ANNEX 4

REPORT OF THE WORKING GROUP ON ECOSYSTEM MONITORING AND MANAGEMENT
(St Petersburg, Russia, 23 July to 1 August 2008)

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REPORT OF THE WORKING GROUP ON ECOSYSTEM MONITORING AND MANAGEMENT

(St Petersburg, Russia, 23 July to 1 August 2008)

INTRODUCTION

Opening of the meeting

1.1 The fourteenth meeting of WG-EMM was held at Giprorybflot (State Research and Design Institute for the Development and Operation of Fishing Fleet), St Petersburg, Russia, from 23 July to 1 August 2008. The meeting was convened by Dr G. Watters (USA).

1.2 Dr Watters opened the meeting and welcomed the participants (Appendix A). He also thanked Giprorybflot for hosting the meeting with the support of the State Committee for Fisheries.

1.3 Dr V. Bizikov (Russia) welcomed the participants to St Petersburg and wished the Working Group success in its deliberations during the meeting. He noted that Russia had a long history of scientific research and commercial harvesting in Antarctica, and appreciated the role of CCAMLR and WG-EMM in developing approaches to the conservation of the Antarctic marine ecosystem.

1.4 The Working Group paused in memory of Dr Edith Fanta who passed away in May 2008. Dr Fanta will be remembered for her contributions to Antarctic science and the work of WG-EMM, her gentle and dedicated leadership of the Scientific Committee which she chaired from 2005 until her death, and the guidance which she provided to the working groups.

Adoption of the agenda and organisation of the meeting

1.5 The provisional agenda was discussed and the Working Group agreed to introduce a separate agenda item (new Item 6) to consider the ecosystem effects of fisheries that target finfish. With these changes, the agenda was adopted (Appendix B).

1.6 WG-EMM noted the changes in the format of its meeting in 2008, with the inclusion of two focus topics:

- (i) risk assessment for Stage 1 subdivisions of the precautionary krill catch limit among SSMUs in Area 48 (Item 2);
- (ii) discussion to progress the implementation of spatial management measures that aim to facilitate the conservation of marine biodiversity (Item 3).

1.7 Item 2, dealing with subdivision of precautionary krill catch limits amongst SSMUs in Area 48, was chaired by Dr P. Trathan (UK).

1.8 Item 3, dealing with spatial management measures to facilitate conservation of marine biodiversity, was chaired by Dr P. Penhale (USA).

1.9 The Working Group considered discussions from three intersessional meetings:

(i) WG-EMM's Predator Survey Workshop convened by Dr C. Southwell (Australia);

(ii) WG-SAM convened by Dr A. Constable (Australia);

(iii) ad hoc TASO co-convened by Dr D. Welsford (Australia) and Mr C. Heinecken (South Africa).

1.10 Documents submitted to the meeting, including documents submitted to the Predator Survey Workshop, are listed in Appendix C.

1.11 The report was prepared by Drs D. Agnew (UK), A. Constable (Australia), S. Fielding (UK), M. Goebel (USA), S. Grant (UK), S. Hanchet (New Zealand), S. Hill (UK), Mr J. Hinke (USA), Drs R. Holt (USA), C. Jones (USA), S. Kawaguchi (Australia), É. Plagányi (South Africa), D. Ramm (Data Manager), K. Reid (Science Officer), C. Reiss (USA), P. Trathan (UK), W. Trivelpiece (USA), J. Watkins (UK) and D. Welsford (Australia).

Feedback from previous meetings of the Commission, the Scientific Committee, and the working groups

1.12 Dr Watters noted that feedback from previous meetings of the Commission, Scientific Committee and other working groups had been used to structure WG-EMM's agenda, and he summarised this feedback by reviewing the agenda and highlighting key points of relevance from those previous meetings:

(i) The Commission endorsed a staged approach to the development of the krill fishery in Area 48, with advice on a Stage 1 subdivision of the precautionary krill catch limit among SSMUs[1] to be based on a risk assessment (CCAMLR-XXVI, paragraphs 4.18 and 4.19; see also SC-CAMLR-XXVI, paragraph 2.14). Work to advise on the Stage 1 SSMU allocation was endorsed as priority work for WG-EMM in 2008 (SC-CAMLR-XXVI, paragraph 3.40), and a focus topic (Item 2) was developed to provide opportunity for this work and for consideration of relevant advice from WG-SAM.

(ii) The Commission continues to implement an array of spatial management measures in the Convention Area, and the Scientific Committee has requested advice on scientific aspects such as bioregionalisation (SC-CAMLR-XXVI, paragraphs 3.85 to 3.87 and 3.93) and methods to select and designate MPAs (SC-CAMLR-XXV, paragraph 3.33). Furthermore, in light of urgent requirements specified in UNGA Resolution 61/105, the Scientific Committee had encouraged its working groups to collaborate in considering VMEs (SC-CAMLR-XXVI, paragraph 14.9). A focus topic (Item 3) was developed to provide opportunity for addressing these issues.

[1] Referred to hereafter as 'Stage 1 SSMU allocation'.

(iii) The Scientific Committee requested information on the status and trends in the krill fishery including, *inter alia*, information on how to quantify effort in the krill fishery (SC-CAMLR-XXVI, paragraph 4.17), the requirements for biological data collected from the krill fishery (SC-CAMLR-XXVI, paragraph 3.51), the collection of data by scientific observers (including a review of the report of ad hoc TASO (SC-CAMLR-XXVII/BG/6)), and data requirements relevant to exploratory krill fisheries (SC-CAMLR-XXVI, paragraph 3.53). These topics were addressed in Item 4.

(iv) The Scientific Committee requested advice on aspects relating to the krill-centric ecosystem. The Working Group agreed to, *inter alia*, review the report of the Predator Survey Workshop (WG-EMM-08/8), work needed to revise estimates of krill yield (SC-CAMLR-XXVI, paragraph 3.40) and advice from WG-SAM on implementing ordination methods to present trends in CEMP indices (SC-CAMLR-XXVI, Annex 4, paragraphs 5.75 and 5.76). These topics were addressed in Item 5.

(v) The Scientific Committee recognised the need for WG-EMM to evaluate interactions involving targeted finfish and other top predators (SC-CAMLR-XXVI, paragraph 3.99). This topic was addressed in Item 7.

(vi) The Scientific Committee requested that WG-EMM and WG-FSA collaborate to adopt preliminary terms of reference for a second FEMA Workshop (SC-CAMLR-XXVI, paragraph 3.100). Work to progress the forthcoming Joint CCAMLR-IWC Workshop is also required (WG-EMM-08/15). These points were discussed in Item 8.

1.13 The Working Group also agreed to consider CCAMLR's input to the agenda and work plan of the Joint SC-CAMLR–CEP Workshop proposed for 2009 (see Item 9).

FOCUS TOPIC: RISK ASSESSMENT FOR STAGE 1 SUBDIVISIONS OF THE PRECAUTIONARY CATCH LIMIT AMONG SMALL-SCALE MANAGEMENT UNITS IN AREA 48

Subdivision of the Area 48 krill catch limit amongst SSMUs

2.1 Dr Trathan, as chair of this focus topic, presented the Working Group with a review of the development of progress on this topic. The Working Group recalled that, in the past, the Scientific Committee had requested that WG-EMM consider and develop modelling approaches that allow subdivision of the precautionary catch limit for Antarctic krill (*Euphausia superba*) in Area 48 among several SSMUs.

2.2 WG-EMM has been developing models to assist with this task since 2004, notably through three workshops:

(i) Siena, Italy (at the 2004 meeting of WG-EMM and the Workshop on Plausible Ecosystem Models for Testing Approaches to Krill Management) – A broad range of model structures and functional relationships were discussed (SC-CAMLR-XXIII, Annex 4, Appendix D, paragraph 3.16) and it was generally agreed that it would be important to explore a variety of model structures that captured the potential ecosystem effects of fishing. It was agreed that spatially structured krill population models were required (SC-CAMLR-XXIII, Annex 4, Appendix D, paragraph 7.6) that allowed interactions to be explored, principally between:

(a) the krill population
(b) spatial catch limits and the fishery
(c) krill predators
(d) transport of krill.

(ii) Yokohama, Japan (at the 2005 meeting of WG-EMM and the Workshop on Management Procedures), where it was agreed that at least three key additional aspects should be incorporated into models (SC-CAMLR-XXIV, Annex 4, paragraph 2.11). These were:

(a) shorter time steps and/or seasonality
(b) alternative movement hypotheses, so-called krill flux
(c) a threshold krill density below which a fishery will not operate.

(iii) Walvis Bay, Namibia (at the 2006 meeting of WG-EMM and the Second Workshop on Management Procedures), where model definitions were further refined.

Options for subdividing the catch limit

2.3 The Working Group recalled that three models relevant to the subdivision of the precautionary krill catch limit have been considered previously; these are EPOC, FOOSA and SMOM[2]. These models have been used to examine six candidate options to inform WG-EMM about how best to subdivide the precautionary catch limit for krill:

1. the spatial distribution of historical catches by the krill fishery;

2. the spatial distribution of predator demand;

3. the spatial distribution of krill biomass;

4. the spatial distribution of krill biomass minus predator demand;

5. spatially explicit indices of krill availability that may be monitored or estimated on a regular basis;

6. structured fishing strategies in which catches are rotated within and between SSMUs.

[2] EPOC (Ecosystem, Productivity, Ocean, Climate modelling framework) Constable (2005, 2006, 2007, WG-SAM-08/15); FOOSA – formerly KPFM (Krill–Predator–Fishery Model) – Watters et al. (2005, 2006, WG-EMM-08/13); SMOM (Spatial Multi-species Operating Model) Plagányi and Butterworth (2006, 2007, WG-SAM-08/17).

2.4 In 2007, WG-SAM reviewed the body of work available to help identify a program of work that could lead to advice on a subdivision of the krill catch limit among SSMUs (SC-CAMLR-XXVI, Annex 7, paragraphs 5.7 to 5.51).

2.5 At that time, WG-SAM agreed that management advice and its implementation to subdivide the krill catch limit among SSMUs needed to occur in a staged approach. Such an approach would involve an evaluation of the risks to krill, predators and the fishery arising from the different candidate options for subdividing catch limits, given the uncertainties in model structures, our understanding of the dynamics of the krill-based ecosystem and the future interactions of the fishery with the system. This staged approach was endorsed by SC-CAMLR last year (SC-CAMLR-XXVI, paragraph 3.36).

2.6 WG-SAM had suggested that Stage 1 of a subdivision could be an initial subdivision based primarily on Options 2, 3 or 4, noting that Option 1 had been previously found to achieve the poorest balance of ecosystem and fishery objectives, and that the development of approaches under Options 5 and 6 would help in the assessment processes in subsequent stages, but required additional work and so should be accorded a high priority starting in 2009. This approach was also endorsed by SC-CAMLR last year (SC-CAMLR-XXVI, paragraph 3.36).

2.7 WG-SAM had also suggested that the use of empirical data in models would help with model development, including agreement of an *a priori* set of benchmarks (SC-CAMLR-XXVI, Annex 7, paragraphs 5.24 to 5.26). WG-SAM developed an initial list of potential benchmarks for consideration by WG-EMM – the WG-SAM 'calendar' of known or suspected changes in the ecosystem. This calendar covers the period from 1970 to 2007. The rates and timing of events in the calendar are only approximate, levels of abundance and variability are not provided, and no reference observations are provided for fish.

Stage 1 scenarios

2.8 WG-SAM recommended that models should simulate eight essential scenarios when evaluating the different SSMU candidate options (SC-CAMLR-XXVI, Annex 7, paragraphs 5.37 and 5.38):

(i) the initial conditions set in the model need to be defensible, ideally by using available data;

(ii) the baseline model period needs to be consistent with management strategy or simulation requirements;

(iii) simulations should include a 20-year period with fishing followed by a 20-year recovery period with no fishing;

(iv) model outputs during this stage should focus on comparing SSMU Options 2, 3 and 4;

(v) simulations should be run for different levels of harvest rate so as to provide advice on the risks, given the attendant model and ecosystem uncertainties of the aggregate catches and subdivision strategy causing problems for krill, predators or the fishery at different stages in the development of the fishery;

(vi) the role of flux in krill dynamics needs to be considered, with alternative representations shown, such as scenarios with flux bounded by the seasonal movement matrices based on OCCAM output and no movement;

(vii) a range of interaction functions should be investigated to represent uncertainty in the relationship between krill availability and predator population responses;

(viii) the following scenarios were considered desirable but optional:

(a) scenarios capturing the uncertainty in predator survival rate estimates
(b) scenarios including climate change effects
(c) consideration of fleet dynamics (depending on flexibility within options).

Performance measures

2.9 Ecosystem models have been developed to simulate and compare the performance of the candidate options for allocating the precautionary krill catch limit, where relative performance is judged according to how well these options meet the objectives of Article II of the CAMLR Convention. WG-SAM recommended that performance measures should be derived for the status of krill, predator populations and the fishery over relevant time scales (SC-CAMLR-XXVI, Annex 7, paragraphs 5.39 to 5.47).

Risk assessment of Stage 1 scenarios

2.10 WG-SAM suggested that the provision of advice should be based on a risk assessment using elements of the performance measures (SC-CAMLR-XXVI, Annex 7, paragraph 5.48).

2.11 It was agreed that the following elements should be considered:

(i) suitable fishery performance measures could be model specific, provided they represented long-term performance and variability;

(ii) suitable predator performance measures should indicate the probability of change in the populations;

(iii) performance measures for krill should be based on the existing decision rules used to set krill yields;

(iv) a risk matrix of the performance of different candidate options relative to these measures should be presented.

Process for providing advice on Stage 1

2.12 WG-SAM recognised that to make progress towards developing management advice to allocate krill catch limits to SSMUs during 2008, it would be necessary to follow an agreed intersessional plan. The intersessional plan proposed by WG-SAM was endorsed by SC-CAMLR in 2007 (SC-CAMLR-XXVI, paragraph 3.36).

Advice from WG-SAM

2.13 Three modelling approaches have been developed (FOOSA, SMOM and EPOC) for use in evaluating the subdivision of the Area 48 krill catch limit amongst SSMUs, hereafter termed 'SSMU allocation'. Dr Constable (Convener of WG-SAM) summarised the advice from WG-SAM regarding these different modelling approaches, with discussion focused on:

(i) tools for population, food-web and ecosystem modelling (Annex 7, paragraph 5.9);

(ii) evaluation of management strategies (Annex 7, paragraph 6.21).

Tools for population, food-web and ecosystem modelling

2.14 Dr Constable summarised discussions on:

(i) use of the WG-SAM calendar and the numerical calendar of events for tuning krill-based food-web models and on their potential development (Annex 7, paragraphs 5.12 to 5.16);

(ii) how FOOSA and SMOM are capable of capturing the trends in predator populations as specified in the calendar, given krill as a driver of the ecosystem (Annex 7, paragraphs 5.21 and 5.30);

(iii) how the FOOSA-like implementation in EPOC could provide a useful comparison with the modelling approaches used in FOOSA and SMOM (Annex 7, paragraphs 5.28 and 5.30);

(iv) the advice that WG-EMM should review the evidence and attendant uncertainty in support of the krill trend represented in the WG-SAM calendar (Annex 7, paragraph 5.16).

2.15 Dr Constable reported that WG-SAM advised that both FOOSA and SMOM could replicate the numerical calendar (WG-EMM-08/10) and consequently no further technical queries on model structure were raised by WG-EMM. However, the Working Group did consider a number of ecological issues and interpretations in relation to the models.

2.16 Firstly, Dr Kawaguchi queried whether the scenarios implemented in FOOSA that included krill movement (WG-EMM-08/13) were plausible and how the krill turnover rates for each scenario compared with known ecological values. Dr Watters responded that the initial conditions in FOOSA were set up to ensure that the initial rates of predator population increase were consistent with the numeric calendar. Dr Watters added that a metric could be provided to illustrate the simulated ratio between krill turnover rate and the extent to which the system was sustained by movement of krill from surrounding areas. He noted that when considering results from simulations, there were downward trends in krill that might be an artefact of the model implementation; however, no such trends were evident in model performance statistics when comparing between trials with fishing and trials with no-fishing.

2.17 Dr Constable noted that it was important to assess the extent to which the ecosystem model predictions were consistent with expectations from the single-species krill yield model, and how one might deal with any observed incompatibilities such as might result from an incorrect parameterisation of krill movement. Dr Constable suggested that this was important because, at present, there has been only limited exploration of scenarios that investigate what would happen if the fishery reduced krill to 75% of its pre-exploitation abundance.

2.18 Secondly, Dr T. Ichii (Japan) commented that top-down control may be unrealistically strong in FOOSA, as in many SSMUs predator demand exceeded krill biomass such that the model predicted that there would be zero krill surplus in many coastal SSMUs. He further queried whether the large consumption of krill by fish included in the model was realistic, noting that this results in advice that fishing should operate in pelagic rather than coastal areas.

2.19 Dr Watters confirmed that FOOSA results indicated that there was a greater risk of predator declines under scenarios with more fishing in coastal areas and a greater risk to the fishery that it will not be able to take all of its quota when fishing was concentrated in pelagic SSMUs. He explained that estimates of the krill surplus in SSMUs needed to be evaluated in the context of krill flux rather than just of standing stock. Furthermore, he referred to examples provided in WG-EMM-08/13 (e.g. Figure 10 in that paper) which demonstrated that bottom-up control was very strong in FOOSA as krill abundance was strongly limiting predator dynamics. Dr Watters indicated that if necessary, metrics were available to analyse simulation outputs to assess the relative strength of bottom-up control. Finally, Dr Watters agreed that there was considerable uncertainty in modelling fish, particularly given that mesopelagic fish were not well represented in many field sampling programs. Moreover, the WG-SAM calendar did not specify how fish abundance had changed over the period from 1970 to 2007; consequently, FOOSA was not tuned for the fish component, rather it used a parameterisation based on a compilation of information from the literature. Available information suggests that fish are major consumers of krill in the Antarctic ecosystem.

2.20 Dr V. Siegel (Germany) added that krill surplus is a function of not only flux but also the local production of krill.

Evaluation of management strategies

2.21 Dr Constable summarised the advice provided by WG-SAM on the evaluation of management strategies (Annex 7, paragraphs 9.6 and 9.7); this was considered under three headings:

(i) framework for Stage 1 evaluations
(ii) performance measures
(iii) risk assessments.

Framework for Stage 1 evaluations

2.22 General advice from WG-SAM on the SSMU allocation is provided in Annex 7, paragraphs 6.5 to 6.25. WG-SAM recommended that both FOOSA and SMOM can be used to provide advice on SSMU allocation; however, WG-EMM should discuss the relative plausibility of each scenario.

Performance measures

2.23 Dr Constable summarised discussions from WG-SAM related to:

(i) departures from baseline norms indicated by no-fishing trials (Annex 7, paragraph 6.26);

(ii) whether fish should be included in performance measures given the paucity of data on this component (Annex 7, paragraph 6.27);

(iii) the need for WG-EMM to consider the paucity of data on fish when considering outputs from the models (Annex 7, paragraph 6.28);

(iv) the use of CSIs (Annex 7, paragraphs 6.29 and 6.30).

2.24 Dr Hill explained that estimates of krill consumption by myctophids were based on extrapolations from small-scale surveys which suggested that myctophids are major consumers of krill. Corroboration of these conclusions has recently been provided by British Antarctic Survey (BAS) through additional analyses of myctophid diet data from large-scale surveys across the Scotia Sea. Dr Hill noted that fish have been parameterised as well as possible within the models given available information and literature as presented in Hill et al. (2007).

2.25 Dr Constable noted that models capture the general dynamic of how the system might respond under fishing, but stressed that the outputs cannot be expected to reflect the dynamics of an individual predator in an individual SSMU. Rather, they describe the behaviour of generic predators and hence it is necessary to include fish because they capture the dynamics of that kind of predator.

Risk summaries

2.26 Dr Constable reported that WG-SAM had reviewed a number of tools that could be used in formulating advice on SSMU allocation, including new tools (CSI – WG-SAM-08/16) and an implementation of the risk summaries (WG-EMM-08/44) outlined by WG-SAM in

2007. Dr Constable reported that WG-SAM had recommended that WG-EMM should consider use of these tools when formulating its advice. General advice on risk summaries is given in the WG-SAM report (Annex 7, paragraphs 6.31 to 6.44).

2.27 Discussions by the Working Group on potential ecological aspects pertaining to risk summaries focused on the role of climate change and how this could be included in modelling approaches. It was noted that such considerations were considered by WG-SAM in 2007, and were considered to be optional for the evaluation of the Stage 1 SSMU allocation. Dr Siegel recommended that, based on existing work relating to identifying different climate oceanographic regimes, these different scenarios could be represented in modelling work undertaken as part of subsequent stages.

2.28 Dr Kawaguchi noted that the impacts of climate change on an ecosystem are generally thought to involve cascading effects and that some of these enhance one another in a non-linear manner. It is therefore important to consider such synergistic effects when modelling the future impacts of climate change on an ecosystem.

2.29 Dr M. Naganobu (Japan) and Dr Kawaguchi both noted that it is difficult to predict the effects of climate change but that some fishers have reported that they have detected some changes in the ecosystem that they believe may potentially be related to climate change. Dr Constable suggested that using a management feedback approach was one way of helping to assess such issues, as illustrated by WG-SAM-08/16 which suggested a methodology for including fisheries data to capture the changing dynamics of the ecosystem and hence creating feedback management information. Dr Holt stressed the potential usefulness of relating such fisheries-derived data to the krill fishery to further inform on various aspects of climate change.

2.30 The Working Group recognised that Stage 1 advice on SSMU allocation could be provided this year, but that a range of alternative climate-change scenarios would need to be considered as part of a broader- and longer-term risk assessment for subsequent stages.

Analyses and risk assessment

2.31 The Working Group noted that in order to estimate SSMU allocation for Stage 1, a number of tasks are needed:

(i) To use the best available data to estimate SSMU allocation proportions for the different options following the methods detailed in Hewitt et al. (2004a) and in WG-EMM-08/12:

(a) Option 2: estimates of predator demand in each SSMU from available predator abundance data and consumption rates;

(b) Option 3: estimates of the proportion of krill in each SSMU derived from the CCAMLR-2000 Survey;

(c) Option 4: uses the difference between estimates of krill standing stock and predator demand.

(ii) Assess the relative risks under the different options using the modelling tools available (FOOSA, SMOM, EPOC). The risk assessments are based on yield multipliers that scale the yield from zero, through the current trigger level, to 1.25 × the precautionary catch limit.

(iii) Calculate the SSMU allocations using the proportions determined in (i) above, multiplied by the yield multiplier determined in (ii) above, multiplied by the yield (from the GYM).

Krill fishery performance measures

2.32 The Working Group discussed aspects of performance of the fleet in coastal and pelagic SSMUs (see below). Discussions of the performance of the krill population, predators and the fleet in FOOSA and SMOM models are given in paragraphs 2.45 and 2.49.

2.33 WG-EMM-08/55 reported on analyses of data from 22 oceanographic surveys carried out in Subarea 48.2 between 1962 and 1997. Based on an analysis of geostrophic circulation, four different patterns of water movement were identified by the authors, the most common being one (Type I) in which there is an anti-cyclonic circulation around the South Orkney Islands of water arising in the Weddell Sea. In Type II there is no such anti-cyclonic circulation, but Weddell Sea water is still diverted westwards across the northern limit of the island group. Both these types lead to a concentration of krill in the main fishing grounds in SSMUs SOW and SONE. In Type III and IV, water moves to the east and is not entrained around the South Orkney Islands. A Type III pattern was present during the CCAMLR-2000 Survey, and resulted in a large krill biomass being present in the northeast of SOPA, with relatively little biomass concentrated in the traditional fishing areas in coastal SSMUs. The high biomass in the pelagic area was therefore not typical of the pattern that has been exploited successfully by the fishery.

2.34 WG-EMM-08/24 presented data sampled on the 29th cruise of the FV *Konstruktor Koshkin* in Subarea 48.2 from March to April 2008. The paper examined the distribution of commercial aggregations of krill, their fishable biomass in the different periods of observation, krill biological state, hydro meteorological and ice conditions. The paper noted that for Ukrainian vessels to be profitable, they required krill concentrations of a density of 250 g m^{-2}. These concentrations form only rarely in the pelagic SSMU and they are extremely unstable. The paper reported that fishing in pelagic areas is unlikely to be commercially feasible in the near future, and proposed an alternate SSMU allocation in Subarea 48.2.

2.35 WG-EMM-08/16 used the CCAMLR-2000 Survey acoustic dataset to compare pelagic and shelf SSMUs in terms of the frequency of 1 n mile integration units with krill densities above and below a range of threshold values. In general, pelagic SSMUs had markedly lower frequencies of fishable integration units where the threshold density for fishing was set at 100 g m^{-2} following Kasatkina and Ivanova (2003). The contrasting probability of encountering fishable concentrations in pelagic and shelf SSMUs suggests that the fishery will be less efficient and, perhaps, less economically viable in pelagic SSMUs. This is despite the fact that the absolute abundance of both krill and fishable concentrations of krill is higher in pelagic than in shelf SSMUs. The paper also derived empirical relationships between

SSMU-scale krill density and the frequency of fishable integration units for the full range of threshold levels. These relationships may be useful for linking the scales represented in operating models with those that affect the behaviour and performance of the fishery.

2.36 Dr V. Spiridonov (Russia) recalled that in the 1980s the former Soviet Union had concerns about potential impacts of krill fishing in coastal areas on predators. However, attempts at that time to reallocate fleets to pelagic areas failed because suitable concentrations of krill could not be found. He further noted that there were some seasonal aspects to the formation of krill concentrations, with concentrations forming particularly in coastal areas in the late autumn, but that this behaviour was still poorly understood.

2.37 Dr Watters noted that CCAMLR krill catch records (WG-EMM-08/5) suggest that in the early 1980s significant catches were taken from pelagic SSMUs. However, Dr Spiridonov suggested that the precise location of these catches may not have been accurately recorded in the very early years of the fishery. Dr Kawaguchi further suggested that the fishing strategy followed by the early Soviet fishery may not have needed as high a density of krill as is needed by current commercial operations.

2.38 The Working Group noted that these studies were important in helping to understand how the fishery might be impacted by the various options being considered for the SSMU allocation, which it had specifically requested in 2007 (SC-CAMLR-XXVI, Annex 4, paragraph 6.41). They could be used in a number of ways, including:

(i) to assist with parameterisation of fishery behaviour in the current models using the relationship shown in WG-EMM-08/16 between SSMU-scale krill density and threshold densities for krill operations;

(ii) to inform interpretation of the performance of different allocation options under modelling scenarios, for instance where two options may perform equally in respect of predators but differ in the proportion of krill taken in pelagic and coastal SSMUs.

2.39 Further work on determining the relationship between SSMU-scale krill density and the threshold density for krill operations would be beneficial. Dr S. Kasatkina (Russia) suggested that this might be achieved by acquiring acoustic data from commercial vessels, and noted that a recent ICES workshop (ICES, 2007) had established protocols for acquiring and using such data. Dr Kawaguchi suggested that further analysis of krill fishery behaviour (such as described in WG-EMM-08/40) would also be valuable in this regard.

Risk assessment of Stage 1 scenarios

2.40 The Working Group discussed the risk assessments undertaken for providing advice on SSMU allocations as requested by the Commission (CCAMLR-XXVI, paragraphs 4.18 and 4.19; see also SC-CAMLR-XXVI, paragraph 2.14) under this agenda item. Specific requirements and important issues relevant to the risk assessment are provided in SC-CAMLR-XXVI, Annex 7, paragraphs 5.37 to 5.48 and SC-CAMLR-XXVI, Annex 4, paragraphs 6.39 to 6.46. Based on these guidelines, it was agreed that Stage 1 advice could be provided to the Scientific Committee in 2008.

2.41 Throughout this section, the precautionary catch limit is estimated as γB_0. The risk assessments considered here are based on yield multipliers that scale the yield from zero, through the current trigger level (equivalent to 0.15 × the precautionary catch limit), to at least 1.25 × the precautionary catch limit.

Review of fishing options

2.42 WG-EMM-08/12 reviewed the six fishing options identified in Hewitt et al. (2004a). Since the original presentation of the fishing options in 2004, additional data and analyses have become available with which to ascertain whether the fishing options still have the potential to meet the needs of the fishery, yet retain the principles of Article II of the CAMLR Convention. The authors noted that Options 5 and 6 remain under development and Option 1 has already been excluded as an option by this Working Group. For Options 2 (spatial distribution of predator demand for krill) and 4 (krill biomass less predator demand), limited data on krill consumption, particularly by flying seabirds, squid and fish, creates considerable uncertainty in our understanding of the spatial distribution of consumption. For Options 3 (spatial distribution of krill biomass) and 4, uncertainty arises from the estimates of krill biomass. The authors noted that the CCAMLR-2000 Survey provides the best available data, but that changing analytical methods have not converged on more precise estimates of biomass. Additionally, little data exist on how krill in the Scotia Sea are linked to the Weddell Gyre or the ACC. The data on krill biomass, however, is considered to be more comprehensive than the data on predator demand for krill. The authors suggested that a strong case can be made against Option 4, which is likely to increase ecosystem risk when the underlying estimates of consumption are incomplete, especially if they are biased. The paper suggested that the data on the distribution of krill standing stock are likely to be more reliable than those documenting the distribution of predator demand, favouring Option 3 for Stage 1 advice. Finally, the authors suggested that delay in subdividing the catch could incur some risk to the ecosystem, as the status quo is equivalent to Option 1.

2.43 The Working Group noted that the uncertainty associated with predator demand can be addressed through better assessments of predator abundance. The Working Group recalled that the Predator Survey Workshop (WG-EMM-08/8) has initiated work to compile data from the Scotia Sea region to update estimates of abundance and devise methods that account for uncertainty in abundance estimates. Recent surveys of pack-ice seals (WG-EMM-PSW-08/6) and preliminary estimates of penguin abundance in the Scotia Sea region (WG-EMM-08/53) were identified as important contributions to our knowledge of krill predator abundances. However, gaps in predator data remain, especially for flying seabirds, squids and fish.

2.44 In terms of a risk assessment, the Working Group questioned whether subsets of data without bias or substantial uncertainty could be identified to better constrain estimates of predator consumption. Dr Trathan noted that the Predator Survey Workshop attempted such subsetting, whereby only the major consumers of krill identified in Croxall et al. (1985) were considered. Of the subset considered (see WG-EMM-08/8), crabeater seals (*Lobodon carcinophagus*) were identified as the major consumers of krill in the Scotia/Weddell Sea region. The Working Group also noted that uncertainty in krill demand can be accounted for within the simulation frameworks being used in the risk assessment. Such consideration was suggested as a course of work for providing advice in subsequent stages.

Risk assessment

2.45 The Working Group considered WG-EMM-08/30, which presented a risk assessment of Options 2, 3 and 4 using FOOSA. Example metrics of risk for krill, predators and the fishery that could be used for providing advice were presented. For krill and predators, risk was assessed relative to a baseline abundance that was determined by an initial model condition or by a comparable no-fishing trial. Risks for each predator group were presented on SSMU scales, and based on individual parameterisations or weighted-average risks across all parameterisations. Weighted-average risks were based on plausibility weights for each parameterisation in the reference set and the authors assigned unequal weights to illustrate the model-averaged risks. For all groups, risk was presented as a probability of exceeding a threshold of performance as a function of increasing harvest rates from 0.15γ (the current trigger level) to 1.25γ (25% more than the precautionary catch limit).

2.46 The Working Group noted that the risk metrics presented in WG-EMM-08/30 are based on the existing decision rules for krill. In the paper, changes in krill biomass were referenced to: (i) initial model conditions (rather than median krill biomass over a period prior to the start of fishing); and (ii) medians of comparable no-fishing trials[3]. For the purpose of presentation, the risks to krill were assessed on a regional scale, rather than for any particular SSMU.

2.47 The risk to predators was measured in terms of (i) the probability of depletion to a fraction of a baseline abundance, and (ii) the probability of not recovering to a fraction of a baseline abundance after a period of no fishing. WG-EMM-08/30 presented results referenced to 75% of the baseline abundance on SSMU-specific and regional scales. Presenting results referenced to other fractions of baseline abundance is possible.

2.48 The risk to the fishery was assessed with the log of the mean catch, the CV in the mean catch and the probability that, during the fishing period, krill density would fall below a threshold that would require an involuntary change in the fishery. For the purposes of the latter risk metric, WG-EMM-08/30 presented krill density thresholds of 10, 15 and 20 g m^{-2}. Presenting results referenced to other threshold densities is possible. The Working Group requested that fishery performance also be measured by comparing the catch relative to the full allocation for each yield multiplier.

2.49 The Working Group also considered risk assessment results from SMOM that were produced by Dr Plagányi during the meeting of WG-SAM. WG-SAM recommended that those results be considered by WG-EMM. Results available to the Working Group were for predators only, and the presentation of risk used the same format as FOOSA, as described in paragraph 2.47.

2.50 The Working Group considered the method of using CSIs for the risk assessment, as described in WG-SAM-08/16 (see Appendix D). WG-SAM recommended that the methods presented in this paper be considered by WG-EMM. Risk can be assessed with an aggregate performance measure across all predators at SSMU-specific and regional scales, from an ensemble of results from one or more simulation models. The CSI is used to measure the

[3] The second risk metric for krill described in WG-EMM-08/30 was computed as the probability that, at the end of the fishing period, the abundance of krill falls below 75% of the median abundance computed for the same time from Monte Carlo trials that simulate the absence of fishing.

range of variation in ecosystem response, and risk is assessed by considering whether fishing causes the CSI to depart significantly from the range of variation recorded during a baseline period. Thresholds defining a significant departure could be specified by nominating a quantile from the distribution of the index from the baseline period, for example, the lower 10th percentile. Risk is then assessed as a probability that fishing causes the CSI to exhibit values below the nominated percentile.

2.51 The use of the CSI to assess risk is predicated on the assumption that changes in abundance of krill will cause changes in the performance of predators, depending on the degree to which predators are dependent on krill for satisfying their life-history requirements. A precautionary approach would require that the probability of departure from baseline variability in the CSI not increase too much as the yield multiplier increases. Dr Constable suggested that until more data were available to describe how individual predator groups respond to krill fishing, the CSI provides a useful metric for measuring the general ecosystem response to fishing.

2.52 The CSI approach is not model specific; results from an ensemble of models, like SMOM and FOOSA, can be combined to aggregate across the uncertainties represented in each model. The Working Group noted that combining model results may be helped by weighting the scenarios in terms of plausibility. Dr Watters cautioned, however, that aggregating across model results may be inappropriate in some cases. For example, the basic model used to create the results available from SMOM was very similar to the 'nst' parameterisation used in FOOSA (i.e no krill movement and hyperstability). Creating an ensemble of results with duplicate scenarios would implicitly weight those scenarios higher, which could also introduce bias into the aggregated results.

2.53 The Working Group questioned how different model results should be weighted when an ensemble of results is compiled. Dr Watters noted that weighting schemes could be based on quantitative and qualitative considerations of both statistical and ecological plausibility. For example, WG-EMM-08/30 presented results with unequal weightings based on the authors' experience during parameter estimation and resulting dynamics of the predator groups. Some parameterisations were assigned lower weights because they were less able to capture the relevant dynamics specified in the WG-SAM calendar and proved difficult to fit to the data. Other parameterisations could not be so distinguished and were therefore assigned equal weighting. Dr Plagányi explained that model results from SMOM were assigned equal weighting because all 12 parameterisations in the reference set described in WG-SAM-08/17 fitted to the WG-SAM calendar equally well and are equally plausible. Dr Constable suggested that model plausibility might also be assessed relative to the future dynamics in simulation trials. The Working Group agreed that equal weighting of all model scenarios would be most appropriate if defensible methods for alternative weighting schemes could not be agreed.

