ANNEX 4

REPORT OF THE WORKING GROUP ON ECOSYSTEM MONITORING AND MANAGEMENT

(Bergen, Norway, 6 to 17 July 2009)

CONTENTS

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INTRODUCTION

Opening of the meeting

1.1 The fifteenth meeting of WG-EMM was held in Bergen, Norway, from 6 to 17 July 2009. The meeting was convened by Dr G. Watters (USA) and local arrangements were coordinated by Mr S. Iversen (Norway).

1.2 Dr Watters opened the meeting and welcomed the participants (Appendix A). He thanked Mr Iversen, the Institute of Marine Research (IMR) and the Ministry of Foreign Affairs, Norway, for hosting the meeting.

1.3 The Working Group conveyed its best wishes to Prof. C. Moreno (Chile), who had resigned from his position as Chair of the Scientific Committee in March 2009 due to ill health. The Working Group noted that Mr Iversen (senior Vice-Chair of the Scientific Committee) had agreed to take on Prof. Moreno's role, with the assistance of Dr V. Bizikov (second Vice-Chair and Russia) in 2009.

1.4 The Working Group recognised Dr D. Miller's long service within the CCAMLR community and noted that he will be retiring as Executive Secretary in February 2010. The Working Group thanked him for all of his contributions to the Working Group and to CCAMLR over many years.

Adoption of the agenda and organisation of the meeting

1.5 The Working Group reviewed the provisional agenda and agreed to include consideration of by-catch in the review of removals by the commercial fishery and methods of characterising predator and *Dissostichus* spp. fishery overlap (Item 2.5). The Working Group also agreed to remove subitems under Item 4 and develop subheadings as required by the content of papers submitted under that item. The adopted agenda is in Appendix B.

1.6 The agenda included a focus topic (Item 2) entitled 'Second Workshop on Fisheries and Ecosystem Models in the Antarctic' (FEMA2). This focus topic was co-chaired by Drs C. Jones (USA and Convener of WG-FSA) and Watters.

1.7 The Working Group considered discussions from four meetings held during the 2008/09 intersessional period:

- Joint SC-CAMLR–CEP Workshop (SC-CAMLR-XXVIII/6)
- meeting of SG-ASAM (Annex 8)
- meeting of WG-SAM (Annex 6)
- meeting of ad hoc TASO (Annex 9).

1.8 Documents submitted to the meeting are listed in Appendix C.

1.9 The Working Group noted the Secretariat's high translation workload and discussions at CCAMLR-XXVII (CCAMLR-XXVII, paragraph 3.13), and agreed to make every effort to reduce the overall size of its report and subsequent translation. The report captured essential background, discussion and advice, and made full use of CCAMLR's archive of publications and meeting documents.

1.10 The Working Group agreed to follow WG-SAM's initiative and highlight sections of the report dealing with advice to the Scientific Committee and its working groups, and list these paragraphs in both Advice (Item 6) and Future Work (Item 7).

1.11 The report was prepared by Drs D. Agnew (UK), A. Constable (Australia), M. Goebel (USA), S. Grant (UK), S. Hanchet (New Zealand) and S. Hill (UK), Mr J. Hinke (USA), Drs Jones, S. Kawaguchi (Australia), P. Penhale (USA), D. Ramm (Data Manager), K. Reid (Science Officer), C. Reiss (USA), G. Skaret (Norway), C. Southwell (Australia), P. Trathan (UK), W. Trivelpiece (USA), J. Watkins (UK) and Watters.

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

1.12 Dr Watters outlined the feedback from previous meetings of the Commission, Scientific Committee and other working groups which had been used to structure WG-EMM's agenda, and highlighted key requirements for advice on:

- scientific observation of the krill fishery
- SSMUs and management strategies for the krill fishery
- research and data collection plan for the exploratory krill fishery in Subarea 48.6
- B_0 and precautionary yield estimates
- FEMA2
- VMEs
- protected areas
- CCAMLR Performance Review.

SECOND WORKSHOP ON FISHERIES AND ECOSYSTEM MODELS IN THE ANTARCTIC (FEMA2)

Introduction

2.1 The terms of reference for FEMA2 were initially drafted by the Conveners of WG-EMM and WG-FSA, and further developed in consultation with the two working groups. The Scientific Committee reviewed the terms of reference and agreed that FEMA2 be structured in a manner that treats fisheries for toothfish in the Ross Sea (Subareas 88.1 and SSRUs 882A–B) as a case study of how ecosystem considerations can be used to advise on the management of fisheries that target finfish (SC-CAMLR-XXVII, paragraph 3.58). The terms of reference for FEMA2 were to (SC-CAMLR-XXVII, paragraph 3.60):

(i) Review existing information on predator species (Weddell seals, toothed whales etc.) in the Ross Sea known to consume *Dissostichus* spp. This may be aided through a comparative analysis of the importance of *Dissostichus* spp. as prey in different regions throughout the Southern Ocean.

(ii) Consider the current estimates of biomass, distribution and productivity of *Dissostichus* spp. in the Ross Sea, as well as annual removals by the fishery.

(iii) Review rationale for existing escapement level of 0.5 for *Dissostichus* spp., and determine if 0.5 is an appropriately precautionary level of escapement in the Ross Sea, given the predator requirements, foraging ranges, toothfish stock biomass, distribution and productivity.

(iv) Review other methods or options for mitigating risks in the Ross Sea toothfish fishery.

(v) Development of methods to monitor changes in predators in the Ross Sea.

2.2 The Scientific Committee also agreed that it would be useful for FEMA2 to conduct a general discussion about appropriate escapement levels when the age (or size) at which fish recruit to a fishery is contrasted with the age (or size) at which the fish are vulnerable to predation by other predators (SC-CAMLR-XXVII, paragraph 3.61).

2.3 The information and deliberations undertaken in this agenda item refer solely to Ross Sea ecosystem components and the toothfish fishery in Subarea 88.1, unless otherwise stated. The Working Group noted that papers tabled under this agenda item included WG-EMM-09/13 to 09/16, 09/40 to 09/42 and 09/P1 to 09/P4. In reviewing these papers, it was agreed that WG-EMM-09/13, 09/14 and 09/P4 would more appropriately be considered under Item 5. The Conveners of WG-EMM and WG-FSA also brought WG-SAM-09/18 forward for consideration within FEMA2.

2.4 The Working Group noted work in other areas of the Southern Ocean on the food-web interactions of toothfish, including studies at Heard Island and Macquarie Island (He and Furlani, 2001).

Review of information on historical and current biomass, productivity, distribution and ontogenetic movement patterns of *Dissostichus* spp. in the Ross Sea

2.5 WG-EMM-09/40 provided a synthesis of information on the distribution and abundance of Antarctic toothfish (*Dissostichus mawsoni*) from commercial and research fishing in the Ross Sea region. Dr Hanchet presented the findings of the paper together with a brief outline of the hypothetical life history of *D. mawsoni*, including its ontogenetic movements.

2.6 The Working Group noted the synthesis and concluded that:

(i) toothfish generally do not move far in the short term (1–2 years) but that, over time, are likely to disperse across the Ross Sea region;

(ii) the CASAL assessment model provided an estimate of abundance for the entire Ross Sea region and that catch limits for subregions were based on the seabed area and CPUE calculations. Further, that a spatial population modelling approach (such as the SPM) would be needed to derive model-based local abundance estimates;

(iii) there appeared to be high spatial and temporal (both within- and between-year) variability in catch rates from commercial and research fishing on the shelf;

(iv) there had been observations of toothfish in midwater, but that the spatial and temporal extent of this was unknown.

2.7 WG-EMM-09/41 presented a circulation model for the Ross Sea region, which identified two gyres to the north of the Ross Sea itself. The Working Group noted that the circulation model had been used to simulate the drift of toothfish eggs and larvae in the development of the hypothetical life history of *D. mawsoni* (Hanchet et al., 2008).

2.8 WG-SAM-09/18 outlined the development of spatially explicit ASPMs for *D. mawsoni* in the Ross Sea (see also Annex 6, paragraph 4.1). Mr A. Dunn (New Zealand) noted that the SPM program was not toothfish-specific but could be used to model other fish species, and could be further developed to model interactions with one or more predator or prey species as a Minimum Realistic Model (MRM). The Working Group thanked the authors for providing this paper and noted that it would be useful for evaluating alternative scenarios using different spatial assumptions. This was considered further in paragraphs 2.44 to 2.53.

The diet of *Dissostichus* spp. in the Ross Sea

Size and species composition of prey

2.9 The Working Group noted data on the size and species composition of prey in *D. mawsoni* contained in WG-EMM-09/16, 09/40 and 09/42. On the basis of these analyses, toothfish appear to be generalist predators, with diet varying as they grow and change habit and habitat (Table 1). The Working Group recalled that diet analyses of *D. eleginoides* also support this hypothesis (SC-CAMLR-XXI/BG/30).

2.10 The Working Group recalled that stable isotope analyses of *D. mawsoni* (WG-EMM-08/27) support the conclusion that toothfish occupy a high trophic level, with large toothfish caught in the longline fishery in Subarea 88.1 having a trophic level equivalent to that of Weddell seals and killer whales.

2.11 The Working Group noted that there was evidence that *D. mawsoni* changes from negatively to neutrally buoyant as they grow and accumulate lipid stores (Near et al., 2003), and that understanding the relative importance of pelagic versus demersal prey to toothfish would assist with understanding the ecosystem role of toothfish and food webs in the Ross Sea.

2.12 The Working Group noted that mixture analyses to disaggregate stable isotope signals in toothfish tissues may assist in evaluating the relative importance of different prey for different life stages and in different habitats, although uncertainties due to the unknown rates of tissue turnover in toothfish, as well as the assumptions of proposed disaggregation algorithms such as IsoSource[1], need to be considered when ascribing sources of isotopes to specific prey types.

2.13 The Working Group noted that scientific observers in the Ross Sea have been monitoring stomach contents of toothfish in the catch for several years, and that this dataset has the potential to detect changes in toothfish diet through time.

2.14 The Working Group encouraged continued monitoring of stomach contents of toothfish, and recommended that such monitoring should include measures of the size of toothfish analysed, the size of the prey, as well as the species composition.

Distribution and abundance of prey species

2.15 The Working Group noted that the majority of information on the distribution of toothfish demersal fish prey is derived from by-catch in the toothfish fishery in the Ross Sea; however, the recent IPY survey by New Zealand had provided some valuable fishery-independent data on fish distribution and abundance, including biomass estimates of Whitson's rattail (*Macrourus whitsoni*) (SC-CAMLR-XXVII, Annex 5, paragraphs 6.16 to 6.22).

2.16 The Working Group also noted that preliminary analyses had been performed by New Zealand scientists to estimate distribution and abundance of Antarctic silverfish (*Pleuragramma antarcticum*) from the IPY survey in the Ross Sea (SG-ASAM-09/5).

2.17 The Working Group noted that a comparison of rates of toothfish catch and by-catch of toothfish prey species may assist with understanding patterns and detecting changes in the distribution and abundance of prey. However, the quality of by-catch data identification, availability of size distribution data for by-catch (where size as well as presence determines availability of prey), and the effect of by-catch move-on rules would need to be considered in such analyses.

Consumption rates of prey by *Dissostichus* spp.

2.18 The Working Group recalled that comprehensive reviews of the trophic structure of the Ross Sea ecosystem, including toothfish and their key prey taxa, had been considered previously by WG-EMM (WG-EMM-07/18), and noted that a mass-balance model had been successfully constructed based on this review (WG-EMM-09/42).

[1] www.epa.gov/wed/pages/models/stableIsotopes/isotopes.htm

2.19 The Working Group noted that the analyses presented in WG-EMM-09/42 indicate that large toothfish are the dominant large fish predator in the Ross Sea, and may consume a large proportion of the production of medium-sized fish (representing taxa such as macrourids and blue antimora (*Antimora rostrata*)).

Information on *Dissostichus* spp. predator species in the Ross Sea

2.20 The Working Group reviewed the available information contained in WG-EMM-09/15, 09/42 (and associated website) and 09/P1 to 09/P4 that concerned predators of *Dissostichus* spp. in the Ross Sea. The Working Group focused its discussions on Weddell seals (*Leptonychotes weddellii*), killer whales (*Orcinus orca*) and Arnoux's beaked whales (*Berardius arnuxii*). The Working Group also considered a number of more general points.

Current and historical abundance/biomass of predator species

2.21 The Working Group noted that point estimates of killer whale occurrence from Cape Crozier in WG-EMM-09/P1 reflected a small part of their population, range and habitat. Consequently, scaling-up to a regional scale from these sightings was not possible; the Working Group also noted that the negative trend in sightings reported in WG-EMM-09/P1 was not statistically significant.

2.22 Dr Southwell reported that unpublished results from APIS suggest that populations of Weddell seals in the Ross Sea region may be much more abundant than population estimates used in WG-EMM-09/42 and 09/P2. The Working Group encouraged the publication of these results.

Temporal and spatial extent of predator foraging ranges

2.23 The Working Group noted that Weddell Seals regularly forage within localised areas, but that satellite telemetry has also revealed long-distance movements of both adults and weaned juveniles. WG-EMM-09/P2 reported on a telemetry dataset that shows that Weddell seals migrate northwards from McMurdo Sound, apparently preferring coastal areas and shallow shelf areas with submarine banks.

2.24 No data were available to examine the spatial or temporal distribution of killer whales or Arnoux's beaked whales, although both are known to occur in the pack-ice zone which makes determining population size and distribution problematic.

Consumption rates of *Dissostichus* spp. by predators

2.25 The Working Group noted that the most comprehensive consumption rate data available were contained in WG-EMM-09/42.

2.26 The Working Group noted that visual observations of toothfish-eating Weddell seals suggest that seals consume large toothfish without ingesting the head, vertebrae or skin, which means that hard-part remains are under-represented in scat analyses. However, both WG-EMM-09/42 and 09/P2 indicated that stable isotope analyses suggests that *Dissostichus* spp. are not large/frequent components of the diet of Weddell seals. These analyses also suggest that *D. mawsoni* is at a trophic level that is approximately equivalent to Weddell seals.

2.27 WG-EMM-09/42 and 09/P1 both reported on stable isotope analyses indicating that *Dissostichus* spp. are not obligate components of the diet of killer whales; indeed, WG-EMM-09/42 suggested that toothfish may only represent 5.9% of their diet.

2.28 The Working Group agreed that the speculation in WG-EMM-09/15 that Arnoux's beaked whales may consume both toothfish and macrourids was interesting but no conclusion could be drawn from this.

Size composition of *Dissostichus* spp. consumed by predators

2.29 The Working Group noted that size-specific data on *Dissostichus* spp. consumed by marine mammals in the Ross Sea are not available and are likely to be difficult to obtain in the future. The Working Group recommended that any size-specific data on *Dissostichus* spp. consumed by predators, collected by non-lethal sampling methods, be submitted for review by WG-EMM in order to better address the term of reference outlined in SC-CAMLR-XXVII, paragraph 3.61.

