ANNEX 4

REPORT OF THE WORKING GROUP ON ECOSYSTEM MONITORING AND MANAGEMENT

(Walvis Bay, Namibia, 17 to 28 July 2006)

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REPORT OF THE WORKING GROUP ON ECOSYSTEM MONITORING AND MANAGEMENT

(Walvis Bay, Namibia, 17 to 28 July 2006)

INTRODUCTION

Opening of the meeting

1.1 The twelfth meeting of WG-EMM was held at the Pelican Bay Hotel, Walvis Bay, Namibia, from 17 to 28 July 2006. The meeting was convened by Dr K. Reid (UK).

1.2 The meeting was opened by the Hon. Minister of Fisheries and Marine Resources, Dr A. Iyambo, who welcomed participants and outlined the fisheries management and environmental challenges which Namibia shares with CCAMLR. These challenges include the development and implementation of ecosystem-based management, consideration of natural and anthropogenic changes, the conservation of living resources and the sustainability of fishery resources. Namibia became a Member of CCAMLR in 2001.

1.3 Dr Reid thanked the Hon. Minister and his team at the Ministry of Fisheries and Marine Resources for their warm hospitality and for hosting the meeting.

1.4 Dr Reid extended his welcome to the participants, and outlined the program of work for the meeting. This work included:

- the Second Workshop on Management Procedures to Evaluate Options for Subdividing the Krill Catch Limit among Small-scale Management Units (SSMUs) during the first week of the meeting (Section 2 and Appendix D);
- discussion of the core business of the Working Group during the second week of the meeting.

1.5 The Working Group observed the passing of Dr Geoff Kirkwood, colleague and long-serving participant of CCAMLR. It recognised that its work had greatly benefited from Dr Kirkwood's intellect and scientific contributions, and he would be greatly missed.

Adoption of the agenda and organisation of the meeting

1.6 The provisional agenda was discussed and the Working Group agreed to include consideration of the reorganisation of the work of the Scientific Committee under 'Other Business' (Item 7). The adopted agenda is in Appendix A.

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

1.8 The report was prepared by Drs D. Agnew (UK), A. Constable (Australia), R. Holt (USA), Mr J. Hinke (USA), Drs S. Kawaguchi (Australia), S. Nicol (Australia), M. Pinkerton (New Zealand), D. Ramm (Data Manager), K. Reid (Convener), C. Reiss (USA), V. Siegel (Germany), W. Trivelpiece (USA), G. Watters (USA) and P. Wilson (New Zealand).

SECOND WORKSHOP ON MANAGEMENT PROCEDURES

2.1 The Second Workshop on Management Procedures to Evaluate Options for Subdividing the Krill Catch Limit among Small-scale Management Units, referred to hereafter as the Second Workshop on Management Procedures, was held at the Pelican Bay Hotel, Walvis Bay, Namibia, from 14 to 21 July 2006. The report of the workshop appears in Appendix D of this report.

2.2 The Working Group agreed that there had been a considerable amount of work done since WG-EMM-05 to develop models (krill–predator–fishery model (KPFM2), ecosystem, productivity, ocean, climate (EPOC) modelling framework and spatial multispecies operating model (SMOM)), and to build parameter sets (WG-EMM-06/30 Rev. 1) on which the provision of advice could be based. The Working Group noted that the workshop had focused on the output of KPFM2, and also explored structural uncertainty about allocation options using both KPFM2 and SMOM.

2.3 In simulation trials conducted using KPFM2 it is apparent that, should the fishery occur entirely in Subarea 48.1 and catch an amount of Antarctic krill (*Euphausia superba*) equivalent to 9% of B_0, then there will be considerable negative impacts on the ecosystem in that region and, under the assumptions of flux, there would also be negative consequences for the downstream SSMUs in Subareas 48.2 and 48.3 (paragraph 5.23).

2.4 Simulation trials using both KPFM2 and SMOM indicate that Fishing Option 1 would have relatively greater negative impacts on the ecosystem compared to the other fishing options (paragraph 5.43).

2.5 The Working Group agreed that even when KPFM2 and SMOM were used to integrate uncertainties, differences in the consequences of the different fishing options were still evident. The Working Group also agreed that further evaluation of Fishing Options 2 to 4 (paragraph 5.43) will require additional work on the development and interpretation of performance measures.

2.6 The Working Group also agreed that all simulations indicated that the performance of Fishing Options 2 to 4 would be improved when monitoring data are used to update the allocation of catches among SSMUs, i.e. in a manner analogous to Fishing Option 5 (paragraph 5.43).

2.7 The Working Group noted that EPOC was used as a tool to explore the potential variability in the productivity of krill between SSMUs and across Area 48 based on an empirical model of primary production using ice, sea-surface temperature and chlorophyll data from satellites (WG-EMM-06/38 Rev. 1). The Working Group agreed that the fits to existing data for the Antarctic Peninsula are promising and noted the workshop discussion on

how these results could inform decisions on the metapopulation structure of krill (Appendix D, paragraphs 6.1 and 6.2) and encouraged future work to tune the EPOC models to data and to provide important parameters for existing models.

2.8 The Working Group encouraged future work to further develop the adaptive management framework in SMOM.

2.9 The Working Group recognised the considerable work in the development of KPFM2 to date and encouraged the authors to continue that development, particularly in relation to evaluation of feedback management procedures and conditioning to data.

2.10 The Working Group encouraged the development of an agreed set of aggregate performance measures which are comprehensive, reliable, and cover the range of information outlined in paragraph 2.12 of Appendix D.

2.11 The Working Group recognised that it will be important for future modelling frameworks to capture some of the dynamics of the fishery. For example, how fishing masters make decisions about where they fish and when. Factors such as the abundance, condition, location and colour of krill, ice conditions and fishing experience are important considerations in targeted fishing and might affect model outputs.

STATUS AND TRENDS IN THE KRILL FISHERY

Fishing activity

Season 2004/05

3.1 Dr Ramm advised that the total catch of krill reported from the fishery in Area 48 in the 2004/05 season was 127 035 tonnes (WG-EMM-06/5). Vanuatu reported the largest catch of krill with a total of 48 389 tonnes. The Republic of Korea, Japan and Ukraine also reported large catches (26 920, 22 793 and 22 440 tonnes respectively). Poland and the USA reported catches of 4 335 and 2 159 tonnes respectively.

3.2 The Working Group noted that the Vanuatu-flagged vessel had used a conventional trawl and an unconventional continuous pumping system for catching krill, and ceased operating at the end of the season.

3.3 The Working Group noted that, with the exception of the Republic of Korea, all Contracting Parties fishing for krill in the 2004/05 season had submitted fine-scale data. Korea had advised that the fine-scale data for 2004/05 were on board the fishing vessels, and that these data would be submitted as soon as the vessels returned to port.

3.4 The Working Group expressed its appreciation to Japan for resubmitting the entire time series of catch and effort data from the Japanese fleet on a haul-by-haul basis. As a result of this submission, a substantial amount of the fine-scale data from the krill fishery is now available from the CCAMLR database on a haul-by-haul basis (WG-EMM-06/5, Table 7).

3.5 The Working Group requested that the Secretariat liaise with Members to ascertain whether or not haul-by-haul catch and effort data were available for seasons where aggregated data had been submitted in past seasons.

3.6 The Working Group noted the new format used to map the geographic distribution of catches of krill based on fine-scale data (WG-EMM-06/5, Figure 1). Dr Ramm reported that this format had been developed following a request by the Scientific Committee for the Secretariat to draft a policy governing the presentation and publication of aggregated fine-scale data (CCAMLR-XXIV, paragraph 4.62). This policy would be discussed by the Scientific Committee at its next meeting.

3.7 The Working Group agreed that the maps provided useful information on the krill fishery, and reaffirmed that the use of such maps is subject to the 'Rules for Access and Use of CCAMLR Data' and further consideration of the draft policy on the presentation and publication of aggregated fine-scale data.

Current season (2005/06)

3.8 Dr Ramm reported that so far this season (2005/06) seven vessels had harvested krill and had reported a catch of 64 415 tonnes, caught mostly in Subarea 48.1 (61 508 tonnes) between March and May (WG-EMM-06/5). The Republic of Korea had reported the largest catch (27 875 tonnes), followed by Japan (18 503 tonnes), Ukraine (15 022 tonnes), Poland (1 635 tonnes), Malta (1 081 tonnes) and Norway (298 tonnes).

3.9 The Working Group noted that the vessel *Dalmor III* had begun its fishing campaign under the Maltese flag, and was subsequently reflagged to Poland.

3.10 Based on the catch of krill reported so far this season to the end of May, and the equivalent catch reported to the end of May last season, the preliminary estimate of total catch for the 2005/06 season was approximately 97 090 tonnes. The Working Group noted that this estimate is based on catches taken over a five-month period.

3.11 The Working Group noted that the Norwegian-flagged vessel *Saga Sea* was fishing with a conventional trawl and an unconventional continuous pumping system. The vessel began fishing in Subarea 48.1 in June 2006, and had reported a catch of 298 tonnes to the Secretariat by 29 June (WG-EMM-06/5). The vessel was collecting fine-scale catch and effort data in accordance with a new trial procedure which had been developed in consultation with Norwegian and UK scientists and the Secretariat (see also paragraph 3.27).

Notifications for 2006/07

3.12 The Working Group reviewed the notifications of Members' intentions to fish for krill in the forthcoming season (WG-EMM-06/6 Rev. 1). Five Members had notified their intention to fish in 2006/07 using nine vessels in Subareas 48.1, 48.2, 48.3 and 48.4. The expected total catch of krill notified by Members was 239 000 tonnes.

3.13 The Working Group noted that the expected catches notified by Members varied widely (WG-EMM-06/6 Rev. 1), ranging from 14 400 to 100 000 tonnes per vessel. In particular, the Working Group noted that the highest expected catch was notified by Norway and that some of this catch may be taken using the new pumping system (see also paragraphs 3.25 to 3.33 and 3.51 to 3.58).

3.14 The Working Group noted that Members had advised of their maximum expected catch. In previous seasons, the expected catch notified overestimated the actual catch taken (e.g. in 2004/05, the expected catch notified was 226 000 tonnes and the reported catch was 127 035 tonnes (see SC-CAMLR-XXIII, Annex 4, paragraph 3.4; WG-EMM-06/5)).

Deployment of scientific observers

3.15 The Secretariat had received two notifications for the placement of CCAMLR scientific observers on krill fishing vessels in Area 48 in 2005/06 (one national scientific observer on the Ukrainian-flagged vessel *Konstruktor Koshkin* and one international scientific observer (UK) on the Norwegian-flagged vessel *Saga Sea*).

3.16 Eight scientific observer datasets were submitted for the 2004/05 season. These data were collected by CCAMLR scientific observers on board the vessels *Niitaka Maru* (Japan), *InSung Ho* (Republic of Korea), *Foros* (Ukraine), *Feolent* (Ukraine), *Top Ocean* (USA) and *Atlantic Navigator* (Vanuatu).

3.17 At present, the CCAMLR database holds scientific observer data from 28 trips/deployments between 1999/2000 and 2004/05 in Subareas 48.1, 48.2 and 48.3 (WG-EMM-06/5, Appendix 1).

3.18 The Working Group noted that the report from the Uruguayan scientific observer deployed on the *Atlantic Navigator* in 2005 had not been submitted to the Secretariat. However, it recalled that a descriptive analysis of the data collected by the observer had been submitted as WG-EMM-05/12 at last year's meeting (SC-CAMLR-XXIV, Annex 4, paragraph 3.29).

By-catch of fish and invertebrates

3.19 The Working Group noted that CCAMLR scientific observers had observed by-catch in 9.6% (4 511 tows) of the total number of tows conducted in the krill fishery in Area 48 between 1999/2000 and 2004/05 (WG-EMM-06/5). By-catch observations were made in Subarea 48.1 in the 2000/01 and 2004/05 seasons, Subarea 48.2 in 2004/05 and Subarea 48.3 in 2001/02, 2003/04 and 2004/05. These data indicated that the by-catch of fish in the krill fishery represented approximately 0.01% of the total catch of krill by weight, but the Working Group noted the discussion in paragraphs 3.34 to 3.36.

By-catch of birds and mammals

3.20 The Working Group noted that the data submitted to CCAMLR for the 2004/05 season indicated that one Cape petrel (*Daption capense*) had been killed after becoming entangled in the mesh of a seal excluder panel, and one southern fulmar (*Fulmarus glacialoides*) had been released uninjured after becoming caught on a cable splice. A total of 21 fatalities of Antarctic fur seal (*Arctocephalus gazella*) was observed and 72 fur seals were caught and released alive.

3.21 Dr Ramm also reported that a total of 229 fur seals had been observed to have been killed accidentally in the krill fishery in Area 48 up to 2003/04. Another two seals (species unknown) were reported killed in 2003/04. There were no observations or reports of incidental catches in the krill fishery between 1999/2000 and 2002/03 (WG-EMM-06/5).

3.22 The Working Group noted that the number of seal fatalities in 2003/04 and 2004/05 which had been reported to the meeting last year (SC-CAMLR-XXIV, Annex 4, paragraphs 3.14 and 3.16) had been revised by the Secretariat following data correction and validation.

3.23 The Working Group also noted that the information on incidental catches in the krill fishery is transmitted annually to ad hoc WG-IMAF by the Secretariat.

Ecosystem implications

3.24 The Working Group noted the time series of preliminary estimates of the FPI which had been updated by the Secretariat (WG-EMM-06/5). The limitations of this index were briefly discussed, and the Working Group agreed that further work was required to develop indices of fishery–predator overlap which may provide inputs to ecosystem models (paragraphs 6.12 and 6.13).

Description of the fishery

3.25 WG-EMM-06/18 outlined the trawling methods, and sampling and data recording protocols developed for the *Saga Sea*. The protocols had been developed at the request of the Scientific Committee which had agreed that the fishery using the new pumping system would not be considered as a 'new and exploratory fishery' if adequate information on this operation was collected and submitted to CCAMLR (SC-CAMLR-XXIV, paragraph 4.8).

3.26 The Working Group noted that the *Saga Sea* was using a conventional trawl and an unconventional pumping system. The unconventional continuous trawl allowed the vessel to take and process krill without having to recover the trawl; continuous trawling can extend over periods of days.

3.27 WG-EMM-06/18 described a trial reporting procedure to record the date, time, position, characteristics of trawl, depth of fishing and estimated catch at two-hourly intervals

during continuous trawling. This procedure had been requested by the Scientific Committee in 2005 (SC-CAMLR-XXIV, paragraph 4.8), and full details would be submitted to the Scientific Committee at its next meeting for consideration.

3.28 WG-EMM-06/18 also described biological sampling protocols, including krill demography, fish by-catch, within-swarm study of krill and the use of video to record predator behaviour. These protocols were developed in response to concerns of the impact of the new pumping system on other elements of the ecosystem (SC-CAMLR-XXIV, paragraph 4.9). One CCAMLR international scientific observer and a national observer are currently deployed on the *Saga Sea*.

3.29 WG-EMM-06/27 raised concerns about the continuous krill fishing technology, and its potential impact on various components of the marine ecosystem, such as an increased catch of small-sized krill and by-catch of fish larvae, compared with conventional midwater trawls. Other effects, such as noise affecting the behaviour of predators, and the impact of bubble screens and clouds on pelagic organisms, were also examined. The authors noted the importance of scientific observations to understand the nature of the new fishing method and its ecosystem impact.

3.30 Dr T. Knutsen (Norway) informed the Working Group of his recent correspondence with the Aker Seafoods Company about its new continuous pumping system. The company's representative had stated clearly that no air bubbles were introduced into the codend of the trawl nor into the surrounding water. The pump system is basically a Mammut pump (or airlift system) that transfers air from one (air supply) hose to the other (codend water extraction) hose at depth. The air released in the second hose rises to the surface expanding on its way, and initiates a suction of seawater on the codend side of the trawl that allows water and krill to be brought to the storage tank on board the vessel. Hence, it should be reasonably clear that at least one of the points raised by the Working Group has already been addressed. Dr Agnew confirmed that the UK observer on the *Saga Sea* had also indicated that a single air hose was used, and that there was no air released within the net.

3.31 Mr L. Pshenichnov (Ukraine) commented that, in his opinion, the new continuous pumping system constituted a new and exploratory fishery and as such should be covered by a separate conservation measure.

3.32 Drs V. Bizikov, S. Kasatkina and V. Sushin (Russia) suggested that in connection with the concerns mentioned by the Scientific Committee (SC-CAMLR-XXIV, paragraphs 4.8 and 4.9), continuation of this fishing technology implemented on board the *Saga Sea* should be conducted in accordance with the rules and requirements of CCAMLR for exploratory fisheries until the relevant description of the new fishery technology is presented to, and analysed by, the Scientific Committee. Further, they believe that categorising this as an exploratory fishery would not restrict its development while ensuring adequate scientific monitoring and control.

3.33 Drs Agnew, Constable and Knutsen stated that, in their opinion, the role of WG-EMM was to specify the information that the Scientific Committee would need to understand the issues raised in SC-CAMLR-XXIV, paragraph 4.8, and not to make recommendations on the matter in paragraphs 3.31 and 3.32. They noted that decisions about the category of fishing is the responsibility of the Commission.

Scientific observation

3.34 WG-EMM-06/7 described the by-catch of small fish and squid in the krill fishery at South Georgia. The analysis was based on data from four trawlers which operated in 2004.

3.35 Most hauls observed (67%) contained by-catch of small fish. The species assemblage varied according to location, bottom topography and time of day, but was not related to fishing depth or krill density. Juvenile myctophids were thought to be vulnerable to krill trawling at night due to diel vertical migration. In contrast, *Champsocephalus gunnari* and *Lepidonotothen larseni* occurred continuously within the depth range of krill trawling. The authors estimated that 1.5 million *L. larseni* were taken by the krill fishery in 2004, and it was thought that the species' population could withstand this high juvenile mortality. The by-catch of *C. gunnari* was low in 2004 compared with previously observed seasons.

3.36 The Working Group noted that the occurrence of fish larvae by-catch observed in the krill fishery was higher than the previous general understanding of by-catch in the fishery. The Working Group agreed that such results underscore the importance and need to increase observer coverage in the krill fishery.

3.37 At the time of report adoption, a number of participants noted that it would be usual practice to refer the paper described in paragraph 3.34 to WG-FSA to determine whether there are implications for its advice on fish stocks. They suggested that WG-EMM-06/7 be tabled for consideration by WG-FSA.

3.38 The Working Group noted the report by a national observer on a Ukrainian-flagged krill trawler in 2005/06 (WG-EMM-06/34). The observer reported almost no sea-ice, and that krill were almost absent from the traditional fishing ground in Subarea 48.2 (west and north of Coronation Island) from 22 February to 13 March 2006. The estimated CPUE for krill was 11.4 tonnes/hour or 135 tonnes/fishing day. Most of the krill caught ranged between total lengths of 39 and 48 mm. In contrast, in Subarea 48.1, fishing was profitable in the Elephant Island area, Livingston Island area, and Bransfield Strait where CPUE ranged from 17.4 to 20.5 tonnes/hour from March to May. Krill lengths ranged from 33 to 61 mm, with 47–55 mm krill dominating catches at Elephant Island, Livingston Island and north of the Palmer Archipelago. Small krill (two modes of 35–39 and 39–47 mm) were only observed in Bransfield Strait.

3.39 The Working Group welcomed the Ukrainian observer report (WG-EMM-06/34) and agreed that this report provided useful information on the characteristics of fishing ground and krill condition. This information may help understand the dynamics of the fishery.

3.40 Dr Reiss reported on the size distribution of krill taken during a scientific survey undertaken by the USA in the Elephant Island area and in Bransfield Strait in 2006. Krill length ranged from 30 to 60 mm, with large individuals (>50 mm) occurring mostly in the Elephant Island area, and small krill (<40 mm) found in Bransfield Strait.

3.41 Dr Siegel noted that the absence of small- to medium-sized krill in the Elephant Island area is due to continued poor recruitment since 2003.

3.42 WG-EMM-06/24 examined how current data collection through the fishery operation could contribute to a greater understanding of krill biology. The authors proposed a further

way forward to collect krill information, including revisiting historical data accumulated by the fishery operators, and the possible use of the IPY as a driving force in coordinating scientific acoustic surveys, krill sampling, and on-board experiments with commercial krill fishing operations.

Data requirements from the fishery

3.43 The Working Group noted that with the advent of new fishing technology (paragraphs 3.25 to 3.33) it is essential to obtain systematic information from the krill fishery that is comparable across fishing methods.

Information required from krill vessels in general

3.44 The Working Group noted that the following information should be collected and available from all krill fishing methods: catch and effort information capable of characterising CPUE; information on the total mortality of krill (krill caught as well as krill killed but not landed); information on the biological characteristics of krill; and information on the incidental mortality of other ecosystem components. The Working Group recognised that some of these data have been made available from some of the existing or past fisheries.

3.45 The Working Group needs to have an adequate assessment of the by-catch associated with each method of fishing. Currently there are a number of assessments from the trawl fishery but there has not been a broad-scale assessment of the seasonal and areal extent of fish or invertebrate by-catch. There also needs to be a systematic assessment of the by-catch of seals and seabirds.

3.46 Systematic assessment of the effects of fisheries requires systematic collection of data. In the CCAMLR context this information is collected by CCAMLR scientific observers. An impediment to assessing the effects of the krill fishery is the lack of observer coverage on many krill fishing vessels.

3.47 All methods of fishing produce waste either as part of the catching process or as part of the factory process. The Working Group has not been presented with detailed information on the disposal of waste associated with krill fisheries and encouraged the presentation of data that would allow some assessment of this issue.

3.48 Dr Kasatkina noted that special working groups on analysis of fishing technologies are currently operating within the framework of the Fishery Technology Committee (FTC) of ICES. In view of this, it would be useful to evaluate methodological approaches and methods developed by these groups. Experts from FTC may be invited to WG-EMM meetings for consultations. Such cooperation with FTC could be helpful for analysis, both of the continuous fishing method, and for other new fishing methods that could be implemented into the krill fishery in future.

3.49 The Working Group noted that little information from the fishery was currently being used in the formulation of catch limits. Noting that next year there will be a review of precautionary catch limits, the Working Group requested the submission of information arising from the fishery that will be used in next year's review.

3.50 The Working Group recognised that there was now a considerable volume of haul-by-haul data from the krill fishery and scientific observer data and reports. With the exception of the information on marine mammals and birds, which is analysed by ad hoc WG-IMAF, these data are not routinely examined by any working group. The Working Group recommended that in future a subgroup should meet to conduct specified analyses during WG-EMM meetings.

Information required from continuous pumping vessels

3.51 The Working Group noted that WG-EMM-06/27 had suggested that the new pumping system for krill fishing may represent a number of potential threats to the Antarctic marine ecosystem.

3.52 At its 2005 meeting, SC-CAMLR agreed (SC-CAMLR-XXIV, paragraph 4.8) that this technology would not constitute a new or exploratory fishery if there is:

- an adequate description of the selectivity of the method for krill
- a characterisation of the haul (or catch rate)
- information on the location of krill catches.

3.53 The Scientific Committee had also expressed concern (SC-CAMLR-XXIV, paragraph 4.9) that there might be considerable potential for this type of fishing gear to impact other elements of the ecosystem, particularly:

- by-catch associated with the fishery, including seabirds and marine mammals
- larval finfish and immature krill catches
- zooplankton caught in the process of fishing operations.

3.54 Norway fully intends to provide this scientific information requested by the Scientific Committee but, because the *Saga Sea* did not commence fishing until 15 June in the 2005/06 season, there had been no opportunity to acquire, analyse and submit the requested data before the 2006 meeting of WG-EMM.

3.55 A data collection plan was elaborated between Norway, the Secretariat and the UK who are providing an international scientific observer (WG-EMM-06/18). Dr Knutsen reported that Norway was willing to examine other data collection options, such as incorporating a CTD on the net, to obtain additional scientific information.