2.54 The Working Group further agreed that unequal weighting of results from different models would be difficult, particularly if unknown or unquantified biases were present in models. The Working Group noted that bias in the models could arise from different parameterisations or model structures, and assessing the direction and magnitude of bias within an ensemble of model results may not be possible. The Working Group identified three potential sources of bias in the model results of FOOSA and SMOM:

(i) First, the relative competitive abilities of predators and the fishery could result in bias. For the FOOSA results presented in WG-EMM-08/30, predators and the fishery are modelled as equal competitors for krill. In the SMOM results presented to the Working Group, the fishery is modelled as an inferior competitor to predators. In such cases, the fishery does not always take its full allocation although in reality this could possibly occur in the future (paragraphs 2.86 to 2.88).

(ii) A second bias could have been introduced by the trend in krill biomass, as specified by the WG-SAM calendar. Negative trends in krill abundance could result in higher probabilities of violating the krill decision rules in fishing scenarios.

(iii) A third potential source of bias derives from the use of bathtubs and how the movement of krill is modelled. The Working Group suggested that movement could sustain local krill stocks despite fishery removals.

2.55 The Working Group agreed that negative bias would be introduced under all three scenarios. Negative bias would decrease the perceived risk to the ecosystem for a given yield multiplier. The Working Group agreed that such bias could lead to advice on SSMU allocations that was not as precautionary as intended. In this case, the risks reported in a risk assessment should be considered as the minimum risks to the ecosystem for a given harvest rate.

2.56 The foregoing discussions about the model bias and weighting in FOOSA and SMOM, and the use of FOOSA results to compile a set of CSIs, led to a number of proposed analyses that would be undertaken during the course of the meeting. First, given the possible biases in model results, the Working Group requested that the risk assessment results presented in WG-EMM-08/30 be recalculated using equal weighting for all parameterisations. Second, the Working Group requested that fishery performance also be assessed as the ratio of catch to allocation.

2.57 The main results from the risk assessment are provided in paragraphs 2.58 to 2.74.

Interpretation of model results

Assessment of Fishing Options 2, 3 and 4

2.58 The Working Group noted the advice of WG-SAM-08 (Annex 7, paragraph 9.6) that although there are differences between the models, FOOSA and SMOM could each be considered to be an adequate implementation of the methodological approaches specified by WG-SAM-07 and WG-EMM-07. During the course of WG-EMM-08, the models were re-run in a manner that would most closely allow comparisons between their results. It was agreed that the scenario results from FOOSA should be combined with equal weighting, and that the SMOM parameterisation most closely approximates the 'nst' scenario in FOOSA.

2.59 The Working Group noted how CSIs could be interpreted to indicate the indirect food-web effects of krill fishing on krill predators. It agreed that the CSIs were useful for understanding the aggregate effects of fishing across the region but expressed concern that this might mask the spatial variability of effects, i.e. potential for greater effects to be evident in individual SSMUs. During the course of WG-EMM-08, Dr Constable used the software tool developed and reviewed in WG-SAM (Annex 7, paragraphs 6.37 to 6.42) to present the CSI results from FOOSA outputs for candidate Options 2 to 4, including plots for Option 3 showing how the region-wide CSI compares to an SSMU-specific CSI.

2.60 The results were presented by Dr Watters (FOOSA), Dr Plagányi (SMOM) and Dr Constable (CSI plots of FOOSA results). The results were presented in Figures 1 to 11 following the graphical probability risk assessment suggested in WG-EMM-08/30 and the CSI approach detailed in Appendix D. The model outputs show that there are trade-offs inherent in selecting among Options 2, 3 and 4, and these trade-offs are expressed as the risks to predator populations and fishery distribution and performance.

Impacts on the krill population

2.61 The effects on the krill population predicted by FOOSA and SMOM are shown in Figures 1 and 7.

2.62 In all options in FOOSA, the probability that minimum krill abundance during the fishing period is <20% of the abundances from comparable no-fishing trials remains at 0 as the yield multiplier increases up to 1.0 (Figure 1).

2.63 The responses in respect to krill abundance at the end of the fishing period are similar in Options 2 and 3 for both FOOSA and SMOM. There is an increase in risk that krill abundance measured at the end of the fishing period is less than 75% of the median abundances from comparable no-fishing trials in Subarea 48.3 as the yield multiplier increases beyond 0.15 (equivalent to the current trigger level) and in Subareas 48.1 and 48.2 and Area 48 as a whole as the yield multiplier increases beyond 0.5. However, for Option 4 the risk appears to be limited to Subarea 48.3.

2.64 For Options 2 and 3, there is substantial variation in risk to individual SSMUs that the local krill population abundance falls below 75% of its abundance in comparable no-fishing trials (Figure 7).

Impacts on predator populations

2.65 The results of FOOSA and SMOM indicate that, for yield multipliers up to 0.15, Options 2 and 3 do not pose a significant risk that predator populations would be reduced to 75% or less of the abundances that might occur in the absence of fishing (Figures 2, 3 and 8).

2.66 The risks to predators associated with Option 4 are much higher than Options 2 and 3 in both SMOM and FOOSA. Implementation of Option 4 would increase the risk that predator populations would be reduced to 75% or less of the abundances that might occur in the absence of fishing compared to Options 2 and 3. These results are consistent for both FOOSA and SMOM (Figures 2, 3 and 7) and arise from the increasing limitation of the spatial distribution of the fishery to coastal SSMUs in Option 4. The proportion of the total catch allocated to coastal SSMUs in Options 2, 3 and 4 of FOOSA were 30, 38 and 66% respectively (WG-EMM-08/30, Table 1). Results from FOOSA indicate that the risks to predators at the trigger level (0.15 × yield) are greater under Option 4 than Options 2 and 3.

2.67 At higher levels of the yield multiplier, the results of FOOSA and SMOM differ in respect to predators. The risk that predators would be depleted below 75% of the abundances that might occur in the absence of fishing rises markedly at yield multipliers approaching 0.5 for both Options 2 and 3 in SMOM (Figure 8), but only for Option 3 in FOOSA (Figure 3). The probability of significantly depleting predator abundances remains low for Option 2 of FOOSA until the yield multiplier approaches 1.0. Thus Option 2 would appear to offer lower risks of negatively impacting predator populations than Option 3 given the model structure in FOOSA, but in SMOM the two options appear to result in similar risks to predators. This is partly attributable to the movement scenarios depicted in FOOSA but not SMOM indicating greater risk under Option 3.

2.68 In both models penguin and fish predators are impacted at lower levels of harvest rate, with low probability of significant impacts on seals and negligible impacts throughout all tested harvest rates for whales. A significant difference between the models is the increased risk to fish in SMOM compared to FOOSA (Figure 8 compared to Figure 2 'nst'). Dr Plagányi suggested that this might arise from the inclusion of historical catches of fish in SMOM whereas those catches are not included in FOOSA. At moderate harvesting rates the approach in SMOM results in high relative impacts on fish when compared to the no-fishing option since fish are assumed to be on a recovery trajectory in the latter case.

2.69 A presentation of the CSI analysis described in WG-EMM-08/16 is shown in Figure 10 (see Appendix D). The results are similar to those presented in Figure 2, and particularly demonstrate the difference in risks resulting from the use of the scenarios with and without krill movement. The Working Group agreed that this analysis captured the general properties of change within SSMUs and summarised well the sorts of magnitudes of change that may be expected even at the individual SSMU level (an example of which is given in Figure 11).

Impacts on the fishery

2.70 Implementation of Options 2 and 3 would require that the fishery mostly operate away from coastal areas, with 70 and 62% respectively of catch being allocated, within the models, to pelagic SSMUs. Although available biomass may be higher in pelagic SSMUs (because the total area of these SSMUs is substantially greater than the area of coastal SSMUs), the risks that krill densities will fall below thresholds which necessitate involuntary changes in the behaviour of the fishing fleet are substantially increased in pelagic SSMUs (Figure 4). Nevertheless, both SMOM and FOOSA predict that catches could be greatest in pelagic SSMUs (Figures 5 and 9). There is also a higher probability that the fishery will not be able to catch the allocated catch limit of krill in some SSMUs (Figure 6). Using results from FOOSA, the performance of the fishery is significantly worse under Option 4 than Options 2 and 3, and marginally worse in Option 3 than Option 2.

2.71 The Working Group noted that in Figure 5 many SSMU-specific model-averaged catches predicted from the implementation of Option 4 were low compared to other options because all of the parameterisations in the reference set implicitly describe initial conditions that would prohibit fishing in many SSMUs. It recalled that the SSMU allocation within the model trials would result in allocations different to that arising in reality. This is because the model simulates the estimation of krill biomass or predator demand to represent the process that would be undertaken in reality, which is described in detail in paragraph 2.31.

2.72 Dr Watters noted that the poorer relative performance of the fishery at higher harvest levels was because, as the yield multiplier increases, the fishery comes into stronger competition with predators and at some point it cannot catch its allocation. Even at the trigger level the fishery cannot catch all its allocation in some SSMUs.

2.73 Dr Plagányi noted the lower steepness of the trend in log mean catches seen in Figure 9 compared to Figure 5. She suggested that the cause was the fact that in SMOM the fishery was an inferior competitor to predators (fishing occurs only after predators have taken their catch) whereas in FOOSA they are equal competitors, so that as harvest rate increases, the fishery can realise a greater proportion of the allocation.

2.74 Dr Agnew noted that the flat trajectories seen in Figure 6 suggest that there are some SSMUs where the fleet may not be able to achieve its catch levels even when these are very low. Dr Constable suggested that it might be possible to examine this feature by analysing the data from the current fishery and combining this with a fleet dynamic model.

Consideration of uncertainty

2.75 The Working Group discussed the implications of a number of areas of uncertainty in FOOSA and SMOM.

Model conditioning

2.76 The Working Group reviewed evidence for the magnitude and timing of the specified step-change in krill abundance suggested by WG-EMM-08/10, noting that the specified trend in krill could result in negative bias in the models. The step-change was based on an analysis of FIBEX and CCAMLR-2000 Survey results, which suggested a halving of krill density in the Scotia Sea between the early 1980s and the 1999/2000 season. A decline of this magnitude was supported by published net-haul data (Atkinson et al., 2004; WG-EMM-08/P4). The regional coherence of krill density in AMLR surveys suggests that the 50% reduction in krill biomass could be applied to all SSMUs.

2.77 The Working Group noted that the comparison of FIBEX and CCAMLR-2000 Survey data may not be appropriate and that net-haul data might be a better indicator of changes in density over time. In general, the Working Group agreed that the true magnitude of any step-change in krill biomass is generally unknown, but no alternative estimates were provided by the Working Group for future consideration.

2.78 The Working Group examined evidence for whether a step-change in krill abundance had occurred. The WG-SAM calendar specifies that the step-change occurred in the late 1980s. The Working Group noted that penguins are particularly sensitive to changes in krill availability and that available evidence from penguins supports a step-change decline in krill. Dr Trivelpiece noted that the abundance of Adélie penguins (*Pygoscelis adeliae*) at Admiralty Bay exhibited a sharp decline in the late 1980s, concurrent with the first in a series of ice-free years. The decline was likely driven by reductions in juvenile survival during winter, rather than a reduction in adult survival.

2.79 Dr Kawaguchi questioned whether local availability of krill to penguins might have changed, rather than the overall density of krill throughout the region. Dr Trivelpiece clarified that, at the scale of foraging areas during the breeding season, there is no clear evidence that krill availability has changed. The aggregations of krill thought to be necessary for breeding success of penguins in Subarea 48.1 appear to continue to support chick production on a consistent basis. The Working Group noted that there appeared to be a general coherence of penguin responses at the South Orkney Islands and at South Georgia and that this supported the view of a more regional-scale change in krill density.

2.80 Some members of the Working Group noted that there is a large body of evidence for climatically driven changes in the Antarctic Peninsula region and asked whether other predators may have also declined. Specifically, the idea of a step-change in krill biomass raised the question of whether a regime shift might have occurred. The large amount of environmental variability evident in the Scotia Sea suggests that some predator groups will co-vary strongly with krill. Other predators that are less dependent on krill may show less correlation with environmental indices. However, if a step-change had occurred, it would be difficult to accept a scenario where other krill-dependent predators had not also responded. Dr Goebel noted that fur seal recruitment at Cape Shirreff had declined to near zero in recent years, but noted that these data do not span the step-change in krill.

2.81 The Working Group agreed that the available evidence for changes in krill-dependent predators supported the conclusion that a step-change in krill was likely to have occurred, but that the magnitude should be considered less certain.

2.82 Drs P. Gasyukov (Russia), Bizikov and Kasatkina noted that the Working Group did not discuss the WG-SAM calendar in sufficient detail. They also noted that the WG-SAM calendar does not give any indication of the dynamics of fish populations. The role of fish in the ecosystem remains an important source of uncertainty in this work.

2.83 The Working Group agreed that existing data may be useful for updating the calendar in the future to include the general expectations for fish dynamics (Annex 7, paragraphs 5.14 and 5.15).

2.84 Drs Gasyukov, Bizikov and Kasatkina also noted two issues arising from the use of the CCAMLR-2000 Survey to provide SSMU-scale estimates of krill density (Hewitt et al., 2004a; WG-EMM-08/30) included in the WG-SAM calendar. These were:

(i) the total krill biomass in Subareas 48.1, 48.2 and 48.3 calculated from multiplying SSMU krill density by SSMU area (values from Table 1 of Hewitt et al., 2004a) is 150% of the survey estimate B_0;

(ii) existing analysis of the CCAMLR-2000 Survey has provided density estimates by survey stratum (Hewitt et al., 2004b). In the WG-SAM calendar, these densities were assigned to SSMUs following Hewitt et al. (2004a). This potentially masks SSMU-scale heterogeneity in krill density. It is the opinion of Drs Gasyukov, Bizikov and Kasatkina that the densities used in the calendar do not reflect the real SSMU-scale krill biomass. Furthermore, it is necessary to estimate SSMU-scale density directly from CCAMLR-2000 Survey data for further application in models. This should be based on the reanalysis of survey data using the most up-to-date methods agreed by SG-ASAM and compatible with the assessment of the precautionary catch limit.

2.85 Dr Hill noted that:

(i) the difference between the survey estimate of biomass and the total biomass implied by Hewitt et al. (2004a, Table 1) is attributable to the different areas considered. It is necessary to extrapolate to the whole of Subareas 48.1, 48.2 and 48.3 in order to progress the work on SSMU allocation. However, to be precautionary, the B_0 estimate must be constrained by the area surveyed;

(ii) although SSMU-scale krill density might be more heterogeneous than implied by Hewitt et al. (2004a), this is the only available analysis that gives information on krill density at this scale. The model results should be considered in the context of this source of uncertainty along with the other sources listed in paragraphs 2.52 to 2.56 and 2.75 to 2.81.

(iii) FOOSA and SMOM are designed to evaluate SSMU allocations of catches determined within the models. There is no requirement for strict correspondence between the biomass estimates used to set the precautionary catch limit and those used to initialise the models. However, the work presented here makes use of the current estimate of γ (i.e. $\gamma = 0.093$) (SC-CAMLR-XXVI, Annex 4).

Model results

2.86 Dr Constable commented on the relatively flat response of krill population dynamics to increasing levels of yield multipliers displayed by both FOOSA and SMOM (Figures 1 and 7). He suggested that the fact that the models predicted a probability of less than 50% of the krill population being depleted at the end of the fishing period to 75% of its median spawning abundance in the no-fishing scenario indicated that the krill population was not responding as expected to increasing catch levels. In his opinion, this suggested that should the models be wrong, and that if, in reality, a higher probability of depletion of the krill population should arise, then the choice of harvest rate would not have been precautionary and the impact on predators would be likely to be higher than anticipated. A suitable precautionary approach to this uncertainty would therefore be needed to decrease the harvest rate suggested by the model runs to indicate a rate with an acceptable level of risk (paragraph 2.55).

2.87 Drs Plagányi and Watters stated that in their models the krill population did respond appropriately to increasing levels of yield multipliers. The apparently flat response in Figures 1 and 7 was caused by: (i) the fact that, in some areas, the fishery, acting as either an equal (FOOSA) or inferior (SMOM) competitor to predators, is not realising the full catch levels associated with the yield multiplier, and there is a high probability of the density of krill falling to levels that limit fishery performance particularly in pelagic SSMUs; and (ii) in the models containing movement of krill, these movements would be allowing a redistribution of krill amongst SSMUs that would reduce the amount of depletion of the krill population.

2.88 Dr Agnew recalled the discussions reported in paragraphs 2.32 to 2.39 which indicated that the fishery is unlikely to be able to efficiently take the catch limits allocated to pelagic SSMUs in the foreseeable future. Dr Constable noted that because it may be possible in the future for the krill fishery to develop technologies that make it economically and technologically feasible to achieve the catch allocations even in pelagic SSMUs, it is necessary that scenarios be developed to investigate what would happen if the fishery could take the full catch limit. At present the scenarios have not addressed this possibility even for coastal SSMUs.

2.89 Conservation Measure 51-01 limits the krill catch in Subareas 48.1, 48.2, 48.3 and 48.4 to 620 000 tonnes until the Commission has defined an SSMU allocation and, conversely, does not require an SSMU allocation to be determined while the catch remains below this trigger level. The Working Group noted that in all scenarios of each model there was only a very small risk to predators when the yield multiplier was set at a rate that corresponds to the trigger level of 620 000 tonnes (0.15 × the yield) and the SSMU allocation was determined by Options 2 or 3. Predictions from FOOSA indicated that implementation of Option 4 could lead to risks for predators.

2.90 The Working Group recalled its previous advice (SC-CAMLR-XXV, Annex 4, paragraph 5.24) that Option 1 would have relatively greater negative impacts on the ecosystem compared to the other fishing options. Preliminary analysis by the Working Group suggested that this would probably involve a higher risk to predators at yield multipliers of 0.15 than the negligible risks identified above for Options 2 and 3. There may therefore be some negative ecosystem impacts arising from the retention of the current fishing pattern as the total catch approaches 620 000 tonnes.

2.91 Dr Holt emphasised that a worst-case scenario (from the point of view of the predators) might be a concentration of catches close to 620 000 tonnes, for instance such that the total catch was taken from a single or a few SSMUs. Dr Bizikov noted that the trigger level should not be a barrier to fishery development nor should it carry an appreciable risk of negatively impacting the ecosystem.

2.92 The Working Group recognised that, should the allocations appropriate to Options 2 to 4 be applied to the current fishery, this would constrain the present catch in a number of SSMUs even though the total annual catch is only 17% of the trigger level.

2.93 The Working Group noted that decisions regarding the current trigger level are matters for the Commission.

2.94 Dr Bizikov recalled that very large catches of krill had been taken in the mid-1980s (400 835 tonnes in 1986/87, primarily from the Antarctic Peninsula, Elephant Island, SOW and SGE SSMUs) and significant ecosystem impacts had not been observed. Dr Trathan suggested that there might have been impacts that were unobserved (in SSMUs with no CEMP monitoring site or where the CEMP monitoring system was not fully developed at that time).

Advice to the Scientific Committee

2.95 The Working Group agreed that the overall conclusions to be drawn from the model analyses were:

(i) Option 4 performs significantly worse than Options 2 and 3 across all performance indicators;

(ii) Options 2 and 3 appeared to perform equally well under a number of scenarios; the differences in performance of Options 2 and 3 between models were due to the different model structures, for instance the inclusion of movement, parameterisation of predator dynamics and treatment of fish;

(iii) under Options 2 and 3 the risk of negative impacts on predators was negligible at yield multipliers of 0.15 (the harvest rate consistent with the trigger level);

(iv) under Options 2 and 3 the risk of negative impacts on predators increased at yield multipliers greater than 0.25 to 0.5 with penguins and fish being most significantly affected, seals affected to a minor degree and whales unaffected;

(v) Options 2 and 3 include allocations of 70 and 62% respectively of total catch to pelagic SSMUs, where indications from the models and from paragraphs 2.32 to 2.39 suggest that fishery performance will be significantly negatively impacted.

2.96 The Working Group recalled its discussion surrounding the model results on the catches of the fishery and the variation in the performance of the fishery under the different options (paragraphs 2.70 to 2.74).

2.97 The Working Group noted discussions relevant to bias (paragraphs 2.52 to 2.56) and uncertainty (paragraphs 2.75 to 2.94).

2.98 The Working Group noted discussion relative to the trigger level reported in paragraphs 2.92 and 2.93.

2.99 The Working Group noted that the current spatial distribution of catches does not follow the pattern assumed under Options 2 or 3, but more closely reflects that under Option 1, the historical fishing distribution. The Working Group could not provide explicit advice to the Scientific Committee on the risks associated with distributions of catches under Option 1, which may apply as the total catch approaches the trigger level. However, it noted that its previous advice (SC-CAMLR-XXV, paragraph 3.11) had suggested that allocations based on historical fishing distribution would have greater negative impacts on the ecosystem than other options.

2.100 The Working Group noted that the development of the models leading to the provision of advice for Stage 1 SSMU allocation had been technically challenging and that to develop the necessary models for advice in subsequent stages would be equally challenging, if not more so. Therefore, the Working Group wished to highlight this fact to the Scientific Committee and to emphasise that WG-EMM would need the necessary time (and information) to develop the models so that they were formulated appropriately.

2.101 The Working Group agreed that considerable progress has been made in assessing the relative risks of the different allocation options (see paragraph 2.31(ii)) and that this was sufficient for Task 2 of the Stage 1 SSMU allocation as detailed in paragraph 2.31.

2.102 The Working Group noted that estimates of predator consumption are uncertain primarily as a result of incomplete estimates of abundance of predators (WG-EMM-08/8 and 08/12). It also noted that the SSMU-scale krill density is not adequately estimated in available analyses of the CCAMLR-2000 Survey and it will remain uncertain until the issues surrounding methods for estimating krill abundance from the acoustic data are resolved (paragraph 5.111).

FOCUS TOPIC: DISCUSSION TO PROGRESS THE IMPLEMENTATION OF SPATIAL MANAGEMENT MEASURES THAT AIM TO FACILITATE THE CONSERVATION OF MARINE BIODIVERSITY

Background

3.1 Dr Penhale, as chair of this focus topic, presented the Working Group with a review of the development of progress on the topic of area protection and the development of candidate MPAs by CCAMLR.

3.2 The Working Group recalled that during the early 2000s, the work of the Subgroup on Designation and Protection of CEMP Sites had expanded in scope to include the review of management plans containing marine areas that are submitted to CCAMLR for approval. In 2002 this subgroup was renamed as the 'Advisory Subgroup on Protected Areas' (CCAMLR-XXI, paragraph 4.17). In 2003 the revised terms of reference of this subgroup were endorsed by the Commission (CCAMLR-XXII, paragraph 4.26) and included providing advice on the implementation of MPAs that may be proposed in accordance with provisions of Article IX.2(g) of the Convention.

3.3 In 2004 the Commission addressed the topic of MPAs and urged the Scientific Committee to proceed with this work as a matter of priority. It also reaffirmed the need to develop advice on MPAs commensurate with Articles II and IX of the Convention (CCAMLR-XXIII, paragraph 4.13). This was followed by the 2005 CCAMLR Workshop on Marine Protected Areas (SC-CAMLR-XXIV, Annex 7) held in the USA. The objectives of this workshop included a discussion of how the establishment of MPAs could be used to contribute to furthering the objectives of CCAMLR, including conservation and rational use.

3.4 In 2005 the Commission endorsed the Scientific Committee's advice arising from the 2005 CCAMLR Workshop, agreeing that the primary aim was to establish a harmonised regime for the protection of the Antarctic marine environment across the Antarctic Treaty System (CCAMLR-XXIV, paragraph 4.12). It was recognised that both CCAMLR and the CEP (through Article V of the Protocol on Environmental Protection to the Antarctic Treaty) have an interest in protected areas. The Commission also endorsed the Scientific Committee's work plan to hold a workshop to advise on a bioregionalisation of the Southern Ocean, including a fine-scale subdivision of biogeographic provinces (CCAMLR-XXIV, paragraph 4.17).

3.5 Plans for the Bioregionalisation Workshop progressed in 2006, including the establishment of a steering group comprising members from CCAMLR and the CEP (CCAMLR-XXV, paragraph 6.1). Additionally, the Commission commented that the Bioregionalisation Workshop would be an important step in the Commission's activities to develop a representative network of MPAs (CCAMLR-XXV, paragraphs 6.1 to 6.6). The 2007 Workshop on Bioregionalisation of the Southern Ocean was held in Brussels (SC-CAMLR-XXVI, Annex 9).

3.6 The Working Group noted that this workshop considered available bathymetric, physical oceanographic and biological data, and that benthic and pelagic systems were considered separately. The Working Group noted that the Scientific Committee had endorsed the outcome of the workshop, noting that it can be used to inform spatial management and is a primary foundation for understanding the biological and physical heterogeneity in the Southern Ocean (SC-CAMLR-XXVI, paragraph 3.71 to 3.89). The Commission endorsed the recommendations for future work on bioregionalisation and noted the Scientific Committee's view that further work should be undertaken within the context of WG-EMM, given the existing focus within that Working Group on issues relating to Southern Ocean ecosystems and spatial management (CAMLR-XXVI, paragraphs 7.18 and 7.19).

3.7 The Working Group noted the advice of the Scientific Committee with respect to the application of the BRT method toward further refinement of Southern Ocean bioregionalisation (SC-CAMLR-XXVI, paragraph 14.4(iv)), which was further explored during WG-SAM-08.

3.8 Dr Hanchet summarised the WG-SAM discussions with respect to BRTs (Annex 7, paragraphs 4.13 to 4.19). The Working Group encouraged work to further develop the application of this method, which may be applicable in further work on bioregionalisation.

3.9 Dr Constable was concerned that the use of common species with the BRT approach might not be useful, and that extrapolating outside the geographic range may not be appropriate due to issues surrounding endemism.

3.10 Dr Grant questioned whether data layers from the BRT analysis should be incorporated into the current bioregionalisation maps, or used as separate layers providing information on individual species where available.

3.11 The Working Group agreed that the existing benthic and pelagic bioregionalisations were adequate, although further refinement may be undertaken as more data layers and products become available.

3.12 Dr Holt noted that data around the Southern Ocean remain relatively sparse, and that it is important to recognise the quality and quantity of data with respect to the various regions, particularly when predictive methods are used to infer data-sparse regions. Dr Siegel noted the importance of data coverage at large spatial scales.

3.13 With respect to benthic bioregionalisation, Dr Constable noted that there is a great degree of endemism and heterogeneity, and that the existing bioregionalisation is likely to be adequate for the purposes of CCAMLR. With respect to the pelagic realm, he felt that the work that has been conducted is also sufficient.

3.14 The Working Group noted that it was important that bioregionalisation incorporate not only species information, but structure and function of species assemblages as well.

3.15 Dr Grant noted that there are some aspects of ecosystem function that may not be amenable to being captured in a bioregionalisation.

3.16 The Working Group agreed that it is very difficult to include all aspects into a single bioregionalisation map, and that such information on species distributions and ecosystem processes may be more appropriately utilised as separate data layers, for example as may be used in a systematic conservation planning process.

3.17 Dr Naganobu agreed that the topic is highly complex, and that it is currently in a relatively early stage in relation to terrestrial bioregionalisation studies. He noted that there are still great uncertainties with respect to basic environmental indices in the Southern Ocean, and that more research should be directed toward basic tasks to better elucidate these indices.

3.18 Dr Constable noted that the existing bioregionalisation maps could be used to help identify areas of interest. Although these areas of interest may change in character over time, they are unlikely to change significantly in their location. Bioregionalisation maps could therefore be used to highlight key areas in which small-scale patterns could then be investigated further. Dr Holt noted the importance of establishing criteria for the identification of areas of interest.

3.19 Dr Spiridonov noted that other schemes of bioregionalisation can be interpreted in terms of oceanographic boundaries. He drew attention to a publication written by a physical oceanographer (Maslennikov, 2003) that has been produced in Russian. He indicated that it may be valuable in better constructing a bioregionalisation of the Southern Ocean. He inquired as to the possibility of having the book translated, so that it would be more useful for the Working Group as a whole.

3.20 The Working Group agreed that this publication could provide valuable additional insights into factors that influence bioregionalisation and encouraged Russia to pursue mechanisms to have the book translated into English.

Identifying vulnerable marine ecosystems

3.21 The Working Group noted Conservation Measure 22-06 and recalled that the working groups were tasked by the Scientific Committee to collaborate in work that includes methods to identify VMEs, develop operational definitions of what constitutes significant harm to VMEs and mitigate impacts (SC-CAMLR-XXVI, paragraph 14.9). There were three papers tabled for consideration towards addressing these topics.

3.22 WG-EMM-08/37 presented a risk management framework for avoiding significant adverse impacts of bottom fishing gear on VMEs. This approach is proposed for implementing the requirements of Conservation Measure 22-06 and based on the discussion by the Scientific Committee last year. The framework is similar to that used by ad hoc WG-IMAF to minimise the risk of longline mortality on seabirds. The framework has three parts:

(i) Risk analysis –

Evaluation of

(a) current and proposed fishing activities in specified areas including method and footprint (spatial and temporal extent, frequency);

(b) evidence of potential VMEs in an area of proposed fishing activity, with associated uncertainty;

(c) expected scale of interactions between fishing activities and VMEs, with associated uncertainty;

(d) possible impact of interactions on VMEs, with associated uncertainty;

(e) potential for recovery of VMEs following fishing disturbance, with associated uncertainty.

(ii) Options to eliminate risk –

Management options will be evaluated for the degree to which the risks will be reduced. Such options could include specific at-sea activities based on operational indicators and by-catch or spatial management. Research activities will be specified, when needed, to help identify suitable alternatives for eliminating risk and/or to evaluate the effectiveness of specific management options.

(iii) Review –

This aims to determine whether the measures for eliminating risk need to be updated, revised and/or supplemented. The plans for reviews would include timelines and the data requirements for undertaking such reviews.

3.23 In support of the risk analysis, WG-EMM-08/37 proposed the use of a risk analysis matrix, which relates the qualitative likelihood of an interaction with VMEs and the qualitative and semi-quantitative consequence of the impact of bottom fishing on VMEs. The paper noted that this matrix allows for gear- and operation-specific consideration of what might be vulnerable, knowing that taxa and habitats will have different vulnerabilities depending on the types of gear and the scale of the fishing operations. Importantly, consideration needs to be given to whether species and habitats have low resistance and/or low resilience to disturbance caused by fishing activities.

3.24 WG-EMM-08/37 also used publicly available databases, including SCAR MarBIN, to begin the development of a CCAMLR-specific guide to categories of VMEs and associated qualitative life-history characteristics of benthic taxa in the CAMLR Convention Area.

3.25 The Working Group agreed that a risk analysis framework represents a sensible approach to implementing Conservation Measure 22-06, and thanked the author for tabling this paper for consideration by WG-EMM. It recommended the author continue developing this approach, along with other interested members, for use by WG-FSA.

3.26 The Working Group recalled that the endorsed aim for managing interactions with non-target species was, in order of priority (SC-CAMLR-XXII, paragraphs 4.135 and 4.136 and Annex 5, paragraph 5.230):

(i) avoidance
(ii) mitigation
(iii) catch limits.

3.27 The Working Group noted that the vast majority of Antarctic benthic invertebrate species exhibit slower growth rates and longer life spans than their global counterparts. Further, different parts of the Southern Ocean are likely to exhibit different benthic properties, processes and disturbance regimes, and these should be considered and integrated into the risk framework. As a consequence, further precaution may be required in managing bottom fisheries between different areas of the Southern Ocean.

3.28 The Working Group noted that specific longline gear configuration (e.g. Spanish system, dropline, trotline) will most likely result in differences in the degree of interaction with the seabed, as was indicated by ad hoc TASO (SC-CAMLR-XXVII/BG/6, paragraph 2.10). These factors should be further explored at the 2008 meeting of WG-FSA. The Working Group recommended that strategies used to limit the impact of gear types on benthos and benthic communities, such as the current requirement that longline gear deployments in some exploratory fisheries be limited to depths greater than 550 m, could be further explored. The Working Group indicated that by-catch information from longlines using different configurations could be useful toward identifying VMEs.

3.29 Mr B. Weeber (New Zealand) informed the Working Group that New Zealand held a workshop on VMEs as part of its notification process for fishing in the Ross Sea in the 2008/09 season. A report of this workshop, along with a proposed definition of VMEs and preliminary assessment of potential impact by the longline fishery for *Dissostichus* spp. by the New Zealand fishery in the Ross Sea, will be included in their notification and presented at the upcoming meeting of WG-FSA.

3.30 The Working Group agreed that Antarctic benthic invertebrate ecosystems have not historically been on the agendas of WG-EMM and WG-FSA.

3.31 Dr Jones noted that it is important to begin a process for reducing the uncertainty in our knowledge of the types of taxonomic groups and habitats that may be vulnerable to CCAMLR bottom fisheries. He also noted that there are a number of publications and individual databases that might help in this regard, such as numerous records of gorgonian or antipatharian communities in the Southern Ocean (Barry et al., 2003). He proposed that a workshop be held to help bring these data together, and to provide guidance on the following points that are necessary to reduce uncertainty on the potential for CCAMLR bottom fisheries for causing significant adverse impacts on VMEs:

(i) vulnerability of Southern Ocean benthic taxa to CCAMLR bottom fisheries;

(ii) characterisation of habitats and habitat-forming taxonomic groups and rare taxa that would be consistent with a VME, including methods for assisting in identifying the extent of habitats based on distributions and densities of habitat-forming taxonomic groups;

(iii) methods for identifying potential locations of vulnerable taxa;

(iv) indicators that could be used by fishing vessels to signal when they are fishing on VMEs;

(v) quality of available data, such as in the SCAR MarBIN database, for this purpose.

3.32 Dr Jones also proposed that the workshop be held under the auspices of CCAMLR and include Antarctic benthic invertebrate specialists.

3.33 The Working Group agreed that a workshop of this nature is urgently needed, and should include benthic invertebrate specialists, gear specialists, scientific observers and other key CCAMLR scientists. Such a workshop could be held in conjunction with TASO, WG-FSA, or under alternative arrangements. In addition to information collected through research expeditions on potential locations of VMEs, the Working Group agreed that information collected by observers on invertebrate by-catch would be critical for the workshop to evaluate the levels of interaction between demersal fishing gears and benthic habitats in the Convention Area.

3.34 WG-EMM-08/38 presented a notification of two VMEs that were detected in SSRU 5841H. Evidence is based on direct video observation during the CEAMARC-CASO cruise conducted from December 2007 to January 2008. Camera transects were <2 n miles apart; thus, there is some degree of uncertainty associated with the extent of the VME. The paper suggested a buffer zone of 5 n miles around the observed area to mitigate the effect of spatial inaccuracy. Included in WG-EMM-08/38 is a proposed pro forma that could be used to notify the Scientific Committee and working groups when a VME is detected. The pro forma includes elements that detail the type of VME, the evidence used to detect the VME, the location of observations and the data repository.

3.35 Dr Naganobu questioned whether the content of the notification in WG-EMM-08/38 was meant to proceed directly into a conservation measure. He was concerned that the process of notifying the presence of a VME in the Convention Area is overly simplified, and felt that only video/photo observations are not strong enough evidence. He felt that the information contained in WG-EMM-08/38 was preliminary and the observations should be recorded as initial information.

3.36 Some Members indicated that these notifications are part of the obligations of Members under Conservation Measure 22-06. Dr Constable noted that the notifications provide the detail of the locations of two VMEs and a suggested strategy for ensuring fishing does not cause significant adverse impacts on them. The Working Group also noted that it was the responsibility of the Commission to decide on the management of VMEs.

