMM-05/5).

3.2 Dr Ramm advised that Vanuatu had submitted all overdue data during the week prior to the meeting. Based on this season's catch reported to April 2005, and the equivalent catch reported to April 2004, the preliminary estimate of total catch for the 2004/05 season was approximately 165 000 tonnes. The Working Group noted that this forecast indicated a 33% increase from last year's total catch.

3.3 In the 2003/04 fishing season, based on STATLANT data, the total catch of krill in Area 48 was 118 166 tonnes. Japan remained the largest taker of krill with a total catch of 33 583 tonnes. The Republic of Korea and Vanuatu also reported large catches, followed by Poland, Ukraine, USA, Russia and the UK (WG-EMM-05/5, Table 6).

3.4 Krill catches in Area 48 have been relatively steady since the 1999/2000 season (104 425–125 987 tonnes per annum) however, catches by Japan decreased markedly during this period, from 80 597 tonnes (1999/2000) to 33 583 tonnes (2003/04). Catches by Poland have also declined from 20 049 tonnes (1999/2000) to 8 967 tonnes (2003/04). In contrast, catches by the Republic of Korea increased from 2 849 tonnes (1997/98) to 24 522 tonnes (2003/04). Vanuatu entered the fishery in 2003/04 with a reported catch of 29 491 tonnes (WG-EMM-05/5).

3.5 Distribution of catch among SSMUs was analysed using fine-scale data by weighting the catch to the total catch reported in STATLANT data (WG-EMM-05/5, Table 8). Catches in excess of 30 000 tonnes of krill in a single season have been taken in nine SSMUs, and in the past six seasons (1998/99 to 2003/04), the maximum annual catch per SSMU was taken within three SSMUs.

3.6 The Working Group was in agreement that fine-scale data submission on a haul-by-haul basis is preferred to adequately describe krill catch from each SSMU.

3.7 A total of 10 vessels from six Members (Japan, Republic of Korea, Norway, Russia, Ukraine and the USA) notified their intention to fish for krill in Area 48 in 2005/06. The total expected catch was 247 500 tonnes. Notably, Norway expressed its intention to fish for the first time, and expected to catch 100 000 tonnes which is the highest expected catch among the notifying Members. This is followed by 50 000 tonnes by the USA, approximately 30 000 tonnes by Ukraine, approximately 25 000 tonnes each by Japan and the Republic of Korea and 15 000 tonnes by Russia. The type of product was wide ranging: raw, boiled, peeled, meal, oil, frozen and dried shell (WG-EMM-05/6). In addition, the Secretariat advised that Uruguay had notified its intent to fish for krill using a single vessel. This notification had been made during the week prior to the meeting and no further detail was available.

3.8 Dr V. Siegel (Germany) asked for clarification through the Secretariat as to whether Vanuatu would continue fishing in the 2005/06 fishing season. Dr Ramm advised that, in follow-up correspondence with Norway regarding its notification, Norway had indicated that the Vanuatu-flagged vessel *Atlantic Navigator* would cease fishing for krill in August 2005, and be replaced by the Norwegian-flagged vessel *Saga Sea* which would begin fishing in December under the Norwegian notification.

3.9 The Working Group noted the increasing number of recent new entrants into the fishery. It also noted that the expected catch from the 2004/05 season of 165 000 tonnes was less than last year’s total intention of 226 000 tonnes.

3.10 Some members interpreted this as an indication of possible growing demand or development of a new market. However, other members noted that the expression of intent to fish is arbitrary. The fishing operators tend to indicate the maximum possible catch and not necessarily the realistic catch, therefore discussion of trends should be based on reported catches.

3.11 Dr Shin noted that the total expected catch is often determined by the overly optimistic projections by new entrants and has not been a reliable prediction. He also noted that there is not a great deal of evidence to indicate a rapid expansion of the krill fishery.

By-catch

Fish

3.12 The Secretariat advised that scientific observers have reported by-catch of fish and invertebrates from a total of 4 431 tows in the krill fishery in Area 48, indicating a by-catch of approximately 0.05% by weight. The by-catch in Area 48 is dominated by *Champsocephalus gunnari*, both by number (69%) and weight (39%) (WG-EMM-05/5).

3.13 Fish by-catch from Japanese-flagged krill trawlers at South Georgia was also reported (WG-EMM-05/19). Japan now has accumulated an extensive amount of fish by-catch data from Area 48. The Working Group thanked Japan for its ongoing contribution to knowledge of the krill fishery and encouraged further overall analysis of the entire by-catch data.

Fur seals

3.14 Based on data submitted to the Secretariat, 208 Antarctic fur seals and two individuals of an unknown species have been reported as killed accidentally in the krill fishery in Area 48, and all fatalities occurred in the 2003/04 season (WG-EMM-05/5). There were no records of incidental catches in the krill fishery between 1999/2000 and 2002/03 in the CCAMLR database. However, the Working Group noted that 53 seals were killed in 2002/03 (SC-CAMLR-XXIII, paragraph 5.34) but the data were not reported to the Secretariat in the specified format and hence were not included in WG-EMM 05/5.

3.15 In 2004, the Scientific Committee recommended that exclusion devices should be employed by all vessels engaged in the krill fishery so as to minimise the incidental catch of fur seals and that observers should be deployed on all vessels to assess the effectiveness of these devices (SC-CAMLR-XXIII, paragraph 5.37).

3.16 The Secretariat noted that 25 Antarctic fur seals had been killed accidentally in the krill fishery during 2004/05 thus far, however there was no information available as to whether exclusion devices were employed on these vessels or not, therefore it was unclear how this fur seal by-catch was influenced by the use of exclusion devices.

3.17 The Working Group recognised that there was a paper in preparation for *CCAMLR Science* reviewing mitigation measures. The paper had been prepared in response to a request from the Scientific Committee last year (SC-CAMLR-XXIII, paragraph 5.37). The Working Group requested that the paper be presented to ad hoc WG-IMAF at its meeting in 2005.

3.18 The Working Group emphasised the need for the evaluation of exclusion devices and agreed that WG-IMAF has the appropriate expertise to deal with this problem, and therefore agreed to ask WG-IMAF to further consider this issue at its next meeting.

Description of fishery

Historical pattern of fishing ground selection

3.19 WG-EMM-05/28 summarised succession of fishing ground usage in space and time since the early 1980s. Among the 15 SSMUs within Subareas 48.1, 48.2 and 48.3, including the pelagic SSMUs, only one-third of these were identified as the main contributors to the total catch (SGE, SOW, APEI, APDPE, APDPW).

3.20 A shift of operational timing towards later months within fishing seasons was observed in Subarea 48.1 (from December–February to March–May). However, operational timing stayed relatively constant in Subareas 48.2 (March–May) and 48.3 (June–August).

3.21 These patterns of seasonal SSMU selection were characterised using cluster analysis. Frequently used SSMUs did not always match the areas of high krill densities observed by scientific surveys. This may be because skippers tended to fish at preferred fishing grounds. However, in the long term, it was thought that the patterns may also change with time, possibly through gaining experience, analysis of available information, and in response to changing economic environments.

3.22 The Working Group noted that the information would be useful in developing the SSMU management procedure (Appendix D, paragraphs 3.28 to 3.35).

New technology

3.23 WG-EMM-05/12 provided details of the fishing methods employed by the *Atlantic Navigator*. The vessel used a conventional fishing system with pelagic net and a continuous fishing system using midwater trawl with air-bubbling suspension which continuously pumped krill from the codend to the vessel. Both methods were alternatively used, depending on the distribution, density and behaviour of krill concentrations, weather and sea state, skipper's decision and processing capacity of the factory. The continuous fishing system was best used to fish shallow aggregations of krill within reach of the pumping hose.

3.24 Dr Kawaguchi noted that the observer data (see paragraph 3.28) gave the Working Group an opportunity to understand the operation pattern of the fishery early in its development, as well as the difference in the krill catch composition between these two different fishing methods.

3.25 Selectivity and mortality of krill by the new method needs to be understood to estimate the impact on the krill population. Dialog between fishing operators and Working Group members was encouraged to obtain this information.

3.26 The Working Group examined whether or not the pumping method could be categorised as a 'new or exploratory fishery'. It was concluded that the fishery based on this method would not be considered new or exploratory if selectivity of krill, characterisation of the haul (how to describe the catch rate), and spatial information of where (SSMU) the catch was caught could adequately be described.

3.27 The Working Group agreed to seek advice from WG-FSA on the kind (type of format) of information and data needed to allow cross-fleet comparison between different fishing methods in order to understand the trends in the krill fishery.

3.28 The Working Group thanked the Uruguayan observers for submitting their useful observer report, and hoped that the entire observer dataset would be submitted to the Secretariat in the near future.

Scientific observation

CCAMLR international scientific observers

3.29 The Secretariat has received two notifications for scientific observers on krill fishing vessels in Area 48 in 2004/05:

(i) Ukraine: one national scientific observer on *Foros* (Ukraine)

(ii) Uruguay: one international scientific observer on *Atlantic Navigator* (Vanuatu), whose observer report was submitted to the current Working Group meeting.

3.30 Six scientific observer datasets from the krill fishery were submitted in the 2003/04 season. At present, the CCAMLR database holds scientific observer data from 20 trips/deployments in the krill fishery between 1999/2000 and 2003/04 in Subareas 48.1, 48.2 and 48.3.

3.31 Although the krill fishing season extends from summer to winter, deployment of CCAMLR scientific observers occurred mainly during summer and autumn (WG-EMM-05/28). The Working Group agreed that CCAMLR scientific observers should be evenly distributed throughout the fishing season to increase the observation coverage.

3.32 As there was no appreciable observer information from Subareas 48.1 and 48.2, the Working Group re-emphasised the need of wider international observer coverage in space and time to further improve the understanding of the operation of the fishery in the entire Area 48 (paragraph 3.45).

3.33 WG-EMM-05/31 summarised the result of a preliminary analysis of krill fishing behaviour based on the questionnaire provided in the *Scientific Observers Manual*. The analysis found that it was difficult to interpret the time-budget data without diagrams of vessel track and positions of krill aggregations. Possible inconsistency of search time definition employed among the skippers and nations was also pointed out.

3.34 WG-EMM-05/30 analysed the behaviour patterns of Japanese krill fishery vessels in Area 48 using questionnaires on the reasons why the vessels changed their fishing grounds.

3.35 The Working Group noted that the type of questionnaire issued routinely in the Japanese krill fishery provided very useful information to understand fishing behaviour, and it was agreed to incorporate these questions in the CCAMLR questionnaire form together with the diagrams of vessel track and positions of krill aggregations.

Regulatory issues

Data submission

Monthly reporting

3.36 The Secretariat advised that most Contracting Parties fishing for krill reported monthly catch and effort by subarea. However, some Parties reported monthly catch and effort by area only. As a result, it is not possible for the Secretariat to estimate catches by SSMU in the current season, nor accurately estimate catch by subarea (WG-EMM-05/5).

3.37 The Working Group agreed to the need for monthly catch and effort reports to be provided at SSMU resolution to support the current move towards the SSMU management regime. Therefore, it recommended that paragraph 2 of Conservation Measure 23-06 be modified to read:

> 'Catches shall be reported in accordance with the monthly catch and effort reporting system set out in Conservation Measure 23-03. When fishing in SSMUs in Area 48, each Contracting Party shall report monthly catch and effort data by SSMU. When fishing in other areas, each Contracting Party shall report monthly catch and effort data by subarea/division.'

3.38 While Dr Naganobu agreed in principle with the reporting of monthly catch and effort data by SSMU, he wished to reserve his position at this meeting because SSMUs are not contained in any of the current conservation measures and he wished to consult with the relevant groups.

Fine-scale catch and effort data reporting

3.39 Dr Ramm reported that all Contracting Parties fishing for krill in the 2003/04 season had submitted fine-scale data. Some of these data were submitted after the deadline of 1 April 2005 (Conservation Measure 23-06).

3.40 The current minimum requirement for fine-scale data is catch and effort aggregated by 10 x 10 n mile rectangle by 10-day period. However, the Commission has encouraged Members to submit fine-scale data on as detailed a level as possible. Recently, with the exception of two Members, all Contracting Parties now submit all their fine-scale data from the krill fishery on a haul-by-haul basis.

3.41 Because of the complex shape of SSMUs, the Working Group agreed that submission of fine-scale data on a haul-by-haul basis is likely to be required to adequately monitor the fishery and allow future management under SSMU subdivision.

3.42 Dr Naganobu stated that, although Japan agreed to the provision of haul-by-haul catch and effort data for scientific purposes on a voluntary basis, it is not agreeable to make it compulsory due to the commercial confidentiality of these data.

3.43 The Working Group requested that the Secretariat revise the data reporting format to accommodate the information arising from the new fishing method (pumping method) so that the properties of the fishing activities are adequately archived (paragraphs 3.23 to 3.27).

Scientific observation

3.44 WG-EMM-05/32 requested scientific observers (international or national) be compulsory for the Antarctic krill fishery.

3.45 The Working Group was in agreement that there is an urgent need for international observers to be deployed on all krill fishing vessels operating in the Convention Area to adequately understand the nature of the krill fishery, especially given the situation of recent change in fishing/processing technology, and needs to maximise seasonal and spatial coverage.

3.46 The majority of members agreed in principle that the deployment of scientific observers should be required on all krill fishing vessels. However, the Working Group could not reach a consensus agreement.

3.47 Dr Naganobu noted that, although Japan was willing to contribute to the international observer scheme on a voluntary basis, at this stage it was difficult to accept the scheme as compulsory due to reasons such as commercial confidentiality.

3.48 Dr R. Holt (USA) expressed his disappointment that Japan could not accept a compulsory observer scheme and hoped that in the near future this could be resolved.

Key points for consideration by the Scientific Committee

3.49 Starting in the 2003/04 fishing season, a new operation method (continuous pumping method) has been employed by one of the operators (paragraph 3.23).

3.50 The Working Group requested the Secretariat to revise the data reporting format to accommodate the information arising from the new fishing method (pumping method) (paragraph 3.43).

3.51 The Working Group agreed that ad hoc WG-IMAF has the appropriate expertise to deal with the problem of fur seal by-catch in the krill trawl fishery and therefore agreed to ask WG-IMAF to consider this issue at its next meeting (paragraph 3.18).

3.52 The Working Group agreed to seek advice from WG-FSA about the kind (type of format) of information and data needed to allow cross-fleet comparison between different fishing methods in order to understand the trends in the krill fishery (paragraph 3.27).

3.53 The Working Group agreed that the *Scientific Observers Manual* should include the type of questionnaire used by the Japanese krill fishery together with diagrams of the vessel track and positions of krill (paragraph 3.35).

3.54 The Working Group agreed that the monthly catch and effort report should be provided at SSMU resolution and recommended modification of paragraph 2 of Conservation Measure 23-06 to read (paragraph 3.37):

> 'Catches shall be reported in accordance with the monthly catch and effort reporting system set out in Conservation Measure 23-03. When fishing in SSMUs in Area 48, each Contracting Party shall report monthly catch and effort by SSMU. When fishing in other areas, each Contracting Party shall report monthly catch and effort data by subarea/division.'

Note Dr Naganobu's reservation in paragraph 3.38.

3.55 The majority of members agreed on the compulsory deployment of an international observer on all vessels operating in the krill fishery, but the Working Group could not reach consensus (paragraph 3.46).

STATUS AND TRENDS IN THE KRILL-CENTRIC ECOSYSTEM

Predators

4.1 WG-EMM-05/4 reported on progress on data validation and logic testing for all data submissions to the Secretariat of all CEMP indices up to 1 June 2005. This paper reported on predator indices following agreement last year to discontinue maintaining and reporting environmental indices. Fishery indices and measures of overlap with predators are reported in WG-EMM-05/5 (section 3.1). The Secretariat reported progress on the previously agreed recommendation of the Working Group to move from reporting CEMP indices as positive and negative anomalies to an ordination approach. It anticipates reporting in the new style within one to two years. WG-EMM-05/4 also reported results based on the new method for calculating fur seal pup growth as a mean annual growth deviate.

4.2 Dr Ramm reported that the Secretariat has developed data forms for the submission of Antarctic shag diet data collected in accordance with the newly established protocol (SC-CAMLR-XXIII, Annex 4, paragraphs 4.93 to 4.96). This work had been done in consultation with Drs E. Barrera-Oro and R. Casaux (Argentina) and the new data forms are available on the CCAMLR website. In addition, Dr Ramm reported that Dr Casaux had submitted an annual series (1991–2005) of Antarctic shag diet data from the Argentine monitoring program for archiving with the Secretariat. The Secretariat will develop an index based on this series for consideration by WG-EMM and WG-FSA in 2006.

Pinnipeds

4.3 WG-EMM-05/23 presented results from a survey designed to estimate the abundance of pack-ice seals off east Antarctica conducted in the early summer of 1999/2000 using an icebreaker and two helicopters. The survey collected data on crabeater, Ross and leopard seals in an area of 1.5 million km^2 of pack-ice between 60° and 150°E. The paper described the efforts to correct for the proportion of the population not hauled out using ARGOS satellite-linked dive recorders on 33 crabeater and 2 Ross seals. Using double observer linetransect methods and a number of geographic covariates including depth, slope, distance to the shelf break, distance to the ice-edge, ice cover and ice width, the authors estimated 700 000 to 1.4 million crabeater seals in the survey area. Ross and leopard seals were more difficult to estimate but estimates for these species are also provided.

4.4 Dr Southwell added that a point estimate for population abundance of crabeater seals in the surveyed region in the 1970s was within the confidence interval for this survey, and hence there was no evidence for a change in crabeater populations between the 1970s and 2000.

4.5 Reid and Forcada (2005) reported on the causes of pup mortality in Antarctic fur seals breeding at South Georgia and the role of intrinsic (density of seals at breeding beaches) and extrinsic processes (e.g. offshore prey availability and maternal foraging success). The mean survival rate from 1989 to 2003 was 77.6% (range 52.6–92.8%). Starvation was the most common cause of death (47%) and negatively correlated with overall pup survival but showed no relationship with the number of pups born. The second most common cause of death, traumatic injury (19%), increased significantly with number of pups produced. It was concluded that the rate of increase in the fur seal population at South Georgia appears to be controlled by food availability rather than the availability of breeding habitat.

4.6 Forcada et al. (in press) examined the role of environmental forcing and climate-induced changes in the marine ecosystem on Antarctic fur seal pup production at South Georgia from 1984 to 2003. Non-linear mixed effects models indicated that positive sea-surface temperature anomalies were correlated with reductions in pup production. Warm anomalies at South Georgia, which occur three years after ENSO events in the Pacific, lead to a reduction in pup production in the following year. The Working Group agreed that studies such as this are important in separating the influences of environmental forcing and the effects of fisheries on CEMP indicator species.

Seabirds

4.7 WG-EMM-05/9 provided an update in trends in penguin population dynamics, as well as interannual variation in penguin diet and foraging behaviour at Cape Shirreff, Livingston Island. The chinstrap population continued to decline and is at its lowest size since the start of the eight-year study. In addition, fledging success was low compared to earlier years. However, the gentoo penguin breeding population has remained relatively stable and the fledging success in 2004/05 was similar to the long-term mean. Fledging weights of both species decreased from last year, and were the lowest average weights seen over nine years. The diet of both chinstrap and gentoo penguins contained primarily adult female Antarctic krill in the 46–50 mm length range. This continued a four-year trend of increasing proportions of female krill and increasing size of krill in the diets of the penguins at this site.

4.8 In response to a query from the Working Group, Dr Trivelpiece noted that the proportion of female krill in the penguin diets increased with the number of years since a strong krill recruitment event had occurred. He suggested that female krill may move to inshore habitats that are more productive if they are not in condition to spawn; while males may remain offshore where most spawning occurs. He further noted that the concurrent net samples, collected largely offshore in the adjacent region, did not show the extreme sex ratio skewing reported in the penguin data.

4.9 Dr Goebel noted that diet data from fur seals at Cape Shirreff show interannual differences in krill sex ratios (WG-EMM-05/26). However, he noted that fur seal and penguin foraging areas do not overlap during the chick/pup-rearing period of January to February at Cape Shirreff; both chinstrap and gentoo penguins forage inshore on the shelf, while fur seals forage well offshore at the shelf break.

4.10 WG-EMM-05/21 examined the relationship between breeding success and foraging trip duration on fledging weights of Adélie penguins measured over 11 years at Béchervaise Island. Concordance between the latter two was apparent when considering guard stage foraging trip durations but this was not as strong for the crèche foraging trips later in the season. Fledgling weights which are measured at the end of the breeding season were more strongly correlated with later foraging trips than with earlier trips. In some seasons, there appeared to be constant levels of resources throughout the breeding season resulting in good breeding success with heavy fledglings or poor breeding success with below-average weight fledglings. In other seasons, there was a disparity between breeding success and fledgling weight. Concerns raised by Williams and Croxall (1990) that fledgling weight may increase with an associated truncation of the distribution in poor seasons for seabirds with prolonged chick-rearing periods were unfounded for the Béchervaise Island Adélie penguin population. The authors suggested it would be useful to determine the demographic consequences of variable fledgling weights in terms of subsequent chick survival for this population.

4.11 Lynnes et al. (2004) reported that the diet of Adélie and chinstrap penguins at Signy Island, South Orkney Islands, was almost exclusively krill (>99% by mass) between 1997 and 2001; however, there was considerable interannual variation in reproductive output. Detailed analysis of the population size structure of krill in the diet indicated a lack of recruitment of small krill into the population from 1996 to 2000. A simple model of krill growth and mortality indicated that the biomass represented by the last recruiting cohort would decline dramatically between 1999 and 2000. Thus, despite the lack of a change in the proportion of krill in the diet, the demographics of the krill population suggested that the abundance of krill may have fallen below the level required to support normal breeding success of penguins during the 2000 breeding season. The authors noted that the role of marine predators as indicator species may be greatly enhanced when those species can also indicate links between the population dynamics of krill and its availability to predators.

4.12 WG-EMM-05/37 reported an outbreak of avian cholera (*Pasteurella multocida*) in a single colony at Marion Island that killed about 2 000 macaroni penguins in November 2004. Other colonies of macaroni penguins and other species of seabirds were not affected. This was the first known occurrence of the disease at the island; however, in March 1993 an unknown disease killed several thousand macaroni penguins, again in a single colony, but other colonies or other species of seabirds were not affected.

4.13 The Working Group was reminded that field researchers encountering die-offs of seabirds in the field should refer to *CEMP Standard Methods*, Part IV, Section 6 ‘Protocols for collection of samples for pathological analysis in the event of disease being suspected among monitored species of birds’.

4.14 Dr Constable suggested that a collation of known disease outbreaks and the numbers of affected seabird populations might be valuable to the work of the Working Group.

4.15 WG-EMM-05/38 suggested that winter conditions may be an important factor determining breeding success. Rockhopper penguin breeding success was correlated with female arrival mass, while date of arrival was affected by winter conditions in macaroni penguins. Arrival mass and the timing of breeding may have substantial impacts on future recruitment to the breeding populations of these species.

4.16 Dr Southwell noted that the time series in WG-EMM-05/38 provided some insight into an important question that arose from the CEMP review, namely whether a single site is representative of a larger region.

Krill

4.17 WG-EMM-05/15 examined the distribution of female krill of different maturity stages to reveal the preferred bottom depths of spawning. Calculations based on data from scientific surveys and observers revealed no statistically significant trend for gravid females to move offshore to deeper waters. The authors cast doubts on the conventional view of krill spawning and proposed that the distribution of gravid females is determined by hydrodynamics and food supply.

4.18 Members noted that the data, presented only in relative proportions, made it difficult to deduce the actual quantity of krill in different stages and depth ranges. It was also thought that the distinction between onshore and offshore at 500 m depth was arbitrary. Dr V. Sushin (Russia) explained that the proportion of animals in different stages as well as the occurrence in trawl samples of animals in different stages was presented, and this analysis was from an extensive dataset. Members encouraged further quantitative analysis, particularly more detailed examination of spatial variability of occurrence of gravid females.

4.19 WG-EMM-05/29 used an LMM to analyse growth trends of Antarctic krill with sex, length, season and region using over 10 years of instantaneous growth rate (IGR) measurements. A model of inter-moult period (IMP) as a function of temperature was used to predict seasonal IMP. Growth rates and life span may differ between sexes. The period of rapid growth was in December in the Indian Ocean sector whereas in the Scotia Sea it appeared to be earlier. Seasonal specific growth rates estimated in this study were compared to previous studies, and suggested that wild krill show more rapid growth over a shorter period than previously thought.

4.20 WG-EMM-05/27 introduced an alternative approach to predict the trajectory of krill body length over time using a step-growth function combining models of IGR with a model of temperature-dependent IMP. A number of growth trajectories were generated starting from an age 1+ mean length for different scenarios of winter and spring growth. The models indicate that, allowing for shrinkage, age 6+ mean length for the Indian Ocean sector was close to 53 mm compared to 57 mm from studies for the Atlantic sector.

4.21 Some Members enquired if temperature is the only key factor to determine krill growth in the model and how food condition is taken into account. It was explained that varying temperature determines the IMP, which is required to convert IGR to specific growth rates, and that food conditions were indirectly considered at this stage by using growth rate measurements from each region representing different food conditions. Dr Sushin noted that the period of rapid growth of krill in the Scotia Sea area a few months earlier than December does not seem to agree well with field observations, and this may be because the model used a far smaller number of IGR measurements from the Scotia Sea area compared to the Indian Ocean sector. He was of the view that spatial and temporal variability in food condition play a significant role in krill growth and this deserves due consideration in model development. Dr Kawaguchi responded that there are publications which show that krill grow rapidly in the Scotia Sea before December (e.g. Reid, 2001; Siegel, 1986).