Proportion of predator population targeting *Dissostichus* spp.

2.30 The Working Group noted that no data were submitted that would enable the proportion of predator populations that prey on *Dissostichus* spp. to be assessed and recognised that there may be important temporal and spatial variation in the consumption of *Dissostichus* spp.

Development of methods to monitor changes
in *Dissostichus* spp. predators

2.31 The Working Group recalled WG-EMM's discussion in 2008 concerning the monitoring of predator species preying on *Dissostichus* spp. (SC-CAMLR-XXVII, Annex 4, paragraphs 6.28 to 6.36).

General discussion

2.32 WG-EMM-09/42 emphasised that a balanced ecosystem model for the Ross Sea provided no support for the hypothesis that depletion of toothfish stocks would greatly change the diet of toothfish predators. The authors noted that further work would be done on the dynamics of the food web in future.

2.33 The Working Group encouraged Members to contribute to, provide comments on, and review the background documents of, the different compartments of the trophic model described in WG-EMM-09/42 (www.niwa.co.nz).

2.34 The Working Group thanked the authors for all papers considered in this section. It noted that the ecosystem framework that CCAMLR used to manage fisheries required considerable ecological information and insight. It noted that such insights were important to successful management practice, particularly for new and exploratory fisheries and where ecological links were poorly documented. The Working Group also agreed that, where new ecological ideas and links were hypothesised, it was critically important that these hypotheses were evaluated in the context of management questions.

Removals from the fishery and overlap between the fishery and predators

2.35 The Working Group agreed that consideration of overlap between the fishery and predators should take the following into account:

(i) the horizontal distribution of the toothfish population, as well as predators and the fishery;

(ii) the vertical (depth) and spatial distribution of different life-history stages of both toothfish and predators, and the depth distribution of the fishery;

(iii) the size classes of toothfish that are likely to be important to predators.

2.36 Information from WG-EMM-09/40 showed that the fishery has concentrated on the slope, where larger (sub-adult and adult) toothfish are encountered and fishing is primarily in depths greater than 800 m. Fishing over the shelf has taken place in three areas:

(i) The deep gully off Terra Nova Bay, in the west of SSRU M which was fished mostly between 2006 and 2008. This area was closed in 2009. A bimodal distribution of fish was encountered here, with modal lengths of 80 and 125 cm.

(ii) The deep-water area north of Ross Island at the southern boundary of SSRUs M and J, which was fished in 1999, 2007 and 2008. The early fishery encountered fish of modal length 80 cm and the later two years, fish of modal length 110 cm.

(iii) An area to the south of SSRU L, which was fished in 2001, 2004 and 2008, and encountered fish of modal lengths between 100 and 110 cm.

2.37 The hypothetical life history for toothfish (Hanchet et al., 2008) suggests that juvenile fish are distributed on the shelf in nursery, and later in sub-adult feeding grounds, then move to the slope. The spatial distribution of median fish lengths, recorded from the fishery, is largely consistent with this hypothesis.

2.38 Information from predators on the overlap with toothfish is sparse. The mass balance model of Pinkerton (WG-EMM-09/42) suggests that there is sufficient toothfish production to satisfy 6.6% of the diet of Weddell seals and 5.9% of the diet of killer whales. Nevertheless, the possibility that toothfish may be locally important to these predators, and therefore that the overlap between the fishery and predators may be important, was considered by the Working Group.

2.39 Killer whales are regularly observed foraging close to the ice edge, and have been observed eating toothfish (WG-EMM-09/P1), but they have not been observed interacting with vessels fishing either on shelf or slope areas (information from the CCAMLR Scheme of International Scientific Observation). The distributional extent of killer whale overlap with the toothfish population is therefore uncertain, but their overlap with the fishery appears to be negligible. Vertically, killer whales do not forage deeper than about 300 m, and the fishery is limited to waters deeper than 550 m, suggesting again that the overlap between killer whale distribution and the fishery is minimal. However, toothfish are known to occur in midwater and may, in this situation, become available to air-breathing predators such as killer whales.

2.40 Toothfish are eaten by Weddell seals (WG-EMM-09/P2) although they are probably not obligate components of their diet. Some information on the distribution of Weddell seals was available from satellite tracking of individuals at McMurdo Station, which indicated that those adults and weaned juveniles that were tracked, foraged in areas that had negligible overlap with the fishery. Information on the wider distribution of Weddell seals, obtained during the APIS surveys, was not available for analysis by the Working Group.

2.41 Weddell seals can dive deeper than killer whales (up to 750 m, although depths of <350 m are more common – WG-EMM-08/43), and WG-EMM-09/P2 reported photographed encounters with toothfish at up to 363 m in shelf waters of 575 m depth. While there is a possibility for them to vertically overlap with toothfish on the slope, this would depend on toothfish undergoing vertical migrations to shallow waters. Furthermore, the evidence from the fishery is that sub-adult and adult toothfish are primarily demersal in habit and Weddell seals have not been recorded by scientific observers from the area of the main fishery.

2.42 The Working Group concluded that the evidence suggests that the overlap of Weddell seals and killer whales with the fishery is negligible. There is overlap between the distribution of these two predators and elements of the toothfish population which may be impacted by the fishery, but this is limited to shallow areas of the shelf and to the sub-adults of the toothfish population which are taken in small numbers by the fishery.

2.43 The Working Group noted that the information currently available addressed the distribution of predators (and toothfish) only during the summer. Information on toothfish distribution, and the distribution and behaviour of predators in the winter may assist this analysis of potential overlap. Models such as the SPM could be used to help evaluate whether this would be important.

Focus group – Assessment and management approaches
for *Dissostichus* spp. in the Ross Sea

Review historical and current assessment methods

2.44 WG-EMM noted the evolution of approaches to establishing catch limits for *Dissostichus* spp. in the Ross Sea:

(i) Assessment of yield for *Dissostichus* spp. evolved from the method encapsulated in the KYM (WG-Krill-92/4; Butterworth et al., 1994) to that encapsulated in the GYM (Constable and de la Mare, 1996) resulting in estimates of yield for Subarea 48.3 in 1995 (SC-CAMLR-XIV, paragraphs 4.37 to 4.61) and Division 58.5.2 in 1996 (SC-CAMLR-XV, paragraphs 4.100 to 4.110).

(ii) WG-FSA used comparative CPUE and seabed areas along with a discount factor to provide advice on possible catch limits in new and exploratory fisheries for *Dissostichus* spp. in 1998. This practice was discontinued in 2003 when it was deemed unsatisfactory (SC-CAMLR-XXII, paragraphs 4.182 to 4.186).

(iii) Integrated assessments of the status of *Dissostichus* spp. began for the Ross Sea with the introduction of CASAL in 2005 (SC-CAMLR-XXIV, paragraphs 4.150 to 4.166). This method has been used as the basis for assessments of yield since that time (see Fishery Report in SC-CAMLR-XXVII, Annex 5, Appendix I).

Review of rationale for existing escapement level
of 0.5 for *Dissostichus* spp.

2.45 WG-EMM noted the development of the decision rules began in discussions in the CCAMLR Working Group on Developing Approaches to Conservation (1987–1989) and later in SC-CAMLR's WG-Krill and WG-FSA (see Kock, 2000; Constable et al., 2000). The decision rules aim to set catch limits that will achieve operational definitions of Article II despite uncertainties in stock status and the dynamics of the stock and fishery. It was also noted that, where target species are important prey of predators, such as krill, the escapement level of 0.75 is to be used until further information is available to better determine the required escapement level (an example study is Thomson et al., 2000). If a target species is a top predator, and less important as a prey species in its own right, then an escapement level of 0.5 has been used. The 0.5 escapement level of the spawning stock has been regarded in the past as being the escapement level when predator requirements are not taken into account, while no fishing would imply only consideration of predators. However, this needs to be understood in the context of the selectivity functions of the predators of the target species compared to the fishery (see paragraph 2.46).

Approaches to mitigating risks to predator populations
from the Ross Sea toothfish fishery

2.46 WG-EMM noted that the escapement level in the decision rule for the spawning biomass may need to be modified upwards if the size/age classes of *Dissostichus* spp. that are

important prey for predators are reduced below a suitable escapement level for those classes. It noted the work presented in WG-EMM-97/42 investigating the escapement of juvenile *Dissostichus* spp., which may be prey of elephant seals, and found escapement likely to be above 0.8 for those classes when there is an escapement level of 0.5 for the spawning stock.

2.47 The Working Group reviewed the mean results from CASAL projections from the Ross Sea integrated assessment for *Dissostichus* spp. showing the current escapement levels of juvenile toothfish from that assessment in 2007 and projected future escapement (Figure 1). It was also noted that the results for escapement at the end of the projection are dependent on the stock-recruitment relationship in the assessment, which may change in future assessments. The results in Figure 1 demonstrate that the current status of size classes of interest can be routinely monitored as part of the assessment.

2.48 WG-EMM recommended that WG-FSA consider whether other strategies for monitoring important prey size classes might be employed, noting that their efficacy would best be evaluated using simulation models such as SPM.

2.49 WG-EMM noted that an additional part to the decision rule could be developed regarding finding a catch that would achieve a target level of escapement of the size classes of toothfish that are important prey. The current two parts concerned with escapement of the spawning biomass and the avoidance of depletion of the spawning biomass need to be retained for maintaining the productivity of the stock. The last part of the decision rule would then choose the lower of the catches in all of the parts.

2.50 WG-EMM noted that escapement levels designed to maintain 'ecological relationships' may need to accommodate the effects on prey, as well as the effects on predators, particularly if the predators control superior competitors at lower trophic levels.

2.51 WG-EMM encouraged further modelling of the Ross Sea food web, such as that proposed in WG-EMM-09/42, to help evaluate the possible ecosystem effects of fishing in the region.

2.52 WG-EMM noted that the areas over the shelf, where evidence of overlap between toothfish and predators of toothfish occurs, may comprise mostly small fish (paragraph 2.37). With respect to these predators, a large portion of the shelf area is contained in SSRU 881M, or less than 550 m depth, which is currently closed to fishing. It also noted that seasonal closures to fishing would be no different to area closures because of a short time period of fishing due to sea-ice.

2.53 The Working Group encouraged Members to undertake research to determine relevant spatial and temporal overlaps of *D. mawsoni* with different components of the Ross Sea ecosystem, which could include:

(i) development of plausible alternative hypotheses of the life history of *D. mawsoni*, and simulation studies of how these alternatives may impact its spatial distribution and abundance;

(ii) investigation of the functional relationships and associated parameters, including investigation of alternative hypotheses about predator dynamics and movement,

that could be important to develop MRMs of *D. mawsoni* as predators and prey. Further, that simulation studies be carried out using these models to compare food-web effects under alternate exploitation assumptions;

(iii) simulation studies to investigate the relative importance of density-dependent processes on movements of toothfish;

(iv) simulation studies to identify and develop indices that could be used in monitoring population and trophic effects under alternate exploitation assumptions.

ECOSYSTEM EFFECTS OF FISHING FOR KRILL

Krill

3.1 WG-EMM-09/11 indicated that:

(i) the catch efficiency of some Soviet krill trawls operating in the Area 48 fishery was between 10 and 20% (i.e. only 10–20% of the krill that entered the trawls are landed on board the vessel), and that the mortality rate of krill that escape through the net was between 0 and 100%;

(ii) these mortality rates were also related to fishing vessel speed and trawl mouth dimensions, and the Working Group noted that:

(a) the start and end positions, and times, are already recorded on the C1 form (thus average tow speed can be computed from the information available);

(b) trawl net dimensions are now required to be specified in the notifications of intent to participate in the fishery (Conservation Measure 21-03).

3.2 The Working Group also noted existing research that indicated that mortality of escaped krill from some trawls in the Soviet krill fishery did not exceed 1% (Kasatkina and Latogursky, 1990; Kasatkina and Ivanova, 2003; Zimarev et al., 1990). However, studies on German commercial-sized pelagic trawls indicated a mortality rate of krill passing through the net of between 5 and 35% depending on haul duration (WG-EMM-07/28).

3.3 The Working Group noted the FAO discussions concerning the impact on target fish populations of mortality of escaped catch (Surronen, 2005). It agreed that the total mortality of krill arising from escapement through the net would be termed ‘escape mortality’, which is calculated as the amount of krill escaping through the mesh × the proportion of those krill that die.

3.4 The Working Group agreed that there is the potential that the escape mortality could equal or exceed the mortality owing to catch alone, and it was concerned about this potential level of escape mortality given the importance of the total amount of krill killed by fishing operations to any assessment and to catch allocation schemes.

3.5 Given the discrepancy between the estimates of mortality of escaped krill, together with the lack of data on the rates at which krill escape from nets in different fishing gear, the Working Group recommended that there should be a concerted effort to estimate escape mortality in the krill fishery, including through the evaluation of existing results and the continued development of existing models (e.g. WG-Krill-93/34).

3.6 The Working Group agreed that such studies could also include acoustic, video and physical sampling of krill within and outside the net. Specific experiments could include:

- attachment of small-mesh plankton nets at a variety of locations around the trawl net
- video analysis of damage to krill escaping from the net
- acoustic estimate of krill at the head of the net versus the catch in the net to estimate efficiency.

3.7 The Working Group further recommended that the Scientific Committee ask the Members fishing for krill in the 2009/10 season to actively investigate the effects of different fishing gear on 'escape mortality' of krill.

3.8 The Working Group considered two papers (WG-EMM-09/44 Rev. 1 and 09/47) on the potential causes for the variability in the availability of krill to the krill fishery owing to oceanography and climate forcing. Noting that there were multiple potential influences on the operation of the fishery, the Working Group agreed that these analyses could be improved by the use of a standardised CPUE index before correlations are performed.

3.9 The Working Group noted that data on krill length and maturity stage collected in Subarea 48.2 on board the *Maksim Starostin* (WG-EMM-09/29) and *Saga Sea* (WG-EMM-09/10) indicated that the size and stage composition did not differ between conventional and continuous trawls on the same vessel, but that there were differences in length and maturity stage between vessels. The differences potentially arose from differences in net selectivity and the use of fresh versus preserved samples. There were also differences in sampling size. The Working Group thanked the authors of these reports and looked forward to receiving further information on the integration of these results with the under-way acoustic data collected by fishing vessels.

Krill-dependent predators

Strong anomaly at South Georgia in 2009

3.10 The Working Group acknowledged that three papers (WG-EMM-09/23, 09/27 and 09/28) described a strong anomaly at South Georgia in 2009 that was manifest in the lowest krill density on record, very low land-based predator performance, changes in the diet of icefish and anomalous values for a range of physical parameters including sea-surface temperature.

3.11 The Working Group thanked the authors for providing these results to the meeting in such a timely manner and noted the potential of using rapid assessments such as this in a feedback monitoring context (see additional considerations of feedback management under Item 3.6).