3.37 Dr Jones noted that there are potentially three methods of detecting VMEs in the Southern Ocean: direct, indirect and predicted (WG-EMM-08/37), with ‘direct’ providing the strongest evidence. He felt that the information provided in WG-EMM-08/38 represented direct, clear indications of the presence of two VMEs in SSRU 5841H.

3.38 The Working Group endorsed the approach of providing information on a potential VME outlined in WG-EMM-08/38. This information could potentially be used to update the

VME registry that was adopted by the Scientific Committee. The Working Group noted that the method for approval of adding a VME to the VME inventory identified in Conservation Measure 22-06 would need to be further considered by the Scientific Committee.

3.39 WG-EMM-08/18 provided an overview of the New Zealand IPY-CAML survey of the Ross Sea region of Subarea 88.1 that was conducted in February–March 2008. The paper described the benthic survey of distribution and abundance of benthic assemblages for shelf, slope, seamount and abyssal sites in the Ross Sea region by means of sled, beam trawl, video transects and multicorer. The paper noted that the results of this benthic sampling will be useful for better understanding the distribution and abundance of benthic invertebrates found in VMEs. The authors noted that, combined with physical data, this may be useful for prediction of other areas where VMEs may occur. A summary report of the distribution of benthic invertebrates found in VMEs collected during this and previous surveys will be prepared for the 2008 meeting of WG-FSA.

3.40 Dr Jones noted that modelling approaches, such as the BRT method, may be useful for predicting where VMEs may exist within the Ross Sea outside of where the survey sampled.

3.41 Dr Constable emphasised the urgency to adopt and refine methods that can be used to ensure that risks to VMEs are reduced so that future fishing activities do not adversely impact VMEs, given that damaged VMEs will likely take a long time to recover, and that the cumulative effects of fishing will increase the risk of damaging VMEs. The Working Group agreed that cumulative impacts are very important, and that the rate of regeneration of the taxa that comprise VMEs is likely to be on a very long time scale.

3.42 Dr Spiridonov noted that the impact of bottom longlining is very poorly understood, and although documenting by-catch is important, the Working Group should also be concerned about the quality of the information. He suggested that photographs of benthic by-catch should be taken by observers.

3.43 The Working Group noted that the information on invertebrate by-catch contained in the CCAMLR database is generally at a variable level of taxonomic resolution and may be of limited value with respect to identifying potential VMEs.

3.44 The Working Group agreed on the need to establish levels of appropriate taxonomic groupings, including those that are considered vulnerable, to inform scientific observers as to the appropriate level of sampling. The Working Group noted that there are taxonomic guides being developed for Southern Ocean observers, and some of these should be available for review at WG-FSA.

Defining candidate marine protected areas

3.45 The Working Group recalled that recent discussions by CCAMLR and the CEP have concluded that the issues of where and how to establish a system of marine areas for the conservation of biodiversity in the Southern Ocean should be addressed as a matter of priority (CCAMLR-XXIII, paragraph 4.13; CEP, 2006, paragraphs 94 to 101).

3.46 Recent work on this topic has addressed a number of theoretical aspects, including bioregionalisation analysis (SC-CAMLR-XXVI, Annex 9), the potential for using conservation measures to achieve protection of marine biodiversity (SC-CAMLR-XXV/BG/19), and the definition of criteria for selecting areas for protection (SC-CAMLR-XXVI/BG/24).

3.47 The Working Group noted that a number of methods could be used for designing a representative system of MPAs, including, *inter alia*, bioregionalisation and 'systematic conservation planning'.

3.48 The Working Group considered the attributes of a process based on systematic conservation planning. In 2007 the Bioregionalisation Workshop had highlighted systematic conservation planning as an appropriate process by which important areas for conservation could be selected and designed (SC-CAMLR-XXVI, Annex 9). This process requires the definition of conservation objectives and uses spatial information on biodiversity patterns, ecosystem processes and human activities to identify the areas that should be included within a protected-area system in order to achieve the defined objectives.

3.49 Dr Trathan introduced WG-EMM-08/49 which provided a worked example of how the systematic conservation planning methodology might be applied in identifying important areas for conservation in the pelagic environment, using Subarea 48.2 (South Orkney Islands) as a pilot study area. The aim of WG-EMM-08/49 was not to identify areas for protection or management at this stage, but rather to test the utility of this methodology, and to demonstrate the types of data and the range of decisions that would be required to undertake such an analysis.

3.50 WG-EMM-08/49 demonstrated that systematic conservation planning is an objective and transparent methodology that assists in the identification of options for spatial protection of biodiversity and other valuable features. The systematic conservation planning process can be summarised into six stages:

(i) define the planning region (broad area of interest in which the study will be undertaken), and divide this into a grid of 'planning units';

(ii) compile relevant ecological data relating to the biodiversity of the planning region;

(iii) set conservation targets;

(iv) review existing conservation areas within the planning region;

(v) select additional conservation areas;

(vi) implement conservation actions.

3.51 WG-EMM-08/49 used MARXAN software to focus on steps (i) to (v) of the above process, and provided an illustration of how important marine areas for conservation might be identified using currently available data. Step (vi) was not considered as part of this study.

3.52 The Working Group noted that MARXAN software has been widely used for systematic conservation planning in a range of habitats worldwide.

3.53 The Working Group noted that, for using MARXAN, it is important to consider a combination of objectives, and not simply individual species or habitats. It noted that the use of MARXAN aims to optimise all conservation objectives at a minimum cost and that costs can be evaluated in a variety of units; potentially these could include such metrics as habitat area, financial cost or CPUE. The analysis described in WG-EMM-08/49 aimed to achieve all of the conservation objectives set in the pilot study in the smallest possible area, thus looking for areas in which more than one conservation objective can be met in the same location.

3.54 The Working Group noted that the results described in WG-EMM-08/49 are largely consistent with expected outcomes based on existing knowledge of the ecological processes in the study region. It therefore concluded that important pelagic areas for conservation could be identified using the methodology described in this pilot study, and on the basis of currently available information.

3.55 The Working Group noted that the systematic conservation planning approach requires data on a range of species and ecological processes, and that input is needed from scientific experts to define which datasets, and which parameters, are most appropriate for inclusion in the analysis. If required, data on human activities such as scientific research activities, fishing and tourism, could be incorporated. However, the Working Group recognised that the spatial distribution of existing human activities may change in the future and therefore a strategic network of representative MPAs should not simply consider those areas where existing human activities are ongoing.

3.56 The Working Group noted that a critical step in systematic conservation planning was the development of appropriate conservation objectives, and that this must be done on a scientific basis with input from appropriate experts as far as possible. The Working Group agreed that if systematic conservation planning were to be used, then conservation objectives would need to be developed in light of the objectives set out by the 2005 CCAMLR Workshop (SC-CAMLR-XXIV, Annex 7). Such objectives would also need to take into account criteria defined by Annex V to the Protocol on Environmental Protection.

3.57 WG-EMM-08/49 focused on the pelagic environment as an example, however, the Working Group agreed that it would be valuable to undertake similar analyses for the benthic environment. Once this has been completed, pelagic and benthic results could feasibly be considered together, to identify areas that may be important for conservation in both environments.

3.58 The Working Group noted that the outcomes from a systematic conservation planning process could be used to complement existing management tools such as SSMUs. MARXAN is one of a suite of tools that might be employed to assist with identifying important areas for conservation, but it cannot be used in isolation. Results from MARXAN do not provide a definitive 'solution' to the question of where important areas for conservation are located, but the outcomes can be helpful in informing decision-making.

3.59 The Working Group therefore endorsed the use of MARXAN as one feasible method for undertaking systematic conservation planning.

3.60 The Working Group noted that key outcomes of the 2007 Bioregionalisation Workshop had been the primary and secondary maps of pelagic bioregions (SC-CAMLR-

XXVI, Annex 9, Figures 3 and 4), and that some of these data had been used in the analysis described in WG-EMM-08/49. The secondary regionalisation map shows that there is a high level of heterogeneity in Subarea 48.2, and the Working Group noted that other such heterogeneous areas also exist elsewhere in the Southern Ocean (Figure 12). The Working Group recognised that many of these heterogeneous areas occur in regions of complex bathymetry and in areas where ecosystem processes are thought to be complex. It agreed that these areas should be given priority in more closely examining how a representative system of protected areas could be identified.

3.61 The Working Group therefore agreed that it should, as a priority, initiate a process to develop representative systems of MPAs across these areas. Therefore, Members were encouraged to use appropriate methodologies to further this work, using, *inter alia*, bioregionalisation and/or systematic conservation planning.

3.62 The Working Group noted that further work would contribute to the development of 'best-practice' guidance, which could then be employed in the selection of important areas for conservation of marine biodiversity, and the implementation of appropriate conservation actions.

Developing a harmonised approach

3.63 The Working Group noted that both CCAMLR and the CEP have obligations for protecting marine biodiversity. A system for establishing protected areas exists under Annex V of the Protocol on Environmental Protection, with a mechanism for approval by CCAMLR of such areas with a marine component. CCAMLR has also initiated a process to identify and establish areas to protect marine biodiversity.

3.64 The Working Group agreed on the importance of cooperation between CCAMLR and the CEP, to improve approaches for area protection by both bodies and to develop further means for practical cooperation.

3.65 WG-EMM-08/52 summarised the CEP discussions on the proposal for a Joint SC-CAMLR–CEP Workshop to be held in 2009, immediately prior to the CEP XII meeting in Baltimore, USA. The CEP has nominated its chair and two vice-chairs as representatives of a joint workshop steering group, and recommended that this group should be convened as soon as practical.

3.66 The Working Group agreed that the topics identified by the CEP for possible consideration by the joint workshop were important topics of mutual interest. The issues of protected areas and spatial management measures were recognised as being of particular relevance. The Working Group also noted that there are synergies between the CCAMLR bioregionalisation work and the CEP Environmental Domains Analysis for Terrestrial Antarctica.

3.67 The Working Group further agreed that the proposed joint workshop should not address these topics in substantive detail, but that it should focus on the development of mechanisms for practical cooperation.

3.68 The Working Group agreed to support the proposal for a joint workshop, and to support the attendance of the SC-CAMLR working group conveners. Members were also encouraged to consider the attendance of other individuals who would be able to contribute to these discussions.

3.69 The Working Group recommended that the Scientific Committee discuss the types of information that would be most useful for presentation to the workshop on behalf of SC-CAMLR, and to provide advice on this to the working group conveners in preparation for the workshop. Further discussion on the development of an agenda and practical arrangements for the workshop are reported in paragraphs 8.19 and 9.1 to 9.5.

Work plan

3.70 The Working Group agreed that further work to progress the implementation of spatial management measures for the conservation of marine biodiversity should include:

(i) further development of the BRT method;

(ii) a workshop to be held under the auspices of CCAMLR to bring together data on the types of taxonomic groups and habitats that may be vulnerable to CCAMLR bottom fisheries, and to provide guidance on points that are necessary to reduce uncertainty on the potential for CCAMLR bottom fisheries for causing significant adverse impacts on VMEs (paragraph 3.31);

(iii) initiation of processes to develop representative systems of MPAs across the priority areas identified in Figure 3.1, using, *inter alia*, bioregionalisation and/or systematic conservation planning;

(iv) identification of the types of information that would be most useful for presentation to the Joint SC-CAMLR–CEP Workshop on behalf of SC-CAMLR, and consideration of the attendance of individuals who would be able to contribute to the workshop discussions.

Key points for consideration by the Scientific Committee and its working groups

3.71 The Working Group recalled that recent discussions by CCAMLR and the CEP have concluded that the issues of where and how to establish a system of marine areas for the conservation of biodiversity in the Southern Ocean should be addressed as a matter of priority (CCAMLR-XXIII, paragraph 4.13; CEP IX Final Report, paragraphs 94 to 101) (paragraph 3.45).

3.72 The Working Group agreed that the existing benthic and pelagic bioregionalisations developed by the 2007 Bioregionalisation Workshop were adequate, although further refinement may be undertaken. The Working Group encouraged work to further develop the BRT method (paragraphs 3.7 and 3.8).

3.73 The Working Group agreed that a risk-analysis framework represents a sensible approach to implementing Conservation Measure 22-06. It recommended that this approach should continue to be developed for use by WG-FSA.

3.74 The Working Group agreed that a workshop should be held under the auspices of CCAMLR to bring together data on the types of taxonomic groups and habitats that may be vulnerable to CCAMLR bottom fisheries, and to provide guidance on points that are necessary to reduce uncertainty on the potential for CCAMLR bottom fisheries for causing significant adverse impacts on VMEs (paragraph 3.31).

3.75 The Working Group endorsed the approach of providing information on a potential VME outlined in WG-EMM-08/38. It noted that the approval of the addition of a notification of a VME to the VME inventory would require endorsement of the Scientific Committee.

3.76 The Working Group noted that a number of methods could be used for designing a representative system of MPAs, including, *inter alia*, bioregionalisation and/or systematic conservation planning (paragraphs 3.48 to 3.58). It endorsed the use of MARXAN software as one feasible method for undertaking systematic conservation planning (paragraph 3.59).

3.77 The Working Group agreed that it should, as a priority, initiate a process to develop representative systems of MPAs across the priority areas identified in Figure 12 (paragraphs 3.60 and 3.61). Therefore, Members were encouraged to use appropriate methodologies to further this work, using, *inter alia*, bioregionalisation and/or systematic conservation planning.

3.78 The Working Group agreed on the importance of cooperation between CCAMLR and the CEP and agreed to support the proposal for a Joint SC-CAMLR–CEP Workshop, which will address topics related to protected areas and spatial management measures.

STATUS AND TRENDS IN THE KRILL FISHERY

Fishing activity

4.1 WG-EMM-08/5 reported on the krill fishery in the 2007/08 season. So far this season, six vessels from five Member countries have fished for krill, exclusively in Area 48. A total of 84 110 tonnes of krill was caught to the end of May. Projections based on catches reported to the end of May suggest that the total catch for the season will be approximately 108 000 tonnes. This estimate is below the recent (2004/05) and long-term (1986/87) maximum annual catches for Area 48 (129 026 and 400 835 tonnes respectively), and within 4% of catch totals in the previous two seasons. Nonetheless, the catches taken by individual Members over recent years have varied considerably, with catches taken by Norway increasing dramatically. The catch statistics show a pattern of monthly accumulation (Figure 9 in WG-EMM-08/5) that is reasonably consistent between seasons but also may indicate an anomalous slow-down in May 2008, suggesting that the final total catch for 2007/08 might be lower than the estimate. The paper also provided details of the deployment of scientific observers in the krill fishery from 1999/2000 to 2006/07 where the observers followed the CCAMLR Scheme of International Scientific Observation.

4.2 The Working Group thanked the Secretariat for WG-EMM-08/5 and noted the importance of this information in its work.

4.3 The Working Group noted that Poland had not yet submitted haul-by-haul data for 2006/07 and that Korean haul-by-haul data for 2004/05 remained incomplete. Dr Ramm advised that the Polish authorities had experienced difficulties with their fishery computing systems, and would submit the outstanding data as soon as possible. The Republic of Korea had advised that some haul-by-haul data from 2004/05 were not collected and, therefore, cannot be submitted to CCAMLR.

4.4 The Working Group noted the variety of net configurations reported by scientific observers (WG-EMM-08/5). The wide range of net configurations, including the size of the mouth opening of nets, is likely to have a strong influence on gear selectivity and catchability. The Working Group agreed that information on net configuration is likely to be important for understanding fishery performance.

4.5 The Working Group also urged scientific observers to include information on seal exclusion devices in observer reports (SC-CAMLR-XXVII/BG/6, paragraph 2.7).

4.6 WG-EMM-08/6 summarised krill fishery notifications for 2008/09. Nine countries submitted notifications for 23 vessels. All notifications included an intent to fish in Area 48, and the notification from Russia included an intent to fish in Subarea 58.4. In addition, Norway and Russia had notified for exploratory fisheries for krill in Subareas 48.6 and 88.3 respectively. The Working Group noted that the Secretariat had been advised prior to the meeting that Russia had withdrawn its notification for the exploratory fishery for krill in Subarea 88.3.

4.7 The total notified catch was 879 000 tonnes of krill (excluding the Norwegian exploratory fishery notification). This exceeds the trigger level for Area 48 (Subareas 48.1, 48.2, 48.3 and 48.4) for the second consecutive year. However, actual catches have remained relatively constant over recent years (and fallen as a proportion of notifications, see WG-EMM-08/6). The notifications were for fisheries using four different gear types including beam trawls.

4.8 With regard to the Russian and US notifications, the Working Group noted that the intention to fish in Subarea 48.3 during the austral summer is a departure from previous practice.

4.9 There is uncertainty about the potential impacts of beam trawls, as indicated in the Russian notification, used in the krill fishery. Dr Bizikov advised that the beam trawls will be used for midwater fishing, in combination with a pumping method, and would be unlikely to have a greater benthic impact than other krill fishing methods.

4.10 The Working Group requested that details of gear characteristics and patterns of use be included in future notifications. The Working Group encouraged Members who notified for krill fisheries in 2008/09 to provide this information in advance of this year's meeting of the Scientific Committee.

4.11 The Working Group also requested that details of gear used be reported, by haul or haul range, in the future by scientific observers (e.g. net configuration, how many nets are used, and how often nets are switched) (see SC-CAMLR-XXVII/BG/6, paragraph 2.7).

4.12 The Working Group noted that 12 new vessels are intending to enter the fishery. The Working Group agreed that a fishery consisting largely of new vessel entrants could make it particularly difficult for the development of its work. The Working Group therefore agreed that it was important to have a structured program of data collection to rapidly establish a profile of new vessels.

4.13 The Working Group drew the Scientific Committee's attention to the discrepancy between notified and actual catches, noting that the Working Group is currently unable to assess the seriousness of the intent to fish in the majority of notifications. The Working Group had previously requested that Parties provide notifications that more accurately predict catches, but the discrepancy has increased dramatically over recent years. The request to improve the accuracy of notifications should be repeated.

4.14 The Working Group noted that details of the vessels notified to fish for krill in the 2008/09 season indicate that sufficient vessel capacity exists to exceed the trigger level. This emphasised the need to make rapid progress on SSMU allocation.

4.15 The Working Group noted that Norway had notified its intention to conduct an exploratory fishery for krill in Subarea 48.6 (CCAMLR-XXVII/13). Fishing will be conducted by the vessel *Thorshøvdi* using both conventional trawling and a continuous pumping method with a target catch of 15 000 tonnes of krill. The notification of intent includes a commitment to comply with all relevant conservation measures, and is associated with relevant krill density estimates, stock structure information and by-catch issues which are reported in WG-EMM-08/28 and 08/29.

4.16 The Working Group noted that there is an increasing trend in the capacity of vessels in the krill fishery and there is currently some uncertainty among Working Group members about how this capacity may be utilised (e.g. for storing processed catch transhipped from other vessels, for storing catch originating from this vessel, or use as a processing factory). For example, the capacity of *Thorshøvdi* (7 720 m^3) greatly exceeds that of other vessels included in this year's notifications.

4.17 The Working Group indicated that uncertainty about the practical details of certain notifications submitted to the Working Group would need to be supplemented to facilitate full advice on the likely course of the krill fishery in the forthcoming season and suggested the Scientific Committee may wish to consider additional information provided to it in respect of:

(i) update on the status of vessels intending to enter the fishery for the first time in 2008/09, and the anticipated dates when these vessels will be operational (Chile, Cook Islands, Norway, Russia, Ukraine, USA) (paragraphs 4.12 and 4.13);

(ii) configuration and use of beam trawls (Russia) (paragraph 4.9).

Description of the fishery

4.18 WG-EMM-08/32 examined the krill fishing records from 1973 to 2008 available from the CCAMLR database (C1 data). In total, 94% of the historical catches were taken in depths between 0 and 200 m, with a peak at 50 m. Efficient and stable fishing grounds were distributed in a narrow range, with steep meridional gradients between –1.0° and 1.0°C for the mean water temperature from the surface to 200 m (MTEM-200). In the main fishing regions off East Antarctica, the Scotia Sea and the north of South Georgia, large fishing catches were concentrated in waters colder than –0.5°, 0.0° and 1.0°C respectively. Especially large fishing catches indicated two remarkable peaks, –0.5°~0.1°C and 0.5°~0.8°C, which were located in the Scotia Sea and north of South Georgia respectively. MTEM-200 seems to provide habitat information on circumpolar-distributed species for krill and also other organisms.

4.19 Dr Naganobu added some further points to the review in paragraph 4.18. The historical krill distribution, based on the *Discovery Reports'* net sampling, similarly coincided with this study's results and each of the isopleths of MTEM-200 substantially corresponded with each oceanic front in the Southern Ocean. MTEM-200 can be applied for the further analysis of seasonal and/or annual variability.

4.20 WG-EMM-08/39 characterised the behaviour of the krill fishery using CCAMLR krill C1 data from the more recent 10 years by analysing distances travelled by vessels in relation to catch level. This revealed a pattern that mean travel distances are longer after the least catch levels, and the travel distances decrease as catch level increases to certain catch levels, and then distances travelled increase again above that catch level for Japanese vessels. The paper suggested the need for updates of some of the parameters used in the krill fishery fleet dynamics models published in late 1980s, to reflect changes in the efficiency and scale of the krill fleet's operations. A considerable year-to-year variability was revealed for the probabilities of repeated operation at same locations. Fishing vessels showed a pattern of frequent change of fishing grounds. The analysis suggested that krill availability for the fishery in 2000 seemed to be at its lowest in the last 10 years (WG-EMM-08/40). Fishery behaviour differentiates between market-type considerations/strategies, which are often the argument for changing fishing patterns, and catching efficiency/operational requirements in an area. It underscores the importance of high-quality year-round data from observers from all vessels participating in the krill fishery to assist in interpreting the annual fishing results (WG-EMM-08/39).

4.21 The Working Group welcomed the analysis for its contribution to understanding the fishery dynamics, and encouraged the author to further develop the analysis by: (i) aggregating fishing operations in space and time to attempt to identify any broader-scale patterns in time and space; (ii) comparing behaviours between coastal and pelagic areas to inform possible difference in operation between these areas; and (iii) taking into account the captain's experience in the analysis to help understand learning curves in operations of new entrants. Analysis of fishing behaviour in relation to predator colony positions and use of length-frequency distribution to inform the status of the krill population were also suggested. It was noted that C1 data do not include krill length-frequency data.

4.22 Dr Kasatkina noted the importance of including the number of vessels operating at the same fishing ground at the same time in the vessel behaviour analysis, since it may affect krill availability per vessel and consequently affect vessels' operational behaviour.

4.23 WG-EMM-08/24 summarised scientific observations conducted for 42 days by a national observer on board a Ukrainian krill trawler in Subarea 48.2 during March–April 2008. A total of 565 tows were made. Mean CPUE was 18.3 tonnes of krill per hour, and the average catch was 208.5 tonnes of krill per day. Size distributions of krill in March and April were similar (ranging between 23 and 61 mm) but the percentage of large krill (>48 mm) and small krill (<40 mm) fell by 20% in April. Juvenile fish by-catch (*Champsocephalus gunnari*) was only recorded from one tow, with fish having a mean body length of 14.3 cm and average weight of 13.0 g. No seal by-catch was recorded. Large-sized whales were repeatedly observed off the South Orkney Islands during the observation.

4.24 The Working Group noted that the two modal sizes observed in the krill length-frequency distribution were consistent with the sizes observed in the US AMLR Program conducted in the same region during the same season, although their proportions were different (WG-EMM-08/26).

4.25 WG-EMM-08/57 reported on fish by-catch caught by the *Niitaka Maru* from 6 to 30 August 2007 to the north of South Georgia. Fish by-catch was observed in 26 of 87 net tows examined (29.9%). Among the seven fish species observed (three Myctophidae, one Zoarcidae, one Nototheniidae and two Channichthyidae), *Krefftichthys anderssoni* (Myctophidae) was most frequently observed (38.5% of hauls examined). Owing to the small amount of by-catch, no clear relationships between krill CPUE and fish by-catch could be confirmed in the present study.

4.26 Dr Naganobu noted that the Japanese fish by-catch observation program has been continuing for over 10 years, and had developed a fish identification sheet for at-sea use by observers (WG-EMM-07/32).

4.27 The Working Group noted that the major by-catch species was myctophiids, whereas the major by-catch species usually reported from this area is icefish larvae. The Working Group commented that this may reflect the difference in at-sea sorting protocols, since this observation was undertaken before the fish and fish larvae by-catch protocol was updated in the electronic observers logbook (paragraph 4.43). The difference in the depth of the net hauls, as well as interannual variation of the species compositions, could also be the reason. The importance of using a consistent protocol across vessels was reiterated.

Scientific observation

Observer deployment

4.28 Six scientific observer logbooks were submitted to the Secretariat for the 2006/07 season from observations conducted by CCAMLR scientific observers on the *Saga Sea* (Norway), *Niitaka Maru* (Japan) and *Dalmor II* (Poland).

4.29 In addition, the Secretariat has received five notifications of the placement of CCAMLR international scientific observers on krill fishing vessels in Area 48 in 2007/08.

4.30 At the request of WG-EMM (SC-CAMLR-XXVI, Annex 4, paragraph 4.58), the Secretariat provided a summary of all observer data submitted to the Secretariat for the krill fishery from 1999/2000 to 2006/07 (WG-EMM-08/5). The Working Group noted that the percentage of tows observed varies greatly between observers, seasons and vessels. For example, in 2006/07 between 20 and 86% of the tows were observed per trip, including both the traditional trawling method and the continuous fishing system (WG-EMM-08/5, Table A1).

4.31 The Working Group noted that observer coverage reported in WG-EMM-08/5 was reported as the proportion of tows observed while the observer was on board. The Working Group requested the Secretariat to also indicate the proportion of total tows observed in future reports.

4.32 The Working Group noted the submission of some national scientific observer data in accordance with the CCAMLR Scheme of International Scientific Observation, and encouraged all Parties with national observers to collect and submit data to the Secretariat in accordance with this scheme.

4.33 The Working Group agreed that the information provided in WG-EMM-08/5 was very useful in understanding the extent of scientific observer data held by the Secretariat.

Conversion factors

4.34 Vessel-derived conversion factors have been reported consistently since 2001/02, however, the observer-calculated conversion factors are less common due to the difficulties experienced by observers in obtaining accurate data or gaining access to the processing factory (SC-CAMLR-XXVII/BG/6, paragraph 3.14). The Working Group noted the need to develop a set of protocols and guidelines for observers to assist in the collection of accurate conversion factor data (WG-EMM-08/6).

4.35 WG-EMM-08/46 examined uncertainties in krill catch arising from the use of product conversion factors from scientific observer data, and a limited amount from fine-scale (C1) data reported over the past five years. Conversion factors ranged between 1 and 26 across product types. Given this variability in conversion factors, a nominal reported catch of 600 000 tonnes may represent a catch of 2.5 million tonnes in an extreme case, assuming all the catch was boiled product. Information on product-specific conversion factors, as well as the product composition of the catch, is critical to better quantify the level of uncertainty in reported krill catches.

4.36 In the current reporting system, the product-specific catches and conversion factors are not reported and therefore it is not possible to identify whether the catch reported was based on conversion factors or direct measure of green weight.

4.37 The Working Group further noted the range of new products produced by the krill fishery and recognised that estimation of conversion factors for some of these novel krill products may be impractical.

4.38 Dr T. Knutsen (Norway) noted that Norway has implemented a flow-scale system and is now reporting fine-scale data based on a measurement of 'green weight' of krill prior to processing.

4.39 The Working Group expressed its serious concern over the inconsistency in the way the amount of krill removed from the ecosystem may be recorded, which is causing uncertainties in the catch reported to the Secretariat. The Working Group advised the Scientific Committee to encourage Members to evaluate the possibility of accurately reporting catch on the basis of green weight caught, recognising that this is a matter of some urgency.

By-catch

4.40 No seabird and seal by-catch was observed by scientific observers in 2006/07 (WG-EMM-08/5, Table A5).

Ad hoc Technical Group on At-Sea Operations

4.41 Dr Welsford presented the report of ad hoc TASO (SC-CAMLR-XXVII/BG/6). The Working Group noted TASO's discussions on the design and operation of krill fishing gears in the Convention Area (SC-CAMLR-XXVII/BG/6, paragraphs 2.1 to 2.8). The Working Group agreed with TASO's recommendation for the establishment of a standard format for reporting gear configuration in the observer report.

4.42 The Working Group also noted the discussions by ad hoc TASO on data collection priorities in the krill fishery (SC-CAMLR-XXVII/BG/6, paragraphs 3.1 to 3.16). The Working Group noted that the observer priorities in the current CCAMLR *Scientific Observers Manual* were not consistent with those agreed by SC-CAMLR (SC-CAMLR-XXVI, paragraph 3.6). The Working Group requested that appropriate changes are made to ensure that the data priorities are consistently represented.

4.43 The Working Group also noted that observers considered the newly adopted CCAMLR larval fish by-catch protocols (observer logbook form K11), which provides increased coverage and data collection, and a more efficient use of the observer's time to collect these data. The Working Group agreed to the proposal by ad hoc TASO (SC-CAMLR-XXVII/BG/6, paragraph 3.5) that a small workshop of experts be held to assess the digital images of larval fish archived through the new larval fish by-catch protocol, as a way to assess at-sea identifications by observers.

4.44 The Working Group agreed with the recommendation of ad hoc TASO that all data requested to be collected by observers in the krill fishery should be evaluated in terms of their value for providing advice to the Scientific Committee without causing excessive workloads for observers.

4.45 The Working Group reviewed the terms of reference developed by ad hoc TASO and agreed that it was the role of the Working Group to specify data requirements for observers and that TASO's role is to provide advice on how these requirements could be achieved.

4.46 The Working Group thanked ad hoc TASO for its report. It agreed that the information collated by the experts brought together in TASO had greatly enhanced the ability of the Working Group and its observer subgroup to understand the operations of fishing vessels and practicalities of at-sea data collection. The Working Group looked forward to future meetings of TASO and particularly encouraged Members participating in the krill fishery to send observers, technical coordinators and industry representatives to attend future meetings.

Scientific Observers Manual

4.47 WG-EMM-08/45 examined the quantity and quality of data submitted by CCAMLR scientific observers. This analysis considered the spatial coverage as well as a consideration of length and sex/maturity stages of krill.

4.48 The Working Group agreed with the suggestion in WG-EMM-08/45 that 200 krill should be measured for five net hauls every 30-day period, and if the vessel moves 50 n miles (based on analysis in WG-EMM-08/39) or into another SSMU, then a new sampling period should begin.

4.49 The Working Group also agreed, on the basis of the analysis in WG-EMM-08/45, that the current instructions for observers on sexing and maturity stages should be simplified.

4.50 The Working Group also discussed the difficulties of using the colour chart included in the manual to identify greenness of krill. However, the Working Group agreed that observer protocols should not be altered without appropriate assessment of the utility of the current protocol and the resulting data. The Working Group recommended a review of the collection of krill colour data, which should address the following questions:

- Are there any past, current or intended analyses of these data?
- What level of detail do such analyses require?
- Is the same information available from other data sources that are currently collected or might be collected more efficiently than krill colour data (e.g. product information, captains' decisions)?

4.51 The Working Group further recalled that it had referred to WG-FSA for further development the existing guides to the identification of larval fish taken as by-catch in the krill fishery (SC-CAMLR-XXVI, Annex 4, paragraph 4.37). Subsequently, WG-FSA had requested that the Secretariat translate into English the guide published by VNIRO in 1986 (SC-CAMLR-XXVI, Annex 5, paragraph 10.10). WG-EMM noted that a preliminary English version of this guide was now available.

4.52 The Working Group advised the Scientific Committee that a revision of the instructions in the *Scientific Observers Manual* is required to reflect the changed priorities for data collection (paragraph 4.66), as well as to reflect the changes in data requirements:

(i) measure 200 krill from five randomly selected hauls during each 30-day period (or from one sample of 200 krill each five-day period for the continuous fishing methods). All krill should be measured to the nearest millimetre from the eye to the tip of the telson;

(ii) the maturity and sex stage to be reported in five classes (juvenile, males, females, mature males and gravid females) of the krill measured for their length;

(iii) a new krill length measurement reporting period will commence if the vessel moves operation >50 n miles or moves between SSMUs;

(iv) fish by-catch should be observed twice a day following the existing fish by-catch protocol, including the fish-larvae sampling protocol.

4.53 The Working Group agreed that protocols for observation of incidental mortality of seabirds and marine mammals should be revised according to clarification to be made by ad hoc WG-IMAF on the application of the CCAMLR warp-strike protocol, including operation on continuous fishing methods.

4.54 The Working Group noted that a fish by-catch protocol that includes a procedure for sampling fish of all sizes (and is consistent with the existing fish-larvae sampling protocol) should be developed.

Observer coverage for krill fishery

4.55 A plan for systematic scientific observer coverage (WG-EMM-08/34) was submitted by Japan in response to the request by the Scientific Committee (SC-CAMLR-XXVI, paragraph 3.13). Japan proposed deployment of well-trained government-appointed observers with 50% vessel-day coverage, with the achievement of 100% (spatial and temporal coverage) every two years, and prompt submission of data to the Secretariat.

4.56 The Working Group welcomed Japan's proposal and supported its intention to formalise systematic observer coverage on krill vessels.

4.57 The Working Group recalled the two-staged approach put forward by the Scientific Committee in 2007, stressing the high level of coverage needed to understand the overall behaviour and impact of the fishery during the earlier stage, and to collect sufficient data to evaluate the regime for routine monitoring of the fishery to inform population and ecosystem models (SC-CAMLR-XXVI, paragraphs 3.7 to 3.12).

4.58 The Working Group agreed that the 100% vessel coverage (i.e. a minimum of one observer on each vessel for all the period that the vessel is in the Convention Area) using government-appointed or international observers should be undertaken as soon as possible. During the initial phase of 100% observation, monthly submission of some of the data (krill measurement, by-catch and warp strikes) might be required to allow real-time feedback. This would require an increased workload for the Secretariat and WG-EMM to ensure assessment and provision of feedback on the performance of the observer program in the krill fishery.

4.59 The Working Group requested the Scientific Committee to consider the most practical way of initiating such coverage (for example, to take effect from December 2009), as this will allow sufficient time to recruit and train the observers to be deployed while being prepared to have coverage over a full fishing season.

4.60 The Working Group agreed that all observers need to be government trained and accredited, and that Members should be encouraged to arrange bilateral agreements to deploy international observers wherever possible.

4.61 The Working Group agreed that after a two-year period of 100% coverage, it would be in a position to provide advice to the Scientific Committee on the level of ongoing observer coverage, given the expectation of systematic coverage of not less than 50% vessel-days in the krill fishery.

4.62 The Working Group agreed that any new entrants (Members or vessels) and vessels using new fishing methods must comply with a two-year 100% vessel-time coverage by government-appointed or international observers, noting that this could be reviewed after two years to determine the required coverage for subsequent years.

4.63 The Working Group noted that vessels with increased catch and processing capacity may also need more than one observer to ensure data collection to be equivalent to the proportion of catch observed in other vessels.

4.64 The Working Group reiterated that for any level of coverage, the data must be of high quality, consistent across vessels and fishing methods, and collected in accordance with the CCAMLR Scheme of International Scientific Observation, following the instructions outlined in the *Scientific Observers Manual*.

4.65 The Working Group noted that there were inconsistencies with the priorities outlined by the Scientific Committee and those in the *Scientific Observers Manual*, and suggested that the latter be revised to reflect the new priorities.

4.66 The Working Group agreed that the priorities for data collection from the krill fishery should be:

- fish by-catch including larvae
- krill length-frequency distribution and maturity and sex stage
- trawl warp strikes
- incidental mortality of seabirds and marine mammals
- fishery dynamics and operation details.