4.22 Members welcomed this exercise and expected it might enable simulation of krill growth across space and time, and would be of great utility in the formulation of management procedures. Members encouraged further development of the model, which may include the incorporation of other critical factors, particularly food supply for krill.

4.23 A study by Atkinson et al. (2004) combined all available scientific net sampling data from 1926 to 2003. The productive southwest Atlantic sector contains >50% of Southern Ocean krill stocks, but here their density has declined since the 1970s. Spatially, within their habitat, summer krill density correlates positively with chlorophyll concentrations. Temporally, within the southwest Atlantic, summer krill densities correlated positively with sea-ice extent the previous winter. This study concluded that, as krill densities decreased last century, salps appear to have increased in the southern part of their range. The authors noted that this might have management implications.

4.24 A study by Yoshitomi (2005) examined digestive enzyme activity throughout a fishing season in Area 48, and demonstrated how krill fishery samples could be used to describe seasonal trends in biological properties of krill.

Environmental influences

4.25 WG-EMM-05/16 described a multidisciplinary survey carried out in the Ross Sea and adjacent waters by the RV *Kaiyo Maru* during the summer of 2004/05. The survey was designed to collect simultaneous data on Antarctic krill, other zooplankton and krill predators in order to relate their mesoscale distribution and abundance to the physical and biological environment.

4.26 The paper presented some preliminary results from the full-depth synoptic oceanographic section along 175°E (60°–77°S). Antarctic Surface Water (<0°C) occupied the shelf area and extended in a narrow surface band northwards beyond the shelf edge where it reached a depth of approximately 150 m. The authors suggested that the distributions of both Antarctic krill (*Euphausia superba*) and crystal krill (*E. crystallorophias*) were related to water temperature, based on the average value between the surface and 200 m. The authors suggested that Antarctic krill occurred in the warmer waters north of the shelf slope while crystal krill occurred in the colder shelf waters.

4.27 Dr P. Wilson (New Zealand) reminded the meeting that the distribution of Antarctic and crystal krill is reflected in differences in the diet of Adélie penguins breeding in the Ross Sea. He recalled that over 1 million pairs bred in the western Ross Sea and that of these, approximately one-third bred south of Coulman Island (approximately 73°S 170°E) (principally those colonies on Ross Island) and approximately two-thirds bred north of Coulman Island (particularly at Cape Adare, Cape Hallett and at Possession Island). Dr Wilson reported that diet studies of penguins at these locations reflected the distribution of krill reported in WG-EMM-05/16. North of Coulman Island penguins primarily fed on Antarctic krill (together with some fish), while south of the island they fed on crystal krill (also with some fish).

4.28 Dr Trathan enquired whether long-term information was available on diet and whether it indicated any interannual variability. Dr Wilson indicated that the diet data from the Ross Sea colonies showed interannual variability that appeared to be related to pack-ice cover. Fish (mainly *Pleuragramma antarcticum*) were more important than crystal krill when pack-ice was reduced or absent in the foraging area of penguins (and crystal krill more important when pack-ice was more extensive). Dr Wilson further indicated that diet data from the northern colonies were much more limited and that interpretation was therefore more difficult. Dr Naganobu enquired whether any information was available on the status of Adélie penguin populations in the region. Dr Wilson responded that populations at Ross Island had increased in the past, but that these had now declined to their former levels and overall, the Ross Sea penguin population remained relatively stable.

4.29 WG-EMM-05/17 described an atmospheric index calculated from 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) on the Antarctic Peninsula. The Working Group has considered the DPOI at previous meetings (SC-CAMLR-XXIII, Annex 4, paragraph 4.45), when it noted that DPOI reflected environmental variability that related to the krill-centric ecosystem (see also Naganobu et al., 1999). Dr Naganobu suggested that it would be interesting to carry out a reanalysis of krill recruitment in the context of DPOI now that both time series were longer and contained more data points.

4.30 WG-EMM-05/41 examined the characteristics of geostrophic flow across the Scotia Sea based on Russian oceanographic stations sampled since the 1960s in Area 48. The station data included in the analysis were used to estimate geostrophic flows referenced to 1 000 m. The analysis does not account for non-geostrophic components of water velocity.

4.31 The authors suggested that average water velocity was approximately 20 cm s^{-1}, but that there was considerable spatial variability, with geostrophic velocities at different locations varying by more than one order of magnitude (<5 cm s^{-1} to 60 cm s^{-1}). The authors also suggested that the reported water velocities were sufficient to cause the complete replacement of water in some SSMUs several times during one fishing season. The authors further suggested that such levels of transport could significantly affect the dynamics and distribution of krill biomass in the Scotia Sea, particularly if krill were passive particles carried in the geostrophic flow.

4.32 Dr C. Reiss (USA) noted that this was an interesting paper and a useful approach; however, he suggested that it was critical to better understand how the data had been referenced to 1 000 m as the methodology was not detailed and not referenced to either standard textbook methods or recent relevant papers such as Panteleev et al. (2002) or Yaremchuk and Maximenko (2002). Dr Reiss indicated that it was important to understand the basis of the method used so that the meeting could better appreciate how the reported flows related to errors consequent on water shear below 1 000 m and on the shelf.

4.33 Dr Reiss also suggested that it would be useful to examine the data seasonally. The current analysis temporally smooths the data and this may introduce bias, whereas a seasonally resolved analysis would help the Working Group better appreciate the importance of geostrophic flow.

Methods

4.34 WG-EMM-05/20 and 05/22 presented analyses of the data collected as part of the Australian contribution to CEMP carried out on Béchervaise Island, East Antarctica. The analyses in both papers suggested some revisions for sample sizes were required in Standard Methods A5 (penguin foraging trip duration) and A7 (penguin fledging mass).

4.35 WG-EMM-05/20 examined the potential for fledging mass to be biased by differential mortality, i.e. years with low breeding success when only a few large chicks reach fledging age. However, the authors indicated that in the analysis there was no indication that situation had occurred in this dataset. However, Dr Wilson commented that he had observed this situation in the penguin monitoring in the Ross Sea region.

4.36 WG-EMM-05/22 reviewed the power to detect changes in penguin foraging trip duration (Standard Method A5) and found that there was a much greater power to detect step changes compared to gradual changes. Furthermore, the analysis suggested that monitoring the foraging trip durations of more than 30 birds is unlikely to significantly improve the power to detect changes.

4.37 The Subgroup on Methods commended the Australian program and recognised that it is essential for any monitoring program to be under a continual process of review in order to accommodate specific operational and logistical constraints. The subgroup recognised that the power to detect changes will depend on the level of natural variability and that this is likely to vary with regions. Therefore, it was recognised that the papers were not suggesting that the CEMP standard methods be revised at this time, but the subgroup encouraged other Members to analyse monitoring data and to provide advice on optimising sample sizes.

4.38 WG-EMM-05/26 presented results of an analysis of the relationship between krill carapace length and width to determine the sex of krill from the South Shetland Islands in comparison to a previous study at South Georgia (Reid and Measures, 1998). The multi-year approach highlighted the effect of krill size and maturity on the ability to discriminate the sex of krill such that for krill with carapace lengths of ≥13 mm sex could be determined with >80% success. The subgroup agreed that this provided a very useful means of obtaining additional data on krill consumed by predators in samples where whole krill are not available (e.g. fur seal scats) and noted that it was important to use appropriate regionally derived allometric relationships to account for regional differences in growth rates.

Acoustic

Report of SG-ASAM

4.39 Dr Watkins presented a summary of the Report of the First Meeting of SG-ASAM (SC-CAMLR-XXIV/BG/3) which met in La Jolla, USA, from 31 May to 2 June 2005, to consider models of krill target strength (TS) and classification of volume backscattering strength (S_v).

Models of target strength

4.40 The TS model (Greene et al., 1991) presently used by CCAMLR for the estimation of biomass is a linear regression model derived from measurements of northern hemisphere zooplankton. Although the model was corroborated with empirical data (e.g. Foote et al., 1990) it was recognised at the outset that there were a number of problems with the model when applied to krill. In particular:

- it is only accurate for krill that are larger than the wavelength of the sound pulse (e.g. λ_{120kHz} = 12.5 mm);
- it does not account for changes in target morphology, physiology and orientation, all of which have been shown to significantly affect TS (Demer and Martin 1994, 1995);
- it was not actually derived from measurements of *E. superba* at 120 kHz;
- it predicts that TS of crustacean zooplankton is dependent on the animal's volume, when it is actually thought to be dependent on its area (Demer and Martin, 1994, 1995).

4.41 Since 1991 a physics-based TS model has been developed (distorted-wave Born approximation (DWBA): Morse and Ingard, 1968; Stanton et al., 1993, 1998; Chu et al., 1993a, 1993b; McGehee et al., 1998, 1999) that represents an improvement to the Greene et al. (1991) model because it considers not just size, but the other parameters (shape, material properties and orientation) that contribute to TS.

4.42 McGehee et al. (1998, 1999) empirically validated the DWBA model obtaining a good fit between empirical measurements and DWBA model predictions when the sound impinged on the animal from a dorsal, ventral or lateral aspect but a poor fit at other orientations.

4.43 Demer and Conti (2003a, 2004a) theoretically explained the poor fit between DWBA predictions and empirical measurements at orientations away from 90° using a modified DWBA model (the so-called 'stochastic DWBA', or SDWBA), which takes additional account of three stochastic parameters:

(i) scattering in a field with noise
(ii) the complexity of krill shape
(iii) the flexure of the body as it swims.

4.44 Demer and Conti (2002, 2003b, 2004b) went on to validate the theoretical SDWBA model with empirical measurements of krill total TS (TTS) using a new technique (De Rosny and Roux, 2001). The empirical measurements agreed closely with the SDWBA model predictions over the frequency range 60–202 kHz ('to better than about 1 dB'); the empirical measurements at lower frequencies (36–60 kHz) were slightly higher than theory and the discrepancies were attributed to noise.

4.45 In a final step, Demer and Conti (2004c, 2005) applied the SDWBA to data from the CCAMLR-2000 Survey (Watkins et al., 2004) to explore the consequences of their new TS model on the overall estimate of B_0. Depending on the orientation distribution used, the original B_0 estimate of 44.3 million tonnes (CV 11.4%) was increased to as much as 192.4 million tonnes (CV 11.7%).

4.46 SG-ASAM recognised that there are a variety of parameters that influence TS and that these were not all encompassed in the Greene et al. (1991) model. The subgroup agreed that theoretical models have the capacity to encompass all of the relevant parameters implicated in TS. Further the subgroup endorsed the change in philosophy from the use of an empirical-only TS model (i.e. Greene et al., 1991) towards the use of theoretically-based empirically-validated models.

4.47 The subgroup considered which type of theoretical TS model was most appropriate to use for krill. The subgroup agreed, based on the information available to them at the time, that the most appropriate theoretical model for krill TS was currently the SDWBA; however, the subgroup also agreed that the use of the SDWBA is subject to the caveats described below.

- The SDWBA utilises multiple parameters and the range of values associated with each parameter is not well characterised, the subgroup recognised that determining the distributions of these parameters should be accorded a high priority.

- The subgroup emphasised the importance of determining krill orientation distributions that are representative of those occurring under the ship during survey conditions.

- The orientation distribution used in the published application of the SDWBA (Demer and Conti, 2005) was derived from the CCAMLR-2000 Survey data, however another plausible orientation distribution was calculated at the workshop. Further work to assess the implication and appropriateness of these different distributions was required.

- The phase variability term of the SDWBA (φ) takes account of noise, complexity of shape and flexure of the body (Demer and Conti, 2003a). While these terms should ideally be individually characterised and used in the DWBA, this is not practical at present and the SWDBA offers a pragmatic solution.

4.48 In addition to recommending the use of the SDWBA to estimate krill TS, the subgroup also recommended that:

- a 'simplified SDWBA' with constrained parameters be used to generate a 'base-case' estimate of B_0 for CCAMLR acoustic surveys of krill;

- model parameters be considered as probabilistic as opposed to deterministic and that the uncertainty associated with the input parameters must be accounted for in estimates of TS and hence B_0.

4.49 SG-ASAM considered that, given the time available at its workshop, it would not be possible to use a full probability density function (PDF) for each parameter to estimate TS and its variability. Moreover, there is presently insufficient empirical data to adequately characterise the PDF of any parameter. As a compromise, the subgroup considered each parameter in terms of its mean value ±1 SD. The values used to parameterise the simplified SDWBA are provided in SC-CAMLR-XXIV/BG/3, Table 1.

4.50 The TS values for the constrained simplified SDWBA using the above parameter values are shown graphically in SC-CAMLR-XXIV/BG/3, Figure 4 (krill TS as a function of L at 38, 70, 120 and 200 kHz). There is a large range of uncertainty in TS (and hence B_0), and this range is both frequency and length dependent. For instance, at f = 120 kHz where (i) L = 25 mm, SDWBA-predicted krill TS ranges from –88 to –73 dB (range = 15 dB); and (ii)where L = 50 mm, SDWBA-predicted TS ranges from –77 to –71 dB (range = 6 dB). The subgroup recommended that this uncertainty should be incorporated into estimates of krill TS and hence B_0.

Classification of volume backscattering strength

4.51 SG-ASAM recognised that early classifications of hydroacoustic data by taxon typically relied on the subjective visual analysis of echograms combined with information from net catches if available. For the CCAMLR-2000 Survey analysis a formalised and objective classification method was used. This was based on the dual-frequency dB-difference technique (ΔS_v) described by Madureira et al. (1993a, 1993b) and further validated and refined by Watkins and Brierley (2002).

4.52 When employing this ΔS_v method for classifying krill, the subgroup recognised that there are two major types of misclassification that can occur: (i) non-krill targets are classified as krill (‘acoustic by-catch’); and (ii) krill targets are not classified as krill (‘acoustic bypass’). The effect of ‘acoustic by-catch’ will be to overestimate the biomass of krill, while the effect of ‘acoustic bypass’ will be to underestimate the biomass of krill.

4.53 SG-ASAM recognised that with the adoption of a physics-based model for TS, it would now be possible to derive theoretical backscattering spectra that can be used to improve ΔS_v classification of krill currently derived from empirical observations.

4.54 The subgroup agreed that, for the time being, the ΔS_v technique continues to represent the most objective and pragmatic technique for classifying Sv by taxon. The subgroup recommended that when using the ΔS_v technique, acoustic by-catch and bypass should be minimised by constraining the ΔS_v windows to the size range of krill measured in the survey area. To facilitate this step, the subgroup calculated the minimum and maximum ΔS_v values for different size ranges of krill using the constrained, simplified SDWBA model (SC-CAMLR-XXIV/BG/3, Table 3).

Working Group discussion of SC-CAMLR-XXIV/BG/3 and recommendations

4.55 The Working Group endorsed SG-ASAM's recommendation that krill TS should be estimated using the SDWBA model and appropriate values of parameters in the model for surveys and, as appropriate, different areas within a survey be applied.

4.56 Currently, the classification of hydroacoustic data by taxon is undertaken by using the ΔS_v technique described by Madureira et al. (1993a, 1993b). The Working Group recognised that with the adoption of a physics-based model for TS (SDWBA) it would now be possible to derive theoretical backscattering spectra that could be used to improve ΔS_v classification of krill. The Working Group therefore recommended that when using the ΔS_v technique, misclassification of taxa should be minimised by constraining the ΔS_v windows to the size range of krill measured in the survey area.

4.57 The Working Group recognised that use of the SDWBA to calculate levels of uncertainty associated with the estimate of TS was an important development that had not been available with previous TS estimates.

4.58 It was also noted that it is important to understand to what degree acoustic surveys are able to produce an unbiased estimate of krill biomass.

4.59 It was recognised that the present levels of uncertainty are large and this is likely to be reflected in recalculations of B_0 for surveys already undertaken. However, these levels of uncertainty may be reduced if parameters for the SDWBA model are estimated directly for individual surveys or areas. The Working Group therefore recommended that actual measurement of the relevant parameter values be undertaken in all future surveys to minimise the uncertainty associated with the estimation of TS. The Working Group also recommended that, where possible, parameters be estimated for past surveys and areas.

4.60 With regard to recalculation of B_0 estimates for previous large-scale surveys used to generate precautionary catch limits, the Working Group agreed that recalculation incorporating the appropriate level of uncertainty was a high priority and should be undertaken within the next two years.

Estimation of material properties of krill

4.61 WG-EMM-05/36 described studies to estimate the material properties (sound speed and density contrast) of krill sampled during cruises of the RV *Kaiyo Maru* in 2000 and 2004/05. Measurements of sound speed contrast were made using a similar method to that described by Foote et al. (1990). Density contrast was measured using a series of bottles, each containing water of a different density. A mean density contrast of 1.0295 and 1.0448 (for krill of mean length 43.5 and 41.7 mm) was derived for the years 2000 and 2005 respectively. Corresponding sound speed contrasts of 1.0442 and 1.0348 for krill of mean length 25.1 and 48.6 mm were derived for the two years.

4.62 The Working Group welcomed the presentation of this study, particularly given the new importance of such information for the parameterisation of the SDWBA krill TS model.

4.63 In this context it was noted that the range of values presented in WG-EMM-05/36 was comparable with the range of values utilised in SC-CAMLR-XXIV/BG/3, Table 1.

4.64 The Working Group noted the difficulties of estimating krill density at sea and suggested that a comparison of the different techniques used to date would be valuable.

Estimate of biomass using maximum entropy techniques

4.65 WG-EMM-05/42 presented results of an analysis of the CCAMLR-2000 Survey using an alternative method of estimating krill abundance and producing maps of krill distribution. The method used a probabilistic Bayesian Maximum Entropy (MaxEnt) technique to interpolate density values for the unsurveyed off-transect portions of the survey area. These density values were then summed to infer total biomass across the survey region and within individual SSMUs. The resulting total biomass inferred for the survey area was 208 million tonnes (SD = 10 million tonnes).

4.66 It was noted that there was insufficient expertise within the Working Group to be able to evaluate this paper in detail. However studies using this developing technique were being submitted to other organisations (ICES) dealing with abundance estimates of exploited fish stocks and so it was likely that the technique would be evaluated appropriately in due course.

4.67 The Working Group agreed that in its present state of development the technique should not be seen as an alternative to the Jolly and Hampton (1990) method of calculating B_0 estimates that were to be used for setting precautionary catch limits.

Future surveys

Survey of Division 58.4.2

4.68 WG-EMM-05/11 provided an update of plans for the Australian BROKE-West acoustic survey to estimate a new krill B_0 for use in setting a new precautionary catch limit for Division 58.4.2. Plans for this cruise had previously been presented to WG-EMM in 2004 for comment and approval. The overall cruise design and strategy was based on a design approved by WG-EMM in 1995.

4.69 The Working Group endorsed the proposed cruise plan with the following additional suggestions:

(i) to minimise the level of uncertainty associated with estimation of TS using the new SDWBA, the values of parameters used in the model should be measured during the cruise if possible;

(ii) the Working Group welcomed the proposed comparisons with ships (Germany and Japan) surveying in adjacent areas. It was recognised that the value of such comparisons would be maximised if coordinated and common protocols for equipment settings and calibrations could be agreed and used.

CCAMLR-IPY-2008 Survey

4.70 At its 2004 meeting the Scientific Committee agreed that a synoptic acoustic survey in the South Atlantic region would be the most appropriate activity for CCAMLR in the IPY 2008 (SC-CAMLR-XXIII, paragraphs 15.4 to 15.7). It was agreed that a synoptic acoustic/net sampling survey in the South Atlantic region should focus on krill but would collect a range of ancillary physical and biological data including observations on marine zooplankton, marine mammals and birds.

4.71 The Scientific Committee established an intersessional steering group under Dr Siegel to formulate CCAMLR's Expression of Intent (EoI) for activities in the IPY. The Steering Group developed a document and submitted this to the IPY Joint Committee by the deadline of 14 January 2005. Concurrently, contact was established with the IWC, the SCAR Group of Experts on Birds and the Census of Antarctic Marine Life (CAML) Group inviting them to actively participate in the CCAMLR-IPY-2008 Survey. In response, representatives of all three groups welcomed the CCAMLR initiative and indicated that they will circulate the CCAMLR proposal among their members for closer consideration.

4.72 By the end of March the CCAMLR initiative received formal recognition by the IPY Joint Committee and was listed as EoI 148. After comprehensive assessments and discussions, the CCAMLR Steering Group developed a revised clustering scheme for related IPY projects.

4.73 On 6 June 2005 the CCAMLR Steering Group received a response from the IPY Joint Committee that it agreed with the reclustering suggested by the CCAMLR Steering Group and that the CCAMLR-IPY-2008 Survey should become the 'lead project' for the topic 'Natural Resources, Antarctic'. Consequently, the CCAMLR Steering Group will have to prepare and submit an 'umbrella proposal' and coordinated research plan for all related EoIs by the deadline 30 September 2005 or 16 January 2006.

4.74 Leaders of all potentially related projects were contacted before the WG-EMM meeting and almost all expressed their interest in close cooperation with the planned CCAMLR activity.

4.75 A close link was established with CAML EoI 83, the lead project for 'Biodiversity', which also has a strong pelagic component. Dr Watkins participated as a member of the CCAMLR Steering Group at the CAML Workshop in Brussels, Belgium, from 26 to 28 May 2005.

4.76 Dr Watkins reported to the subgroup of the Steering Group that a representative from most projects interested in biodiversity issues attended, and that most had limited access to or expectation of shiptime. The CAML Group was therefore developing a plan under the leadership of Prof. M. Stoddard (Australia) that was flexible and could incorporate shiptime as it became available. Dr Watkins gave a presentation to CAML. He suggested that CCAMLR would be able to offer CAML its experience in developing and coordinating large multi-ship surveys with standard protocols. While CCAMLR would likely benefit from the CAML program through access to additional vessels and coverage in areas that were not sampled by the CCAMLR-IPY-2008 Survey. There was an extreme diversity of CAML plans from biological to oceanographic studies. There was considerable debate as to whether CAML should focus on unsampled areas or better understand the areas already sampled.

There was consensus that the Bellingshausen area was very undersampled, and that the basic science plan should address the lowest common denominator, that is the presence or absence of animals in areas.

4.77 The subgroup discussed the status of shiptime for those interested in participating in the CCAMLR-IPY-2008 Survey.

(i) Germany will provide the *Polarstern* for the IPY, but there are around 15 competing proposals for the shiptime. A German shiptime steering group meeting will take place within the next two months.

(ii) Ukraine stated that it will not be able to contribute a ship for the CCAMLR-IPY-2008 Survey, but commercial fishing vessels will provide additional data from the fishery during the IPY.

(iii) New Zealand has no plans to contribute a ship for a CCAMLR-type survey, but individuals will be participating in the general IPY program.

(iv) The UK BAS DISCOVERY-2010 Programme has allocated 45 days of shiptime but will be heavily constrained by program goals. It will undertake process studies and limited survey work in the Scotia Sea and to the east of the South Sandwich Islands. BAS will continue its surveys north of South Georgia during the period of the CCAMLR-IPY-2008 Survey.

(v) Russia wishes to participate and expects to have a ship, but it will not know of the status of its request until 2007.

(vi) Japan wishes to take part but at this stage final participation remains to be confirmed.

(vii) Brazil will be participating in the general IPY program, but will not have a ship available for a Scotia Sea survey.

(viii) Norway has intentions of participating in the IPY program. It expects to have a ship available for two to three months, and will focus its survey in Subarea 48.6. It will undertake both acoustical and net sampling.

(ix) The USA will participate fully in a CCAMLR-IPY-2008 Survey, and will contribute approximately one month of shiptime. The USA will also survey the South Shetland Islands as currently performed.

(x) The Republic of Korea is expecting to contribute some shiptime to IPY activities, but there will be competing proposals. A pelagic ecosystem survey may be funded which is likely to take place in the early summer around the South Shetland Islands.

(xi) There was also a report that Chile, through INACH, would charter a vessel for the IPY, and would be looking for appropriate acoustic, net and hydrographic equipment.

(xii) Dr E. Fanta (Chair, Scientific Committee) informed the group that Chile, Argentina, Peru, Brazil and Uruguay are discussing a collaboration and may conduct a joint CCAMLR survey using a Peruvian research vessel. Further information should be available by the time of the Scientific Committee meeting in 2005.

(xiii) South Africa presently has no plans to participate in the CCAMLR-IPY-2008 Survey, however it will be undertaking a biodiversity survey around Prince Edward Islands.

4.78 The subgroup reviewed the terms of reference of the CCAMLR-IPY-2008 Survey Steering Group (Appendix E) and asked that the Scientific Committee, at its next meeting in October 2005, discuss the membership of the steering group and endorse its terms of reference.

4.79 Given that the CCAMLR-IPY-2008 Survey has become the 'lead project' for the core topic 'Natural Resources, Antarctic', the subgroup discussed the wider context of the objectives of the CCAMLR-IPY-2008 Survey. It was agreed that a primary focus of the IPY was the facilitation of multidisciplinary circumpolar science. In particular it was recognised that successful IPY core programs would need to provide sufficient breadth and scope of goals so that constituent projects could be included in the proposal. The subgroup therefore proposed that in addition to the core focus on the South Atlantic, the scope of the proposal should be developed to increase the area of interest to be circumpolar. This would increase the direct benefit to CCAMLR by facilitating opportunities for surveys in other areas by CCAMLR Members who are unable to work in the South Atlantic.