New CEMP monitoring sites

3.12 The Working Group welcomed the establishment of a new CEMP monitoring site by the UK at Cumberland Bay, South Georgia (WG-EMM-09/28) and plans for a new site at Petermann Island on the Antarctic Peninsula through collaboration between Ukraine and Russia (described to the Working Group by Dr G. Milinevsky (Ukraine)), noting that these new sites would provide monitoring data from within SSMUs for which there is currently no CEMP data.

Tourist impacts

3.13 WG-EMM-09/P7 described a 12-year study of the impacts of tourism on gentoo penguins (*Pygoscelis papua*) at Goudier Island on the Antarctic Peninsula. Data from this study, and that reported by Dr Southwell from studies at Béchervaise Island, suggest that the recruitment may be lower at colonies that are frequently visited by scientists and/or tourists.

3.14 The Working Group agreed that colony counts and breeding success data from Goudier Island control colonies that were collected in a manner consistent with the CEMP standard methods, would be a welcome addition to CEMP. It urged the UK to submit these data to the Secretariat for inclusion in CEMP, noting that this would extend the spatial coverage of CEMP.

3.15 The Working Group noted the CEP proposal to examine the environmental impacts of tourism and non-governmental activities in Antarctica (ACTM XXXII) and recognised the potentially similar requirements for monitoring the impacts of fisheries and tourism. It was agreed that both CEP and CEMP would benefit from coordination between the two groups in the future (see Item 5.3 for additional discussion).

Trends in predator populations; environmental and ecological variability

3.16 The Working Group discussed two papers that examined population dynamics of penguins in the Scotia Sea (WG-EMM-09/17 and 09/43) and from three sites around Antarctica (WG-EMM-09/34).

3.17 From the discussion of these papers, the Working Group noted that:

(i) the populations of both Adélie penguins (*P. adeliae*) and chinstrap penguins (*P. antarctica*) were declining at a range of sites in the Antarctic Peninsula and Scotia Sea region and that there was convincing evidence to suggest that the paradigm of reciprocal changes in the population of these two species in this region (e.g. McClintock et al., 2008) was no longer valid;

(ii) the variability in the breeding success in Adélie penguins at the South Shetland Islands was primarily driven by failure during the incubation stage that was linked to winter sea-ice and spring weather conditions, although there was no long-term trend in breeding success;

(iii) in contrast to the Antarctic Peninsula, variability in breeding success of Adélie penguins in East Antarctica was primarily driven by the extent of fast-ice during the chick-rearing period;

(iv) there were differences in the population trajectories and demographic parameters (e.g. age-at-first breeding) between Adélie penguin populations in the Ross Sea and the Antarctic Peninsula.

3.18 The Working Group recognised that this suite of papers (and WG-EMM-09/P9) highlighted an increased understanding of the factors affecting penguin population dynamics across the Antarctic and helped to better understand how they are responding to changes in the ecosystem.

3.19 Dr Southwell (Convener, WG-EMM-STAPP) outlined continued progress in estimating krill consumption in Area 48 by air-breathing predators (pack-ice seals, fur seals, penguins and flying seabirds) initiated by the Predator Survey Workshop (WG-EMM-08/8), and indicated anticipated intersessional progress up to WG-EMM-10 (WG-EMM-09/39 and Table 2). The Working Group noted that:

(i) the newly completed estimate of krill consumption by crabeater seals (*Lobodon carcinophagus*) (WG-EMM-09/21) for all SSMUs combined is likely to be robust, but estimates for individual SSMUs are dependent on habitat conditions (pack-ice extent), which can change substantially between and within years;

(ii) aerial surveys of fur seals in Subarea 48.3 were completed in 2008/09 and analysis of the data has commenced. It is expected that analyses of abundance, at-sea distribution, diet and energetics data will be well advanced by WG-EMM-10;

(iii) collation of penguin count data into an agreed standard database structure (Appendix to WG-EMM-09/39) is well advanced, an estimation method using a parametric bootstrap model written in R (ICESCAPE, WG-EMM-09/20) has been developed, Members were requested to provide data to WG-EMM-STAPP for adjusting raw penguin count data, and work on abundance estimation will commence prior to WG-EMM-10;

(iv) the collation of at-sea data for flying seabirds to examine the extent and utility of using these data to estimate population size will continue over the intersessional period.

3.20 The Working Group acknowledged the substantial progress made by WG-EMM-STAPP in advancing estimation of krill consumption by predators in Area 48, and endorsed the work program proposed for the coming intersessional period as a matter of priority. In addition, the Working Group requested WG-EMM-STAPP to investigate ways of addressing potential biases in penguin abundance estimates arising from breeding sites with very old count data, and to consider estimation of prey consumption by fish predators.

3.21 Dr Goebel (Convener, Subgroup on Methods) reported on the continued refinement, validation and quality testing of CEMP data. This included a review of the application and reporting of the standard methods for A2 (penguin incubation shift duration), A3 (penguin

breeding population size), A6c (penguin breeding success, chicks fledged per chicks hatched), and a simplified presentation for A8 (penguin chick diet) to a single dietary index based on an index of importance.

3.22 The Working Group noted that no new CEMP methods were proposed and thanked the subgroup and the Secretariat for its ongoing work on CEMP data validation. It noted that the photographic method used in WG-EMM-09/38 in penguin breeding population estimates could be incorporated as a modification to CEMP Standard Method A3 (penguin breeding population size) for some penguin species. Dr Southwell offered to further review the utility of this system with a view to developing a modification to A3 for WG-EMM-10.

The krill fishery and scientific observation of the fishery

Fishing activity

Current season

3.23 Five Members (six vessels) fished for krill in Area 48 in 2008/09, and have taken 82 849 tonnes of krill to date (Norway 33 482 tonnes, Republic of Korea 23 522 tonnes, Japan 13 515 tonnes, Russia 9 654 tonnes and Poland 2 676 tonnes). Most of this catch was taken in Subarea 48.2 (51 316 tonnes) with the remainder in Subarea 48.1 (31 533 tonnes). The forecast total catch of krill for the current season falls in the range 109 000–147 000 tonnes (WG-EMM-09/6).

3.24 The Working Group noted that if the situation of low krill abundance in Subarea 48.3 remains as described in paragraphs 3.10 and 3.11, and the fishery is unable to increase its catches in Subareas 48.1 and 48.2, the forecast catch could be an overestimate if the fishery follows the same spatio–temporal pattern as in previous years.

2007/08 season

3.25 Norway reported the largest catches of krill in 2007/08 with a total catch of 63 293 tonnes. Japan and the Republic of Korea also reported large catches (38 803 tonnes and 38 033 tonnes respectively). Ukraine, Poland and Russia reported catches of 8 133, 8 035 and 222 tonnes respectively (WG-EMM-09/6).

3.26 In 2007/08 all of the total krill catch of 156 521 tonnes was taken from Area 48; this compares with the total catch of 125 063 tonnes reported to the Scientific Committee last year (SC-CAMLR-XXVII, paragraph 4.3). The Working Group noted that this discrepancy arose because the Secretariat did not receive monthly catch and effort data for four months, totalling a krill catch of 19 262 tonnes, due to an email failure (WG-EMM-09/6). This problem arose in part because the Secretariat was unaware that the vessel in question was actually fishing and was therefore not expecting to receive monthly catch and effort data.

3.27 The Working Group expressed its concern over this problem since it may have influenced the interpretation of the catch data in the Scientific Committee and Commission meetings, as the catch last year was the highest since the 1991/92 season.

Notifications for 2009/10

3.28 Seven Members (13 vessels) have notified their intention to fish for krill in 2009/10 in Subareas 48.1, 48.2, 48.3 and 48.4, and Divisions 58.4.1 and 58.4.2 (Table 3). The People's Republic of China has notified, for the first time, its intent to harvest a total of 9 000 tonnes of krill with three vessels (WG-EMM-09/7). In addition, Norway has notified for an exploratory fishery for krill in Subarea 48.6 (CCAMLR-XXVIII/14) (paragraphs 3.33 to 3.36). The total notified catch for 2009/10 is 363 000 tonnes compared to a notified catch of 629 000 tonnes for 2008/09 (Figure 2).

3.29 The Secretariat received an additional notification for a krill fishery in 2009/10 from Chile after the deadline in Conservation Measure 21-03; the Working Group did not consider this notification.

3.30 The notifications in respect to the three Chinese vessels did not include information on the use of marine mammal exclusion devices. The Working Group was informed that China will provide amended notifications to include all the necessary information to the Scientific Committee for its consideration.

3.31 In their notifications, Japan and the Republic of Korea indicated the use of streamer lines on their vessels. Japan clarified that streamer lines are used when conducting other fishing operations outside the Convention Area where streamer line use is required; streamer lines are not used in the Convention Area when fishing for krill. The Republic of Korea informed the Working Group of its occasional use of streamer lines within the Convention Area while fishing for krill. The Working Group also noted that Japan and the Republic of Korea had not presented diagrams of their seal exclusion devices. It requested both Members to provide those diagrams to the Scientific Committee for its consideration.

3.32 The Working Group noted that some notifications were prepared in official CCAMLR languages other than English, and therefore were not able to be assessed fully at the Working Group meeting. The Working Group recommended that notifications in official languages other than English may need to be translated in order to be assessed at its meeting. This may require an earlier notification deadline in order for translations to be completed in time for review at the meeting.

Exploratory krill fisheries

3.33 The Working Group noted that, although Norway had proposed the use of a new marine mammal exclusion device in its notification for an exploratory krill fishery, the operator had notified the Secretariat that this device will be replaced with a mesh-type device similar to the design used by other continuous trawlers operating in the Convention Area.

3.34 The Working Group agreed the need for acoustic instruments on vessels undertaking exploratory krill fisheries to be calibrated within a year prior to their operation to enable the data to be used at least as a relative index of krill density. Calibration data would need to be reported with data from research transects.

3.35 The Working Group agreed that the design of the research program to accompany exploratory krill fisheries should be kept under review, particularly in relation to how the

results can be used in assessments of precautionary yield for these fisheries. It was noted that continual review and development had been required in the exploratory longline fisheries. It was suggested that WG-SAM be asked to review how acoustic data might be used as relative indices of abundance in these fisheries.

3.36 The Working Group thanked Norway for its commitment to develop and refine the exploratory krill fishery survey plan.

Data collection plans for exploratory krill fisheries

3.37 Norway notified the meeting that it is not conducting an exploratory krill fishery in Subarea 48.6 in the 2008/09 season, but that it did intend to do so in 2009/10 (CCAMLR-XXVIII/14). In considering the plan by Norway to conduct this exploratory fishery, the Working Group noted that this request is to undertake an acoustic survey for krill prior to fishing rather than as specified in Conservation Measure 51-04 for it to be done after fishing.

3.38 WG-EMM recognised that this was a reasonable request and recommended amendments to Conservation Measure 51-04 to account for this change to the research plan.

3.39 The Working Group currently requests that notifications identify the research plan that the vessel will undertake in order that the Working Group can evaluate the notification. The Working Group recommended that the notification should also include the details of any research institute that the fishing company is collaborating with, including who will provide results of the research, and advice on how these results will be used to meet Conservation Measure 51-04.

3.40 The Working Group advised that the following amendments should be made to Conservation Measure 51-04:

(i) The vessel could carry out the research plan either before or after the commercial fishery.

(ii) If the vessel is collaborating with a research institute to conduct the research plan, it should identify the collaborating institute.

(iii) If the survey is undertaken after the commercial fishery, it should follow the current guidelines within Conservation Measure 51-04, where the measure defines the number of exploratory units to be visited as the catch divided by 2 000 tonnes. If the survey is conducted prior to the commercial fishery, then the fishing vessel must:

(a) undertake a research plan for the exploratory units based on the area where it intends to fish;

(b) complete additional surveys to fulfil the number of exploratory units required if the number of exploratory units completed at the end of fishing is less than the catch divided by 2 000 tonnes;

(c) carry out its fishery and survey in a manner in which the research exploratory units surround and include the units where the fishery is carried out.

(iv) The echo sounder (minimum frequency 38 kHz, minimum observing depth range 200 m) should preferably be calibrated in the actual fishing grounds, however, this is often impossible due to logistical problems of identifying suitable locations for this. Therefore, as a minimum, the echo sounder should be calibrated prior to the vessel leaving the harbour. Calibration data would need to be reported with data from research transects.

(v) If a vessel is unable to calibrate its echo sounder within the fishing grounds:

(a) acoustic survey grids comparable/identical with the first survey (assuming it covers the fishing area) should be conducted on subsequent visits;

(b) vessels undertaking continuous trawling should attempt to match some acoustic observations with the respective trawl catches since they have the possibility to trawl acoustic layers more or less immediately after they have been recorded.

3.41 WG-EMM recommended that relevant expert groups consider appropriate methods for data collection and reporting for each of the research plans identified by Conservation Measure 52-04 as they are selected within exploratory fishery notifications.

Data reporting

Fine-scale data

3.42 All Members that fished for krill have submitted complete sets of fine-scale haul-by-haul data for 2007/08 (WG-EMM-09/6).

3.43 With regard to fine-scale haul-by-haul data reporting by vessels using the continuous trawling method, the Working Group noted the improvements made in the last 12 months. Reporting now occurs independently for every two-hour interval compared to previous reports based on daily totals being allocated equally across the two-hour intervals fished.

Historical data

3.44 The Working Group noted that a research project to digitise former Soviet krill fishing research, as well as exploratory and commercial expedition data, has been started by Ukraine (WG-EMM-09/30) and looked forward to seeing the results, noting that Russia may have additional data from the same period.

Technical Group for At-Sea Operations

3.45 The Working Group noted the following advice to WG-EMM in the ad hoc TASO-09 report (Annex 9):

(i) Krill trawling methods (Annex 9, paragraphs 2.1 to 2.8) –

Details of vessel gear types should be catalogued to provide a reference for the *Scientific Observers Manual*, and the general terms in use for all trawl types operating in the Antarctic krill fishery as summarised in Annex 1 of TASO-09/5 should be put on the CCAMLR website.

(ii) Methods of estimating green-weight removals in krill trawl fisheries (Annex 9, paragraphs 3.1 to 3.7) –

Further assessment is needed of the implications of using variable and fixed conversion factors, noting the need for the implementation of an accurate, repeatable volume-to-mass conversion for krill where volumetric measures are used.

(iii) Revision of the *Scientific Observers Manual* (Annex 9, paragraphs 3.14 to 3.21) –

Agreement on a new method to quantify finfish by-catch (both larvae and finfish), which would involve the collection of one 50 kg random sample of krill catch for analysis, as well as requesting the crew to retain all the remaining large fish from the haul.

Members are requested to review the proposed changes in the *Scientific Observers Manual* (TASO-09/4) and provide feedback to the Secretariat prior to the meeting of WG-FSA-09.