Regulatory issues

4.67 The Working Group reviewed conservation measures that apply to krill fisheries (reported in WG-EMM-08/5), and agreed to advise the Scientific Committee on Conservation Measures 21-03 and 21-02.

4.68 With regard to Conservation Measure 21-03, the Working Group recalled the need to record information that describes the fishing technique to be used by krill fishing vessels (Annex 21-03/A). The Working Group agreed with the recommendation of TASO (SC-CAMLR-XXVII/BG/6, paragraph 2.16) to advise the Scientific Committee that it would be useful for Members to include information on specific details of the gear configuration when notifying their intent to participate in any krill fishery. This would include mesh size of the net, the mouth opening of the net, as well as the presence and design of a seal exclusion device, and any changes in trawl configuration during the trip. The addition of a relevant diagram in the scientific observer's report to CCAMLR should be considered to record this. It was recommended that a new notification pro forma should be developed for recording this information.

4.69 The Working Group noted that Conservation Measure 21-02 requires Members to notify the Commission of intent to participate in an exploratory fishery not less than three months in advance of the next regular meeting of the Commission. The Working Group agreed that the notification deadline in Conservation Measure 21-02 could lead to situations in which notifications of Members' intent to participate in an exploratory krill fishery were provided after the annual meeting of WG-EMM; such situations would not allow WG-EMM to provide advice to the Scientific Committee on any issues pertaining to such notifications. The Working Group therefore recommended that Conservation Measure 21-02 be revised so that notifications for exploratory krill fisheries must be received prior to the annual meeting of WG-EMM.

4.70 The Working Group recognised that Norway's notification of its intent to participate in an exploratory krill fishery in Subarea 48.6 (CCAMLR-XXVII/13) was provided to the Commission with sufficient time for WG-EMM to consider the notification and advise the Scientific Committee on aspects related to the data collection plan required by Conservation Measure 21-02 (paragraph 3). WG-EMM thanked Norway for its timely notification.

Exploratory krill fishery research data collection requirements

4.71 The Working Group recalled the request in 2007 from the Scientific Committee (SC-CAMLR-XXVI, paragraph 3.29) that WG-EMM should consider the information that would be required from exploratory krill fisheries. This could include consideration of stock sizes and definition, any subdivision of the statistical areas that might facilitate surveying or management, the requirement for SSMUs and trigger levels and the information available on krill, predators and the environment that could assist with management of exploratory fisheries.

4.72 The Working Group noted the notification by Norway for an exploratory krill fishery for the forthcoming season in Subarea 48.6, an area where little data on krill or krill predators exists. However, the Working Group noted that Germany and Norway have conducted recent scientific surveys in this subarea. The Working Group requested that Germany and Norway make analyses of acoustic and net data from the surveys on krill collected within Subarea 48.6 available for consideration by WG-EMM during the 2009 meeting (paragraph 5.51).

4.73 The Working Group noted that, at present, there is no formal estimate of biomass in Subarea 48.6, and thus no precautionary catch limit. It was also noted that there is currently no existing exploratory fishery research data collection plan for krill, as there are in exploratory toothfish fisheries (Conservation Measure 41-01) and crab fisheries (Conservation Measure 52-01).

4.74 The Working Group noted the requirement of Conservation Measure 21-02 for an orderly development of any exploratory krill fishery, with its attendant requirements for data to be collected that could be used to refine subsequent management decisions. With respect to a vessel entering an exploratory krill fishery, a set of research requirements and a data collection plan, similar to those set out for exploratory toothfish fisheries, is needed. The Working Group agreed that it would be best if these research requirements were generic, and suitable for any exploratory krill fishery notification in any subarea or division.

4.75 The Working Group recalled Conservation Measure 21-02, paragraph 3, which specifies that a data collection plan shall include, where appropriate:

(i) a description of the catch, effort and related biological, ecological and environmental data required to undertake the evaluations described in paragraph 1(ii) of the measure, and the date by which such data are to be reported annually to CCAMLR;

(ii) a plan for directing fishing effort during the exploratory phase to permit the acquisition of relevant data to evaluate the fishery potential and the ecological relationships among harvested, dependent and related populations and the likelihood of adverse impacts;

(iii) a plan for the acquisition of any other research data by fishing vessels, including activities that may require the cooperative activities of scientific observers and the vessel, as may be required for the Scientific Committee to evaluate the fishery potential and the ecological relationships among harvested, dependent and related populations and the likelihood of adverse impacts;

(iv) an evaluation of the time scales involved in determining the responses of harvested, dependent and related populations to fishing activities.

4.76 The Working Group recognised that there were four major considerations in the development of such a research plan:

(i) Any research requirement should include a strategy for collecting additional data outside the specific region where the vessel is actively targeting krill or transiting. The Working Group agreed that some measure to distribute effort would likely be necessary to collect this information, as this would provide information on spatial demographics and biomass that would be needed for assessment purposes.

(ii) Acoustic data provide valuable information that can be used to determine distribution and abundance of *E. superba*, and therefore, would be an important component of any research data collection plan.

(iii) Information should be collected from commercial trawls.

(iv) A system of SSRUs could be employed in an effort to learn more about the spatial distribution of the krill stock being fished. The Working Group noted that there is precedent in using this approach in both toothfish exploratory research requirements (Conservation Measure 41-01) and the crab fishery experimental harvest regime (Conservation Measure 52-02).

4.77 The Working Group agreed to provide a hierarchical approach to a data research collection plan. This will consist of different levels of data collection effort that would correspond to different levels of management advice. This could provide an indication as to the benefit and likelihood of meeting the management objectives with respect to each combination of data level and requirement.

4.78 Tables 1 and 2 detail such hierarchical approaches. Each table first details the key assessment questions required that will lead to advice on ecosystem-based management of a krill fishery (left column). Four levels of research based on fishery-dependent data collection are presented in the top row of Table 1. For each research plan based on fishery-dependent data, the table details how well that particular data collection strategy can address each of the key assessment questions.

4.79 The Working Group noted that the first two research strategies, commercial fishing and logged under-way acoustics, do not impose additional time and travel burden on fishing vessels. Thus, all research data for these strategies are collected while vessels are conducting fishing operations consistent with purely commercial activities while appropriate acoustic instruments are installed. In contrast, the two acoustic/trawl transect strategies do require additional time and travel effort by fishing vessels.

4.80 With respect to the fishery-dependent data collection, the Working Group agreed that the systematic acoustic trawl transect strategy would provide the best information with which to estimate a precautionary level of yield most rapidly. A proposed outline plan to operationalise the elements of this strategy is detailed as follows:

> Krill SSRUs (equivalent to fine-scale rectangles) are defined as areas of 0.5° latitude by 1° longitude across the larger CCAMLR areas. This previous definition is minimally acceptable given the large area of pelagic environments:
>
> 1. ‘Fishing’ is defined as any time that fishing gear, conventional trawls, pumped codends and newer continuous pumping gear are in the water.
>
> 2. A research haul is defined as a dedicated oblique haul made with a net (CCAMLR-approved design) to a depth of 200 m with a surface to depth to surface duration of 0.5 h.
>
> 3. A set of research hauls is defined as three research hauls where each research haul shall be a minimum of 10 n miles apart.
>
> 4. An acoustic transect is defined as a continuous path at constant speed and direction with a minimum distance of 30 n miles between the start and end points. Such transects can include continuous fishing operations.
>
> 5. Required research strategy –
>
>   (i) upon entry into a krill SSRU to fish, and before fishing, the vessel will be required to (a) conduct an acoustic transect across the krill SSRU, and (b) undertake a set of research hauls;
>
>   (ii) if after five days (continuous or discontinuous) of fishing the fishing vessel decides to stay in the same krill SSRU, then the fishing vessel must conduct a further acoustic transect and a further set of research hauls;

(iii) prior to leaving the krill SSRU, the fishing vessel will be required to complete an acoustic transect across the krill SSRU, along with a set of research hauls.

It is recognised that, in general, the search behaviour of the fishing vessels may encompass many of these attributes when entering an SSRU and searching for fishable aggregations of krill. Likewise, it is recognised that the continuous fishing techniques may also provide similar data.

4.81 Some members of the Working Group agreed that a research strategy such as this would impose a relatively small amount of additional steaming time, but would yield a large amount of data that could potentially be used towards an assessment of the resource.

4.82 Other members felt that the system was too complex, and may be difficult for the vessel to successfully execute.

4.83 The Working Group noted that any exploratory krill fishery should include some form of safeguard to ensure that the Commission could achieve its objectives with respect to Article II. One such safeguard could be a 'move-on rule', as well as a limitation on catch within certain areas. The Working Group agreed that fishing in a region which is close to an island or shelf area is more likely to impact land-based predators, and such regions should be afforded additional protection.

4.84 With respect to scientific observation, the Working Group recognised that some exploratory fisheries are required to carry two scientific observers. Dr Welsford indicated that ad hoc TASO concluded that the workload for one observer on a krill vessel is tractable, but if more data is needed, there would likely be the need for more observers. The data requirements, and therefore observer requirements, for the different levels of fishery-dependent data collection are given in Table 1.

4.85 The Working Group agreed that the appropriate level of observer coverage is essential to ensure the success of whichever data collection plan is approved.

4.86 With respect to the acoustic system, the Working Group agreed it would be beneficial to specify a set of guidelines as to the optimal frequency for detecting krill. It was recommended that previous SG-ASAM reports and the ICES report on 'Collection of acoustic data from fishing vessels' (ICES, 2007) may provide guidance or recommendations as to the optimal frequency or frequencies for subsequent data analyses.

4.87 The Working Group recognised that the analysis of the collected acoustic data requires expertise, and represents a significant expenditure of time and effort. It was recognised that not all Members may have such resources available. The Working Group noted that these potential limitations may be overcome by Members collecting the data and then sub-contracting the data analysis to other Members or Parties. The Working Group requested that the Scientific Committee consider this issue further.

4.88 With respect to data reporting, the Working Group agreed to a minimum set of reporting requirements for an exploratory krill fishery when fishing commercially:

(i) 10-day catch and effort reporting system in accordance with Conservation Measure 23-02;

(ii) haul-by-haul catch and effort data in accordance with Conservation Measure 23-04, including monthly deadline;

(iii) scientific observer data in accordance with the CCAMLR Scheme of International Scientific Observation;

(iv) if acoustic data is being provided, the vessel will need to follow specific requirements and recording format as agreed by the Commission bearing in mind paragraph 4.86.

4.89 The Working Group agreed that any research collection plan must also include research hauls, since there is little information that can be used towards addressing basic assessment questions with commercial hauls only.

4.90 The Working Group agreed on the need to identify the specific data requirements for research hauls, including what kind of data is needed, the timing of the collection, and who would collect the research data.

4.91 Data required from every research haul should include:

(i) start and end position;

(ii) estimate of total catch (green weight) of krill;

(iii) random sample of 200 krill to be taken from the haul by the observer – length, sex and maturity staged according to the CCAMLR *Scientific Observers Manual*;

(iv) species composition of the by-catch.

4.92 The Working Group recognised that the proposed fishery-dependent research data collection strategy set out in paragraph 4.80 is only one example of how a research data collection plan could be achieved, and that other plans could be equally effective. For example, with respect to the timing of research hauls, some members agreed that research hauls should be taken every five days as set out in the proposed strategy. This would result in two research sampling events per 10-day reporting period. Other members felt it was more adequate to have research hauls taken every 10 days. There were also questions raised with respect to the optimal size of each sampled SSRU.

4.93 The Working Group agreed that it would be highly advantageous that gear used during research hauls be standardised across all vessels participating in an exploratory fishery, as this would considerably reduce uncertainty when comparing results across different gear types. However, the Working Group did not have adequate time to consider details on specifications for a standardised research trawl. The Working Group requested advice from ad hoc TASO as to what type of standardised gear could be deployed, given that this gear may need to be swapped with the principal commercial krill trawl, and thus must be able to be changed quickly and with minimal effort.

4.94 The Working Group emphasised that any research data collection plan using fishery-dependent data collection strategies should be standardised across all exploratory krill fisheries.

4.95 The Working Group recognised that an alternative form of data collection could be to collect data through fishery-independent collection strategies. This could consist of a predator monitoring program for krill predators foraging in the exploratory fishing area, or a fishery-independent scientific krill survey. The former could potentially provide data that could be used to monitor whether predator performance is being degraded by the exploratory fishery. The latter could directly be used to provide an estimate of B_0, and an assessment of the resource. Details on such fishery-independent monitoring strategies are set out in Table 2.

Key points for consideration by the Scientific Committee and its working groups

4.96 Krill fishery:

(i) haul-by-haul data remain to be submitted by Poland for 2006/07 (paragraph 4.3);

(ii) trends in the krill fishery (paragraphs 4.1 and 4.6 to 4.8);

(iii) notifications of intention to fish for krill in the 2008/09 season (paragraphs 4.6 to 4.17).

4.97 Scientific observation in the krill fishery:

(i) lack of data on product-specific catches and conversion factors are creating difficulties in verifying the accuracy of 'green weight' of krill caught (paragraph 4.36).

(ii) the request for Members to be encouraged to evaluate the possibility of accurately reporting catch on the basis of direct estimates of 'green weight' to resolve the problem of inaccurate catch reporting (paragraphs 4.39);

(iii) WG-EMM agreement on the role of ad hoc TASO (paragraph 4.45);

(iv) revisions required in the *Scientific Observers Manual* (paragraphs 4.52, 4.65 and 4.66);

(v) the need for a fish by-catch sampling protocol consistent with the existing larval fish sampling protocol (paragraph 4.54);

(vi) an agreed strategy for implementing a scientific observer program to achieve systematic coverage in the krill fishery (paragraphs 4.58 to 4.63).

4.98 Regulatory issues:

(i) the need to record information that describes the fishing technique to be used by krill vessels (paragraph 4.68);

(ii) the consideration of notifications for exploratory krill fisheries and requirements for data collection plans needed to implement Conservation Measure 21-02 (paragraphs 4.69 to 4.95).

STATUS AND TRENDS IN THE KRILL-CENTRIC ECOSYSTEM

Report of WG-EMM-STAPP

5.1 Dr Southwell presented the report on the Predator Survey Workshop (WG-EMM-08/8), which was held at the CCAMLR Headquarters, Hobart, Australia, from 16 to 20 June 2008. The terms of reference for the workshop are outlined in WG-EMM-08/8, paragraph 1.5. Participants at the workshop included two experts from SCAR (Ms D. Patterson-Fraser and Dr B. Raymond) and an independent, invited expert (Dr R. Fewster). A report from Dr Fewster on her findings on the workshop is presented in WG-EMM-08/9.

5.2 The workshop agreed to restrict its deliberations to 11 priority species (1 ice-breeding seal, 1 land-breeding seal, 4 penguins and 5 flying seabirds) that breed in Area 48 and whose consumption of krill had previously been estimated to be close to, or greater than, 100 000 tonnes per annum. These species are listed in WG-EMM-08/8, Table 1, and are considered to be the most important land-based krill consumers in the Scotia Sea (Croxall et al., 1985).

5.3 Workshop participants had been invited to submit new survey results, reviews and summaries of existing data, raw data and new estimation procedures for priority species. A database structure had been developed prior to the workshop to facilitate the submission of penguin abundance data. Submissions included:

(i) new survey results for the crabeater seal (WG-EMM-PSW-08/6), Antarctic fur seal (*Arctocephalus gazella*) (WG-EMM-PSW-08/14), macaroni penguin (*Eudyptes chrysolophus*) (WG-EMM-PSW-08/4) and white-chinned petrel (*Procellaria aequinoctialis*) (WG-EMM-PSW-08/5);

(ii) a review of flying seabird surveys and abundance estimates in the published literature (WG-EMM-PSW-08/10);

(iii) penguin count data from unpublished sources (ASI), published literature (BAS) and CEMP;

(iv) two new procedures for estimating penguin abundance (WG-EMM-PSW-08/11 and 08/15).

5.4 A general framework for estimating abundance was established and a distinction made between count data and data required to adjust counts for issues such as detectability, availability and sampling (collectively termed adjustment data). The count and adjustment data for each of the identified priority species in each SSMU were then reviewed (WG-EMM-08/8, Attachment 4, Tables 4.1 to 4.11):

(i) Both count and adjustment data for the crabeater seal were considered to be good, although availability data were based on haul-out of seals in regions outside of Area 48, resulting in possible bias.

(ii) Spatial coverage of fur seal count data in Subarea 48.1 was good and recent. Spatial coverage of count data in Subarea 48.3 was good but data are relatively old; however, ongoing surveys are scheduled for completion in 2009.

(iii) For the four penguin species, the spatial cover of count data was generally good, but the recency of data varied from current to relatively old. Adjustment data for detectability and sampling are generally assumed to be unnecessary for estimation of penguin abundance because most counts are assumed or known to be a census where all target objects are counted. However, adjustment data for availability were generally limited for all four penguin species.

(iv) Count data were generally poor or old for all species of flying seabirds except the white-chinned petrel at South Georgia, where a recent survey has been conducted. There is no adjustment data of any sort for the Antarctic prion (*Pachyptila desolata*), southern fulmar (*Fulmarus glacialoides*) and Cape petrel (*Daption capense*), while adjustment data for the white-chinned petrel and South Georgia diving petrel (*Pelecanoides georgicus*) are good but could be improved.

5.5 The workshop then reviewed the estimation procedures that have been previously and currently applied to these data:

(i) the estimation procedures applied to crabeater seal data were considered state-of-the-art;

(ii) the estimation procedures used to derive a total abundance estimate for fur seals at South Georgia have not been described in detail. Estimation of abundance from new surveys planned for 2009 will involve modelling of haul-out and demographic data;

(iii) a number of different methods have been used for adjusting penguin count data for availability. The workshop recognised that there was a need to standardise availability adjustment methods where possible;

(iv) estimation methods for flying seabirds are often poorly described. The workshop noted that one of the key issues limiting estimation of flying seabird abundance from land-based surveys was the lack of habitat maps.

5.6 Two new procedures for estimating penguin abundance were submitted to the workshop. WG-EMM-PSW-08/15 described a three-stage hierarchical Bayesian model to correct off-peak counts and make them comparable with CEMP standard method counts. WG-EMM-PSW-08/11 reported a parametric bootstrap method developed in the R language. The workshop welcomed both of these new estimation methods and encouraged their further development and application.

5.7 The workshop agreed that it could provide the following recommendations and advice to WG-EMM at varying time-scales:

(i) Immediate recommendations –

(a) recent survey work in Area 48 provided major improvements in the state of knowledge about the abundance of crabeater seals, fur seal pup production in the South Shetland Islands, macaroni penguins at South Georgia and white-chinned petrels at South Georgia;

(b) aerial surveys of Antarctic fur seals are scheduled for completion in the 2008/09 field season;

(c) the continued development of a new database containing existing penguin count data that can serve as a basis for the production of large-scale abundance estimates;

(d) the development of two new methods to account for bias and uncertainty in raw count data when estimating total abundance that provide complimentary utility for estimating SSMU-specific abundance;

(e) a major gap in abundance data for priority species is for flying seabirds throughout Area 48, except for white-chinned petrels at South Georgia. Given the lack of land-based data for this group, the workshop recommended that WG-EMM invite submissions on at-sea data for flying seabirds in Area 48 for consideration at WG-EMM-09. The workshop identified US AMLR summer cruise data, US-LTER summer and winter cruise data, and BAS data at South Georgia and across the Scotia Sea as potential datasets.

(ii) Short-term (immediate intersessional for WG-EMM-08) –

The development of SSMU-scale estimates of penguin abundance as an illustration of the compiled database, provided in WG-EMM-08/53. These estimates are preliminary in that they only account for uncertainty in the accuracy of the count data and only approximate adjustments for availability are made.

(iii) Medium-term (intersessional for WG-EMM-09) –

(a) if feasible, production of SSMU-specific crabeater seal abundance estimates based on the habitat modelling approach presented in WG-EMM-PSW-08/6;

(b) the anticipated completion of the Antarctic fur seal survey at South Georgia in early 2009 will provide an important update to the existing abundance estimates from 1991;

(c) further development and testing of the new estimation procedures for penguins, and implementation of those procedures to quantify bias and uncertainty in adjusting raw counts.

(iv) Future work. The workshop identified several gaps in data that can only be filled through a long-term work plan –

(a) recent count data for penguins in the western South Shetland Islands and eastern Antarctic peninsula;

(b) count data for flying seabirds throughout Area 48;

(c) adjustment data for most species in most areas. Strategic collection of adjustment data to improve estimation of penguin abundance is of particular importance;

(d) development of alternate survey methods for large penguin colonies.

5.8 The Working Group thanked Dr Southwell for his report and for convening the Predator Survey Workshop. The work of WG-EMM-STAPP represents a substantial contribution to the work of CCAMLR and for quantifying predator abundance within SSMUs.

5.9 In particular, the Working Group noted that a combined database of penguin count data, comprising data collected under CEMP, data from the ASI and historical data from the literature, was an essential contribution to the work of CCAMLR.

5.10 Dr Trathan noted that such a database would eventually be made available to CCAMLR. Data access would fall under the Rules for Access and Use of CCAMLR Data.

5.11 The Working Group noted that the submission by BAS on crabeater seal distribution and abundance alone was important and a significant progress to quantifying abundance of important krill-consuming predators.

5.12 One of the aims of the Predator Survey Workshop was to identify gaps in our knowledge of predator abundance and with this in mind (as also noted in WG-EMM-08/53), geographic areas with poor coverage were identified (e.g. SSMU APE). Future survey work would best focus on these geographic gaps.

5.13 The Working Group also appreciated the attempts by the Predator Survey Workshop towards estimating uncertainty in predator abundance estimates and noted that this will be particularly useful for modelling estimations.

5.14 It was noted by the Predator Survey Workshop and the Working Group that one of the problems in using existing data to derive regional-scale abundance estimates for penguins, was that the year of the most recent count at individual colonies varies substantially, so some standardisation or adjustment for year of count is necessary. Data collected at long-term monitoring sites are important for making this kind of adjustment. It will also be important, if possible, to report the year to which each abundance estimate applies. There is a need to incorporate work addressing these issues into the long-term work plan of the group.

5.15 Dr Southwell noted that the work of the group with regard to quantifying predator abundance was a staged process and the work of the Predator Survey Workshop was merely the first stage of a multi-stage process with the ultimate goal of regional-scale estimates.

5.16 The Working Group noted that future work should include fish predators. With this in mind, a first step might be, similar to what was undertaken by the Predator Survey Workshop, to identify which of the list of krill consumers were also important fish predators.

Status of predators, krill resource and environmental influence

Predators

5.17 Dr Ramm presented WG-EMM-08/4, a summary of CEMP indices. Processing and validation of data submissions from Member countries continued with particular emphasis on adherence of data submissions to standard methods. This year, data were submitted by seven countries reporting from 11 sites.

5.18 Figure 3 of WG-EMM-08/4 presented a summary of CEMP parameters and Table 1 provided a summary of CEMP indices in the database. This indicated that there has been a decrease in the number of sites from which data are submitted and a decrease in the number of parameters submitted from some other sites. The Secretariat had been advised that the Edmondson Point site was not monitored in 2007/08; aerial photographs of the penguin colonies at the Ross Island site were collected in 2007/08, photographs taken since 2003/04 are being processed and the derived A3 data will be submitted in due course.

5.19 The Working Group noted that some CEMP data from the Australian CEMP program were awaiting analysis and would be submitted to the Secretariat in the future.

5.20 The Working Group also noted that CEMP data from the Bouvet Island site were collected in 2007/08 (WG-EMM-08/28).

5.21 Dr Trivelpiece presented WG-EMM-08/P12, 08/50, 08/51 and 08/P11 to the Working Group.

5.22 WG-EMM-08/P12 presented an analysis of at-sea data on Cape petrel, chinstrap penguin (*P. antarctica*) and krill distributions near Elephant Island during January for the 2004–2006 summers. Patch dynamics of krill strongly influenced the local abundance and distribution of seabirds, suggesting that future modelling work incorporate the impact of krill patchiness in relation to predator foraging demand. The authors suggested that information on the distribution of seabirds may provide a mechanism to better understand choices made by the fishery, given the changes in patchiness, search time and predator distribution at sea. Such information could be used to interpret potential interactions between seabirds and the krill fishery. Negative effects, such as competition through the depletion of patches by fishing vessels, may impact predator populations at the local scale. Other studies have proposed that krill fishing be restricted within 50–100 km of penguin breeding colonies; this study reinforces that proposition.

5.23 The Working Group endorsed the suggestion of the Predator Survey Workshop (WG-EMM-08/8, paragraph 6.9) that it would be helpful to investigate whether at-sea observations of seabirds might be an alternative method for estimating abundance and consumption values for these species within SSMUs. The Working Group encouraged Members with pertinent data to prepare papers for review at the 2009 meeting of WG–EMM.

5.24 WG-EMM-08/50 examined interannual changes in the foraging strategies and diet of gentoo penguins in the South Shetland Islands, Antarctica, over five years (2002–2005 and 2008). *Euphausia superba* was the primary diet item, and fish the secondary. The number of chicks that survived from hatching to crèche was nearly constant among years, while diet composition and diving patterns were highly variable. These results indicate that gentoo penguins (*P. papua*) could forage on several types of prey, and at different depths without compromising their ability to provision their chicks. The authors suggested that this flexibility may contribute to why gentoo penguin populations have remained stable, or are increasing, in the region, while populations of their congeners with less flexible foraging strategies have declined. Predator monitoring of several species simultaneously provides additional insight into how changes in krill abundance may affect population dynamics of predators and should be important considerations for modellers of krill–fishery–predator interactions in the Southern Ocean.

5.25 The Working Group noted that although the foraging strategy of gentoo penguins was flexible, krill dominated the diet in all years. It seems unlikely that gentoo penguins would be able to entirely compensate their diet with fish if there were a more serious depletion of krill as evidenced by gentoo penguins at South Georgia, which experience a near-total collapse in breeding success during years when krill biomass in the region is substantially reduced.

5.26 The Working Group noted that gentoo penguins, though more flexible in their foraging strategies than their congeners, still respond to changes in krill biomass through prey-switching. In addition, they provide valuable opportunities for comparative studies with chinstrap and Adélie penguins in response to environmental change and variability.

5.27 WG-EMM-08/51 reported preliminary progress to apply FOOSA at the scale of interactions among the three breeding penguin populations, krill and environmental variability at Admiralty Bay, King George Island.

5.28 This work-in-progress serves two purposes:

(i) Down-scaling FOOSA will allow for the estimation of parameters, including stock-recruitment parameters and the shape parameters that describe the sensitivity of predator survival to changes in krill density. Little information on these parameters at the regional (i.e. Scotia Sea) scale exists, but detailed information is available at the local scale. The ability of FOOSA to predict the observed changes in penguin abundance at the small scale of this study site may be useful for advancing the implementation of ecosystem-based management objectives in the entire Scotia Sea region.

(ii) Syntheses of diverse data from Admiralty Bay have identified alternative hypotheses about juvenile penguin survival that can be incorporated into FOOSA. The alternative hypotheses can be formally tested as competing models using standard model selection criteria. By testing competing hypotheses, the authors expect to gain valuable insight on the dominant drivers of change within the study populations and improve the biological realism of FOOSA.

5.29 The authors noted that the relative importance of bottom-up (krill availability and food-web changes) versus top-down (predator) control of the penguin populations may be changing under conditions of low breeder abundances. Predation pressure may accelerate downward trends in populations when these populations reach small sizes, further reducing the time period when conservation measures might be put in place to help mitigate the declines in predators.

5.30 WG-EMM-08/P11 presented data from a long-term ecosystem monitoring program of the predators at South Georgia together with a krill population model to simulate natural and fisheries-induced variability in krill abundance and examine the power to detect the effects of different levels of fishing. The results indicate that although the monitoring program has a proven ability to detect the effects of natural variability in krill abundance, its ability to detect the effects of fishing may be limited if there is a requirement for statistical significance at the 95% level.

5.31 Changing the probability of a Type I error (α) from 0.05 to 0.2 produced a marked increase in statistical power. The authors suggested that when considering methods for using predator response data to detect the effect of fishing, it might be appropriate to set the α level higher than used in normal statistical hypothesis testing, which would reduce the risk of Type II error (i.e. not detecting a real effect) but increase the risk of Type I error (falsely identifying an effect). The authors argued that this is consistent with the precautionary approach.

5.32 The authors suggested that developing a better understanding of the role of environmental processes on variability in krill abundance would, in effect, allow the environment to be included as a covariate in the analysis of monitoring data. This could effectively control for the environmentally driven component of the overall variability and increase the power to detect change arising specifically from the effects of the krill fishery.

5.33 The Working Group noted that it is important to correctly identify the environmental variables that are driving the variability when exploring this approach.

5.34 The Working Group further noted that the analyses presented in WG-EMM-08/P11 illustrate the trade-offs in making management decisions. An understanding of the relative impacts of making Type I and Type II errors in management actions can lead to a more dynamic approach to management.

5.35 Dr Goebel presented WG-EMM 08/25, 08/31 and 08/35 to the Working Group.

5.36 WG-EMM-08/25 presented data on minke whale (*Balaenoptera acutorostrata*) diet from whaling expeditions over four years from 1982/83 to 1985/86 in whaling Areas 1–4 and 6. Sixty-five percent of the whales taken were from CCAMLR Area 48. Over 12 000 minke whales were harvested and over 11 000 (*N* = 11 652) stomachs were analysed. Of these, 46% (*N* = 5 354) contained prey. All stomachs with prey had *E. superba* and 94% of the stomachs were composed entirely of *E. superba*. Secondary items included crystal krill (*E. crystallorophias*) and Antarctic silverfish (*Pleuragramma antarcticum*). Most of the *Pleuragramma* came from minke whales taken from Area 2. Krill in stomachs were staged for sex and maturity according to standard protocol. No length-frequency data are given, but the author did report on median krill length, maturity and sex ratio. Although no statistical analyses are presented, the author did report differences in krill composition by area and season.

5.37 Both WG-EMM-08/31 and 08/35 report on a multi-vessel oceanographic study of the Ross Sea in the 2004/05 season. In many regards they are similar studies of oceanography in relation to krill and whale distribution for parts of Subareas 88.1 and 88.2. However, there are some important differences. The study area in WG-EMM-08/31 covered from 160°E to 160°W and from 78°S to 60°S. Sampling extended further north than in WG-EMM-08/35 and included waters of the ACC. The study area used for WG-EMM-08/35 covered from 165°E to 155°W, and from 69°S to the Antarctic continent. Temporal coverage was greater in WG-EMM-08/31 and covered from late December through most of February. The study reported in WG-EMM-08/35 was a one-month study from mid-January to mid-February.

5.38 Both studies found similar results in the distribution of *E. superba* and *E. crystallorophias*. The latter species occurred in greater abundance in colder waters over the continental shelf, while *E. superba* was found in warmer deeper water. *Euphausia superba* and *E. crystallorophias* distributions are presented for both papers.

5.39 WG-EMM-08/31 reported on whale distributions for three species, humpback (*Megaptera novaeangliae*), blue (*B. musculus*) and minke whales. WG-EMM-08/35 reported on the distribution of minke whales only. Minke whales in both studies had a similar distribution in colder water (relative to humpback whales) and were found in greater abundance in the shelf slope region and at the ice edge and fed primarily on *E. superba*. Humpbacks, on the other hand, occurred only in the warmer water of the ACC. Only minke whales were sampled for diet studies.

5.40 Dr Naganobu suggested that these papers provide evidence of the strong relationships between oceanographic variability in water mass and circulation patterns of the surface layer (MTEM-200) with the distribution and abundance of krill and baleen whales. He suggested that this close relationship would allow results from the local scale of the survey to be widely applied to the whole region.

Krill

Observations at depths below 200 m

5.41 Most observations to date indicate that the bulk of the population of post-larval krill is typically confined to the top 150 m of the water column. For example, WG-EMM-08/32 described how 94% of all krill catches in the fishery occur at depths shallower than 200 m, while analysis of the CCAMLR-2000 Survey (Demer, 2004) indicated that acoustic biomass of krill was essentially confined to the top 150 m.

5.42 In contrast, WG-EMM-08/P1 reported observations using a deep-water remotely operated vehicle in the austral summer of 2006/07 which revealed the presence of adult *E. superba*, including gravid females, at depths down to 3 500 m in the Marguerite Bay region on the western Antarctic Peninsula. Adult krill were found close to the seabed at all depths but were absent from fjords close inshore. At all locations where krill were detected, they were seen to be actively feeding, and at many locations there were exuviae (cast moults).

5.43 Two other papers presented at the meeting dealt with krill occurring deeper than 200 m. WG-EMM-08/P10 reported on the vertical distribution of euphausiids in the Ross Sea and its adjacent waters in 2004/05. In depth-stratified RMT8 net samples, juvenile *E. superba* were distributed in the top 200 m in the offshore region near the SACCB, but gravid females were dominant in the slope region and were most abundant in the 400–600 m layer.

5.44 Similarly, WG-EMM-08/28 provided a preliminary report on acoustic and trawl catch data collected during the Antarctic Krill and Ecosystem Studies (AKES) survey conducted in

Subarea 48.6 on board RV *G.O. Sars*. While the acoustic data showed that *E. superba* were mainly found above 150 m, the trawl catches indicated that a small part of the stock resides in water deeper than 500 m.

5.45 The Working Group recalled that there are extensive data from the winter fishery around South Georgia that show that, in winter, krill are likely to occur deeper in the water than in summer. However, the Working Group agreed that the observations presented in WG-EMM-08/P1 were novel and challenging to the view of krill as essentially a pelagic organism.

Krill surveys

Surveys in Subarea 48.6

5.46 WG-EMM-08/28 provided an overview of the Norwegian 2008 AKES survey around South Georgia in Subarea 48.3 and along transects in the region of the 0° meridian in Subarea 48.6. Preliminary results suggested some differences between the population structures in the two subareas. The large adult *E. superba* found in the South Georgia region were less mature than those sampled in Subarea 48.6. The authors also noted that pygmy krill (*E. frigida*) and spiny krill (*E. triacantha*) were more abundant in the South Georgia region compared to Subarea 48.6.

5.47 WG-EMM-08/28 also presented a preliminary biomass estimate of ~14 million tonnes of *E. superba* for the part of Subarea 48.6 covered by the two transects undertaken during the second leg of the AKES cruise. Given that the survey area covered 302 000 n miles^2 this equates to a krill biomass density of ~13.6 g m^{-2}.

5.48 The Working Group thanked Norway for the effort expended to undertake this survey in an area for which there was little previous information and looked forward to the full analysis and future publication of the results.

5.49 WG-EMM-08/7 reported on a German contribution to CCAMLR-IPY in the austral summer of 2007/08 where a standardised krill net sampling survey was conducted in the Lazarev Sea (south of 60°S) (part of Subarea 48.6). *Euphausia superba* were found in 49 out of 52 RMT samples but krill density was only 0.87 g m^{-2}, the second-lowest values in a series of four surveys. Bigeye krill (*Thysanoessa macrura*) occurred in high numbers during the current summer survey and outnumbered the density of *E. superba* five times. South of 62°S, size composition of *E. superba* was dominated by 1- and 2-year-old krill, however, the proportion of 1+ was lower than 2+ krill, indicating only a moderate 2007 year class. Between 60° and 62°S, older length classes larger than 35 mm dominated the krill stock. The krill population was in a developing maturity stage and krill larvae were scarce. A comparison with 2006 data revealed that spawning occurred at least three weeks later in the 2008 season than during the 2006 study. *Euphausia crystallorophias* occurred only at few neritic Antarctic coastal stations and numbers were relatively low.