4.80 The subgroup, with the approval of the Working Group, agreed that the Steering Group will continue to develop the proposal for submission to the IPY Joint Committee by the September deadline. This proposal would also be submitted to the Scientific Committee meeting in October 2005. Any revisions to the proposal as a result of comments from the Scientific Committee will then be submitted to the IPY Joint Committee in January.

Key points for consideration by the Scientific Committee

Predators

4.81 Based on an aerial survey carried out during 1999/2000, the abundance of pack-ice seals in an area (1.5 million km^2) off east Antarctica (between longitudes 60° and 150°E) was (95% confidence intervals): crabeater seals 0.7–1.4 million animals, Ross seals 37 000–124 000 and leopard seals 1 300–17 000. A point estimate for the population abundance of crabeater seals made in the 1970s for the same survey area was within the confidence interval for the 1999/2000 survey; as a consequence, there was no clear evidence for a population change (paragraphs 4.3 and 4.4).

4.82 The role of environmental forcing and climate-induced change on the population processes of Antarctic fur seals at South Georgia are becoming increasingly evident. Over the period from 1984 to 2003, positive sea-surface temperature anomalies explained extreme reductions in pup production; lagged correlations (by three years) with large-scale ENSO events in the Pacific explained much of the variability. Such relationships help explain environmental forcing and are important for interpreting potential impacts of fisheries on the ecosystem (paragraph 4.6).

4.83 The chinstrap penguin population breeding at Cape Shirreff, Livingston Island, continued to decline and is currently the smallest in the eight years of study. In addition, breeding success was poor compared with earlier years and fledging weights were the lowest recorded in the study (paragraph 4.7).

4.84 An outbreak of avian cholera occurred in November 2004 at Marion Island. It killed about 2 000 macaroni penguins at one colony but other colonies and other seabird species were not affected (paragraph 4.12).

Environmental influence

4.85 Preliminary results from a multi-disciplinary survey carried out in the Ross Sea during the summer of 2004/05 suggested a close relationship between water temperature and the distributions of both Antarctic and crystal krill; Antarctic krill occurred in the warmer waters north of the shelf slope while crystal krill occurred in the colder shelf waters (paragraphs 4.25 to 4.28).

Methods

4.86 It was recognised that there are a variety of parameters that influence krill TS and that these were not all encompassed in the empirical model currently used by CCAMLR (Greene et al., 1991). The Working Group therefore endorsed a change from the current model towards the use of a theoretically-derived empirically-validated model. Based on the information available, the Working Group agreed that the most appropriate theoretical model for krill TS was currently the SDWBA model. The Working Group therefore endorsed the subgroup recommendation that krill TS should be estimated using the SDWBA model and appropriate values of parameters in the model for surveys and, as appropriate, areas be applied as discussed in paragraphs 4.55 and 4.56.

4.87 Following the adoption of a physics-based model for TS (SDWBA), the Working Group recognised that the present levels of uncertainty are large and this is likely to be reflected in recalculations of B_0 for surveys already undertaken. However, these levels of uncertainty may be reduced if parameters for the SDWBA model are estimated directly for individual surveys or areas. The Working Group therefore recommended that actual measurement of the relevant parameter values be undertaken in all future surveys to minimise the uncertainty associated with the estimation of TS. The Working Group also recommended that, where possible, parameters be estimated for past surveys and areas (paragraph 4.59).

4.88 With regard to the recalculation of B_0 estimates for previous large-scale surveys used to generate precautionary catch limits, the Working Group agreed that recalculation incorporating the appropriate level of uncertainty was a high priority and should be undertaken within the next two years (paragraph 4.60).

4.89 The Working Group agreed that the Jolly and Hampton (1990) method of estimating B_0 should still be used when setting precautionary catch limits (paragraph 4.67).

Future surveys

4.90 The Working Group endorsed the plans for the Australian BROKE-West acoustic krill biomass survey of CCAMLR Division 58.4.2 in the 2006/07 season. The Working Group suggested using the new SDWBA TS as well as measuring the necessary data to parameterise the TS model. The Working Group welcomed the proposed comparisons with ships (Germany and Japan) surveying in adjacent areas. It was recognised that the value of such comparisons would be maximised if coordinated and common protocols for equipment settings and calibrations could be agreed and used (paragraphs 4.68 and 4.69).

4.91 The CCAMLR-IPY-2008 Survey initiative received formal recognition by the IPY Joint Committee and was listed as EoI 148; it has become the 'lead project' for the topic 'Natural Resources, Antarctic'. A close link has also been established with CAML EoI 83, the lead project for 'Biodiversity', which also has a strong pelagic component (paragraphs 4.72 to 4.75).

4.92 A number of Members will contribute shiptime to the IPY. At the moment, only the USA can commit to full participation in the CCAMLR-IPY-2008 Survey; other Members will need to win shiptime through their respective national IPY processes. Other vessels may also be available following joint international initiatives (paragraph 4.77).

4.93 The Working Group reviewed the terms of reference for the CCAMLR-IPY-2008 Survey Steering Group (Appendix E) and asked that the Scientific Committee discuss the membership of this steering group and endorse its terms of reference (paragraph 4.78).

4.94 The Working Group agreed that a primary focus of the IPY was facilitation of multidisciplinary circumpolar science. In particular, it was recognised that successful IPY core programs would need to provide sufficient breadth and scope of goals so that constituent projects could be included in the proposal. The Working Group therefore proposed that in addition to the core focus on the South Atlantic, the scope of the proposal should be developed to increase the area of interest to a circumpolar scale. This would increase the direct benefit to CCAMLR by facilitating opportunities for surveys in other areas by CCAMLR Members who are unable to work in the South Atlantic (paragraph 4.79).

4.95 The Working Group agreed that the CCAMLR-IPY-2008 Survey Steering Group should continue to develop the proposal for submission to the IPY Joint Committee by the September deadline. This proposal should also be submitted to the next Scientific Committee meeting. Any revisions to the proposal as a result of comments from the Scientific Committee should then be submitted to the IPY Joint Committee in January (paragraph 4.80).

STATUS OF MANAGEMENT ADVICE

Protected areas

5.1 Dr Penhale, Chair of the Subgroup on Protected Areas, reported that 14 Members and interested parties participated in the meeting of the subgroup.

5.2 Progress made during the intersessional period included the transmittal from CCAMLR to the ATCM advising of CCAMLR's approval of the management plans for ASPA Nos. 145 and 149. Advice for improvement of these plans also was transmitted to the ATCM and the originators of the plans. Informal comments on the proposed ASPA at Edmonson Point were provided by CCAMLR to the ATCM and originator of the plans, with formal comments to be provided following the 2005 meeting of the Commission.

5.3 The Chair of the subgroup reported that new material on MPAs was added to the subgroup section of the CCAMLR website, along with an updated list of the subgroup membership.

5.4 Dr Penhale provided information on the revised ATCM Decision regarding protected area management plans containing marine areas. Decision 9 (2005) entitled 'Marine Protected Areas and other areas of interest to CCAMLR' (ATCM-XXVIII Final Report) replaced Decision 4 (1998, ATCM-XXII Final Report). The revised decision eliminated the list of sites that should be considered by CCAMLR and deferred to the principle of reviewing sites in which there would be CCAMLR interest.

5.5 The Working Group agreed to transmit to the Scientific Committee approval recommendations for two ATCM management plans containing marine areas. These include the ASPA at Edmonson Point (WG-EMM-05/7) and a revised plan for the ASMA at Admiralty Bay (WG-EMM-05/8).

5.6 Dr Penhale introduced the topic of the CCAMLR MPA Workshop by providing an update on progress. A workshop Steering Committee consisting of nine members was created through Party nominations. A consensus was reached to hold the workshop from 29 August to 2 September 2005 in the Washington DC area. It was recognised that there was insufficient time for all interested Members to attend. However, due to the importance ascribed to the topic by the Commission, the decision was made to proceed. Eight Member countries had indicated an intention to send participants to the workshop.

5.7 The Chair of the subgroup, who is Convener of the workshop, reported that papers are expected to be submitted which will report on the progress that some countries have made in establishing MPAs in their EEZs. Additionally, papers that discuss potential MPAs within the CCAMLR Convention Area, as well as papers on the general topic of MPAs as related to CCAMLR, are expected. Participants were encouraged to submit papers two weeks prior to the workshop in order for the papers to be placed on the MPA section of the CCAMLR website. It was agreed that the deadline for papers would be 0900 h on the first day of the workshop.

5.8 Dr Penhale reported the subgroup's discussion on the topic of workshop participation by those not nominated by Members. The Chair referred to the recommendation arising from the 2004 Scientific Committee report (SC-CAMLR-XXIII, paragraph 3.51) that the workshop include invited experts to take advantage of the large body of MPA knowledge that could be used to promote the goals of CCAMLR. The Convener reported that the Steering Committee had supported the idea of inviting an expert who was affiliated with IUCN, one organisation specifically mentioned in the Scientific Committee report.

5.9 Some subgroup participants were strongly supportive of opening the workshop to observers, with the rationale that all stakeholders with interests in the Convention Area should be brought into the discussion. Others strongly felt that observers should not be participants, due to previous agreements regarding observer participation in CCAMLR working groups.

5.10 The Working Group continued this discussion, expressing varying opinions as to whether experts were limited to those affiliated with IUCN and whether observers could attend. Most members agreed with the Scientific Committee report, which allowed for experts to be invited and which made no provision for the attendance of observers.

5.11 The Convener noted that the full membership of the Steering Committee would need to be involved in an agreement on the invitation of any expert and that this process would require knowledge of the credential.

Harvesting units

5.12 Dr Naganobu reported on the discussions of the Correspondence Subgroup on Harvesting Units that has been considering the subdivision of the large FAO statistical areas into smaller areas that have greater ecological, oceanographic or biological homogeneity. Dr Naganobu reported that he and Dr Constable had begun discussions on this topic several years ago, and that Dr S. Nicol (Australia) had replaced Dr Constable last year. The correspondence subgroup spent time examining the large-scale distribution of krill to define ecologically based subdivisions. There was consensus within the correspondence subgroup members that they would wait until the Australian survey (acoustic and hydrographic data) is completed in Division 58.4.2, which will complement the 1996 survey of Division 58.4.1. The combined dataset will include information on one-third of the Antarctic coastline, and thus will facilitate the examination and delineation of smaller more ecologically based subdivisions of the large FAO subareas in eastern Antarctica.

5.13 The Working Group then considered the issue of bio-regionalisation as suggested by Dr Constable. Dr Constable provided a brief overview of the concept and its implementation in Australia to subdivide large management areas into local areas that may engender differential management strategies tailored to specific management objectives in adjacent areas of potentially larger management units.

5.14 There was some discussion among members of WG-EMM that this is, in some ways, the original concept in the evaluation and development of SSMUs for the allocation of fishing, but would revise structure of regions to achieve long-term conservation as per Article II of the Convention. This may require better integration of data across areas.

5.15 Dr Siegel posed two questions regarding the establishment of these bioregions. The first was whether development would require different bioregions for fish, krill etc., or would the areas be similar or the same. The second question was whether the Working Group would wish to establish these similar bioregions before it understands more about a system such as Subarea 48.6.

5.16 Dr Constable responded to these questions by clarifying that the bioregions should not be individually tailored to individual species components, and that the bioregion concept provides an integrated view of the ecosystem. He further clarified that implementation could be sequential, incorporating new information as this was developed. Dr Naganobu generally agreed but thought that such a decision to establish bioregions should include more discussion and he believed that the acquisition of more information about the Southern Ocean was important for this concept.

5.17 Dr Hewitt indicated that Dr I. Everson (UK) had previously used this type of integrated approach to look at oceanographic units in developing the foundation for establishing the FAO subdivision of the Convention Area. It was agreed that further data may not need to be collected in order to start the process such as for Subareas 48.6, 58.4, 88.1, 88.2 and 88.3, as initial work might expose gaps for future research.

Small-scale management units

5.18 The Working Group agreed that it was unable, at this time, to comment on the robustness of the candidate options for subdividing the catch limit for krill in Area 48 amongst SSMUs. Nevertheless, it has made substantial progress in developing the tools and parameter sets for providing advice on a subdivision of the Area 48 catch limit in the near future (Appendix D, paragraph 6.4).

5.19 The Working Group agreed that sufficient progress had been made with the KPFM development this year for it to believe that a further year's work should allow appropriate advice, based on runs with a revised version of the simulation model, to be provided by WG-EMM to the Scientific Committee and Commission next year. The Working Group agreed, however, that it would also be valuable if results were available from other models (Appendix D, paragraphs 5.18 to 5.20).

5.20 The Working Group recognised that there was a range of possible formats for the presentation of information for making decisions. Graphical presentation, particularly for the trade-offs between predator and fishery performance, was thought to convey important properties of performance measures, particularly with respect to what might be considered to be robust performance, especially where large amounts of data were to be summarised (Appendix D, paragraphs 4.7 and 4.8).

Analytical models (summary of WG-FSA-SAM)

5.21 The third meeting of WG-FSA-SAM was held immediately prior to WG-EMM-05, from 27 June to 1 July 2005, also at the NRIFS. WG-FSA-SAM was tasked to examine, develop and agree on the use of assessment methods to be implemented during WG-FSA-05.

5.22 WG-FSA-SAM held discussions primarily relevant to advancements in assessment methods for *Dissostichus* spp. Topics included methods for estimation of recruitment, abundance indices, alternative assessment approaches, and plausible operating models for use in evaluating assessment methods. The subgroup focused discussions principally on evaluation of alternative assessment approaches, including methods that use mark–recapture information, and integrated approaches for stock assessment.

5.23 With respect to mark–recapture methods, WG-FSA-SAM agreed that advancements were made in the understanding of potential bias in estimates of stock size of *D. eleginoides* in Subarea 48.3 arising from imperfect mixing and uneven distribution of fishing effort. The subgroup recognised that toothfish tagging efforts in Subareas 88.1 and 88.2 are now yielding a number of valuable results in terms of movement and growth, and that continued tagging studies will result in further knowledge of the Ross Sea *Dissostichus* stocks. The subgroup agreed that mark–recapture estimates of abundance would be useful not only by themselves, but also as inputs to integrated assessment methods.

5.24 The principal integrated assessment methods considered by WG-FSA-SAM were the ASPM and CASAL.

5.25 The ASPM was applied to *D. eleginoides* in Subarea 48.3 in two separate studies and in Subarea 58.7. Although the former two studies yielded contrasting conclusions, the subgroup agreed that the properties of the ASPM as an integrated modelling technique were being adequately explored in relation to Subareas 48.3 and 58.7.

5.26 Model structure, assumptions, and implementation for calculating precautionary yields of *Dissostichus* spp. using CASAL were considered by the subgroup. Using a point estimate, CASAL does not strictly reproduce precautionary yields by the method of the current GYM. However, using samples from the posterior distribution generated by Bayesian Monte Carlo Markov Chain (MCMC) runs of CASAL followed by future projections of each sample, a set of projections closer to the current GYM could potentially be generated.

5.27 A framework for implementing the precautionary approach in cases where a number of different datasets are integrated was considered, with application to the *D. eleginoides* assessment in Division 58.5.2 using CASAL and the GYM. The framework comprises four components, with the process managed by the use of a controller. This methodology represents an extension of the current practice, and better coordinates the integration of the different steps in the precautionary approach used by CCAMLR.

5.28 WG-FSA-SAM was encouraged by the advancements and continued exploration of the behaviour and suitability of CASAL for *Dissostichus* spp. assessments, and recommended further development of CASAL models for Subareas 48.3 and 88.1 and Division 58.5.2.

5.29 However, the subgroup recommended that the comparability of yield estimates resulting from the GYM and CASAL would need to be investigated. It agreed that the development of any assessment methods include: (i) examination of whether the method had been applied correctly, as well as whether model construction is robust; (ii) a need to undertake comparison of methods; and (iii) evaluation of robustness to operating model uncertainties.

5.30 WG-FSA-SAM provided advice on generating or refining parameter estimates for use at WG-FSA-05, including recommendations pertaining to natural mortality, recruitment, selectivity, age and growth, and movements.

5.31 An assessment timetable was discussed for the period leading up to WG-FSA-05. The subgroup recognised that the proposed integrated assessment methods to be explored for toothfish assessments are time consuming and will be extremely difficult to run during the course of WG-FSA. The subgroup therefore suggested that (i) the Convener of WG-FSA request members of the Stock Assessment Subgroup meet during the week prior to the beginning of WG-FSA-05 (beginning 6 October 2005); and (ii) proposed methodologies and input data for new methods be circulated as early as possible to the WG-FSA Stock Assessment Subgroup.

5.32 In cases where the proposed methodology is found unacceptable, the subgroup recommended that the methodology used in previous years be applied. In a worst-case scenario where new assessment are not agreed upon, WG-FSA-SAM recommended that the Commission may want to utilise management measures in force in 2004/05 during the 2005/06 season.

5.33 The subgroup provided specific advice for assessment methodologies to be employed during WG-FSA-05. It agreed that a CASAL assessment be attempted for *D. eleginoides* in Subarea 48.3 (South Georgia), with papers describing other assessments welcomed as well. WG-FSA-SAM had no new information from which to formulate assessment advice for *C. gunnari* in Subarea 48.3. Assessment advice for *D. eleginoides* in Division 58.5.2 included updates to input parameters (recruitment, growth, selectivity), CPUE and mark–recapture estimates of abundance. The subgroup endorsed the use of the GYM with these revised parameters. It also noted it would be possible to explore the use of CASAL in the toothfish assessment in this division, although it recognised that there may not be sufficient time to complete the work this year. With respect to Subareas 58.6/58.7 (Prince Edward and Marion Islands), WG-FSA-SAM recommended a revised and updated ASPM assessment, further development of operating models for testing candidate management procedures, and an examination of commercial pot fishing data to potentially evaluate the impact of predation by cetaceans in this fishery.

5.34 The subgroup agreed that further work was required to develop and implement a new assessment methodology, although the extent of this work would depend largely on consideration of integrated assessments and comparison of long-term projections made using integrated assessments and CASAL. WG-FSA-SAM therefore agreed to defer advice on future work until this work was partially undertaken during the time leading up to and during WG-FSA-05.

5.35 The Working Group thanked Dr Jones, convener of the subgroup, for his report. It noted that integrated methods and other assessment procedures now being developed by WG-FSA-SAM might be utilised in assessments of krill yield.

Existing conservation measures

5.36 WG-EMM-05/32 proposed that it should be mandatory for all vessels fishing for krill in the Convention Area to carry a scientific observer (national or international). Most members agreed that deployment of international scientific observers should be compulsory on krill vessels, but it was not possible to achieve consensus onthis recommendation (paragraphs 3.44 to 3.48).

5.37 In order to achieve monthly reporting of krill catch and effort at the resolution of SSMUs, the Working Group recommended modification of paragraph 2 of Conservation Measure 23-06 to read:

> 'Catches shall be reported in accordance with the monthly catch and effort reporting system set out in Conservation Measure 23-03. When fishing in SSMUs in Area 48, each Contracting Party shall report monthly catch and effort data by SSMU. When fishing in other areas, each Contracting Party shall report monthly catch and effort data by subarea/division.'

5.38 While Dr Naganobu agreed in principle with the reporting of monthly catch and effort data by SSMU, he wished to reserve his position at this meeting because SSMUs are not contained in any of the current conservation measures and he wished to consult with the relevant groups. See also paragraphs 3.36 and 3.38.

Key points for consideration by the Scientific Committee

5.39 The Working Group agreed to transmit to the Scientific Committee approval recommendations for two ATCM management plans containing marine areas. These include the ASPA at Edmonson Point (WG-EMM-05/7) and a revised plan for the ASMA at Admiralty Bay (WG-EMM-05/8) (paragraph 5.5).

5.40 Views relating to possible participation in the CCAMLR MPA Workshop by those not nominated by Members are contained in paragraphs 5.8 to 5.11.

5.41 The Working Group agreed that it was unable, at this time, to comment on the robustness of the candidate options for subdividing the catch limit for krill in Area 48 amongst SSMUs. Nevertheless, it has made substantial progress in developing the tools and parameter sets for providing advice on a subdivision of the Area 48 catch limit in the near future (paragraph 5.18).

5.42 The Working Group agreed that sufficient progress had been made with the KPFM development this year for it to believe that a further year's work should allow appropriate advice, based on runs with a revised version of the simulation model, to be provided to the Scientific Committee and Commission next year by WG-EMM. The Working group agreed, however, that it would also be valuable if results were also available from other models (paragraph 5.19).

5.43 The Working Group recognised that there was a range of possible formats for the presentation of information for making decisions. Graphical presentation, particularly for the trade-offs between predator and fishery performance, was thought to convey important properties of performance measures, particularly with respect to what might be considered to be robust performance, especially where large amounts of data were to be summarised (paragraph 5.20).

5.44 The Working Group noted that integrated methods and other assessment procedures now being developed by WG-FSA-SAM might be utilised in assessments of krill yield (paragraph 5.35).

5.45 Most members of the Working Group agreed that deployment of international scientific observers should be compulsory on all vessels fishing for krill in Convention Area waters, but it was not possible to achieve consensus on this recommendation (see paragraphs 3.44 to 3.48 and 5.36).

5.46 In order to achieve monthly reporting of krill catch and effort at the resolution of SSMUs, the Working Group recommended modification of paragraph 2 of Conservation Measure 23-06 to read:

> 'Catches shall be reported in accordance with the monthly catch and effort reporting system set out in Conservation Measure 23-03. When fishing in SSMUs in Area 48, each Contracting Party shall report monthly catch and effort data by SSMU. When fishing in other areas, each Contracting Party shall report monthly catch and effort data by subarea/division.'

5.47 Dr Naganobu agreed in principle with this requirement, but wished to reserve his position at this meeting (paragraph 5.38).

FUTURE WORK

Predator surveys

6.1 Four working papers relating to predator surveys were submitted (WG-EMM-05/23, 05/24, 05/25 and 05/39).

6.2 WG-EMM-05/23, which provided estimates of the abundance of crabeater, leopard and Ross seals in the pack-ice between 60° and 150°E in East Antarctica, is described in paragraph 4.3. The remaining three papers relate to surveys of land-based predators.

6.3 WG-EMM-05/25 described the preliminary development of a GIS tool to assist in developing sample survey designs for broad-scale surveys of colonial breeding species. Sample survey designs have the advantages of maximising the use of existing colony map information and minimising the counting effort required. When the GIS tool was applied to a regional population in the Mawson area using a simple stratified random design, only a few percent of the population needed to be counted to derive an estimate of abundance that was close to the true value with high probability. Although the tool needs more development, it could be refined to address more complex and efficient designs.

6.4 WG-EMM-05/39 provided a summary of information provided in the Antarctic Site Inventory (ASI). At the 2004 meeting of the Scientific Committee, the Chair of CEP informed the Scientific Committee on progress in the ASI project. The Scientific Committee then asked the Secretariat to discuss with CEP the nature of the data contained within the inventory, and to liaise with working groups as to whether the information in the inventory may be of use to them. The ASI contains three forms of information: (i) site information, such as key physical and topographical features and distribution of flora; (ii) variable site information and data on weather, environmental conditions, counts of nests and chicks in selected colonies of penguins and other seabirds; and (iii) maps and photo-documentation, including locations of colonies, assemblages of fauna, and oblique aerial photography from a helicopter. Data of particular interest to CCAMLR includes counts of several land-based predator species and maps of colonies at each of the locations. The inventory includes data from 639 visits to 93 sites on the Antarctic Peninsula over 11 years (1991–2003), with regular data available for 17 sites. The Working Group considered that there is much information in the inventory of great interest to CCAMLR, particularly with regard to estimating land-based predator abundance, and recommended that the usefulness of the data to CCAMLR should be conveyed to the Scientific Committee and CEP.

6.5 WG-EMM-05/24 summarised deliberations by the land-based predator survey correspondence group from the time of the group's inception in 2001 until the time of submission of papers to WG-EMM-05. The correspondence group was formed to assess the feasibility of undertaking future surveys of land-based predator abundance as a requirement for estimating predator demand. In addition, in 2004 the Scientific Committee asked the correspondence group to review the usefulness of status and trend information provided by the SCAR expert groups on birds and seals, after the utility of these data for CCAMLR was examined within WG-EMM and the Scientific Committee.

6.6 During the meeting further substantial discussions by the correspondence group took place. The outline below covers both the contents of WG-EMM-05/24 and the outcome of discussions.

6.7 At WG-EMM-05, much of the group's discussion focused on the practical issues of securing the logistics required for future surveys. In this regard the Working Group recognised that:

(i) surveys of land-based predators would be logistically very difficult due to the need to survey multiple species with varying techniques, and using multiple types of survey platforms;

(ii) logistics would need to be sought from various sources, and the chances of securing enough resources are uncertain;

(iii) the IPY is likely to tie up logistic resources until 2008/09, so unless predator surveys were proposed as part of the IPY it may not be possible to undertake any surveys for another four to five years. The Working Group felt it was unwise to rush the planning of surveys to be part of the IPY;

(iv) a major concern was that securing logistics would require a full commitment from one or more members of the Working Group over a substantial period with an unknown probability of success. This would require that such members re-prioritise their domestic commitments.