(iv) Observer recruitment and training (Annex 9, paragraph 4.5) –

Training of observers should include the areas outlined in the TASO-09 report, paragraph 4.5.

Scientific observation

Observer deployment

3.46 Eight scientific observer logbooks were submitted to the Secretariat for the 2007/08 season, and six notifications of the placement of CCAMLR international scientific observers on krill fishing vessels in Area 48 for the 2008/09 season have been received.

By-catch

3.47 There were no reported incidents of seabird mortality, but four Antarctic fur seals were reported to have been killed by krill trawler operations in Subarea 48.3. It was noted that all vessels have reported use of seal exclusion devices.

3.48 The Working Group advised the Scientific Committee and WG-IMAF that although fur seals are now rarely killed in the krill fishery in Subarea 48.3, seal exclusion devices may not all be 100% effective for avoiding by-catch of these animals.

Conversion factors

3.49 The Working Group drew attention to the discussion related to a volume-to-mass conversion factor (catch volume including seawater-to-mass of krill) which has for the first time been identified as a potential problem in estimating catch. Conversion factors discussed in previous meetings were limited to product-to-mass conversion. The UK agreed to implement a trial procedure involving the collection of volume-to-mass data for krill samples from the krill fishery and to report the results to TASO and WG-EMM next year (Annex 9, paragraph 3.6).

Observer coverage in the krill fishery

3.50 WG-EMM-09/18, 09/25 and TASO-09/7 were presented to facilitate discussion over appropriate observer coverage to address the CCAMLR objectives. The Working Group noted that all three documents identified the importance of having a high level of coverage by scientific observers in order to design an observer program for the long term.

3.51 The Working Group noted the intention of Japan to voluntarily deploy Japanese government-appointed observers in areas other than Subarea 48.3. The Working Group also noted that observer coverage on Japanese fishing operations has mainly been in Subarea 48.2 in 2008/09.

3.52 The Working Group further noted that Japan is not currently submitting observer data collected by their government-appointed observers.

3.53 The Working Group requested the Secretariat to determine whether it would be possible to develop a suitable mechanism to have the data submitted for use when needed in work of the Scientific Committee, in a manner consistent with any sensitivities surrounding those data.

3.54 The Working Group agreed that systematic coverage will generate a rich dataset and allow for detailed examination of future observation strategies.

3.55 The Working Group agreed that, to address one of the objectives agreed by the Scientific Committee in 2007, i.e. to understand the overall behaviour and impact of the fishery, it is first necessary for all krill fishing vessels participating in the krill fishery to have systematic deployment of scientific observers to be able to collect the relevant data. The

results reported in WG-EMM-09/25 suggest that in Subarea 48.3 about four years of systematic partial observer coverage was required before the characteristics of the observer data were sufficiently well understood to develop an efficient sampling program. It was noted that a partial coverage program, such as that being used in Subarea 48.3, requires a high level of coordination that would be complex to implement in Subareas 48.1 and 48.2. Consideration would need to be given to how partial coverage could deliver the required information in Subareas 48.1 and 48.2.

3.56 WG-EMM noted that the purpose of designing an observer program for the krill fishery is to determine an efficient observer program that can provide reliable data to accurately estimate the total mortality (in biomass) of krill and by-catch species (e.g. larval fish, seals and birds) in the krill fishery, as well as the krill length composition in different areas, e.g. SSMUs and seasons. It is expected that the length composition of the krill catch will be used in integrated assessments of krill (SC-CAMLR-XXVI, Annex 4, paragraphs 2.52 to 2.54), the by-catch of larval fish be used in assessments of finfish, and the by-catch of birds and seals be considered in advice by WG-IMAF.

3.57 WG-EMM-09/25 showed how the precision of estimated parameters (i.e. the CV of mean krill length and larval fish catch) would vary as functions of the proportion of vessels that were sampled and the proportion of hauls within vessels that were sampled. Increasing proportions of sampling will increase precision, although the relative improvement in precision declines at high levels of sampling. The Working Group welcomed this analysis.

3.58 The Working Group recommended that WG-SAM consider this issue further with the aim of providing advice on how the accuracy and precision of these quantities influence assessment outputs, and hence the extent to which different levels of observer coverage will improve assessments. Following the format in WG-EMM-09/25 and noting possible additional sources of variation (e.g. variation between subareas), the Working Group encouraged Members to investigate the observer deployment strategies that would deliver data at appropriate spatial and temporal scales. It was noted that observer data need to be stratified in space and time in a way appropriate to the ecology of krill (spatial and depth segregation and/or patchiness of life stages and the chronology of its life history) and the management strategy.

3.59 The Working Group noted that estimates of levels of total krill removal, by-catch and krill length composition from these data will need to be robust to other potential sources of variation, including:

(i) between-haul variation (noting that catch of the haul may need to be a covariate);

(ii) gear deployment (including method, e.g. conventional trawl versus continuous, mesh size, configuration and deployment strategy, such as speed and targeting, e.g. product type);

(iii) vessels;

(iv) other factors, e.g. depth of hauls.

3.60 The Working Group recommended that WG-SAM be asked to advise on:

(i) an appropriate estimation structure of an integrated krill assessment that might utilise observer-derived data on krill length, which could be used to evaluate the efficacy of the observer program;

(ii) how the accuracy and precision of quantities estimated in the observer program influence assessment outputs, and hence the extent to which different levels of observer coverage will improve assessments, taking note of the considerations in paragraphs 3.58 and 3.59;

(iii) a provisional observer program that could be used in the interim and to help design the observer program in the longer term.

3.61 WG-EMM agreed that this issue is a high priority and recommended that a provisional program for observer coverage be adopted next year, following consideration at WG-SAM and WG-EMM.

Fishery dynamics

3.62 The Working Group noted the efforts to characterise fishery dynamics in WG-EMM-09/18, 09/P5 and 09/P10.

3.63 The Working Group noted the usefulness of fine-scale haul-by-haul data as a data source to derive movement patterns of krill fishing fleets, i.e. Levy-type random walk (WG-EMM-09/18), and updates of some parameters used in the krill fishery model developed in the late 1980s (WG-EMM-09/P5).

3.64 The Working Group noted that these analyses may help develop fishery models to allow simulation of various fishing patterns for operating models to evaluate the effects of alternative management strategies on the performance and operation of the krill fishery.

Regulatory issues

3.65 The Working Group reviewed conservation measures that apply to krill fisheries, and agreed to advise the Scientific Committee on Conservation Measures 10-04, 21-03 and 51-04.

3.66 With regard to Conservation Measure 10-04, in all CCAMLR fisheries other than the krill fishery, Flag States are required to notify the Secretariat of 'each entry to, exit from and movement between subareas and divisions of the Convention Area by each of its fishing vessels' (Conservation Measure 10-04, paragraph 13). However, this requirement currently does not apply to krill fisheries (Conservation Measure 10-04, footnote 4) and this was part of the reason why the Secretariat was not aware of a significant amount of catch being made during the 2007/08 fishing season until receiving fine-scale data after the end of the fishing season.

3.67 The Working Group advised the Scientific Committee that problems with catch reporting, however they may arise, may be resolved if the krill fishery was not excluded from the requirements of paragraph 13 of Conservation Measure 10-04.

3.68 With regard to Conservation Measure 21-03, the Working Group agreed the need to clarify footnote 1 with respect to the deadline of 1 June for the submission of notifications for exploratory fisheries for krill made under Conservation Measure 21-02.

3.69 The Working Group noted that, while Conservation Measure 23-04 does not apply to the krill fishery, there were the following advantages of aligning the deadline for the submission of fine-scale catch and effort data from krill fisheries with the deadline applicable in other fisheries:

(i) WG-EMM will be provided with improved availability of fine-scale information, including timely access to fine-scale data during preparation for the annual krill fishery report;

(ii) it would facilitate improved data validation by enabling more timely and frequent communication between the Secretariat and data providers, and timely cross-checking with monthly catch and effort reports;

(iii) it would improve the scheduling of data processing and validation in the Secretariat by alleviating the large amount of fine-scale data received by the Secretariat in late March each year.

3.70 The Working Group recommended that Members submit fine-scale data at reporting intervals such as employed in other fisheries.

3.71 With regard to Conservation Measure 51-04, the Working Group noted that there would be advantages if fishing vessels were to conduct research operations prior to commercial operations since:

(i) it will provide information of krill distribution prior to any disturbance by fishing;

(ii) vessels are likely to conduct research in the area of interest prior to commercial operation in order to find suitable fishing locations;

(iii) there would be a greater likelihood that research operations be completed.

3.72 The Working Group recommended revision of the research plan (Conservation Measure 51-04, Annex 51-04/B) to include an option to allow conduct of a research survey prior to commercial operations and other considerations listed in paragraph 3.40.

Krill surveys and monitoring

Acoustic estimates of krill biomass

3.73 The report from the recent meeting of SG-ASAM (Annex 8) was considered with respect to the determination of the levels of uncertainty in acoustic estimates, the definition of an agreed protocol for the acoustic estimation of krill biomass and the use of ancillary surveys in assessing krill biomass.

3.74 The Working Group noted that present published estimates of B_0 only include uncertainty attributed to sampling design, i.e. variation between transects (Annex 8, paragraph 31).

3.75 The Working Group agreed (Annex 8, paragraphs 30 to 32) that in the future, other elements of uncertainty in the B_0 estimate should be included, particularly with regard to uncertainty due to target strength estimation and target identification. It was recommended that, in addition to an estimate of total uncertainty associated with B_0, this estimate should be subdivided into uncertainty associated with survey design and sampling, and uncertainty associated with other processes in the assessment procedure, such as krill availability to the survey.

3.76 The Working Group recommended that the Scientific Committee consider a joint meeting between SG-ASAM and WG-SAM to combine appropriate expertise to evaluate broader aspects of uncertainty in the acoustic estimate of krill biomass.

3.77 The Working Group noted that some of the coefficients used in the simplified SDWBA had been omitted when the analysis to estimate the precautionary catch limit for Area 48 was undertaken in 2007 (Annex 8, paragraph 51), and that correct coefficients had been provided by SG-ASAM (Annex 8, Table 3).

3.78 The Working Group agreed that B_0 should be recalculated using the coefficients given in the SG-ASAM report.

3.79 The Working Group further noted that, given the complexity of the steps to calculate B_0, the outline protocol given in Appendix 3 of Annex 8, which is to be completed by the Secretariat, would be a valuable step in provision of a detailed protocol for the analysis of the CCAMLR-2000 and other acoustic data. Such a protocol should exhibit sufficient detail so that Member countries are themselves able to implement the protocol in their own post-processing systems.

3.80 The Working Group agreed that the ideal next step to recalculate B_0 would be for Members to undertake, independently, reanalyses of the CCAMLR-2000 data utilising the protocols outlined in Appendix 3 of Annex 8. Such an approach would provide a method of validating individual calculations of B_0 and such validation is recommended.

3.81 The Working Group noted that, at the current time, the only Member with the complete set of code to reprocess the CCAMLR-2000 dataset is the USA. Other Members were utilising the simplified SDWBA model to analyse their own datasets but would have to invest a substantial amount of time and effort to undertake a complete analysis of the CCAMLR-2000 dataset.

3.82 The Working Group agreed that simply distributing and utilising existing Matlab computer code held by the USA would not constitute a full independent recalculation and would not achieve the aim of having independent validation of an individual calculation of B_0.

3.83 The Working Group therefore agreed that it would not be possible to have a fully validated reanalysis of the CCAMLR-2000 dataset in time for the 2009 meeting of the Scientific Committee. Nevertheless, any Member that may be able to provide an updated biomass estimate was encouraged to do so.

3.84 The Working Group considered whether other krill acoustic datasets would provide insight into the likely result of a reanalysis of CCAMLR-2000 B_0. The US AMLR time series in the South Shetland and Elephant Island regions, and the BAS time series in the South Georgia region, have been analysed using the simplified SDWBA with the most up-to-date SDWBA model parameter values and the three-frequency krill identification protocol. The Working Group noted that these analyses generated biomass values comparable in magnitude to the earlier analyses based on the Greene et al. (1991) TS model, and the CV was generally higher when using the simplified SDWBA.

3.85 The Working Group considered that, on the basis of US AMLR and BAS results, a recalculation of B_0 (see paragraph 3.90) was unlikely to be higher than the biomass estimate presently in use (SC-CAMLR-XXVI, paragraph 3.21).

3.86 On this basis, the Working Group recommended that the current Conservation Measures 51-01, 51-02 and 51-03 are adequate interim conservation measures until the fully validated reanalysis is performed.

3.87 The Working Group agreed that, in the future, if implementation errors to an agreed protocol were discovered, then these should be corrected as soon as possible and WG-EMM and the Scientific Committee notified.

3.88 The Working Group endorsed the recommendation of SG-ASAM (Annex 8, paragraph 50) that the Secretariat work with Members to develop detailed acoustic protocols and make them available on the CCAMLR website, this would include any computer code developed to implement the protocol. Such computer code should be submitted to the Secretariat as soon as possible.

3.89 The Working Group recognised that, at present, a single estimate of absolute acoustic biomass for a CCAMLR area or division is utilised in the estimation of a precautionary catch limit. It was agreed that, in the future, it may be appropriate to consider how both large-scale and regional acoustic survey time series, might be combined to form an integrated assessment of krill biomass. The Working Group suggested that a joint meeting of SG-ASAM and WG-SAM may be an appropriate forum to consider such integrated analyses.

3.90 The Working Group recommended the following work plan for SG-ASAM prior to, and during, its next meeting:

(i) Review documentation of the acoustic protocol to be prepared by the Secretariat (Annex 8, Appendix 3).

(ii) Undertake a reanalysis of CCAMLR-2000 data:

(a) confirm steps of analysis by correspondence prior to the next meeting;

(b) independent calculations of B_0 undertaken by Members during the intersessional period prior to the next SG-ASAM meeting, with correspondence between Members as appropriate to clarify pertinent issues;

(c) submit documented results to SG-ASAM for review;

(d) discuss results and add clarification to protocols if necessary;

(e) agree validated B_0 estimate and submit to the 2010 meeting of WG-EMM.

3.91 The Working Group advised that the work plan specified in paragraph 3.90 should be considered a high priority and that the plan would require SG-ASAM to meet in 2010.

Other krill surveys

3.92 WG-EMM-09/45 presented a krill density estimate from Subarea 48.6 from the Norwegian 2008 AKES survey. The Working Group noted that parts of the method used for estimation of biomass differed from the present CCAMLR protocol. The Working Group further noted that SG-ASAM recommended that any departures from the CCAMLR acoustic protocol and associated uncertainties and influences on results should be documented. The Working Group agreed that this was an important analysis and looked forward to a more detailed presentation of results and associated levels of uncertainty at SG-ASAM with follow-up reporting to WG-EMM.