5.50 The Working Group noted that in addition to *E. superba*, other euphausiid species in Subarea 48.6 are also important, which will provide alternative pathways through the food web and will have implications for the relationships between harvested and dependent species.

5.51 The Working Group also noted that acoustic survey data taken on the German cruise would provide important information on the biomass of krill in Subarea 48.6 and encouraged submission of an appropriate biomass assessment to the next meeting of WG-EMM.

Surveys of the Ross Sea area

5.52 WG-EMM-08/P10 reported on distribution and population structure of euphausiids in the Ross Sea and its adjacent waters during the summer of 2004/05. Among the euphausiid species, *E. triacantha* was dominant in biomass north of the SACCB, *Thysanoessa* spp. was widely distributed north of the continental slope, while *E. superba* was distributed from the SACCB to the slope. *Euphausia crystallorophias* were found at 200–300 m in the colder water of the continental shelf. *Euphausia superba* individuals with body lengths of 40 to 51 mm were dominant. While 26 to 40 mm individuals were conspicuously scarce in the survey, the authors suggest that this probable 2+ year class was distributed separately from other year classes north of the slope area and was not captured because of the coarse sampling grid.

5.53 WG-EMM-08/31 and 08/35 both provided biomass estimates of krill in Ross Sea. WG-EMM-08/35 described a two-ship survey with each ship carrying out a different but overlapping survey design. Krill were identified using a two-frequency dB difference of 2–16 dB and TS was calculated using Greene et al. (1991). The mean biomass densities of *E. superba* were 5.13 (±7.11 g m^{-2}) and 2.53 (±2.25 g m^{-2}) for the two ships. This resulted in a combined biomass of 1.4 million tonnes (CV 0.32) from an area of ~110 000 n $miles^2$. A biomass estimate for *E. crystallorophias* of 0.6 million tonnes was calculated.

Multi-year data series

South Georgia

5.54 WG-EMM-08/48 presented data on the multiple time scales of variability in the krill populations at South Georgia. Krill acoustic density data from surveys conducted in the early, middle and late period of the summers of 2001 to 2005, together with krill population size structure over the same period from predator diet data, were used with a krill population dynamics model to evaluate potential mechanisms behind the observed changes in krill biomass. Krill abundance was highest during the middle of the summer in three years (in 2001, 2002 and 2005) and in the late period in two years (2003 and 2004); in the latter there was evidence that krill recruitment was delayed by several months. A model scenario with empirically derived estimates of both the magnitude and timing of recruitment in each year showed the greatest correlation with the acoustic series. The results are consistent with a krill population with external (allochthonous) recruitment entering a retained adult population. The results highlight the importance of the timing of recruitment, especially where this could introduce a mismatch between the peak of krill abundance and the peak demand from predators which may exacerbate the effects of changes in krill populations arising from climate change.

5.55 The Working Group discussed the magnitude of krill flux and migration in the South Georgia region. It recognised that there is considerable retention, spatial stability and predictability of the krill population found over the South Georgia shelf. However, it was stressed that the South Georgia krill population is not self-sustaining and is totally dependent on the recruitment of krill that will have originated from the ice-dominated regions to the southwest of the island.

5.56 The Working Group recognised that the results of WG-EMM-08/48 had important implications for the management of krill, especially if there is an assumption that a temporal separation between fishing and the period of peak predator demand could reduce competition for krill between fisheries and predators at South Georgia.

South Shetland Islands region

5.57 WG-EMM-08/19 reported on a recalculated US AMLR time series of net-derived abundance of *E. superba* and three species of other Antarctic zooplankton for the Elephant Island region. Over the period from 1992 to 2007 three equal-sized peaks in the abundance of *E. superba* were detected in 1996, 1998 and 2002/03.

5.58 WG-EMM-08/41 presented updated krill recruitment data for the Elephant Island region of the South Shetland Islands for 2002–2008. All recruitment indices showed that high recruitment (R1) occurred in 2003 and in 2007/08, with low recruitment occurring during the intervening years. Significant differences in the proportional recruitment indices occurred between legs within years indicative of the changing pattern of krill recruitment within the Elephant Island region.

5.59 WG-EMM-08/P12 reported on influences of spatial variability of *E. superba* on seabird foraging behaviour near Elephant Island (paragraph 5.22). In the context of describing the status of krill, the paper presented measures of krill patchiness in relation to the abundance of krill and showed that when krill is significantly less abundant, the scale of patchiness increases.

5.60 The Working Group noted the clear interannual trend in population recruitment in these data and re-emphasised the strong links established between krill recruitment, sea-ice dynamics and global climate processes, such as ENSO, that impact the Scotia Sea.

South Orkney Islands

5.61 WG-EMM-08/26 compared the biomass of *E. superba* around the South Shetland and South Orkney Islands in 1999, 2000 and 2008. Length-frequency distributions of krill in 2000 and 2008 at Elephant Island and the South Orkney Islands were similar. On the basis of this observed similarity in population structure, a biomass estimate using acoustic data collected as part of US AMLR finfish surveys in 1999 and the krill length distribution derived from Elephant Island in the same year was derived. In 2008 a dedicated krill biomass survey resolved a total of ~2.7 million tonnes of krill in the South Orkney region. Overall, the comparison of biomass from these three years suggests that krill biomass in the South Orkney Islands is similar to the biomass in the South Shetland Islands, especially the Elephant Island region.

5.62 The Working Group welcomed this approach to derive krill biomass using acoustic data collected as part of a finfish survey and noted such data, derived from ancillary studies, can be used to better resolve the temporal trends in krill biomass in this region.

5.63 The Working Group noted that although at times the population structure at the South Orkney Islands is highly variable, it appears that much of this variability may be due to sampling in relation to water masses originating from the Weddell Sea. In addition, the detection of similar krill recruitment classes in predator diet data collected at the South Orkney and South Shetland Islands also supports the congruence between the krill population in the two regions.

5.64 In summary, the Working Group emphasised the importance of the long-term datasets on krill abundance that were now resulting from national programs in the Scotia Sea and urged their continuation into the future.

Large-scale distribution and abundance of *E. superba*

5.65 The krill fishery tends to focus on the shelf and shelf-break regions (for example, WG-EMM-08/55 and 08/32), although, historically, considerable fishing effort has been expended in oceanic regions in both the southwest Atlantic and the area between 30° and 150°E.

5.66 WG-EMM-08/P4 presented a quantitative circumpolar distribution map of *E. superba* based on a net sample database (8 137 samples) collected between 1926 and 2004. The numerical densities were standardised to a common sampling method. From this analysis 70% of the total stock is concentrated between 0° and 90°W and, overall, 87% of the total stock live over deep oceanic water (>2 000 m) and occupy regions of moderate food (0.5–1.0 mg chl-*a* m^{-3}). Advection models suggest some loss northwards from these regions and into the low chlorophyll belts of the ACC. The authors found possible evidence for a compensating southwards migration, with an increasing proportion of krill found south of the ACC as the season progressed. The authors indicated that the retention of krill in moderately productive oceanic habitats is a key factor in their high total production. While growth rates are lower than those over shelves, the ocean provides a refuge from shelf-based predators. The unusual asymmetrical circumpolar distribution of krill thus reflects a balance between advection, migration and top-down and bottom-up processes.

5.67 WG-EMM-08/17 undertook a re-appraisal of the total biomass and annual production of *E. superba*. Net-based databases of density and length frequency (KRILLBASE) yield a summer distributional range of ~19 × 10^{6} km^{2} and a mean total abundance of 8 × 10^{14} post-larvae with a circumpolar biomass of 379 million tonnes. For the CCAMLR-2000 Survey area, this equates to a krill biomass estimate of 106 million tonnes. These values are based on a standardised net sampling methodology but they integrate over the period 1926–2004, during which krill abundance has fluctuated.

5.68 In WG-EMM-08/17, gross post-larval production is estimated conservatively at 342–536 million tonnes y^{-1}, based on three independent methods. These are high values, within the upper range of recent estimates, but consistent with the concept of high energy throughout for a species of this size. The similarity between the three production estimates reflects a broad agreement between the three growth models used, plus the fact that, for a given population size, production is relatively insensitive to the size distribution of krill at the start of the growth season. These production values lie within the envelope of what can be supported from the Southern Ocean primary production system and what is required to support an estimated predator consumption of 128 to 470 million tonnes y^{-1}.

5.69 The Working Group recognised that these large global syntheses obtained from the combination of many different datasets had an extremely valuable contribution to make to our understanding of the operation of the oceanic ecosystem. In addition, the Working Group noted that net-based estimates of krill biomass may be useful for comparison with those obtained from acoustic surveys.

5.70 The Working Group also recognised that the patterns of small-scale variability and change in krill biomass (over annual to decadal time scales) were often masked through the requirement to average over long time scales so that circumpolar coverage could be derived. The Working Group concluded that further submissions providing assessment of time trends in such datasets would be welcomed and noted that further discussion may be possible in the context of the forthcoming Joint CCAMLR-IWC Workshop.

Krill parasites

5.71 WG-EMM-08/P9 presented data on the histopathology of *E. superba* bearing black spots. Such spots have been noticed on the cephalothorax of krill since January 2001. Histological observations from krill sampled in the winters of 2003, 2006 and 2007 in the South Georgia region revealed that the black spots were melanised nodules composed of hemocytes surrounding either bacteria or amorphous material. In the 2007 samples, 42% of krill had such melanised nodules. Unidentified parasites were observed in some krill that had melanised nodules. The authors suggested that krill had been initially affected by parasite infections, and the parasitised spots were secondary infections by environmental bacteria after the parasites had escaped from the host body.

5.72 The Working Group recalled its request for data on the frequency of krill infected with black spots to be recorded by scientific observers on krill fishing vessels (SC-CAMLR-XXVI, Annex 4, paragraph 4.67) in order to consider the potential consequences of this condition on krill reproductive performance and mortality (SC-CAMLR-XXVI, Annex 4, paragraphs 5.52 to 5.56). Given the negative effect of a black spot disease on the reproductive success of North Atlantic shrimp (*Pandalus borealis*), the Working Group encouraged further work to understand whether such effects may also occur in *E. superba*.

Environment and climate impacts

5.73 Six papers were submitted for consideration by the Working Group under this topic. These consisted of four published papers (WG-EMM-08/P2, 08/P3, 08/P5 and 08/P6) and two working group papers (WG-EMM-08/32 and 08/33).

5.74 In WG-EMM-08/32 the authors explained increased understanding on the importance of the MTEM-200 index as it relates to the global scale, and to the distribution of krill. The authors used the commercial krill fishery data from 1973 to 2008 to document the vertical distribution of effort and found that most krill were caught within 50 m of the surface. To derive a global MTEM-200 index, the authors used the global summary of water column temperature using the *World Ocean Atlas* (Locarinni et al., 2005) to calculate the integrated temperature index. The authors show that krill catches are associated with a narrow temperature range (–0.5° to 0.5°C), with more defined peaks associated with certain areas. The authors further concluded that this association is considerable even using historical data from the Discovery surveys, suggesting a consistent feature of the krill environment.

5.75 In WG-EMM-08/P3 the authors used temperature data collated from a number of historical datasets around South Georgia to examine the seasonal and long-term temperature trends in this region. They examine the time period from the mid-1920s to the early 2000s.

5.76 The authors used a Restricted Maximum Likelihood (REML) mixed-model approach to examine the temporal trends in water temperature. The model included a simple sinusoidal model for seasonal heating and cooling, and a spatial model to account for geographical variability in the temperature distribution in this area. The authors found that there is a significant warming in the upper 100 m of the water column over this period. Importantly, the authors found that the rate of warming was greater for winter than for summer. These changes (0.9° and 2.3°C in summer and winter respectively) are greater than observed in other studies (e.g. Gille, 2002). The authors further determined that this warming has resulted in a southward movement of the mean ice edge by 150 km. Finally, the authors showed that minimum temperatures have changed (rising to a winter minimum from –0.5° to about 0.25°C over this time period) and they have inferred that this could impact zooplankton, phytoplankton and krill growth, reproduction and community structure.

5.77 In WG-EMM-08/33 the authors provided an update to their ongoing efforts to document the importance of the DPOI which is defined as the sea-level pressure difference between Rio Gallegos, Argentina, and the Esperanza Base in the Antarctic Peninsula. This index reflects the strength of the westerly winds, and has been used to correlate krill abundance in previous studies (Naganobu et al., 1999). The authors used CTD data from two transects off the Antarctic Peninsula to determine the MTEM-200 index and correlate these two indices. The authors found a significant correlation between the two indices firmly linking them together. This analysis continues to build local indices that have a global importance in determining krill distribution (WG-EMM-08/32), and may be correlated with broad-scale atmospheric climate modes.

5.78 Dr Naganobu noted that the CTD data were provided by the US AMLR Program and thanked it for providing data for this research. He further noted the importance of the US AMLR's data collection program to the work of CCAMLR and encouraged the continued collection of these data.

5.79 The Working Group noted that the work presented in WG-EMM-08/33 clearly linked broad-scale atmospheric forcing to measurable variability in the ecosystem, and that the greatest effects are shown during ENSO conditions (e.g. 1997/98), and encouraged the continued development of this approach.

5.80 WG-EMM-08/P2 and 08/P6 examined the importance of global climate modes of variability, principally the ENSO-scale variability, on the Southern Ocean environment, krill and predator populations.

5.81 In WG-EMM-08/P2 the authors examined how ENSO variability affects the net-abundance and acoustically derived biomass of krill in the South Georgia region of the Scotia Sea. They developed an index of the SST anomaly for the period 1990 to 2004 to elucidate periods of higher than average and lower than average temperature. They also examined the importance of sea-ice to these relationships.

5.82 The authors of WG-EMM-08/P2 correlated these temperature anomalies with the ENSO signal at a variety of lags, in order to account for direct (0-lag) and delayed (2–3 year lags) effects of the atmospheric modes to the local impacts across the Scotia Sea. The authors used data derived from Atkinson et al. (2004) describing the long-term decline in krill abundance. Using a detrended data series, they showed how SST anomalies and sea-ice are associated with changes in krill abundance and biomass. They further examined these impacts on upper trophic level predators.

5.83 The Working Group discussed the projection in WG-EMM-08/P2 of a 95% decline in krill over the next 100 years and suggested the model may not reflect areas outside the South Georgia/Scotia Sea region, given the regional focus of the model and the life history of krill. The Working Group also noted that the dependence of krill fluctuations at South Georgia may reflect processes upstream. Discussion also focused on what the implications of this would be for collecting data to separate the effects of climate from fishing given this variability.

5.84 WG-EMM-08/P6 examined the influence of environmental forcing, specifically the role of climate drivers like ENSO on the population dynamics of predators and prey in the Southern Ocean. The authors provided a list of 10 ways that the environment can influence the predator and prey groups. Among these are simple things, such as changing the distribution of animals to more complex interactions involving entire communities of animals and species groups. The authors identified a variety of confounding factors, including previous removals and local extirpations of higher-level predators that would impact the ability to detect the response of the ecosystem to climate change. The authors noted that detecting longer-term climate signals in predator dynamics will be difficult as the time series are relatively short, even in the longer biological time series that exist.

5.85 The final paper considered in this section (WG-EMM-08/P5) attempted to model the impact of changing environments and climate on a variety of species around the Antarctic. The authors used a stochastic matrix model for the population dynamics of a variety of predators, including fur seals, to examine the sensitivity of life history traits and vital rates across the life span of animals. The authors tested the hypothesis that life-history traits are buffered and show low variability in the face of environmental changes.

5.86 The authors of WG-EMM-08/P5 chose the SST anomaly previously described for the South Georgia region as the representative climate driver in their model. The authors also used the relationships developed by WG-EMM-08/P5, including the effect of changing food availability on krill abundance, to examine the capacity to buffer environmental conditions. The authors found that fitness of fur seals in the South Georgia region declined with increased SST anomalies, beginning in the 1990s. Other species (other seals, penguins and some flying seabirds) did not exhibit the same loss of fitness in these modelling efforts, suggesting that the loss of fitness by fur seals was a regional, rather than global, problem. The authors concluded that, as environmental variability increases with climate change, those species with more constrained life histories should exhibit considerable negative responses to that change and variability.

5.87 The Working Group noted that this was an interesting approach to examine the sensitivity of vital rates and species responses to environmental variability.

Other prey species

5.88 WG-EMM-08/36 examined the community structure of copepods in the Ross Sea. Three communities were found: an ACC community, a Ross Sea community and a community spatially located between these two. The authors concluded that the copepod community in the Ross Sea is characterised by low densities of animals. The authors further suggested that the associations of copepods among communities were related to different physical regimes. In addition to the water mass associations, they suggested that the mixing environments may influence the community structure. The authors hypothesised that over long time scales environmental conditions could spatially shift community structure.

5.89 The Working Group noted that this was an interesting study as there are few studies on zooplankton community structure in the Ross Sea. The Working Group encouraged further work on such topics.

5.90 WG-EMM-08/P8 compared the zooplankton community structure around South Georgia in the South Atlantic with historical information. The authors used physical data collected during each time period to characterise the physical environment, and to examine temporal changes in the environment that could affect the community structure of the planktonic (phytoplankton and zooplankton) community over this time period. The environmental signal they examined in most detail was the potential effect of temperature associated with ENSO forcing. It should be noted that the impact of ENSO and other climate modes can impact the productivity of the system. The authors resolved a number of issues associated with taxonomic nomenclature required when comparing the data collected over a long time period. Despite a comprehensive review, the authors did not find strong evidence for a change in the zooplankton community structure.

5.91 The Working Group discussed why the zooplankton community around South Georgia seemed relatively insensitive to changes in the environment, given the observed changes in water column temperature over this same time period. It was concluded that this may reflect the lack of a continual time series, but may also reflect the relatively common and widespread distribution of zooplankton across the Scotia Sea.

5.92 The Working Group noted that although long-term trends in community change were not detectable, the community structure was affected by ENSO, and so would be sensitive to changes when the changes are large.

5.93 It was noted that the zooplankton community analysis was also conducted to reinforce the recently developed CPR program that has been started by the BAS in the southwest Atlantic.

5.94 Dr Fielding noted that myctophid data were collected during the RV *Tangaroa* survey (WG-EMM-08/18) and that these data would be useful in the future, given the uncertainty surrounding the magnitude of the midwater fish in relation to a number of issues relevant to WG-EMM. The authors were encouraged to more fully develop these data.

Methods

CEMP standard methods

5.95 The Subgroup on Methods (convened by Dr Goebel) met and considered two issues concerning CEMP standard methods. The first was Standard Method A7 (fledging weights for gentoo penguins). The subgroup had noted in earlier discussions that gentoo penguins, unlike Adélie and chinstrap penguins, do not 'fledge' in the sense of having a single departure from the colony to sea. Rather, they have a 1–2 week 'fledging period' that entails frequent trips to sea followed by returns to the colony, where they continue to be provisioned by their parents. Thus, the current methodology for collecting fledging weights for Adélie and chinstrap penguins is not applicable for gentoo penguins, and a new methodology needs to be proposed and considered by the subgroup. Since no revision was proposed to the Working Group this year, it was decided to defer this issue to the future after a proposed change can be completed for review by the subgroup.

5.96 The second issue concerned Standard Method A3 (penguin breeding population size (number of pairs)), and the timing of nest counts for estimation of penguin adult breeding population. The concern arose during the Predator Survey Workshop, when a paper addressing such counts reported incorrectly that some historical counts were conducted in relation to a fixed calendar date. However, after some discussion the Subgroup on Methods determined that Standard Method A3 already requires that nest counts be conducted on the basis of annual phenology for each species (i.e. nest counts in relation to the median date of egg laying).

Methods of zooplankton sampling

5.97 WG-EMM-08/19 reported an error in the calculation of water volume filtered by the IKMT that is used in the long-term zooplankton time series (late 1980s to present day) collected by the US AMLR Program. This error has affected the estimated densities of all zooplankton, including krill, since 2000. The US AMLR Program cautions Members to enquire about data previously provided by AMLR that may be in error.

Acoustic methods for TS estimation and identification of *E. superba*

5.98 WG-EMM-08/29 described the use of stereo cameras mounted on a lowered TS probe to observe krill *in situ* around South Georgia and Bouvet Island. A variety of krill behaviours were photographed including swarming, loose aggregations and synchronised schooling.

5.99 The Working Group recognised the importance of *in situ* orientation as a key variable in the TS estimation of krill using the SDWBA model. The Working Group noted the paucity of information on the orientation of krill and looked forward to receiving the analysis of the measurements made during this survey.

5.100 WG-EMM-08/54 presented a reanalysis of a dataset used to assess the two-frequency (120 and 38 kHz) fixed window (2–12 dB) identification of *E. superba*. The authors extended the identification method to include the three-frequency variable window identification adopted by CCAMLR and a two-frequency variable window suggested by SG-ASAM, all using the SDWBA model with a fixed orientation of 11° (SD 4°). Net-validated krill aggregations were identified very well by the two-frequency variable window of identification. The authors noted that in comparison with the fixed window, the variable window would reduce the amount of acoustic by-catch that may occur when targets other than krill are present. However, the three-frequency variable window, as presently configured, was not always able to identify krill swarms and this may result in an underestimation of krill biomass.

5.101 The Working Group welcomed such independent validations of the krill identification technique adopted by CCAMLR in 2007. However, it was recognised that due to the technical nature of the paper, further consideration of the issues should be referred to the next meeting of SG-ASAM. The Working Group supported a proposal that work to collate international acoustic data from known krill targets would enable a rigorous assessment of the current krill identification techniques.

5.102 The Working Group noted the conclusion of WG-EMM-08/54 that developing the ability to use long-term datasets for generating management advice through tracking variation in relative krill abundance should also become an important goal for CCAMLR.

5.103 Other key variables in estimating the TS of *E. superba* are the density and speed of sound contrasts. WG-EMM-08/56 Rev. 1 detailed such measurements made on krill from the South Shetland Islands and the Ross Sea. The density and sound speed contrasts measured were in the region of previously published values, although Ross Sea values were greater than the South Shetland Islands and previously published values. The TS of a 'standard length' krill was calculated with these values using the SDWBA model and shown to vary by ~6 dB.

5.104 The Working Group discussed the importance of the work in WG-EMM-08/56 Rev. 1 and 08/28 to attain well constrained values for density and speed of sound contrast for TS models. It was noted that these values would likely vary seasonally, geographically and ontogenetically.

5.105 The Working Group identified that the three papers, WG-EMM-08/29, 08/54 and 08/56 Rev. 1, were trying to assess key uncertainties in the acoustic estimate of krill biomass. A discussion ensued regarding the measurement of uncertainties in acoustic estimates and to what level this should be revised. It was agreed that, given time, these variables could be categorised and related to more simply measured variables, such as length and maturity stage.

5.106 WG-EMM-08/26 presented krill biomass estimations around the South Orkney Islands (discussed in paragraphs 5.61 and 5.62) using acoustic data collected during finfish surveys. A simple bootstrapping approach was used to generate confidence intervals.

5.107 The Working Group welcomed an approach that could be used to derive krill biomass estimates from surveys not designed specifically for that purpose. It was recommended that the applicability of such techniques for using alternative survey designs in acoustic studies could be investigated by SG-ASAM.

5.108 The Working Group noted that acoustic data collected by commercial fishing vessels could provide valuable data for use in deriving estimates of krill biomass (details are provided in paragraph 4.76). In this context, the Working Group noted the recently published ICES report on 'Collection of acoustic data from fishing vessels' (ICES, 2007).

5.109 WG-EMM-08/28 introduced the January–March 2008 IPY AKES survey carried out on the RV *G.O. Sars*. An aspect of this survey was to establish *in situ* TS values for krill using both hull-mounted and lowered echo sounders, to investigate the distribution of krill using a Simrad MS70 quantitative sonar, and to investigate the identification of krill targets using a hull-mounted multi-frequency (six frequencies: 18, 38, 70, 120, 200 and 333 kHz) echo sounder.

5.110 The Working Group noted that this was an exciting project that could offer many insights into acoustic techniques in the Southern Ocean, particularly the multi-frequency (six frequencies) identification techniques reported.

5.111 The Working Group further noted that several different acoustic methods for krill biomass estimation were utilised within WG-EMM-08/26, 08/28, 08/31, 08/35, 08/54 and 08/P2. The Working Group asked that an appendix of the accepted identification technique and current TS estimation model coefficients be included in the next SG-ASAM report.

5.112 The Working Group reiterated the importance of estimating uncertainties and providing measures, such as probability density functions, of confidence in the B_0 estimate. The Working Group discussed the implication this may have on the estimate of B_0 and recalled paragraph 2.20(i) of WG-EMM-07 (SC-CAMLR-XXVI, Annex 4) which states:

> 'A consistent set of protocols should be maintained for a period of five years. At the end of this period, any improvements to these protocols should be agreed on and implemented. This would include the reanalysis of existing datasets. However, it was also recognised that mid-period improvements in acoustic protocols will likely be in the peer-reviewed literature where appropriate.'

5.113 The Working Group noted that this refers specifically to the use of protocols in setting the precautionary catch limit and indicated that it would welcome submissions on revisions and updates to acoustic protocols so that these could be assessed by SG-ASAM at the earliest opportunity.

Recommendations to SG-ASAM

5.114 SG-ASAM should provide advice that will assist in quantifying uncertainties in krill B_0 estimates. In particular, SG-ASAM should:

(i) validate acoustic identification techniques – by collating a set of net-validated acoustic data and evaluating whether acoustic target identification methods are biased;

(ii) evaluate and consider available information and current methods for the measurement of krill orientation and material properties, and use analyses of tilt angle from recent research cruises;

(iii) provide a probability density function of the estimate of B_0 based on the current understanding of uncertainties in various parameter values.

5.115 SG-ASAM should document the current agreed protocols for B_0 assessment in an appendix to its next meeting.

5.116 SG-ASAM should investigate the use of ancillary acoustic data (e.g. from finfish surveys, exploratory fisheries data and commercial fisheries' echo sounders) and the required analytical methods with a view to:

(i) providing krill biomass estimates from areas that are not regularly surveyed
(ii) documenting protocols for exploratory fisheries acoustic data processing and interpretation.

Future surveys

5.117 One Member notified the Working Group of future surveys in the coming year. As part of the US AMLR's monitoring program in the South Shetland Islands area, the US program will conduct a bottom trawl survey in the South Orkney Islands during the second of two legs in February and March of 2009. The survey will be the second bottom trawl survey of the area, and will occur a decade after the last survey conducted in 1999. Acoustic data and some krill hauls will be conducted in order to extend the utility of this survey.

5.118 Following this notification, the Working Group discussed the importance of extending surveys by individual countries or in developing interest in a second Scotia Sea-wide survey to estimate the biomass of krill in Area 48 for assessment purposes. It was noted by a number of members of the Working Group that there had been an attempt to develop such a survey during the 2007/08 IPY. Others noted that the development of a second large-scale survey would require a number of years, as was the case for the CCAMLR-2000 Survey.

5.119 Ecosystem considerations:

(i) the outcomes of WG-EMM-STAPP on abundance of krill predators, noting the substantial progress on assessing abundance of krill predators and how it may guide further work assessing abundance of other predators (paragraphs 5.1 to 5.16);

(ii) the increasing work on climate change impacts on the Southern Ocean which may assist the Commission in understanding the consequences of climate change for the CAMLR Convention Area (paragraphs 5.74 to 5.86);

(iii) the request by WG-EMM to SG-ASAM for advice on quantifying uncertainty in the acoustic estimation of krill biomass (paragraphs 5.114 to 5.116).

(iv) the importance of continued improvement in acoustic methodologies for providing advice on estimates of B_0 (paragraphs 5.112 and 5.113).

ECOSYSTEM EFFECTS OF FISHERIES THAT TARGET FINFISH

A historical perspective

6.1 WG-EMM-08/P7 hypothesised that a major mid-1980s shift in the ecological structure of significant portions of the Southern Ocean was partially due to the serial depletion of fish by intensive industrial fishing, rather than solely to climate factors as previously hypothesised. Over a brief period (1969–1973), several finfish stocks were on average reduced to <50%, and finally (mid-1980s) to <20%, of their original size. A climate index, the Southern Annular Mode, once oscillated between two states, but has remained in its 'positive mode' since the time of the fish extraction. As breeding stocks decreased, the authors hypothesised that availability of annually produced juvenile fish, fed upon by upper-level predators, remained low. Correlations between predator populations and fish biomass in predator foraging areas indicate that southern elephant seal (*Mirounga leonina*), Antarctic fur seal, gentoo penguin, macaroni penguin and 'imperial' shag (*Phalacrocorax atriceps*) – all feeding extensively on these fish, and monitored at Marion Island, Crozet Islands, Kerguelen Islands, Heard Island, South Georgia, South Orkney Islands and South Shetland Islands, where fishing was concentrated – declined simultaneously during the two periods of heavy fishing. The authors concluded that these patterns indicate the past importance of demersal fish as prey in Antarctic marine systems.

6.2 The Working Group thanked the authors for their contribution, but noted that there were some inconsistencies in the citations of the results of other papers as well as the treatment and interpretation of potential lag effects between the decline in prey and the decline in predators. It also considered that trends in fish populations were an important aspect of the krill ecosystem models and that future models could investigate the inclusion of some of the results presented in this paper.

Ross Sea

6.3 WG-EMM-08/18 provided details of a major New Zealand research voyage to the Ross Sea region during February and March 2008, in support of IPY-CAML. The 50-day voyage on the RV *Tangaroa* involved an extensive survey of marine organisms from viruses to pelagic and demersal fish and cephalopods from the surface down to depths of 3 500 m, and from the continental shelf and slope of the Ross Sea to unexplored seamounts and abyssal plains immediately to the north. A wide range of pelagic and benthic sampling gear, including plankton nets, midwater and demersal trawls, seabed cameras, sleds and corers were deployed.

6.4 The authors anticipated that the results of the survey will be directly relevant to many aspects of the work of CCAMLR and its working groups. An important aspect of the survey was to collect quantitative (both density and abundance) data on key species or species groups, such as *E. crystallorophias* and *P. antarcticum*, that will provide quantitative inputs to the Ross Sea ecosystem model. Other data collected during the survey will contribute to work being carried out on the biodiversity and bioregionalisation in the Southern Ocean (paragraphs 3.4 to 3.20), and VMEs in the Ross Sea region (paragraphs 3.21 to 3.44).

6.5 Dr Holt expressed his appreciation to New Zealand for including US and Italian scientists in the survey, noting the international nature of the voyage. The Working Group thanked New Zealand for carrying out such a comprehensive survey and for making the data available to CCAMLR for consideration. It was noted that this was the first such comprehensive survey of the Ross Sea.

6.6 WG-EMM-08/42 reported on the further development of a mass-balanced carbon-budget trophic model of the Ross Sea as a step towards investigating ecosystem effects of the fishery for Antarctic toothfish (*D. mawsoni*). The model now has 30 trophic groups representing all major biota of the Ross Sea. Many of the lower trophic-level species in the model are grouped by functional role because information is not available at greater taxonomic resolution. The model separates seven key apex predators by species. A survey of the available literature, and both published and unpublished data, provided an initial set of parameters describing the abundance, energetics (growth, reproduction, consumption) and trophic linkages (diets, key predators) for each model group.

6.7 The authors described the method used to adjust the parameters to give a balanced model taking into account estimates of parameter uncertainty and the large range of magnitude in trophic flows between different groups of organisms. Biomass, production, consumption, export and diet fractions were adjusted simultaneously. Changes to the initial set of parameters needed to obtain balance were significant, especially for bacteria. Excluding bacteria, the adjustments required for balance from the parameters estimated *a priori* were <46% (biomass), <15% (production, consumption) and <28% (diet fractions). The authors noted that the balanced model presented had not yet been validated and should be considered a work in progress. Future work is aimed at developing a plausible minimum-realistic model with which to investigate and manage the effects of the *D. mawsoni* fishery on the Ross Sea ecosystem.

6.8 Dr Naganobu noted the recent reports of freshening of the upper layer (Shelf Water) (Jacobs et al., 2002) and Antarctic Bottom Water (Rintoul, 2007) in the Ross Sea region. He noted that this needs to be understood when considering simulation modelling of the Ross Sea ecosystem.

6.9 Dr Southwell noted that new estimates of the abundance and distribution of pack-ice seals in the Ross Sea region were available. Dr Watters queried the high consumption:biomass ratios used for sperm (*Physeter catodon*) and killer whales (*Orcinus orca*) and noted that new estimates for these parameters, as well as estimates of abundance of other top predators, should become available from the Joint CCAMLR-IWC Workshop. The Working Group thanked the authors for their contribution and encouraged New Zealand to continue its work on ecosystem modelling in the Ross Sea.

6.10 WG-EMM-08/27 amalgamated over 500 stable isotope values for fish, squid and octopod samples obtained from longline fishing vessels from four CCAMLR SSRUs (881C, H, I and J). The samples included six species of fish including *D. mawsoni* and *D. eleginoides*, together with four of their main fish prey species (De Witt's icefish (*Chionobathyscus dewitti*), blue antimora (*Antimora rostrata*), Whitson's rattail (*Macrourus whitsoni*) and a moray cod (*Muraenolepis* spp.)), four squid, including the colossal squid (*Mesonychoteuthis hamiltoni*), and three benthic octopod species.

6.11 Most fish showed a δ15N range greater than 3.4‰, spanning more than one trophic level, whilst *D. mawsoni* exhibited a range of 7‰ (9–16‰), which is equivalent to two trophic levels. This implies that the diet of all species sampled is quite variable, and this variation was analysed using regression methods. Length and SSRU were the most significant variables in explaining the variation of δ15N and δ13C. Overall, *D. mawsoni* and *D. eleginoides* occupied a trophic level equivalent to killer whales and Weddell seals (*Leptonychotes weddellii*). The four fish prey species were all at least one trophic level below them.

6.12 There was no significant difference in *D. mawsoni* δ15N and δ13C values between the northern area, Ross Sea slope and Terra Nova Bay trench. In contrast, each of the main prey fish species caught in the northern area had enriched δ13C values compared to the Ross Sea slope. Since this enriched δ13C signature is not found in *D. mawsoni*, this suggests that *D. mawsoni* are mainly feeding on the Ross Sea slope area and the authors inferred that they are likely to have a moderately short residence time in the other two areas.

6.13 Dr Watters questioned whether stable isotope analysis had been carried out for *P. antarcticum*. Dr Hanchet replied that new estimates for this species suggested δ15N and δ13C values consistent with other toothfish prey taken from the Ross Sea shelf.

6.14 Dr Constable noted that it was also important to look at the temporal variation in stable isotope signatures. Dr Hanchet noted that New Zealand scientists were intending to collect a range of tissue types (blood, muscle, hard parts) from *D. mawsoni* in the future so that the recent history of stable isotopes within an individual fish could be better understood.

6.15 WG-EMM-08/43, 08/22, 08/23, 08/21, 08/20 and 08/24 were presented to the Working Group. A general discussion of these papers took place surrounding the potential decline in *D. mawsoni* at McMurdo Sound and the plausibility of using aerial census counts of Weddell seals to monitor the ecosystem effects of the toothfish fishery in the Ross Sea.

6.16 WG-EMM-08/43 addressed the importance of *D. mawsoni* as a prey item of Weddell seals in the southern Ross Sea. It reviewed: the life history of Weddell seals with particular reference to the McMurdo Sound region; direct information on the diet of Weddell seals including habitat overlap, stomach contents analysis, scat and vomit remains; direct observations by divers and scientists and animal-mounted camera information. The paper presented a preliminary analysis of recent stable isotope data using the IsoSource mixing model. Finally, the paper compared the assumed natural mortality rate of *D. mawsoni* in the McMurdo Sound region to the estimated consumption by Weddell seals. The authors provided various estimates of the proportion of toothfish in the Weddell seal diet, but noted that they are very dependent on the assumptions used in the calculations.