6.8 Taking all these factors into account, the correspondence group considered that the most useful and practical way forward was to: (i) examine existing data for potential biases and uncertainties; (ii) where possible develop estimates of abundance and its uncertainty from the existing data; and (iii) identify areas where data were inadequate or absent. The Working Group agreed with this approach.

6.9 The Working Group also agreed that a workshop should be held to develop procedures to estimate land-based predator abundance and associated uncertainty from existing data in SSMUs in Area 48. The timing of this workshop was discussed in paragraphs 6.39 and 6.49.

6.10 The Working Group discussed the suitability of the status and trend summary information provided by SCAR, and recognised that some essential attributes of count data (such as dates) were not included in the summary. As a result, some of the summary information cannot be used in its current form to determine the uncertainty in abundance estimates as required by CCAMLR. The Working Group also recognised that in the past CCAMLR had not provided any specific guidance to SCAR on the format in which data would be most useful for CCAMLR's work.

6.11 As CCAMLR has requested summary information from SCAR at approximately five-year intervals in the past, and the last summary was provided by SCAR in 2000, the Working Group was aware that SCAR may now be expecting another request for information. However, noting that no specific guidance had been supplied to SCAR on the most appropriate format in relation to CCAMLR's present specific needs, and recognising that a workshop proposed in the near future (paragraph 6.9) will consider, amongst other issues, the format required for existing data to meet CCAMLR's needs, the Working Group considered that it would not formally request further information from SCAR at this time.

6.12 The Working Group felt that the Scientific Committee should communicate to SCAR its intention to hold a workshop in the future, and extend an invitation for SCAR representatives to attend that workshop when it occurs.

Ecosystem models, assessments and approaches to management

Operating models to evaluate management procedures

6.13 The Working Group noted the work undertaken at the Workshop on Management Procedures to Evaluate Options for Subdividing the Krill Catch Limit among Small-scale Management Units. In particular, it noted the steps to evaluate options (management procedure/strategy) for managing a fishery (Appendix D, paragraphs 6.1 to 6.3), which require the development of operating models (plausible simulation models of the ecosystem and fishery). In general, a management procedure comprises a program to monitor indicators (acquisition of data from the target species, the fishery and/or the ecosystem), method/s to assess the indicators (stock and/or ecosystem assessments) and rules for deciding on the harvest strategy (decision rules) to be used over one or many years (e.g. spatially and/or temporally adjusted catch limits).

6.14 The Working Group agreed that its focus over the last five years has been to progress the development of a feedback management procedure for krill based on information from the fishery, krill population surveys and CEMP. In the past four years, workshops have focused on:

(i) 2001 – design of the work program
(ii) 2002 – delineation of SSMUs
(iii) 2003 – review of CEMP
(iv) 2004 – elaboration of plausible marine ecosystem models for the Antarctic.

6.15 This year, the workshop made substantial progress on evaluating spatially-structured harvest strategies that can appropriately account for predator requirements in SSMUs.

6.16 In considering future work in this area, the Working Group noted that the primary advances over the last year were in the development of operating models for evaluating management procedures. Three papers were presented to the workshop elaborating operating models being developed for use by the Working Group (WG-EMM-05/13, 05/14 and 05/33; Appendix D, paragraphs 5.1 to 5.5) (see paragraphs 2.5 to 2.7). A fourth paper was considered relevant to this work (WG-EMM-05/34; Appendix D, paragraph 5.6). Two other papers were available to the Working Group for general consideration of the development of operating models (WG-EMM-05/18; Atkinson et al., 2004).

6.17 The Working Group noted the suggestions from the workshop for models to be used for evaluating candidate methods for subdividing catch limits in Area 48. These suggestions regarded parameterisation of the models, as well as structural and functional issues relating to the operation of the ecosystem and the manner in which these could be presented in a plausible model. These included (Appendix D, paragraph 3.36):

(i) the benefits of a seasonally resolved model, compared to those of a model with a single annual time step;

(ii) the transport of krill from one region (or SSMU) to another (or other SSMU);

(iii) predators and fisheries may have different selection criteria for krill;

(iv) the availability of krill to the fishery and to predators was important, and that factors such as density and/or swarm characteristics would be important;

(v) the recognition that the movement of predators between SSMUs was potentially important;

(vi) the recognition that the dynamics of some pelagic predators may be independent of krill availability assessed at the scale of SSMUs;

(vii) the method for allocating catch and consumption, particularly when the combined demand was greater than the available abundance of krill;

(viii) the need to account for harvesting of fish that are krill predators in some SSMUs.

6.18 The Working Group endorsed the workshop view that at least three key aspects that should be given further attention in the models and their implementation are the incorporation of (Appendix D, paragraphs 5.10 to 5.13):

(i) shorter time steps and/or seasonality
(ii) alternative movement hypotheses
(iii) a threshold krill density below which a fishery will not operate.

6.19 The Working Group also noted the work identified by the workshop that could usefully be undertaken for the development of these models to evaluate candidate methods for subdividing the krill catch limit in Area 48 among SSMUs, including complementary development of the different modelling approaches (Appendix D, paragraphs 5.18 to 5.26).

6.20 WG-EMM-05/34 described a minimally realistic model of the dynamics of krill, four baleen whale (blue, fin, humpback and minke) and two seal (Antarctic fur and crabeater) species in two large sectors of the Antarctic. The model was developed to investigate whether predator–prey interactions alone can broadly explain observed population trends since the onset of seal harvests in 1780. It concluded that the answer to this question is yes, although not without some difficulties. The authors identified the paper to be a first step towards the development of models of predator–prey interactions at a circumpolar scale, which could with further development assist in providing scientific advice for management measures for the krill and other fisheries in the region which take account of the indirect effect of harvesting on dependent and related species.

6.21 Dr E. Plagányi (South Africa) noted that this model had used existing data to develop a model reconstruction of the Antarctic marine ecosystem. She had also noted in the workshop that the model in WG-EMM-05/34 is not currently suitable for the development of management advice in the context of subdividing catch limits amongst SSMUs but could be used to explore the effect of trends in abundances over larger spatial scales than those addressed for Area 48 (Appendix D, paragraph 5.24).

6.22 Dr Hewitt drew the attention of the Working Group to the estimates of krill biomass in this model for the Scotia Sea, which were similar to existing estimates from surveys in the region of 100–200 million tonnes.

6.23 Dr Constable indicated that it would be useful for the authors to explore alternative hypotheses that might explain the data rather than focusing on the single hypothesis of competitive interactions amongst species.

6.24 Dr Plagányi agreed, noting that it would be useful for modellers to explore more fully the role of environmental factors generally.

6.25 WG-EMM-05/18 reported on the development of a carbon-budget trophic model for the Ross Sea. The food web was characterised with 22 functional compartments. The authors noted that this work is preliminary. The next step in its development is to determine the range of ecosystem variables that are consistent with the current understanding of the constraints on ecosystem functioning. It is intended to further develop the model to help investigate potential trophic impacts of the Antarctic toothfish fishery in this region.

6.26 Dr M. Pinkerton (New Zealand) also highlighted that the development of this model was a useful exercise in collating the information into a form that could be useful to CCAMLR in the future.

6.27 The Working Group noted the utility of this work in establishing feasible parameter space for the Ross Sea.

6.28 Dr K. Shust (Russia) noted that it was important to recognise that the Ross Sea ecosystem may not be dependent on Antarctic krill.

6.29 Atkinson et al. (2004) examined potential long-term decline in krill stock and increase in salps within the Southern Ocean. They combined all available scientific net sampling data from 1926 to 2003 and examined correlations between the abundances of different biota to draw inferences on changes in the Southern Ocean. The authors suggested that krill densities may have decreased since the 1970s, whilst salps may have increased in the southern part of their range over the last century. They noted that such changes would potentially introduce increased levels of uncertainty for fisheries managers as they attempt to manage the fishery in the face of regional climate variability.

Subgroup on Development of Operating Models

6.30 The Working Group noted the work now being undertaken on modelling the Antarctic marine ecosystem. In terms of its own work, it considered that the development of operating models could be facilitated by a subgroup in preparing for future work on the evaluation of management procedures. To that end, the Working Group agreed that a Subgroup on Development of Operating Models be established according to the terms of reference in Appendix F.

6.31 The Working Group agreed that the primary function in the beginning would be to establish a newsgroup as part of the subgroup with the assistance of the Secretariat. Dr Constable undertook to facilitate the establishment of the newsgroup with the Secretariat and to help coordinate the work of the subgroup in providing support to the conveners of the workshop of WG-EMM next year. The Working Group noted that this may have budgetary implications and requested that the Secretariat provide advice to the Scientific Committee.

6.32 The Working Group agreed that members and experts desiring access to the newsgroup would require approval of their representative to the Scientific Committee in order to ensure they are aware of the terms of reference and the rules governing participation in the group.

Parameters in large-scale models of the Antarctic marine ecosystem

6.33 In reflecting on the modelling work described in paragraphs 6.16 to 6.29 and the considerable work undertaken by the working groups of the Scientific Committee on developing plausible models of the Antarctic marine ecosystem, WG-EMM noted that CCAMLR is a leading body in the development of such models, given the breadth of expertise brought to its work by biologists, oceanographers and modellers. Nevertheless, it also recognised that other bodies, including the IWC, are developing models of the Antarctic marine ecosystem for their purposes. In particular, large-scale models looking at circum-Antarctic trends and prognoses are drawing on ecosystem information being collated and synthesized by CCAMLR. These large-scale models are also important to CCAMLR in understanding trends and dynamics at these larger scales. The Working Group agreed that it would be desirable to ensure that parameters were consistent across these models.

6.34 The Working Group noted that there was a range of academic groups involved in developing large-scale circumpolar models of the Southern Ocean. In particular the Integrated Analysis of Circumpolar Climate Interactions and Ecosystem Dynamics in the Southern Ocean (ICCED), which is the Southern Ocean component of the IGBP's Integrated Marine Biogeochemistry and Ecosystem Research (IMBER) program, has a similar set of aims to those large-scale models indicated above. At the recent meeting of the ICCED steering committee, membership of which includes scientists involved in both CCAMLR and IWC, it was recognised that interaction and integration of the modelling efforts of a range of experts would be required to develop circumpolar ecosystem models.

6.35 Dr Constable proposed that a way forward to provide consistency in the use of model parameters would be to hold a workshop involving the IWC and other ecosystem modelling groups, including modellers, biologists and physical scientists. In terms of the work of CCAMLR, such a workshop could focus on determining the key parameters and their characteristics required for large-scale ecosystem models developed to explore the role and response of krill predators in the Antarctic marine ecosystem. This would help facilitate work of both WG-EMM and WG-FSA in the development of operating models. Given that such a proposal would require time for coordinating with the IWC and other groups, it would be conceivable to hold the meeting in the first half of 2007. He offered to help coordinate a proposal with members of WG-EMM and WG-FSA, as well as the subgroup promoting the development of operating models, for consideration by the Scientific Committee at its meeting in October 2005.

6.36 The Working Group agreed that such a workshop would be useful, particularly if it included the diversity of groups involved with Antarctic marine ecosystem modelling. For example, it would be beneficial for workshop organisers to correspond with the IWC and ICCED among others in developing its plans. Some Members indicated there may be sensitivities with the inclusion of the IWC Scientific Committee in this work.

6.37 The Working Group agreed that a proposal to hold a workshop to discuss the parameterisation of large-scale ecosystem models should not be considered as part of the work of WG-EMM but should be undertaken as an activity of the Scientific Committee. It would be expected that the Scientific Committee would establish a steering committee should it agree to the proposal.

Long-term work plan

6.38 To initiate discussion on its long-term work plan, the Working Group recalled both its objective of developing a feedback approach to the management of the krill fishery and its review of progress made towards this objective (paragraph 6.14).

6.39 The Working Group agreed that useful progress had been made towards its objective but acknowledged that there are still a large number of items for future work. The Working Group identified the following items of importance that may need intensive work in the coming years:

(i) facilitate the continued evaluation of procedures to allocate the precautionary krill catch limit in Area 48 among SSMUs (paragraphs 2.10 and 5.19);

(ii) consider revising estimates of B_0 and γ in all areas taking account of recent developments in estimating parameters used in assessments, thereby revising estimates of precautionary yield (paragraph 4.60);

(iii) develop SSMU-specific estimates of predator abundance and demand in Area 48 (paragraph 6.9);

(iv) plan for and coordinate future surveys and field efforts related to krill (paragraphs 4.78 to 4.80 and Appendix E) noting that these efforts may ultimately require workshops to facilitate collaborative data analyses;

(v) continue the development of plausible ecosystem models (paragraphs 6.16 to 6.19).

6.40 It was agreed that the first three work items should have priority status and form the basis of ensuing workshops at the next three meetings of WG-EMM (i.e. 2006–2008).

6.41 It was agreed that, in 2006, WG-EMM should hold a workshop focused on continuing the evaluation of procedures to allocate the precautionary krill catch limit in Area 48 among SSMUs. The workshop could therefore be titled the 'Second Workshop on Management Procedures'.

6.42 The Working Group acknowledged that evaluating options for allocating the krill catch limit among SSMUs prior to revising area-specific estimates of krill biomass (density) and predator abundance (demand) would pose some challenges because the performance of the candidate options may be sensitive to these estimates. Nevertheless, it was noted that the operating models being developed to conduct such evaluations will be purposefully built to integrate over various sources of uncertainty (paragraphs 2.5 to 2.7).

6.43 Considering the points in paragraph 6.42, the Working Group noted that its decision to convene a Second Workshop on Management Procedures prior to work that will revise the data used to evaluate the candidate options for allocating the krill catch among SSMUs necessitates a flexible approach to providing advice to the Scientific Committee and Commission. The provision of advice, should it be possible, is consistent with CCAMLR's use of the best available scientific evidence. This does not preclude revisions in the future, as knowledge and methods improve.

6.44 The Working Group agreed that the Second Workshop on Management Procedures should build on the work completed this year, and, therefore, it should have the terms of reference identified in the following list.

(i) Review the development of operating models since the 2005 Workshop on Management Procedures.

(ii) Explore the performance of the operating models submitted to the workshop by determining whether they meet necessary benchmarks and conducting appropriate sensitivity analyses.

(iii) Evaluate the candidate options for allocating the precautionary krill catch limit among SSMUs in Area 48.

(iv) Summarise the results of those evaluations in the form of advice to WG-EMM.

6.45 If multiple operating models are submitted to the workshop, successful progress will require a coordinated effort to produce comparable outputs from each model. The Working Group therefore advised that Members constructing models for use at the workshop develop, at a minimum, the capacity to report on the performance measures identified in paragraph 2.3. The Working Group also advised that the workshop conveners should act to facilitate coordination among model-development teams. This facilitation could be done through the subgroup described in paragraphs 6.30 to 6.32 and Appendix F.

6.46 The Convener of WG-EMM asked Ms T. Akkers (South Africa) and Dr C. Reiss (USA) to co-convene the Second Workshop on Management Procedures, and the Working Group agreed with their joint nomination.

6.47 The Working Group agreed not to invite an outside expert(s) to the Second Workshop on Management Procedures, but Members were encouraged, as appropriate, both to independently consult with outside experts and to bring new delegates to the workshop. It was agreed that the latter approach had contributed to the success of the first workshop.

6.48 The Working Group also agreed that a workshop to consider reviewing and revising precautionary catch limits for krill be held no later than 2007. Delaying such work would be problematic for two reasons. First, the report provided by SG-ASAM clearly indicates that biomass (density) estimates from the CCAMLR-2000 Survey need to be revised, and, since the work done this year indicated that the performance of candidate options for allocating the krill catch limit among SSMUs may be sensitive to initial estimates of krill density, such revisions may influence advice provided on management procedures for the krill fishery. Second, some Members have surveys planned for the near future and the results of this field work will need to be reviewed and considered by WG-EMM.

6.49 The Working Group agreed that it would be beneficial to have a strategic planning workshop.

Key points for consideration by the Scientific Committee

Advice from Agenda Item 6.1

6.50 The ASI contains much information of great interest to CCAMLR, particularly with regard to counts of land-based predators. WG-EMM recommended that the Scientific Committee indicate to CEP that the information in the ASI is potentially very useful to the work of CCAMLR (paragraph 6.4).

6.51 The Scientific Committee should communicate to SCAR its intention to hold a workshop in the near future to assess the utility of existing data for estimating land-based predator abundance and its uncertainty, and to extend an invitation for SCAR representatives to attend that workshop when it occurs (paragraph 6.12).

6.52 The Scientific Committee should also communicate to SCAR that it would not formally request further information from SCAR on status and trends in marine mammal and seabird populations at this time (paragraph 6.11).

Advice from Agenda Item 6.2

6.53 In considering future work in ecosystem models, assessments and approaches to management, the Working Group noted that the primary advances over the last year were in the development of operating models for evaluating management procedures (paragraphs 6.13 to 6.16). A future work program for further developing these models has been identified (paragraphs 6.17 to 6.19).

6.54 The Working Group agreed that a Subgroup on Development of Operating Models be established according to the terms of reference in Appendix F to facilitate the further work identified above. The Working Group agreed that the primary function in the beginning would be to establish a newsgroup as part of the subgroup with the assistance of the Secretariat. Dr Constable will be responsible for facilitating the establishment of the newsgroup with the Secretariat and to help coordinate the work of the subgroup in providing support to the conveners of the workshop of WG-EMM next year (paragraphs 6.30 and 6.31). The Working Group agreed that Members and experts desiring access to the newsgroup would require approval of their representative to the Scientific Committee in order to ensure they are aware of the terms of reference and the rules governing participation in the group (paragraph 6.32).

6.55 The Working Group agreed that it would be desirable to ensure that parameters used in large-scale models looking at circum-Antarctic trends and prognoses were consistent across these models. It agreed that CCAMLR was a leading organisation in the acquisition of data for deriving these parameters as well as in developing ecosystem models. The Working Group agreed that Dr Constable correspond with the working groups, including the Subgroup on Development of Operating Models, to develop a proposal for the Scientific Committee this year to consider holding a workshop to focus on determining the key parameters and their characteristics required for large-scale ecosystem models developed to explore the role and response of krill predators in the Antarctic Marine Ecosystem (paragraph 6.33 to 6.37). This would help facilitate work of both WG-EMM and WG-FSA in the development of operating models. Such a workshop should not be considered as part of the work of WG-EMM but should be undertaken as an activity of the Scientific Committee.

Advice from Agenda Item 6.3

6.56 The Working Group agreed that useful progress had been made towards its objective of developing a feedback approach to managing the krill fishery but acknowledged that there are still a large number of items for future work. The Working Group identified the following items of importance that may need intensive work in the coming years:

(i) facilitate the continued evaluation of procedures to allocate the precautionary krill catch limit in Area 48 among SSMUs (paragraphs 2.10, 5.19 and 6.39(i));

(ii) consider revising estimates of B_0 and γ in all areas taking account of recent developments in estimating parameters used in assessments, thereby revising estimates of precautionary yield (paragraphs 4.60 and 6.39(ii));

(iii) develop SSMU-specific estimates of predator abundance and demand in Area 48 (paragraphs 6.9 and 6.39(iii));

(iv) plan for and coordinate future surveys and field efforts related to krill (paragraphs 4.78 to 4.80 and Appendix E) noting that these efforts may ultimately require workshops to facilitate collaborative data analyses (paragraph 6.39(iv));

(v) continue the development of plausible ecosystem models (paragraphs 6.16 to 6.19 and 6.39(v)).

6.57 It was agreed that the first three work items should have priority status and form the basis of ensuing workshops at the next three meetings of the WG-EMM (i.e. 2006–2008) (paragraph 6.40).

6.58 The Working Group agreed that a Second Workshop on Management Procedures should be held in 2006 and that this workshop should build on the work completed this year. The Second Workshop on Management Procedures should have the terms of reference identified in paragraph 6.44.

6.59 The Convener of WG-EMM asked Ms Akkers and Dr Reiss to co-convene the Second Workshop on Management Procedures, and the Working Group agreed with their joint nomination (paragraph 6.46).

6.60 The Working Group agreed not to invite an outside expert(s) to the Second Workshop on Management Procedures, but Members were encouraged, as appropriate, both to independently consult with outside experts and to bring new delegates to the workshop. It was agreed that the latter approach had contributed to the success of the first Workshop on Management Procedures (paragraph 6.47).

6.61 It was agreed that provision of advice, should it be possible from work done at the Second Workshop on Management Procedures, is consistent with CCAMLR's use of the best available scientific evidence. This does not preclude revisions in the future, as knowledge and methods improve (paragraph 6.43).

6.62 The Working Group also agreed that a workshop to consider reviewing and revising precautionary catch limits for krill be held no later than 2007 (paragraph 6.48).

6.63 The Working Group agreed that it would be beneficial to have a strategic planning workshop (paragraph 6.49).

OTHER BUSINESS

Ross Sea

7.1 Dr Wilson reported that, in the absence of Italian representatives at this year's meeting of WG-EMM, a small group of participants interested in research in the Ross Sea had held informal discussions in the margins of the meeting. The discussions focussed on:

- the valuable contribution to knowledge of the Ross Sea which had been made recently by Japan (WG-EMM-05/16);
- progress in the development of a carbon-budget trophic model for the Ross Sea (WG-EMM-05/18);
- the planning for future LTER research in McMurdo Sound;
- the consequence of the current release of the huge icebergs which had effectively blocked the breakout of McMurdo Sound sea-ice for the past five years.

7.2 Dr Naganobu advised that the 3rd International Conference on the Oceanography of the Ross Sea will be held in Venice, Italy, from 10 to 14 October 2005.

CEP

7.3 Dr Penhale reported that SCAR had submitted two working papers to CEP-VIII (Sweden, 2005) which were of relevance to CCAMLR. The first paper was entitled 'De-listing Antarctic Specially Protected Species' (ATCM-XXVIII WP 033) and proposed de-listing two species: *Arctocephalus gazella* (Antarctic fur seal) and *Arctocephalus tropicalis* (sub-Antarctic fur seal)'.

7.4 The second paper was entitled 'Proposal to list a species as a Specially Protected Species under Annex II' (ATCM-XXVIII WP 034) and presented a procedure and format for listing, using the example of the southern giant petrel (*Macronectes giganteus*)'.

7.5 Both papers generated considerable interest and discussion at CEP-VIII. The de-listing paper did not include relevant and readily available data and a discussion of the by-catch of fur seals in the krill fishery. It was noted by CEP that both papers did not correctly describe the relationship between the ATCM, CCAS and CCAMLR. An informal discussion group made progress on delineating an improved process for listing a Specially Protected Species. No formal recommendations arose with regard to either papers. The outcome of discussions is an expectation that SCAR will resubmit improved papers on both topics for CEP-IX.

7.6 WG-EMM expressed interest in these developments and looked forward to the outcome of the CEP deliberations in 2006.

Workshop on 'Practical Biological Indicators of Human Impacts in Antarctica'

7.7 Dr Reid attended an NSF/COMNAP/SCAR sponsored Workshop on 'Practical Biological Indicators of Human Impacts in Antarctica' which was held in Texas, USA, between 16 and 18 March 2005. The objectives of the meeting were to:

- bring together practitioners, experts, scientists, regulators and national operators to assess the state-of-the-art of biological indicators of human impact;
- advise national programs on how to implement meaningful biological monitoring in Antarctica that is economical, feasible, practical and meets legal and treaty obligations.

7.8 WG-EMM noted that one of the primary recommendations was the desirability of much greater collaboration between SCAR, COMNAP, CEP and CCAMLR, particularly with respect to the availability of existing data and information from monitoring programs.

ICCED

7.9 The ICCED program is part of the new joint initiative between the IGBP and SCOR. ICCED will bring together climatologists, oceanographers, biogeochemists, ecosystem and fisheries scientists to generate unique circumpolar datasets and models to address three globally important questions:

- How do climate processes affect the dynamics of circumpolar ocean ecosystems?
- How does ecosystem structure affect circumpolar ocean biogeochemical cycles?
- How should ecosystem structure and dynamics be included in the development of sustainable approaches to managing exploitation?

7.10 WG-EMM noted that ICCED hopes to establish strong ties with international programs and organisations with a Southern Ocean focus, including CCAMLR, SCAR, GLOBEC and IWC.

SCAR Biology Symposium

7.11 WG-EMM noted that SCAR will hold the Ninth International Antarctic Biology Symposium in Curitiba, Brazil, from 25 to 29 July 2005. Three invited keynote speakers from CCAMLR (Drs Kawaguchi, K.-H. Kock (Germany) and Reid) will promote the role and activities of CCAMLR.

Standardising the submission of meeting documents to working groups

7.12 At the request of the Scientific Committee, the Secretariat prepared a reference document which provided guidelines for the submission of meeting documents to the Scientific Committee, WG-EMM and WG-FSA, including ad hoc WG-IMAF (WG-EMM-05/10, Attachment). This reference document has highlighted the elements common to both working groups' guidelines, as well as some specific differences.

7.13 WG-EMM considered the Secretariat's proposal to standardise the working group-specific differences in relation to submission deadlines, exceptions to deadlines and approaches to accepting revised documents (WG-EMM-05/10, Table 1). WG-EMM agreed that standardising the working groups' guidelines would simplify the procedures which participants must follow, as well as the Secretariat's work in preparing information and documents for meetings.

7.14 WG-EMM agreed to revise its guidelines for the submission of meeting documents as follows:

(i) The deadline for the submission of papers would be moved to no later than 0900 h on the Monday exactly two weeks prior to the commencement of the meeting, based on Eastern Australia standard time ('Hobart' time), and the deadline would apply to meeting documents as well as to SC-CAMLR and CCAMLR documents submitted to WG-EMM.