3.56 The method of continuous krill fishing using modified gear and trawl system represents an unconventional fishing technique. The Working Group requested more details of the fishing technology used by the *Saga Sea* to evaluate whether the current reporting system is adequate to provide information required for assessment of the impact of this type of fishing technique on the Antarctic marine ecosystem.

3.57 The Working Group therefore agreed to request details of the trawl and pumping system from the Norwegian company operating it, including further information on the use of air in the system and on the difference in size between krill caught in the conventional trawl compared with those caught by the continuous pumping system.

3.58 Table 1 of WG-EMM-06/27 might also be useful to indicate the sort of information that would assist the Working Group in assessing the ecosystem effects of this type of fishing operation.

3.59 The Working Group recalled that observer reports from the *Atlantic Navigator* were submitted last year (WG-EMM-05/12, and the UK observer report) and include a general description of the operation of the continuous pumping system. Combined data from both types of trawl were presented and, to assess selectivity, these data need to be separated.

3.60 The Working Group noted that information on the sizes of krill caught by conventional trawls and continuous pumping, catch rate and catch locations from the *Atlantic Navigator* and the *Saga Sea* have been submitted to the Secretariat. The Working Group recommended that these data be catalogued.

3.61 The Working Group requested the Chair of the Scientific Committee to ask WG-FSA to examine the catalogued data at its 2006 meeting to assess the difference between the two types of krill fishing and to provide a commentary to the Scientific Committee. It was also noted that these data will be available through the usual data access rules for any Member to analyse, and this option was encouraged.

3.62 The data collection plan (WG-EMM-06/18) identified sampling procedures for the scientific observer specifically to examine the issues of concern to the Scientific Committee. It is intended that the data collected from the *Saga Sea* will be comparable to those of a conventional krill trawl fishery.

3.63 The data collection plan outlined in WG-EMM-06/18 indicated the level of sampling for each type of information and the suggested sample size. Although there was some concern that the stipulated sample size (100 krill per catch for conventional trawls and 150 krill three times a day for continuous trawls) was possibly too low to adequately describe the krill population being fished, there were no suggestions for alternative sampling strategies.

3.64 The Working Group viewed the sampling plan in WG-EMM-06/18 as an interim sampling plan from the continuous pumping system but noted that the plan would be modified as a result of experience over the next year. The results of the sampling program and suggested modifications to the plan should be presented to the Working Group next year.

Ad hoc Group on Fishery Dynamics

3.65 Through discussion at the Second Workshop on Management Procedures, the importance of understanding fishery dynamics and its modelling in future work was identified (paragraph 2.11).

3.66 The Working Group agreed that the primary question that modelling should address is to identify which krill–fishery interactions have important influences on the ecosystem and the fisheries.

3.67 The Working Group further recognised the following question:

> What are the spatial and temporal scales at which krill–fishery interactions operate compared with the scale of resolution used in ecosystem models?

It is therefore important to characterise the relationship between processes at different relevant scales.

3.68 Although some attempts have been made to conceptualise fishery behaviour in the past (e.g. WG-EMM-05/30), most of the fishery information is still anecdotal.

3.69 The Working Group recognised the need for systematic collection and analysis of fishery information, and to further understand the fishery, the need to answer the above questions.

3.70 The ad hoc group listed the sorts of information deemed necessary to adequately model fishing fleet behaviours:

- skippers' decisions to fish and halt fishing
- definitions and types of commercially profitable aggregations
- strategies used in relation to fishery products and fishing gear etc.
- acoustic data from fishing vessels and scientific surveys
- historical haul-by-haul data on CPUE, length-frequency data and fishing locations
- CCAMLR scientific observer data.

3.71 The ad hoc group recognised that most of this information is held by the fishery operators, and therefore voluntary contribution by the data holders was necessary. The Working Group agreed to form an intersessional correspondence group on fishery dynamics to make further progress in:

- identifying the sorts of information available;
- collecting this information through dialog with fishery operators (SC-CAMLR-XXIII, paragraphs 3.31 to 3.42);
- initiate modelling work.

3.72 Dr Kawaguchi agreed to lead the correspondence group.

3.73 Dr M. Naganobu (Japan) commented that Japan:

(i) was generally supportive of the idea of a correspondence group to collect fishery information to support modelling fishery dynamics, but the issue of commercial confidentiality must be retained and data submission must be on a voluntary basis;

(ii) has voluntarily submitted this information to the Working Group continuously, and has contributed to its analysis to understand fleet behaviours;

(iii) suggested that it would be ideal if the outcome of these analyses be fed back to the data originators for their benefit.

Regulatory issues

3.74 The Working Group reviewed the conservation measures in force in the krill fisheries (WG-EMM-06/5). It noted that the change to the monthly reporting of catch in Conservation Measure 23-03 recommended at WG-EMM-05 (SC-CAMLR-XXIV, Annex 4, paragraph 5.46) had been reviewed by the Scientific Committee. The Scientific Committee proposed further changes which were adopted by the Commission. The revised Conservation Measure 23-03 (2005) required that monthly catch and effort reports be submitted at the spatial resolution of the catch limits, and that fine-scale data be submitted on a haul-by-haul basis.

3.75 The Working Group thanked Japan for resubmitting the entire set of catch and effort data on a haul-by-haul basis. The Working Group encouraged all Members participating, or who have participated, in the krill fisheries to resubmit historic fine-scale data on a haul-by-haul basis if these data are available (paragraph 3.5).

3.76 The Working Group agreed to use the biomass and CV estimates from the 2006 BROKE-West Survey in Division 58.4.2 (WG-EMM-06/16) to revise the precautionary catch limit for krill in that division; this is further discussed in paragraphs 5.34 and 5.35.

Key points for consideration by the Scientific Committee

3.77 The Working Group acknowledged that the continuous pumping system presented some unique challenges to recording effective fishing effort, catch and searching effort. Norway has agreed a recording system with the Secretariat, which could be modified on the advice of the Working Group (paragraph 3.55).

3.78 Norway should request further information from the fishing company on the details of the continuous pumping system that are of concern from an ecosystem perspective (paragraph 3.57).

3.79 The Working Group has not yet defined a single effective measure of CPUE in conventional or continuous pumping krill fishing operations; nor is such a measure of CPUE used in stock assessments or management decision rules. Until such time as these issues have been addressed, all krill fisheries should provide information appropriate to the current management system (paragraph 3.44).

3.80 The discussions at this meeting have demonstrated the need for systematic scientific observation of all krill fishing activities (paragraph 3.46).

3.81 The Working Group has made repeated requests for information on fishing methodologies, technology and fishing operations and has had little response from most

fishing nations. In particular, operational data were needed on fishing selectivity and total mortality. The Working Group reiterated its request for detailed information from fishing nations so that their operations can be better understood and thus appropriately managed (paragraph 3.49).

3.82 The Working Group agreed to use the biomass and CV estimates from the 2006 BROKE-West Survey in Division 58.4.2 (WG-EMM-06/16) to revise the precautionary catch limit for krill in that division (paragraph 3.76); this is further discussed in paragraphs 5.34 and 5.35.

STATUS AND TRENDS IN THE KRILL-CENTRIC ECOSYSTEM

Status of predators, krill resource and environmental influences

Predators

4.1 WG-EMM-06/4 reviewed updates to the CEMP indices. The CEMP indices have been updated by eight Members, representing 10 field sites and 13 CEMP parameters for 2005/06. A number of CEMP indices have not yet been provided by some Members, but some data submissions are expected in the near term. Data from Admiralty Bay, King George Island, have not yet been submitted, but the Working Group was assured that the 2005/06 data will be submitted.

4.2 To summarise CEMP indices, the development of an ordination approach was presented in WG-EMM-06/4. The ordination approach requires time-series data with no missing values, and preliminary ordination analyses of the CEMP indices used a three-year running average to interpolate missing values. The Working Group agreed that continued development of the ordination technique needs to be considered in terms of how to provide advice to the Scientific Committee on trends in the ecosystem. In particular, work is needed to identify how to include CEMP data directly in a feedback management procedure. It was also noted that the methods for appropriately dealing with missing years in a CEMP parameter series warrants further exploration (e.g. see de la Mare and Constable, 2000).

4.3 WG-EMM-06/31 reported preliminary findings arising from two New Zealand research voyages that visited the Balleny Islands in early 2006. The voyages collected a diverse array of data and specimens, including the first-ever samples from shallow marine environments and a comprehensive survey of penguin colonies. Data collected during these voyages will assist in the development of New Zealand's approach to encourage marine protection around the Balleny Islands.

4.4 At present, much of the data collected from the research voyages have yet to be analysed, but there appears to be an increase in chinstrap penguin populations since the last known census.

4.5 WG-EMM-06/P1 reported results of the 2005/06 field season of seabird research at the US AMLR site at Cape Shirreff. Chinstrap penguin populations continued to decline; however, reproductive success during the season was above the 10-year mean and chick fledging weights increased compared to the low mean weights of last season. Gentoo penguin populations remained stable and experienced the highest reproductive success in a decade.

Diets of both penguin species were dominated by krill in the 41–55 mm size range, continuing a trend of increasing size and percentage of female krill in the penguins' diets. This pattern was similar to that observed during the period from 1997/98 to 2000/01.

4.6 WG-EMM-06/8 reported that gentoo penguins exhibited delayed dispersal of young coupled with extended parental provisioning, behaviours not observed in the closely related Adélie and chinstrap penguins. During a two-week post-fledging period, gentoo chicks made an average of five trips to sea. The duration of these trips increased significantly with chick age, with trips to sea becoming more similar to adult foraging trips in both timing and duration. These behaviours are hypothesised to provide the opportunity for chicks to gain experience at sea prior to dispersal and may be of importance in explaining why gentoo penguin populations remain relatively stable while both Adélie and chinstrap penguin populations have declined in the Antarctic Peninsula region.

4.7 The Working Group noted that Antarctic fur seal pups may also benefit from a pre-weaning transition by learning to forage near natal colonies. The Working Group suggested future work on this issue could use time-depth recorders to assess the diving behaviour of juvenile gentoo penguins during their extended fledging period. It was noted that such studies are primarily limited by time and budget constraints.

4.8 WG-EMM-06/17 reported on the winter dispersal patterns of chinstrap penguins from two colonies in the South Shetland Islands that were tagged and followed during the 2000 and 2004 winters using the ARGOS satellite tracking system. Comparisons between sites and years revealed a high degree of variability in the winter distributions of chinstrap penguins between sites and years and within sites, across years. The paper provided new information on habitats utilised by chinstrap penguins during the non-breeding season and is of importance to models of predator–prey–fishery interactions in the region.

4.9 The Working Group noted that the hypotheses concerning new versus historical breeding ranges raised in WG-EMM-06/17 suggested that there may be environmental conditions under which new local populations can establish or which may result in inter-site movement of penguins becoming more common. Identifying such environmental conditions, particularly in relation to changes in the extent of sea-ice, would be of interest to the Working Group. The Working Group also suggested that genetic analyses may help to differentiate ancestral stocks within local breeding populations. The different winter distributions of chinstrap penguins also corroborate the utility of seasonal parameterisations of the operational models being developed by members of WG-EMM.

4.10 WG-EMM-06/P4 examined the complexity of foraging dynamics for colonially nesting macaroni penguins. Results indicate that individual penguins do not range evenly over the habitats adjacent to their respective breeding colonies and that animals from one colony tend to forage in locations separate from those used by animals from nearby colonies (or at least overlap can be restricted).

4.11 The Working Group noted that the segregation of foraging areas for adjacent colonies of breeding macaroni penguins is consistent with other research in the Antarctic, and that recognition of such partitioned foraging areas is important for discerning local- versus regional-scale effects on predator populations.

4.12 WG-EMM-06/P5 discussed the spatial and temporal variability in the fish component of the diets of Antarctic fur seals from 10 sites in the South Atlantic Ocean sector of the Antarctic. Although fish is a secondary component of the diet of Antarctic fur seals in the Scotia Sea, the fish component of their diet varied between sites. The authors suggested that these differences reflect differences in marine habitat, variability in oceanographic conditions and the long-term effects of harvesting among the surveyed sites.

4.13 WG-EMM agreed that alternative prey types and the timing of diet switching is important for fur seal foraging and reproductive biology. In particular, it was noted that while fish prey may be more energy rich than krill, the availability and catchability of fish prey is presumably lower than for krill. The Working Group commented that variability in the fish component of fur seal diets would be an important aspect of future modelling work with respect to predator sensitivity to krill availability and welcomed future papers on this topic.

4.14 WG-EMM-06/P6 examined how foraging and reproductive effort in breeding chinstrap penguins responded to interannual variation in the abundance of krill in the vicinity of Seal Island, South Shetland Islands, from 1990 to 1992. Krill density varied by a factor of 2.5 between these years and was positively correlated with annual measures of breeding performance (e.g. adult mass, population size, chick growth, breeding success and fledgling weight). In contrast, measures of penguin foraging effort (dive depth, dive duration, number of trips per day, trip duration, number of dives per trip and dive rate) did not differ between years. The authors concluded that chinstrap penguins reduce reproductive success rather than increase foraging effort in response to decreases in prey abundance in a manner consistent with predictions of life-history strategies for long-lived seabirds.

4.15 WG-EMM-06/21 examined the long-term responses of predator populations to environmental variability at two sites in the South Shetland Islands. The study compared trends in indices of population abundance, juvenile recruitment and summer breeding performance among Adélie, gentoo and chinstrap penguins breeding at these colonies. Recruitment rates of the pygoscelid penguins were related to an index of recruitment of Antarctic krill. The long-term declines in the abundance of Adélie and chinstrap penguins in the South Shetland Islands may be linked to variability in krill recruitment via declines in juvenile penguin survival rates.

4.16 The Working Group commented that the two periods of strong decline in Adélie penguin abundance reported at Admiralty Bay likely derive from multiple, inter-related causes that could include changing environmental conditions, changes in krill availability and predation by skuas.

4.17 With respect to modelling predator populations in the Antarctic, the Working Group also noted that such colony-level processes may depend on more than just food availability and that greater understanding of the factors influencing both intra- and interannual changes in survival of juvenile and adult predators may be an appropriate direction for future model development.

4.18 WG-EMM-06/P2 examined SST anomalies at South Georgia and found these to be cross-correlated with frequent El Niño–La Niña events between 1987 and 1998. Nonlinear mixed-effects models indicated that positive anomalies at South Georgia explained extreme reductions in Antarctic fur seal pup production over 20 years of study. Simulated environmental time series suggested that the observed nonlinearity in responses in pup

production were observed only under persistent high SST levels. These anomalies were likely associated with low availability of prey, largely krill, which affected female Antarctic fur seals over time scales longer than the pup-rearing period.

4.19 WG-EMM-06/P3 examined the relationship between variability in sea-ice cycles with long-term trends in the populations of Adélie, gentoo and chinstrap penguins breeding in the South Orkney Islands. Cycles in sea-ice lead to reduced prey biomass, and simultaneous interannual population changes in the three penguin species. Adélie penguins appeared less buffered against changes in the environment, their numbers fluctuated greatly and their population decline was strong and linear. Chinstrap penguins, considered to be better adapted to ice-free conditions, were affected by discrete events of locally increased ice cover, but showed less variable, nonlinear responses to sea-ice loss. Gentoo penguins were temporarily affected by negative anomalies in regional sea-ice, but persistent sea-ice reductions were likely to increase their available niche. Ultimately, variability in penguin populations reflected the local balance between species that were better adapted to ice conditions and changes in the food web driven by global climate forcing.

4.20 The Working Group commented that, given the contrasting responses of particular predator populations from the same area, choosing the representative species for measuring the effect of fishing versus climate on predator populations will be critical for providing management advice and feedback on krill fishery management procedures. In this regard, it may not be possible to restrict attention to only one 'representative' species.

4.21 The Working Group also noted that trends in the Adélie penguin populations presented in WG-EMM-06/21 mirrored these reported in WG-EMM-06/P3 for much of the historical record, but that these trends have diverged recently. Such a divergence may have occurred because of local differences in environmental conditions or predation pressure at breeding colonies.

4.22 The Working Group noted that analysis of long-term population data from both the South Shetland Islands (WG-EMM-06/21) and South Orkney Islands (WG-EMM-06/P3) revealed consistent declines in both Adélie and chinstrap penguin numbers over the last 20 to 30 years. This is contrary to the prevailing 'conventional wisdom' which suggests increasing chinstrap penguin populations and decreasing Adélie penguin populations associated with decreasing winter pack-ice in this region.

4.23 WG-EMM-06/39 presented data on the fur seal population breeding at Cape Shirreff, South Shetland Islands. First-year survival was found to be important for sustaining fur seal population growth. Pregnancy rates for females breeding at Cape Shirreff are comparable to South Georgia (1983–1992). However, adult female survival is approximately 5% greater at Cape Shirreff than at South Georgia and age-at-first reproduction is higher at Cape Shirreff.

4.24 The Working Group commented that the relatively higher degree of variation in the survival of juvenile fur seals could derive from a lack of foraging experience under increasingly variable environmental conditions, or from relatively higher predation risk from leopard seals. Similar constraints on predator populations during early life stages were identified for the penguin populations considered in WG-EMM-06/8 and 06/21.

4.25 The Working Group agreed that the information provided in the life-tables presented in WG-EMM-06/39 were fundamental for understanding fur seal population dynamics.

4.26 The Working Group further noted that there is sufficiently large interannual variation in the number of adult fur seals returning to breeding colonies that these colonies need to be monitored annually to satisfactorily estimate trends in local populations.

Krill

4.27 Evidence from the fishery suggested that there had been a shift in krill availability between the 2004/05 and 2005/06 seasons (WG-EMM-06/5). Most of the krill catch in the 2005/06 season to date had come from Subarea 48.1, whereas in 2004/05 most of the catch had come from Subarea 48.2. This scarcity of krill in Subarea 48.2 in the 2005/06 season was also reported by an observer on a Ukrainian-flagged vessel (WG-EMM-06/34).

4.28 Results from the US AMLR survey off Elephant Island suggested that in 2005/06 krill biomass in this region was also at the low point of a five- to six-year cycle which also corresponded to a period of low proportional recruitment and this was reflected in the size frequency reported by the fishery (WG-EMM-06/32 and 06/34). The krill population consisted of many large krill. In the 2005/06 season there was extensive warm surface water in the Elephant Island area which may be associated with the lack of krill.

4.29 It was suggested that a large sea-ice year would be required to produce a suitable recruitment pulse but, given the low levels of sea-ice recorded in recent years in the Antarctic Peninsula area, it was uncertain whether a large enough peak would occur in the near future.

4.30 The Working Group suggested that detailed analyses of trends in sea-ice and associated krill biomass and recruitment data be conducted for the entire time series of the data from the AMLR program to examine whether the trends reported earlier were still apparent.

4.31 Analysis of data from upward-looking acoustic sensors deployed on moorings at South Georgia indicated a regular annual cycle of krill biomass – high in summer and low in winter (WG-EMM-06/25). The interannual highs and lows in the time series corresponded reasonably well to high and low biomass estimates derived from ship-based surveys suggesting that these moorings may be able to provide long-term data that reflect the biomass over wider spatial scales.

4.32 The results from the moorings indicate that because of the sharp peaks in the biomass cycle, the exact timing of repeated acoustic surveys may be critical. Surveys that differ in their timing by only a few weeks might exhibit quite different estimates of biomass because they fall at different points of the cycle. Additionally, within this intra-annual framework, annual ship-based surveys may be able to detect differences between high and low krill years only if they differ by densities of 40 g m^{-2}.

4.33 The Working Group recognised the utility of such moorings for linking biological and physical information and for examining functional relationships between krill and krill predators.

4.34 It was noted that the patterns in krill biomass observed in the moorings corresponded well to cycles observed in the krill fishery and reported in WG-EMM-04/44. The fishery data indicated deeper fishing in winter and also a shift in the location of the fishery in the July–

August period which corresponded to a small increase in krill biomass in the mooring data. Because the moorings are fixed at 200 m depth, the changes in biomass recorded may reflect the seasonal vertical migration cycles of krill as well as cycles of annual production.

4.35 Results from a large-scale survey in the Lazarev Sea conducted in December 2005 were presented in WG-EMM-06/10 and were compared to an autumn survey of the same area in 2004. Lower densities were estimated from the net survey for the 2005 survey than for the 2004 survey. The order of magnitude difference in density (3.15 krill per 1 000 m^{-3} in 2005 versus 31.12 krill per 1 000 m^{-3} in the previous year) could be a result of seasonal differences or because of interannual changes in krill distribution and abundance. Acoustic data were collected on both these voyages and could assist with the interpretation of the observed changes from the net surveys. These data would be presented to a future meeting of the Working Group.

4.36 Krill in the Lazarev Sea spawned much earlier in 2005 than anticipated, despite the presence of considerable residual sea-ice in December. Recruitment in 2005 was strong and there was evidence of considerable success from spawning in 2004.

4.37 Two papers reported on the results of a large-scale survey of Division 58.4.2. WG-EMM-06/15 reported an overview of the BROKE-West Survey which included oceanography, a krill biomass survey and ecological measurements at all trophic levels from viruses to cetaceans. The results of this survey will be used to examine whether this large division could be subdivided on the basis of ecological information as requested by the Scientific Committee (SC-CAMLR-XXI, paragraph 3.15). Evidence of the existence of such ecological boundaries is apparent in the preliminary results of the survey and from analyses presented in WG-EMM-06/37.

4.38 A preliminary analysis of the BROKE-West krill demographics indicated considerable similarities with those presented for the neighbouring Lazarev Sea in the same season (WG-EMM-06/10).

4.39 The survey results will also be used, in conjunction with the 1996 BROKE survey of Division 58.4.1, to examine environmental correlates with krill distribution around one-third of the Antarctic coastline which can be used in ecosystem models.

4.40 The results of the acoustic survey of krill in Division 58.4.2 were presented in WG-EMM-05/16. The survey consisted of eleven meridional acoustic transects, spaced at five-degree intervals, across the entire statistical division. Krill were widely distributed throughout the survey area, although there were some transects where little krill was detected. The northern extent of the transect lines was at 62°S and the southern extent was determined either when net samples indicated that *E. crystallorophias* was present, or when ice or the coastline was encountered.

4.41 The acoustic data were collected and analysed so as to be as comparable as possible to the methods used on the BROKE and the CCAMLR-2000 surveys. The target-strength model used was that of Greene et al. (1991) to maintain the comparability between these three surveys. The acoustic results will be reanalysed for the 2007 meeting of the Working Group using the SDWBA model.

4.42 Discrimination of acoustic targets was achieved by using the three-frequency algorithm as used for the CCAMLR-2000 Survey and by conducting 76 directed trawls to confirm the identity of acoustic targets.

4.43 The major differences in survey design between CCAMLR-2000 and BROKE-West were that the CCAMLR-2000 Survey used a stratified random design whereas the BROKE-West Survey used regularly spaced transect lines, and the BROKE-West Survey proceeded 24 hours per day, whereas CCAMLR-2000 surveyed only during the day. These differences were a result of the constraints imposed by using a single ship in the BROKE-West Survey and through the necessity of sharing a sampling design with the oceanographic survey. The survey design, with its deviations from the CCAMLR-2000 design, had been presented to the 2005 meeting of the Working Group (WG-EMM-05/11) and the Working Group had approved the design (SC-CAMLR-XXIV, Annex 4, paragraph 4.90).

4.44 The biomass of krill in Division 58.4.2 (area: 1.57 million km^2) was estimated to be 15.89 million tonnes with a CV of 47.93%. The average density of krill detected acoustically was 10.15 g m^{-2} which falls between the value detected in Division 58.4.1 in the BROKE Survey (5.5 g m^{-2}, CV 19%) and that detected in Area 48 during the CCAMLR-2000 Survey (21.4 g m^{-2}, CV 11.4%).

4.45 The Working Group agreed that this was an excellent survey and that the results should be used to calculate a new precautionary limit for Division 58.4.2. Because the existing precautionary catch limit in Division 58.4.2 was established using a biomass estimate from the 1981 FIBEX Survey which used an outdated methodology and survey design, the new precautionary catch limit should be calculated only using the much more robust estimate from the BROKE-West Survey.