3.93 The analysis presented in WG-EMM-09/45 is a first step in generating a combined B_0 estimate for Subarea 48.6 using acoustic data collected during the AKES survey and the German LAKRIS survey. The proposed production and submission of such a combined estimate was welcomed by the Working Group, particularly given that this subarea is likely to be the focus of an exploratory krill fishery. The Working Group noted the large size of this subarea and that any estimate would need to take account of the appropriate area of coverage and degree of stratification. The Working Group encouraged that details of a proposed stratification for these survey data be presented to WG-SAM.

Acoustic results from IPY surveys in 2008

3.94 New Zealand carried out an IPY survey to the Ross Sea in 2008. Acoustics results from the survey were discussed at SG-ASAM. The main target species of the survey was silverfish, but preliminary biomass estimates for krill and ice krill were presented to SG-ASAM. The krill biomass estimates were not calculated according to the standard CCAMLR protocol and New Zealand agreed to recalculate them using the CCAMLR protocol. The Working Group looked forward to receiving the recalculated estimates.

Climate change

3.95 The Working Group noted summaries of the proceedings of the first Southern Ocean Sentinel (SOS) Workshop (WG-EMM-09/37) and the joint SC-CAMLR–CEP workshop (SC-CAMLR-XXVIII/6), both held in 2009. Both reports indicate broad international consensus that:

(i) climate change impacts in the Antarctic are of major concern
(ii) qualitative assessments of the effects of climate change are possible now
(iii) management decisions will need to consider how climate change will affect Southern Ocean ecosystems.

3.96 The SOS program is intended to be a long-term monitoring program that can be complementary to CEMP and is a project within the ICED program.

3.97 The Working Group noted that the full report of the SOS Workshop will be provided to the Scientific Committee in 2009, along with qualitative assessments of the current understanding of climate impacts on the Southern Ocean. Dr Constable noted that identifying monitoring objectives was a topic for the next meeting of the SOS program and encouraged Members to participate to ensure the alignment of CEMP and SOS monitoring work. The Working Group encouraged Members to become involved in the development of the SOS program and in the ICED program overall.

3.98 WG-EMM-09/24 reported on how current management in the Antarctic might be impacted by climate change and provided a concise overview of the potential impacts of climate change on the biota and management approaches in the Antarctic, specifically noting that:

(i) the precautionary approach to management will need to be examined in the context of climate change;

(ii) harvest strategies may need to be modified to meet the objectives of Article II of the Convention.

The Working Group agreed with this paper that climate change has important implications for management approaches to the krill fishery.

3.99 The Working Group agreed that climate change has the potential to induce rapid change within ecosystems and may impact on how indices generated by CEMP might be used to detect fisheries impacts.

3.100 The Working Group noted that CEMP was designed with an emphasis on detecting fishery impacts and that climate change has implications for how such data are interpreted.

3.101 The Working Group agreed that the detection of climate impacts is likely to benefit from data that are not currently collected under CEMP. It was also agreed that the alignment of CEMP with a broader suite of scientific research would allow integrated datasets to be analysed, and that the broad suite of parameters collected under multiple programs may be useful for management purposes.

3.102 The Working Group agreed that identifying parameters that would be most relevant for distinguishing fisheries impacts from climate impacts is important for future work, and that it would be desirable if such parameters were broadly relevant to a larger scientific and management community.

3.103 The Working Group acknowledged that detection and attribution of climate change impacts at established monitoring sites remains problematic and that the development of monitoring schemes to distinguish between climate and fisheries may require reference (control) sites and/or additional parameters, noting in particular that:

(i) the data currently reported to CEMP are often a component part of research by individual Members and that procuring resources for additional data collection, particularly if new CEMP sites are required, will pose challenges for national programs;

(ii) for new CEMP and reference sites, a number of years of monitoring will be needed for establishing baselines suitable for comparison with data from current monitoring sites;

(iii) there is uncertainty as to how the fishery will respond to climate change (paragraph 3.106), and information on how the fishery might respond to different scenarios of climate change would be helpful to identify potential fishery impacts on krill-dependent predators in the future.

3.104 The Working Group noted that a useful alternative to overcome limitations on data availability is to use qualitative and/or simulation modelling to identify important parameters for monitoring. The Working Group agreed that reviewing CEMP, including the requirements for reference sites for the purposes of monitoring the effects of the krill fishery in an era of rapid climate change, is now a priority issue, noting the comments in paragraph 3.103.

3.105 The Working Group suggested that a review of CEMP and a designation of reference sites be a Focus Topic for its next meeting (paragraph 8.1).

Climate impacts on the fishery

3.106 The Working Group reviewed two papers: one that discussed the impacts of climate change on the krill fishery through the direct effect of sea-ice on the seasonal distribution of the fishery (WG-EMM-09/P6), and one that examined the effect of UV irradiation on the distribution of krill catches (WG-EMM-09/36).

3.107 The Working Group noted the initiation of the project to examine large-scale physical factors, such as ozone depletion, on the Scotia Sea ecosystem and agreed that future results would be important for the Working Group to examine. Dr Milinevsky requested assistance in the analysis of fine-scale fisheries data, noting a difficulty in producing a suitable index for integration with ozone data from the raw catch data.

Climate impacts on predators

3.108 The Working Group reviewed WG-EMM-09/P9 which reviewed evidence for climate effects on penguins, demonstrating a strong correlation between the Southern Annular Mode and population trends of penguins in the Scotia Sea.

3.109 The Working Group noted that identifying the effects of climate change on top predators is a complex problem. The Working Group agreed that climate change has affected predators over a variety of temporal and spatial scales via direct and indirect pathways and will continue to do so. The Working Group also noted that identifying population responses due to climate change may be simplified if appropriate indicator species are selected.

3.110 The Working Group noted substantial evidence for climate-related changes in reproductive performance of predators, but noted that disentangling the effects of long-term climate change and previous harvesting of predator species would be important for a full understanding of predator population dynamics in Area 48.

Feedback management strategies

3.111 The Working Group noted the discussion of the Scientific Committee in 2008 on 'Stage 1 allocation of the precautionary krill catch limit among SSMUs in Subareas 48.1 to 48.3' (SC-CAMLR-XXVII, paragraphs 3.3 to 3.21). It was further noted that the Scientific Committee did not reach consensus, thus could not provide advice to the Commission on this issue.

3.112 The Working Group recalled its advice to the 2008 meeting of the Scientific Committee (SC-CAMLR-XXVII, paragraphs 3.5 and 3.6) concerning the overall conclusions drawn from the risk assessment of three different options to subdivide the precautionary catch limit for krill in Area 48 among statistical subareas (SSMU allocation).

3.113 The Working Group also recalled the history of this work detailed in its report last year (SC-CAMLR-XXVII, Annex 4, paragraphs 2.1 to 2.7), noting the work had been progressed since 2004 (see also paragraph 3.139). The Working Group noted that the six options for consideration in Stage 1 have been (SC-CAMLR-XXVII, Annex 4, paragraph 2.3):

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.

Option 1 is equivalent to status-quo management when recent catches are used to inform the SSMU allocation.

3.114 Options 1 to 4 are discussed in this report.

3.115 WG-EMM-09/12 expanded the assessment of risks to predators, krill and the fishery of the three SSMU allocation options (2, 3 and 4) considered in 2008 (WG-EMM-08/30; SC-CAMLR-XXVII, Annex 4, paragraphs 2.40 to 2.57) along with Option 1. The updated risk assessment includes a detailed consideration of harvest levels up to the equivalent of the precautionary catch limit, including the current trigger level. The paper also proposed three alternative approaches for managing future risks to krill-dependent predators.

3.116 The Working Group divided its discussion on this item into the following:

(i) consideration of the risks of fishing up to the current trigger level; a point of consideration last year (SC-CAMLR-XXVII, paragraph 3.36);

(ii) further development of feedback management procedures using simulations;

(iii) consideration of monitoring in support of feedback management strategies.

Current trigger level

3.117 The Working Group recalled the establishment of the original precautionary catch limit for krill in 1991 (Conservation Measure 32/X) and the outcomes of the discussion of the Commission in establishing that measure (CCAMLR-X, paragraphs 6.13 to 6.17), noting the following points:

(i) The Commission endorsed the advice of the Scientific Committee that:

(a) reactive management is not a viable long-term strategy for the krill fishery
(b) feedback management is to be preferred as a long-term strategy
(c) a precautionary approach is desirable.

(ii) The Commission expected that the distribution of fishing in the coming years would generally follow historical patterns.

(iii) The Commission established the trigger level in response to advice from the Scientific Committee that, with respect to the precautionary catch limit:

(a) the limit needs to be divided into statistical subareas to allow for the possible interaction between krill populations in these subareas;

(b) this limit may need to be supplemented by other management measures to ensure that the catch is not entirely concentrated in the foraging range of vulnerable land-breeding predators;

(c) this limit has not involved an allowance for possible unaccounted mortality (paragraphs 3.4 and 3.49) of krill associated with fishing operations (although there was very limited information on the matter).

(iv) The Commission requested advice on subdividing the catch limit amongst subareas or at finer scales to be considered in the following year.

3.118 In 1992, the Commission agreed to an SSMU allocation according to the following percentages (CCAMLR-XI, paragraph 9.7), noting that the explanation of why the percentages sum to greater than 100% is provided in SC-CAMLR-XI, paragraphs 2.72 to 2.79):

Subarea 48.1	28
Subarea 48.2	49
Subarea 48.3	24
Subarea 48.4	5
Subarea 48.5	5
Subarea 48.6	20

3.119 The Working Group also recalled that the precautionary catch limit was based on an assessment of long-term annual yield, where the yield was determined as a proportion (γ) of the estimate of krill biomass prior to exploitation (B_0) (SC-CAMLR-XIII, paragraphs 5.15 to 5.26). Gamma is determined using the KYM to take account of uncertainties in the estimate of biomass along with uncertainties in model parameters and natural variability. It is chosen to satisfy the decision rules for targeted prey species.

3.120 The Working Group noted that WG-EMM-09/12 presented results on anticipated impacts of different harvest levels on krill, krill predators and the krill fishery, where harvesting levels are expressed as a fraction (the 'yield multiplier') of the precautionary catch limit, which in the model equates to a fraction of γ, set for Subareas 48.1 to 48.3. The relative performance of predators and the fishery for Options 1 to 4 are indicated in Figures 2 and 4 of the paper respectively. The Working Group also noted, for WG-EMM-09/12, that:

(i) the assessment of the long-term annual yield is simulated by multiplying an estimate of biomass in the model by the current γ for Area 48 from the krill yield calculations;

(ii) these results followed those of last year (SC-CAMLR-XXVII, Annex 4, paragraphs 2.95 to 2.102) but included Option 1 'historical fishing strategy' as well;

(iii) there is a clear order of increasing impact on predators of the four SSMU allocation options considered: Option 2, Option 3, Option 4, and finally Option 1 (Figure 3). The options are ranked in the reverse order (1, 4, 3, 2) in terms of the implied degree of change to current fishing patterns represented in Option 1 (Figure 4);

(iv) the yield multiplier (Y) that relates to a trigger level is determined by dividing the trigger level catch in tonnes (TLC) by the catch limit in tonnes (TAC), $Y = TLC/TAC$, e.g. 0.62 million tonnes/3.47 million tonnes in Conservation Measure 51-01.

3.121 The Working Group noted that the high risks to predators implied by Option 4 occur because this option concentrates fishing into a small number of coastal SSMUs.

3.122 The meeting agreed that the results in WG-EMM-09/12 showed that the specification of a trigger level of 620 000 tonnes for the krill fishery in Subareas 48.1 to 48.3 was not as cautious a measure as might have been thought at the time this specification was agreed (see paragraph 3.126).

3.123 The Working Group also noted that WG-EMM-09/12 evaluated risks to krill, the predators and the krill fishery at harvest levels equivalent to the existing trigger level (paragraph 3.115). The current trigger level is a fixed value, while the estimate of B_0 is subject to change pending the results of ongoing analysis (paragraphs 3.77 to 3.80). Any changes to the B_0 estimate would also change the yield multiplier, which is equivalent to the trigger level, as in the formula in paragraph 3.120(iv).

3.124 The Working Group agreed that Option 1 may reduce the Commission's ability to achieve the objectives specified in Article II (see also the 2008 advice to the Scientific Committee – SC-CAMLR-XXVII, paragraph 3.9). This concern would be particularly important if the fishery were to become more spatially concentrated than the historical distribution of catch in areas where predators with restricted foraging ranges occur.

3.125 The Working Group recognised that the results displayed in Figures 3 and 4 summarise anticipated performance of predators and the krill fishery under different levels of krill catch and represent the best scientific evidence currently available.

3.126 The Working Group recommended that the Scientific Committee review the trigger level and its application in Conservation Measure 51-01, taking account of the advice in paragraphs 3.131 and 3.132.

3.127 On the basis of decisions of the Commission (paragraphs 3.117 and 3.118) and deliberations in the Working Group and the Scientific Committee, the Working Group agreed that:

(i) the advice from Members fishing for krill is that the fishery will maintain the distribution of catches according to the historical distribution across Subareas 48.1, 48.2, 48.3 and 48.4;

(ii) the trigger level was set on the understanding that:

(a) the historical fishing pattern would be retained up to the trigger level;

(b) in order for the fishery to proceed beyond the trigger level towards the catch limit, a management procedure needed to be in place that provided for finer-scale management of the krill fishery to achieve the objectives in Article II;

(iii) if the catch by the fishery was near to, but remained less than, the trigger level, it could have an impact on land-based predators if it were to become concentrated into one 'coastal' SSMU or coastal portion of a statistical subarea.

3.128 With respect to the current state of knowledge, the Working Group agreed that:

(i) the distribution of historical catches is mostly known;

(ii) while individual consumption rates of krill predators are mostly understood, the total abundance of krill-dependent predators is currently not known, which means that the total krill consumption by predators cannot be determined at present;

(iii) the CCAMLR-2000 Survey can be used to provide an estimate of relative abundances of krill in SSMUs, although this may be revised following the current review of the estimate of B_0 in Area 48;

(iv) based on the results of the last fishing season, the reported catch of the fishery is currently at 24% of the trigger level, noting that the total mortality of krill may be higher (paragraphs 3.4 and 3.49);

(v) the fishery has the capacity to fish down the krill abundance in a local area before it moves to a new area within a season (SC-CAMLR-XI, paragraphs 5.24 to 5.27; Agnew and Phegan (1995));

(vi) the total catch specified in the notifications is greater than the actual catch taken at present (WG-EMM-09/7, Figure 1; SC-CAMLR-XXVII, paragraph 4.8);

(vii) the catch in any given year, as well as the local distribution of catches, can vary because of oceanographic, climatological, environmental and biological factors, seasonal variation and economic considerations which could give rise to different catches in different local areas (paragraph 3.152).