(ii) Two types of papers may be exempted from the deadline: (i) Secretariat papers dealing with data, and (ii) Members' meeting papers, subject to prior notification and at the discretion of the convener and the Chair of the Scientific Committee. In relation to (i), the Working Group agreed that the exemption applied to papers dealing with data received close to the start of the meeting or reporting Secretariat tasks specifically identified by the convener and/or the working group. In relation to (ii), it was agreed that the exemption would apply only to those papers which would make a significant difference to the conduct of the meeting, or would impact on the decision of the Commission.

(iii) Factual corrections to papers would be accepted at any time. However, if corrections were made after the deadline, then the author(s) must clearly identify the changes (e.g. using track-change or bold in the document).

In addition, WG-EMM agreed that papers would not be limited to 15 pages, but authors should note that long papers may not be given full attention if there is limited time.

7.15 WG-EMM requested that the Secretariat modify the guidelines for the submission of documents to WG-EMM in accordance with the points above. These new guidelines would be circulated to participants prior to the 2006 meeting of WG-EMM.

7.16 In relation to the submission of published papers to the meeting, WG-EMM agreed that authors should continue to provide an electronic version of the published paper. It was also agreed that the author of the published paper was responsible for any copyright issue arising from the submission to the meeting.

7.17 WG-EMM agreed that papers that were 'in press' at the time of the meeting should be considered as published documents with respect to copyright.

7.18 The Working Group agreed that references to in-press and published papers should continue to be listed under 'Other Documents' in the 'List of Documents' which is appended to the report.

7.19 In further discussion, WG-EMM recognised the difficulty in referring to published and in-press papers during the meeting. In particular, the Working Group recognised the need for easily identifying published papers for which the authors have requested consideration by the Working Group. The Secretariat was asked to consider a simple method for identifying such papers for the purpose of the meeting.

7.20 WG-EMM agreed that all meeting documents distributed by the Secretariat should be in locked pdf to avoid any unauthorised use or incidental change to the text. However, in order to facilitate the work of the rapporteurs, it was agreed that the one-page synopses should be made available, separately and in unlocked pdf during the meeting.

Streamlining the work of the Scientific Committee

7.21 WG-EMM considered Dr Constable's proposal to streamline the work of the Scientific Committee by re-arranging the work of its working groups under three general topics (WG-EMM-05/35): (i) Biology, ecology and conservation; (ii) Development of assessment methods; and (iii) Assessments.

7.22 Dr Constable indicated that this proposal had its genesis in a paper he presented at the 25th Anniversary CCAMLR Symposium in Valdivia, Chile, in April 2005. The symposium was a Member-organised event and a report from the symposium co-chairs will be presented to the Commission for consideration in 2005.

7.23 The Working Group noted that WG-EMM-05/35 reported on work in progress, and the concepts and ideas had been further advanced during discussions in the margin of WG-EMM. Dr Constable advised that he would take account of these discussions and the views of WG-EMM expressed below, and would develop a revised proposal which would be submitted to WG-FSA and the Scientific Committee for their consideration later this year.

7.24 In its presently revised state, Dr Constable's proposal was to reform WG-EMM and WG-FSA-SAM into two working groups and an inter-connected workshop, each with its own convener. These groups would meet intersessionally over a three-week period:

(i) A working group on biology, ecology and conservation to discuss the broad issues and ideas about how the Antarctic marine ecosystem works and general conservation requirements, including the use of marine protected areas in the CCAMLR context.

(ii) A workshop to address topical issues of interest to one or preferably both of the working groups.

(iii) A working group to develop methods for (a) assessing fish, krill and by-catch populations, (b) status of predator and other populations and habitats, (c) ecosystem monitoring, and (d) estimation of yield as well as (e) methods for evaluating management systems.

7.25 Dr Constable's proposal also included retaining an assessment working group to apply approved and evaluated methods to assess (i) fish, krill and by-catch populations, (ii) status of predator and other populations and habitats, (iii) status of the ecosystem, and (iv) yield. The present work and structure of ad hoc WG-IMAF would be retained within this working group.

7.26 The following arguments were raised during discussion by WG-EMM:

(i) The proposal would provide more time for consideration of biological and ecological issues of importance to the foundation of operating models.

(ii) Any change from the present multidisciplinary working groups to dedicated focused groups might increase the time commitments and financial cost of Members which are represented at meetings by a single delegate, or small number of delegates.

(iii) The formation of dedicated, focused groups may isolate biologists and modellers, and reduce the present level of synergy of the Working Group.

(iv) The proposed inter-connected workshop could provide the forum for combined multidisciplinary work.

(v) The Workshop on Management Procedures last week demonstrated the value of multidisciplinary workshops to progressing the work of the Working Group.

(vi) WG-EMM, WG-FSA and ad hoc WG-IMAF, might be retained while WG-FSA-SAM could be formed into a methods working group advising on assessment methods of interest to both WG-EMM and WG-FSA, including integrated models and acoustic methods. Under such a structure, the methods working group would need to adequately address the annual assessment cycle for finfish and the multi-year assessment for krill. This would require a clear indication from the Scientific Committee of the work priorities.

7.27 Ms Akkers noted that the Commission faced similar challenges as the Scientific Committee in developing ways of addressing the very high workload.

7.28 WG-EMM thanked Dr Constable for his thought-provoking proposal, and invited other Members to collaborate in further developing ways to address the high workload of the working groups.

New Convener

7.29 In the light of discussions on the possible restructuring of the working groups, WG-EMM agreed to withhold further consideration of convenership, and refer this matter to the 2005 meeting of the Scientific Committee. Dr Hewitt reiterated the urgent need to find a new convener for the 2006 meeting.

ADOPTION OF THE REPORT AND CLOSE OF THE MEETING

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

8.2 In drawing the meeting to a close, Dr Hewitt thanked the participants for the fruitful discussions over the past two weeks. He thanked the rapporteurs, the co-conveners of the workshop and the Secretariat for their efforts in ensuring a successful meeting.

8.3 Dr Hewitt thanked Dr Naganobu and the NRIFS staff for hosting the meeting and for providing excellent facilities. Their generous hospitality was greatly appreciated by all.

8.4 This was Dr Hewitt's last meeting as Convener of WG-EMM. Although the work of WG-EMM had been, and remained, of great interest to him, Dr Hewitt advised the Working Group last year that he would need to step down as Convener due to his new job and a new set of work commitments.

8.5 Over his six-year term as Convener, Dr Hewitt led the Working Group through the development of management procedures for the krill fishery. This work required extensive long-term planning and the reformatting of the meetings so as to allow the necessary thematic workshops and multidisciplinary approach. Substantial new work was also required to develop the Working Group's understanding of krill and the marine ecosystem. Dr Hewitt's leadership greatly contributed to the overall success of the work. Further, the Working Group was now well placed to carry this work into the future.

8.6 Dr Constable, on behalf of the Working Group, thanked Dr Hewitt for his very significant contribution to the work of WG-EMM and the Scientific Committee, and in the development of management procedures for the krill fishery. The Working Group hoped that Dr Hewitt would be able to continue his participation in its work.

8.7 The meeting was closed.

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APPENDIX A

AGENDA

Working Group on Ecosystem Monitoring and Management
(Yokohama, Japan, 4 to 15 July 2005)

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

2. Workshop on Management Procedures to evaluate options for subdividing the krill catch limit among SSMUs

3. Status and trends in the krill fishery
   3.1 Fishing activity
   3.2 Description of the fishery
   3.3 Scientific observation
   3.4 Regulatory issues
   3.5 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 Methods
   4.3 Future surveys
   4.4 Key points for consideration by the Scientific Committee

5. Status of management advice
   5.1 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 Ecosystem models, assessments and approaches to management
   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

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(Yokohama, Japan, 4 to 15 July 2005)

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APPENDIX C

LIST OF DOCUMENTS

Working Group on Ecosystem Monitoring and Management
(Yokohama, Japan, 4 to 15 July 2005)

WG-EMM-05/1	Provisional Agenda and Provisional Annotated Agenda for the 2005 Meeting of the Working Group on Ecosystem Monitoring and Management (WG-EMM)
WG-EMM-05/2	List of participants
WG-EMM-05/3	List of documents
WG-EMM-05/4	CEMP Indices: 2005 update Secretariat
WG-EMM-05/5	Krill fishery report: 2005 update Secretariat
WG-EMM-05/6	Summary of notifications of krill fisheries in 2005/06 Secretariat
WG-EMM-05/7	Management Plan for Antarctic Specially Protected Area (ASPA) No. XYX, Edmonson Point, Wood Bay, Victoria Land, Ross Sea Delegation of Italy
WG-EMM-05/8	Review of the Admiralty Bay Antarctic Specially Managed Area Management Plan (ASMA No. 1) Delegations of Brazil and Poland
WG-EMM-05/9	Seabird research at Cape Shirreff, Livingston Island, Antarctica, 2004/05 A.K. Miller, E. Leung and W.Z. Trivelpiece (USA) (*AMLR 2004/2005 Field Season Report*, in press)
WG-EMM-05/10	Proposal to standardise the submission of meeting documents to working groups Secretariat
WG-EMM-05/11	The BROKE-West acoustic krill biomass survey of CCAMLR Division 58.4.2 S. Nicol, S. Kawaguchi, T. Jarvis and T. Pauly (Australia)

WG-EMM-05/12	Descriptive analysis of haul data from FV *Atlantic Navigator* in Elephant Islands (48.1), South Georgia Islands (48.3) and South Orkney Islands (48.3) krill fishery (summer 2004 to early winter 2005) O. Pin, H. Nión, E. Delfino and P. Meneses (Uruguay)
WG-EMM-05/13	A krill–predator–fishery model for evaluating candidate management procedures G.M. Watters, J.T. Hinke (USA), K. Reid and S. Hill (United Kingdom)
WG-EMM-05/13 Appendix 3	Summary of work done to augment and enhance that presented in WG-EMM-05/13 G.M. Watters, J.T. Hinke (USA), K. Reid and S. Hill (United Kingdom)
WG-EMM-05/14	Modelling the impact of krill fishing on seal and penguin colonies É.E. Plagányi and D.S. Butterworth (South Africa)
WG-EMM-05/15	Some additional data challenge the concept of the distribution of the gravid krill females related to bottom depths V.A. Sushin, F.F. Litvinov, A.S. Sundakov and G. Andrianov (Russia)
WG-EMM-05/16	Preliminary report of the Japanese RV *Kaiyo Maru* survey in the Ross Sea and adjacent waters, Antarctica, in 2004/05 M. Naganobu, K. Taki and T. Hayashi (Japan)
WG-EMM-05/17	Time series of Drake Passage Oscillation Index (DPOI) from 1952 to 2005, Antarctica M. Naganobu and K. Kutsuwada (Japan)
WG-EMM-05/18	Developing a carbon-budget trophic model of the Ross Sea, Antarctica: work in progress M. Pinkerton, S. Hanchet, J. Bradford-Grieve and P. Wilson (New Zealand)
WG-EMM-05/19	By-catch of fishes caught by the fishery vessel *Niitaka Maru* in the South Georgia area (August to September 2004) T. Iwami, T. Hayashi, K. Taki and M. Naganobu (Japan)
WG-EMM-05/20	Quantifying within- and between-season variability in Adélie penguin fledgling weights: statistical and practical implications for detecting change L. Emmerson, C. Southwell and J. Clarke (Australia) (*CCAMLR Science*, submitted)

WG-EMM-05/21	Do Adélie penguin fledgling weights provide an index of prey availability? L. Emmerson, C. Southwell and J. Clarke (Australia)
WG-EMM-05/22	Detection of systematic change in Adélie penguin foraging trip duration: consequences of high inter-annual variability and usefulness of ice cover as a covariate J. Clarke, C. Southwell and L.M. Emmerson (Australia) (*CCAMLR Science*, submitted)
WG-EMM-05/23	Estimating the abundance of pack-ice seals off east Antarctica C. Southwell (Australia), D. Borchers, C. Paxton (United Kingdom), B. de la Mare (Canada), P. Boveng (USA), A.S. Blix and E.S. Nordoy (Norway)
WG-EMM-05/24	Developments, considerations and recommendations by the land-based predator survey group: a summary and up-date C. Southwell (Australia), P. Trathan (United Kingdom), W. Trivelpiece, M. Goebel (USA) and P. Wilson (New Zealand)
WG-EMM-05/25	A GIS tool to assist in the planning and design of sample surveys of the abundance of colonial breeding species C. Southwell, R. Dreissen, S. Candy, G. McPherson and J. Clarke (Australia)
WG-EMM-05/26	Using carapace measurements to determine the sex of Antarctic krill (*Euphausia superba*) J.D. Lipsky, M.E. Goebel, C.S. Reiss and V. Loeb (USA)
WG-EMM-05/27	Modelling growth of Antarctic krill: a new approach to describing the growth trajectory S. Candy and S. Kawaguchi (Australia)
WG-EMM-05/28	Fishing ground selection in krill fishery: trends in its patterns across years, seasons, and nations S. Kawaguchi (Australia), K. Taki and M. Naganobu (Japan) (*CCAMLR Science*, submitted)
WG-EMM-05/29	Modelling growth of Antarctic krill: growth trends with sex, length, season, and region S. Kawaguchi, S. Candy, R. King (Australia), M. Naganobu (Japan) and S. Nicol (Australia)
WG-EMM-05/30	A conceptual model of Japanese krill fishery S. Kawaguchi, S. Nicol (Australia), K. Taki and M. Naganobu (Japan) (*CCAMLR Science*, submitted)

WG-EMM-05/31	CCAMLR observer manual questionnaires: summary results of preliminary analysis during its introductory period S. Kawaguchi and S. Nicol (Australia)
WG-EMM-05/32	On the use of scientific observers on board krill fishing vessels Delegation of Ukraine
WG-EMM-05/33	Implementing plausible ecosystem models for the Southern Ocean: an ecosystem, productivity, ocean, climate (EPOC) model A.J. Constable
WG-EMM-05/34	Modelling the predator–prey interactions of krill, baleen whales and seals in the Antarctic ecosystem M. Mori and D.S. Butterworth (South Africa) (*CCAMLR Science*, submitted)
WG-EMM-05/35	A proposal for streamlining the work of the Scientific Committee for the Conservation of Antarctic Marine Living Resources A.J. Constable (Australia)
WG-EMM-05/36	Preliminary report of sound-speed contrast and density of krill measured on board RV *Kaiyo Maru* Y. Takao, H. Yasuma , R. Matsukura and M. Naganobu (Japan)
WG-EMM-05/37	Mortality of macaroni penguins (*Eudyptes chrysolophus*) at Marion Island caused by avian cholera (*Pasteurella multocida*) in 2004/05 R.J.M. Crawford, B.M Dyer, M.S. De Villiers, G.J.G. Hofmeyr and D. Tshingana (South Africa)
WG-EMM-05/38	Breeding numbers and success of *Eudyptes* penguins at Marion Island, and the influence of arrival of adults R.J.M. Crawford, J. Cooper, B.M. Dyer and L.G. Underhill (South Africa) (*CCAMLR Science*, submitted)
WG-EMM-05/39	Information on the CEP'S Antarctic site inventory Secretariat
WG-EMM-05/40	Withdrawn
WG-EMM-05/41	Some characteristics of krill transport in the Scotia Sea based on the Russian survey data S.M. Kasatkina, V.N. Shnar and O.V. Berezhinsky (Russia) (*CCAMLR Science*, submitted)

WG-EMM-05/42	A quantified Bayesian maximum entropy estimate of Antarctic krill abundance across the Scotia Sea and in small-scale management units from the 2000 CCAMLR survey B.G. Heywood, S.F. Gull and A.S. Brierley (United Kingdom) (*CCAMLR Science*, submitted)
WG-EMM-05/43	Report of the Workshop on Management Procedures (Yokohama, Japan, 4 to 8 July 2005)

Other Documents

WG-FSA-05/4	Report of the WG-FSA Subgroup on Assessment Methods (Yokohama, Japan, 27 June to 1 July 2005)
SC-CAMLR-XXIV/BG/2	Convener's summary on intersessional activities of the Subgroup for the Implementation of the CCAMLR 2008 IPY Survey V. Siegel (Convener, Steering Group 'CCAMLR 2008 IPY Survey')
SC-CAMLR-XXIV/BG/3	Report of the First Meeting of the Subgroup on Acoustic Survey and Analysis Methods (SG-ASAM) (La Jolla, USA, 31 May to 2 June 2005)
	Long-term decline in krill stock and increase in salps within the Southern Ocean A. Atkinson (United Kingdom), V. Siegel (Germany), E. Pakhomov (Canada/South Africa), P. Rothery (United Kingdom) (*Nature*, 432: 100–103)
	The effects of global climate variability in pup production of Antarctic fur seals J. Forcada, P.N. Trathan, K. Reid and E.J. Murphy (United Kingdom) (*Ecology*, in press)
	Diet and reproductive success of Adélie and chinstrap penguins: linking response of predators to prey population dynamics A.S. Lynnes, K. Reid and J.P. Croxall (United Kingdom) (*Polar Biol*., 27: 544–554 (2004))
	Seasonal variation of crude digestive protease activity in Antarctic krill *Euphausia superba* B. Yoshitomi (Japan) (*Fisheries Science*, 71: 12–19 (2005))
	Causes of offspring mortality in the Antarctic fur seal, *Arctocephalus gazella*: the interaction of density dependence and ecosystem variability K. Reid and J. Forcada (United Kingdom) (*Can. J. Zool*., 83: 1–6 (2005))

APPENDIX D

REPORT OF THE WORKSHOP ON MANAGEMENT PROCEDURES
(Yokohama, Japan, 4 to 8 July 2005)

CONTENTS

REPORT OF THE WORKSHOP ON MANAGEMENT PROCEDURES

(Yokohama, Japan, 4 to 8 July 2005)

INTRODUCTION

1.1 The Workshop on Management Procedures to Evaluate Options for Subdividing the Krill Catch Limit among Small-scale Management Units was held at the National Research Institute of Fisheries Science (NRIFS), Yokohama, Japan. The workshop was conducted during the first week of WG-EMM-05 (4 to 8 July 2005) and was co-convened by Drs K. Reid (UK) and G. Watters (USA).

1.2 The Provisional Agenda was discussed and adopted without change (Attachment 1), and the meeting participants are listed in Attachment 2.

1.3 The report was prepared by Drs A. Constable (Australia), R. Hewitt (USA), R. Holt (USA), S. Kawaguchi (Australia), G. Kirkwood (UK), D. Ramm (Data Manager) and P. Trathan (UK).

REVIEW OF AIMS OF THE WORKSHOP

2.1 The workshop Co-conveners presented the background to the workshop and how it had evolved since the establishment of the precautionary catch limit for krill in 1991, noting:

(i) the known overlap in spatial distributions of krill catches and foraging areas of dependent species and the potential for fishing to impact on those species;

(ii) the limitation of fishing to 620 000 tonnes in Area 48 until a method for distributing the catch amongst subareas has been determined (Conservation Measure 51-01);

(iii) the request by the Commission to advise on a subdivision of the krill catch limit in Area 48 according to the SSMUs developed by WG-EMM and endorsed by the Commission in 2002 (CCAMLR-XXI, paragraph 4.6).

2.2 Following the past four workshops at WG-EMM in support of the development of a revised management procedure for krill, there was agreement by WG-EMM, which was endorsed by the Scientific Committee, that the first workshop to evaluate management procedures for the krill fishery should examine how well six candidate methods for subdividing the krill catch would meet the objectives of CCAMLR (SC-CAMLR-XXIII, Annex 4, paragraphs 6.12 to 6.24). The candidate methods to be evaluated included subdivisions based on:

(i) the spatial distribution of catches by the krill fishery;

(ii) the spatial distribution of predator demand;

(iii) the spatial distribution of krill biomass;

(iv) the spatial distribution of krill biomass minus predator demand;

(v) spatially explicit indices of krill availability that may be monitored or estimated on a regular basis;

(vi) pulse-fishing strategies in which catches are rotated within and between SSMUs.

2.3 The workshop agreed that its overall aim was to evaluate these six allocation options for subdividing the catch limit of Area 48 amongst the 15 SSMUs to meet the objectives of CCAMLR. In order to meet these aims the workshop agreed that there was a requirement to:

(i) identify models suitable to make appropriate evaluations;

(ii) discuss key topics relating to uncertainty and structural assumptions of such models;

(iii) discuss information required to facilitate the provision of management advice;

(iv) consider a mechanism to advance the outcomes of the workshop.

STRUCTURAL AND NUMERICAL ASSUMPTIONS OF THE OPERATION OF THE ECOSYSTEM AND FISHERIES IN AREA 48

3.1 At the previous meeting of the Working Group, three correspondence groups were established to consider krill, krill predators and the krill fishery (SC-CAMLR-XXIII, Annex 4, paragraphs 6.12 to 6.24). Dr Reid reminded the workshop that these correspondence groups had been tasked with the following issues in anticipation of the current workshop:

(i) to consider the range of datasets that would be necessary to initialise any models formulated to consider the candidate procedures;

(ii) to consider the range of alternative structural and functional assumptions that would be relevant to the dynamics of the predator–krill–fishery system and the formulation of any models constructed to consider the candidate procedures;

(iii) to identify important measures of performance. These measures would be used to determine whether the candidate procedures would be likely to produce results that were robust or sensitive both to the initialisation data and conditions, and to the alternative structural assumptions.

Review of reports from the Krill Correspondence Group

3.2 Dr Hewitt reported on communications among members of the Krill Correspondence Group. The correspondence group advised that three datasets describing the demography, distribution and abundance of krill in portions of the Scotia Sea would be appropriate for initialising models used to examine candidate procedures. These include:

(i) the surveys conducted by the British Antarctic Survey in the vicinity of South Georgia;

(ii) the series of surveys conducted in the vicinity of the South Shetland Islands by the US AMLR Program and Germany;

(iii) the CCAMLR-2000 Survey.

3.3 The correspondence group also advised that the most important assumptions regarding the dynamics of the predator–krill–fishery system were those that described the movement of krill within the Scotia Sea. The correspondence group noted that the possible range of assumptions could be characterised by two extremes:

(i) krill populations actively maintain their position in the vicinity of the major archipelagos (South Shetlands, South Orkneys, South Georgia) and there is no exchange between them (i.e. a situation with no krill flux);

(ii) all krill passively drift with the ACC, generally moving west to east through the Scotia Sea.

3.4 The correspondence group further advised that neither extreme was likely and that reality was somewhere in between. However, the correspondence group advised that by modelling these two extremes the range of possibilities would be covered.

3.5 The correspondence group also advised that it was likely that there were two sources of krill in the Scotia Sea: the Bellingshausen Sea via the ACC and the Weddell Sea via the Weddell Gyre.

3.6 Dr Hewitt noted evidence within the datasets described in paragraph 3.2 for large interannual variations in krill recruitment and that these variations may be autocorrelated in time. He further suggested that krill recruitment parameters be adjusted to reflect the degree of variability observed and that competing hypotheses of random versus autocorrelated variability be investigated.

3.7 Two papers were tabled at WG-EMM-05 that provided further information to be considered in the initialisation of models used to examine candidate procedures. These were:

(i) WG-EMM-05/41, which described geostrophic flow across three sections of the ACC as derived from hydrographic data collected on Russian surveys in the Scotia Sea;

(ii) WG-EMM-05/42, which described a reanalysis of acoustic data collected during the CCAMLR-2000 Survey.

These papers provided the basis for computing alternative parameters for initialising the movement matrix and initial krill densities respectively.

Review of reports from the Predator Correspondence Group

3.8 Dr Trathan reported on the intersessional work of the Predator Correspondence Group.

Relevant datasets

3.9 The Predator Correspondence Group recommended that the workshop utilise available CEMP data to provide information on predator population size, diet and breeding success. Further, that the matrices of available data that were developed for the CEMP Review Workshop (SC-CAMLR-XXII, Annex 4, Appendix 3) should be used to identify the most useful combinations of data.

Alternative assumptions

3.10 The Predator Correspondence Group advised that the following assumptions were likely to have differing implications for krill management, and that these should therefore be considered during the workshop:

(i) The presence or absence of krill flux (paragraph 3.3) will affect the breeding performance of land-based predators.

(ii) Land-based predators do/do not have traditional foraging grounds, and may/may not use alternative locations under differing environmental conditions.

(iii) Different predator species do/do not target krill swarms that have different aggregation characteristics, as revealed by their foraging behaviour.

(iv) Krill predator responses (foraging behaviour, output performance etc.) do/do not differ as a result of prey density or prey switching.

(v) Predators do/do not spend their winter periods outside the main summer breeding areas.

Indicators

3.11 The correspondence group advised that field-based indicators of reproductive performance should have a defined set of characteristics; this recommendation was based on ideas developed at the CEMP Review Workshop (SC-CAMLR-XXII, Annex 4, Appendix 3). Thus:

(i) indicators should relate to the krill-based food web
(ii) they should be sensitive to change and be based on practical field methods
(iii) indicators should have sufficient statistical power to detect change
(iv) both step changes and trend changes in the food web should be detectable.

3.12 The correspondence group advised that, as the workshop would be exploratory, the range of data, assumptions and indicators suggested (paragraphs 3.9 to 3.11), would enable a range of scenarios to be tested and that these would help the workshop in its task.