4.46 A conceptual model of the krill maturity cycle based on long-term experimental observations was presented in WG-EMM-06/23. The effects of light, food and temperature were examined and the key parameters appeared to be food and temperature. Additionally, the moulting physiology of krill means that once a krill has regressed in winter it cannot immediately respond to increased food concentrations by maturing but has to pass through several moult cycles before reproduction is possible. The details of this interaction between environmental variables and the physiology of the animal needs to be captured in ecological models that aim to examine variation in krill production.

Environment

4.47 WG-EMM-06/13 provided an update of the relationships between DPOI, oceanographic conditions (e.g. upper ocean temperature and salinity), and parameters related to krill recruitment and density. The Working Group agreed that long time series of data, and rigorous statistical methods, are needed to establish the significance of such relationships.

4.48 The Working Group agreed that it is important to identify plausible causal mechanisms which may be responsible for relationships between environmental/climatic drivers and biological parameters. Explicitly articulated assumptions and links between various components of the environment and ecosystem are needed to test to what extent each

conceptual view of reality is consistent with the empirical evidence. A rigorous approach is needed to understand if/how environment–biological relationships can be used in developing operating models for various parts of the Southern Ocean ecosystem.

4.49 WG-EMM-06/31 summarised preliminary results from two New Zealand research voyages to the Balleny Islands, Ross Sea. These voyages are part of a continued New Zealand focus of intense scientific research in this region. The Working Group also recognised the work of other Member countries, including Japan, in the region.

Other prey species

4.50 There were no papers tabled and no discussion under this agenda item.

Report of the Subgroup on Methods

4.51 The Subgroup on Methods (convened by Dr M. Goebel (USA)) met to discuss four papers (WG-EMM-06/11, 06/16, 06/32, 06/36) and the report of SG-ASAM (SC-CAMLR-XXV/BG/5) which dealt with various aspects of acoustic assessments and methodology. An additional paper, WG-EMM-06/8, which presented results of a recent study of gentoo penguin fledging behaviour, was also considered by the group.

4.52 Results presented in WG-EMM-06/8 had implications for the modification of CEMP Standard Method A7 'Chick weight at fledging', specifically, to account for the fact that fledging and dispersal of gentoo penguins from the natal colony are not simultaneous. The subgroup recommended appropriate modifications of the A7 index be considered. Dr Trivelpiece offered to draft intersessionally some text to be appended to CEMP Standard Method A7 to reflect the difference in gentoo fledging behaviour compared to other pygoscelid penguins for consideration by WG-EMM-07.

4.53 In the absence of expertise on krill acoustics, the Working Group felt that no recommendations for changes in methodology based on the tabled papers should be provided. The biological aspects of the methodological approaches in the following papers were considered by the Working Group.

4.54 WG-EMM-06/11 presented an analysis of acoustic data collected in the Ross Sea by an exploratory fishery for toothfish along with a later directed study of mesopelagic backscatter by a research vessel. Multifrequency data with limited biological sampling from the research cruise were used to compare and interpret the single-frequency opportunistically collected data by the fishery. Net sampling on the research cruise focused on the continental slope region of the eastern Ross Sea and around the Balleny Islands. A general southerly decrease in acoustic density and diversity in mark types was found. This study adds to the knowledge of mesopelagic backscatter and the species composition of different mark types for the Ross Sea and argues the importance of increasing spatial and temporal coverage of acoustic data collection by using fishing vessels operating in the Ross Sea.

4.55 The Working Group agreed that such data were useful in elucidating the level of mesopelagic biomass and further studies should be encouraged.

4.56 WG-EMM-06/36 used acoustic assessments for two SSMUs in two different years to compare total krill biomass with the proportion of 'fishable biomass' defined as densities greater than 100 g m^{-2}. The relationship between total krill biomass and the proportion of densities great enough to make it economically available to the fishery remains unclear. However, the authors argued that the relationship varied significantly interannually and seasonally and the nature of the relationship required additional investigation. They suggest that using the standing stock of krill in an SSMU alone to allocate krill catch fails to consider densities of krill necessary to sustain the fishery.

4.57 The authors reiterated that a reanalysis of data from the CCAMLR-2000 Survey, as well as from other surveys (e.g. US AMLR), to identify the frequency and distribution of fishable biomass from overall biomass, could be useful to understand the local variability in krill available to the fishery in relation to the size of SSMUs.

4.58 WG-EMM-06/32 presented a reanalysis of the krill biomass estimates using guidelines developed from the first meeting of SG-ASAM. Specifically, krill biomass estimates from the long-term US AMLR survey in Subarea 48.1 were adjusted using a simplified SDWBA algorithm which took account of the range of krill size. Applying the modified method resulted in a reduction in the total krill biomass estimate and this result should be considered in allocations of the krill catch. Use of acoustic windows based on the range of krill size affects variability and CVs of the estimate and requires further study and development.

4.59 The Working Group noted three important issues which arose from discussion of WG-EMM-06/36: (i) the acoustic technology is moving forward rapidly; (ii) the current model approved by the Commission for the estimation of acoustic biomass provides a slightly lower biomass and higher CV in the restricted areas of the US AMLR survey area examined; and (iii) the time trends of biomass vary greatly from the historical time series based on the Greene algorithm previously used to describe biomass trends.

4.60 The Working Group suggested that in addition to the work that has been completed regarding the development of a physics-based acoustic model of krill, that two additional sources of uncertainty be examined. First, density contrast differences between krill and the water column could vary and may influence biomass estimates. Second, Demer and Conti (2005) suggested that krill examined during the CCAMLR-2000 Survey were fatter than krill examined when the original krill length–weight relationship had been devised (Hewitt and Demer, 1993), and so this source of uncertainty should also be examined in any acoustic estimate of krill.

4.61 The Working Group also considered the report of the second meeting of SG-ASAM which was held in 2006 (Annex 6). The meeting focused primarily on icefish acoustics but offered advice on general issues relevant to acoustic surveys in CCAMLR waters. In the absence of krill acoustic experts at that meeting the recommendations for improvements were confined to studies of fish biomass, however, they are worth noting to this group. The recommendations for survey design included:

(i) the use of multiple frequencies
(ii) mark identification using directed trawls or other ground truthing methods
(iii) target strength determination by *in situ* measurements
(iv) calibration of acoustic gear used in the survey.

4.62 Recommendations from SG-ASAM included the need for standardisation in the presentation of methodology and results and that any future requirements agreed to should be discussed jointly for krill and fish. The report included nine recommendations to the Scientific Committee for assessments and protocols for icefish surveys (see Annex 6, paragraphs 70 to 78).

4.63 The Working Group noted that there may be an issue of potential target overlap between krill and icefish that could result in mis-identifying icefish as krill, or vice versa.

4.64 The Working Group also considered WG-EMM-06/16 that provided a detailed description of the survey design and methodology used to estimate the krill density in Division 58.4.2. Dr Nicol suggested that this could form the framework for other researchers to apply acoustic techniques in their work.

Future surveys

4.65 At its 2005 meeting the Commission (CCAMLR-XXIV, paragraphs 4.76 to 4.80):

(i) recalled the Scientific Committee's progress in developing CCAMLR's contribution to the IPY in 2008;

(ii) noted that the Scientific Committee had established a 'lead project' under the IPY topic 'Natural Resources, Antarctic' as the umbrella proposal 'Integrated circumpolar studies of Antarctic marine ecosystems to the conservation of living resources' with the short form title listed as 'Antarctic Marine Ecosystem Studies (AMES)';

(iii) urged all Members to participate in the CCAMLR core project, which is the large-scale survey in the Atlantic sector of the Southern Ocean (EoI 148), noting that firm commitments for ship-time and other research activities should be provided to the next round of consultations in association with the WG-EMM meeting in July 2006;

(iv) welcomed Peru's proposal to participate in the CCAMLR-IPY projects as an Acceding State.

4.66 Early in 2006 the Convener of the CCAMLR-IPY Steering Group (Dr Siegel) received the official endorsement of the CCAMLR umbrella project by the IPY Joint Committee. The CCAMLR AMES project is now listed as IPY Project 131 on the official IPY website (www.ipy.org).

4.67 The steering group was also informed that IWC and SCAR have established subgroups for future coordinated planning with CCAMLR on whale and marine bird censuses during the CCAMLR-IPY 2008 multiship survey.

4.68 The Working Group noted that it would also be beneficial to keep close contact with other IPY projects (e.g. CAML, ICED), which might collect scientific data of value to the work of WG-EMM and the Scientific Committee.

4.69 The CCAMLR-IPY Steering Group met during the WG-EMM meeting and reviewed the current status of progress in the implementation of the CCAMLR-IPY program. Despite the request of the Commission, at the time of the WG-EMM meeting, no firm commitments could be made by Members to participate in the large-scale CCAMLR survey in 2008. However, it was recognised that a few Members are more advanced in the process of final commitment with respect to research vessel ship-time than others.

4.70 The Working Group and the steering group expressed their concern about the lack of commitment for the necessary ship-time to the CCAMLR-IPY survey. The Working Group noted that the current situation could be embarrassing to CCAMLR and its Members if the survey must be cancelled as a core research activity of the entire CCAMLR-IPY project. It was noted that all the necessary scientific requirements had been fulfilled to obtain the full endorsement of the IPY community and to finalise the necessary planning for the 2008 field season. However, final decisions are still outstanding on the required ship-time to conduct the multiship survey.

4.71 The Working Group, therefore, supported the proposal of the steering group, that the convener of the steering group and the Chair of the Scientific Committee write an urgent CCAMLR circular letter and inform Commission Members about the serious situation and the potential consequences for the entire CCAMLR-IPY program. Commission representatives should be asked to assist, where possible, in the decision-making process at national levels for the necessary budget and logistics support to facilitate support where possible.

Key points for consideration by the Scientific Committee

4.72 The CEMP indices have been updated by eight Members, representing 10 field sites and 13 CEMP parameters for 2005/06. A number of CEMP indices have not yet been provided by some Members, but some data submissions are expected in the near future (paragraph 4.1).

4.73 The Working Group noted that analysis of long-term population data from both the South Shetland and South Orkney Islands revealed consistent declines in both Adélie and chinstrap penguin numbers over the last 20 to 30 years. This is contrary to the prevailing 'conventional wisdom' which suggests increasing chinstrap penguin populations and decreasing Adélie penguin populations associated with decreasing winter pack-ice in this region (paragraph 4.22).

4.74 Evidence from the krill fishery suggested that there had been a shift in krill availability between the 2004/05 and 2005/06 seasons (WG-EMM-06/5). Most of the krill catch in the 2005/06 season to date had come from Subarea 48.1, whereas in 2004/05 most of the catch had come from Subarea 48.2. This scarcity of krill in Subarea 48.2 in the 2005/06 season was also reported by an observer on a Ukrainian-flagged vessel (paragraph 4.27).

4.75 Results of a large-scale survey of Division 58.4.2 (BROKE-West) which included oceanography, a krill biomass survey and ecological measurements at all trophic levels from viruses to cetaceans were presented. These will be used to examine whether this large division could be subdivided on the basis of ecological information as requested by the

Scientific Committee (SC-CAMLR-XXI, paragraph 3.15). Evidence of the existence of such ecological boundaries is apparent in the preliminary results of the survey and from analyses completed to date (paragraph 4.37).

4.76 The biomass of krill in Division 58.4.2 was estimated to be 15.89 million tonnes with a CV of 47.93%. The average density of krill detected acoustically was 10.15 g m^{-2} which falls between the value detected in Division 58.4.1 in the BROKE survey (5.5 g m^{-2}, CV 19%) and that detected in Area 48 during the CCAMLR-2000 Survey (21.4 g m^{-2}, CV 11.4%) (paragraph 4.44).

4.77 The Working Group noted the urging last year by the Commission for Members to participate in the CCAMLR-IPY project (paragraph 4.65) but that, at the time of the WG-EMM meeting, no firm commitments could be made by Members to participate in the large-scale CCAMLR survey in 2008. It was recognised that a few Members are more advanced in the process of final commitment with respect to research vessel ship-time than others (paragraph 4.69).

4.78 The Working Group expressed its concern about the lack of commitment for the necessary ship-time to the CCAMLR-IPY survey. It was noted that the current situation could be embarrassing to CCAMLR and its Members if the survey must be cancelled as a core research activity of the entire CCAMLR-IPY project. It was noted that all the necessary scientific requirements had been fulfilled to obtain the full endorsement of the IPY community and to finalise the necessary planning for the 2008 field season. However, final decisions are still outstanding on the required ship-time to conduct the multiship survey (paragraph 4.70).

4.79 The Working Group, therefore, requested that the Convener of the steering group and the Chair of the Scientific Committee write an urgent CCAMLR circular letter and inform Commission Members about the serious situation and the potential consequences for the entire CCAMLR-IPY program. Commission representatives should be asked to assist, where possible, in the decision-making process at national levels for the necessary budget and logistics support to facilitate support where possible (paragraph 4.71).

STATUS OF MANAGEMENT ADVICE

Protected areas

5.1 The Advisory Subgroup on Protected Areas (convened by Dr Wilson) met during the WG-EMM meeting and discussed matters relating to Item 5.1 of the WG-EMM agenda. These discussions were considered by WG-EMM.

CEMP sites

5.2 The Working Group noted that CEMP site protection under Conservation Measure 91-01 (2004) is required to be reviewed every five years. It also noted that the management plans for the Cape Shirreff and Seal Islands CEMP sites had been modified and renumbered in 2004 (CCAMLR-XXIII, paragraphs 10.26 and 10.27). However, it was

unclear from the record whether this constituted a formal review of the two relevant measures (Conservation Measures 91-02 and 91-03 respectively). This would suggest that Conservation Measures 91-02 and 91-03 could have been reviewed in 2005 or will come up for review in 2009. The Working Group referred the matter to the Subgroup on Protected Areas for clarity and requested that, should the measures have required review in 2005, then such a review should be undertaken urgently and, if possible, before the Scientific Committee's meeting in 2006. In addition, the Working Group was informed that all CEMP-related work on Seal Islands has ceased and that, after a formal notification on the matter has been received from the USA, Conservation Measure 91-03 (2004) 'Protection of the Seal Islands CEMP Site' is likely to become redundant.

5.3 It was also noted that revision of CEMP site maps will only be complete on receipt of the Admiralty Bay CEMP site map (King George Island). The USA advised that the required map has been completed in collaboration with Brazil and will be provided in the near future.

ATCM draft management plans for protected areas with marine components

5.4 The Working Group noted that there were no new draft management plans for Antarctic protected areas received for consideration from the ATCM by CCAMLR.

5.5 The Working Group noted the reports of two New Zealand research voyages to the Balleny Islands (Ross Sea) (WG-EMM-06/31), and investigations carried out by Ukraine in the vicinity of the Argentine Islands (Antarctic Peninsula) (WG-EMM-06/33). The Working Group noted that research in both regions may, in future, result in New Zealand and Ukraine submitting proposals to the ATCM to designate the Balleny Islands and Argentine Islands (respectively) as ASPAs.

5.6 The Working Group noted the two criteria stated in ATCM Decision 9 (2005) that draft management plans that contain marine areas which require a prior approval of CCAMLR are those:

(i) where there is actual harvesting or potential capability of harvesting of marine living resources which might be affected by site designation; or

(ii) for which there are provisions specified in a draft management plan which might prevent or restrict CCAMLR-related activities.

5.7 The Working Group noted that, by the time of its meeting, no feedback was received from Members following SC CIRC 06/7 regarding two questions posed by the Scientific Committee relating to the implementation of ATCM Decision 9 (2005) (SC-CAMLR-XXIV, paragraph 3.63), namely:

(i) The Scientific Committee asked WG-EMM and WG-FSA to develop guidelines to indicate what percentage of the range of a known harvestable resource could be covered by protected areas within a statistical unit before CCAMLR would need to determine if a protected area proposed by ATCM might impact on rational use.

(ii) The Scientific Committee asked each Member of CCAMLR to indicate which of the recent proposals from ATCM concerning protected areas with marine components should, in retrospect, have been required to be submitted to CCAMLR according to the criteria in ATCM Decision 9 (2005).

5.8 To avoid potential confusion in the future, the Working Group recommended that standard terminology be adopted within CCAMLR to distinguish between 'ATCM draft management plans with marine components' and 'marine protected areas (MPAs)' *per se*.

5.9 The Working Group recognised that work on both questions given in paragraph 5.7 would help to develop a procedure that could be provided to ATCM to determine whether a draft ATCM plan for protected areas with marine components should be referred to CCAMLR for review. However, the Working Group noted that it has not, as yet, developed such procedures.

5.10 In response to question (i), the Working Group noted that the development of such guidelines had not commenced at the time of the meeting. In response to question (ii), the Working Group noted that no information had been obtained from individual Members of CCAMLR. The Working Group noted that all draft ATCM protected area proposals with marine components to date (SC CIRC 06/7, Appendix II) have been reviewed and approved by CCAMLR. However, it remains uncertain in retrospect how many of these actually needed to have been considered by CCAMLR.

5.11 The Working Group recommended that, at least in the near future, all ATCM protected area proposals with marine components should continue to be provided to CCAMLR for review unless they are clearly not required according to ATCM Decision 9.

5.12 The Working Group considered that it was not possible at this stage to specify a generic process for considering those ATCM proposals with marine components that are submitted to CCAMLR for consideration. The Working Group noted that the assessment process requires flexibility, and generic guidelines would be overly restrictive until such time as a sufficient number of proposals have been reviewed that meet the criteria in Decision 9.

Bioregionalisation

5.13 The Working Group noted that the Scientific Committee had provided two broad terms of reference to deal with how MPAs could contribute to furthering the work of CCAMLR (SC-CAMLR-XXIV, paragraphs 3.53 to 3.59) and how to consider proposals currently under development, or in a conceptual phase, for MPAs in the Convention Area (SC-CAMLR-XXIV, paragraphs 3.60 to 3.73). The latter also outlined detailed terms of reference for a steering committee to facilitate collaboration with CEP to organise a workshop to establish a bioregionalisation of the Convention Area and to consolidate advice on a system of protected areas (SC-CAMLR-XXIV, paragraphs 3.65, 3.66 and 3.66(4) particularly).

5.14 The Working Group noted that the Scientific Committee had endorsed the suggestion that CEP be invited to undertake the initial work to develop bioregionalisation of coastal provinces, as an extension of its terrestrial bioregionalisation work, while the Scientific Committee undertakes the initial work to delineate oceanic provinces (SC-CAMLR-XXIV, paragraph 3.67). This message was conveyed to CEP in June 2006. It was also noted that

such a division of work between CCAMLR and CEP on bioregionalisation may not be so clear in the future as the CCAMLR scientific community also has expertise for coastal areas and the separation of coastal and oceanic provinces may only emerge after comprehensive analysis.

5.15 In respect to the workshop on bioregionalisation, it was noted that a high priority had been attached to this work by the Commission and that the Commission had indicated that the workshop should be brought forward from 2008 to 2007 (CCAMLR-XXIV, paragraph 4.18). It was also noted that the steering committee has not yet nominated its convener and, as such, has not yet commenced the work required to prepare for the workshop. The Working Group noted that any further delays were likely to compromise the optimal and timely use of available expertise from within WG-EMM and that this would be likely to affect the timeline envisaged by the Commission.

5.16 The Working Group recommended that the steering committee should make full use of available expertise within WG-EMM and WG-FSA in its workshop preparations to ensure adequate identification of work to address various aspects, such as essential ecosystem components, environmental parameters and fisheries considerations, for incorporation into a comprehensive bioregionalisation of the Southern Ocean. In order to facilitate coordination of work on the proposed workshop, the Working Group recommended that conveners of all SC-CAMLR working groups also become members of the steering committee.

5.17 Dr Constable presented a statistical method for undertaking regionalisations of ocean areas (WG-EMM-06/37). The demonstration used sea-surface height, bathymetry and sea-ice climatologies, but the method can include any number of datasets at a variety of spatial scales. The method was applied to each CCAMLR statistical area. There was good qualitative agreement between the initial regionalisations and the broad characteristics of the region given in the literature. The Working Group agreed that it would be useful to continue the development of this method to assist CCAMLR in both its ecosystem modelling work and in undertaking a bioregionalisation of the Convention Area.

5.18 Dr Constable indicated that a small independent workshop will be held in early September 2006 in Hobart, Australia, to develop the regionalisation work further. The workshop is being hosted by the Antarctic Climate and Ecosystems Cooperative Research Centre and WWF, sponsored by Peregrine Adventures. All members of WG-EMM are welcome to attend the workshop and should contact Dr Constable if they are interested. It is intended that a report of the workshop will be provided to the Scientific Committee in October 2006. The report will be valuable with respect to the CCAMLR Bioregionalisation/ Protected Area workshop.

5.19 Dr Pinkerton thanked Dr Constable for his valuable contribution to bioregionalisation, pointing out that for Area 88, in general, the preliminary results shown in WG-EMM-06/37, Figure 4, were a good match of the system delineated by work presented in WG-EMM-06/14, and suggested it could also be used on a smaller scale around, for example, the Balleny Islands.

Harvesting units

5.20 A correspondence group comprising Drs Nicol and Naganobu had been tasked with examining the issue of determining ecological boundaries within large statistical areas with the aim of defining smaller harvesting units (SC-CAMLR-XXI, paragraph 3.15).

5.21 The group had agreed to focus on the east Antarctic region and was awaiting the analysis of the 2006 BROKE-West Survey of Division 58.4.2 which collected data that would be of use in the process of defining ecological boundaries. The combination of the datasets of BROKE-West and the 1996 BROKE survey of Division 58.4.1 would allow a comprehensive analysis of the ecosystems of the 30–150°E region. The group agreed to provide some analyses based on these and other datasets for the 2007 meeting of WG-EMM.

5.22 The process of defining harvesting units will also be assisted by the bioregionalisation process outlined in WG-EMM-06/37.

Small-scale management units

5.23 By reviewing the results from simulations conducted using KPFM2 (Appendix D), the Working Group agreed that, should the fishery occur entirely in Subarea 48.1 and catch an amount of krill equivalent to 9% of B_0, then there will be considerable negative impacts on the ecosystem in that region and, under the assumptions of flux, there would also be negative consequences for predators in Subareas 48.2 and 48.3 (paragraph 2.3).

5.24 The Working Group agreed that further simulation trials conducted using both KPFM2 and SMOM indicate that Fishing Option 1 (allocation of catches according to the historical distribution of catches, among SSMUs, by the krill fishery) would have relatively greater negative impacts on the ecosystem compared to the other fishing options.

5.25 The Working Group also agreed that all simulations indicated that the performance of Fishing Options 2, 3 and 4 (allocation of catches, respectively, according to the spatial distributions of predator demand, standing krill biomass, and the difference between standing krill biomass and predator demand) would be improved when monitoring data are used to update the allocation of catches among SSMUs, i.e. in a manner analogous to Fishing Option 5 (allocation of catches based on monitoring data).

5.26 The Working Group noted that larger areas, such as groups of SSMUs or statistical subareas, may be better suited to the modelling of krill dynamics. However, it was also agreed that the scale of SSMUs was appropriate for modelling both predator dynamics and the interactions between predators and the fishery.

Analytical models

5.27 Dr Agnew introduced the report of the 2006 meeting of WG-FSA-SAM (WG-FSA-06/6), noting that assessments for three stocks of toothfish (Subarea 48.3, Division 58.5.2 and the Ross Sea) had now been developed in the integrated assessment software CASAL. Whilst the structure of the individual models is somewhat different, they include provisions for

spatial structure of the stock, multiple fishing fleets and multiple data sources, such as recruitment surveys, length frequency in the catch, CPUE and mark–recapture data. Methods for applying the CCAMLR decision rules within CASAL to determine catch limits have been developed by WG-FSA-SAM and WG-FSA, and the results of such methods agree with the results using the stochastic projection method of GYM.