3.129 The Working Group recalled that:

(i) the trigger level represents the aggregate of the highest catches from each subarea during the 1980s;

(ii) that, prior to the current work program of WG-EMM (2004 to 2009) the assumptions surrounding the trigger level were not evaluated against current understanding of ecosystem parameters, processes and variability;

(iii) Atkinson et al. (2004) have shown a decline in krill abundance (in the order of up to 80%) in Area 48 since the 1980s;

(iv) Adélie and chinstrap penguin populations in the Antarctic Peninsula region have declined over the same period (paragraph 3.17(i));

(v) climate change is known to be impacting ecosystem components in the region and is likely to continue to do so (paragraphs 3.95 to 3.110).

3.130 The Working Group agreed that, together, this evidence indicated the precautionary approach agreed by the Commission (paragraph 3.117(i)) will need to include a precautionary spatial allocation of the trigger level in Conservation Measure 51-01.

3.131 The Working Group also agreed that in applying such a spatial allocation:

(i) the catch from a smaller area[2] in any year could be up to a set proportion of the trigger level;

(ii) the sum of the proportions across the smaller areas could be greater than the trigger level overall, recognising the consideration of the Scientific Committee and Commission in 1992 (paragraph 3.118);

(iii) the distribution of catches across the smaller areas need not be the same as the historical distribution in every year, provided that the trigger level and the proportions of that trigger level are not exceeded;

(iv) these proportions would be replaced by the management procedure to be adopted for the fishery to expand beyond the overall trigger level.

3.132 The Working Group also agreed that the following options could be used for spatially allocating the trigger level:

(i) the proportions of historical krill catches in each smaller area, which would require a lower trigger level relative to the biomass (Table 4);

(ii) the proportions of krill biomass in each smaller area estimated from the CCAMLR-2000 Survey (Table 4);

(iii) the spatial allocations between smaller areas used previously in the conservation measure (paragraph 3.118).

3.133 Options based on estimates of predator abundance were currently considered inappropriate because of the incomplete data on predator abundances.

3.134 Some Members expressed concern that there is currently insufficient information to spatially allocate the trigger level amongst SSMUs.

3.135 The Working Group agreed that a spatial allocation of the trigger level could be made amongst statistical subareas considered in Conservation Measure 51-01 according to the procedure in paragraphs 3.130 and 3.132 to take account of the need for a precautionary approach as the trigger level is approached.

3.136 The Working Group encouraged Members to collaborate and contribute information and strategies that could be used to spatially allocate catches amongst SSMUs (paragraph 3.147).

3.137 The Working Group agreed that an audit or compilation of information related to elements involved in the development of feedback management strategies would assist in

[2] At present, smaller management areas inside Area 48 are statistical subareas and SSMUs.

addressing concerns raised about uncertainties involved in the risk assessment. Audits of the modelling approaches, the types of data being collected and the field work programs were suggested as useful (see also paragraph 3.141). It was noted that Hill et al. (2007) and the ongoing work arising from the Joint CCAMLR-IWC Workshop meets most of the requirements of a data audit.

3.138 Members were encouraged to contribute any pertinent information beyond that which is routinely submitted to CCAMLR, in order to assist in further characterising risk to the fishery.

Developing feedback management strategies

3.139 The Working Group recalled the long history of the development of feedback management strategies for krill and how this development is required by the precautionary approach (CCAMLR-X, paragraph 6.13; SC-CAMLR-XXVI, paragraph 3.36). The Working Group also noted that the FOOSA (WG-EMM-05/13 and 06/22) model was well developed and suitable for the task of providing management advice on a Stage 1 SSMU allocation (SC-CAMLR-XXVII, Annex 7, paragraphs 6.5 to 6.25). The Working Group recognised that FOOSA had therefore been endorsed and adopted for work during previous meetings of WG-SAM (SC-CAMLR-XXVII, Annex 7, paragraphs 6.5 to 6.25) and WG-EMM (SC-CAMLR-XXVII, Annex 4, paragraphs 2.1 to 2.102).

Documentation

3.140 The Working Group agreed that documentation of the methods, validation and the manner in which results are presented should be enhanced to improve communication with both the Scientific Committee and the Commission with regard to the advice given by WG-EMM on options for allocating the precautionary catch limit for krill amongst the SSMUs in Subareas 48.1 to 48.3 and on feedback management strategies as well.

3.141 One suggestion was to produce a paper or manual, which would describe technical developments in modelling approaches in terms that would inform the non-specialist, so that management advice could be understood as it moves from the Working Group to the Scientific Committee to the Commission. This type of paper or manual, which would be appropriately referenced to technical papers, and updated annually, would document the history of model development in one place. The Working Group noted that this should be straight forward given the documentation already available on the current procedures.

3.142 The Working Group noted that models and their use of data need to be validated and developed for use by the Working Group according to the procedure recommended by WG-SAM (Annex 6, paragraphs 5.11 to 5.18) and taking account of its conclusions last year (SC-CAMLR-XXVII, Annex 4, paragraph 8.16).

Feedback management strategies and their performance

3.143 The Working Group agreed that the design of a feedback management system will require consideration of data collection, analysis and decision rules for adjusting the harvest strategy. Members were invited to consider the designs of such systems, including the feasibility of different data collection and monitoring programs.

3.144 The Working Group noted that an important part of evaluating management strategies is to use metrics of their performance that relate to the objectives in Article II. It noted that WG-EMM-09/12 used a performance measure of the risk of depleting predator populations to 75% or less than the abundances that might occur in the absence of fishing. The Working Group agreed that this was reasonable and that it may be useful to also examine median plots and the distribution of risk.

3.145 The Working Group noted that besides performance measures which characterise the risk of depleting populations, it is important to also consider Article II.3(c), which aims to prevent or minimise the risk of changes in the marine ecosystem which are not potentially reversible over two or three decades.

Data

3.146 The Working Group noted that, with regard to Options 2 and 4, WG-EMM-STAPP and others were collating existing krill-dependent predator population survey data with a view to revising abundance estimates and estimating krill consumption.

Provision of advice

3.147 The Working Group noted that during its 2008 meeting it developed advice from two separate models (FOOSA and SMOM). It was agreed that results which are robust to differences between models (as were the results provided last year) generally provide greater confidence. Members were therefore encouraged to continue developing alternative models to better explore the consequences of management strategies under different scenarios.

3.148 The Working Group also recognised the need to increase participation and expertise in this work in order to reach the level of scientific understanding for communicating the advice arising from this work. Future inquiry into potential mechanisms to support such capacity building would be welcome (paragraphs 8.6 to 8.9).

Considerations of monitoring in support of feedback management

3.149 WG-EMM-09/31 recommended that WG-EMM develop a research and monitoring plan with the aim to progressively reduce the scientific uncertainties and data gaps

affecting the SSMU allocation in Area 48. Additionally, it was suggested the implementation of this plan would benefit from the development of a mechanism which would create the funds available for the needed tasks in scientific research and monitoring.

3.150 WG-EMM-09/26 reviewed a range of methods for detecting an impact that could be used with some CEMP or CEMP-like data as part of a feedback management system for the krill fishery. The paper evaluated the ability of each method to detect a known non-fisheries impact on fur seal pup production at Bird Island. The preferred method, which assesses the frequency of values below a fixed reference point, detected this impact with no time lag. It is relatively easy to evaluate the various risks (type I and type II error and late detection of an impact) associated with the preferred method. This facilitates specification of the criteria for declaring an impact based on trade-offs between these risks. The Working Group noted that many of the monitoring time series are now long enough to be amenable to these methods and looked forward to further application with appropriate datasets.

3.151 The Working Group noted that these issues have been considered in the past (SC-CAMLR-XII, Annex 4, paragraphs 6.5 and 6.6 and Appendix D; SC-CAMLR-XIX, Annex 4, paragraphs 3.45 to 3.54; SC-CAMLR-XX, Annex 4, paragraphs 3.58 to 3.83), and recommended that further consideration be given to scaling results to populations, taking account of spatial and temporal variability and the influence of density-dependent processes. Caution was raised that there is a trade-off between the preference for the use of various types of data in analyses and the costs associated with obtaining such data.

3.152 WG-EMM-09/23 reported an extreme event at South Georgia in early 2009 within a few months of it occurring (paragraph 3.10). The krill shortage that was central to this event affected the reproductive output of krill predators, the performance of the mackerel icefish (*Champsocephalus gunnari*) fishery and, ultimately, the performance of the krill fishery when vessels arrived at South Georgia in June 2009.

3.153 Early detection and reporting of such extreme events may be useful in a feedback management context and to provide advanced information on the likely performance of the fishery. Data which are routinely collected as part of long-term monitoring programs at South Georgia, the South Orkney and the South Shetland Islands could be used to assess krill availability over short time scales. Some of these data are submitted to CCAMLR as part of CEMP. The deadline for CEMP data submission is currently in June. Selected data from these monitoring programs and indicative availability dates are given in Table 5. The full suite of potential indices is reported in WG-EMM-09/23, Reid et al. (2005) and US AMLR Field Season Reports.

3.154 With appropriate coordination and prioritisation, data can generally be made available within a few days of collection. For datasets which require a high degree of processing (e.g. diet composition and length frequency), the data made available shortly after a breeding season will be based on gross analysis but may be appropriate for assessing krill availability. This implies that an indication of krill availability could be provided from 1 February each season, and that a broad suite of krill availability indicators (providing the most robust indication of krill availability) could potentially be provided by mid-May.

3.155 The Working Group agreed that analysis of diet data as an indirect measure of the abundance of prey in specific locations is useful for predators that are constrained to

feeding at small scales. For example, it might be usefully applied to icefish and fur seals diets. Changes in feeding locations indicated by tracking data are expected to be more appropriate indicators for widely ranging taxa such as whales and pack-ice seals.

ECOSYSTEM EFFECTS OF FISHING FOR FINFISH

4.1 The Working Group noted that this is a new agenda item and relatively new topic within the work plan of WG-EMM, and was requested by the Scientific Committee as a means to promote further collaboration between WG-EMM and WG-FSA (SC-CAMLR-XXVII, paragraph 3.56). The Working Group recognised that further deliberations during this and future meetings might lead to further refinement of the elements of this agenda item.

Dissostichus mawsoni trophic considerations

4.2 The Working Group noted many of the discussions about *D. mawsoni* as both predator and prey (within the Ross Sea) were taken under Item 2 of this report.

(i) Prey species: papers on prey of Antarctic toothfish include WG-EMM-09/16, 09/40 and 09/42. There have been several instances reported where colossal squid (*Mesonychoteuthis hamiltoni*) had been consumed by toothfish, based on the evidence of squid beaks in toothfish stomachs.

(ii) Predators: papers on potential toothfish predators were WG-EMM-09/15, 09/42, 09/P1 and 09/P2.

The Working Group also noted WG-FSA-06/P3, which provided evidence of a colossal squid and toothfish interaction. The Working Group agreed that such interactions may be more common than previously thought, but the few stable isotope data that exist suggest different relative trophic positions of squid and toothfish in different areas. The Working Group suggested that collecting more stable isotope data on toothfish predators and prey would assist in resolving these issues.

4.3 The Working Group noted WG-FSA-08/50, which identified medium-term (5–7 year) research objectives for examining ecosystem effects of the Ross Sea toothfish fishery. The paper identified two main objectives which were to address the maintenance of ecological relationships (i.e. predator/prey relationships) and to characterise wider potential ecosystem effects (e.g. by-catch and trophic cascades/keystone predator effects etc.).

4.4 The Working Group suggested that Members consider these objectives and provide feedback to New Zealand scientists who are working to develop an MRM for toothfish and macrourids on the Ross Sea slope, as well as developing monitoring techniques for the two main by-catch taxa (macrourids and skates). The Working Group encouraged continued progress on these research projects.

Other ecosystem considerations

4.5 The majority of the discussion with respect to climate impacts was considered by the Working Group under Item 3.5. Consideration of climate impacts under this agenda item was restricted to those papers or topics therein pertaining explicitly to finfish.

4.6 The SOS Workshop Report (WG-EMM-09/37) recognised 'harvested species, including icefish and krill' as one of several categories of ecosystem components vulnerable to climate change. The Working Group noted and endorsed the conclusions and future work as outlined in the SOS program relative to finfish.

4.7 WG-EMM-09/27 examined the spatial distribution of prey types implied by icefish stomach contents. The Working Group agreed that this represents a useful method for indirectly examining the spatial patterns of several prey taxa. The utility of this approach is further considered in paragraph 3.155.

4.8 The Working Group noted that the low CPUEs of *C. gunnari* (WG-EMM-09/23) in the fishery, and scientific surveys in 2009, could in part be due to a heterogeneous distribution and distributional shifts due to environmental conditions (WG-SAM-09/20). The Working Group also noted that these same conditions could cause a potentially severe perturbation to the *C. gunnari* population due to decreased condition and increased predation mortality (Everson et al., 1999). The Working Group encouraged WG-FSA to include these ecosystem considerations in their deliberations when providing advice on precautionary catch levels of *C. gunnari* in Subarea 48.3.

4.9 The Working Group noted that Italy and New Zealand had provided SG-ASAM with new information on TS relationships of *P. antarcticum* relative to length (SG-ASAM-09/5 and 09/10). There was good agreement between the results for adult fish, but the results for juveniles in both studies were more uncertain. The relationship was used along with data from the New Zealand IPY cruise to derive the first-ever estimate of *P. antarcticum* biomass in the Ross Sea (paragraphs 2.16 and 3.94). The Working Group agreed that these studies have considerably advanced our knowledge about TS and abundance of *P. antarcticum*.

SPATIAL MANAGEMENT TO FACILITATE THE CONSERVATION OF MARINE BIODIVERSITY

Vulnerable Marine Ecosystems

5.1 Conservation Measures 22-06 and 22-07 acknowledge the urgent need to protect VMEs from bottom fishing activities and require the Scientific Committee to advise the Commission on the effectiveness of management measures currently implemented within them this year. Previous discussions on VMEs are summarised in CCAMLR-XXVII, paragraphs 5.4 to 5.30 and SC-CAMLR-XXVII, paragraphs 4.207 to 4.284, Annex 4, paragraphs 3.21 to 3.44 and Annex 5, paragraphs 10.3 to 10.109.

5.2 WG-EMM-09/8 presented a summary of VME notifications and related data received by the Secretariat for the period to June 2009. The Working Group noted that:

(i) the Secretariat had received 30 VME indicator notifications, resulting in the declaration of seven Risk Areas in Subareas 88.1 and 88.2, and the identification of one VME fine-scale rectangle in Subarea 88.2;

(ii) 30 notifications were also made during the course of research surveys conducted by the USA in Subareas 48.1 and 48.2, and by Australia in Division 58.4.1;

(iii) fine-scale data on VME indicator units were reported by 13 out of 18 vessels engaged in exploratory longline fisheries for *Dissostichus* spp. in 2008/09;

(iv) the Secretariat is developing a web-based registry, including digital maps, of all known VMEs in the Convention Area. The registry will contain information on the location of VMEs, Risk Areas and VME fine-scale rectangles and composition of VME indicator taxa. An update on the status of the registry will be provided to WG-FSA.