Review of reports from the Krill Fishery Correspondence Group

3.13 Dr Kawaguchi provided a report from the Krill Fishery Correspondence Group.

Data to be used to initialise the candidate procedures

3.14 Among the six candidate management procedures to subdivide the precautionary catch limit in Area 48, the correspondence group thought options (i) and (vi) were the options to be commented on by the correspondence group.

The spatial distribution of catches (option i)

3.15 The correspondence group advised that historical catches are to be used to initialise management option (i), taking into account:

(i) resolution of the data (spatially and temporally)
(ii) seasons
(iii) definition of fishing seasons.

3.16 The spatial resolution of the data should preferably be haul-by-haul or as fine-scale as possible to account for the curved boundaries of the SSMUs.

3.17 Krill, predators and krill fishery all have seasonality in their properties and the correspondence group suggested that in many cases a separation of the timing of importance between the predators and the fishery occurs. Subdividing a fishing season into quarterly periods was thought to be necessary to adequately reflect seasonal factors in interactions between those components.

3.18 It was also suggested that there were shifts in the main fishing grounds due to changes in the nations engaged in the krill fishery. The largest change in the catch occurred with the changing economic circumstances of the former Soviet Union in the early 1990s.

3.19 From the 1992/93 fishing season onwards, the total annual catch has gradually increased and became stable around 100 000 tonnes with the highest proportion of catch taken by Japan.

3.20 Examples of how the historical catch could be used to subdivide the catch among the SSMUs are, although not exclusively, limited to:

(i) use all historical catch data without subdividing into four seasons;

(ii) use all historical catch data with subdivision into four seasons;

(iii) use historical catch data only from the 1992/93 season onwards without subdividing into four seasons;

(iv) use historical catch data only from the 1992/93 season onwards with subdivision into four seasons;

(v) use of all historical catch data with subdivision into four seasons but weighted by the similarity of the historical fleet to the current fleet.

Pulse-fishing between SSMUs (option vi)

3.21 It was suggested that historical catches could be used to initialise this option such that historical maximum annual catch (520 000 tonnes), the current trigger level (620 000 tonnes) and the recent annual catch level (120 000 tonnes) could be rotated among SSMUs within each of the subareas. This could be further divided into seasons.

Alternative structural and functional assumptions

3.22 The correspondence group listed the following possible structural and functional assumptions.

(i) Fishery–predator interactions

(a) the types of krill aggregations which fisheries are targeting are the same (different) from the ones that predators target (size and density of the patch, distance from shore etc.);

(b) the fishery does (does not) avoid the active foraging areas of predators.

(ii) Fishery–krill interactions

(a) the fishery avoids (does not avoid) low quality krill (green krill);

(b) the fishery prefers (has no preference for) gravid females;

(c) the fishery follows (does not follow) drifting patches;

(d) the fishery prefers (has no preference for) certain types of krill aggregation (e.g. swarms or layers);

(e) the fishery only operates above critical densities; below these densities, vessels move onto nearby SSMUs.

3.23 Interactions between the fishery and krill depend on the decisions on where to fish made by the fishing operators. Therefore, information on fishing strategies and their economic implications are extremely important to understand these processes.

Performance measures

3.24 The following were suggested as candidate performance measures:

(i) catch per towing volume
(ii) catch per towing time
(iii) catch per day
(iv) catch per haul
(v) catch per searching time
(vi) daily factory operation time.

3.25 Each of the performance measures may have different levels of sensitivity to the different processes and fishing strategies involved. Since the sensitivity of performance measures is likely to be dictated by the resolution of data and also how they are modelled, it was recognised that exchanging information between each of the correspondence groups is necessary to give further advice.

Implications of future technical advancement and market demand

3.26 Implications of future technical advances and market demand were considered in relation to size composition of the catch, swarm type targeted, quality of krill being caught, predator by-catch, daily catch and overall catch. Pumping was suggested to be a likely method in the future, where krill are pumped from the codend continuously without hauling the net (WG-EMM-05/12).

3.27 It was recognised that different krill products require a different grade (quality) of krill catch and that using the different conversion factors for these products can dramatically change the estimation of total krill catch. Changes in the market demand may also affect the required quality of krill and product types, which has implications for the fishing and processing methodology.

Analysis of historical catch

3.28 WG-EMM-05/5 reported the annual time series of krill catches from SSMUs in Area 48, which was derived from fine-scale data and scaled to the total catches reported in the STATLANT data (Table 1). Annual catches in excess of 30 000 tonnes of krill have been taken in nine SSMUs.

3.29 The document further presented time series of catch and effort and overlap measure between predators and fishery by SSMU. It was indicated that the relative fishing-to-predation index (FPI) shows the largest value in SOW. Within each SSMU the relative FPI peaked typically in the 10-year period between 1986/87 and 1995/96, however, in APBSW and APW it peaked more recently (2000/01 and 1998/99 respectively).

3.30 WG-EMM-05/28 summarised changes of fishing ground in space and time since the early 1980s. Patterns of fishing ground selection were characterised using STATLANT and CCAMLR fine-scale data. Catch by every quarterly period by each SSMU was analysed. It further noted how SSMUs of relative importance vary dramatically inter- and intra-annually.

3.31 Among the 15 SSMUs within Subareas 48.1, 48.2 and 48.3, including the pelagic SSMUs, only one-third were identified as the main contributors to the total catch (SGE, SOW, APEI, APDPE, APDPW), and these SSMUs generally seem to match with the area of high krill density, but at the same time, other areas identified to show high density, including pelagic areas, were not used as fishing grounds. Dr V. Sushin (Russia) noted that although there are cases when scientific surveys recorded high krill abundances in the pelagic SSMUs, there is published evidence that such aggregations are unstable and therefore it is hard to make a profit by operating on these (Sushin, 1998; Sushin and Myskov, 1992).

3.32 A shift of operational timing towards later months within fishing seasons was observed in Subarea 48.1 (December–February to March–May). However, operational timing stayed relatively constant in Subareas 48.2 (March–May) and 48.3 (June–August).

3.33 In WG-EMM-05/28 patterns of seasonal SSMU selection were characterised into three patterns using cluster analysis. Frequently used SSMUs did not always match the areas of high krill densities observed by scientific surveys. However, the reasons for this are not clear.

3.34 Japan voluntarily submitted its entire haul-by-haul catch and effort data from Area 48 for the purpose of conducting analyses in preparation for this workshop. The workshop welcomed this contribution.

3.35 The workshop recognised that the better resolution of the information provided gives better foundation of the way historical fishery data may be used to subdivide catch limits under candidate management options (i) and (vi).

General discussion on ecosystem structure and function

3.36 After reviewing reports from the three correspondence groups and the relevant papers (WG-EMM-05/13, 05/14, 05/33 and 05/34), the workshop had a more general discussion about the structural and functional issues relating to the operation of the ecosystem and the manner in which these could be represented in a plausible model. These included:

(i) The benefits of a seasonally resolved model, compared to those of a model with a single annual time step.

(a) The workshop noted that it would need to explore seasonality, as ecosystem properties would probably change for different seasons. This was likely to be necessary irrespective of season length. The workshop further noted that physical and biological processes would need to be represented at the same temporal scale.

(b) The workshop recognised that the parameterisation of a model with intra-annual time steps could potentially present a number of challenges, but would be valuable. For example, it may be important to ensure that annual rates are not simply scaled rates estimated from a single season (e.g. from summer) as this could introduce bias.

(c) The potential for spatial and/or temporal separation between harvesting and centrally placed predators foraging during the breeding season. This may be best represented in a seasonal model with intra-annual time steps.

(ii) The transport or flux of krill from one region (or SSMU) to another (or other SSMU). The workshop recognised that transport could be represented by a transition matrix of probabilities derived from an oceanographic model seeded with passive particles (WG-EMM-05/13; Murphy et al., 2004). The workshop noted that:

(a) a probability transition matrix could be derived from flow fields derived from different circulation models of the Scotia Sea, from geostrophic calculations (WG-EMM-05/41), from satellite altimetry, or from oceanographic surface drifters;

(b) different probability transition matrices could be built for years of extreme environmental differences;

(c) the choice of time step was critical to the flux process, particularly where transport rates were very high;

(d) flux was not instantaneous and that mortality could be important during movement;

(e) passive movement may be modified by behaviour.

(iii) The fact that predators and fisheries may have different selection criteria for krill.

(iv) The fact that the availability of krill to the fishery and to predators was important, and that factors such as density and/or swarm characteristics would be important.

(v) The recognition that the movement of predators between SSMUs was potentially important.

(vi) The recognition that the dynamics of some pelagic predators may be independent of krill availability assessed at the scale of SSMUs.

(vii) The method for allocating catch and consumption, particularly when the combined demand was greater than the available abundance of krill. The workshop recognised that a mechanism for altering the relative allocations between the fishery and predators could be included in a model.

(viii) The need to account for harvesting of fish that are krill predators in some SSMUs.

CANDIDATE PERFORMANCE MEASURES

Performance measures for krill

4.1 The Krill Correspondence Group advised that the performance measures currently used by CCAMLR in the management of the krill fishery would be appropriate. These are based on:

(i) the probability that the spawning stock declines below 20% of the median level of the unexploited spawning stock;

(ii) the median spawning biomass of the krill population divided by the median spawning biomass of the unexploited population.

Performance measures for krill predators

4.2 Two categories of potential performance measures for krill predators were presented. These were (i) assessment of the conservation status of local populations based on rates of decline and recovery that are scaled to generation times, and (ii) the frequency of time steps in which these populations were below a reference 'depletion' level or above a reference 'recovery' level.

4.3 It was noted that performance measures should be defined in a manner consistent with the ecological theory represented by a particular model. This may include criteria defined in the simulation environment that represent a healthy ecosystem function as well as critical threshold levels that ensure the stable recruitment of predator species. A large number of performance measures could be developed from the output of a suitable model of the krill–predator–fishery system. The workshop also considered that any such performance measures should reflect both local-scale (SSMU) and global-scale (Area 48) population changes.

Performance measures for the krill fishery

4.4 The following performance measures for the krill fishery were introduced by Dr S. Hill (UK):

- absolute catch
- catch as proportion of allocation
- probability of 'voluntary change' (where krill density falls below a specified threshold).

4.5 The workshop noted that catch rate may also be an appropriate performance measure.

4.6 Deviation of fishing patterns from historical patterns of spatial distribution may also be a useful performance measure for the krill fishery. However, use of deviation from the current fishing patterns as a performance measure may be problematic since fishing patterns may change as annual catch and the number of countries fishing increases.

Presentation of performance measures

4.7 Presentation of performance measure was discussed. Graphical presentation was thought to convey important properties of the measures, and what might be considered to be robust performance (paragraphs 6.1 to 6.3). On the other hand, tables with true/false (i.e. binary) information are difficult to interpret. Overall, the workshop preferred graphical presentation over tabular presentation.

4.8 It was also realised that precise description of presentations is essential to convey the meaning of the graphs correctly. For example, describing fishery performance as absolute catch will often lead to different interpretations than describing fishery performance as the ratio of realised catch to allocated catch.

MODELS FOR PROVIDING ADVICE

Review of models presented to the workshop

5.1 Three papers describing models relevant to the evaluation of options for subdividing the precautionary krill catch limit amongst SSMUs in Area 48 were available to the workshop. These were WG-EMM-05/13, 05/14 and 05/33. Also considered relevant to these discussions was WG-EMM-05/34.

5.2 WG-EMM-05/13 described a krill–predator–fishery model (KPFM) developed specifically to address options for subdividing the precautionary catch limit amongst SSMUs in Area 48. The model is designed to investigate the performance of the identified options and their sensitivity to numerical and structural uncertainty. The model is spatially resolved to the level of SSMUs and surrounding oceanic areas, and it includes the transport of krill between these areas. Krill and predator population dynamics are implemented with coupled delay-difference models, which are formulated to accommodate various assumptions about the recruitment and predation processes. The fishery is represented as a simultaneous and equal competitor with predators for available krill. Monte Carlo simulations can be used to integrate the effects of numerical uncertainty, and structural uncertainty can be assessed by comparing and merging results from multiple such simulations. A range of possible performance measures was also presented that can be used to evaluate catch-allocation procedures and assess trade-offs between predator and fishery performance. The paper provided basic instructions on running the model in S-Plus and illustrated its use. Although the model necessarily simplifies a complex system, it provides a flexible framework for investigating the roles of transport, production, predation and harvesting in the operation of the krill–predator–fishery system.

5.3 WG-EMM-05/14 outlined a proposed spatial modelling framework that could be used to quantify the flux of krill past islands in the Antarctic Peninsula region, in an attempt to quantify what level and localisation of the fishing effort might impact the predators negatively. The approach described represents work in progress as the focus thus far has been on first developing a model of the possible impact of pelagic fishing on seal and penguin colonies on the South African west coast. The latter ecosystem shares a number of common features with the Antarctic Peninsula ecosystem in that there is a substantial advective flux of either pelagic fish or krill, with both species serving as dominant prey items for colonies of land-based predators in the region concerned. Subject to the availability of data from both predator studies and krill surveys, the South African west coast model methodology could potentially be adapted to the Antarctic Peninsula region. This would permit the evaluation of a wide range of management options taking into account the needs of other species when setting precautionary krill catch limits at an appropriate spatial scale.

5.4 WG-EMM-05/33 described an ecosystem, productivity, ocean, climate (EPOC) model that has been developed in the R statistical language to help explore topical issues on Antarctic marine ecosystems, including impacts of climate change, consequences of overexploitation, conservation requirements of recovery and interacting species, and the need to evaluate whether harvest strategies are ecologically sustainable. As such, it can be used to facilitate the development of plausible ecosystem models for evaluating management procedures for krill following the recommendations of the workshop held by WG-EMM in 2004. The EPOC model has been designed as an object-oriented framework currently built around the following modules: (i) biota, (ii) environment, (iii) human activities, (iv) management, (v) outputs, and (vi) presentation, statistics and visualisation. Each element within a module is an object carrying all its own functions and data. The EPOC model is designed to be a fully flexible plug-and-play modelling framework. This is because of the need to easily explore the consequences of uncertainty in model structures but, more importantly, to enable ecosystem modelling to proceed despite widely varying knowledge on different parts of the ecosystem and avoiding the need to guess model parameters for which no information exists. The EPOC model provides these opportunities as well as examining the sensitivity of outcomes to changes in model structures, not only in the magnitude of parameters but in the spatial, temporal and functional structure of the system. The paper presented a case study for Antarctic krill as an example.

5.5 In presenting his model, Dr Constable also provided an example of alternative ways of modelling different taxa rather than solely as age-structured or biomass models. This example illustrated that, within the same simulation, different species can be modelled at different spatial and temporal scales as well as with different biological and ecological complexity.

5.6 WG-EMM-05/34 described a model of the dynamics of krill, including four baleen whale (blue, fin, humpback and minke) and two seal (Antarctic fur and crabeater) species in two large sectors of the Antarctic. The model was developed to investigate whether predator–prey interactions alone can broadly explain observed population trends since the onset of seal harvests in 1780. It concluded that the answer to this question is yes, although not without some difficulties.

5.7 The workshop agreed that given the limited time available, it would concentrate its review on the KPFM described in WG-EMM-05/13.

Discussion of model selection/suitability

5.8 The process adopted by the workshop for reviewing the KPFM involved a number of steps. These included:

(i) detailed examination of the dynamics of the modelled krill and predator populations in a single SSMU under a range of different key biological parameter values, a fixed fishing pattern, and with and without movement. The emphasis here was on confirming that trends predictable from the input parameters chosen could be reproduced by the model;

(ii) as for (i), but with two coupled SSMUs;

(iii) a review of structural assumptions made in the model, with particular emphasis on identifying any factors that were not currently accounted for in the model, but which should be;

(iv) a review of appropriate parameter values for each of the main processes (biological dynamics of krill and predators, fishery characteristics and movement patterns between SSMUs);

(v) examination of runs of the full model (with 15 SSMUs) using updated parameter values.

5.9 A summary report of the model performance with only one or two SSMUs is included in Attachment 3. The workshop agreed that the model had performed very satisfactorily on these trials, with outcomes corresponding to predictions in each trial experiment.

5.10 The review of structural assumptions of the model is discussed under Agenda Item 3 (paragraph 3.36). The workshop agreed that at least three key aspects should be given further attention in the models and their implementation:

(i) incorporation of shorter time steps and/or seasonality
(ii) incorporation of alternative movement hypotheses
(iii) incorporation of a threshold krill density below which a fishery will not operate.

5.11 In respect of seasonality, it was agreed that this was important both to model more accurately the seasonality of the dynamics and feeding behaviour of predators and to take account of variable timing within a year of the fisheries and peak predator foraging in different SSMUs (see also paragraphs 3.10 and 3.17).

5.12 At present, movement matrices estimated for the model allow either for no movement between SSMUs, or movements estimated from runs of the Ocean Circulation Climate Advanced Modelling (OCCAM) project (see Murphy et al., 2004). It was agreed that incorporation of a seasonal time step might allow a more realistic portrayal of movements between SSMUs than is currently possible with an annual time step.

5.13 Different movement patterns and rates may be implied by the results presented in WG-EMM-05/41, but it was not possible during the meeting to develop alternative movement matrices to reflect these (see paragraph 3.36(ii)). The workshop agreed that these should be developed during the coming year. However, it was noted that when different water movement rates are applied, the seasonal changes in krill abundance have to be considered along with the water exchange rates to avoid an overestimate of the overall annual krill flux.

5.14 Subject to incorporation of these structural changes, which could be carried out in the coming year, the workshop agreed that the KPFM was in principle suitable for use to investigate the different options for catch limit subdivision, however it noted that a final decision would have to await demonstration of suitable performance of the model when applied to all 15 SSMUs and revised parameter sets. This is discussed in the next section.

5.15 The workshop congratulated the authors of WG-EMM-05/13 for the large amount of work they had carried out, and especially for the excellent progress that had been made on model development and parameterisation in such a short time. In particular, several participants noted that, despite many attempts elsewhere in the world, there are very few examples of ecosystem models that are being, or are capable of being, used to develop explicit management advice on catch limits or the subdivision of catches in an ecosystem context. The progress that has been achieved so far with the KPFM is therefore very encouraging.

Choice of parameters for the KPFM

5.16 Small groups of workshop participants with expertise in each of the main species groups were asked to review the parameters used to generate the KPFM results presented in WG-EMM-05/13 for the full set of SSMUs. Unfortunately, only limited time was available for this after completion of the initial model structural review. Consequently, while some revisions were made to parameter values, each group reported that it had had insufficient time to consider these in sufficient depth and to take account of all relevant data.

5.17 It was therefore not entirely unexpected that when these revised parameter sets were used in test runs of the full model, it became clear that additional work would be needed to further refine the parameter values and to ensure consistency between them. In the absence of time to allow this, the workshop agreed that it would not be appropriate to attempt to conduct simulation trials with a view to providing advice on the different catch allocation options or subdivision of catch limits amongst SSMUs at this meeting.

Future work necessary to provide advice on SSMU catch limit subdivision

5.18 The workshop agreed that sufficient progress had been made with the KPFM development this year for it to believe that a further year's work should allow appropriate advice based on runs with a revised version of the simulation model to be provided by WG-EMM to the Scientific Committee and Commission next year.

5.19 In order to achieve this, however, it is essential that appropriate benchmarks be established. It was agreed that it would be necessary to present to WG-EMM next year sets of results that demonstrated the sensitivity of results and performance measures to plausible ranges of model parameters and structural hypotheses and robustness to uncertainties.

5.20 For the KPFM, the work required is relatively easily specified. The workshop agreed, however, that it would also be valuable if results were also available from other models (see also paragraph 5.26).

5.21 In relation to the model in WG-EMM-05/14, Dr É. Plagányi (South Africa) commented that she was now more confident that data were available to allow her to attempt to apply the approach. Preliminary work on this would be carried out in the next few months. If this confirmed the potential applicability of the model, she hoped to be able to present a paper describing its application to Area 48 at the next meeting of WG-EMM.

5.22 In relation to the EPOC model (WG-EMM-05/33), Dr Constable indicated that he had already started work on developing a model that would be complementary to the KPFM, and that he intended to continue this work in the coming months. He noted that one of the potential advantages of the EPOC framework was that it was possible to incorporate different assumptions regarding the dynamics of the main component species. By doing so and comparing results with those of the KPFM, this may allow identification of which are the key parameters in the system and allow partial validation of the results of the two models. He noted, however, that an important difference at present between the EPOC model and the KPFM was that the former is much slower to run.

5.23 The workshop noted that it would be desirable for WG-EMM to provide opportunities for the Working Group to become familiar with these models when they are presented, as was done for the KPFM.

5.24 Dr Plagányi noted that the model in WG-EMM-05/34 is not currently suitable for the development of management advice in this context, but could be used to explore the effect of trends in abundances over larger spatial scales than those addressed in the KPFM.

5.25 The workshop agreed that, in order to be in a position to provide advice next year, it is essential that the benchmarks identified in paragraph 5.19 be achieved. The workshop further agreed that scientists undertaking development of the KPFM or other models during the intersessional period coordinate as necessary through the steering group set up by WG-EMM last year (SC-CAMLR-XXIII, Annex 4, paragraph 5.62). Given the experience of the workshop, however, it is essential that this group include the full range of necessary expertise. It therefore recommended that WG-EMM bear this in mind when reviewing the group at its meeting this year (see also paragraph 7.6).

5.26 The workshop noted that procedures will need to be determined for how to assess and use the results of multiple models in this work, given that three models may be available to assist with this task. It recommended that WG-EMM ask the steering committee to provide advice on this to the Working Group next year.

PERFORMANCE OF INDIVIDUAL OPTIONS

6.1 The workshop noted that the evaluation of the candidate options for subdividing catch limits required an examination of their robustness in meeting the objectives of CCAMLR. This is achieved in a number of steps:

- erecting a sufficiently plausible description of the ecosystem, the fishery and the candidate option in a simulation model, termed the ‘operating model’;

- using the operating model to simulate the system, keeping track of the important states of each species, the fishery as well as other parameters;

- determining the performance of the system according to important ecosystem and fishery 'performance measures';

- doing this many times to account for natural variability and uncertainty, thereby providing probabilities of different levels of the chosen performance measures.

6.2 A candidate strategy would be considered 'robust' to underlying uncertainties if the objectives of CCAMLR can be met, irrespective of model structure, uncertainty in parameter estimates or natural variability. Robustness is estimated by the probability of 'good' performance shown by the performance measures. As such, the measures of performance need to relate to the objectives of CCAMLR; each performance measure articulates, in a quantitative way, aspects of the objectives.

6.3 Of course, each candidate option will not perform the same way across all performance measures. The important part of this evaluation work is to illustrate the trade-offs between performance measures as well as to present the potential consequences of different options to krill, dependent species and the fishery. The workshop agreed that advice may not be able to be provided as to the relative importance of different measures. It agreed that methods for presenting the trade-offs need to continue to be explored but that a graphical presentation, such as in Figure 1, would be a good foundation for such presentations.

6.4 The workshop agreed that it was unable, at this time, to comment on the robustness of the candidate options for subdividing the catch limit for krill in Area 48 amongst SSMUs. Nevertheless, it has made substantial progress in developing the tools and parameter sets for providing advice on a subdivision of the Area 48 catch limit in the near future. The workshop agreed that advice to the Scientific Committee should be possible next year.

ADVICE TO WG-EMM

7.1 Following the past four workshops at WG-EMM in support of the development of a revised management procedure for krill, there was agreement by WG-EMM in 2004 (SC-CAMLR-XXIII, Annex 4, paragraph 6.13), which was endorsed by the Scientific Committee (SC-CAMLR-XXIII, paragraphs 3.86 to 3.90), that the first workshop to evaluate management procedures for the krill fishery should examine how well six candidate methods for subdividing the krill catch would meet the objectives of CCAMLR (paragraph 2.2).

7.2 The workshop agreed that the performance measures for krill based on the current operational decisions used by CCAMLR in the management of the krill fishery would be appropriate (paragraph 4.1). Two categories of potential performance measures for krill predators were suggested (paragraphs 4.2 and 4.3). In addition, performance measures for the krill fishery were provided (paragraph 4.4).

7.3 Three papers describing models relevant to the evaluation of options for the subdivision of the precautionary krill catch limit in Area 48 amongst SSMUs were presented (paragraphs 5.1 to 5.7). The workshop agreed that, given the limited time available, it would concentrate its review on the KPFM described in WG-EMM-05/13.

7.4 The workshop agreed that sufficient progress had been made with the KPFM development this year for it to believe that a further year's work should allow appropriate advice based on runs with a revised version of the simulation model to be provided by WG-EMM to the Scientific Committee and Commission next year (paragraph 5.18). The workshop agreed, however, that it would be valuable if results were also available from other models (paragraphs 5.20 to 5.26).

7.5 The workshop noted that the evaluation of the candidate options for subdividing catch limits required an examination of their robustness in meeting the objectives of CCAMLR. This could be achieved by the work and approaches outlined in paragraphs 6.1 to 6.3.

7.6 The workshop discussed possible ways of continuing its work intersessionally, and recommended that a means to facilitate this be considered by WG-EMM.

ADOPTION OF THE REPORT AND CLOSE OF THE MEETING

8.1 The report of the workshop was adopted.

8.2 The workshop agreed that the KPFM, with its extensive documentation, graphic outputs and diagnostics, had successfully engaged participants from a wide range of backgrounds, including those with and without sophisticated modelling skills. This level of participation encouraged exploration of the effects of various parameter combinations and structural assumptions, as well as facilitated consensus agreement on future work.