6.17 The authors concluded that while there is strong evidence that toothfish are eaten by Weddell seals in the McMurdo Sound region between October and January, it is plausible but unproven that they are an important prey item. They go on to note that the fishery for *D. mawsoni* in the Ross Sea could have a detrimental effect on Weddell seal populations in the McMurdo Sound region if: (i) the commercial fishery (directly or indirectly) reduces the abundance of toothfish in the McMurdo Sound region, (ii) the magnitude of the change in toothfish abundance is enough to change the behaviour and/or foraging success of seals there, and (iii) the change of behaviour and/or foraging has an adverse effect on the seal population.

The authors recommended further data collection and stable isotope analysis of samples of blood, muscle tissue and hair from breeding and non-breeding seals in the McMurdo Sound region to help determine trophic overlap.

6.18 WG-EMM-08/22 addressed the importance of *D. mawsoni* as a prey item of Weddell seals and killer whales in the southern Ross Sea. It reviewed aspects of their life history and behaviour with reference to the McMurdo Sound region, direct observations by divers, scientists and animal-mounted cameras, and results of biochemical (stable isotope and fatty acid) analyses. The authors asserted that biochemical analyses are inconclusive because of the timing and location of the animals sampled, and that more weight should be accorded to direct observations.

6.19 The authors of WG-EMM-08/22 used direct observations from scientists and video footage to derive an estimate of the daily food intake and likely proportion of toothfish in the diet of Weddell seals. They then went on to estimate that the non-breeding part of the Weddell seal population in McMurdo Sound consumes 52 tonnes of toothfish during the spring and summer months. They further noted that the annual consumption based on the breeders and other months of the year is likely to be substantially higher. They concluded that there is strong evidence that *D. mawsoni* are important in the diet of top predators and that monitoring (e.g. initiation of CEMP in regard to toothfish fisheries) is required for effective management of the ecosystem effects of the toothfish fishery.

6.20 WG-EMM-08/23 concerned aerial census counts of Weddell seals along the Victoria Land coast in the eastern Ross Sea. The paper noted that there is currently no ecosystem monitoring program (CEMP) in place under CCAMLR with respect to the Ross Sea fishery. In a previous paper to WG-EMM (WG-EMM-07/13), the authors described protocols for an aerial census of Weddell seals in this area. In the present paper, they compared counts made from the air with those from the ground in Erebus Bay, McMurdo Sound, in November 2007, and also summarised historical results of aerial surveys made along the coast of Victoria Land. The authors noted that the high correlation ($r = 0.99$) between air and ground counts shows that aerial photography can successfully be used to document changes in distribution and abundance of Weddell seals. Ground counts of Erebus Bay colonies, made annually from 1974 to 2007, demonstrate the sensitivity of count data to environmental variability. The authors concluded that on the basis of this and the 2007 paper, a Weddell seal monitoring program can now be put into effect under CEMP, and noted that this would need to begin with a one-off survey to identify all important haul-out locations and the ones that best lend themselves to aerial surveillance.

6.21 WG-EMM-08/21 provided a preliminary summary of data recorded by US scientists fishing through the ice for *D. mawsoni* at McMurdo Sound. They noted that since 1971, about 4 500 *D. mawsoni* have been captured, with total captures of 200–500 per year. They noted that more recently, with similar effort, numbers are nearly zero. The authors presented daily data on catch and effort for the year 1987 (a year they report as being typical of catch results before the exploratory fishery started) and for 2001 (just after the onset of the exploratory fishery and after about 1 500 tonnes had been caught). Catch data, but no corresponding effort data, have been provided since 2001. The authors noted that the entire dataset awaits computerisation, but that the subset of data clearly shows a marked decline in CPUE in McMurdo Sound once the Ross Sea fishery had reached maturity in 2001/02.

6.22 WG-EMM-08/21 also presented daily sightings of killer whales from a lookout at Cape Crozier on Ross Island during December and January of each year from 2003 to 2007, and noted that killer whales have become infrequent since January 2006. Lastly, the paper presented data on the proportion of *P. antarcticum* in the diet of Adélie penguins since 2003/04, noting that the proportion of *P. antarcticum* in their diet in 2007/08 was the highest in the 5-year time series presented and was similar to 1996/97. On the basis of these observations, the authors concluded that the fishery has caused a trophic cascade at McMurdo Sound. The paper recommended that the catch limit in the fishery be reduced, including a moratorium on the shelf, until the McMurdo Sound toothfish population is restored and a program is in place to monitor ecosystem effects of the fishery.

6.23 WG-EMM-08/20 was a letter authored by 25 Antarctic scientists in regard to WG-EMM-08/21 on the decline of *D. mawsoni* from McMurdo Sound. They express concern that this is the first sign that the Ross Sea ecosystem is being irreparably altered, and that several extensive time series of unequalled climate records and responses of the biota to climate change are in jeopardy of being compromised. They state that five time series, each extending for more than 40 years, have been 'blindsided' by the impacts of overfishing. The time series include annual counts of Adélie and emperor penguins (*Aptenodytes forsteri*), benthic community composition and growth, Weddell seal demography and toothfish prevalence as indicated by scientific catch rates. The paper recommended a steep reduction in the catch limit in the fishery, including a moratorium on the shelf, until the McMurdo Sound toothfish population is restored and a program is in place to monitor ecosystem effects of the fishery.

General discussion

6.24 The Working Group identified several inconsistencies in WG-EMM-08/21 which required further elaboration by the authors:

(i) The authors noted that they have caught 4 500 fish over a 30-year period (1971–2001), implying an average catch of 150 fish per year. This is inconsistent with the claim that total captures once numbered 200–500 fish per year before exploitation started.

(ii) The authors also claimed that they chose 1987 as a 'typical year in catch results' for the pre-exploitation period. However, as shown in Figure 6 of the paper, the catch in that year was 412 fish – this is not a typical year if the average was only 150 fish.

(iii) There were several other inconsistencies in the text. For example, the caption to Figure 7 states that 10 sets were made in 2001 – however, a total of 29 sets were reported for 2001 in Appendix 2 of the paper. Also, the paper stated that in 1996/97, vessels fished off Cape Crozier for long periods (page 12); however, in that year, the first year of the exploratory fishery, the total catch of toothfish was <1 tonne and this was taken well outside the Ross Sea itself.

6.25 The apparent decline in toothfish catches coincided with a change in the scientific fishing location. Although the authors state that catch rates were similar before and after the change in fishing location, not enough detail is presented to determine whether this is the case. Furthermore, although the text says the new site was only 0.5 km from the original site, this is not consistent with the scale on the map shown in Figure 4 of the paper or with it being a distance of 4 km from McMurdo Station. The physical and environmental features of the two sites with respect to bottom depth, current, substrate, temperature, distance from the edge of the fast-ice etc. should also be provided. Commercial catch rates are very dependent on fishing location, therefore it would be surprising if this was not the same for a research fishing site.

6.26 In considering the above issues, the Working Group was unable to adequately assess the conclusions of the paper at the current time. It requested the authors to provide the following historic data on:

(i) the location, number of sets, number of hooks, number of fish caught, soak-time and CPUE (number of fish per set) by day, month and year for all years since sampling started in 1971. Other details, such as weight of fish caught, fate of fish (e.g. kept, released, tagged) and bait used each year, would also be useful;

(ii) the length-frequency distribution – perhaps grouped over 2- or 3-year intervals;

(iii) specific details of the two sites with respect to bottom depth, current, substrate, water temperature, distance from the edge of the fast-ice etc.

6.27 The Working Group also noted that the evidence for a switch in Adélie penguin diet was rather weak. Although the highest percentage of *P. antarcticum* in the diet occurred in 2007/08 (55%), the lowest percentage of *P. antarcticum* in the diet had occurred the previous year (32%). The Working Group further recalled that research carried out by Emison in the 1960s suggested that the annual proportion of *P. antarcticum* in the diet of Adélie penguins ranged from 40–60% (Emison, 1968).

6.28 The Working Group then considered the proposal for an aerial census of the Weddell seal population as a CEMP index outlined in WG-EMM-08/23. It recalled its advice on this matter at last year's meeting where it noted: (i) that the monitoring program would need to be well designed (be theoretically sound and pragmatic), (ii) the minimum data requirements for a viable program, and (iii) the need for a long-term funding commitment (SC-CAMLR-XXVI, Annex 4, paragraph 5.25).

6.29 Several members recalled the detailed process followed when developing the CEMP indices, including identifying objectives, agreeing on standard methodologies, the likelihood of detecting change (power analysis), the collection of ancillary data (e.g. dietary studies and monitoring other prey species), the risk that the program may be unable to detect impacts, and the need for long-term commitment to the program.

6.30 The Working Group agreed that an aerial census was likely to be the most appropriate method for monitoring the abundance of Weddell seals. However, it also noted that, by itself, an aerial census may not be sufficient to determine possible ecosystem effects of the toothfish fishery. It considered that: (i) the program may be unable to detect impacts within a reasonable timeframe, and (ii) it would be difficult to prove that any changes in the Weddell seal population were a result of the fishery and not due to other factors, such as climate change or changes in other more important prey.

6.31 The Working Group noted the high level of variability in the seal counts shown in Figure 1 of WG-EMM-08/23 and that, given this high level of variability, the power of detecting changes in the abundance of the Weddell seal population was likely to be quite low unless the variability can be explained with covariates. The Working Group also noted the need for other ancillary data to be collected as part of the monitoring program. This would include data on the distribution and abundance of key species such as *D. mawsoni*, *P. antarcticum* and *E. crystallorophias*, and the need to obtain unbiased estimates of Weddell seal diet.

6.32 Dr Watkins noted that it may be possible to use upward-looking moored acoustic transducers to measure krill and silverfish abundance in the McMurdo Sound region. This approach had been successfully carried out at South Georgia and would enable the recording of year-round acoustic backscatter and ancillary data.

6.33 Although no *D. mawsoni* hard parts are found in Weddell seal scats and vomits, Dr Welsford noted that it may be possible to use DNA techniques to determine whether scats and vomits contained traces of toothfish muscle. This could be used to obtain better estimates of the occurrence of toothfish in the Weddell seal diet.

6.34 The Working Group was also concerned that Weddell seals may not be a very good candidate for monitoring ecosystem effects caused by the toothfish fishery. This is because Weddell seals could potentially prey-switch from toothfish to silverfish or squid if there was a reduction in the local toothfish abundance. Such a prey-switch would be hard to detect because toothfish also feed on these species.

6.35 The Working Group also considered the question of relative foraging efficiency when Weddell seals forage for silverfish and toothfish. It noted that further work needs to be done to evaluate potential trade-offs in foraging between the two species that could affect the physiology and condition of the breeding and non-breeding parts of the population.

6.36 Dr Plagányi noted that the relationships between the Weddell seal and its prey could be explored through simulation and modelling – which could take into account such direct competitive and indirect foraging effects. Dr Constable agreed, noting that the lack in spatial and temporal overlap between the fishery and the Weddell seal population would make it difficult to interpret population trends, especially when any effects on the seal population are likely to be lagged.

6.37 The Working Group noted that a spatial population model was being developed by New Zealand to address movement of toothfish within the Ross Sea, and that the model could potentially be used to examine ecosystem effects of fishing (paragraph 6.7; Annex 7, paragraphs 5.1 to 5.6). It noted that there was a considerable amount of data on satellite tracking of Weddell seals in the western Ross Sea and also on movements of tagged toothfish which could help inform the model.

6.38 The Working Group noted that in the absence of ecosystem monitoring techniques, it may be more prudent to treat toothfish as a prey species rather than as a predator species. This would imply the use of the 75% escapement rule rather than the 50% escapement rule currently used for toothfish.

6.39 However, Dr Hanchet noted that the current stock assessment suggests that the stock is at about 82% of its unexploited biomass (SC-CAMLR-XXVI, Annex 5, Appendix I). If there has really been a decline in toothfish predators at that biomass level, then even a 75% escapement level would be too low. The Working Group noted that an alternative option would be to have a fishing-free buffer zone along the coastline of the western Ross Sea – which would remove direct fishing pressure from areas immediately adjacent to the land-based predators.

6.40 The Working Group agreed that it would be useful to discuss these issues with WG-FSA members at the future FEMA meeting (paragraph 8.6).

Advice to the Scientific Committee

6.41 The Working Group agreed that an aerial census was probably the best method for monitoring Weddell seal abundance in the western Ross Sea and indicated that the work proposed to identify all important haul-out locations (paragraph 6.20) would be useful. However, at this time, it was unable to endorse the aerial census as a CEMP index because it was not clear whether a change in the index could be directly attributed to the toothfish fishery (paragraph 6.30).

6.42 The Working Group recommended further work on designing a program to fully monitor effects of fishing. It noted that additional data would be needed in developing a monitoring program, including data on the distribution and abundance of *D. mawsoni*, species of demersal fish and silverfish, and estimates of the importance of diet components to Weddell seal production (paragraph 6.31).

6.43 The Working Group also recommended the development of a spatial population model to explore interactions between *D. mawsoni* and Weddell seals in the western Ross Sea (paragraph 6.37).

Future work

6.44 The Working Group recommended further collection of material for stable isotope analysis, including a range of tissue types from fish and Weddell seals in the McMurdo Sound region to help determine trophic interactions (paragraphs 6.14 and 6.17).

STATUS OF MANAGEMENT ADVICE

Protected areas

7.1 The Scientific Committee is referred to the outcomes of the focus topic on spatial management measures that aim to facilitate the conservation of marine biodiversity (paragraphs 3.71 to 3.78).

Harvesting units

7.2 No new information on harvesting units was available for consideration.

Small-scale management units

7.3 WG-EMM-08/11 summarised the data available on land-based predators that could be used for subdividing Subarea 48.4 into SSMUs. It indicated that chinstrap penguins are the dominant predators and present on all islands, while the smaller abundances of gentoo and macaroni penguins and fur seals are concentrated in the six northern-most islands. It is proposed that Subarea 48.4 be subdivided into two SSMUs consistent with the approach for separating pelagic and coastal SSMUs in Subareas 48.1, 48.2 and 48.3.

7.4 The Working Group noted that, based on the use of foraging density and species composition, it may be possible to further subdivide the coastal SSMU in Subarea 48.4 into one encompassing the six northern-most islands and one encompassing the remaining islands in the south. It was also noted that Adélie penguins were present despite the absence of sea-ice in summer. In winter, sea-ice regularly extends northwards into the chain of islands.

7.5 The Working Group recommended that the proposal in WG-EMM-08/11 to partition Subarea 48.4 into a coastal and a pelagic SSMU be adopted, noting that further analyses may indicate the need for further subdivision of the coastal SSMU into northern and southern areas when additional data are available.

Analytical models

7.6 The Scientific Committee's attention is drawn to the discussion on advances in modelling in support of the SSMU allocation discussed in paragraphs 2.13 to 2.30.

Existing conservation measures

7.7 The Scientific Committee's attention is drawn to the discussion on regulatory issues in paragraphs 4.67 to 4.95. Specific points for consideration are indicated in paragraphs 7.9, 7.10 and 7.12.

Key points for consideration by the Scientific Committee and its working groups

7.8 SSMU allocation:

(i) the risk assessment for the Stage 1 SSMU allocation is completed and advice on this is contained in paragraphs 2.95 to 2.101;

(ii) a range of climate-change scenarios will need to be considered as part of a broader-and longer-term risk assessment in subsequent stages of the SSMU allocation (paragraph 2.30).

7.9 Spatial management measures that aim to facilitate the conservation of marine biodiversity:

(i) development of a representative system of marine protected areas through, *inter alia*, bioregionalisation and/or systematic conservation planning (paragraphs 3.71 to 3.73 and 3.76 to 3.78);

(ii) implementation of Conservation Measure 22-06 concerning VMEs, including a risk-analysis framework (paragraph 3.73), a workshop to provide guidance on identifying taxonomic groups and habitats and reducing uncertainty associated with identifying VMEs (paragraph 3.74), and for the process of notification of VMEs (paragraph 3.75).

7.10 Krill fishery:

(i) haul-by-haul data remain to be submitted by Poland for 2006/07 (paragraph 4.3);

(ii) trends in the krill fishery (paragraphs 4.1 and 4.6 to 4.8);

(iii) notifications of intention to fish for krill in the 2008/09 season (paragraphs 4.6 to 4.17).

7.11 Scientific observation in the krill fishery:

(i) lack of data on product-specific catches and conversion factors are creating difficulties in verifying the accuracy of 'green weight' of krill caught (paragraph 4.36);

(ii) the request for Members to be encouraged to evaluate the possibility of accurately reporting catch on the basis of direct estimates of 'green weight caught' to resolve the problem of inaccurate catch reporting (paragraph 4.39);

(iii) WG-EMM agreement on the role of ad hoc TASO (paragraph 4.45);

(iv) revisions required in the *Scientific Observers Manual* (paragraphs 4.52, 4.65 and 4.66);

(v) the need for a fish by-catch sampling protocol consistent with the existing larval fish sampling protocol (paragraph 4.54);

(vi) an agreed strategy for implementing a scientific observer program to achieve systematic coverage in the krill fishery (paragraphs 4.58 to 4.63)

7.12 Regulatory issues:

(i) the need to record information that describes the fishing technique to be used by krill vessels (paragraph 4.68);

(ii) the consideration of notifications for exploratory krill fisheries and requirements for data collection plans needed to implement Conservation Measure 21-02 (paragraphs 4.69 to 4.95).

7.13 Ecosystem considerations:

(i) the outcomes of WG-EMM-STAPP on abundance of krill predators, noting the substantial progress on assessing abundance of krill predators and how it may guide further work assessing abundance of other predators (paragraphs 5.1 to 5.16);

(ii) the increasing work on climate change impacts in the Southern Ocean which may assist the Commission in understanding the consequences of climate change for the Convention Area (paragraphs 5.74 to 5.86);

(iii) advice on research to detect the ecosystem effects of toothfish fishing in the Ross Sea (paragraphs 6.41 to 6.43);

(iv) the request from WG-EMM to SG-ASAM for advice on quantifying uncertainty on the acoustic estimation of krill biomass (paragraphs 5.114 to 5.116);

(v) the importance of continued improvement in acoustic methodologies for providing advice on estimates of B_0 (paragraphs 5.112 and 5.113).

7.14 General:

(i) consideration of the future work program of WG-EMM, including:

- the proposed terms of reference for the FEMA2 workshop to consider the ecosystem effects of the toothfish fishery in the Ross Sea (paragraphs 8.1 to 8.6);
- a proposed revision to the Working Group agenda (paragraphs 8.8 to 8.10);
- consideration of the subjects for discussion and the CCAMLR representatives of the Joint SC-CAMLR–CEP Workshop Steering Group (paragraphs 3.65 to 3.69 and 9.1 to 9.5).

FUTURE WORK

Second Workshop on Fisheries and Ecosystem Models in the Antarctic (FEMA2)

8.1 The Conveners of WG-EMM and WG-FSA introduced a set of topics for the Second Workshop on Fisheries and Ecosystem Models in the Antarctic (FEMA2). In proposing the topics, the Conveners noted that:

(i) there is considerable interest in considering the ecosystem effects of fishing for toothfish in the Ross Sea;

(ii) fisheries for toothfish in the Ross Sea are exploratory;

(iii) there are parallels between the SSRUs in the Ross Sea and the SSMUs in the Scotia Sea;

(iv) experience gained from advising on spatial management strategies for krill in Area 48 could be applied to advise on the management of fisheries in the Ross Sea;

(v) ecosystem models are not always required to provide useful advice from an ecosystem perspective.

8.2 Given the points outlined above, the Conveners thus proposed that the FEMA2 Workshop be structured in a manner that treats fisheries for toothfish in the Ross Sea as a case study of how ecosystem considerations can be used to advise on the management of fisheries that target finfish.

8.3 The Conveners proposed four topics for consideration at the FEMA2 Workshop:

(i) Evaluate whether the level of escapement currently espoused in existing decision rules for toothfish in the Ross Sea is sufficiently precautionary when these fish are viewed as important prey as well as predators. Such an evaluation should include a comparative analysis of the importance of toothfish as prey in different regions throughout the Southern Ocean.

(ii) Evaluate whether the existing boundaries of SSRUs in the Ross Sea could be revised on the basis of overlap between the spatial distribution of the fishery, the foraging areas of predators on toothfish, and other information, such as the presence or density of VMEs. Such an evaluation should include work similar to that used for defining SSMUs in Area 48 (SC-CAMLR-XXI, Annex 4, Appendix D).

(iii) Evaluate whether the existing basis for distributing the precautionary catch limits for toothfish among SSRUs in the Ross Sea could be revised on the basis of the information considered in (ii) above.

(iv) Evaluate whether steps to implement possible revisions evaluated in (ii) and (iii) above would impact results from the ongoing tagging studies that are important components of the research plan and stock assessment process for exploratory fisheries for toothfish in the Ross Sea.

8.4 The Working Group agreed that it would be useful to consider the FEMA2 Workshop as a focus topic (paragraph 8.11) during its 2009 meeting. It was further agreed that the conveners of WG-EMM and WG-FSA should jointly chair the workshop.

8.5 However, it was suggested that, given the short time available to conduct FEMA2 (paragraph 8.11), the workshop would not likely be able to address all four topics. It was also suggested that FEMA2 should address the first two topics and that the remaining topics may be taken up in the future.

8.6 It was noted, however, that WG-FSA may want to comment on the desirability of discussing topics (iii) and (iv). The fourth topic has wider application to WG-FSA than WG-EMM. Therefore, the Working Group agreed to provide WG-FSA its advice relative to all four topics. After discussion by WG-FSA on what topics might be considered at the FEMA2 Workshop, it was suggested that the conveners of WG-EMM and WG-FSA provide a proposal on the terms of reference for FEMA2 to the Scientific Committee.

Revised agenda and long-term work plan for WG-EMM

8.7 The Working Group discussed how it might structure its agenda for future meetings. It was recognised that an agenda should aim to facilitate the achievement of long-term objectives while simultaneously maintaining the flexibility needed to address the annual requirements for scientific review and advice that will be expected by the Scientific Committee and the Commission in the future.

8.8 The Working Group agreed that at least four topics require work over the long term, all of which have previously been endorsed by the Scientific Committee or have been identified as a topic of interest to the Commission.

(i) The development and evaluation of feedback management strategies for the krill fishery, including work to estimate predator abundance and demand (e.g. SC-CAMLR-XXV, paragraph 3.25) and to support the staged development of the krill fishery in Area 48 (e.g. SC-CAMLR-XXVI, paragraph 3.36(vii)).

(ii) The development and application of methods to facilitate the conservation of marine biodiversity in the Convention Area, including work to identify VMEs (e.g. SC-CAMLR-XXVI, paragraph 14.5) and define candidate MPAs (e.g. SC-CAMLR-XXVI, paragraph 3.87) and to achieve a harmonised approach (e.g. SC-CAMLR-XXV, paragraph 3.32) within the Antarctic Treaty System and within CCAMLR.

(iii) Consideration of the ecosystem effects of fishing for finfish (e.g. SC-CAMLR-XXVI, paragraph 3.99), including further collaboration with WG-FSA.

(iv) Consideration of the impacts of climate change on the Antarctic marine ecosystem (e.g. CCAMLR-XXVI, paragraph 15.36).

8.9 The Working Group agreed that focus topics (as per Items 2 and 3 of the agenda for this meeting) provided a mechanism to facilitate requirements for short-term advice, and that long-term work objectives should form the primary items of its future agenda. It was noted that the topic of climate change was a cross-cutting issue that could be considered under multiple agenda items.

8.10 The Working Group agreed that the Scientific Committee should review the following proposal for structuring the future agenda of the Working Group:

1. Introduction (opening of the meeting, adoption of the agenda and appointment of rapporteurs, review requirements for advice and interaction with other working groups)

2. Focus topic (to be determined on an annual basis with priority given to topics that relate to needs for short-term advice)

3. Ecosystem effects of fishing for krill (krill, dependent predators, the fishery and scientific observation, surveys and monitoring, climate impacts and feedback management strategies)

4. Ecosystem effects of fishing for finfish (fish, dependent predators, fisheries and scientific observation, surveys and monitoring, climate impacts and collaboration with WG-FSA)

5. Spatial management to facilitate the conservation of marine biodiversity (VMEs, protected areas, and harmonisation of approaches, both within CCAMLR and across the ATS)

6. Advice to the Scientific Committee and its working groups

7. Future work

8. Other business

9. Adoption of the report and close of the meeting.

8.11 With respect to the proposal for Agenda Item 2, the Working Group agreed that a focus topic might not be required in every year. Nevertheless, it was recognised that the FEMA2 Workshop is a priority matter for the Scientific Committee and would likely provide a useful focus topic in 2009 (further discussion on FEMA2 is summarised in paragraphs 8.1 to 8.6). Beyond 2009, it was envisaged that focus topics would be agreed at the preceding meeting of SC-CAMLR where the conveners of the working groups and the Chair of the Scientific Committee can consult with Members. This would also provide an opportunity for considering the time required for, and timing of, the focus topics. It was noted that, generally, focus topics should not occupy more than two to three days of the annual WG-EMM agenda.

8.12 The Working Group also highlighted the importance of increased collaboration with WG-FSA to successfully conduct work on the proposed Item 4, including receiving information from annual Fishery Reports and from surveys designed to study finfish. The Working Group would itself aim to provide WG-FSA with advice that broadens the ecosystem context of finfish stock assessments, possibly ultimately including the development of ecosystem operating models that could be used to evaluate management strategies for finfish.

Joint CCAMLR-IWC Workshop

8.13 Dr Constable introduced the papers presented to WG-EMM on the Joint CCAMLR-IWC Workshop due to be held in Hobart, Australia, from 11 to 15 August 2008. WG-EMM-08/16 provided a summary by the workshop co-conveners of progress in preparing for it, noting that:

(i) the workshop is currently well within budget, potentially leaving funds available for commissioning post-workshop work if required;

(ii) all expert groups were progressing well, except for the expert group on flying seabirds, which is being progressed by the co-conveners in consultation with experts involved with ACAP in order to obtain a review paper by the end of the year;

(iii) consultations with the SC-IWC were held by Dr Constable attending the SC-IWC meeting in Santiago, Chile, in May 2008.

8.14 WG-EMM-08/15 is a background paper for the workshop providing an introduction on the requirements for modelling in CCAMLR and IWC. Its genesis was in response to many requests from expert group coordinators to provide the context in which they were developing their review papers. It is intended that, should the paper be developed with the other papers in publication, then the modellers of CCAMLR and IWC are requested to participate in the production of an updated manuscript.

8.15 WG-EMM-08/47 provided a summary of progress on papers by the expert groups at the time of the deadline for submissions to WG-EMM. Dr Constable updated the Working Group as to progress on the manuscripts, as the final deadline for completion was one week before the workshop. He indicated that, other than flying seabirds, manuscripts have been received from all groups but baleen whales, protists and oceanography, although a draft of the baleen whales manuscript had been prepared in time for the SC-IWC meeting and a draft protist manuscript was available. Members of the Working Group were encouraged to read the manuscripts and provide input to the workshop by corresponding with Dr Constable if they were unable to attend.

Additional key points for consideration by the Scientific Committee and its working groups

8.16 Validation and access to models advising on SSMU allocations:

(i) The Working Group noted that at present it is in the process of developing three models to allocate catch between SSMUs in Area 48. However, except for the authors, few people in the Working Group are familiar with the operation of the models. In fact, the preparation of input data, parameterisation of the models, calculations provided by the models, and analysis of the results are not transparent and are not easily accessible to other members of the groups. As a result, it is difficult to validate the output or conclusions provided by the models.

(ii) The Working Group noted that all models applied for developing krill management procedures are complex and their effective implementation requires that an independent and critical approach be taken. This can be ensured by establishing within WG-EMM, a subgroup of experts from interested Members who will be able to verify calculations and applications of the models used, including the raw data preparation, calculation procedures and analysis of the results. The subgroup could ensure that the application of the models is transparent and that they are verified.

(iii) It was agreed that for the subgroup to undertake its work, it would require preparation of detailed descriptions of the models, preparation of user manuals for the models, and provision to the Secretariat that the model software is in accordance with all the requirements of CCAMLR, including test cases.

(iv) Interested Members should appoint to this subgroup scientists with sufficient expertise to verify the model application.

(v) The Working Group noted that, as necessary and in accordance with procedures in SC-CAMLR-XXVI, Annex 7, paragraph 6.3, WG-SAM could continue to review the methodological implementation of models used for SSMU allocation.

(vi) The Working Group also agreed that, for models to be used by the Working Group in providing advice, they should be sufficiently developed for use by members of the Working Group other than the model developers. This will enable wider participation of Working Group members, as needed, in the development, validation and review of results of assessments with respect to SSMU allocation. The Working Group agreed that participation by Members in the assessment work, as is done in WG-FSA, is highly desirable. In order to facilitate the participation of others in this assessment work, the Working Group recommended that:

   (a) sufficient documentation is provided with a model to guide its use by others, for example, as has been provided for CASAL and GYM;

   (b) software, example input files and test cases are submitted to the Secretariat for access by Members.

8.17 Workshop on Antarctic benthic invertebrate ecosystems to be held in conjunction with TASO, WG-FSA or under alternative arrangements (paragraphs 3.31 to 3.33 and 3.74).

8.18 Initiation of a process to develop a representative system of MPAs across heterogeneous areas (paragraphs 3.60 to 3.62).

8.19 Joint SC-CAMLR–CEP Workshop on ‘opportunities for collaboration and practical cooperation between the CEP and CCAMLR’ (paragraphs 3.63 to 3.70 and 9.1 to 9.5).

OTHER BUSINESS

Joint SC-CAMLR–CEP Workshop

9.1 The Working Group discussed the proposal for a joint workshop between SC-CAMLR and the CEP (‘Opportunities for collaboration and practical cooperation between the CEP and SC-CAMLR’) (WG-EMM-08/52). This workshop is currently scheduled to be held in early April 2009, immediately prior to the CEP XII meeting in Baltimore, USA (see also paragraphs 3.63 to 3.69).

9.2 Noting suggestions outlined in WG-EMM 08/52 and SC CIRC 08/31, the Working Group indicated that, in its view, it would be appropriate for CCAMLR representation on a Joint SC-CAMLR–CEP Workshop Steering Group to comprise the working group conveners and current Scientific Committee Vice-Chairs. The Steering Group would plan the workshop terms of reference and agenda, with the SC-CAMLR participants providing an outline of likely CCAMLR interests in time for consideration by the Scientific Committee at its 2008 meeting. The Working Group also noted an expectation that the two Scientific Committee Vice-Chairs would be replaced on the Steering Group by the new Scientific Committee Chair when elected.

9.3 In considering the themes proposed by the CEP for the workshop, the Working Group highlighted the importance of all proposed items. However, it noted that two themes ('Protected areas and spatial management measures' and 'Species requiring special protection') appeared particularly worthy of SC-CAMLR attention. In the case of species protection, the Working Group noted that consideration should be given on how interactions and practical cooperation between SC-CAMLR and the CEP could be developed to facilitate the process of affording additional protection to species in which SC-CAMLR and/or the CEP had an interest(s).

9.4 The Working Group anticipated that the Steering Group will undertake its work electronically, and that there may be an opportunity for some of the group to meet at SC-CAMLR-XXVII in October 2008.

9.5 Given the shortage of time available to develop SC-CAMLR's input into the workshop, the Working Group agreed that the Secretariat would urgently circulate the Working Group's views to all SC-CAMLR Members to expedite development of SC-CAMLR's involvement in the Steering Group. It was envisaged that such development would take into account any suggestions made by the joint Steering Group and would comprise a draft agenda and work plan for consideration by SC-CAMLR-XXVII.

SCAR climate change review

9.6 The Executive Secretary noted that SC CIRC 08/41 conveyed an invitation from SCAR for CCAMLR to comment on a recent SCAR review ('Antarctic climate change and the environment') comprehensively (495 pages) addressing climate change in the Antarctic. This invitation had arisen from discussions at CEP XI in June 2008.

9.7 The Working Group noted that the time available for comment (before 1 September 2008) was very short. It was not, therefore, in a position to provide any consolidated advice to the Scientific Committee on the SCAR review. Consequently, it was also noted that the heavy CCAMLR meeting schedule in July–August 2008, and the timing of the SCAR request for comments, provided no real opportunity for an institutional response from the Scientific Committee.

Southern Ocean Sentinel Workshop

9.8 Dr Constable drew the meeting's attention to SC CIRC 08/37 describing plans for a workshop ('Monitoring climate change impacts – establishing a Southern Ocean sentinel program') to be hosted by Australia at the CCAMLR Headquarters, from 20 to 24 April 2009. Further details of the workshop are available by email at sos@aad.gov.au.

CCAMLR Science

9.9 As the new *CCAMLR Science* Editor-in-Chief, Dr Reid reiterated that the aim of the journal is to communicate the science being done in CCAMLR to the broader scientific community. The journal is also a vehicle to advertise CCAMLR's work and to encourage scientists to become involved in it.

9.10 The Working Group recognised that there should be a clear distinction between working group papers and peer-reviewed papers in *CCAMLR Science*. The latter need to be accessible to a broader readership. As such, *CCAMLR Science* emphasises and clearly describes the context of CCAMLR's scientific work and aims to communicate any consequences/conclusions beyond CCAMLR.

9.11 Dr Reid reminded potential authors to ensure that they conform with the Rules for Access and Use of CCAMLR Data in respect of CCAMLR and working group data released into the public domain via publication in *CCAMLR Science*. To ensure that this is done, a new tick box will be included on the *CCAMLR Science* manuscript submission form to indicate that permission to publish (and to cite working group papers) has been granted by the data originators/owners.

9.12 The Working Group noted that Dr Reid was inviting comments from all SC-CAMLR working groups on manuscript submission and *CCAMLR Science* editorial process. A Secretariat paper will be submitted to SC-CAMLR-XXVII.

9.13 The Working Group inquired whether it would be possible for press-ready *CCAMLR Science* manuscripts to be placed on the website in a manner similar to the 'First View' system used by other journals.

9.14 In discussing availability of *CCAMLR Science* papers on the website, the Working Group noted that the Secretariat was in the final stages of implementing a password-protected web-based archive for all CCAMLR publications, including working group papers. Currently the archive was in library form, but its second phase will provide a fully searchable document database. The Working Group congratulated the Secretariat for developing and providing this very valuable resource.

ADOPTION OF THE REPORT AND CLOSE OF THE MEETING

10.1 At the time of adoption, Dr G. Skaret (Norway) extended an invitation by Norway to host the meetings of WG-EMM and WG-SAM in 2009. The Working Group thanked Dr Skaret and Norway for the invitation.

10.2 The report of the fourteenth meeting of WG-EMM was adopted.

10.3 In closing the meeting, Dr Watters thanked all participants for their valuable contributions to the work of the Working Group. The meeting had completed several important tasks, including the risk assessment for the Stage 1 SSMU allocation, an agreed strategy for deploying scientific observers in krill fisheries, and the elaboration of a fishery-based research plan and data collection plan for exploratory fisheries for krill. The Working Group had also revised its agenda for future meetings so as to better integrate its work with that of WG-FSA, and further consider ecosystem effects of fishing for finfish and spatial management to facilitate the conservation of marine biodiversity.

10.4 Dr Watters thanked the Russian Federation for hosting the meeting and providing excellent meeting facilities and support.

10.5 Dr Watters thanked Drs Penhale and Trathan for chairing the two focus topics, and the rapporteurs for bringing together the results and advice from the meeting. Dr Watters also thanked the Secretariat staff for their support.

10.6 Dr Watters acknowledged Dr Holt's long-standing contributions to, and support of, the work of WG-EMM. Dr Holt was due to retire prior to the next meeting of the Working Group.