5.3 The Working Group noted that it had been requested by the Scientific Committee to review and provide comments on VME notifications. However, although WG-EMM-09/8 provided information on numbers of indicator units encountered in each location (Table 2 of the paper), this is based only on by-catch data, and it is therefore difficult to assess whether the locations defined as Risk Areas should be given an alternative categorisation. The Working Group noted that, while reporting of benthos by-catch improved substantially in the current season and that the thresholds had been reached on some sets, it was difficult to assess the effectiveness of interim Conservation Measure 22-07 without data on the relationship between the by-catch and the habitats on which the sets had fished. However, the Working Group also noted that some vessels failed to report VME indicator catch levels for any hauls (WG-EMM-09/8, Table 7). It was also noted that WG-FSA is the appropriate body to provide information on how to mitigate the risks to VMEs.

5.4 The Working Group requested that the VME Workshop should consider what proportions of fishable areas would comprise different benthic habitats. It further requested that WG-FSA should consider whether the frequency of observations of benthos in by-catch is consistent with the proportional coverage of these different habitats.

5.5 WG-EMM-09/32 described the detection of VMEs in the southern Scotia Arc (Subareas 48.1 and 48.2) during the 2006 and 2009 US AMLR surveys, using research bottom trawl sampling and underwater imagery. High densities of VME indicator taxa were encountered in 17 areas off the northern Antarctic Peninsula and 11 areas off the South Orkney Islands, and these areas have been proposed for inclusion in the CCAMLR VME Registry.

5.6 WG-EMM-09/32 noted that Conservation Measure 22-06 does not provide a threshold level for the abundance of VME taxa that is sufficient to trigger designation of the sampled location as a VME. Annex 22-06/B provides a notification form for Contracting Parties to notify the Secretariat when evidence of VMEs has been encountered, and has not otherwise been reported under Conservation Measure 22-07. The authors proposed a standardised measure of VME indicators per unit area (10 kg/1 200 m^2 of swept area in the trawl) for consistency with the requirements of Conservation Measure 22-07, to differentiate between areas where VME indicator species might be found at very different levels of abundance.

5.7 The Working Group agreed that relevant data can be collected and systematically collated from research surveys to provide information on VMEs. Such data could provide proxies to forecast other locations in which these habitats might occur. Historical datasets may also be useful in providing information on VMEs, and Members were encouraged to examine such data in this context.

5.8 The Working Group recommended that WG-EMM-09/32 should be forwarded to WG-FSA for commentary on its proposals, and on operational considerations including the overlap of some VME areas with the experimental harvest regime for crabs in Subarea 48.2 (Conservation Measure 52-02, Annexes 52-02/B and 52-02/C).

5.9 The Working Group also agreed that the following points should be considered by the VME Workshop:

(i) Data collected from the Scotia Arc suggest that the current minimum depth limit applied by CCAMLR in measures to protect benthic habitats is appropriate, but that there may be deeper locations which also require attention. The VME Workshop should consider whether it is possible to define a depth range suitable for application in such measures throughout the Convention Area.

(ii) In certain locations, there was insufficient evidence of indicator taxa in the catch to trigger the 10 kg/1 200 m^2 threshold, although the video transect provided ample evidence of a VME. In particular, the substantial difference in mass between 'heavy' and 'light' indicator taxa means that 'light' taxa are much less likely to occur in sufficient mass to trigger the presence of a VME at the current threshold. It is proposed that a lower threshold for 'light' indicator taxa should be considered, and that the level of this threshold should be discussed further.

(iii) The presence of high densities of rare taxonomic groups or unique community assemblages specific to the Southern Ocean may warrant additional attention, and perhaps an increased level of precaution. In addition, high densities of unique and potentially endemic taxonomic groups not listed in Annex 22-06/B or the CCAMLR Benthic Invertebrate Classification Guide (e.g. Pterobranchia) had been encountered off the South Orkney Islands, and could be considered for inclusion as VME indicator taxa.

5.10 The Working Group noted two additional papers that will be useful in informing further work to model the vulnerability and resilience of benthic habitats:

(i) WG-EMM-09/35 described a method to predict the vulnerability of benthic organisms to disturbance, using relationships between life-history characteristics and physical and chemical habitat variables. These relationships can be used as predictive tools to provide values for life-history parameters, and suggest that many of these taxa will show low resilience to disturbance, with recovery trajectories predicted to be in the orders of many decades or centuries.

(ii) WG-SAM-09/21 developed a simulation model to capture key properties of the benthic system, such as rates of decay, recovery and connectedness between areas (Annex 6, paragraphs 4.8 to 4.19).

5.11 The Working Group agreed that there was a need to further develop plausible bounds for parameters used in the models described in WG-SAM-09/21 and WG-EMM-09/35 for consideration by the VME Workshop and WG-FSA. It also agreed that it would be useful to expand the approach set out in WG-EMM-09/35 to other taxonomic groups.

5.12 With reference to WG-SAM-09/21, the Working Group noted the conclusions of WG-SAM concerning the model itself (Annex 6, paragraphs 4.7 to 4.15) and model evaluation and validation (Annex 6, paragraphs 4.11 to 4.17), in particular the recommendations that WG-EMM and the VME Workshop should:

(i) discuss ecologically appropriate parameterisations and functional forms for use in the simulation model;

(ii) distinguish, as far as possible, between appropriately interpreted empirical observations and subjective expert knowledge to inform the parameterisation and selection of functional forms.

5.13 The Working Group provided the following advice for further development of the model described in WG-SAM-09/21, for the VME Workshop and WG-FSA:

(i) Map –

(a) data layers that would be of value for modelling the dynamics of habitats, fish and fishery include depth, proximity to glaciers and ice shelves as well as data that could drive fish or habitat distributions;

(b) the development of example maps by Members that could be imported into the simulations, for areas where adequate data exists (e.g. portions of the Ross Sea slope), based on bathymetry, satellite data, geomorphology or bioregionalisations, would be valuable for including in the evaluations.

(ii) Fish –

(a) fish may or may not have distributions related to habitats, depending on their habit and locations and the different spatial scales at which fish can be expected to respond to environmental variation. Options to vary these dependencies will be helpful.

(iii) Habitats –

(a) there is a need to identify what each habitat layer represents, whether that be broad biophysical classification, spatial patch type, species or population, noting that the opportunity for many layers in the model means that many different levels of biological/ecological resolution can be included within a single simulation;

(b) there may not be a need to have a decay function if the recovery and disturbance models can be developed to be independent of that requirement;

(c) options for considering rare species and local endemism would be useful in the model but this is likely to be best represented in user-defined maps and inputs of habitat data;

(d) using available data and bioregionalisation work, some consideration could be given to how to characterise the spatial variation and covariation of habitat layers within cells and between habitats and how fish may be related to these.

(iv) Natural disturbance –

(a) disturbance by ice scour is likely to be the most important natural disturbance to represent, but that this should be restricted to cells in shallow areas of maps that are eventually constructed, although a further consideration may be the proximity to iceberg sources.

(v) Fishery –

(a) the use of an ideal free distribution to model the fishery (i.e. the intensity of fishing effort is directly proportional to the abundance of the fish) seems sensible with variation in its performance in individual cells, subject to (b) below;

(b) it was suggested that it is important to be able to represent spatial limitations of a fishery when this occurs, such as could occur when constrained by the seasonal advance and retreat of sea-ice (as in the Ross Sea), taking account of interannual variation if needed;

(c) taking account of previous fishery disturbances would be useful;

(d) the observations of benthic by-catch should be scaled by the degree of impact;

(e) it is important to account for both footprint width and the degree of impact within the footprint when calculating the impact of fishing on VMEs.

5.14 The Working Group requested that the author of WG-SAM-09/21 provide the VME Workshop with a summary table of the parameters and questions to be addressed for the model to be appropriately configured for evaluating strategies for conserving VMEs at the meeting of WG-FSA. The Working Group encouraged Members to contribute information to the workshop that could be used as inputs to the model and to help construct scenarios for these evaluations.

Protected areas

5.15 The Working Group recalled its previous deliberations on protected areas, noting the conclusions of the Scientific Committee last year (SC-CAMLR-XXVII, paragraph 3.55) and that WG-EMM-09/9 provided a useful summary of approaches within CCAMLR and the Antarctic Treaty on this issue, as well as outlining how a range of tools for spatial

management can be used to help the Commission achieve its objectives on MPAs. It also noted that the Commission had 'urged the Scientific Committee to proceed with this work as a matter of priority. The Commission reaffirmed the need to develop advice on MPAs which was commensurate with Articles II and IX of the Convention' (CCAMLR-XXIII, paragraph 4.13).

5.16 The Working Group noted the endorsement by the Scientific Committee of the priority areas (SC-CAMLR-XXVII, Annex 4, paragraph 3.77 and Figure 12) on which focus should be given for developing a representative system of MPAs (SC-CAMLR-XXVII, paragraph 3.55(iv)). It also noted that these areas are not expected to become MPAs in their entirety, but that smaller areas within, but not limited to, the priority areas may be identified for designation as MPAs. The Working Group also noted that the priority areas had been endorsed by the Committee on Environmental Protection (CEP XII Report[3], paragraph 163).

5.17 The Working Group noted that a number of papers are pertinent to further consideration of protected areas in the following four priority areas:

(i) Priority Area 1 – Antarctic Peninsula, including the spatial distribution of whales being determined by distribution of life stages of krill (WG-EMM-09/33). It also noted:

  (a) the predictable spatial segregation of different whale species and how this was likely to apply for other krill predators around the South Shetlands;

  (b) the potential for ships of opportunity, such as tourist vessels, to be used to identify distributions of predators;

  (c) the potential to use spatial distributions of predators as data layers in analyses of potential areas for MPAs.

(ii) Priority Area 2 – South Orkney Islands, including collation of data for the area and analyses within a systematic conservation planning framework (WG-EMM-09/22), which is discussed further below.

(iii) Priority Areas 10 and 11 – Ross Sea and adjacent area, including consideration of oceanography (WG-EMM-09/41), food webs (WG-EMM-09/42), toothfish dynamics (WG-EMM-09/40) and the ecosystem as a whole (WG-EMM-09/13, 09/14 and 09/P3). It also noted that many of these papers are consistent with the identification of these areas as priority areas.

5.18 With respect to Priority Area 11, Dr B. Sharp (New Zealand) presented preliminary outcomes from a New Zealand workshop on bioregionalisation and spatial ecosystem processes in the Ross Sea region, held in June 2009. He noted the main outcomes for the Ross Sea region were:

(i) a fine-scale pelagic bioregionalisation
(ii) a fine-scale benthic/demersal bioregionalisation
(iii) a list/map of important ecosystem processes that may be amenable to protection using spatial management tools.

[3] www.ats.aq/documents/ATCM32/att/atcm32_att084_rev2_e.doc

5.19 The Working Group noted that the Ross Sea bioregionalisations will make a significant contribution to the work of the Scientific Committee and looked forward to the results being submitted in the near future.

5.20 WG-EMM-09/22 described an updated method and preliminary results for the selection of benthic and pelagic areas of conservation importance in Subarea 48.2, noting that the work was now at a stage that a preliminary assessment on MPAs in this area can be provided for consideration by the Scientific Committee this year.

5.21 The Working Group noted the following points about this assessment using MARXAN in Subarea 48.2:

(i) the objectives used as inputs to the MARXAN analysis were given values at the lower end of the ranges typically used in such analyses. It was noted that increasing these values tended not to significantly increase the size or locations of the core areas identified for inclusion in MPAs;

(ii) the data layers included in the analysis accommodated a range of scales of ecological processes expected to operate in the vicinity of the South Orkney Islands;

(iii) increasing the number of data layers would potentially result in the inclusion of highly correlated data, which would tend to bias the results towards those data that are over-represented in the analysis;

(iv) more selective use of data may provide a refined result but potentially would not reflect appropriate ecological processes.

5.22 The Working Group noted that the use of fishery data appears not to take account of socio-economic requirements, which were identified as a factor that had been considered at WSSD. However, the Working Group agreed that the analysis of the fishery requirements was sufficient given the following:

(i) the economics of fishing activities is not currently considered by the Commission and therefore cannot be incorporated into the analysis unless this policy is changed;

(ii) information provided to the Working Group in section 3.6 indicates that the fishery already concentrates on a number of favoured areas and, as a result, the analysis incorporates adequate knowledge of fishing operations. Further, no new information is available that would result in changes to preferred fishing areas.

5.23 The Working Group agreed that the data used in WG-EMM-09/22 have been used appropriately and that the analyses are likely to yield a conservative and unbiased estimate of target areas for MPAs in the South Orkney Islands region. It therefore recommended that the Scientific Committee consider these results (see Figures 5 and 6) and any extension to the analysis in WG-EMM-09/22 to identify MPAs in Subarea 48.2 for inclusion in a representative system of MPAs.

5.24 The Working Group thanked the authors of WG-EMM-09/22 for providing their analysis and the procedure for identifying areas for inclusion in a representative system of MPAs which should be easily understood by scientists, fishers and policy makers. The Working Group encouraged Members to continue the application of this approach (SC-CAMLR-XXVII, Annex 4, paragraph 3.59), and other approaches, within the priority areas (paragraphs 5.16 and 5.32).

Harmonisation of approaches (both within CCAMLR and across the ATS)

5.25 SC-CAMLR-XXVIII/6 is the report of the Joint SC-CAMLR–CEP Workshop held in Baltimore, USA, on 3 and 4 April 2009. Two papers that were provided to the workshop were also submitted to WG-EMM and have been discussed in other sections – WG-EMM-09/9 (see paragraph 5.15) and WG-EMM-09/24 (see paragraph 3.98). It was noted that both papers were well received by the Joint Workshop and the authors were congratulated for their work.

5.26 WG-EMM noted that the CEP had accepted all of the recommendations of the workshop report and, in commending it to SC-CAMLR, the CEP had stressed the importance of maintaining momentum on the issues identified (CEP XII Report, paragraph 267).

5.27 The Working Group agreed with the recommendations of the Joint Workshop (SC-CAMLR-XXVIII/6), noting the five areas of common interest:

(i) climate change and the Antarctic marine environment
(ii) biodiversity and non-native species in the Antarctic marine environment
(iii) Antarctic species requiring special protection
(iv) spatial marine management and protected areas
(v) ecosystem and environmental monitoring,

and it recommended that the report of the Joint Workshop be published as an annex to the Scientific Committee's report in order to make the recommendations readily available to Members.