5.28 The Working Group considered that there may be some merit in examining the potential of such models for krill. Currently the krill assessment uses a stochastic projection model (GYM) whereas CASAL is an estimation model. Integrated models could, for instance, include the CCAMLR krill synoptic survey data, other survey data, CPUE data, relative and absolute estimates of recruitment, recruitment variability, and length-frequency data from the catch. The Working Group noted that CASAL was one of a suite of integrated assessment methods, and that the development of integrated models could proceed using various software platforms.

5.29 The Working Group acknowledged that construction of such integrated assessment models could present significant challenges, not least in representing the complex spatial structure of the stock and fishery. Models also need to be harmonised with the Working Group's development of integrated ecosystem models.

5.30 CASAL allows the construction of operating models for simulation studies of the performance of different integrated assessment models. Such simulation models would allow investigation of the sensitivity of integrated assessments to input data, for instance the relationship between recruitment variability and natural mortality, and the level of catches relative to the size of the stock. Such models could also be used to investigate the performance of management procedures against uncertainty in parameters.

5.31 WG-EMM encouraged participants to investigate the potential of integrated assessments for krill, and to present papers for consideration of both WG-FSA-SAM and WG-EMM.

Existing conservation measures

5.32 The Working Group reviewed conservation measures which apply to krill fisheries in 2005/06 (a list was provided in WG-EMM-06/5) with the objective of identifying whether updated or new scientific information should be considered in the potential application of conservation measures to krill fisheries during 2006/07. It was agreed that new information from a krill biomass survey conducted in Division 58.4.2 and reported in WG-EMM-06/16 bears directly on the future application of Conservation Measure 51-03 (Precautionary catch limitation on *E. superba* in Division 58.4.2).

5.33 WG-EMM-06/16 reported a standing stock of 15.89 million tonnes of krill in Division 58.4.2. The CV for the estimate was reported as 47.9%, which is larger than the CV for the CCAMLR-2000 Survey in Statistical Area 48.

5.34 The Working Group requested that the Data Manager use the information reported in WG-EMM-06/16 to estimate a precautionary catch limit for krill in Division 58.4.2 in a manner that is consistent with the most recent estimates made for Statistical Area 48 (resulting from the CCAMLR-2000 Survey) and Division 58.4.1 (resulting from the BROKE

survey). This request was made because: (i) the Working Group agreed that consistency of computation is important, and (ii) the latest version of the GYM which was available at the meeting was not the same as that used to compute precautionary catch limits for Area 48 and Division 58.4.1.

5.35 Assuming that time and resources are available for the Data Manager, it was agreed that he should endeavour to complete the aforementioned calculations prior to the forthcoming meeting of the Scientific Committee, to which the results would be presented. It was acknowledged that this should provide the Scientific Committee with the information needed to advise the Commission on updating the precautionary catch limit in Conservation Measure 51-03, a value equal to the γ estimated by the Data Manager multiplied by the B_0 estimate of 15.89 million tonnes.

5.36 The Working Group recalled that precautionary catch limits for krill are constrained by one of two possible harvest rates, an estimate of γ that is determined by performance relative to an escapement criterion, and an estimate of γ that is determined by performance relative to a depletion criterion. The precautionary catch limits for krill in Area 48 and Division 58.4.1 were constrained by the former estimate of γ, but it was noted that the CV reported in WG-EMM-06/16 may be sufficiently large to cause a revised estimate of the precautionary catch limit for krill in Division 58.4.2 to be constrained by the latter estimate.

Key points for consideration by the Scientific Committee

Protected areas

5.37 The Working Group noted that CEMP site protection under Conservation Measure 91-01 (2004) in respect of Conservation Measures 91-02 and 91-03 may need to be reviewed in 2006 (paragraph 5.2).

5.38 The Working Group recommended that, at least in the near future, all ATCM protected area proposals with marine components should continue to be provided to CCAMLR for review (paragraph 5.11).

5.39 To avoid potential confusion in the future, the Working Group also recommended that standard terminology be adopted within CCAMLR to distinguish between 'ATCM draft management plans with marine components' and 'marine protected areas (MPAs)' *per se* (paragraph 5.8).

5.40 The Working Group noted a number of important points relevant to the topic of bioregionalisation (paragraphs 5.13 to 5.19):

(i) despite the fact that the Commission has indicated that a workshop on bioregionalisation and the consolidation of advice on marine protected areas is of high priority (CCAMLR-XXIV, paragraph 4.18), a convener for this workshop has not been nominated and preparations for the workshop have not commenced (paragraphs 5.13 and 5.15);

(ii) the steering committee tasked with developing the workshop on bioregionalisation would benefit from full use of the available expertise within

WG-EMM and WG-FSA with coordination being facilitated by the conveners of SC-CAMLR working groups participating in the steering committee (paragraph 5.16);

(iii) the development of statistical approaches to bioregionalisation like that presented in WG-EMM-06/37 should continue (paragraph 5.17);

(iv) an independent workshop on bioregionalisation will be hosted by the Antarctic Climate and Ecosystems Cooperative Research Centre and WWF, sponsored by Peregrine Adventures in Hobart, Australia, during September 2006, and this workshop will provide information that is useful to CCAMLR (paragraph 5.18).

Harvesting units

5.41 The Working Group was unable to advise the Scientific Committee on harvesting units at this time. Work on this topic will continue during the forthcoming intersessional period (paragraph 5.21).

Small-scale management units

5.42 Recalling the work and discussion outlined in paragraphs 2.1 to 2.11 and in the Report of the Second Workshop on Management Procedures (Appendix D), the Working Group noted that simulation results indicate that, should the fishery occur entirely in Subarea 48.1 and catch an amount of krill equivalent to 9% of B_0, then there will be considerable negative impacts on the ecosystem in that region and, under the assumptions of flux, there would also be negative consequences for predators in Subareas 48.2 and 48.3 (paragraph 5.23).

5.43 The Working Group recalled the six candidate methods for subdividing the krill catch, also called fishing options (SC-CAMLR-XXIV, Annex 4, Appendix D, paragraph 2.2). The agreed candidate methods were based on:

(i) the spatial distribution of catches by the krill fishery (Fishing Option 1);

(ii) the spatial distribution of predator demand (Fishing Option 2);

(iii) the spatial distribution of krill biomass (Fishing Option 3);

(iv) the spatial distribution of krill biomass minus predator demand (Fishing Option 4);

(v) spatially explicit indices of krill availability that may be monitored or estimated on a regular basis (Fishing Option 5);

(vi) pulse-fishing strategies in which catches are rotated within and between SSMUs (Fishing Option 6).

5.44 Despite substantial uncertainty in various aspects of the predator–prey–fishery system, further simulation trials indicate that Fishing Option 1 would have relatively greater negative impacts on the ecosystem compared to the other fishing options (paragraph 5.24).

5.45 Evaluation of Fishing Options 2 to 4 will require additional work on the development and interpretation of performance measures, but all simulations indicated that the performance of these options would be improved when monitoring data are used to update the allocation of catches among SSMUs, i.e. in a manner analogous to Fishing Option 5 (paragraph 5.25).

5.46 In considering the results of separate simulations intended to complement those indicated in the preceding three paragraphs (see also paragraph 2.7), the Working Group noted that larger areas, such as groups of SSMUs and statistical subareas may be better suited to the modelling of krill dynamics. The Working Group also noted that the scale of SSMUs was appropriate for the modelling of predator dynamics and interactions between predators and the fishery (paragraph 5.26).

5.47 The Working Group recognised that substantial and important progress had been made in developing models and performance measures for use in advising the Scientific Committee on spatially explicit management strategies for krill in Statistical Area 48. Nevertheless, there is considerable scope for additional work, and the Working Group encouraged participants to continue work following the suggestions in paragraphs 2.8 to 2.11 and the future work identified in the Report of the Second Workshop on Management Procedures (Appendix D, section 6).

Analytical models

5.48 Noting the discussions outlined in paragraphs 5.27 to 5.31, the Working Group reiterated that there may be merit in examining the potential of integrated stock assessment models for krill, and encouraged participants to present papers on this topic for consideration by both WG-FSA-SAM and WG-EMM.

Existing conservation measures

5.49 The Working Group again noted that CEMP site protection under Conservation Measure 91-01 (2004) in respect of Conservation Measures 91-02 and 91-03 may need to be reviewed in 2006 (paragraph 5.2).

5.50 The Working Group reviewed conservation measures which apply to krill fisheries in 2005/06 (a list was provided in WG-EMM-06/5) with the objective of identifying whether updated or new scientific information should be considered in the potential application of conservation measures to krill fisheries during 2006/07. It was agreed that new information from a krill biomass survey conducted in Division 58.4.2 and reported in WG-EMM-06/16 bears directly on the future application of Conservation Measure 51-03 (Precautionary catch limitation on *E. superba* in Division 58.4.2) (paragraph 5.32).

5.51 The Working Group requested that the Data Manager use the information reported in WG-EMM-06/16 to estimate a precautionary catch limit for krill in Division 58.4.2 in a

manner that is consistent with the most recent estimates made for Statistical Area 48 (resulting from the CCAMLR-2000 Survey) and Division 58.4.1 (resulting from the BROKE survey). This request was made because: (i) the Working Group agreed that consistency of computation is important, and (ii) the version of the GYM which was available to the Working Group was not the same as that used to compute precautionary catch limits for Statistical Area 48 and Division 58.4.1 (paragraph 5.34).

5.52 Assuming that time and resources are available for the Data Manager, it was agreed that he should endeavour to complete the aforementioned calculations prior to the forthcoming meeting of the Scientific Committee, to which the results would be presented. It was acknowledged that this should provide the Scientific Committee with the information needed to advise the Commission on updating the precautionary catch limit in Conservation Measure 51-03 to be the γ estimated by the Data Manager multiplied by the B_0 estimate of 15.89 million tonnes (paragraph 5.35).

FUTURE WORK

Predator surveys

6.1 The Working Group noted that a number of its participants had been involved in intersessional discussions regarding predator surveys. These discussions were summarised for the group by Drs Goebel and Constable.

6.2 During the intersessional period, the *Wildlife Awareness Manual: Antarctic Peninsula, South Shetland Islands, South Orkney Islands* was published by the UK to provide practical information on breeding colony locations for those operating aircraft in these areas (Harris, 2006). It was felt that this manual would be a useful basis for initiating discussion on the design and conduct of predator surveys. To facilitate this process it would, however, be useful for participants to gain a better understanding of the data presented in the manual and clarify whether other sources of data (e.g. Antarctic Site Inventory – see SC-CAMLR-XXIV, Annex 4, paragraph 6.4) might be available to assist in future planning and design of predator surveys.

6.3 Intersessional discussions indicated that future predator surveys should aim to fill important spatial gaps in existing count and census data. Identifying such gaps will be an important component of work to complete in planning for large-scale predator surveys.

6.4 Intersessional discussions also suggested that holding a workshop to discuss the abundance of predators and surveys needed to fill key information gaps in such estimates of abundance, should be deferred by the Working Group to 2008.

Ecosystem models, assessments and approaches to management

6.5 The Working Group considered a number of papers on ecosystem models along with their use in providing advice on options to subdivide the precautionary catch limit for krill in Area 48 amongst SSMUs. These models included SMOM (WG-EMM-06/12, 06/28),

KPFM2 (WG-EMM-06/20, 06/22, 06/30 Rev. 1) and EPOC (WG-EMM-06/38 Rev. 1). The details of these discussions and their application are in the report of the Second Workshop on Management Procedures (Appendix D).

6.6 Dr Constable suggested that the authors of these papers submit them for publication in *CCAMLR Science*. This is because the papers all contribute directly to the work of, and provision of advice by, the Scientific Committee and have arisen directly from discussions in and with the advice of the Working Group.

6.7 Dr Reid noted that the choice of journal is the choice of the authors and that there may be domestic reasons for choosing alternative journals.

6.8 WG-EMM-06/14 presented progress towards a trophic model of the ecosystem of the Ross Sea for investigating ecosystem effects of the Antarctic toothfish fishery. It reported on the further development of a carbon-budget trophic model of the Ross Sea. The Ross Sea is a low primary production system, with production being localised in space and time. The middle-trophic level is dominated by the Antarctic silverfish (*Pleuragramma antarcticum*).

6.9 The Working Group noted that conclusions on the effects of toothfish fishing on the ecosystem cannot yet be made. It encouraged further work on this model to provide insights into the dynamics of the Ross Sea system and to identify the important trophic linkages through which fisheries may indirectly affect the food web of the region.

6.10 The Working Group thanked Dr Pinkerton for his paper as it represented significant progress in the development of trophic models for the region. Dr É. Plagányi (South Africa) noted that there were improvements in this paper on approaches to trophic models in the literature and that this modelling work can be used to help identify the key trophic linkages that may need to be represented in the simplified multispecies models to be used for evaluating management procedures.

6.11 Dr Pinkerton noted that this study has funding for a further three years. It has already identified that the primary area that could be affected by toothfish fishing would be in the western part of the Ross Sea with possible effects on demersal prey species and on toothfish predators such as Weddell seals and killer whales. Future work will aim to develop dynamic models of the food web.

6.12 Drs Holt and Wilson noted the overlap between predators and fisheries in the Ross Sea and indicated work being undertaken by scientists in the USA and New Zealand to develop a proposal for an index for Weddell seals to be considered for inclusion in CEMP in order to monitor for effects of the toothfish fishery in the Ross Sea. The Working Group welcomed these developments and looked forward to receiving proposals for such an index.

6.13 The Working Group noted the need for linkages between experts in WG-EMM and WG-FSA on this work. These linkages would need to involve experts with respect to ecosystem modelling and assessments as well as experts with respect to understanding the biology and ecology of the region and how to interpret changes in CEMP indices developed for the region.

6.14 WG-EMM-06/19 presented further work on modelling the krill–predator dynamics of the Antarctic ecosystem. Results indicated that krill is unable to fully utilise the primary

production available. The precision of parameters is reported. The model is extended in this version to include other predators as a group variable, reflecting squid, fish and seabirds, in order to ensure the crabeater seal variable is not a surrogate for these predators as well as the seal group itself. This is work in progress with a number of areas identified for improvement in the future. The development of an improved set of abundance and trend estimates of various krill predators is seen as a priority for improving the reliability of current models, and it is suggested that this should be a key focus of the joint CCAMLR-IWC workshop on this topic.

6.15 The Working Group noted that a strength of the approach in WG-EMM-06/19 is the use of data to condition the models. This paper provides an illustration of how this is done.

6.16 WG-EMM-06/26 updated information presented to the Working Group at its 2005 meeting on the program on the Integrated Analyses of Circumpolar Climate Interactions and Ecosystem Dynamics in the Southern Ocean (ICED). This program is an international initiative launched in May 2005 in response to the increasing need to develop integrated circumpolar analyses of Southern Ocean ecosystems. CCAMLR community scientists have been instrumental in developing this initiative, and a key aim of ICED is to link with CCAMLR scientists to develop management procedures that include relevant aspects of the wider operation of ocean ecosystems.

6.17 An important aspect of developing ecosystem models and in developing management advice is to consider the movement of biota from one management unit to another. WG-EMM-06/35 discussed a number of issues that need to be addressed in modelling movement, particularly if modelling units are large compared to the ability of the biota to rapidly mix over the entire unit. It provides a solution to the usual movement transition matrices that ensures biomass is not moved in and out of model polygons faster than is biologically reasonable.

6.18 The Working Group noted the progress in developing operating models for use by SC-CAMLR to evaluate management procedures. It noted the current and future work programs of WG-FSA-SAM to develop operating models to evaluate toothfish and icefish management procedures. Some papers presented to WG-EMM this year have direct relevance to the work of WG-FSA-SAM.

Operating Models Subgroup

6.19 The Working Group noted that the Scientific Committee endorsed the recommendation of the Working Group last year to establish the 'Subgroup on Development of Operating Models' (convened by Dr Constable) and to begin a newsgroup to facilitate this work (SC-CAMLR-XXIV, paragraph 3.37). It recommended that the name be shortened to 'Operating Models Subgroup' for ease of translation and correspondence.

6.20 The Working Group thanked and congratulated the Secretariat on establishing a very useful newsgroup, which is now available for Members to use. It noted the ease of access and the utility of the newsgroup to maintain a record of correspondence on issues being considered by the subgroup. The Working Group noted that the main discussion items in the newsgroup would currently be:

- newsgroup structure and coordination
- single-species models for krill
- multispecies and ecosystem models
- data and parameters for use in existing models
- developments in data and parameters
- organisation of the CCAMLR-IWC Workshop.

6.21 The Working Group noted that the newsgroup might be useful to WG-FSA-SAM in developing:

- single-species models for icefish
- single-species models for toothfish.

6.22 The Working Group noted that it will take time for users to become familiar with this form of correspondence and for the newsgroup to be fully utilised. Nevertheless, it encouraged experts developing operating models for use in evaluating management procedures to begin to utilise the newsgroup as a means of generally exchanging ideas and approaches to facilitate the work of WG-EMM.

6.23 Dr Constable indicated that his intention as moderator of the newsgroup was to circulate updates to members of the newsgroup on the activities of the group each month. In order to facilitate rapid exchange of information, it would be useful if members of the newsgroup have in their electronic profile advice on whether they wish to be sent notices when other members post a message on the newsgroup.

6.24 The Working Group agreed that the general tasks for the subgroup would include, *inter alia*:

(i) further development of models presented to the Second Workshop on Management Procedures;

(ii) development of feedback management procedures, including identifying what data might be available from monitoring and how they could be used in such procedures;

(iii) how to adapt models from one area to others within CCAMLR and also how to adapt models and tools developed outside SC-CAMLR;

(iv) review and update parameters used in models;

(v) comparisons of model data and parameters derived using different estimation methods and whether model outcomes are robust to the different approaches;

(vi) development of models that are conditioned on available data.

6.25 The Working Group did not attempt to prioritise these tasks but encouraged Members to participate as much as possible in this work.

6.26 The Working Group noted that the outcomes of the FAO Workshop on Modelling Ecosystem Interactions for Informing an Ecosystem Approach to Fisheries to be held in 2007 would be of interest to WG-EMM in its development of ecosystem models for CCAMLR (paragraph 7.16).

CCAMLR-IWC Workshop

6.27 The Working Group noted that the Scientific Committee had endorsed the recommendation of the Working Group last year to hold a joint workshop with the Scientific Committee of the IWC (SC-IWC) on the development of models of Antarctic krill predators, particularly to discuss the data inputs to those models (SC-CAMLR-XXIV, paragraphs 13.44 to 13.53). The terms of reference for the workshop adopted by the Scientific Committee are given in paragraph 13.47 of SC-CAMLR-XXIV.

6.28 The Scientific Committee established a steering committee to develop a work plan and initiate subgroups to begin preparations of materials for the workshop in 2008 over the intersessional period and provide next year a consolidated proposal for the workshop, including details of a work plan over 2007–2008, a venue and a budget. It also agreed that the new CCAMLR Headquarters would be an appropriate workshop venue pending consideration of timing, budget and the availability of the Secretariat (SC-CAMLR-XXIV, paragraph 13.52).

6.29 The Working Group noted that the CCAMLR Executive Secretary, Dr D. Miller, and Dr K.-H. Kock (IWC Observer) had undertaken their tasks to convey the invitation of SC-CAMLR to the SC-IWC to participate in the workshop (SC-CAMLR-XXIV, paragraph 13.51).

6.30 Prof. D. Butterworth (SC-IWC Observer) provided the Working Group with the results of the deliberations of the SC-IWC (CCAMLR-XXV/BG/5; SC-CAMLR-XXV/BG/6). The SC-IWC had expressed a desire to be involved in the workshop and established a steering committee to oversee the process from its perspective. It identified a number of questions and issues to be addressed by the workshop as well as the input that it could make to the workshop. It also outlined a set of tasks and options to be considered by the steering group to facilitate this work. These are outlined in the SC-IWC Report 2006, Annex K, Appendix 6. In particular, the SC-IWC would hope that the workshop should at least provide:

(i) improvements in the development of multispecies spatial models that provide reliable advice regarding krill consumption by large whales in the Southern Ocean and in the southern hemisphere;

(ii) improvements in the ability to compare the performance of alternate models in providing management advice that is robust to uncertainty;

(iii) improvements in the characterisation of the temporal and spatial distribution of krill in the Southern Ocean, as well as improvements in the understanding regarding the nature and extent to which sea-ice is an important covariate;

(iv) improvements in the collation and integration of time series of data for information on: (a) oceanographic and other environmental data, (b) phytoplankton/other sources of primary production, (c) other zooplankton, (d) forage fish, and (e) other upper trophic level species.

6.31 In addition, where possible, the SC-IWC would expect analyses that use agreed criteria to test for the relative importance of competitive interactions in the Southern Ocean ecosystem. If this is not possible, it would at least expect advances in the development of experiments that could be undertaken to test various aspects of the family of hypotheses considered.

6.32 As the convener of the SC-CAMLR steering committee for the workshop, Dr Constable convened a discussion by a small group to develop advice to the joint workshop steering group (i.e. the combined steering committees from SC-CAMLR and the SC-IWC) on matters that may need to be considered in developing the work plan and approaches to the workshop from the SC-CAMLR perspective. Such advice is provided below on the objectives and scope of the workshop, the data requirements for the workshop, organisation of the workshop and steps that will need to be taken for reporting to SC-CAMLR.

6.33 With respect to the objectives and scope of the workshop, the Working Group suggested that the following points be considered by the steering group:

(i) The requirements of the two scientific committees are very similar. However, it noted that the expectations of the SC-IWC may be much greater than can be achieved. In particular, there may be insufficient time to consider models to as full an extent as suggested by the SC-IWC. The highest priority should be to ascertain the data available for modelling and the attendant uncertainties in those data so that they can be used appropriately in the current and foreseen modelling approaches. The steering group might wish to consider whether the workshop could be undertaken over a longer period than one week in order to provide time for discussions on models. If this occurred, the workshop agenda might be structured in such a way that experts need not attend for the whole meeting.

(ii) It will be important to identify the current suite of ecosystem/multispecies modelling approaches that might be used to form management advice in order to determine the data to be considered by the workshop. For example, SC-CAMLR has considered relatively small-scale krill–predator models in the southwest Atlantic, while the SC-IWC has considered Antarctic-wide models of large-scale krill–predator dynamics. While a broad discussion on issues in modelling aspects of the Antarctic marine ecosystem might be useful, it was considered that the primary focus would best be on current and identifiable future modelling needs, including, *inter alia*:

(a) What are the spatial and temporal scales appropriate for each species in these models for the purposes of SC-CAMLR and the SC-IWC?

(b) How do the dynamics of krill need to be modelled to examine the relative importance of predator consumption versus environmental forcing on those dynamics, and what data are needed to satisfactorily model the dynamics and to discriminate between these hypotheses?

(iii) In order to identify the important data requirements for these models, it would be useful to identify the associated key sources of uncertainty and how those uncertainties can best be dealt with, i.e. what data would be most useful for dealing with those uncertainties?

6.34 The Working Group identified a number of issues that need to be clarified with respect to the data to be considered by the workshop:

(i) Data need to be collated at the metadata level for use in modelling (time trends in abundance, population parameters and so on) rather than collating raw data.

(ii) The concept of 'metadata' as it relates to the workshop objectives needs to be clearly articulated. In that sense, it was noted that metadata (or summary data) are the actual numeric estimates for the quantities to be used in models. Such data need to be at the appropriate level of resolution and to include actual numeric estimates of uncertainty (e.g. variance, covariances or CI). They also need to be accompanied by a reasonably comprehensive description of the data sources and estimation methods used to generate the data. These descriptions should be sufficient for determining the degree of bias in the data and what the ranges of the associated uncertainties might be. The issue of process error (i.e. error other than that arising from survey sampling variance), where relevant, should be included in the description as well as estimates of this where possible. In addition, where there are alternative reasonable interpretations and/or analyses of the underlying data that can lead to substantially different absolute estimates or trends, these should be provided. Single best estimates should not be provided in isolation in situations where substantial uncertainty exists.