10.7 Dr Trathan, on behalf of the Working Group, thanked Dr Watters for his patience, good humour and expertise in convening his first meeting of WG-EMM and for leading the Working Group into a new phase of its work.

10.8 Dr D. Miller (Executive Secretary) presented Mrs L. Zaslavskaya with a small gift in appreciation of the great support provided by her team at the Institute.

10.9 The meeting was closed.

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Table 1: Fishery-dependent data collection modes, and the ability of the data types collected to address specific assessment questions derived from Conservation Measure 22-01 as it relates to exploratory krill fisheries.

	Fishery-dependent data collection			
	Commercial fishing	Logged under-way acoustics	Standardised systematic/random research trawls by fishing vessels	Standardised systematic acoustic transects by fishing vessels
Data types:	Location of fishing not constrained. Data collected by observers and vessel, equivalent to established fisheries.	Calibration and SST required. Data collected during fishing operations and transits between aggregations. Data collected by observers and vessel, equivalent to established fisheries.	Trawl stations need to be nominated and sampling standardised. Data collected by observers and vessel, equivalent to established fisheries.	Location and extent of transects need to be nominated. Calibration and SST required for acoustics.
Key assessment questions*	Can the fishing/data collection strategy address the key assessment question?			
1. What is the distribution and density of krill across the management unit?	Unlikely – temporal and spatial coverage likely to be limited to areas of high krill density.	Partial – some temporal and spatial coverage partially independent of areas of high density as vessels locate krill aggregations.	Likely – temporal and spatial coverage independent of areas of high density.	Likely – temporal and spatial coverage independent of areas of high density.
2. What is the population structure of krill within the management unit?	Unlikely – temporal and spatial coverage likely to be limited to areas of high density.	Partial – some temporal and spatial coverage partially independent of areas of high density as vessels locate krill aggregations.	Likely – temporal and spatial coverage independent of areas of high density.	Likely – temporal and spatial coverage independent of areas of high density.
3. What is the distribution and density of by-catch across the management unit?	Unlikely – temporal and spatial coverage likely to be limited to areas of high density.	Unlikely – current acoustic-based analyses provide no information on likely by-catch rates.	Likely – temporal and spatial coverage independent of areas of high density.	Unlikely – current acoustic-based analyses provide no information on likely by-catch rates.
4. What is the proximity of krill aggregations/fishery operations to predator foraging areas?	Possible – fishing may occur in some areas of a krill aggregation that are also used by predators.	Possible – fishing may occur in some areas of a krill aggregation that are also used by predators.	Likely – temporal and spatial coverage independent of areas of high density.	Unlikely – current acoustic-based analyses provide no information on predators.
5. What are the catch rates/selectivity of krill relative to areas where assessments exist?	Possible – data may be available if the same vessel/gear fishes in the exploratory area and assessed areas allowing standardisation.	Possible – data may be available if the same vessel/gear fishes in the exploratory area and assessed areas allowing standardisation.	Possible – data may be available if the same vessel/gear fishes in the exploratory area and assessed areas allowing standardisation.	Possible – data may be available if the same vessel/gear fishes in the exploratory area and assessed areas allowing standardisation.
6. What are the fleet dynamics of the fishery in the management area?	Possible – searching strategies and move-on decisions by vessels in commercial fishing context may be collected by observer/vessel data.	Possible – searching strategies and move-on decisions by vessels in commercial fishing context may be collected by observer/vessel data.	Unlikely – systematic fishing unlikely to reflect fishing strategies of commercial fishing.	Unlikely – systematic fishing unlikely to reflect fishing strategies of commercial fishing.
7. What is the impact of fishing on the standing stock of krill?	Unlikely – temporal and spatial coverage likely to be limited to areas of high density.	Possible – data may be available if the same vessel/gear systematically transits area immediately before and after fishing in a region.	Possible – data may be available if the same vessel/gear performs systematic fishing immediately before and after fishing in a region.	Possible – data may be available if the same vessel/gear performs systematic transects immediately before and after fishing in a region.

(continued)

Table 1 (continued)

	Fishery-dependent data collection			
	Commercial fishing	Logged under-way acoustics	Standardised systematic/random research trawls by fishing vessels	Standardised systematic acoustic transects by fishing vessels
Pre/post-collection data processing and management	Secretariat required to collate and summarise data for use by working groups for review and assessments.	Requires Members to calibrate acoustic gear and collect and archive large volumes of data by vessel using acoustic logging system. Members required to provide post-processing and analysis to produce biomass/density estimates. Secretariat required to collate and summarise data for use by working groups for review and assessment.	Members required to provide post-processing and analysis to produce biomass/density estimates. Secretariat required to collate and summarise data for use by working groups for review and assessments.	Data collected by observers and vessel. Requires Member to calibrate acoustic gear and collect and archive large volumes of data by vessel using acoustic logging system. Members required to provide post-processing and analysis to produce biomass/density estimates. Secretariat required to collate and summarise data for use by working groups for review and assessments.

* Questions 1 and 2 relate to Conservation Measure 22-01, paragraph 1(ii)(a), questions 3 and 4 to paragraph 1(ii)(b) and questions 5 to 7 to paragraph 1 (ii)(c) of the measure.

Table 2: Fishery-independent data collection modes, and the ability of the data types collected to address specific assessment questions derived from Conservation Measure 22-01 as it relates to exploratory krill fisheries.

	Fishery-independent data collection	
	Predator monitoring	Research survey from scientific vessel
Data types:	Data on predator abundance, population dynamics and foraging, equivalent to CEMP monitoring.	Scientific acoustic and trawl sampling data, equivalent to large-scale surveys, e.g. BROKE-West, CCAMLR-2000.
Key assessment questions*	Can the fishing/data collection strategy address the key assessment question?	
1. What is the distribution and density of krill across the management unit?	Unlikely – temporal and spatial coverage likely to be limited to areas where predators forage.	Likely – temporal and spatial coverage independent of areas of high density or projected fishing effort.
2. What is the population structure of krill within the management unit?	Unlikely – temporal and spatial coverage likely to be limited to areas where predators forage.	Likely – temporal and spatial coverage independent of areas of high density or projected fishing effort.
3. What is the distribution and density of by-catch across the management unit?	Unlikely – temporal and spatial coverage likely to be limited to areas where predators forage.	Likely – temporal and spatial coverage independent of areas of high density or projected fishing effort.
4. What is the proximity of krill aggregations/fishery operations to predator foraging areas?	Likely – key objective of predator monitoring.	Likely – temporal and spatial coverage independent of areas of high density or projected fishing effort.
5. What are the catch rates/selectivity of krill relative to areas where assessments exist?	Unlikely – predator selectivity unlikely to provide data on fishing gear selectivity across areas.	Possible – data may be available if the same vessel/gear fishes in the exploratory area and assessed areas allowing standardisation.
6. What are the fleet dynamics of the fishery in the management area?	Unlikely – predator selectivity unlikely to provide data on fishing gear selectivity across areas.	Unlikely – survey fishing unlikely to reflect fishing strategies of commercial fishing.
7. What is the impact of fishing on the standing stock of krill?	Possible – predator responses may indicate impact of krill fishery on the stock in the medium to long term.	Possible – data may be available if the same vessel/gear performs survey fishing immediately before and after fishing in a region.
Pre/post-collection data processing and management	Requires Members to commit to long-term monitoring of predator populations foraging in the area of the exploratory fishery.	Requires Member to develop research plan for review by working groups. Requires Member to provide vessel with calibrated acoustic gear and collect and archive large volumes of data by vessel using acoustic logging system. Members required to provide post-processing and analysis to produce biomass/density estimates and report to the working groups. Secretariat required to collate and summarise data for use by working groups for review and assessment.

* Questions 1 and 2 relate to Conservation Measure 22-01, paragraph 1(ii)(a), questions 3 and 4 to paragraph 1(ii)(b) and questions 5 to 7 to paragraph 1 (ii)(c) of the measure.

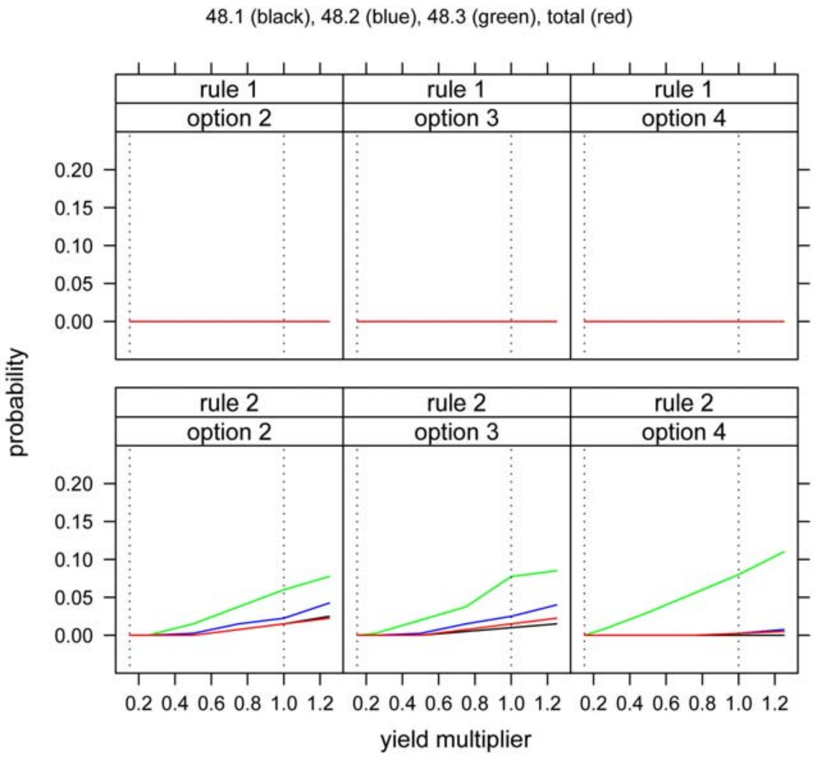


Figure 1*: FOOSA: effects on the krill population. Model-averaged, fishing-option-specific probabilities that minimum krill abundance during the fishing period is <20% of the abundances from comparable no-fishing trials (krill decision rule 1; upper panels) and that krill abundance measured at the end of the fishing period is <75% of the abundances from comparable no-fishing trials (krill decision rule 2; lower panels). Probabilities are averaged across parameterisations in the reference set using equal weights for the four scenarios (described in Figure 2). Results in each panel are aggregated across all SSMUs. The x axis is harvest rate, labelled 'yield multiplier'. Option 2 is the SSMU allocation proportional to predator abundance, Option 3 is the SSMU allocation proportional to the CCAMLR-2000 Survey krill abundance and Option 4 is the SSMU allocation proportional to predator abundance minus krill abundance. The vertical dotted lines mark yield multiplier values of 0.15 (indicating the harvest rate at the trigger level) and 1.0 (indicating the harvest rate at the full precautionary catch limit).

* This figure is available in colour on the CCAMLR website.

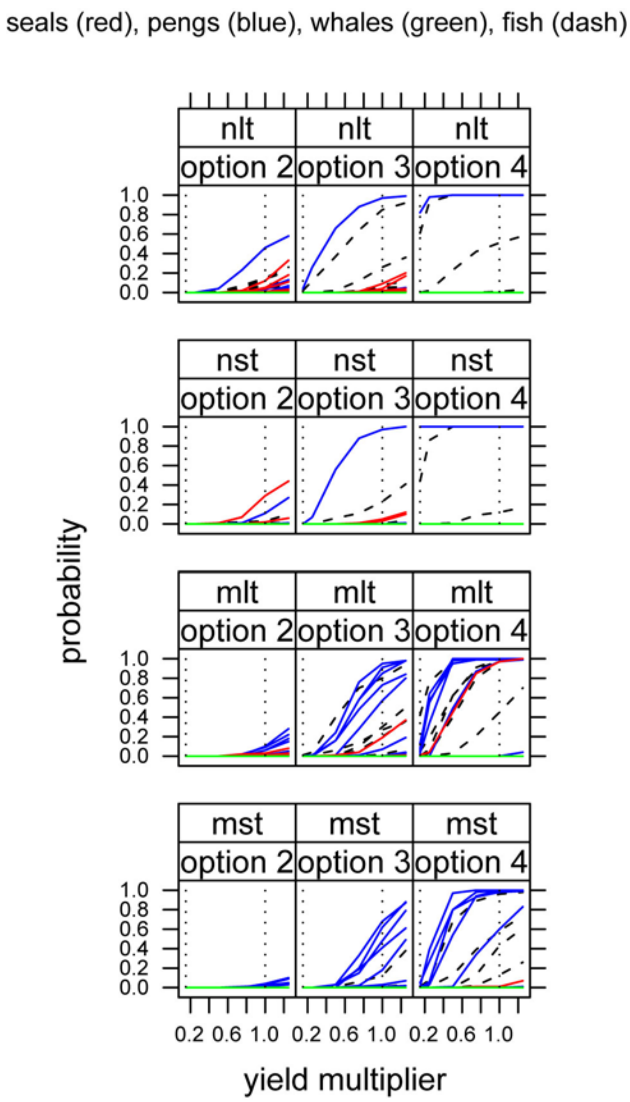


Figure 2*: FOOSA: effects on predators. Parameterisation- and fishing-option-specific probabilities that, at the end of the fishing period, the abundances of predators will be reduced to values less than 75% of abundances predicted from comparable no-fishing trials. The trend lines for each predator group are SSMU-specific. The vertical dotted lines mark yield multiplier values of 0.15 (indicating the harvest rate at the trigger level) and 1.0 (indicating the harvest rate at the full precautionary catch limit). The four scenarios are no movement + linear predator response (nlt) , no krill movement + stable predator response (nst), movement + linear predator response (mlt) and krill movement + stable predator response (mst) .

* This figure is available in colour on the CCAMLR website.

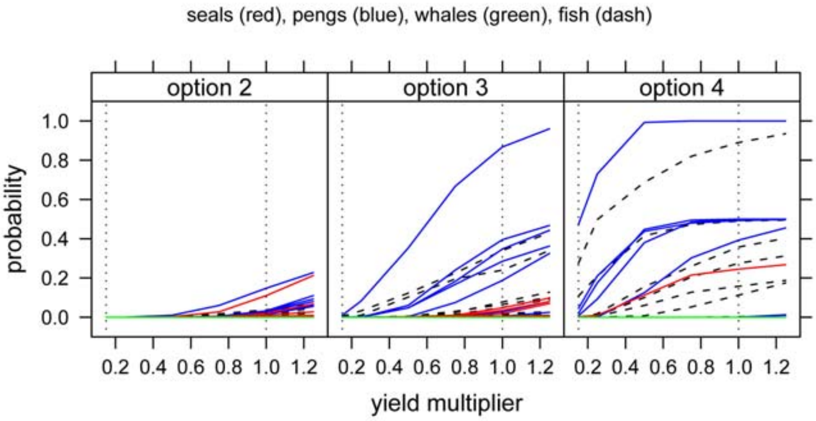


Figure 3*: FOOSA: effects on predators. Model-averaged, fishing-option-specific probabilities that, at the end of the fishing period, the abundances of predators will be reduced to values less than 75% of abundances from comparable no-fishing trials. Other details as in Figure 1.

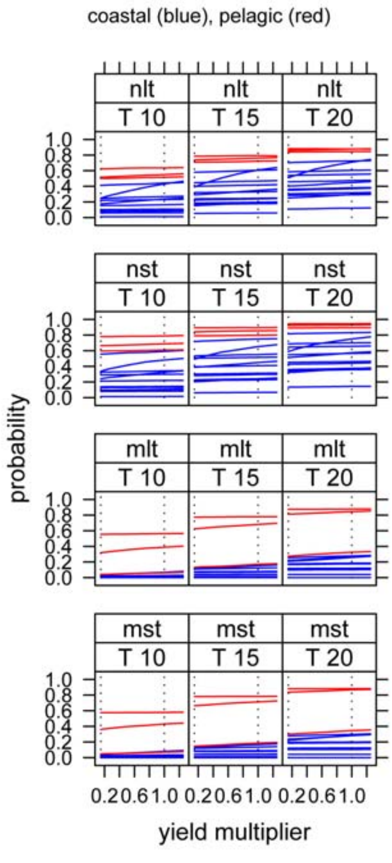


Figure 4*: FOOSA: effects on the fishery. Parameterisation-specific probability across all trials under Option 3 that krill density falls below a specified threshold (T) of 10, 15 or 20 g m^{-2} during fishing. The trend lines are SSMU-specific. The vertical dotted lines mark yield multiplier values of 0.15 (indicating the harvest rate at the trigger level) and 1.0 (indicating the harvest rate at the full precautionary catch limit). The four scenarios are described in Figure 2.

* These figures are available in colour on the CCAMLR website.

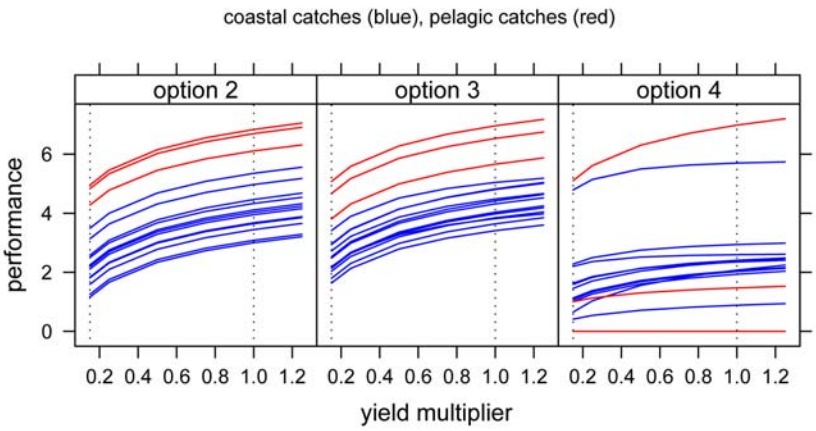


Figure 5*: FOOSA: effects on the fishery. Model-averaged, fishing-option-specific log of mean catches. Probabilities are averaged across parameterisations in the reference set using the equal weights for the four scenarios. The trend lines are SSMU-specific. The vertical dotted lines mark yield multiplier values of 0.15 (indicating the harvest rate at the trigger level) and 1.0 (indicating the harvest rate at the full precautionary catch limit). Note, many SSMU-specific, model-averaged catches predicted from the implementation of Fishing Option 4 were low compared to other options because all the parameterisations in the reference set implicitly describe initial conditions that would prohibit fishing in many SSMUs.

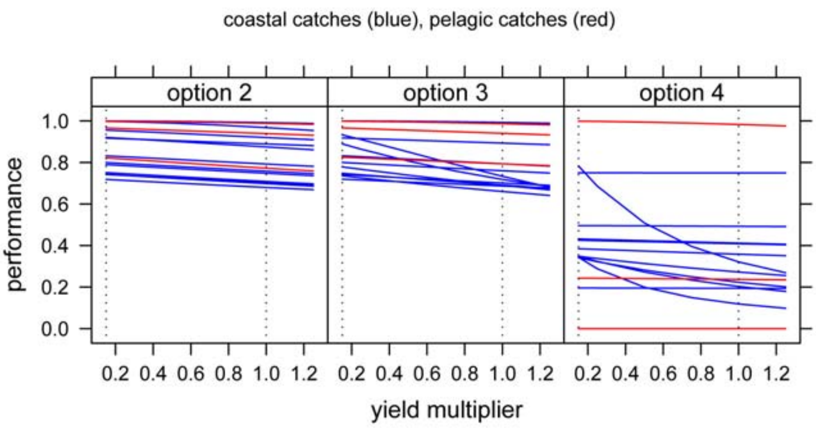
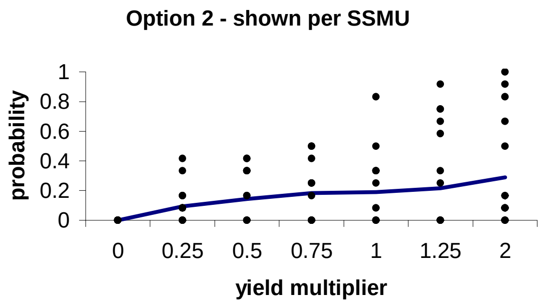


Figure 6*: FOOSA: effects on the fishery. Fishery performance across all trials, expressed as the proportion of the total allocation taken by the fishery. Performance metrics are averaged across parameterisations in the reference set using equal weights for the four scenarios. The trend lines are SSMU-specific. The vertical dotted lines mark yield multiplier values of 0.15 (indicating the harvest rate at the trigger level) and 1.0 (indicating the harvest rate at the full precautionary catch limit).

* These figures are available in colour on the CCAMLR website.



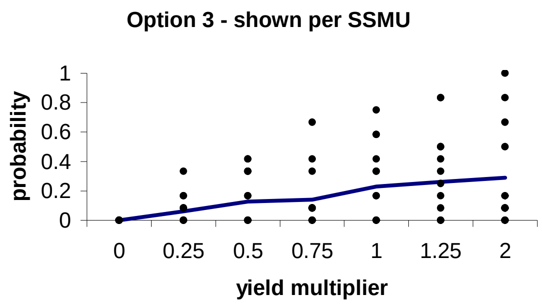
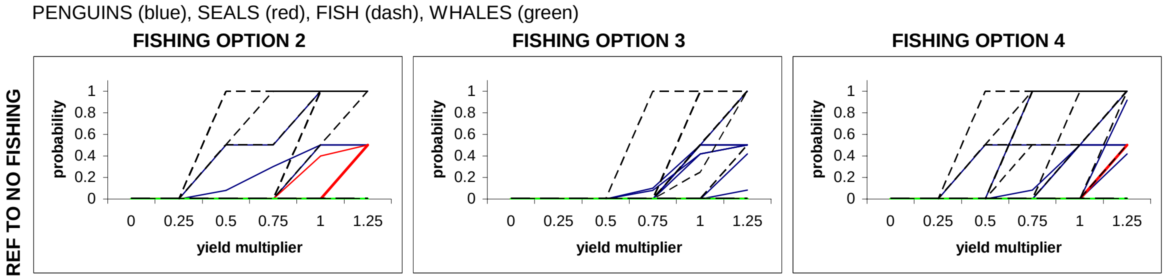


Figure 7: SMOM: effects on the krill population. Probability that krill abundance across all SSMUs measured at the end of the fishing period is <75% of the abundances from comparable no-fishing trials, with results presented for individual SSMUs and the line indicating the average over all SSMUs. Probabilities are averages, assuming equal weighting, from a reference set including 12 alternative paramerisation combinations. Options are defined in Figure 1.

(a)



(b)

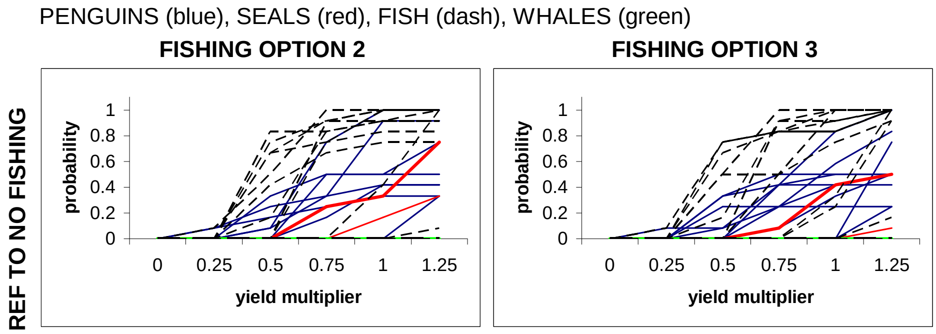


Figure 8*: SMOM: effects on predators. Probability that predator abundance across all SSMUs measured at the end of the fishing period is <75% of the abundances from comparable no-fishing trials, with results presented for individual SSMUs and predator groups. Probabilities are averages, assuming equal weighting, from a reference set including 12 alternative paramerisation combinations. Options are defined in Figure 1. This implementation of SMOM is most similar to the FOOSA 'nst' scenario (see Figure 2). (a) is a simplified diagram showing the general results of the three options. (b) shows the detailed results of Options 2 and 3 when more closely aligning model parameterisation with that used in FOOSA.

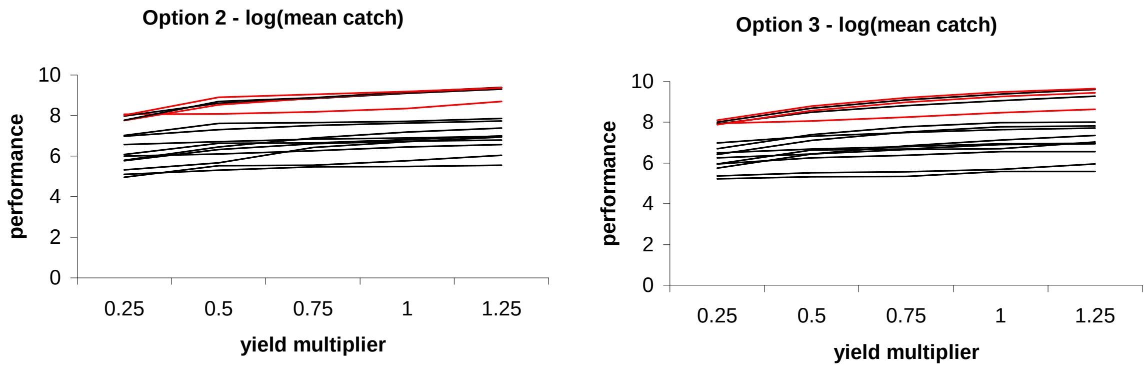


Figure 9*: SMOM: effects on the fishery. Model-averaged, fishing-option-specific natural logarithm of mean catches. The trend lines are SSMU-specific. Red lines are catches in pelagic SSMUs, black are catches in coastal SSMUs.

* These figures are available in colour on the CCAMLR website.

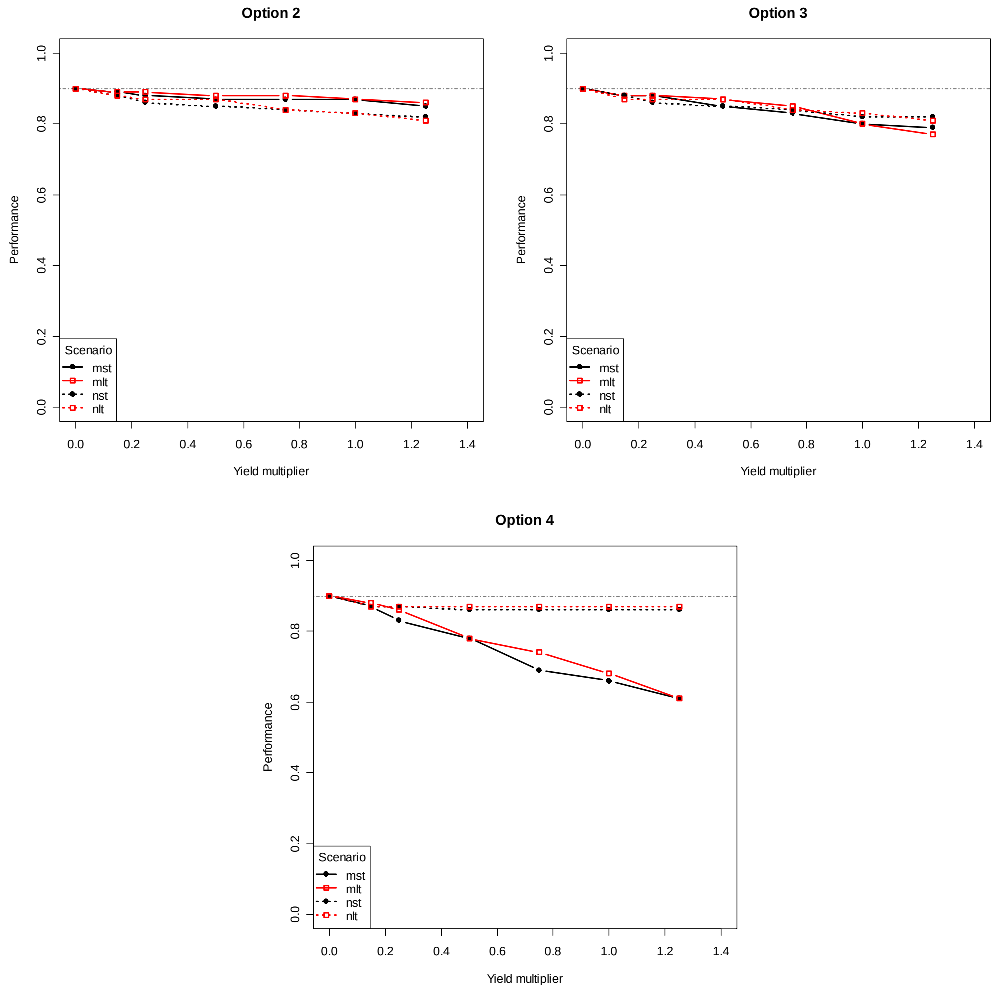


Figure 10: FOOSA predator performance results integrated with the CSI (WG-SAM-08/16). Performance is the probability that the CSI will be above a reference level, defined as the lower 90th percentile of the distribution of CSIs at the end of the fishing period in the absence of fishing. For example, when there is no fishing, there is a 90% probability that the CSI is above this reference level at the end of the prescribed fishing period; for scenario 'mlt' when fishing effort is 1.25 × yield, there is approximately an 85% probability that the performance is above this reference level.

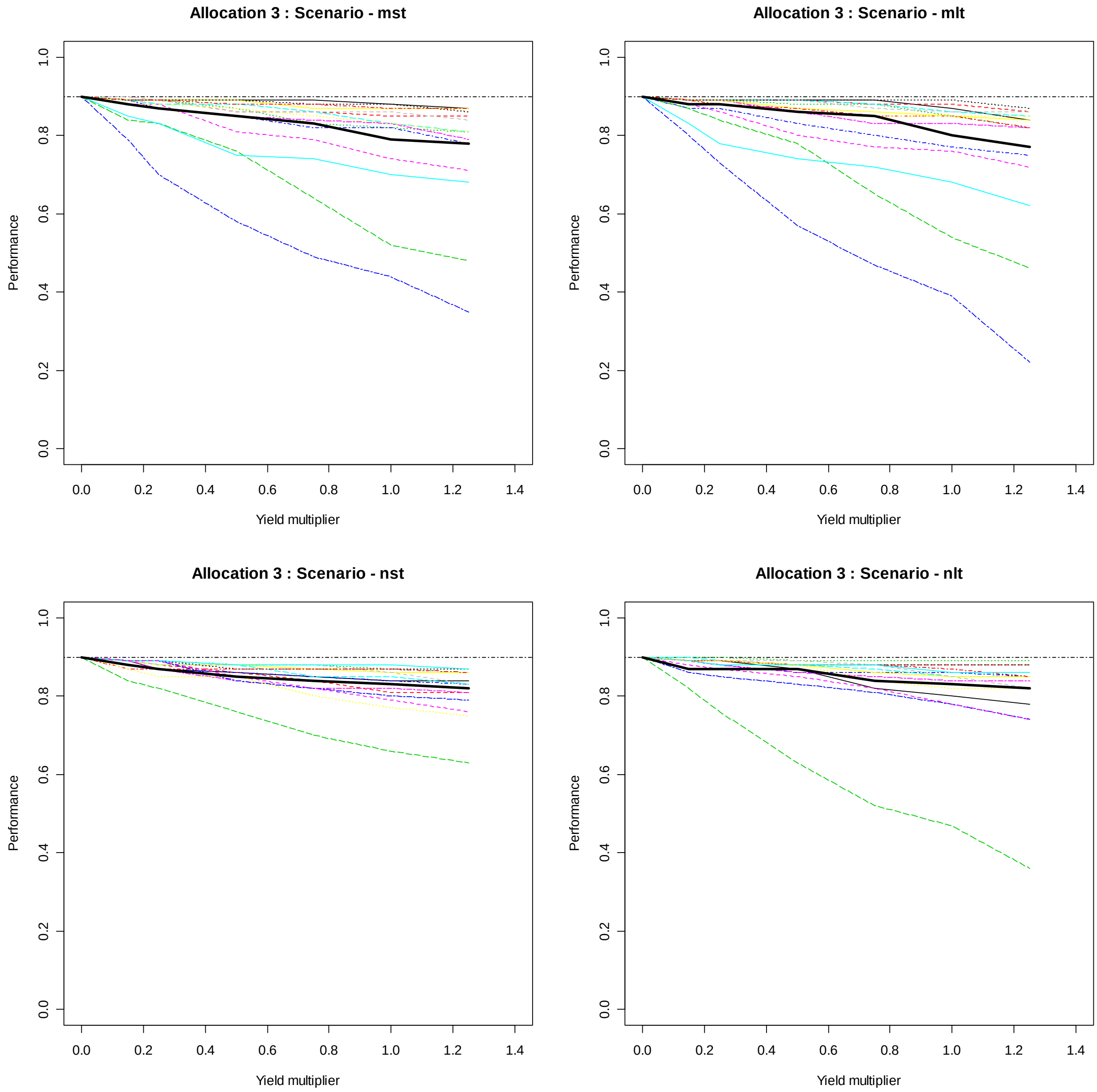


Figure 11*: FOOSA predator performance results integrated with the CSI for each scenario in SSMU allocation Option 3. Thick lines show results as provided in Figure 10. Thin lines are SSMU-specific performance based on SSMU-specific CSIs.

* This figure is available in colour on the CCAMLR website.

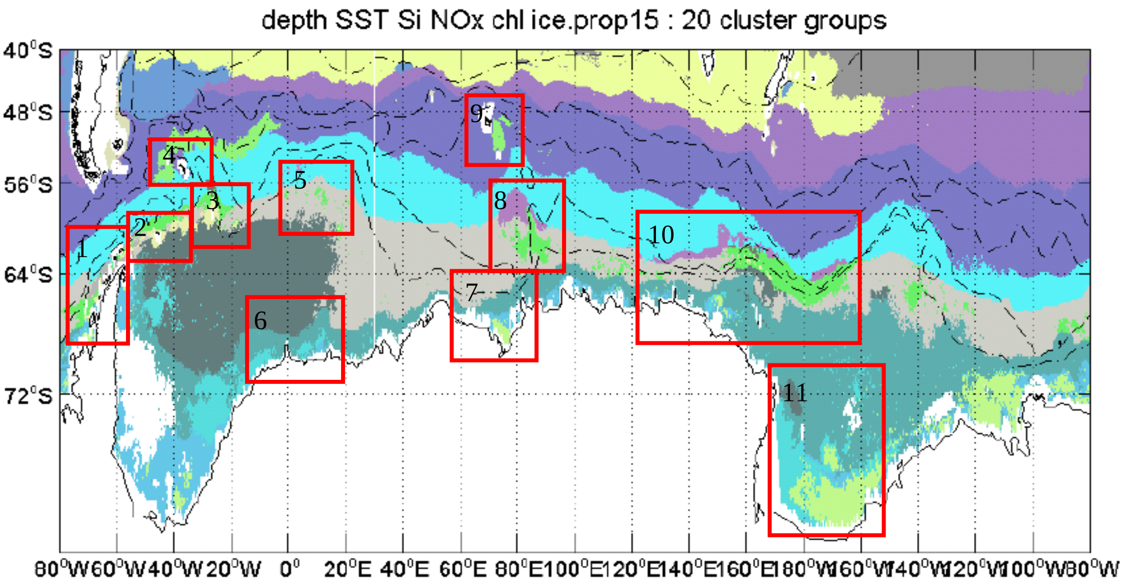


Figure 12*: Secondary regionalisation agreed by the CCAMLR Bioregionalisation Workshop (2007) (analysis based on depth, SST, silicate concentration, nitrate concentration, surface chlorophyll-*a* and ice concentration). Red boxes show areas of highest heterogeneity, which have been identified by the Working Group as priority areas for identifying MPAs as part of a representative system (numbers refer to area descriptions, and are not in any order of priority). 1 = Western Antarctic Peninsula, 2 = South Orkney Islands, 3 = South Sandwich Islands, 4 = South Georgia, 5 = Maud Rise, 6 = Eastern Weddell Sea, 7 = Prydz Bay, 8 = BANZARE Bank, 9 = Kerguelen, 10 = Northern Ross Sea/East Antarctica, 11 = Ross Sea shelf.