8.3 The Co-conveners of the workshop, Drs Reid and Watters, thanked the participants for their work and cooperation during the workshop. They also thanked Drs Hewitt, Kawaguchi and Trathan, the coordinators of the correspondence groups, for their contributions in preparation for, and during, the workshop, and the Secretariat for its contribution and support.

8.4 Dr Constable, on behalf of the participants, thanked the Co-conveners for their leadership in developing an approach to the evaluation of the management procedures for the krill fishery. The workshop also thanked the Co-conveners, and Dr Hill and Mr J. Hinke (USA), the co-authors of the KPFM, for their great effort in developing and testing that model.

8.5 The Co-conveners thanked Dr Naganobu and his organising team for their support and hospitality.

8.6 The workshop closed on 8 July 2005.

REFERENCES

Murphy, E.J., S.E. Thorpe, J.L. Watkins and R. Hewitt. 2004. Modelling the krill transport pathways in the Scotia Sea: spatial and environmental connections generating the seasonal distribution of krill. *Deep-Sea Res., II*, 51: 1435–1456.

Sushin, V.A. 1998. Distribution of the Soviet krill fishing fleet in the South Orkneys area (Subarea 48.2) during 1989/90. *CCAMLR Science*, 5: 51–62.

Sushin, V.A. and A.S. Myskov. 1992. Location and intensity of the Soviet krill fishery in the Elephant Island area (South Shetland Islands), 1988/89. In: *Selected Scientific Papers, 1992 (SC-CAMLR-SSP/9)*. CCAMLR, Hobart, Australia: 305–335.

Table 1: Annual catch (tonnes) of krill from the fishery in Area 48, by season and SSMU. Antarctic Peninsula (AP) 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 (SO) SSMUs: Pelagic Area (SOPA); North East (SONE); South East (SOSE); West (SOW). South Georgia (SG) SSMUs: Pelagic Area (SGPA); East (SGE); West (SGW). Other: Area 48, unspecified or outside SSMUs. Source: fine-scale data weighted to catches reported in the STATLANT data (see WG-EMM-05/5 for detail).

Season	SSMU group weighting factor			Total catch (tonnes)	SSMU															Other
	AP	SG	SO		APBSE	APBSW	APDPE	APDPW	APE	APEI	APPA	APW	SGE	SGPA	SGW	SONE	SOPA	SOSE	SOW	
1980/81	18.9		*	154474	887	27	22047	8522	134	16199	45630	271					*60540			217
1981/82	13.2		187.2	326788		1	7277	15186		5062	40407	260				1081	238628		18887	
1982/83	1.2	*	13.5	65115				4			2290			*2004		631	51731		7710	745
1983/84	1.0	*	1.0	40534	5	0	9725	3619	17	4196	12411	258		*73		1145	59	1	9025	
1984/85	1.2	*	6.2	212011	6		3108	477		6370	2961	11		*60724		8517	10975		118863	
1985/86	1.2	*	12.2	378739	32		8317	2705		21051	7367	1574		*110596		4656	5336		217104	1
1986/87	1.0	3.6	1.0	400835		1	9022	187		53785	7274		312134			196	1102		17128	5
1987/88	1.1	1.0	1.0	388953		0	34171	10363		24967	9387	30	105990	105636	24	4323	4627	19284	70047	104
1988/89	1.0	1.0	1.0	352271		18	37689	17193		42132	8490	33	157204	1412		14	72755		15332	
1989/90	1.0	1.0	1.0	376099	106		13847	691		24002	6097	8	89557	11349	6907	12657	81808		129067	
1990/91	1.0	1.2	1.0	331318	1035	6	16580	15508		29719	6818		88023	8339	5307	12774	5249		141961	
1991/92	1.0	0.9	1.4	257663	32	5	21668	40754		6355	6735	15	49115	331	14801	3665	48708		65429	50
1992/93	1.0	1.1	1.0	60783		43	928	29870		2373	54		3478	124	11139	4111	1253		7306	104
1993/94	1.0	1.0	1.0	84645		107	1066	26237		17659	11	5	19908	381	11	80	4	1303	17872	
1994/95	1.0	1.2	1.0	134420		179	2922	11674		15030	8359		46624	473	325	1273	27	24	47509	
1995/96	1.0	1.0	1.3	91150		507	5772	36695	25	12613	6351		23872	14	2566	4	51		2679	
1996/97	1.0	1.0	*	75653	13	87	17489	20389		9143	1722		26605		106		*99			
1997/98	1.0	1.0	1.0	90024	102	679	18853	24205		5808	4047	2879	23301	54	3422	290	602		5781	
1998/99	1.0	*	1.0	101957	914	24	10732	11364		8970	2982	3910		*985		3379	984	12324	45389	
1999/00	0.9	1.3	1.0	114425	3728	4950	21073	30090		10673	1362	101	14992	8335	2230	1130	3145	1493	11123	
2000/01	0.9	1.5	1.0	104182	609	3255	16444	21902		4133	5	430	37186	534	14703	1354	2	2511	1114	
2001/02	1.0	1.1	1.3	125987	94	285	1449	4672		4114	32		30856	3079	9346	3354	70	1161	67474	
2002/03	1.1	1.0	0.9	117728	18	256	2029	31905		1040	67	62	52003	791	14131	54	509	44	14821	
2003/04	2.3	1.2	1.7	118166	4282	862	439	3534		3414	836	514	26158	309	31362	348	261	17	45830	

* Weighting cannot be determined (STATLANT data reported for SSMU group, fine-scale data for related SSMU insufficient), catch is for the SSMU group.

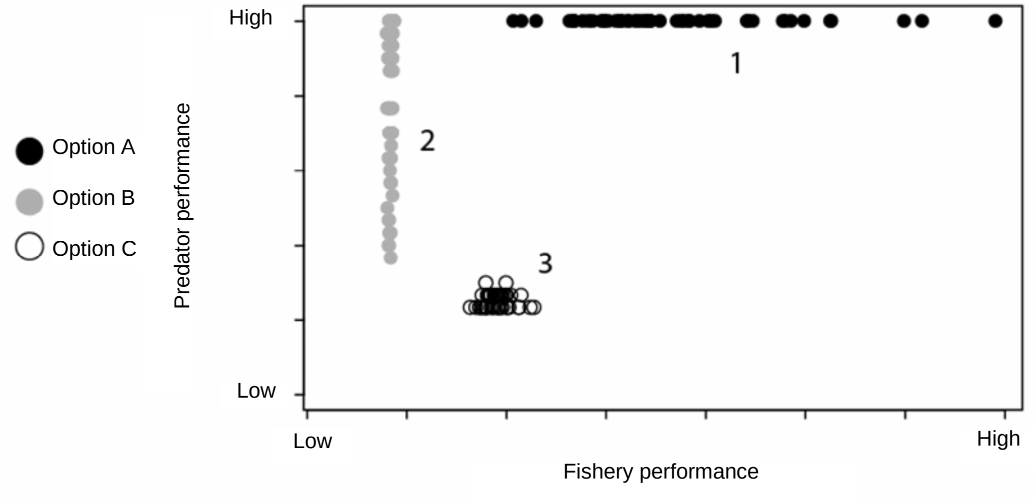

Figure 1: An example illustration of the trade-offs associated with three candidate management procedures (identified as Options A–C). A hypothetical measure of fishery performance is used to define the x-axis of the plot, and a hypothetical measure of predator performance is used on the y-axis. Three groups of points are illustrated in the plot, and each group is associated with one of the candidate procedures. The points in group 1 illustrate the outcomes of simulations in which Option A is used as the fishery management procedure. This procedure results in variable fishery performance and high predator performance. The points in group 2 illustrate the outcomes of simulations using Option B; this procedure results in poor fishery performance and variable predator performance. The points in group 3 illustrate simulated outcomes from Option C. This management procedure results in low fishery performance and low predator performance. The examples presented here are simply illustrative.

ATTACHMENT 1

AGENDA

Workshop on Management Procedures
(Yokohama, Japan, 4 to 8 July 2005)

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

2. Review of aims of the Workshop on Management Procedures to evaluate options for subdividing the krill catch limit among SSMUs

3. Structural and numerical assumptions of the operation of the ecosystem and fisheries in Area 48
   3.1 Review of the reports from the Correspondence Group on Krill
   3.2 Review of the reports from the Correspondence Group on Predators
   3.3 Review of the reports from the Correspondence Group on the Krill Fishery

4 . Candidate performance measures
   4.1 Performance measures for krill
   4.2 Performance measures for krill predators
   4.3 Performance measures for the krill fishery

5. Models for providing management advice
   5.1 Review of model(s) presented to the workshop
   5.2 Discussion of model selection/suitability
   5.3 Choice of parameters for model(s) selected in subitem 5.2

6. Performance of individual options

7. Advice to WG-EMM.

ATTACHMENT 2

LIST OF PARTICIPANTS

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ATTACHMENT 3

SOME EXPLORATIONS WITH KPFM –
MOVING FROM PREDICTING OUTCOMES TO EXPLAINING OUTCOMES

**SOME EXPLORATIONS WITH KPFM –
MOVING FROM PREDICTING OUTCOMES TO EXPLAINING OUTCOMES**

The Workshop on Management Procedures used a set of simplified examples to review the Krill–Predator–Fishery Model (KPFM) (paragraphs 5.7 and 5.8). Those examples are provided in this attachment. Tables 1 and 2 provide the parameter values and initial information used to generate the examples. This attachment is presented as a series of Microsoft Powerpoint slides that are taken from an original presentation made at the workshop.

Table 1: State variables and parameters for krill and other initial conditions used in Examples 1 to 13. Parameter and variable names are identified as they are implemented in the S-Plus version of the KPFM; definitions of these parameters and variables are provided in WG-EMM-05/13. In the movement matrices (v.matrix), the letter 'S' is used to indicate an SSMU, and the letters 'BT' are used to indicate boundary areas.

<table>
<tr><th>Parameter or variable name in S-Plus</th><th>Values used in Examples 1–9</th><th>Values used in Examples 10–13</th></tr>
<tr><td>M0</td><td>Examples 1–9: 0</td><td>Examples 10–13, SSMUs 1–2: 0</td></tr>
<tr><td>Ralpha</td><td>Examples 1–3, 7–9: $2.5 \cdot 10^{11}$
Examples 4–6: $2.7 \cdot 10^{11}$</td><td>Examples 10–13, SSMUs 1–2: $2.5 \cdot 10^{11}$</td></tr>
<tr><td>Rbeta</td><td>Examples 1–9: $1.0 \cdot 10^{8}$</td><td>Examples 10–13, SSMUs 1–2: $1.0 \cdot 10^{8}$</td></tr>
<tr><td>krill.Rage</td><td>Examples 1–9: 2</td><td>Examples 10–13, SSMUs 1–2: 2</td></tr>
<tr><td>Rphi</td><td>Examples 1–9: 0</td><td>Examples 10–13, SSMUs 1–2: 0</td></tr>
<tr><td>wbar</td><td>Examples 1–9: 1</td><td>Examples 10–13, SSMUs 1–2: 1</td></tr>
<tr><td>historical.catch</td><td>Examples 1–9: $2.28 \cdot 10^{11}$</td><td>Examples 10–13:
SSMU 1: $4.56 \cdot 10^{11}$ SSMU 2: $2.28 \cdot 10^{11}$</td></tr>
<tr><td>areas</td><td>Examples 1–9: $1.58 \cdot 10^{10}$</td><td>Examples 10–13, SSMUs 1–2: $1.58 \cdot 10^{10}$</td></tr>
<tr><td>v.matrix</td><td>Examples 1–7:
<table>
<tr><th></th><th></th><th colspan="3">to</th></tr>
<tr><th></th><th></th><th>S1</th><th>BT1</th><th>BT2</th></tr>
<tr><td rowspan="3">from</td><td>S1</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>BT1</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>BT2</td><td>0</td><td>0</td><td>0</td></tr>
</table>
Example 8:
<table>
<tr><th></th><th></th><th colspan="3">to</th></tr>
<tr><th></th><th></th><th>S1</th><th>BT1</th><th>BT2</th></tr>
<tr><td rowspan="3">from</td><td>S1</td><td>0</td><td>0</td><td>0.1</td></tr>
<tr><td>BT1</td><td>0.5</td><td>0</td><td>0</td></tr>
<tr><td>BT2</td><td>0</td><td>0</td><td>0</td></tr>
</table>
Example 9:
<table>
<tr><th></th><th></th><th colspan="3">to</th></tr>
<tr><th></th><th></th><th>S1</th><th>BT1</th><th>BT2</th></tr>
<tr><td rowspan="3">from</td><td>S1</td><td>0</td><td>0</td><td>1</td></tr>
<tr><td>BT1</td><td>0.1</td><td>0</td><td>0</td></tr>
<tr><td>BT2</td><td>0</td><td>0</td><td>0</td></tr>
</table>
</td><td>Examples 10, 12–13:
<table>
<tr><th></th><th></th><th colspan="4">to</th></tr>
<tr><th></th><th></th><th>S1</th><th>S2</th><th>BT1</th><th>BT2</th></tr>
<tr><td rowspan="4">from</td><td>S1</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>S2</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>BT1</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>BT2</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
</table>
Example 11:
<table>
<tr><th></th><th></th><th colspan="4">to</th></tr>
<tr><th></th><th></th><th>S1</th><th>S2</th><th>BT1</th><th>BT2</th></tr>
<tr><td rowspan="4">from</td><td>S1</td><td>0</td><td>0.1</td><td>0</td><td>0</td></tr>
<tr><td>S2</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>BT1</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>BT2</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
</table>
</td></tr>
<tr><td>sd.krill.Rdev</td><td>Examples 1–9: not used (random.Rkrill = F)</td><td>Examples 10–13: not used (random.Rkrill = F)</td></tr>
<tr><td>env.index</td><td>Examples 1–9: not used (env.index = NULL)</td><td>Examples 10–13: not used (env.index = NULL)</td></tr>
<tr><td>init.density</td><td>Examples 1–9: 37.7</td><td>Examples 10–13, SSMUs 1–2: 37.7</td></tr>
<tr><td>available.fraction</td><td>Examples 1–6, 8–9: 0.95
Example 7: 0.2</td><td>Examples 10–12, SSMUs 1–2: 0.95
Example 13:
SSMU 1: 0.8 SSMU 2: 0.2</td></tr>
<tr><td>actual.gamma</td><td>Examples 1–9: 0.17</td><td>Examples 10–13: 0.17</td></tr>
<tr><td>nyears</td><td>Examples 1–9: 50</td><td>Examples 10–13: 50</td></tr>
<tr><td>start.fishing</td><td>Examples 1–9: 11</td><td>Examples 10–13: 11</td></tr>
<tr><td>stop.fishing</td><td>Examples 1–9: 31</td><td>Examples 10–13: 31</td></tr>
<tr><td>fishing.option</td><td>Examples 1, 3–4, 7–9: NULL
Examples 2, 5–6: 1</td><td>Examples 10–11: NULL
Examples 12–13: 1</td></tr>
</table>

Table 2: State variables and parameters for predators used in Examples 1 to 13. Parameter and variable names are provided as they are implemented in the S-Plus version of the KPFM; definitions of these parameters and variables are provided in WG-EMM-05/13.

Parameter or variable name in S-Plus	Values used in Examples 1–9	Values used in Examples 10–13
M	Examples 1–9, Penguins: 0.16	SSMUs 1–2, Penguins: 0.16
	Examples 3–6, Seals: 0.08	
Rage	Examples 1–9, Penguins: 7	SSMUs 1–2, Penguins: 3
	Examples 3–6, Seals: 3	
Ralpha	Examples 1–9, Penguins: 0.5	SSMUs 1–2, Penguins: 0.5
	Examples 3–6, Seals: 0.5	
RRpeak	Examples 1–5, 7–9, Penguins: $8.2 \cdot 10^5$	SSMUs 1–2, Penguins: $8.2 \cdot 10^5$
	Example 6, Penguins: $6.56 \cdot 10^5$	
	Examples 3–5, Seals: $1.153 \cdot 10^4$	
	Example 6, Seals: $6.9 \cdot 10^3$	
RSpeak	Examples 1–5, 7–9, Penguins: $2 \cdot 10^6$	SSMUs 1–2, Penguins: $2 \cdot 10^6$
	Example 6, Penguins: $2.5 \cdot 10^6$	
	Examples 3–5, Seals: $7.3 \cdot 10^4$	
	Example 6, Seals: $1 \cdot 10^5$	
QQmax	Examples 1–9, Penguins: $4.3 \cdot 10^5$	SSMUs 1–2, Penguins: $4.3 \cdot 10^5$
	Examples 3–6, Seals: $1.7 \cdot 10^6$	
Rphi	Examples 1–5, 7–9, Penguins: 2	SSMUs 1–2, Penguins: 2
	Example 6, Penguins: 1	
	Examples 3–5, Seals: 2	
	Example 6, Seals: 0.1	
Qk5	Examples 1–9, Penguins: 20	SSMUs 1–2, Penguins: 20
	Examples 3–6, Seals: 20	
Qq	Examples 1–9, Penguins: 0	SSMUs 1–2, Penguins: 0
	Examples 3–6, Seals: 0	
init.demand	Examples 1–9, Penguins: $2.505 \cdot 10^{11}$	SSMUs 1–2, Penguins: $2.505 \cdot 10^{11}$
	Examples 3–6, Seals: $1.98 \cdot 10^{10}$	

Slide 1: Description of the initial conditions for Examples 1 to 9, where krill–predator–fishery interactions were simulated in a single SSMU.

Basic Setup for 1 SSMU

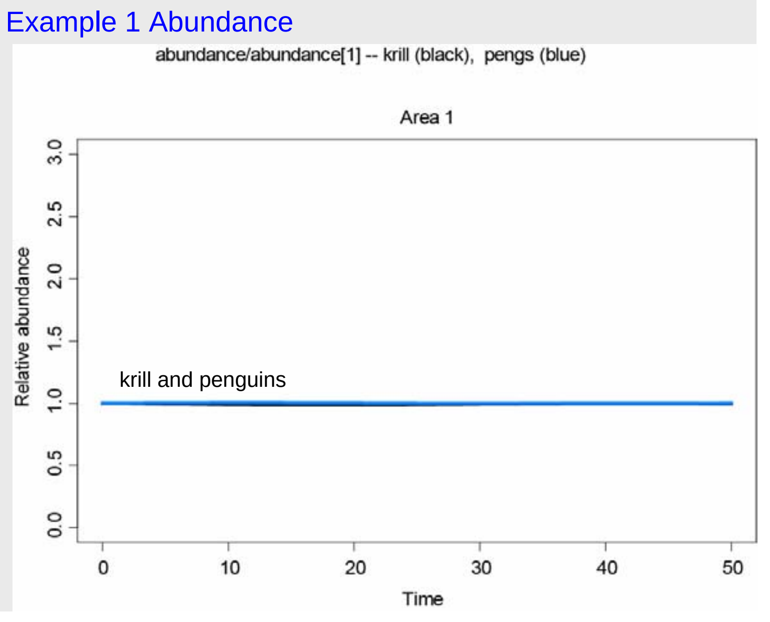
- 50-yr simulations
- If **FISHING** then start = 11 and stop = 31
- No random variation in krill recruitment
- Hyperdepletion in relationship between relative consumption and relative breeders
- Penguins recruit at age 7 and seals recruit at age 3
- If **MOVEMENT** then immigration from and emigration to single bathtub
- If **LOW available.fraction** then change 0.95 to 0.2

Slide 2: The sequence of examples used to review the KPFM when interactions inside a single SSMU are simulated (Examples 1 to 9). The column marked 'setup' describes each example. The column marked 'conditions' describes the initial relationship between krill recruitment (R), demand by predators (D1 for penguins and D2 for seals), and the catch allocated to the fishery (AC). The conditions also describe whether, when the setup includes movement of krill between a boundary area (BT) and the SSMU, imports (I) are greater or less than exports (E). The column marked 'expectations' provides a short description of the dynamics that would be expected in each example.

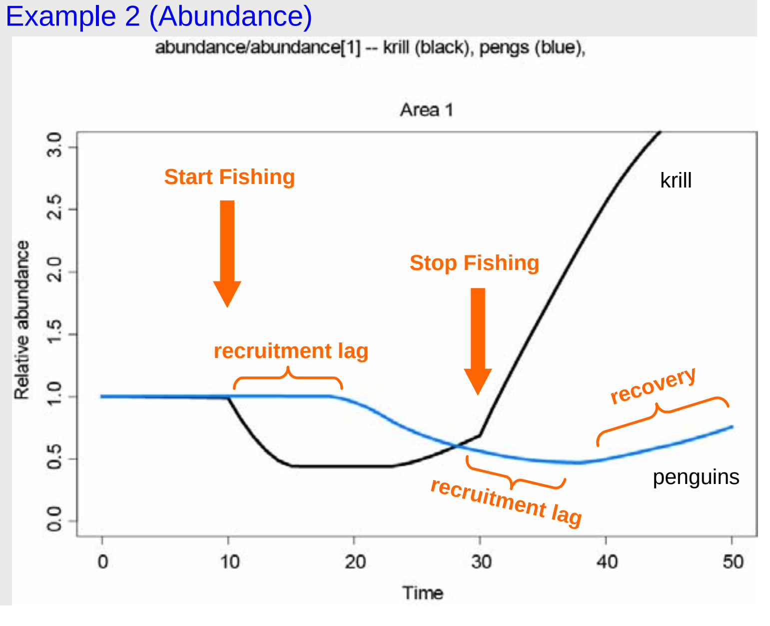
Sequence with Single Area

#	**Setup**	**Conditions**	**Expectations**
1	Penguin	R = D1	Flat lines
2	1 + Fishing	R < D1+AC	Decreases then Increases
3	1 + Seal	R < D1+D2	Decreases
4	3 + More Krill R	R = D1+D2	Flat lines
5	4 + Fishing	R < D1+D2+AC	Decreases & Lagged Increases
6	5 + Proportional Penguins + Hyperstable Seals	R < D1+D2+AC	Increases from 5 with Seals increasing more
7	1 + low available.fraction	R = D1	Penguins decrease then increase and krill increase
8	1 + Movement from BT	R = D1, I > E	Increases
9	1 + Movement from BT	R = D1, I < E	Decreases

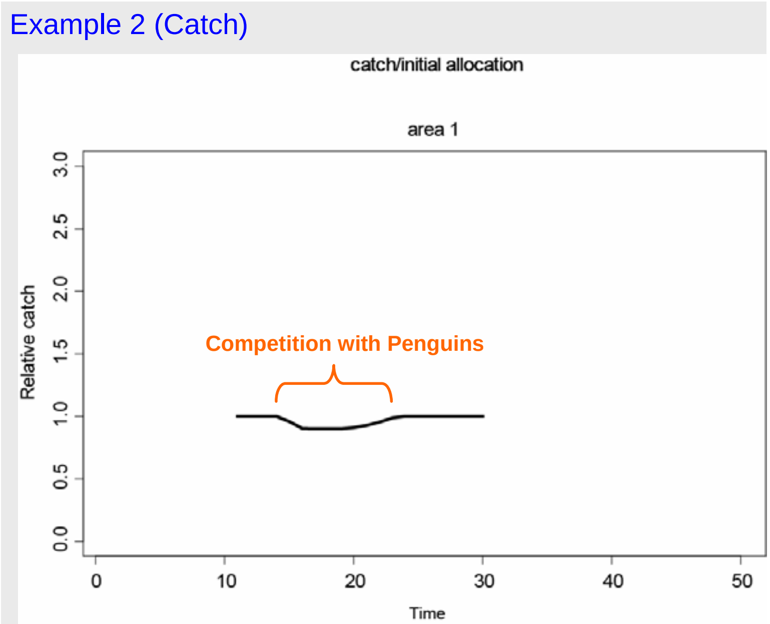
Slide 3: Simulation with a single SSMU and one predator (penguins). Recruitment of krill satisfies predator demand.



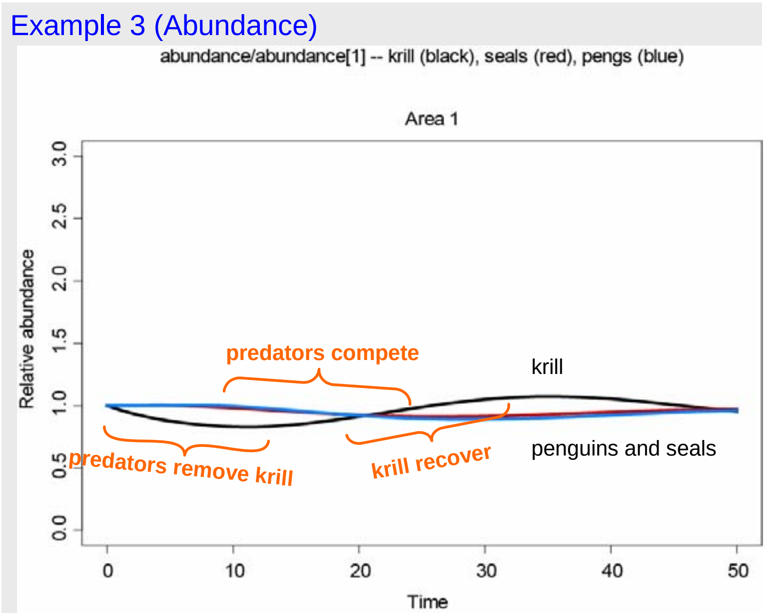
Slide 4: Simulation with a single SSMU, one predator (penguins), and krill fishing. Krill recruitment does not satisfy the sum of demand by predators and catch allocated to the fishery.