(iii) An important outcome would be to determine the comparability of different datasets to be used in the models, e.g. comparability between different surveys of pack-ice seals.

(iv) Data need to be scaled appropriately in order to avoid the potential mismatch between scales, i.e. how does one scale up CCAMLR ecosystem data to large-scale models of the SC-IWC and how does one scale down the IWC data to provide input to smaller-scale SC-CAMLR models?

(v) In the first instance, metadata should be obtained for key species and environmental parameters for the current and imminent modelling approaches at spatial and temporal scales appropriate to those models. It will also be important to identify the degree to which such metadata could be partitioned into smaller spatial and temporal scales in case such modelling became important in the future or became of interest in preparing for the workshop.

6.35 The Working Group identified the following points which will need to be considered by the steering group in organising the workshop:

(i) Achievable milestones will need to be identified in order to create realistic expectations of the potential outcomes of the workshop and to positively engage

participants in the process. It was also considered that the workshop may be a part of a longer-term process for achieving all of the aims identified by SC-CAMLR and the SC-IWC.

(ii) It is expected that each of the steering committees that comprise the steering group will have conveners reporting back to either SC-CAMLR or the SC-IWC. It was noted that the steering group is not a decision-making body except in relation to organising the workshop.

(iii) The steering group will need to undertake its initial organisational work without budgets from the CCAMLR or IWC Secretariats. The steering group is encouraged to work primarily by correspondence and to use opportunities that might arise for some members of the steering group to meet and consider aspects of its work, such as at SC-CAMLR or SC-IWC meetings.

(iv) An important issue in obtaining metadata for the workshop would be to address any concerns of the data holders including, *inter alia*:

(a) the need to treat data holders evenly and openly
(b) data-ownership be recognised
(c) due credit is given to data holders for their contribution to this work
(d) publication of outputs arising from the data is agreed
(e) evaluation of the utility of data in models is with respect only to quantifying the range of uncertainty surrounding the data, therefore identifying how to use the data appropriately.

(v) Given these issues, it was agreed that access to data will need to comply with the data access rules and protocols of both CCAMLR (*CCAMLR Basic Documents*, Part II, Rules for Access and Use of CCAMLR Data) and the IWC (International Whaling Commission 2004 Report of the Scientific Committee, Annex T: Report of the Data Availability Working Group. *J. Cetacean Research and Management*, 6 (Suppl.): 406–407). It was noted that Procedure B of the IWC is likely to be the appropriate procedure from the IWC perspective and that both sets of rules of access have many consistencies. It was agreed that the Secretariats of both organisations should establish the appropriate protocols for data access consistent with these approaches.

(vi) It was noted that some of the information needed for the workshop is not held in either the CCAMLR or IWC Secretariats. It will be useful if the steering group could correspond, with the assistance of the CCAMLR and IWC Secretariats, with data holders in the wider CCAMLR and IWC communities.

(vii) Rules of participation in the workshop will need to be developed by the Secretariats in order to satisfy the rules of procedure of both organisations. It was noted that such rules of participation should enable participation by representatives of Members of both organisations as well as participation of relevant experts. It would be useful if the steering group could determine an appropriate list of experts that might be usefully involved in the meeting in order to help SC-CAMLR and the SC-IWC determine participation in the workshop.

(viii) It was agreed that, depending on budgetary constraints, commissioned reviews by experts prior to the workshop would be useful in collating and reviewing available metadata on relevant taxonomic groups. It would be expected that such reviews be available to workshop participants at least three months prior to the workshop in order to provide the opportunity for participants to use these papers to develop submissions to the workshop.

(ix) It was agreed that the workshop would be usefully held early in 2008 prior to the SC-IWC meeting. It was noted that SC-CAMLR had agreed that the CCAMLR Headquarters would be an appropriate venue. It was agreed that this would be a good venue for the workshop.

6.36 The Working Group congratulated the subgroup on progressing these issues and encouraged the steering group to establish a work program, workshop format and budget in time for advising SC-CAMLR of these details at its meeting in October 2006.

6.37 In view of the positive response of the SC-IWC to holding a joint CCAMLR-IWC workshop and its establishment of a steering committee to support the process, the Working Group recommended that the Chair of the Scientific Committee, with the support of the Executive Secretary, correspond with the IWC Secretariat and the Chair of the SC-IWC to initiate preparations for the workshop, including the following actions:

- formally establish the steering group for the workshop as a combination of the two steering committees;
- establish communication between the two conveners of the steering committees to jointly convene the work of the steering group;
- request that the steering group take note of the comments above;
- begin correspondence between the CCAMLR and IWC Secretariats on the issues described above.

Long-term work plan

6.38 The Working Group noted the following future work arising from the Second Workshop on Management Procedures:

(i) development on models provided to the workshop this year –

(a) EPOC (Appendix D, paragraphs 6.1 to 6.3)
(b) SMOM (Appendix D, paragraph 6.4)
(c) KPFM2 (Appendix D, paragraph 6.5);

(ii) development of performance measures (Appendix D, paragraph 6.6);

(iii) development of suitable models of fleet dynamics (Appendix D, paragraphs 6.7 and 6.8);

(iv) technical discussions on models (Appendix D, paragraph 6.9) –

(a) improvements and refinements to models
(b) incorporation of future needs into models
(c) developing datasets to provide further parameter estimations
(d) evaluation of the performance of models in relation to agreed technical requirements;

(v) development of Fishing Options 5 and 6 (Appendix D, paragraph 6.10), including –

(a) defining Fishing Option 6
(b) determining how to acquire knowledge to assist the development of these options;

(vi) further development of spatially-explicit management frameworks and to advance methods for use by CCAMLR to evaluate such management frameworks for krill (Appendix D, paragraph 6.11), including, *inter alia* –

(a) development of operating models;

(b) development and evaluation of decision rules for adjusting fishing activities (e.g. catch limits) based on field data in the future;

(c) further development of operational objectives and performance measures and the means for providing integrated advice to the Commission on the relative merits of different strategies with respect to Article II.

6.39 The Working Group also noted that it would be useful to further develop models on the Ross Sea, including the development of dynamic models (paragraph 6.10).

6.40 The Working Group discussed and identified work to assist different elements of its agenda, notably:

(i) Krill and krill fishery –

(a) develop an index of CPUE for the krill fishery, noting the differences between vessels (paragraph 3.79);

(b) develop a fleet dynamics model (paragraphs 2.11 and 3.65 to 3.73);

(c) review precautionary catch limits for krill (SC-CAMLR-XXIV, Annex 4, paragraphs 6.39 and 6.48), including, *inter alia*:

- implement the recommendations of SG-ASAM with respect to estimating biomass from acoustic data;

- review method for determining the CV of the acoustic biomass estimate;

- review parameters, including growth and recruitment variability;

- examine whether integrated modelling approaches could be used to estimate recruitment variability and *M* from long-term datasets;

- evaluate the existing krill fishery management strategy;

(d) define harvesting units (paragraphs 5.20 and 5.22);

(e) review available time series of krill data compared to environmental variables (paragraph 4.30).

(ii) CEMP –

(a) consider methods for summarising CEMP indices to signal the effects of fishing on the ecosystem and changes needed in krill fishing (feedback management) (including, *inter alia*, paragraph 4.2):

- review use of ordination methods
- consider how to deal with missing values in time series of CEMP data
- review the use of the FPI for krill;

(b) develop a proposal to consider whether a parameter for Weddell seals could be part of CEMP to monitor effects of toothfish fishing in the Ross Sea (paragraph 6.12).

(iii) Krill predators –

(a) consider estimating age-specific mortality rates for predators, in particular characterising how predator mortality may change with different environmental factors (paragraph 4.17);

(b) consider metapopulation models for predators, in particular the circumstances under which movement between land-based colonies might arise or the colonisation of new areas (paragraph 4.9);

(c) hold a workshop on estimating predator abundance in 2008 (paragraph 6.4).

6.41 The Working Group considered the large volume of work being proposed to assist its work in the future. It considered the priorities of this work in light of the priorities indicated by the Scientific Committee last year (SC-CAMLR-XXIV, paragraph 3.39):

(i) facilitate the continued evaluation of management procedures to allocate the precautionary catch limit in Area 48 among SSMUs;

(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;

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

6.42 The Working Group noted that its timetable of work will need to be cognisant of the other work of the Scientific Committee which includes:

- IPY coordination workshop (2007)
- workshop on bioregionalisation (2007)
- CCAMLR-IWC Workshop (April 2008).

6.43 The Working Group agreed that, although significant progress was made with respect to subdividing the krill catch limit amongst SSMUs, the work on this item remained to be completed and requires a mechanism for considering contributions on this item over the coming years until sufficient work has been completed to adequately address the item.

6.44 The Working Group agreed that a further workshop on the subdivision of krill catch limits next year would not be appropriate. However, this work remains a high priority to be completed. The Working Group noted there was a need for clarity on the operational objectives before substantial further progress can be made. In order to progress work and to help determine when such work might be considered complete, time needs to be set aside during the meeting next year to consider the following issues:

(i) technical improvement of models and parameter inputs (paragraph 6.38(iv))
(ii) operational objectives, performance measures and the means for providing integrated advice to the Commission on the relative merits of different krill fishing strategies with respect to Article II (paragraph 6.38(vi)c).

6.45 To that end, the Working Group requested its members to provide input on these issues to next year's meeting. Some of this work may benefit from input from WG-FSA-SAM, particularly in relation to technically improving models and estimating parameters. The Working Group requested that the Scientific Committee consider whether WG-FSA-SAM could consider contributions on this topic at its next meeting.

6.46 The Working Group noted there has been insufficient time in recent meetings to review the state of knowledge on krill and krill-predator biology. It recommended that such work be brought forward in the work of WG-EMM. For example, the second week of the meeting could give emphasis to one or two topics.

6.47 Given these considerations, the Working Group recommended the following timetable of workshops, although this may be changed if work on these issues is progressed more quickly in the meantime or other items are considered to be of higher priority by the Scientific Committee:

(i) review of B_0 and precautionary catch limits (WG-EMM workshop 2007)
(ii) predator abundance and surveys (WG-EMM workshop 2008)
(iii) mechanism for progressing subdivision of krill catch limits amongst SSMUs (WG-EMM workshop 2009).

6.48 It was agreed that this timetable should not preclude the work being done in other groups or workshops of the Scientific Committee.

6.49 For 2007, the Working Group agreed that a workshop to review estimates of B_0 and precautionary catch limits for krill should be held in conjunction with the Working Group meeting, which could consider the following points:

(i) review of parameters used in the assessment, including growth and recruitment variability;

(ii) examine whether integrated modelling approaches could be used to estimate recruitment variability and *M* from long-term datasets;

(iii) consider the level of krill escapement to provide for predators in the decision rule;

(iv) consider alternative methods for estimating catch limits for krill according to the CCAMLR decision rules and how the different methods might be compared and evaluated for providing advice;

(v) consider sources of uncertainty that may not be able to be included specifically in the estimation of B_0 or the assessment process generally.

6.50 The Working Group requested SG-ASAM and WG-FSA-SAM to provide input to the workshop on what is the most appropriate method for estimating B_0 from survey data, considering design-based versus model-based estimation methods. It also requested SG-ASAM to review the method for estimating CV for the biomass estimate provided by Demer and Conti (2005) and consider whether this is sufficient to determine the uncertainty in B_0 more generally.

6.51 The Convener of WG-EMM asked Dr Nicol to convene the workshop to review B_0 and the precautionary catch limits for krill, and the Working Group agreed with his nomination.

6.52 The Working Group agreed not to invite an outside expert to this workshop but participants were encouraged, as appropriate, both to independently consult with outside experts and to bring new delegates to the workshop.

6.53 In discussing its long-term program of work, the Working Group agreed that it would be timely to review the agenda and how a more flexible approach to each year's meeting might be needed. It was noted that the work program needs to be realistic in order to retain the confidence of the Scientific Committee and Commission. The Working Group agreed that it would be useful if Dr Reid could correspond with the Working Group to develop a work plan for the coming years and an approach to managing the agenda each year. It was considered that this plan should be submitted to the Scientific Committee to provide input to the discussion on reorganising the work of the Scientific Committee. In addition, the Working Group requested that the Scientific Committee provide advice on what it considers to be the priority work programs for WG-EMM over the coming years.

6.54 In terms of meeting organisation, the Working Group noted that it would be useful to absorb the workshop report into the Working Group report. It was agreed that the Working Group should not have to receive and adopt the recommendations and future work of the workshop; agreement by the workshop was sufficient to have obtained agreement from the Working Group.

6.55 Dr Constable noted that this could mean that the work of the Working Group be separated into two parts so that report adoption for the respective parts could be achieved at the end of each part. Such a process would provide flexibility in the order of work in the first and second weeks. The order could be determined by how overlap in experts between WG-FSA-SAM and WG-EMM would best be achieved.

6.56 The Working Group agreed that it is desirable to achieve efficiencies in the organisation of its work in order to maximise the time available for expert consultations.

Key points for consideration by the Scientific Committee

6.57 The Working Group would like the Scientific Committee to consider, as appropriate, the following points arising from discussions of future work:

(i) the progress made on assessing abundance of predators and that the workshop on this topic should be deferred until 2008 to consider estimates of abundance of predators and how gaps may be filled through future surveys or other work (paragraphs 6.1 to 6.4);

(ii) the progress made in developing models of the Antarctic marine ecosystem (paragraphs 6.5 to 6.18);

(iii) the need for linkages between WG-FSA and WG-EMM with respect to: (a) modelling and assessment methods, (b) biology and ecology of relevant species, (c) ecosystem effects of fisheries in fish-based ecosystems such as the Ross Sea (paragraphs 6.13 and 6.18);

(iv) the recommended change to the name of the 'Subgroup on the Development of Operating Models' to 'Operating Models Subgroup' (paragraph 6.19);

(v) the development of the newsgroup to support the Operating Models Subgroup (paragraphs 6.20 to 6.23), including thanking the Secretariat for facilitating the establishment of the newsgroup;

(vi) the general tasks identified by the Operating Models Subgroup (paragraph 6.24);

(vii) the progress made in establishing a steering group for the CCAMLR-IWC Workshop on the development of models of Antarctic krill predators, particularly to discuss the data inputs to those models (paragraph 6.27);

(viii) the general points for future work of WG-EMM (paragraphs 6.38 to 6.40);

(ix) the general discussion surrounding its future work program (paragraphs 6.41 to 6.43);

(x) the request for Members to provide input to next year's meeting of WG-EMM on operational objectives, performance measures and the means for providing integrated advice to the Commission on the relative merits of different krill fishing strategies with respect to Article II (paragraphs 6.44 and 6.45);

(xi) the request for Members to provide input to next year's meetings of WG-EMM and WG-FSA-SAM on technical improvement of models and parameter inputs (paragraphs 6.44 and 6.45);

(xii) the need to consider how to bring forward in the work of WG-EMM, reviews of the biology of key species (paragraph 6.46);

(xiii) the recommendation that the following timetable of workshops be undertaken in conjunction with meetings of WG-EMM, although this may be changed if work on these issues is progressed more quickly in the meantime or other items are considered to be of higher priority by the Scientific Committee (paragraph 6.47) –

(a) review of B_0 and precautionary catch limits (WG-EMM workshop 2007)
(b) predator abundance and surveys (WG-EMM workshop 2008)
(c) mechanism for progressing subdivision of krill catch limits amongst SSMUs (WG-EMM workshop 2009);

(xiv) this timetable should not preclude the work being done in other groups or workshops of the Scientific Committee (paragraph 6.48);

(xv) the workshop in 2007 to review estimates of B_0 and precautionary catch limits for krill should be held in conjunction with the Working Group meeting, and could consider the following points (paragraph 6.49) –

(a) review of parameters used in the assessment, including growth and recruitment variability;

(b) examine whether integrated modelling approaches could be used to estimate recruitment variability and M from long-term datasets;

(c) consider the level of krill escapement to provide for predators in the decision rule;

(d) consider alternative methods for estimating catch limits for krill according to the CCAMLR decision rules and how the different methods might be compared and evaluated for providing advice;

(e) consider sources of uncertainty that may not be able to be included specifically in the estimation of B_0 or in the assessment process generally;

(xvi) the request for WG-FSA-SAM to provide input to the WG-EMM workshop on what is the most appropriate method for estimating B_0 from survey data, considering design-based versus model-based estimation methods (paragraph 6.50);

(xvii) the request for SG-ASAM to also provide input to the WG-EMM workshop on what is the most appropriate method for estimating B_0 from survey data and to include a review of the method for estimating CV for the biomass estimate (paragraph 6.50);

(xviii) the recommended convener for the workshop in 2007 is Dr Nicol (paragraph 6.51);

(xix) the Convener of WG-EMM will correspond with the Working Group to develop a work plan for the coming years and an approach to managing the agenda each year, taking note of the discussion in paragraphs 6.53 to 6.56 and to submit this plan to the Scientific Committee to provide input to the discussion on reorganising the work of the Committee.

OTHER BUSINESS

Meeting of the Steering Committee on the Review of the Structure of the Working Groups of the Scientific Committee

7.1 On 16 July 2006, several members of the SC-CAMLR Steering Committee on the Review of the Structure of the Working Groups of the Scientific Committee met in Walvis Bay, Namibia. The meeting was held on the Sunday before the start of the WG-EMM meeting and included Drs Constable (author of SC-CAMLR-XXIV/BG/30: model reviewed by the Scientific Committee), S. Hanchet (New Zealand) (WG-FSA Convener), Holt (Steering Committee Convener) and C. Jones (USA) (WG-FSA-SAM Convener), Ramm (CCAMLR Secretariat Data Manager), Reid (WG-EMM Convener) and Ms G. Tanner (CCAMLR Secretariat Communications Officer). Absent were Drs K.-H. Kock (Germany) and Naganobu, Ms K. Rivera and Mr N. Smith (Co-conveners of ad hoc WG-IMAF) and Dr E. Fanta (Scientific Committee Chair).

7.2 The steering committee reviewed past correspondence among its members and reiterated that both short- and long-term needs of the Scientific Committee must be accommodated in any plausible reorganisation scheme. The committee also agreed that it would be preferable if the reorganisation of the working groups resembled evolution rather than revolution. In particular, many aspects of the working groups' activities are presently being appropriately addressed so 'it should not be fixed if it is not broken'. The reorganisation process is likely to require considerable time but present needs are being met. It also recognised that any reorganisation should not result in an increase in the total meeting time from the present five weeks (presently two weeks for WG-FSA, two weeks for WG-EMM, and one week for WG-FSA-SAM) and that no increase in resources be required from the Secretariat.

7.3 However, future requirements will need modifications of the present way the Scientific Committee does business. For example, it is anticipated that the Scientific Committee will be required to provide advice to the Commission with respect to marine protected areas, predator–prey–fishery models, stock assessment models, icefish and krill acoustic

measurements, conservation status of seabirds and destructive fishing practices to name a few. In addition, it was recognised that some items presently on the working groups' agendas may be done at multi-year intervals instead of annually, or not at all.

7.4 The committee recognised that the present Scientific Committee working group structure could, with appropriate modification, address present and future needs. It felt that WG-FSA-SAM could be expanded to serve as a technical group to address issues relevant to all three existing working groups (WG-FSA, WG-EMM, ad hoc WG-IMAF). One possible version would be that WG-FSA-SAM be used by all three groups to address technical assessment and modelling issues. These would include fish stock assessment issues (of interest to WG-FSA), krill, seal and seabird stock assessment issues (of interest to WG-EMM), and estimation of the status of seabirds (of interest to WG-IMAF).

7.5 As WG-FSA-SAM would be addressing issues of interest to all working groups, the Scientific Committee would need to provide guidance on priority of tasks to be undertaken. Therefore, WG-FSA-SAM should become a working group of the Scientific Committee. The Scientific Committee would need to conduct a long-term review of its work plan using the model developed by WG-EMM's five-year plan. This would allow long-term planning by WG-FSA-SAM so that the appropriate experts could be present at the appropriate meetings. It would be very fluid in its composition, duration of meeting time and issues addressed. It might meet two weeks if considering both fish and krill–predator–prey issues or one week, for example, when considering only fish stock assessment issues. Conversely, WG-EMM may need to meet for one or two weeks depending on its workload for that year. As the work of WG-FSA becomes more static where assessments are conducted at multi-year intervals instead of annually using standard models, it might need one or two weeks to meet depending on its work load.

7.6 The Working Group agreed that the proposed restructuring of WG-FSA-SAM has the potential of providing flexibility to have the appropriate experts present to address specific questions of interest to WG-EMM. Conversely, this new structure may reduce the total time some members might spend participating in meetings.

7.7 The Working Group agreed that it was necessary to ensure that the restructuring did not create the situation in which biologists and quantitative modellers are separated by groups as it is important to have input from both areas of expertise to develop appropriate management advice.

ICED

7.8 ICED is a multidisciplinary international initiative to develop a coordinated circumpolar approach to understand climate interactions in the Southern Ocean, the implications for ecosystem dynamics, the impacts on biogeochemical cycles, and the development of management procedures (WG-EMM-06/26). Several CCAMLR scientists have been instrumental in developing this initiative and a key aim of ICED is to link with CCAMLR scientists to develop management procedures that include relevant aspects of the wider operation of ocean ecosystems.

7.9 The Working Group recognised the close connection many CCAMLR scientists had with various aspects of ICED and encouraged continued cooperation between the two groups. The Working Group looked forward to seeing results of activities relative to CCAMLR's work completed by the ICED initiative.

Ross Sea ecosystem

7.10 Data on diet, foraging behaviour and habitat use for killer whales, Weddell seals, penguins, petrels and skuas found in the Ross Sea shelf ecosystem are summarised to increase appreciation among fishery managers of the close spatial and temporal ecological overlaps among predators and the Antarctic toothfish fishery and Antarctic minke whale harvest (WG-EMM-06/29). Most top predators in the Ross Sea feed at relatively great depths while three species feed in the entire water column and others forage near the surface to mid-depths.

7.11 The Working Group recognised that, as the Ross Sea fishery has expanded over the last few years, there was an increasing need to investigate effects on top predators and toothfish prey species which overlap spatially and temporally with the toothfish fishery.

7.12 The need to address ecosystem effects in the Ross Sea, and even the entire East Antarctic region, in the future work of WG-EMM was also noted. It was noted that the Ross Sea ecosystem in particular was a fish-centric ecosystem as opposed to the west Atlantic krill-centric ecosystem. The Working Group encouraged researchers working in these areas to participate in future WG-EMM meetings and to submit appropriate information, data and research results during future years.

7.13 It was agreed that WG-EMM needed to provide increased emphasis on ecosystem aspects of the Ross Sea and East Antarctic regions, however, it was also noted that many of the Working Group's agenda items addressed Antarctic-wide issues and that these should not in the future be partitioned into regional initiatives.

Workshop on krill-based ecosystem dynamics

7.14 The Working Group was informed by correspondence to Dr Reid that the Lenfest Ocean Program, a non-profit private organisation that supports scientific research, is considering sponsoring a scientific/technical workshop on krill-based ecosystem dynamics in the southwest Atlantic to be held in April–June 2007. The workshop would further develop a broad-based technical understanding of: (i) the dynamics of the krill-based ecosystem in the southwest Atlantic, (ii) how climate change and fishing might impact those dynamics, and (iii) what might need to be done to enhance measures taken by CCAMLR to conserve species dependent on krill for food.

7.15 The Working Group noted the utility of the proposed workshop and it would be very interested in seeing the outcomes of the workshop. Interested Members should contact the Lenfest Ocean Program directly (www.lenfestoceans.org).

FAO Workshop on Modelling Ecosystem Interactions
for Informing an Ecosystem Approach to Fisheries

7.16 The Working Group was informed that FAO will be conducting a Workshop on Modelling Ecosystem Interactions for Informing an Ecosystem Approach to Fisheries during the second or third quarter of 2007. Participation will be by FAO invitation only. However, as CCAMLR scientists have considerable expertise relative to ecosystem modelling, it is likely that individuals with high level of experience in this topic will be welcomed to participate. The CCAMLR Secretariat was invited to submit the names of a small number of experts who would be able to contribute. Interested individuals should contact the CCAMLR Secretariat.