* This figure is available in colour on the CCAMLR website.

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APPENDIX B

AGENDA

Working Group on Ecosystem Monitoring and Management
(St Petersburg, Russia, 23 July to 1 August 2008)

1. Introduction
   1.1 Opening of the meeting
   1.2 Adoption of the agenda and organisation of the meeting
   1.3 Feedback from previous meetings of the Commission, the Scientific Committee, and the Working Groups

2. Focus Topic: Risk assessment for Stage 1 subdivisions of the precautionary krill catch limit among small-scale management units in Statistical Area 48 – Chair, Dr P. Trathan (UK)
   2.1 Advice from WG-SAM
   2.2 Analyses and risk assessment
   2.3 Key points for consideration by the Scientific Committee and its working groups

3. Focus Topic: Discussion to progress the implementation of spatial management measures that aim to facilitate the conservation of marine biodiversity – Chair, Dr P. Penhale (USA)
   3.1 Background
   3.2 Identifying vulnerable marine ecosystems
   3.3 Defining candidate marine protected areas
   3.4 Developing a harmonised approach
   3.5 Work plan
   3.6 Key points for consideration by the Scientific Committee and its working groups

4. Status and trends in the krill fishery
   4.1 Fishing activity
   4.2 Description of the fishery
   4.3 Scientific observation
   4.4 Regulatory issues
   4.5 Key points for consideration by the Scientific Committee and its working groups

5. Status and trends in the krill-centric ecosystem
   5.1 Report from WG-EMM-STAPP
   5.2 Status of predators, krill resource and environmental influences
      5.2.1 Predators
      5.2.2 Krill
      5.2.3 Environment and climate impacts
   5.3 Other prey species
   5.4 Methods
   5.5 Future surveys
   5.6 Key points for consideration by the Scientific Committee and its working groups

6. Ecosystem effects of fisheries that target finfishes

7. Status of management advice
    7.1 Protected areas
    7.2 Harvesting units
    7.3 Small-scale management units
    7.4 Analytical models
    7.5 Existing conservation measures
    7.6 Key points for consideration by the Scientific Committee and its working groups

8. Future work
    8.1 Second Workshop on Fisheries and Ecosystem Models in the Antarctic
    8.2 Revised agenda and long-term work plan for WG-EMM
    8.3 Joint CCAMLR-IWC Workshop
    8.4 Key points for consideration by the Scientific Committee and its working groups

9. Other business

10. Adoption of the report and close of the meeting.

APPENDIX C

LIST OF DOCUMENTS

Working Group on Ecosystem Monitoring and Management
(St Petersburg, Russia, 23 July to 1 August 2008)

WG-EMM-08/1	Draft Preliminary Agenda for the 2008 Meeting of the Working Group on Ecosystem Monitoring and Management (WG-EMM)
WG-EMM-08/2	List of participants
WG-EMM-08/3	List of documents
WG-EMM-08/4	CEMP indices: 2008 update Secretariat
WG-EMM-08/5	Krill fishery report: 2008 update Secretariat
WG-EMM-08/6	Summary of notifications for krill fisheries in 2008/09 Secretariat
WG-EMM-08/7	Demography of Antarctic krill and other Euphausiacea in the Lazarev Sea – LAKRIS the German contribution to CCAMLR-IPY in summer 2008 V. Siegel, J. Edinger, M. Haraldsson, K. Stürmer, M. Vortkamp (Germany)
WG-EMM-08/8	Report of the Predator Survey Workshop (Hobart, Australia, 16 to 20 June 2008)
WG-EMM-08/9	Report from Invited Expert to WG-EMM-PSW-08 R. Fewster (Invited Expert)
WG-EMM-08/10	Reference observations for validating and tuning operating models for krill fishery management in Area 48 S. Hill (United Kingdom), J. Hinke (USA), É. Plagányi (South Africa) and G. Watters (USA)
WG-EMM-08/11	Proposed small-scale management units for the krill fishery in Subarea 48.4 and around the South Sandwich Islands P.N. Trathan, A.P.R. Cooper and M. Biszczuk (United Kingdom)

WG-EMM-08/12	Allocating the precautionary catch limit for krill amongst the small-scale management units in Area 48: the implications of data uncertainties P.N. Trathan and S.L. Hill (United Kingdom)
WG-EMM-08/13	Developing four plausible parameterisations of FOOSA (a so-called reference set of parameterisations) by conditioning the model on a calendar of events that describes changes in the abundances of krill and their predators in the Scotia Sea G.M. Watters, J.T. Hinke (USA) and S. Hill (United Kingdom)
WG-EMM-08/14	Developing models of Antarctic marine ecosystems in support of CCAMLR and IWC A. Constable (Australia)
WG-EMM-08/15	CCAMLR-IWC Workshop to review input data for Antarctic marine ecosystem models: update on progress 2008 A. Constable and N. Gales (Co-conveners)
WG-EMM-08/16	Distribution of krill at threshold densities suitable for fishing in the Atlantic sector: analysis of the 2000 synoptic survey data S. Hill and D. Agnew (United Kingdom)
WG-EMM-08/17	A re-appraisal of the total biomass and annual production of Antarctic krill A. Atkinson (United Kingdom), V. Siegel (Germany), E.A. Pakhomov (South Africa), M.J. Jessopp (United Kingdom) and V. Loeb (USA) (*Deep-Sea Research*, submitted)
WG-EMM-08/18	Preliminary report of the New Zealand RV Tangaroa IPY-CAML survey of the Ross Sea region, Antarctica, in February–March 2008 S.M. Hanchet, J. Mitchell, D. Bowden, M. Clark, J. Hall, R. O'Driscoll, M. Pinkerton and D. Robertson (New Zealand)
WG-EMM-08/19	Calibration error in the AMLR plankton time series C. Reiss (USA)
WG-EMM-08/20	Letter to Drs Reid, Watters and Jones in regard to 'disappearance of toothfish from McMurdo Sound' D.G. Ainley, S.F. Ackley, K. Arrigo (USA), G. Ballard (New Zealand), J.P. Barry (USA), L. Blight (Canada), P. Broady, B. Davison (New Zealand), P. Dayton, A.L. DeVries, K. Dugger, J.T. Eastman, S.D. Emslie (USA), C. Evans (New Zealand), R.A. Garrott, G. Hofmann, S. Kim, G. Kooyman, S.S. Jacobs (USA), G. Lauriano (Italy), A. Lescroël (France), D.R. MacAyeal (USA), M. Massaro (New Zealand), S. Olmastroni (Italy), P.J. Ponganis (USA), E. Robinson (New Zealand), D.B. Siniff, W.O. Smith (USA), I. Stirling (Canada) and P. Wilson (New Zealand)

WG-EMM-08/21	Decline of the Antarctic toothfish and its predators in McMurdo Sound and the southern Ross Sea and recommendations for restoration A.L. DeVries, D.G. Ainley and G. Ballard (USA)
WG-EMM-08/22	Addressing uncertainty over the importance of Antarctic toothfish as prey of seals and whales in the southern Ross Sea: a review D. Ainley and D. Siniff (USA)
WG-EMM-08/23	Aerial surveys of Weddell seals during 2007/08, with notes on the history of aerial censuses in the Ross Sea and recommendations for continued count effort D. Siniff and D. Ainley (USA)
WG-EMM-08/24	State of Antarctic krill (*Euphausia superba*) fisheries in Statistical Subarea 48.2 in 2008 V.A. Bibik and N.N. Zhuk (Ukraine)
WG-EMM-08/25	Data on feeding and food objects of southern minke whales S.G. Bushuev (Ukraine) (Previously submitted as SC-CAMLR-XXVI/BG/25 Rev. 1)
WG-EMM-08/26	Comparison of the biomass of Antarctic krill (*Euphausia superba*) around the South Shetland and South Orkney Islands in three years: 1999, 2000 and 2008 C. Reiss and A. Cossio (USA)
WG-EMM-08/27	Trophic study of Ross Sea Antarctic toothfish (*Dissostichus mawsoni*) using carbon and nitrogen stable isotopes S.J. Bury, M.H. Pinkerton, D.R. Thompson, S. Hanchet, J. Brown and I. Vorster (New Zealand)
WG-EMM-08/28	The Antarctic krill and ecosystem survey with RV *G.O. Sars* in 2008 S.A. Iversen (Norway), W. Melle, E. Bagøien, D. Chu, B. Edvardsen, B. Ellertsen, E. Grønningsæter, K. Jørstad, E. Karslbakk, T. Klevjer, T. Knutsen, R. Korneliussen, H. Kowall, B. Krafft, S. Kaartvedt, P.B. Lona, S. Murray, L. Naustvoll, L. Nøttestad, M. Ostrowski, V. Siegel, Ø. Skagseth, G. Skaret, H. Søiland, X. Zhao and C.B. Årnes
WG-EMM-08/29	*In situ* measurements of tilt angle distribution and target strength in Antarctic krill (*Euphausia superba*) G. Skaret, S.A. Iversen, T. Knutsen, R.J. Korneliussen, E. Ona, R. Pedersen, A. Totland, T. Torkelsen (Norway) and X. Zhao (China)
WG-EMM-08/30	A risk assessment to advise on strategies for subdividing a precautionary catch limit among small-scale management units during stage 1 of the staged development of the krill fishery in Subareas 48.1, 48.2 and 48.3 G.M. Watters, J.T. Hinke (USA) and S. Hill (United Kingdom)

WG-EMM-08/31	Relationships between oceanographic environment and distribution of krill and baleen whales in the Ross Sea and adjacent waters, Antarctica in 2004/05 M. Naganobu, S. Nishiwaki, H. Yasuma, R. Matsukura, Y. Takao, K. Taki, T. Hayashi, Y. Watanabe, T. Yabuki, Y. Yoda, Y. Noiri, M. Kuga, K. Yoshikawa, N. Kokubun, H. Murase, K. Matsuoka, T. Iwami and K. Ito (Japan) (*CCAMLR Science*, submitted)
WG-EMM-08/32	Relationship between distribution of Antarctic krill (*Euphausia superba*) and environmental index MTEM-200 in the Antarctic Ocean throughout the year M. Naganobu, T. Kitamura and K. Hasunuma (Japan) (*CCAMLR Science*, submitted)
WG-EMM-08/33	Time series of Drake Passage Oscillation Index (DPOI) during 1952–2008 and its possible influence on environmental variability M. Naganobu, J. Kondo and K. Kutsuwada (Japan)
WG-EMM-08/34	Systematic coverage by scientific observers on krill fishing vessels Delegation of Japan
WG-EMM-08/35	Distribution patterns and biomasses of Antarctic krill (*Euphausia superba*) and ice krill (*E. crystallorophias*) with note on distribution of Antarctic minke whales (*Balaenoptera bonaerensis*) in the Ross Sea in 2005 H. Murase, H. Yasuma, R. Matsukura, Y. Takao, K. Taki, T. Hayashi, T. Yabuki, T. Tamura, K. Konishi, K. Matsuoka, K. Miyashita, S. Nishiwaki and M. Naganobu (Japan)
WG-EMM-08/36	Community structure of copepods in epipelagic layers in the Ross Sea and neighbouring waters Y. Watanabe, S. Sawamoto, T. Ishimaru and M. Naganobu (Japan)
WG-EMM-08/37	A risk management framework for avoiding significant adverse impacts of bottom fishing gear on vulnerable marine ecosystems K. Martin-Smith (Australia)
WG-EMM-08/38	Notification of vulnerable marine ecosystems in Statistical Division 58.4.1 (Submitted by Australia)
WG-EMM-08/39	Krill fishery behaviour in the southwest Atlantic S. Kawaguchi (Australia) (*CCAMLR Science*, submitted)
WG-EMM-08/40	Krill fishery behaviour in the 1999/2000 season S. Kawaguchi (Australia)

WG-EMM-08/41	Updated krill recruitment data for the Elephant Island region of the South Shetland Islands, Antarctica: 2002–2008 C. Reiss (USA)
WG-EMM-08/42	A preliminary balanced trophic model of the ecosystem of the Ross Sea, Antarctica, with emphasis on apex predators M.H. Pinkerton, J.M. Bradford-Grieve and S.M. Hanchet (New Zealand) (*CCAMLR Science*, submitted)
WG-EMM-08/43	Trophic overlap of Weddell seals (*Leptonychotes weddelli*) and Antarctic toothfish (*Dissostichus mawsoni*) in the Ross Sea, Antarctica M.H. Pinkerton, A. Dunn and S.M. Hanchet (New Zealand)
WG-EMM-08/44	Conditioning SMOM using the agreed calendar of observed changes in predator and krill abundance: a further step in the development of a management procedure for krill fisheries in Area 48 É.E. Plagányi and D.S. Butterworth (South Africa)
WG-EMM-08/45	Potential requirements for scientific data from the krill fishery Secretariat
WG-EMM-08/46	Catch uncertainty in krill fisheries Secretariat
WG-EMM-08/47	Progress towards expert group manuscripts for the CCAMLR-IWC Workshop to review input data for Antarctic marine ecosystem models: update on progress 2008 A. Constable and N. Gales (Co-conveners)
WG-EMM-08/48	Multiple time scales of variability in the krill population at South Georgia K. Reid, J. Watkins, E. Murphy, P. Trathan, S. Fielding and P. Enderlein (United Kingdom) (*Mar. Ecol. Prog. Ser.*, to be submitted)
WG-EMM-08/49	Proposed approach for the identification of important marine areas for conservation: using 'MARXAN' software to support systematic conservation planning S.M. Grant, J. Tratalos and P.N. Trathan (United Kingdom)
WG-EMM-08/50	Flexible foraging strategies of gentoo penguins help buffer the impacts of interannual changes in prey availability A.K. Miller and W.Z. Trivelpiece (USA)
WG-EMM-08/51	Down-scaling FOOSA to model the Admiralty Bay Pygoscelid penguin colonies: a work in progress J.T. Hinke, G.M. Watters and W.Z. Trivelpiece (USA)

WG-EMM-08/52	Proposal for a Joint CEP-SC-CAMLR Workshop in 2009 Secretariat
WG-EMM-08/53	Preliminary estimation of penguin breeding abundance at spatial-scales of relevance to CCAMLR: incorporating uncertainty in count data H. Lynch, R. Naveen (USA), J. McKinlay, C. Southwell (Australia), P. Trathan (United Kingdom), W. Trivelpiece, S. Trivelpiece (USA) and D. Ramm (CCAMLR Secretariat)
WG-EMM-08/54	Net-based verification of acoustic techniques used to identify Antarctic krill J. Watkins and S. Fielding (United Kingdom) (*CCAMLR Science*, submitted)
WG-EMM-08/55	Properties of krill distribution in pelagic and coastal SSMUs of the South Orkney Islands subarea according to the data of scientific observations and fishery S.M. Kasatkina and V.N. Shnar (Russia) (*CCAMLR Science*, submitted)
WG-EMM-08/56 Rev. 1	Measurements of sound-speed density contrasts of Antarctic krill (*Euphausia superba*) on board RV *Kaiyo Maru* Y. Takao, H. Yasuma, R. Matsukura, K. Amakasu and M. Naganobu (Japan)
WG-EMM-08/57	By-catch of fishes caught by the krill fishing vessel *Niitaka Maru* in the South Georgia area (August 2007) T. Iwami and M. Naganobu (Japan)

Other Documents

WG-EMM-08/P1	Adult Antarctic krill feeding at abyssal depths A. Clarke and P.A. Tyler (*Current Biology*, 18: 282–285 (2008), doi: 10.1016/j.cub.2008.01.059)
WG-EMM-08/P2	Climatically driven fluctuations in Southern Ocean ecosystems E.J. Murphy, P.N. Trathan, J.L. Watkins, K. Reid, M.P. Meredith, J. Forcada, S.E. Thorpe, N.M. Johnston and P. Rothery (*Proc. R. Soc. B*, 274: 3057–3067 (2007), doi: 10.1098/rspb.2007.1180)
WG-EMM-08/P3	Rapid warming of the ocean around South Georgia, Southern Ocean, during the 20th Century: forcings, characteristics and implications for lower trophic levels M.J. Whitehouse, M.P. Meredith, P. Rothery, A. Atkinson, P. Ward and R.E. Korb (*Deep-Sea Res.*, in press)

WG-EMM-08/P4	Oceanic circumpolar habitats of Antarctic krill A. Atkinson, V. Siegel, E. A. Pakhomov, P. Rothery, V. Loeb, R.M. Ross, L.B. Quetin, K. Schmidt, P. Fretwell, E.J. Murphy, G.A. Tarling and A.H. Fleming (*Mar. Ecol. Progr. Ser*., 362: 1–23 (2008), doi: 10.3354/meps07498)
WG-EMM-08/P5	Life history buffering in Antarctic mammals and birds against changing patterns of climate and environmental variation J. Forcada, P.N. Trathan and E.J. Murphy (*Global Change Biology*, in press)
WG-EMM-08/P6	Environmental forcing and Southern Ocean marine predator populations: effects of climate change and variability P.N. Trathan, J. Forcada and E.J. Murphy (*Phil. Trans. R. Soc. B*, 362: 2351–2365 (2007), doi: 10.1098/rstb.2006.1953)
WG-EMM-08/P7	Ecological repercussions of historical fish extraction from the Southern Ocean D. Ainley and L. Blight (*Fish and Fisheries*, in press)
WG-EMM-08/P8	The summertime plankton community at South Georgia (Southern Ocean): comparing the historical (1926/27) and modern (post 1995) records P. Ward, M.P. Meredith, M.J. Whitehouse and P. Rothery (*Progress in Oceanography*, in press)
WG-EMM-08/P9	Histopathology of Antarctic krill, *Euphausia superba*, bearing black spots S. Miwa, T. Kamaishi, T. Matsuyama, T. Hayashi and M. Naganobu (*J. Invertebr. Pathol.* (2008), doi:10.1016/j.jip.2008.04.004, in press)
WG-EMM-08/P10	Horizontal and vertical distribution and demography of euphausiids in the Ross Sea and its adjacent waters in 2004/05 K. Taki, T. Yabuki, Y. Noiri, T. Hayashi and M. Naganobu (*Polar Biol*. (2008), doi: 10.1007/s00300-008-0472-6, in press)
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WG-EMM-08/P12	Interannual spatial variability of krill (*Euphausia superba*) influences seabird foraging behaviour near Elephant Island, Antarctica J.A. Santora, C.S. Reiss, A.M. Cossio and R.R. Veit (*Fish. Oceanogr*., in press)
WG-EMM-08/P13	Withdrawn

WG-EMM-PSW-08/4	A population estimate of macaroni penguins (*Eudyptes chrysolophus*) at South Georgia P.N. Trathan (United Kingdom)
WG-EMM-PSW-08/5	The white-chinned petrel (*Procellaria aequinoctialis*) on South Georgia: population size, distribution and global significance A.R. Martin, S. Poncet, C. Barbraud, P. Fretwell and E. Foster (United Kingdom)
WG-EMM-PSW-08/6	Abundance estimates for crabeater, Weddell and leopard seals at the Antarctic Peninsula and in the western Weddell Sea (90°–30°W, 60°–80°S) J. Forcada and P.N. Trathan (United Kingdom)
WG-EMM-PSW-08/7	Spatial and temporal variation in attributes of Adélie penguin breeding populations: implications for uncertainty in estimation of the abundance of breeding penguins from one-off counts C. Southwell, J. McKinlay, R. Pike, D. Wilson, K. Newbery and L. Emmerson (Australia)
WG-EMM-PSW-08/8	Estimating the number of pre- and intermittent breeders associated with the Béchervaise Island Adélie penguin population L. Emmerson and C. Southwell (Australia)
WG-EMM-PSW-08/9	Aspects of population structure, dynamics and demography of relevance to abundance estimation: Adélie penguins L. Emmerson and C. Southwell (Australia)
WG-EMM-PSW-08/10	Flying seabirds in Area 48: a review of population estimates, coverage and potential gaps in survey extent and methods D. Wilson (Australia)
WG-EMM-PSW-08/11	Seasonal estimation of abundance by bootstrapping inexact research data (seabird): a method for assessing abundance and uncertainty from historical count data using Adélie penguins as a case study J.P. McKinlay and C.J. Southwell (Australia)
WG-EMM-PSW-08/12	A brief summary of Adélie penguin count data from east Antarctica C. Southwell and J. McKinlay (Australia)
WG-EMM-PSW-08/13	Incomplete search effort as a potential source of bias in broad-scale estimates of penguin abundance derived from published count data: a case study for Adélie penguins in east Antarctica C. Southwell, D. Smith and A. Bender (Australia)

WG-EMM-PSW-08/14	Antarctic fur seal pup production and population trends in the South Shetland Islands with special reference to sources of error in pup production estimates M.E. Goebel (USA), D.E. Torres C. (Chile), A. Miller, J. Santora, D. Costa (USA) and P. Diaz (Chile)
WG-EMM-PSW-08/15	Timing of clutch initiation in *Pygoscelis* penguins on the Antarctic Peninsula: towards an improved understanding of off-peak census correction factors H.J. Lynch, W.F. Fagan, R. Naveen, S.G. Trivelpiece and W.Z. Trivelpiece (USA)
WG-SAM-08/15	Implementation of FOOSA (KPFM) in the EPOC modelling framework to facilitate validation and possible extension of models used in evaluating krill fishery harvest strategies that will minimise risk of localised impacts on krill predators A. Constable (Australia)
WG-SAM-08/16	An ecosystem-based management procedure for krill fisheries: a method for determining spatially-structured catch limits to manage risk of significant localised fisheries impacts on predators A. Constable and S. Candy (Australia)
WG-SAM-08/17	An updated description and parameterisation of the spatial multi-species operating model (SMOM) É.E. Plagányi and D.S. Butterworth (South Africa)
CCAMLR-XXVII/13	Notification of Norway's intention to conduct an exploratory trawl fishery for *Euphausia superba* in the 2008/09 season Delegation of Norway

APPENDIX D

ASSESSING PERFORMANCE BASED ON COMBINED STANDARDISED INDICES (CSIs)

(by Dr A. Constable, Antarctic Climate and Ecosystems Cooperative Research Centre and the Australian Antarctic Division)

A method for combining many individual responses of predators into an index was first proposed by de la Mare in 1997 (de la Mare, 1997; de la Mare and Constable, 2000) and later termed the 'Combined Standardised Index (CSI)' by Boyd and Murray (1999, 2001). This appendix describes how such an index can be used to measure the probability that a food web may depart from previously observed norms and thereby measure the risk of different yield multipliers causing significant departures from those norms.

AGGREGATING PREDATOR RESPONSES (E.G. RECRUITMENT) INTO CSIs

2. The indicators of predator responses included in a CSI include those metrics for which changes are thought to reflect changes in krill abundance. The indicators observed can be most easily envisaged as those that reflect the reproductive output of a population. The degree of change and the correlation of changes in such responses will vary between predators. In the absence of knowing the dependencies on krill or the changes in krill, the strength of the responses of predators as an aggregate signal across predators is dependent on the correlation that each predator response has with the other responses. Figure 1 illustrates that if they are all highly correlated, then the aggregate signal will be very strong. If they are weakly correlated, then changes in one predator may not be coincident with changes in another predator. Thus, the aggregate predator response captured in the CSI aims to provide an indicator of how much change is shared by all measures.

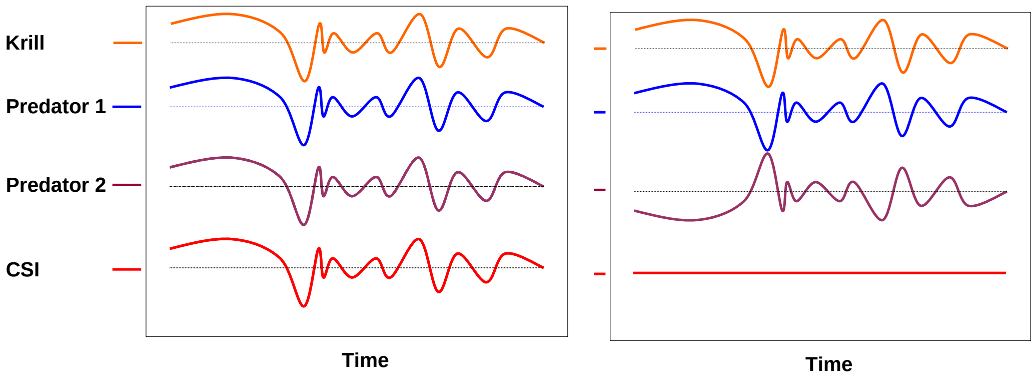

Figure 1: Illustration of the aggregate CSI for highly correlated predators (left – correlation = 1) and inversely correlated predators (right – correlation = –1). In the case of negative correlation with krill, it is suggested that the sign of the predator response is reversed so that changes in all predator responses are in the same direction relative to the change in krill abundance.

USING BASELINES TO ASSESS DEPARTURE FROM BASELINE NORMS

3. The natural variability in the CSI can be determined from a baseline period, i.e. a baseline norm. This may be either prior to the fishing period (or some period of interest) or, in the case of model evaluations, during a period with no fishing. Departures from this range of natural variation can be determined as anomalies (SC-CAMLR-XV, Annex 4; SC-CAMLR-XVI, Annex 4) where such departures could be beyond some confidence interval. This is illustrated in Figure 2.

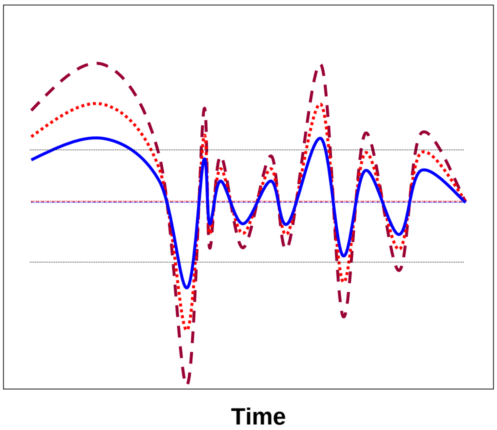

Figure 2: Illustration of departures of a CSI outside the range of natural variation. The solid line indicates the CSI during the baseline period with the mean as the central horizontal line and the upper and lower confidence intervals indicated by the other two lines. Two other CSI time series are shown relative to the baseline indicating an increase in variability in this example and a consequent increase in probability of being outside the natural range of variability. A decline in krill would be expected to cause a decline in the CSI below the lower confidence interval.

PROBABILITY OF DEVIATING FROM THE BASELINE NORMS

4. In the case of an expected decline as a result of decline in krill abundance, the departure can be expected to be below the lower confidence bound. In computer simulations, repeated trials can be used to determine, for a given model scenario, how many trials cause the CSI to fall below a critical value. Figure 3 illustrates the variation in CSI values that may be evident over many trials. The results are presented for 100 trials from a FOOSA scenario. Also indicated is the lower 10th percentile, which could be used as the lower critical value, below which would be considered to be a departure from the baseline norm.

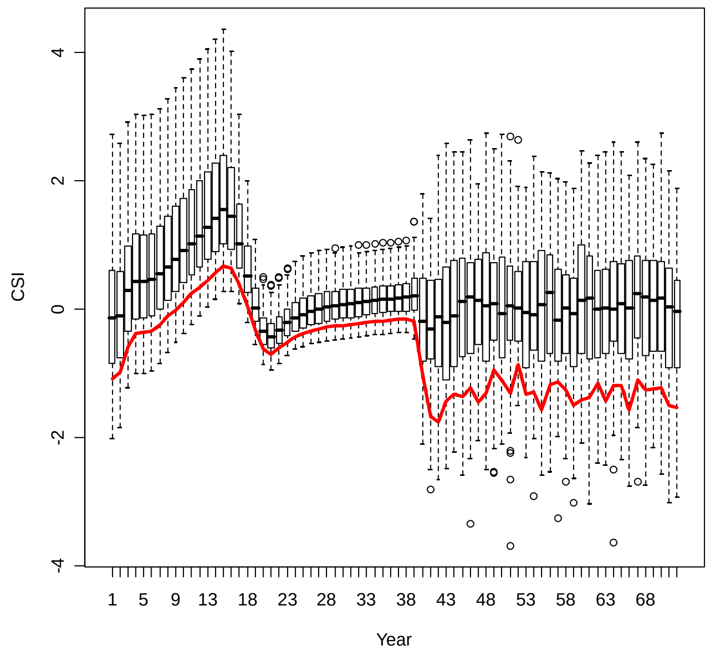

Figure 3: Box plot showing the range of CSIs in each year from 100 trials of a FOOSA scenario. The solid line below the boxes indicates the lower 10th percentile of these distributions.

5. It is expected that the indirect effect of fishing on the predators would be fully evident at the end of the fishing period (after 20 years in the example in Figure 3). Thus, the probability of departure from the baseline norm under a fishing scenario can be determined as the proportion of trials with fishing having a CSI below the critical value (e.g. lower 10th percentile) obtained from the no-fishing trial at the end of the last year of fishing (or some other baseline period).

6. This is determined in the following way:

The distribution of CSI values at the end of the fishing period is determined from the no-fishing trials (Figure 4). The cumulative probability distributions from the no-fishing and fishing trials (Figure 5) can then be used to determine the probability of a fishing trial departing from the baseline norms in the baseline. This is illustrated in Figure 6 for results from FOOSA where the boxplots have been converted to medians and 10th and 90th percentiles for no-fishing and fishing trials.

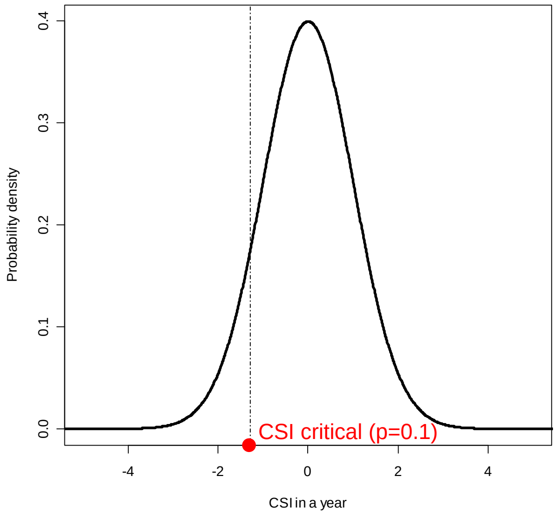

Figure 4: Theoretical distribution of CSI values at the end of a baseline period (the distribution may not always be Gaussian). The vertical line indicates the critical CSI value at the lower 10th percentile.

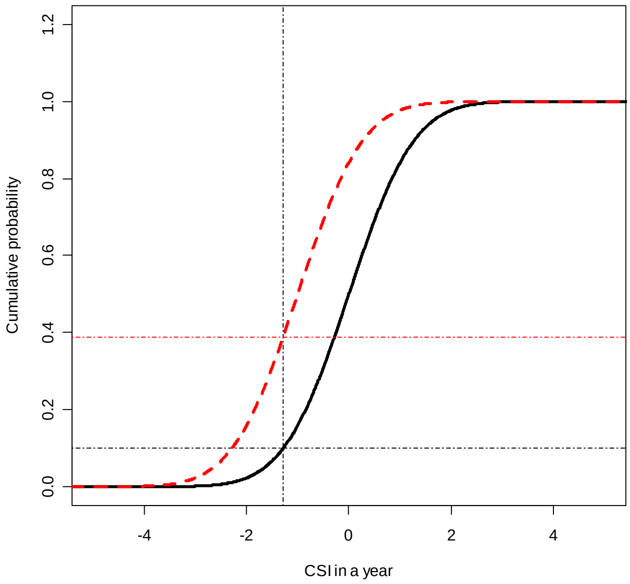

Figure 5: Cumulative probability distributions of CSI values. The baseline distribution is given on the right and a possible fishing scenario on the left. The vertical line indicates the critical CSI value read from the baseline for the lower 10th percentile (bottom horizontal line). The probability of departure from the baseline (natural) norm is shown by the probability of the left line being below the critical CSI, approximately 0.4 in this example.

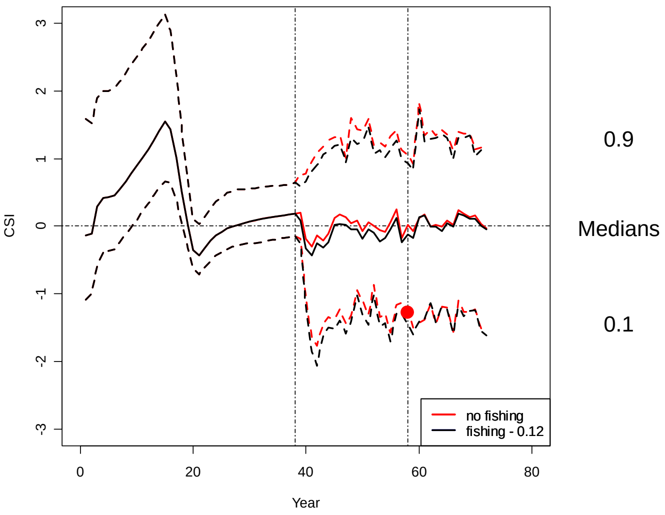

Figure 6: Medians and 10th and 90th percentiles for 100 no-fishing (black) and 100 fishing (grey/red) trials in FOOSA. The horizontal line indicates the mean of the CSI in the no-fishing trials during the fishing period. The vertical lines bound the fishing period. The period to the left of the left-most line is the period during the calendar and the period to the right of the right-most line is the recovery period. (This figure is available in colour on the CCAMLR website.)

ASSESSING RISKS OF DEPARTURE FROM BASELINE NORMS

7. The probability of departure can then be reversed (1 minus that probability) to indicate the performance of the fishing scenario with respect to maintaining the food web within the range of baseline norms. Thus, a no-fishing trial using the lower 10th percentile as the critical CSI will have a performance of 0.9. As the catch of krill increases with increasing yield multipliers, the expectation is that the krill population will decline, causing the predator responses to decline. As such, the probability of the CSI departing from the baseline norms will increase and its consequent performance decrease. This is illustrated in Figure 7.

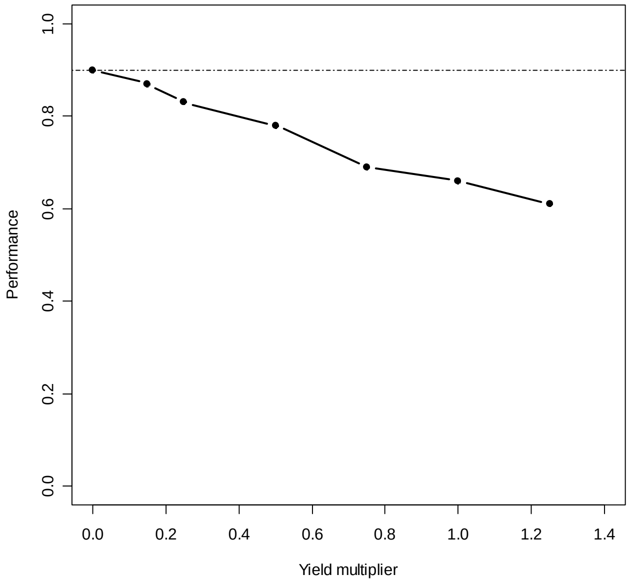

Figure 7: Performance of different yield multipliers applied to a harvest strategy for krill based on a CSI incorporating all predator responses (recruitment) across the SSMUs.

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