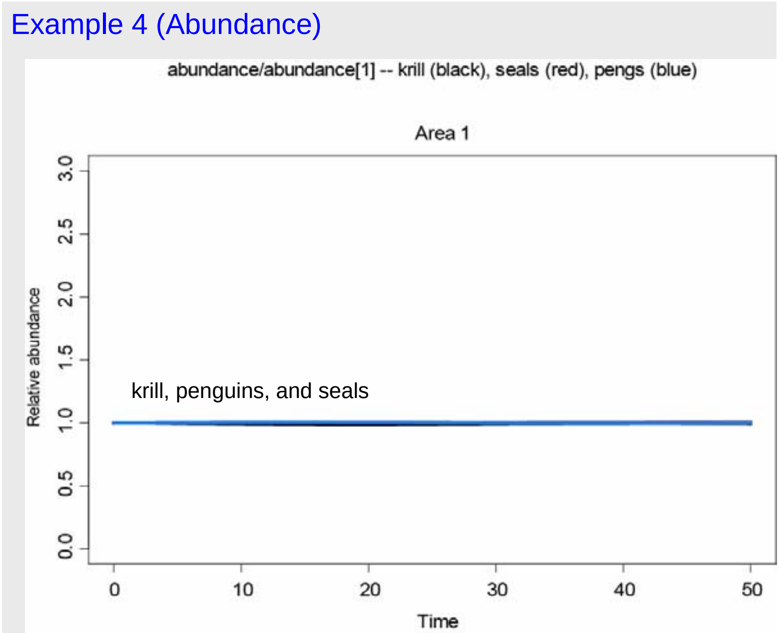
Slide 5: Simulation with a single SSMU, one predator (penguins), and krill fishing. Krill recruitment does not satisfy the sum of demand by predators and catch allocated to the fishery.



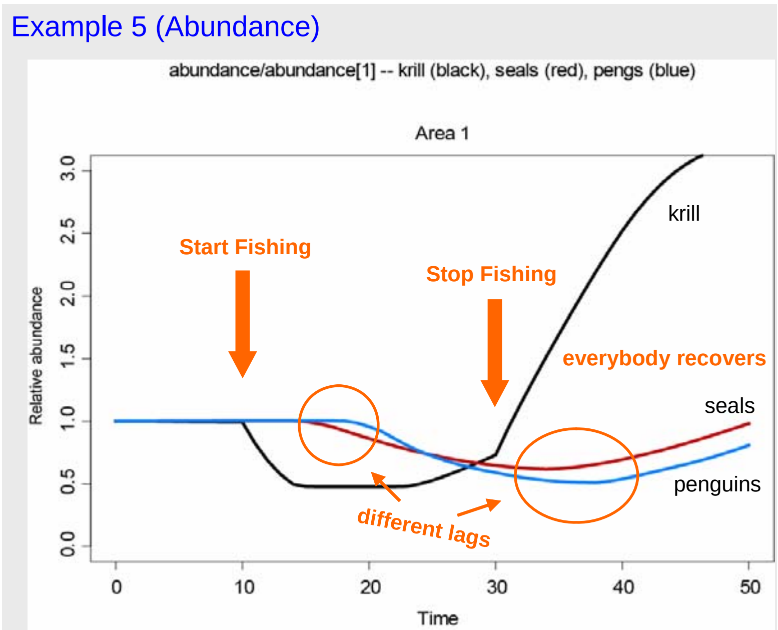
Slide 6: Simulation with a single SSMU and two predators (penguins and seals). Krill recruitment does not satisfy the sum of the demands by both predators.



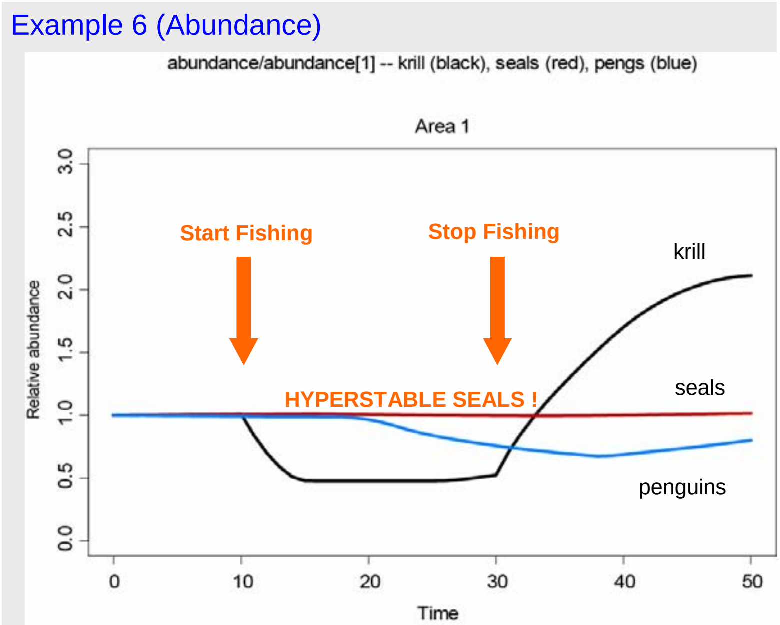
Slide 7: Simulation with a single SSMU and two predators (penguins and seals). Krill recruitment satisfies the sum of the demands by both predators.



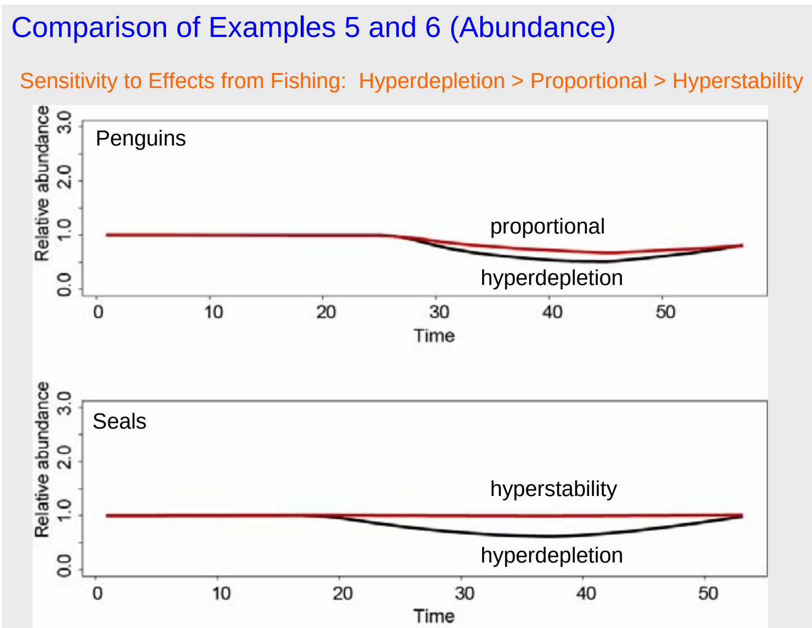
Slide 8: Simulation with a single SSMU, two predators (penguins and seals), and krill fishing. Krill recruitment does not satisfy the sum of demands by predators and catch allocated to the fishery.



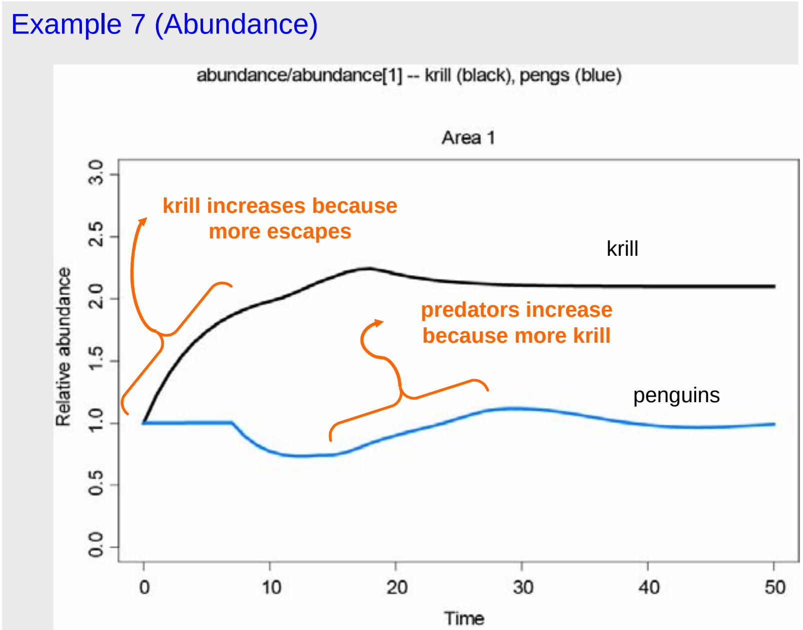
Slide 9: Simulation with a single SSMU, two predators (penguins and seals), and krill fishing. Krill recruitment does not satisfy the sum of demands by predators and catch allocated to the fishery, but decreases in krill consumption have reduced effects on predator breeding.



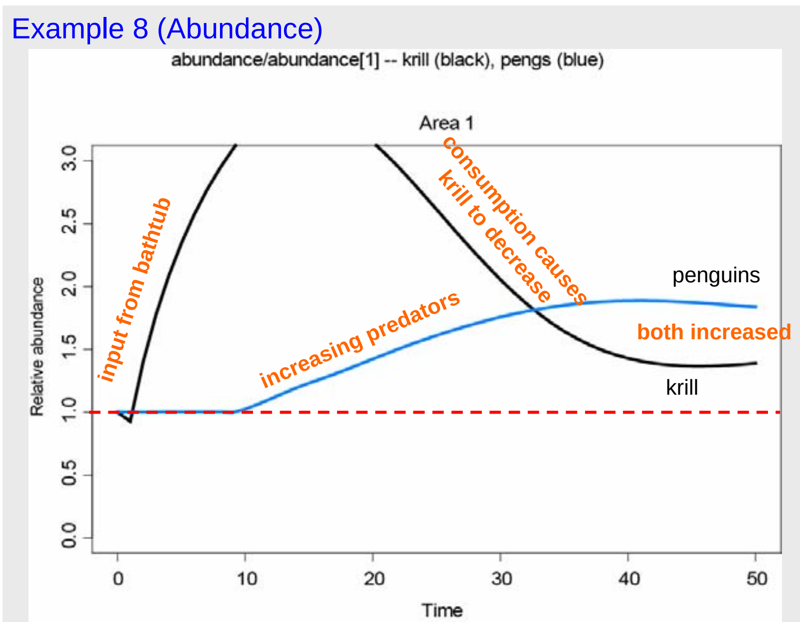
Slide 10: Comparison of simulations presented in Slides 8 and 9.



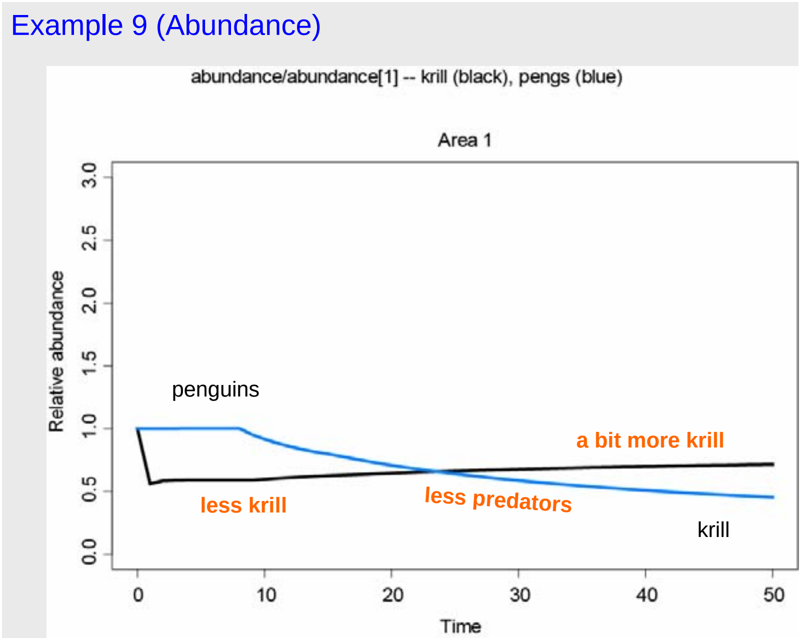
Slide 11: Simulation with a single SSMU and one predator (penguins). Recruitment of krill is sufficient to satisfy predator demand, but less krill are available for consumption.



Slide 12: Simulation with a single SSMU and one predator (penguins). Initially, local recruitment of krill is sufficient to satisfy predator demand, then krill are moved through the SSMU using boundary areas. Movement into the SSMU is greater than movement out of the SSMU.



Slide 13: Simulation with a single SSMU and one predator (penguins). Local recruitment of krill is sufficient to satisfy predator demand, but krill are moved through the SSMU using boundary areas. Movement into the SSMU is less than movement out of the SSMU.



Slide 14: Description of the initial conditions for examples in which krill–predator–fishery interactions were simulated in two SSMUs.

Basic Setup for 2 SSMUs

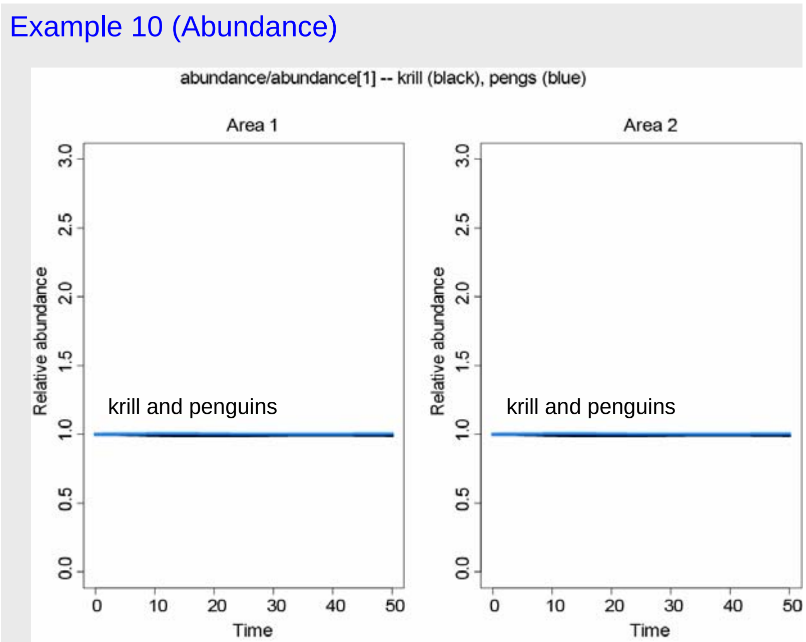
- 50-yr simulations
- If **FISHING** then start = 11 and stop = 31
- If **FISHING** then AC1 = 2 x AC2
- No random variation in krill recruitment
- Hyperdepletion in relationship between relative consumption and relative breeders
- If **MOVEMENT** then krill move from SSMU 1 to SSMU 2
- If **2 available.fractions** then SSMU 1 = 0.8 and SSMU 2 = 0.2

Slide 15: The sequence of examples used to review the KPFM when interactions within two SSMUs are simulated. The column marked ‘setup’ describes each example. The column marked ‘conditions’ describes the initial relationship between krill recruitment (R1 for recruitment in SSMU 1 and R2 for recruitment in SSMU 2), demand by predators (D1 for penguins in SSMU 1 and D2 for penguins in SSMU 2), and the catch allocated to the fishery (AC1 and AC2 for the catch respectively allocated to SSMUs 1 and 2). The column marked ‘expectations’ provides a short description of the dynamics that would be expected in each example.

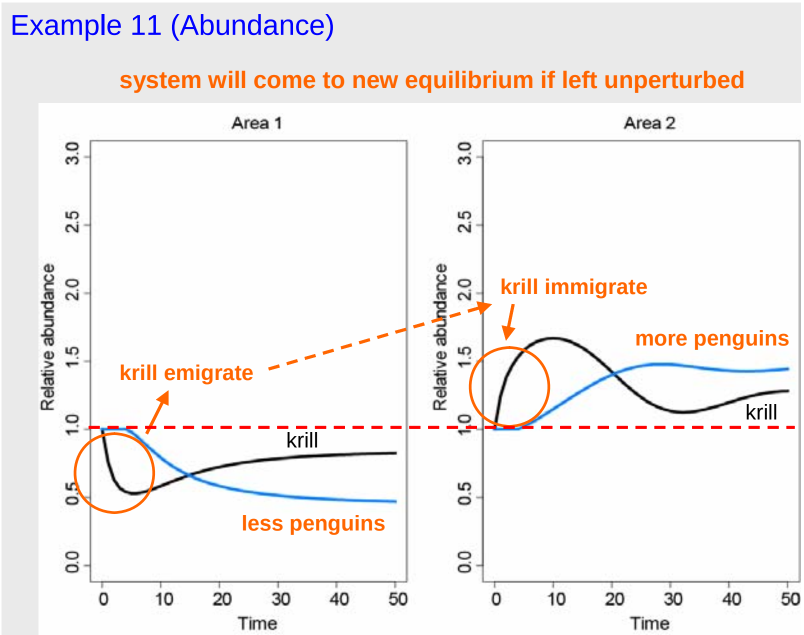
Sequence with Two Areas

#	Setup	Conditions	Expectations
10	Two Penguins	R1 = D1, R2=D2	Flat lines
11	10 + Movement	R1 = D1, R2=D2	P1 Decreases, P2 Increases
12	10 + Fishing	R1 < D1+AC1, R2 < D2+AC2	Unequal Decreases & Increases
13	12 + Two available.fractions	R1 < D1+AC1, R2 < D2+AC2	?

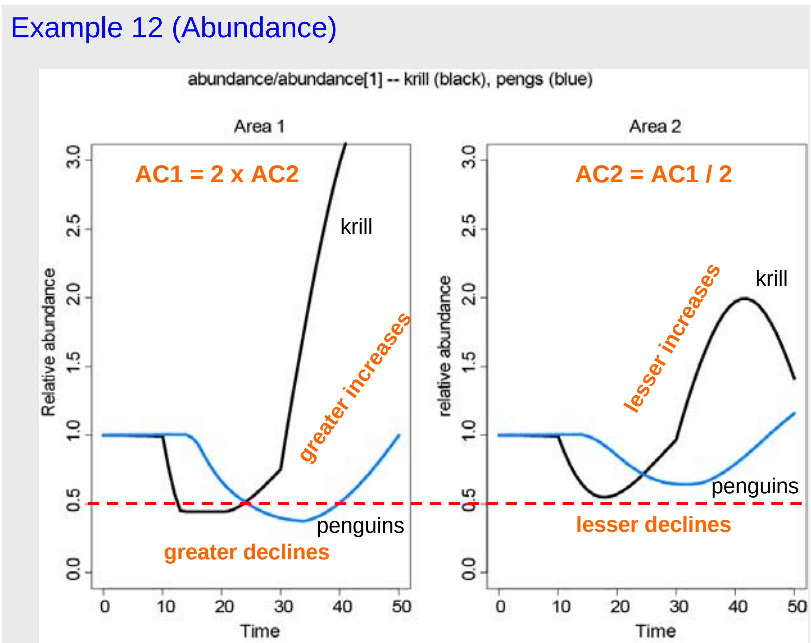
Slide 16: Simulation with two SSMUs and one predator (penguins) in each SSMU. Local recruitment of krill satisfies predator demand in each SSMU.



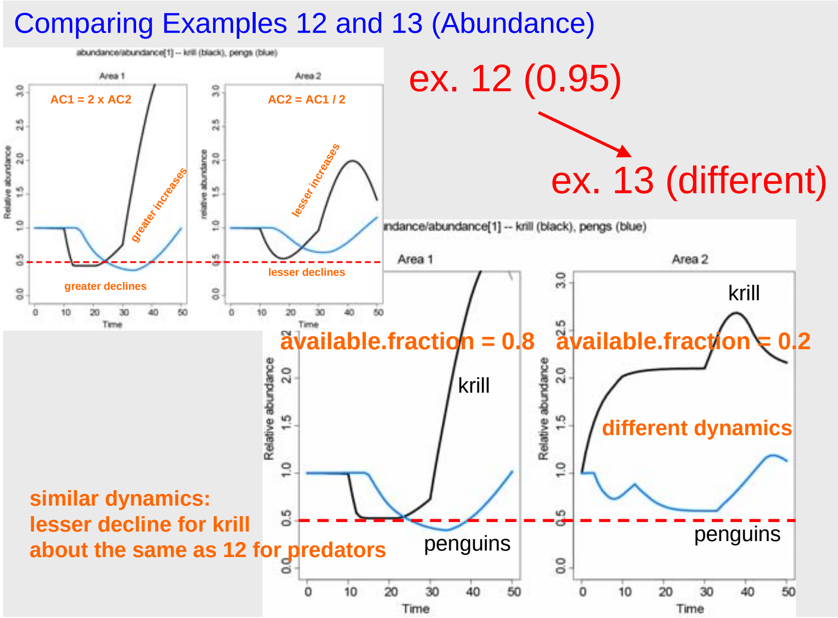
Slide 17: Simulation with two SSMUs and one predator (penguins) in each SSMU. Local recruitment of krill is sufficient to satisfy predator demand in each SSMU, but there is net movement of krill from SSMU 1 into SSMU 2.



Slide 18: Simulation with two SSMUs, one predator (penguins) in each SSMU, and krill fishing in both SSMUs. Local recruitment of krill is not sufficient to satisfy the combined predator demand and allocated catch in each SSMU.



Slide 19: Comparison of the simulation presented in Slide 18 to a simulation in which krill are less available to predation and fishing. All other conditions are the same in each simulation.



APPENDIX E

TERMS OF REFERENCE FOR THE CCAMLR-IPY-2008 SURVEY STEERING GROUP

TERMS OF REFERENCE FOR THE CCAMLR-IPY-2008 SURVEY STEERING GROUP

1. The Steering Group should develop a plan for a joint multi-ship synoptic survey for the assessment of krill biomass to be conducted in the Atlantic Sector of the Convention Area in summer 2008.

   Specific tasks during the planning phase:

   (i) plan a CCAMLR 2008 Synoptic Survey planning meeting;

   (ii) propose survey design;

   (iii) develop primary protocols to cover acoustic, net and CTD sampling;

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

   (v) develop principles for data archiving;

   (vi) coordinate cruise plans and preparations.

2. The Steering Group should act in a proactive way to promote and coordinate the analyses and publication of results relating to the survey.

3. Specifically the Steering Group should:

   (i) Science tasks:

   (a) define analyses to be undertaken collaboratively
   (b) define analyses to be conducted unilaterally.

   (ii) Analysis:

   (a) ensure that all analyses are coordinated and agreed by the Steering Group prior to commencing work;

   (b) define, coordinate and promote analysis workshop(s);

   (c) coordinate analyses of data not undertaken at workshops;

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

   (iii) Publication:

   (a) oversee production of joint publications in a peer-reviewed international journal;

(b) establish an Editorial Board for this issue;

(c) produce a proposed publication list for this issue;

(d) act as arbitrators/mediators for conflicts in all publication authorships;

(e) ensure that all manuscripts are brought to the attention of the Steering Group prior to submission;

(f) maintain a register of all publications relating to the survey.

The tasks of the survey coordinator are:

- to serve as at-sea coordinator
- to ensure the data are supplied to CCAMLR and to participants
- to organise a post-survey data analysis workshop
- to coordinate report generation.

During the planning phase, the Steering Group will liaise with IWC, SCAR, CAML and other 'EoIs' for collaborative work during the 2008 survey.

APPENDIX F

TERMS OF REFERENCE FOR THE
SUBGROUP ON DEVELOPMENT OF OPERATING MODELS

TERMS OF REFERENCE FOR THE SUBGROUP ON DEVELOPMENT OF OPERATING MODELS

The Subgroup on Development of Operating Models is established to provide a group to facilitate the discussion, review and promotion of the development of operating models for use in evaluating management procedures. Such work will include the assessment, estimation or interpretation of model input parameters. It is intended to provide a forum for freely engaging in discussion, reviewing and developing these approaches while recognising the CCAMLR rules governing the use of data, information and conclusions obtained in this way.

1. The subgroup should promote and, where appropriate, coordinate the development of suitable models for evaluating management procedures and the review of appropriate candidate models, including to:

    (i) promote the development of suitable frameworks to include the management and/or implementation of:

    (a) data, parameters, database availability

    (b) required code, platforms, components and protocols

    (c) validation process of the models.

    (ii) promote coordination and collaboration and, where needed, assist in:

    (a) developing timetables and workshops for model development, analyses, estimation of input parameters, model verification and validation;

    (b) coordinating analyses of data not undertaken at workshops;

    (c) identifying and coordinating outputs and products;

    (iii) act as a two-way information conduit such that subgroup members are made aware of individual analyses being conducted by Members, and that individual scientists are made aware of this information;

    (iv) correspond with the conveners of WG-EMM and WG-FSA and conveners of workshops using operating models on their requirements in this work.

2. The subgroup should operate according to (i) the Rules for Access and Use of CCAMLR Data, and (ii) CCAMLR rules governing access to and use of information, unpublished data, analyses and/or conclusions such that they will not be cited or used for purposes other than the work of the CCAMLR Commission, Scientific Committee or their subsidiary bodies without the permission of the originators and/or owners of the data or information.