ADOPTION OF THE REPORT AND CLOSE OF THE MEETING

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

8.2 At the close of the meeting, Dr Pinkerton advised the Working Group that New Zealand had confirmed that it would host the meeting of WG-EMM in 2007. The venue and time of the meeting would be announced as soon as these were finalised.

8.3 In closing the meeting, Dr Reid thanked all participants for their goodwill and collaboration, and for their detailed contributions to the meeting. He also thanked Dr Miller and the Secretariat staff for their support.

8.4 Dr Reid also thanked the Namibian Delegation for their contributions and warm hospitality. He encouraged further participation at future meetings of CCAMLR working groups.

8.5 Dr Holt, on behalf of the Working Group, thanked Dr Reid for his leadership. This was Dr Reid's first year as Convener of WG-EMM and he had met the challenges of this position with enthusiasm, and had led the meeting to a successful conclusion.

8.6 The meeting was closed.

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APPENDIX A

AGENDA

Working Group on Ecosystem Monitoring and Management
(Walvis Bay, Namibia, 17 to 28 July 2006)

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

2. Second 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 Other prey species
   - 4.3 Methods
   - 4.4 Future surveys
   - 4.5 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
   - 7.1 Reorganisation of the work of the Scientific Committee

8. Adoption of report and close of meeting.

APPENDIX B

LIST OF PARTICIPANTS

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(Walvis Bay, Namibia, 17 to 28 July 2006)

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APPENDIX C

LIST OF DOCUMENTS

Working Group on Ecosystem Monitoring and Management
(Walvis Bay, Namibia, 17 to 28 July 2006)

WG-EMM-06/1	Provisional Agenda and Provisional Annotated Agenda for the 2006 Meeting of the Working Group on Ecosystem Monitoring and Management (WG-EMM)
WG-EMM-06/2	List of participants
WG-EMM-06/3	List of documents
WG-EMM-06/4	CEMP indices: 2006 update Secretariat
WG-EMM-06/5	Krill fishery report: 2006 update Secretariat
WG-EMM-06/6 Rev. 1	Summary of notifications for krill fisheries in 2006/07 Secretariat
WG-EMM-06/7	By-catch of small fish in a sub-Antarctic krill fishery K.A. Ross, L. Jones, M. Belchier and P. Rothery (United Kingdom)
WG-EMM-06/8	Development of foraging behaviour and evidence of extended parental care in the gentoo penguin (*Pygoscelis papua*) M. Polito and W.Z. Trivelpiece (USA)
WG-EMM-06/9	Impact of predation by Cape fur seals *Arctocephalus pusillus* on Cape gannets *Morus capensis* at Malgas Island, Western Cape, South Africa A.B. Makhado, R.J.M. Crawford and L.G. Underhill (South Africa) (*African Journal of Marine Science*, submitted)
WG-EMM-06/10	Demography of Antarctic krill in the Lazarev Sea (Subarea 48.6) in the 2005/06 season V. Siegel (Germany)
WG-EMM-06/11	Descriptive analysis of mesopelagic backscatter from acoustic data collected in the Ross Sea R.L. O'Driscoll (New Zealand)

WG-EMM-06/12	A spatial multi-species operating model (SMOM) of krill–predator interactions in small-scale management units in the Scotia Sea É. Plagányi and D. Butterworth (South Africa)
WG-EMM-06/13	Time series of Drake Passage Oscillation Index (DPOI) from 1952 to 2006, Antarctica M. Naganobu and K. Kutsuwada (Japan)
WG-EMM-06/14	Progress towards a trophic model of the ecosystem of the Ross Sea, Antarctica, for investigating effects of the Antarctic toothfish fishery M. Pinkerton, S. Hanchet and J. Bradford-Grieve (New Zealand)
WG-EMM-06/15	An overview of a large ecosystem survey of the southwest Indian Ocean sector of the Southern Ocean (CCAMLR Division 58.4.2) S. Nicol, S. Kawaguchi, T. Jarvis, G. Williams, N. Bindoff, D. Thiele (Australia), J. Schwarz (Germany), A. Davidson, S. Wright, J. Gedamke and P. Thompson (Australia) (IWC SC Meeting Document Number SC/58/E27)
WG-EMM-06/16	Biomass of Antarctic krill (*Euphausia superba*) off east Antarctica (30–80°E) in January–March 2006 T. Jarvis, E. van Wijk, N. Kelly, S. Kawaguchi and S. Nicol (Australia)
WG-EMM-06/17	Winter distribution of chinstrap penguins from two breeding sites in the South Shetland Islands of Antarctica W.Z. Trivelpiece, S. Buckelew, C. Reiss and S.G. Trivelpiece (USA)
WG-EMM-06/18	Technical note on the sampling procedures of the Saga Sea J. Hooper (United Kingdom), T. Knutsen (Norway), D. Agnew (United Kingdom) and S.A. Iversen (Norway)
WG-EMM-06/19	Further progress on modelling the krill–predator dynamics of the Antarctic ecosystem M. Mori (Japan) and D.S. Butterworth (South Africa) (IWC SC Meeting Document Number SC/58/E14)
WG-EMM-06/20	A comparison of model predictions from KPFM1 and KPFM2 J. Hinke, G. Watters (USA), S. Hill and K. Reid (United Kingdom)
WG-EMM-06/21	Comparison of long-term trends in abundance, recruitment and reproductive success of five populations of *Pygoscelis* penguins in the South Shetland Islands, Antarctica J.T. Hinke (USA), K. Salwicka (Poland), S.G. Trivelpiece, G.M. Watters and W.Z. Trivelpiece (USA)

WG-EMM-06/22	KPFM2, be careful what you ask for – you just might get it G.M. Watters, J.T. Hinke (USA), K. Reid and S. Hill (United Kingdom)
WG-EMM-06/23	The krill maturity cycle: a conceptual description of the seasonal cycle in Antarctic krill S. Kawaguchi, T. Yoshida, L. Finley, P. Cramp and S. Nicol (Australia)
WG-EMM-06/24	Learning about Antarctic krill from the fishery S. Kawaguchi and S. Nicol (Australia)
WG-EMM-06/25	Intra-annual variability in the abundance of Antarctic krill (*Euphausia superba*) at South Georgia, 2002–2005: within-year variation provides a new framework for interpreting previous 'annual' krill density estimates R.A. Saunders, J.L. Watkins, K. Reid, E.J. Murphy, P. Enderlein, D.G. Bone and A.S. Brierley (United Kingdom) (*CCAMLR Science*, submitted)
WG-EMM-06/26	Integrated analyses of circumpolar climate interactions and ecosystem dynamics in the Southern Ocean (ICED) E.J. Murphy (United Kingdom), E. Hofmann (USA) and R. Cavanagh (United Kindom)
WG-EMM-06/27	On possible influence of continuous krill fishing technology with the use of 'air-bubbling suspension system' on ecosystem elements S.M. Kasatkina and V.A. Sushin (Russia)
WG-EMM-06/28	An illustrative management procedure for exploring dynamic feedback in krill catch limit allocations among small-scale management units É. Plagányi and D. Butterworth (South Africa)
WG-EMM-06/29	Managing ecosystem uncertainty: critical habitat and dietary overlap of top-predators in the Ross Sea D. Ainley, V. Toniolo, G. Ballard (USA), K. Barton (New Zealand), J. Eastman (USA), B. Karl (New Zealand), S. Focardi (Italy), G. Kooyman (USA), P. Lyver (New Zealand), S. Olmastroni (Italy), B.S. Stewart, J.W. Testa (USA) and P. Wilson (New Zealand)
WG-EMM-06/30 Rev. 1	A compilation of parameters for a krill–fishery–predator model of the Scotia Sea and Antarctic Peninsula S. Hill, K. Reid, S. Thorpe (United Kingdom), J. Hinke and G. Watters (USA) (*CCAMLR Science*, submitted)

WG-EMM-06/31	Preliminary report from New Zealand research voyages to the Balleny Islands in the Ross Sea region, Antarctica, January to March 2006 B.R. Sharp (New Zealand)
WG-EMM-06/32	A review and update of krill biomass trends in the South Shetland Islands, Antarctica, using the simplified stochastic wave born approximation C.S. Reiss and A.M. Cossio (USA)
WG-EMM-06/33	Last investigations of Ukraine in Antarctica connected with assumed marine protected area Delegation of Ukraine
WG-EMM-06/34	The state of krill (*E. supberba*) fisheries in Subareas 48.2 and 48.1 in February–May 2006 V.A. Bibik (Ukraine)
WG-EMM-06/35	A nonparametric algorithm to model movement between polygon subdomains in a spatially explicit ecosystem model T. Lenser and A. Constable (Australia)
WG-EMM-06/36	Estimates of krill biomass with commercial significance in small-scale management units applying geostatistics techniques S.M. Kasatkina and P.S. Gasyukov (Russia)
WG-EMM-06/37	Regionalisation of the Southern Ocean: a statistical framework B. Raymond and A. Constable (Australia)
WG-EMM-06/38 Rev. 1	Using the EPOC modelling framework to assess management procedures for Antarctic krill in Statistical Area 48: evaluating spatial differences in productivity of Antarctic krill A.J. Constable (Australia)
WG-EMM-06/39	A life table for female Antarctic fur seals breeding at Cape Shirreff, Livingston Island M.E. Goebel, B.I. McDonald, J.D. Lipsky (USA), V.I. Vallejos, R.A. Vargas, O. Blank (Chile), D.P. Costa (USA) and N.J. Gales (Australia)
WG-EMM-06/40	Report of the Workshop on Management Procedures (Walvis Bay, Namibia, 17 to 21 July 2006)
Other Documents	
WG-EMM-06/P1	Seabird research at Cape Shirreff, Livingston Island, Antarctica, 2005/06 E.S.W. Leung, R.A. Orben and W.Z. Trivelpiece (USA) (*AMLR 2005/2006 Field Season Report*)

WG-EMM-06/P2	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*, 86 (9): 2408–2417)
WG-EMM-06/P3	Contrasting population changes in sympatric penguin species in association with climate warming J. Forcada, P.N. Trathan, K. Reid, E.J. Murphy and J.P. Croxall (United Kingdom) (*Global Change Biology*, 12: 1–13)
WG-EMM-06/P4	Foraging dynamics of macaroni penguins (*Eudyptes chrysolophus*) at South Georgia during brood-guard P.N. Trathan, C. Green, J. Tanton, H. Peat, J. Poncet and A. Morton (United Kingdom) (*Marine Ecology Progress Series*, in press)
WG-EMM-06/P5	Spatial and temporal variability in the fish diet of Antarctic fur seal *Arctocephalus gazella* in the atlantic sector of the southern ocean K. Reid, D. Davis, I.J. Staniland (United Kingdom) (*Canadian Journal of Zoology*, in press)
WG-EMM-06/P6	Effects of variability in prey abundance on reproduction and foraging in chinstrap penguins (*Pygoscelis antarctica*) D.A. Croll, D.A. Demer, R.P. Hewitt, J.K. Jansen, M.E. Goebel and B.R. Tershy (USA) (*Journal of Zoology*, in press)
WG-EMM-06/P7	See WG-EMM-06/39
CCAMLR-XXV/BG/5	Collaboration with CCAMLR on a workshop regarding Antarctic krill predators Secretariat
SC-CAMLR-XXV/BG/2	Report of the Second Meeting of the Subgroup on Acoustic Survey and Analysis Methods (Hobart, Australia, 23 and 24 March 2006)
SC-CAMLR-XXV/BG/5	Convener's progress report on intersessional activities of the Subgroup for the Implementation of the CCAMLR 2008 IPY Project V. Siegel (Convener, Steering Group 'CCAMLR 2008 IPY Survey')
SC-CAMLR-XXV/BG/6	Observer's Report from the 58th Meeting of the Scientific Committee of the International Whaling Commission (St Kitts, 26 May to 6 June 2006) CCAMLR Observer (K.-H. Kock, Germany)

APPENDIX D

REPORT OF THE SECOND WORKSHOP ON MANAGEMENT PROCEDURES

(Walvis Bay, Namibia, 17 to 21 July 2006)

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REPORT OF THE SECOND WORKSHOP ON MANAGEMENT PROCEDURES

(Walvis Bay, Namibia, 17 to 21 July 2006)

INTRODUCTION

1.1 The Second Workshop on Management Procedures to Evaluate Options for Subdividing the Krill Catch Limit among Small-Scale Management Units (SSMUs) was held at the Pelican Bay Hotel, Walvis Bay, Namibia. The workshop was conducted during the first week of WG-EMM-06 (17 to 21 July 2006) and was co-convened by Ms T. Akkers (South Africa) and Dr C. Reiss (USA).

1.2 The preliminary 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 Dr S. Hill (UK), Mr J. Hinke (USA), Drs C. Jones (USA), S. Nicol (Australia), M. Pinkerton (New Zealand), D. Ramm (Data Manager) and K. Reid (Convener, WG-EMM).

1.4 The first workshop was held in 2005 (SC-CAMLR-XXIV, Annex 4, Appendix D), and aimed to evaluate management procedures for the krill fishery by examining 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.

1.5 At its meeting in 2005, WG-EMM welcomed the developments achieved during the first workshop, and agreed to a second workshop to continue the evaluation of procedures to allocate the precautionary krill catch limit in Area 48 among SSMUs.

1.6 The terms of reference for the second workshop were to (SC-CAMLR-XXIV, Annex 4, paragraph 6.44):

(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 the SSMUs in Statistical Area 48.

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

1.7 Papers tabled for consideration at the workshop were WG-EMM-06/12, 06/20, 06/22, 06/23, 06/28, 06/30 Rev. 1, 06/35, 06/38 Rev. 1 and 06/39.

STATE OF MODELLING

Requested model incorporations

2.1 WG-EMM-05 specified that models relevant to the evaluation of options for subdividing the precautionary limit of krill catch in Area 48 amongst SSMUs should include (SC-CAMLR-XXIV, Annex 4, paragraph 6.18):

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

2.2 WG-EMM-05 requested that candidate operating models should include performance measures that allow results to be compared between models (SC-CAMLR-XXIV, Annex 4, paragraphs 2.3 and 6.45). The performance factors should include measures pertaining to: (i) predators, (ii) krill and (iii) fishery.

2.3 Three models relevant to the evaluation of options for subdividing the precautionary limit of krill catch in Area 48 amongst SSMUs were presented to the workshop. These models, and the relevant documents, were EPOC (Ecosystem, Productivity, Ocean, Climate) (WG-EMM-06/38 Rev. 1), SMOM (Spatial Multispecies Operating Model) (WG-EMM-06/12 and 06/28) and KPFM2 (Krill–Predator–Fishery Model) (WG-EMM-06/20 and 06/22).

2.4 The workshop recognised that it was important that models show how uncertainty in parameters, environmental effects and different model structures/assumptions change the predicted dynamics of the system. EPOC, SMOM and KPFM2 handle uncertainty in a similar way to produce a probability 'envelope' of future states that is considered likely to bound the true state.

Status of EPOC

2.5 The EPOC modelling framework was first presented in WG-EMM-05/33. WG-EMM-06/38 Rev. 1 described a model of krill productivity in Area 48 within the EPOC model framework. Krill productivity was parameterised using data including empirical data on krill growth and reproduction, insolation, and satellite data on ocean dynamics, sea-ice concentration, sea-surface temperature and surface chlorophyll concentration. EPOC was demonstrated to have the potential to investigate the productivity of krill under various scenarios of environmental variability/climate change.

Status of SMOM

2.6 WG-EMM-06/12 described SMOM, which is based on the dynamics of krill and two generic predators (penguins and fur seals). Coded in AD-ModelBuilder, SMOM aims to be a minimally realistic, quantitative representation of current reality and future dynamics.

2.7 WG-EMM-06/28 described an example of how a Management Strategy Evaluation (MSE) approach could be used to manage the allocation of krill catch in Area 48 amongst SSMUs. In this example, the available observations of the state of the system are first identified. Next, SMOM is used as an operating model to predict the state of the resource in the future from the observations under a given management strategy. The likely future states are evaluated using a set of performance statistics. The performance statistics are used to compare candidate management strategies that adjust catches according to control/management rules. The MSE approach suggested here illustrates the potential utility of feedback within a formalised adaptive management method.

Status of KPFM

2.8 KPFM was first presented in WG-EMM-05/13. This model is now referred to as KPFM1. KPFM2 was developed from KPFM1 to address the requirements given during WG-EMM-05 and summarised above (paragraphs 2.1 and 2.2). KPFM2 was recognised by the workshop as having addressed the issues raised in WG-EMM-05.

2.9 In addition, KPFM2 can take into account some further issues identified as potentially important during the WG-EMM-05 Workshop on Management Procedures (SC-CAMLR-XXIV, Annex 4, Appendix D, paragraph 3.36), namely:

(i) predators that can forage outside their natal SSMUs
(ii) various plausible relationships between predator survival and foraging success
(iii) differential access to krill between different predators and fishery.

As well as those performance measures suggested by WG-EMM-05, some novel aggregate performance measures were also included in KPFM2.

2.10 KPFM2 follows from, but is substantially different to, KPFM1. However, WG-EMM-06/20 presented a comparison of KPFM1 and KPFM2 and the workshop was reassured that the models gave very similar results when they were applied to the same scenario.

2.11 WG-EMM-06/30 Rev. 1 presented a preliminary compilation of parameters that were applicable to models used to investigate interactions between krill, predators, environment and fishery in Area 48 (spatially resolved at the scale of the SSMUs and temporally resolved for a six-month time step). The workshop recognised the importance of developing a common parameter set applicable to multiple different models. It is also recognised as important that parameter values have an 'audit trail' so that values are traceable to their source.

2.12 Considerable discussion during the workshop addressed how aggregate performance measures should be used to present complex results to the Scientific Committee. Further

work will be required to agree on a set of aggregate performance measures that are comprehensible and reliable, and cover the range of information deemed necessary. In particular, aggregate performance measures should, *inter alia*:

(i) take into account and appropriately combine all model outputs considered valuable;

(ii) take into account correlations between various measures;

(iii) provide sufficient information to enable performance to be assessed relative to Article II;

(iv) aim to be value-free (e.g. 'high versus low' rather than 'good versus bad' or 'acceptable versus not acceptable').

REVIEW OF PARAMETER PLAUSIBILITY AND SENSITIVITY

3.1 The workshop agreed that an appropriate way to use the three available models would be to use KPFM2 as the primary model to examine the implications of various catch allocation schemes, and to use EPOC and SMOM to provide additional insights and to examine sensitivities to specific sources of uncertainty.

Requested model incorporations

Alternate parameterisation of transport and advection

3.2 The workshop reiterated that a key source of uncertainty is the role of advection (flux) in krill dynamics. The bounds on this uncertainty are: no flux, with local populations maintained by local recruitment; and flux with krill advected as passive drifters on ocean currents. In KPFM2, krill movement between areas is specified in a seasonally resolved matrix of instantaneous transport rates. No flux is represented by setting all cells to zero. Matrices parameterised using output from the circulation model developed by OCCAM are used to represent flux. SMOM can use random krill movements between areas. EPOC has the potential to simulate a range of flux scenarios.

3.3 WG-EMM-06/35 described an algorithm for modelling biomass flow between areas that reduces the underestimation of biomass retention within areas. Many movement algorithms assume instant mixing throughout an area once biomass has entered the area. While this may be satisfactory for modelling the behaviour within that area, it might not be satisfactory for modelling the subsequent departure of the biomass into other areas. This paper provides a solution to this problem and may be of assistance in developing operating models for evaluating krill management procedures. This algorithm has not been used to estimate potential krill flux, but the paper shows that the assumptions of mixing within models need to be considered before accepting that they will adequately reflect the desired movement patterns of the model species, such as krill.

3.4 The workshop agreed that the transport matrices presented in WG-EMM-06/30 Rev. 1 could be used to explore uncertainty about flux.

3.5 The influence of flux on predator populations will depend on the ability of predators to move between areas. Possible bounds on this uncertainty are no movement of predators between SSMUs and a homogenous distribution of predators during the winter (with no movement in summer). It was proposed that this may be a way of parameterising KPFM2 in order to explore this uncertainty. However, the homogenous distribution of all predators is not biologically sensible and produces implausible dynamics in KPFM2. The winter predator distributions presented in WG-EMM-06/30 Rev. 1 were considered more plausible.

Short time steps and/or seasonality

3.6 The time step in KPFM2 can be set to any period. The model runs presented to the workshop, and the parameters presented in WG-EMM-06/30 Rev. 1, were based on a seasonal time step of six months, which captures differences between SSMUs in the seasonal overlap between fishing activities and predator breeding. The time step in EPOC can be any period from one day upwards. SMOM is currently parameterised as an annual model.

Krill density to halt fishing

3.7 KPFM2 allows the analyst to specify the threshold SSMU-scale krill density that causes voluntary cessation of fishing operations. The workshop was unable to identify appropriate values for this threshold, but noted that it might be linked to predator foraging performance.

3.8 The average krill density in an SSMU may well be lower than the threshold density required for profitable operations by the fishing fleet. The average SSMU-scale density will not therefore reflect the density reacted to by the fleet on smaller-scale fishing grounds. Such considerations also apply to krill predators which also use only a portion of the SSMU for foraging. The SSMUs and the modelling process, however, were designed taking account of the distribution of historical catches and predator foraging locations.

Plausibility, sensitivity and uncertainty in other parameters

3.9 Another key source of uncertainty is the form of the relationship between prey availability and predator population responses and how this accommodates processes such as prey switching, predator saturation and dependence on highly aggregated resources. KPFM2 and SMOM can accommodate a range of responses from hyperstable, through linear to hyperdepletion (Figure 1). Uncertainty can be included in EPOC at desired points in the ecological functions of the taxa.

3.10 Other sources of uncertainty include:

(i) The role of mesopelagic fish in the system –

WG-EMM-06/30 Rev. 1 suggested that myctophids may be the most important krill consumers, but this is based on limited evidence (see also subparagraph (iii)).

(ii) The relative competitive abilities of predators and the fishery –

KPFM2 can be used to explore this issue.

(iii) The size and age ranges of krill targeted by different predators and the fishery –

KPFM2 does not represent size-selective targeting, but the competition settings might be used to explore this issue. However, it was noted that EPOC can include age structure in its representation of populations.

(iv) Starting conditions –

KPFM2 runs can be initialised with predator and prey populations at equilibrium. This can be used as a reference point against which to compare the effects of different fishing options. However, it is important to consider scenarios where predator populations might be increasing or decreasing.

(v) Trends in krill recruitment or its variability –

There is published evidence for such trends (Siegel and Quetin, 2003). Decreasing recruitment might make it difficult for the Commission to appropriately manage fisheries to achieve the objectives of Article II. EPOC can model krill recruitment from environmental variables.

(vi) Fleet dynamics –

The current models do not include explicit representations of fleet behaviour, however the aims of the workshop can be partly achieved by considering the distribution of catches at the SSMU scale.

(vii) The mechanisms through which krill availability affects predator dynamics –

In KPFM2 and SMOM this is modelled primarily as an effect on predator recruitment. However, both models can be used to explore the effects of krill availability on predator survival.

3.11 WG-EMM-06/30 Rev. 1 presented a compilation of parameter values for use in ecosystem models. Empirically derived predator parameters should be presented as means and ranges to represent uncertainty in these values. Fur seal mortality parameters were updated using data from WG-EMM-06/P7. This also affected fur seal recruitment parameters.

3.12 The workshop noted that the aggregation of diverse species into 'generic' predators might potentially mask important species-specific responses. It is therefore important that the range of 'generic' predators represents the range of life histories in the predator community.

3.13 The workshop noted that parameters and functions in the models should capture important aspects of the dynamics of krill and its predators but that the parameters do not necessarily need to represent specific biological processes to achieve this.

3.14 WG-EMM-06/22 presented further development of aggregate performance measures, including the use of aggregate trade-off plots to evaluate the candidate fishing options and other model output. Examples of these trade-off figures are presented in Figures 2(a) (using the arithmetic mean) and 2(b) (using the geometric mean). In these plots, the columns represent different fishing options and the rows represent SSMUs. The upper value in each cell represents the aggregate 'Fishery Performance' score, and the lower value represents the aggregate 'Ecosystem Performance' score (on a scale of 0 to 1 with 1 representing highest performance). Individual cells are shaded according to the magnitude of the difference between the two performance values and represent the aggregate trade-off.

3.15 The workshop agreed that aggregate trade-off plots are important in providing a basis for discussion, but should be interpreted with caution. The workshop considered that the value of the performance score may need to be interpreted relative to the range over which most important differences occur.

MODEL OUTPUTS AND PERFORMANCE MEASURES

4.1 The workshop agreed that the two major sources of uncertainty to be addressed in the workshop, and the appropriate parameter sets to bound these uncertainties in KPFM2, were:

(i) the role of flux in krill dynamics: bounded by the seasonal movement matrices based on OCCAM output and no movement;

(ii) the degree of stability in the relationship between krill availability and predator population responses: bounded by *rphi* values of 0.37 and 1 (see Figure 1).

4.2 The workshop noted the broad agreement in trajectories between SMOM and KPFM2 in simulation trials when the parameterisation of the two models was consistent. On this basis, as well as on biological plausibility of the results, it was agreed that there was confidence in these modelling approaches for evaluating the different fishing options.

4.3 The workshop examined results from a large number of KPFM2 scenarios. The workshop first considered the simulated trajectories of abundance for predator groups from trials using random recruitment and allocation of Fishing Options 1 to 4 with 60-year simulations and 50 Monte Carlo trials per simulation.

4.4 It was agreed that use of aggregate outputs of population trajectories should be examined, though it was recognised that: (i) aggregating can potentially smooth projections across all species, and relative effects on species may be different; (ii) the values of the aggregate measures will be influenced by the individual measures that are included; and (iii) the values of the aggregate scores may not be scaled correctly to appropriately reflect the

magnitude of the effects of the fishing options. The workshop recognised the importance of examining all output components before making decisions. The workshop examined a variety of performance measures plotted against each other, and agreed that this was a useful way to examine trade-offs between different ecosystem and fishery characteristics.

4.5 The workshop examined several types of aggregate trade-off plots to evaluate the candidate fishing options. While plots such as these are ultimately desirable to summarise outcomes and trade-offs, it was recognised that at present they require further development. However, they provided a very useful mechanism towards generating discussions (see paragraphs 3.12 to 3.14).

4.6 The workshop agreed that KPFM2 could first be used to explore a fishing scenario which originally concerned the Commission. This scenario is the continued development of the krill fishery towards taking the full catch limit with the potential to concentrate all its fishing effort in only a small area. This scenario was the reason for establishing the process of subdividing the Area 48 krill catch limit amongst SSMUs.

4.7 To examine this concern, a primary simulation scenario was performed where fishing was conducted only in Subarea 48.1 under a constant quota determined as 0.09 (γ) of an estimate of biomass just prior to the fishing period. Other trials were also undertaken, these included having fishing mostly in Subarea 48.1 (87.5%) with some fishing in Subareas 48.2 and 48.3 (12.5%) and carrying out scenarios using different values of γ (0.03, 0.06, 0.09). Each scenario included 50 Monte Carlo trials across 60 years (with fishing starting at year 21 and stopping at year 41 and the sources of uncertainty outlined in paragraph 4.1).

4.8 On the basis of an examination of individual trajectories and performance indicators from these trials, the workshop agreed that under a flux model, increasing fishing in Subarea 48.1 can have an impact on other areas. The magnitude of these effects is dependent on the level of the quota. The workshop noted that if models are run with no movement, localised effects could be more substantial. Results for the primary scenario are presented in Figure 3.

4.9 The workshop agreed that these results corroborate the concerns of the Commission about the effects of localised fishing and are consistent with the notion that this fishery should be managed on a spatial basis.

4.10 SMOM was modified during the workshop to be comparable with KPFM2. SMOM was set up with similar parameters to KPFM2 in terms of: (i) periods of fishing and recovery in the simulation; (ii) allocated fishing catch; (iii) predator depletion and recovery performance measures; and (iv) the parameter set originally detailed in WG-EMM-06/30 Rev. 1 and modified during the workshop.

4.11 Differences between the versions of SMOM and KPFM2 used in the workshop, and the simulations performed, included: (i) penguins and seals are the only predators in SMOM – fish and whales are not included explicitly, though their consumption is included in the model indirectly; (ii) uncertainty in the adult survival rates for predators is included in SMOM; (iii) movement of krill in SMOM is not comparable with movement in KPFM2, so the comparison can only usefully be completed under the 'no movement' scenario; and (iv) the present version of SMOM does not consider differential access to krill between predators and the fishery.

4.12 The workshop next considered the performance measure trade-offs associated with Fishing Options 1 to 4. As an example of this, Figure 4(a) shows predator trajectories (seals, penguins, whales and fish) in two selected SSMUs under Fishing Options 1 and 4 (overlaid). A comparison of Fishing Options 1 and 4 in this figure demonstrated that the former was skewed towards relatively higher fishery performance and the latter slightly skewed towards relatively higher ecosystem performance. Figure 4(b) shows predator trajectories (penguins and seals) from the SMOM model and demonstrates similar trajectories to those from KPFM2, supporting the suggestion that Fishing Option 1 results in lower ecosystem performance.

4.13 Results from the modified SMOM agree well (qualitatively) with simulation results from KPFM2 in those scenarios that could be tested (e.g. Figures 4(a) and 4(b)). The modified SMOM also demonstrated that it can compare performance measures across different management schemes in a similar way to KPFM2. This shows that multiple approaches are useful in exploring how ecosystem dynamics can be modelled for management purposes.

4.14 The workshop next considered the trade-offs under Fishing Option 5. Figure 5(a) shows output from KPFM2 illustrating an example of changes in catch and predator trajectories when catch is adjusted in response to periodic reassessments of resource status. An illustrative feedback catch control rule using SMOM also highlighted the contrast in predator trajectories when assuming that initial catch allocations are fixed over time rather than being adjusted in response to changes in trends observed from monitoring data (Figure 5(b)). Additional KPFM2 and SMOM results showed the extent to which the efficacy of a feedback mechanism relied on the number and types of future monitoring data available. The workshop agreed that this demonstrates how monitoring standing stock and consequent adjustments in fishing allocation can improve performance measures.

4.15 An example was given of how SMOM can be used to develop a management scheme for Area 48 which includes feedback through management control rules. Two management responses to negative changes in monitoring indicators in an SSMU were discussed: (i) transfer of catch from an affected SSMU to a pelagic SSMU with no land-based predators; and (ii) a reduction of catch in the affected SSMU resulting in a lower overall catch.

4.16 The workshop considered how to make judgments regarding optimal trade-offs, and agreed that this was more appropriate to the role of the Commission. However, it was recommended that advice should be developed based on trade-offs relative to Article II of the CAMLR Convention.

4.17 When the workshop specifically considered the trajectories of fish using KPFM2, it was noted that there appear to be more dynamic responses in the model results than might be expected in reality. The parameterisation of this generic predator group may need to be revised.

4.18 The workshop discussed other aspects of the results of Fishing Option 1 and agreed that the performance of this option is highly dependent on the particular subset of the historical catch data used to initialise this option.

4.19 The workshop next examined fishery-based performance measures, which included an analysis of catch versus CV of catch (Figure 6). It was noted that the variance in catch is similar for all allocation options in most SSMUs.

4.20 In addition, the workshop examined the trade-off between the mean realised catch versus the distribution of catch relative to the historical catch. This demonstrated considerable differences between fishing options, including that distribution of catch in Fishing Option 1 most closely represents the historical distribution of catch (Figure 7).

4.21 Due to time constraints some members felt that while Fishing Option 1 had been vetted, other fishing options had not been similarly examined.

ADVICE TO WG-EMM

5.1 The workshop agreed that there had been a considerable amount of work done since WG-EMM-05 to develop models on which the provision of advice could be based (paragraphs 2.5 to 2.10).

5.2 In simulation trials conducted in KPFM2 it was apparent that, should the fishery occur entirely in Subarea 48.1 and catch an amount of krill equivalent to 9% of B_0, then there will be considerable negative impacts on the ecosystem in that region and, under the assumptions of flux, there would also be negative consequences for the downstream SSMUs in Subareas 48.2 and 48.3 (paragraphs 4.6 and 4.7).

5.3 In simulation trials both KPFM2 and SMOM indicated that Fishing Option 1 would have relatively greater negative impacts on the ecosystem compared to the other fishing options (paragraphs 4.12 and 4.13).

5.4 The workshop agreed that even when KPFM2 and SMOM were used to integrate uncertainties there were apparent differences in the consequences of the different fishing options, but the workshop agreed that further evaluation of Fishing Options 2 to 4 will require additional work on the development and interpretation of performance measures (paragraphs 4.13 and 4.16).

5.5 The workshop also agreed that all simulations indicated that the performance of Fishing Options 2 to 4 would be improved when monitoring data are used to update the allocation of catches among SSMUs, i.e. in a manner analogous to Fishing Option 5 (paragraphs 4.14 to 4.17).

FUTURE WORK

EPOC

6.1 The workshop reviewed EPOC and the way that model was used to explore the potential variability, between SSMUs and across Area 48, of the productivity of krill based on a model of krill food using ice, sea-surface temperature and chlorophyll data from satellites (WG-EMM-06/38 Rev. 1). Model results showed that: (i) local productivity (biomass, length

and recruitment) can vary widely between SSMUs at a given time, (ii) variation in recruitment over the time series can be up to 1.2 in some SSMUs, (iii) SSMU-scale processes may be too small for modelling krill dynamics, and (iv) regional movement models may not be needed to model areas within regions. The fits to existing data for the Antarctic Peninsula are promising.

6.2 The workshop noted that larger areas, such as SSMU groups and subareas, may be better suited to the modelling of krill dynamics. The workshop also noted that the scale of SSMUs was appropriate for the modelling of predator dynamics, and the interactions between predators and the fishery.

6.3 The workshop encouraged future work to tune the EPOC models to data and to provide important parameters for existing models (see also paragraph 2.5).

SMOM

6.4 The workshop encouraged future work to further develop the adaptive management framework in SMOM (see also paragraph 2.7). It was noted that some of this development would require considerable work.

KPFM2

6.5 The workshop recognised the considerable work in the development of KPFM2 to date and encouraged the authors to continue that development, particularly in relation to evaluation of feedback management procedures and conditioning to data.

Aggregate performance measures

6.6 The workshop encouraged the development of an agreed set of aggregate performance measures which are comprehensive and reliable, and cover the range of information outlined in paragraph 2.12.

Understanding fleet dynamics

6.7 The workshop recognised that it will be important for future modelling frameworks to capture some of the dynamics of the fishery. For example, how skippers make decisions about where they fish and when. Factors such as the abundance of krill, sea-ice conditions and the condition, location and colour of krill, as well as fishing experience, are important considerations in targeted fishing.

6.8 The workshop encouraged WG-EMM to consider this issue further.

Technical forum

6.9 The workshop encouraged intersessional discussions to provide guidance to model developers on issues such as:

- improvements and refinements to models
- incorporation of future needs into models
- developing datasets to provide further parameter estimations
- evaluation of the performance of models in relation to agreed technical requirements.

Spatially explicit management procedures

6.10 The workshop agreed that Fishing Options 5 (feedback management) and 6 (pulse fishing) need to be explored further. In that respect, the workshop recommended that consideration be given to defining what is meant by Fishing Option 6. In considering and evaluating both options, the workshop recommended that WG-EMM consider how knowledge, such as through field research including monitoring programs, might be acquired to assist in designing these options and for effectively implementing them in the longer term.

6.11 The workshop encouraged further development of spatially explicit management frameworks and to advance methods for use by CCAMLR to evaluate such management frameworks for krill, including, *inter alia*:

(i) development of operating models;

(ii) development and evaluation of decision rules for adjusting fishing activities (e.g. catch limits) based on field data in the future;

(iii) further development of performance measures and the means for providing integrated advice to the Commission on the relative merits of different strategies with respect to Article II.

ADOPTION OF REPORT AND CLOSE OF WORKSHOP

7.1 The report of the workshop was adopted.

7.2 In closing the workshop, the Co-conveners of the workshop, Ms Akkers and Dr Reiss, thanked Drs É. Plagányi (South Africa), A. Constable (Australia), G. Watters (USA), Hill, Mr Hinke and Dr Reid for further developing the three models which had been used by the workshop, and for undertaking numerous trials during the workshop. The Co-conveners also thanked the participants for their contributions which led to the success of the workshop. The workshop had been difficult and covered a substantial amount of work. The Co-conveners also thanked the Secretariat staff for their support.

7.3 Dr Constable, on behalf of the workshop, thanked the Co-conveners for their thorough preparations which had kept the workshop on track. Their guidance and leadership had allowed the workshop to articulate important issues and to achieve its aims.

7.4 The workshop was closed.

REFERENCES

Siegel, V. and R.M. Quetin. 2003. Krill (*Euphausia superba*) recruitment indices from the western Antarctic Peninsula: are they representative of larger regions? *Polar Biol*., 26: 672–679.

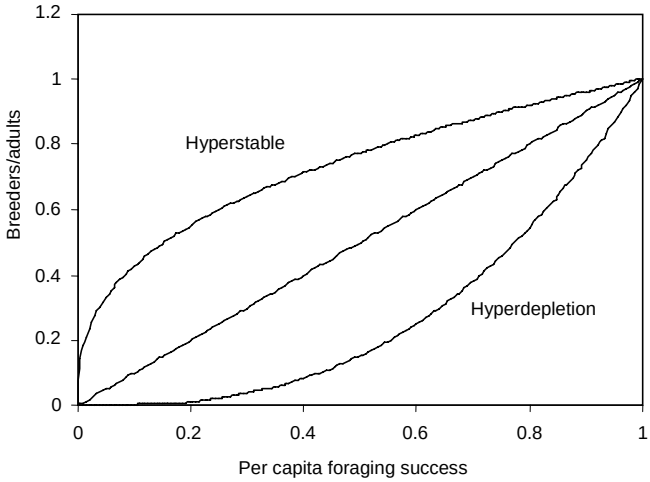

Figure 1: Potential forms of the relationship between prey availability (expressed as per capita foraging success) and the dynamic response of a predator population (the proportion of adults that breed). The central line shows a proportional response (shape parameter used in KPFM2, *rphi* = 1), while the upper (*rphi* = 0.37) and lower curves (*rphi* = 2.70) show the hyperstable and hyperdepletion situations respectively.

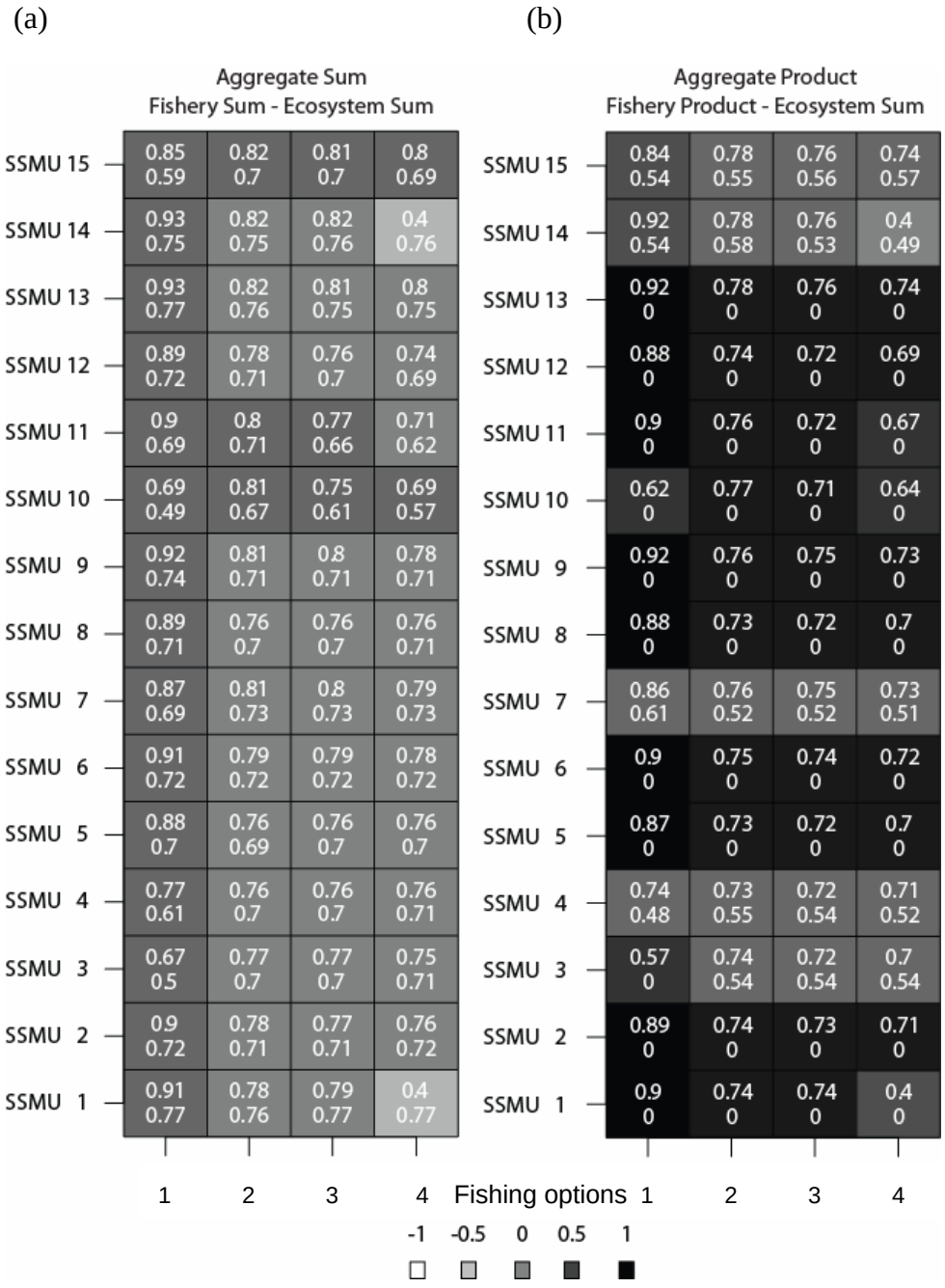

Figure 2: Examples of summarised results from KPFM2. Tables (a) and (b) present aggregate measures of fishery performance (top number in each cell) and ecosystem performance (lower number in each cell), for each SSMU (rows) resulting from each of four fishing options (columns). The shade of each cell indicates the relative value of the fishery and ecosystem aggregates. Dark shades indicate that fishery performance exceeds ecosystem performance while light shades indicate that ecosystem performance exceeds fishery performance. Intermediate shades are closer to a balanced trade-off where fishery and ecosystem performance are similar. The aggregate values in (a) are arithmetic means of component performance measures while those in (b) are geometric means. While arithmetic means show the average performance across components, geometric means indicate the simultaneous performance. Geometric means are sensitive to zeros. An ecosystem aggregate value of zero suggests that at least one ecosystem component is not meeting a performance criterion. The SSMUs are as follows: Antarctic Peninsula pelagic area (1), west (2); Drake Passage west (3), east (4); Bransfield Strait west (5), east (6); Elephant Island (7), east (8); South Orkney Islands pelagic area (9), west (10), northeast (11), southeast (12); and South Georgia pelagic area (13), west (14), east (15).

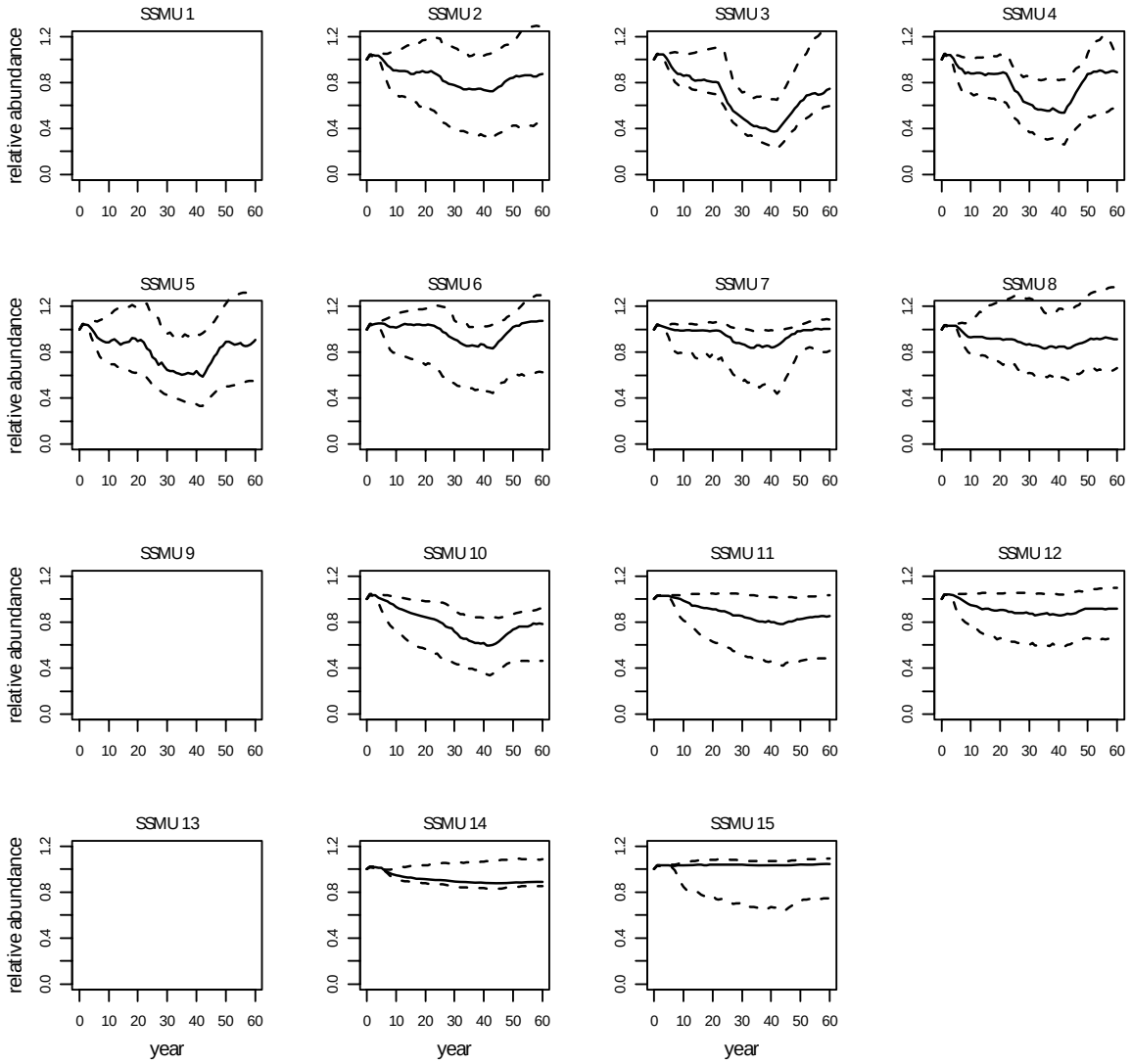

Figure 3: Penguin abundance trajectories demonstrating the effect of fishing occurring only in the SSMUs in Subarea 48.1 (SSMUs 1–8). The solid black lines are medians and the dashed black lines bound the 90% probability envelopes. These simulations were conducted with γ equal to 0.09. Penguins do not breed in SSMUs 1, 9 and 13. See Figure 2 for the list of SSMUs.

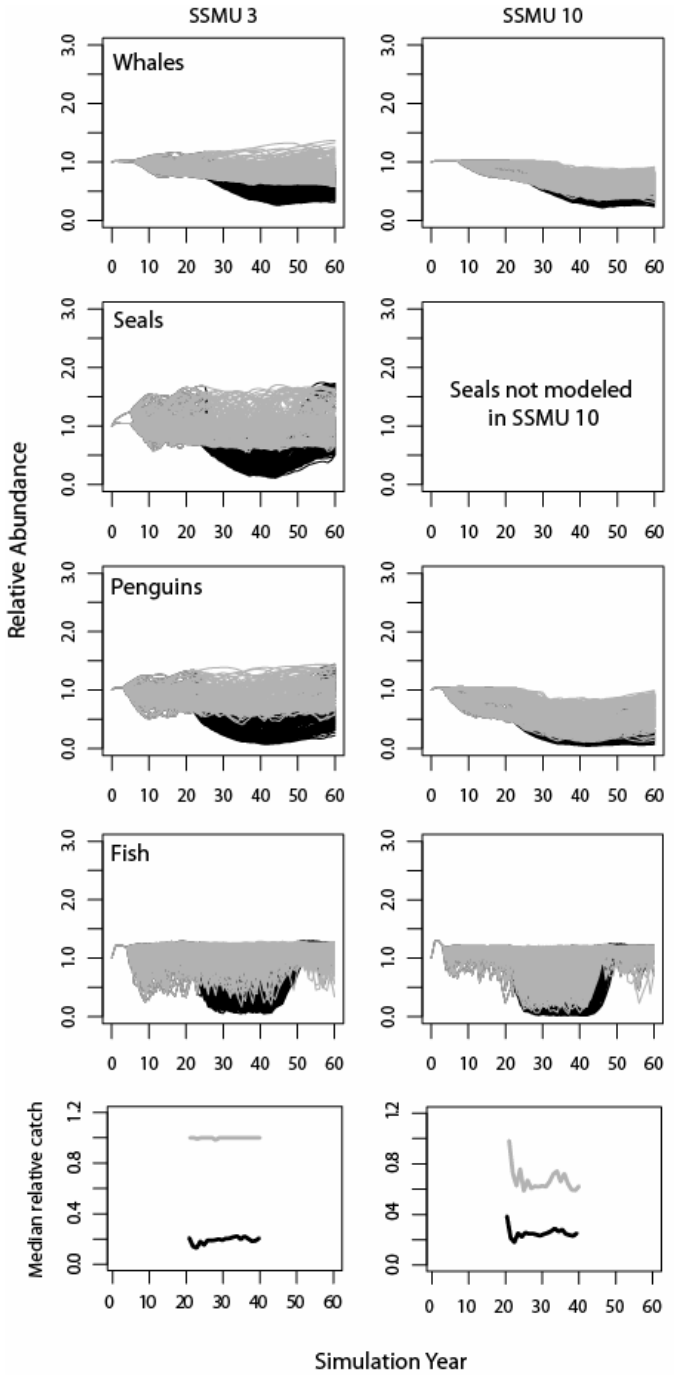

Figure 4(a): Predator abundance trajectories (seals, penguins, whales and fish) and median relative catch from KPFM2 under Fishing Options 1 (black) and 4 (grey) in SSMU 3 (Drake Passage west) and in SSMU 10 (South Orkney west).

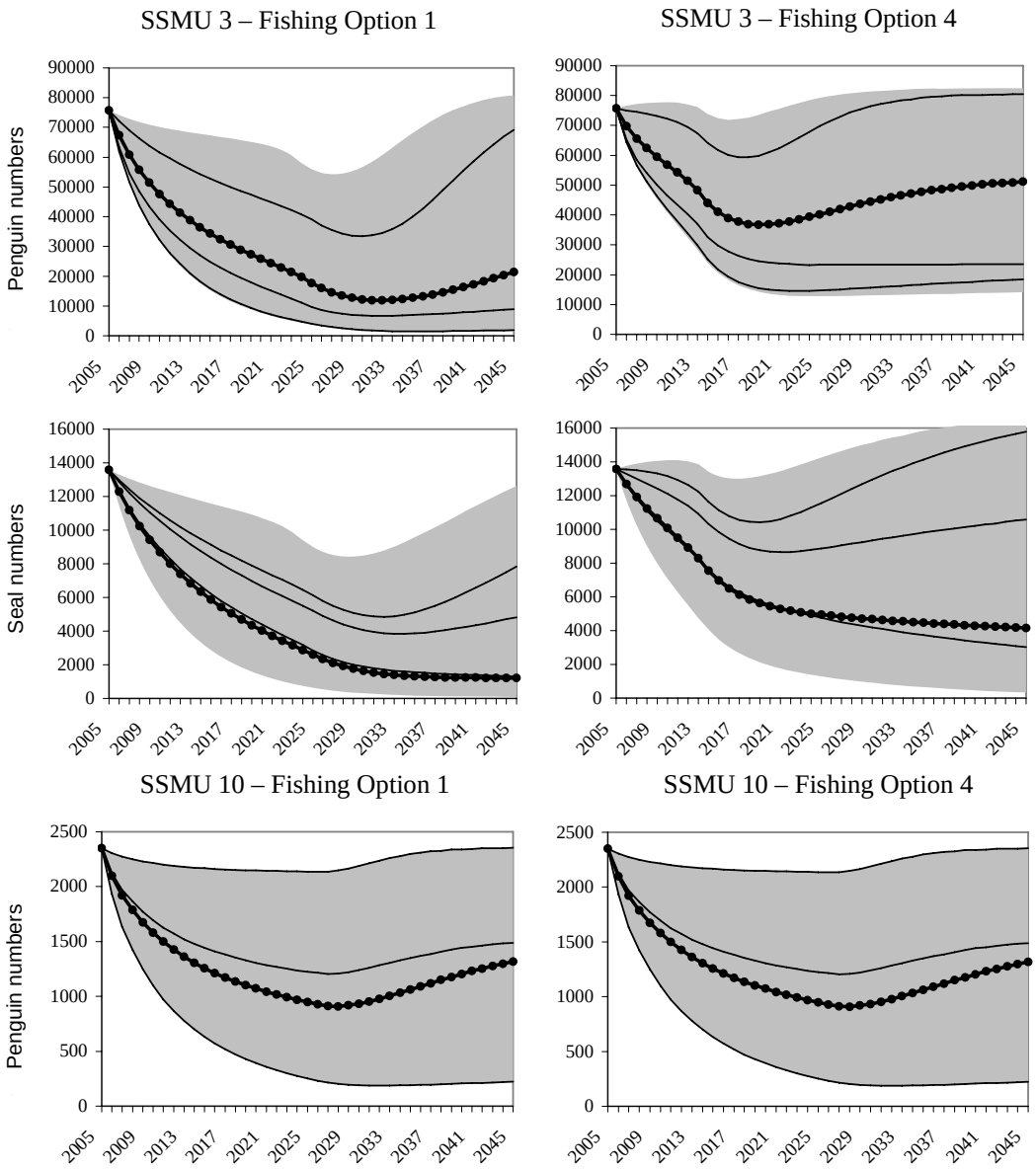

Figure 4(b): Population trajectories generated by SMOM of penguin and seal abundance (in terms of numbers) in SSMU 3 (Drake Passage west) and SSMU 10 (South Orkney west) compared under Fishing Options 1 and 4, from 120 model representations and when using a model version that assumes no krill movement between SSMUs. Three individual trajectories are shown, with the median represented as a dark dotted line and the shaded areas showing the 90% probability envelopes. Note that trajectories assume fishing occurs for the first 20 years, but is set to zero thereafter to assess resource recovery.

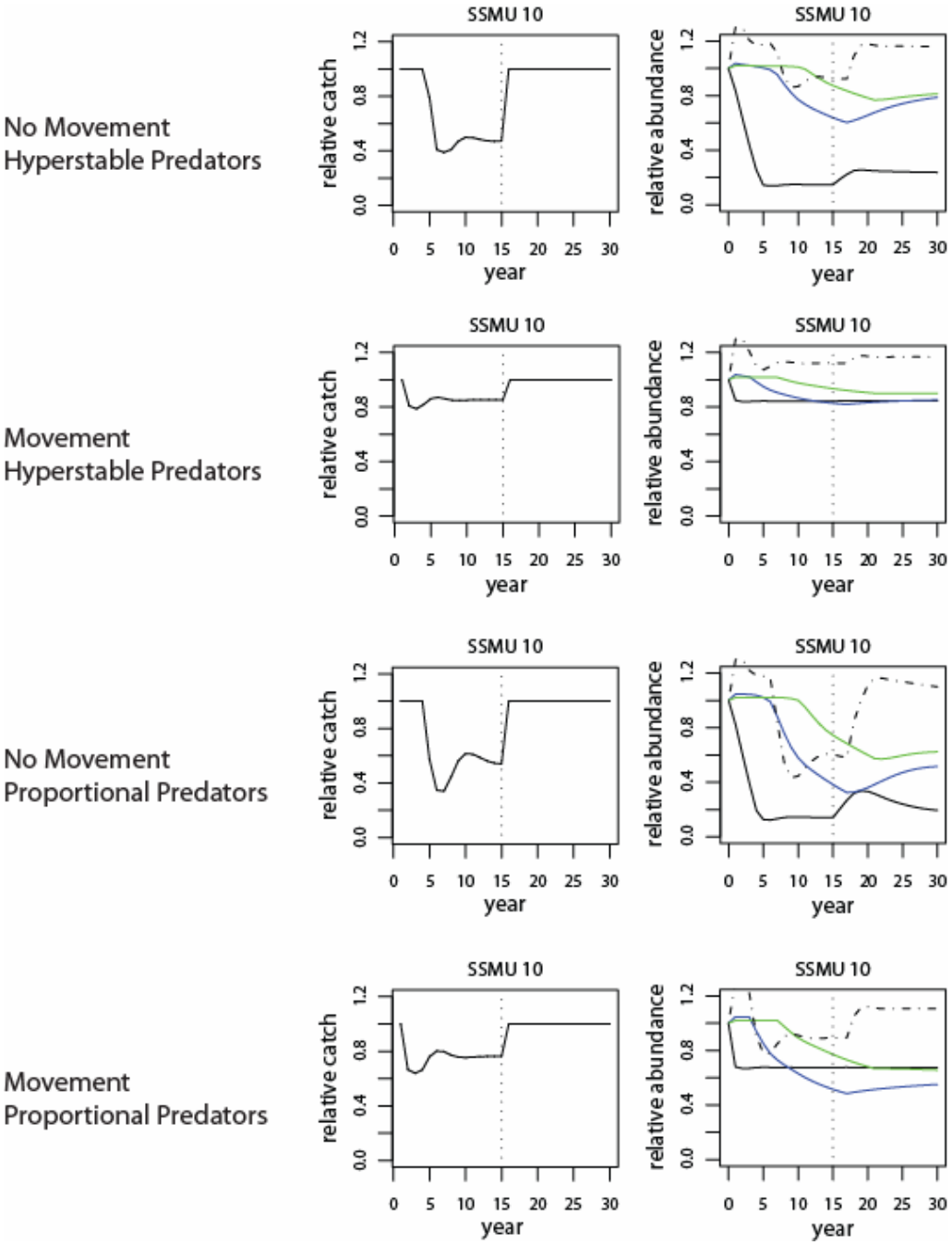

Figure 5(a): KPFM2 example output of an MSE leading to reallocation of fishery catch under four combinations of model uncertainty. In each example, a single reassessment of the difference between krill standing stock and predator demand is conducted in year 15 that results in a reduced reallocation of catch to the fishery in SSMU 10 (South Orkney west). The panels illustrate two main effects of the reallocation. The fishery is able to catch the full allocation after the reassessment because the allocation has been reduced, and predators recover in response to reduced catches (but the degree of this response is uncertain).

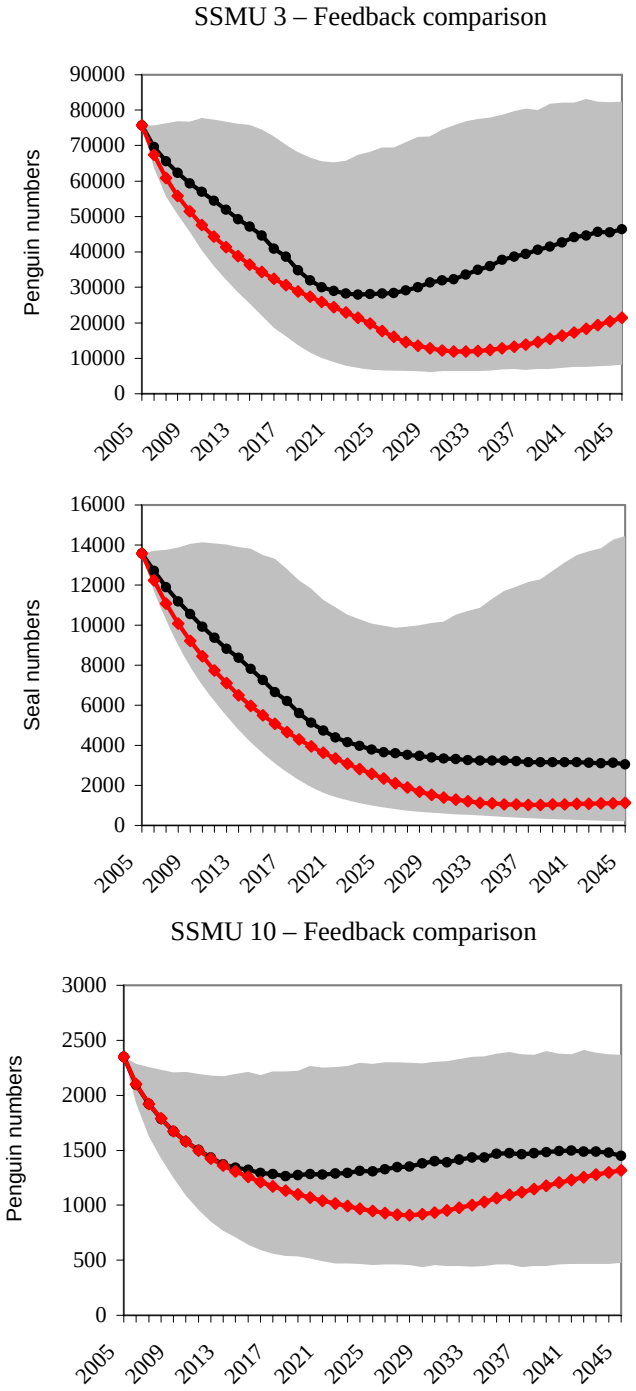

Figure 5(b): SMOM example output of an MSE. Plots show predicted change in abundance for penguins and seals in SSMU 3 (Drake Passage west) and SSMU 10 (South Orkney west, no seals) compared under two scenarios: no feedback in catch allocations (i.e. catches constant as per Fishing Option 1) (diamond symbols); and using a feedback control rule (circle symbols) based on a moderate amount of monitoring information available for all SSMUs. Trajectories represent the median and the shaded areas show the 90% probability envelopes for the feedback scenario – note that the lower 5%ile of the corresponding probability envelop for the no-feedback scenario is not shown but is necessarily lower.

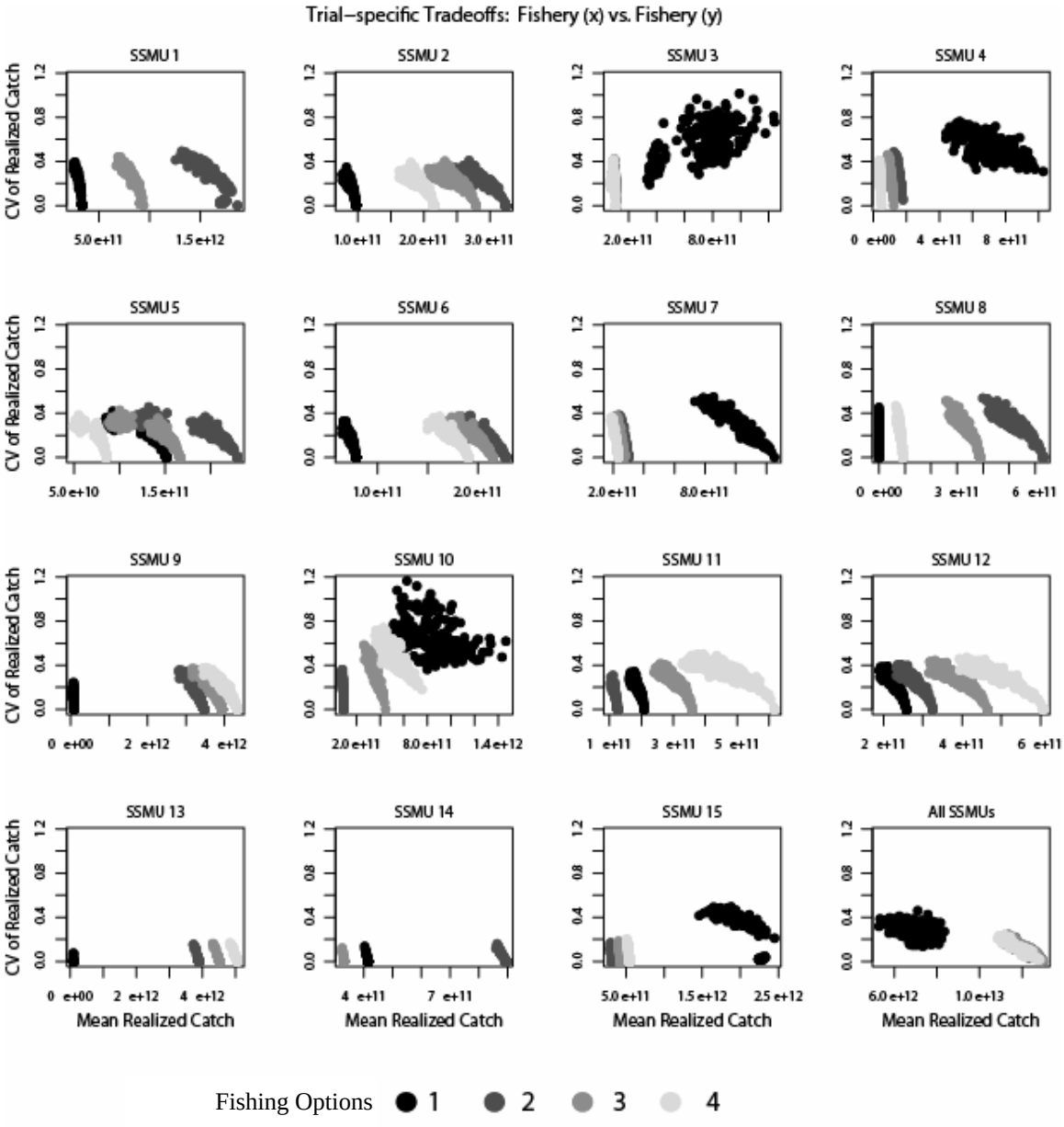

Figure 6: KPFM2 predictions of the trade-offs between mean realised catch and the CV of the catch under the four fishing options. Each cloud of points incorporates four sources of model uncertainty for each fishing option. Fishing Options 1 to 4 are identified by a shaded dot.

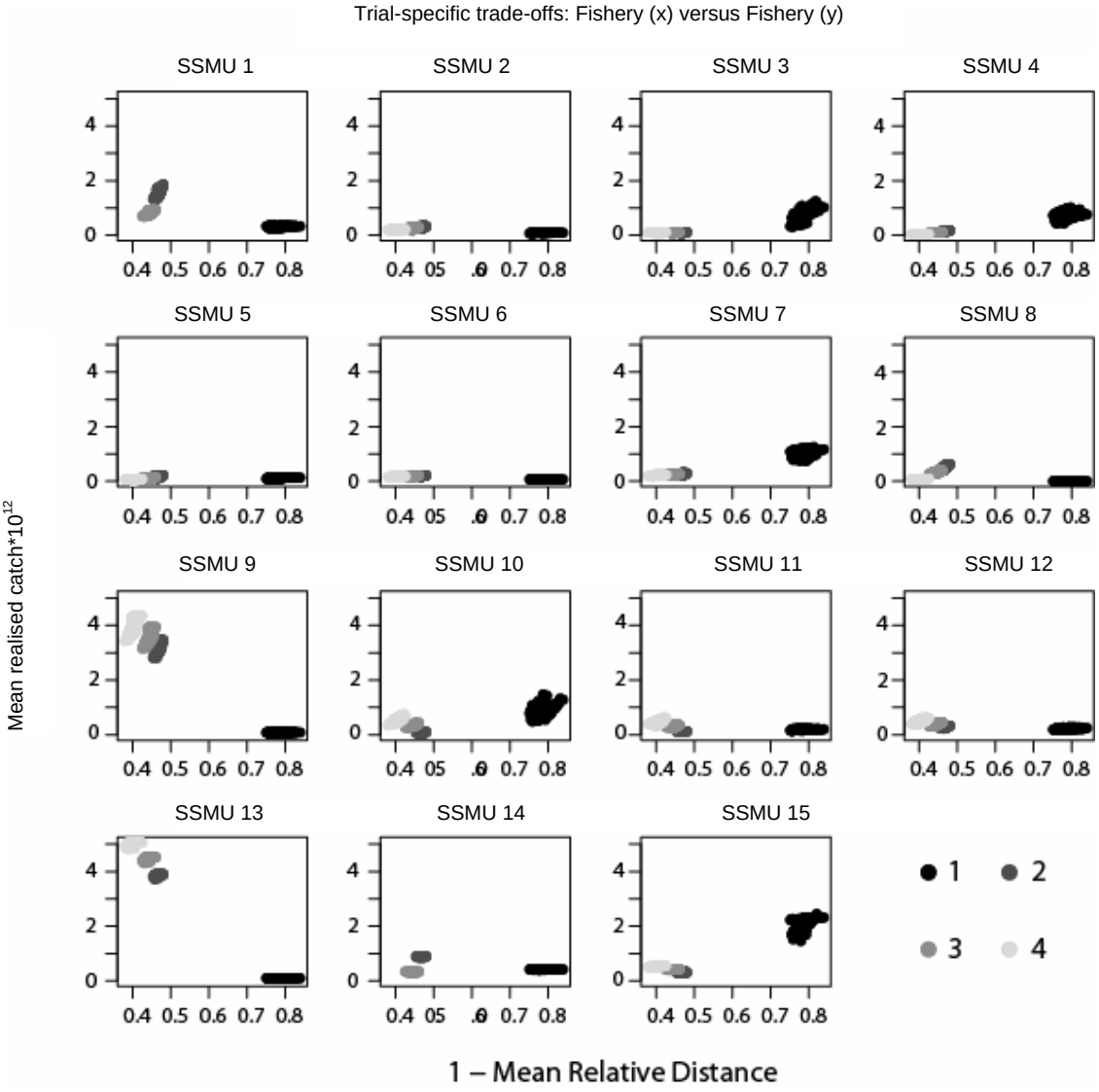

Figure 7: Fishery performance trade-offs between the distributions of catch relative to the historical distributions of catch versus the mean realised catch. Note the scale of each panel is the same, allowing for direct comparison of realised catches in each area. Fishing Options 1 to 4 are identified by a shaded dot and represent model simulations that incorporated the two main sources of uncertainty.

ATTACHMENT 1

AGENDA

Second Workshop on Management Procedures
(Walvis Bay, Namibia, 17 to 21 July 2006)

1. Introduction
   - 1.1 Adoption of agenda
   - 1.2 Co-convener presentation review of 2005 workshop findings: How did we get here?
   - 1.3 Papers tabled for consideration during the workshop

2. State of modelling
   - 2.1 Requested model incorporations
   - 2.2 Status of EPOC
   - 2.3 Status of SMOM
   - 2.4 Status of KPFM

3. Review of parameter plausibility and sensitivity
   - 3.1 Alternate parameterisation of transport and advection
   - 3.2 Short time steps and/or seasonality
   - 3.3 Krill density to halt fishing
   - 3.4 Review plausibility, sensitivity and uncertainty in other parameters

4. Model outputs and performance measures

5. Provisional advice to WG-EMM

6. Future work

7. Adoption of report and close of workshop.

ATTACHMENT 2

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