5.28 WG-EMM-09/46 described how Conservation Measure 91-02 (2004) affords protection of the Cape Shirreff CEMP site. Cape Shirreff is also protected as ASPA 149 through the Antarctic Treaty. The management plans for Cape Shirreff are due for review by CCAMLR in 2009 and by the ATCM in 2010. Both plans recognise the importance of the CEMP site and associated scientific research and afford area protection.

5.29 The Working Group agreed with the recommendation in WG-EMM-09/46 that, to assist with harmonising protection under CCAMLR and the Antarctic Treaty, and to avoid duplication of effort on the part of researchers, national governments and the secretariats of CCAMLR and the ATS, Conservation Measure 91-02 be allowed to lapse with the protection of Cape Shirreff continuing under the management plan of ASPA 149.

5.30 The Working Group noted that with the lapsing of Conservation Measure 91-02, there would be no sites afforded additional protection under the provision of Conservation

Measure 91-01. It recommended that, where sites from which CEMP data are currently collected and afforded protection as ASPAs or ASMAs, they be listed in an annex to Conservation Measure 91-01.

5.31 The Working Group noted that a Special Fund had been established by Belgium in 2005 to support work on MPAs (CCAMLR-XXIV, paragraph 3.29). The Secretariat confirmed that additional funds had been contributed by the UK in 2009, and that the total amount now available in the Special Fund is approximately A$58 000. The Working Group expressed its appreciation to Belgium and the UK for making these funds available.

5.32 The Working Group agreed that significant further work is required to progress the establishment of a representative system of MPAs across the Convention Area by 2012, within the timeline agreed by the WSSD. It also noted the high priority afforded to this work by the Scientific Committee (SC-CAMLR-XXVII, paragraph 3.55) and the Commission (CCAMLR-XXVII, paragraph 7.2), and recalled that the issue of MPAs had been identified as one of the Scientific Committee's priority items in its consideration of the Performance Review Panel Report (SC-CAMLR-XXVII, paragraph 10.10).

5.33 It was agreed that work to progress the establishment of a representative system of MPAs across the Convention Area could include projects which aimed to:

(i) collate physical and biological datasets to support bioregionalisation and systematic conservation planning analyses across the Convention Area and/or for specific region(s);

(ii) identify areas for protection, focusing on the 11 priority areas defined by the Working Group (SC-CAMLR-XXVII, Annex 4, Figure 12), and endorsed by the Scientific Committee (SC-CAMLR-XXVII, paragraph 3.55(iv)) and CEP (CEP XII Report, paragraph 163);

(iii) build capacity among Members to contribute towards systematic conservation planning and other analyses relevant to the development of MPAs;

(iv) work within existing or future research groups to achieve these objectives.

5.34 The Working Group recognised that the MPAs Special Fund could be utilised to facilitate such work, and recommended that a correspondence group should be convened immediately following WG-EMM to expedite the development of coordinated proposals for use of the available funds. The terms of reference for this correspondence group would be to:

(i) consider the types of proposal(s) which might be appropriate for further development, based on the aims outlined in paragraph 5.33;

(ii) elaborate the details of specific proposal(s), as appropriate;

(iii) outline any further work which may be required to facilitate the development of proposals and/or the allocation of funds;

(iv) submit a paper to SC-CAMLR-XXVIII summarising the discussions on (i) to (iii), and requesting specific advice from the Scientific Committee on the next steps, as appropriate.

5.35 The correspondence group would not be responsible for reviewing proposals or making recommendations on the allocation of funds, and the Working Group noted that the Scientific Committee would provide advice on these decisions as required.

5.36 It was agreed that Dr Grant would coordinate the correspondence group. The Working Group requested the Secretariat to communicate details of the correspondence group and its terms of reference to all Members as soon as possible, and to encourage Members to participate in its discussions.

5.37 The Working Group also noted that, if they wish to do so, Members are able to submit individual proposals to the Secretariat for use of the MPA Special Fund, in addition to any coordinated proposals that might be developed by the correspondence group (see CCAMLR-XXVII, paragraph 7.7).

ADVICE TO THE SCIENTIFIC COMMITTEE AND ITS WORKING GROUPS

6.1 The Working Group identified the following advice to the Scientific Committee and its Working Groups:

(i) overlap with toothfish fishery and predators (paragraph 2.42);

(ii) mitigating risks to predator population from the Ross Sea toothfish fishery (paragraphs 2.46 to 2.50 and 2.52);

(iii) potential mortality rate of krill in the fishery (paragraphs 3.4 and 3.7);

(iv) ecosystem anomaly at South Georgia (paragraph 3.10);

(v) new CEMP sites (paragraphs 3.12 and 3.14);

(vi) progress and work plan for WG-EMM-STAPP (paragraph 3.20);

(vii) revised total krill catch in 2007/08 (paragraphs 3.26 and 3.27);

(viii) translation requirements for krill notifications (paragraph 3.32);

(ix) research requirements in exploratory krill fisheries (paragraphs 3.34, 3.35 and 3.38 to 3.41);

(x) efficacy of seal exclusion devices in the krill fishery (paragraph 3.48);

(xi) requirements for observer coverage in the krill fishery (paragraphs 3.54, 3.55, 3.58, 3.60 and 3.61);

(xii) conservation measures relevant to the krill fishery (paragraphs 3.67 to 3.72);

(xiii) acoustic estimation of krill biomass (paragraphs 3.75 to 3.78, 3.80, 3.82, 3.83, 3.85 to 3.88, 3.90 and 3.91);

(xiv) impacts of climate change (paragraphs 3.99, 3.101, 3.102 and 3.104);

(xv) trigger level in Conservation Measure 51-01 (paragraphs 3.122 to 3.126 and 3.130 to 3.137);

(xvi) developing feedback management strategies (paragraphs 3.140 and 3.142);

(xvii) inclusion of ecosystem considerations of icefish by WG-FSA (paragraph 4.8);

(xviii) advice to the VME Workshop (paragraphs 5.4 to 5.9, 5.13 and 5.14);

(xix) representative system of MPAs in Subarea 48.2 (paragraph 5.23);

(xx) report of the Joint SC-CAMLR–CEP Workshop (paragraph 5.27);

(xxi) recommendations with respect to Conservation Measures 91-01 and 91-02 (paragraphs 5.29 and 5.30);

(xxii) development of proposal for projects and access to MPA Special Fund (paragraphs 5.35 to 5.37);

(xxiii) capacity building and burden sharing (paragraphs 8.7 to 8.9).

FUTURE WORK

7.1 The Working Group identified the following future work:

(i) stomach contents of toothfish (paragraph 2.14);

(ii) size-specific data on toothfish consumed by predators (paragraph 2.29);

(iii) models of the Ross Sea ecosystem (paragraphs 2.33, 2.51 and 2.53);

(iv) distribution of toothfish and predators in winter (paragraph 2.43);

(v) potential mortality rate of krill in the fishery (paragraphs 3.5 and 3.6);

(vi) coordination of monitoring with the CEP (paragraph 3.15);

(vii) photographic census methods (paragraph 3.22);

(viii) diagrams of seal exclusion devices from Japan and the Republic of Korea (paragraph 3.31);

(ix) krill conversion factors and volume-to-mass estimation (paragraphs 3.45(ii) and 3.49);

(x) revision of the CCAMLR *Scientific Observers Manual* (paragraph 3.45(iii);

(xi) submission of Japanese observer data to CCAMLR (paragraph 3.53);

(xii) stratification of Subarea 48.6 (paragraph 3.93);

(xiii) characterising risk to the krill fishery (paragraph 3.138);

(xiv) model validation procedures (paragraph 3.142);

(xv) development of alternative models (paragraph 3.147);

(xvi) MRM of toothfish and macrourids (paragraph 4.4);

(xvii) collection of stable isotope data on toothfish predators and prey (paragraph 4.2(ii));

(xviii) data collation to map VMEs and parameterise models (paragraphs 5.7, 5.11 and 5.13);

(xix) application of systematic conservation planning tools in priority areas (paragraph 5.24);

(xx) development of proposal for projects and access to MPA special funds (paragraphs 5.33 and 5.34).

OTHER BUSINESS

Consideration of potential future Focus Topics for WG-EMM

8.1 The Working Group discussed the potential for future Focus Topics on the development of an observer scheme for krill (paragraph 3.61) and the future design of the monitoring requirements to deliver feedback management of krill, especially considering climate change and including the concept of reference sites (paragraph 3.105). In recognising the role of Focus Topics to provide flexibility to address the priorities of the Scientific Committee, the Working Group agreed to await the recommendation of the Scientific Committee meeting this year before determining the requirement for, and potential theme of, any Focus Topic at WG-EMM in 2010.

8.2 The Working Group also noted that it is important to recognise that workshops and Focus Topics often represent the initiation of a longer-term work plan (e.g. the work of WG-EMM-STAPP arising from the Predator Workshop in 2008 (paragraph 3.19)) and that this should be considered in managing future workload and expectation.

CCAMLR Performance Review

8.3 The Working Group discussed the priorities identified by the Scientific Committee arising from the report of the CCAMLR Performance Review Panel (SC-CAMLR-XXVII, paragraphs 10.1 to 10.11) that were relevant to its work.

8.4 The Working Group recognised the importance of the Report of the CCAMLR Performance Review Panel and that the positive nature of the report had been widely acknowledged and provided an opportunity to continue to promote the work of CCAMLR.

8.5 In considering the mechanism to address the priority areas outlined by the Scientific Committee, the Working Group noted that it already had a very full workload and the issues of capacity building and burden sharing provided an overarching theme that would influence its ability to address these in the future. These latter issues were also highlighted as priorities in the Performance Review Panel Report.

Capacity building and burden sharing

8.6 In recognising the issues raised in paragraph 8.5, the Working Group agreed that addressing the issue of capacity building was an important precursor to address burden sharing and discussed a potential mechanism to achieve greater active engagement in its work.

8.7 The Working Group agreed that one potential mechanism to achieve greater participation might be to create a funding mechanism to support the attendance at Working Group meetings of young scientists from Members who otherwise would not have been able to engage in the work of WG-EMM. This would involve the Member nominating a young scientist and providing a CV and an abstract for a paper to be provided to the Working Group. Following the outcomes of the selection process, the successful nominee would be invited to submit their paper to the next meeting of the Working Group. In order to maximise the opportunity to develop an area of work based on the feedback from the Working Group, the successful nominee would be funded to attend their first Working Group meeting through the Special Fund, and there would be a commitment from the Member to fund their attendance at the next meeting of the Working Group (such a commitment would be a prerequisite).

8.8 In addition to the facilitation of attendance at its meeting, the Working Group recognised the potential value of adopting an active mentoring scheme, possibly including collaboration between the successful nominee and an established participant in the Working Group, and being tied to the meeting scholarship program outlined above.

8.9 The Working Group advised the Scientific Committee to consider various mechanisms for capacity building, including those outlined above, as a matter of priority.

ADOPTION OF THE REPORT AND CLOSE OF THE MEETING

9.1 The report of the meeting of WG-EMM was adopted.

9.2 In closing the meeting, Dr Watters thanked all of the rapporteurs, participants and the Secretariat for their helpful engagement and high level of scientific input into the meeting, in particular he thanked Dr Jones for chairing those parts of the meeting during which his own papers were considered. On behalf of the meeting Dr Watters also thanked Mr Iversen, and through him the IMR and Norwegian Foreign Ministry, for providing excellent facilities and meeting arrangements. Dr Watters also thanked the Secretariat for its support.

9.3 Dr Constable, on behalf of the participants, thanked Dr Watters for his good humour, spirit and enthusiasm throughout the meeting.

9.4 The meeting closed.

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Table 1: Progress by WG-EMM-STAPP in estimating krill consumption by air-breathing predators in Area 48. Italics: progress up to WG-EMM-09; bold: likely progress to WG-EMM-10; X: work commenced; XX: work well progressed; XXX: work completed.

Tasks required for estimating krill consumption	Pack-ice seals (at sea)	Fur seals (on land)	Penguins (on land)	Flying seabirds (on land)	Flying seabirds (at sea)
Collection/collation data	*XXX*	*XXX*	*XX***X**	*XXX**	*X***X**
Develop estimation procedure	*XXX*	*X***X**	*XX*	*XXX**	
Estimate abundance: breeders	*XXX*	*X***X**	*XX*	*XXX**	
Estimate abundance: non-breeders	*XXX*	*X***X**	**X**		
At-sea distribution	*XXX*	**XX**			
Diet and energetics	*XXX*	*X***X**	*XX*		*X***X**
Estimate krill consumption	*XXX*				

* For white-chinned petrels in Subarea 48.3 only.

Table 2: Ontogenetic patterns in diet of *Dissostichus mawsoni* in the Ross Sea, based on information in WG-EMM-09/16, 09/40 and 09/42.

Life stage	Size	Habit	Habitat	Main prey
Post-larvae	<15 cm	Nektonic	Oceanic	Krill, zooplankton
Juvenile	15~60cm	Demersal	Shelf	Silverfish, crustaceans
Pre-adult	60~100cm	Bathypelagic	Slope	Icefish, macrourids, squid
Adult	100+ cm	Bathypelagic	Slope, seamounts	Squid, macrourids, *Antimora*

Table 3: Summary of notifications for krill fisheries in 2009/10.

Member	Name of vessel	Expected level of catch (tonnes)	Months during which fishing will proceed												Subareas and/or divisions where fishing will take place						Fishing technique
			2009	2010											Subarea				Division		
			Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	48.1	48.2	48.3	48.4	58.4.1	58.4.2	
China	*An Xing Hai*	3 000	x	x	x	x									x	x	x	x			T
	Kai Li	3 000	x	x	x	x									x	x	x	x			T
	Kai Xin	3 000	x	x	x	x									x	x	x	x			T
Japan	*Fukuei Maru*	30 000		x	x	x	x	x	x	x	x				x	x	x				T
Korea, Republic of	*Insung Ho*	12 000			x	x	x	x	x	x	x				x	x	x				T
	Kwang Ja Ho	18 000			x	x	x	x	x	x	x				x	x	x				T
	Dongsan Ho	35 000		x	x	x	x	x	x	x	x	x	x		x	x	x				T
Norway	*Juvel*	50 000	x	x	x	x	x	x	x	x	x	x			x	x	x				T
	Saga Sea	50 000	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	C
	Thorshøvdi[1]	65 000	x	x	x	x	x	x	x	x	x	x			x	x	x				CPB
Poland	*Dalmor II*	9 000				x	x	x	x	x	x				x	x	x				T
Russia	*Maksim Starotsin*	75 000	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x			TCPB
Ukraine	*Konstruktor Koshkin*	10 000			x	x	x								x	x					T
Total	13 vessels	363 000	7	9	12	13	10	9	9	9	9	5	3	2	13	13	12	4	1	1	

Fishing technique: T – traditional; C – continuous fishing system; P – pumping to clear codend; B – beam trawling

[1] *Thorshøvdi* has notified its intent to fish in the exploratory fishery in Subarea 48.6 – total of 15 000 tonnes included above.

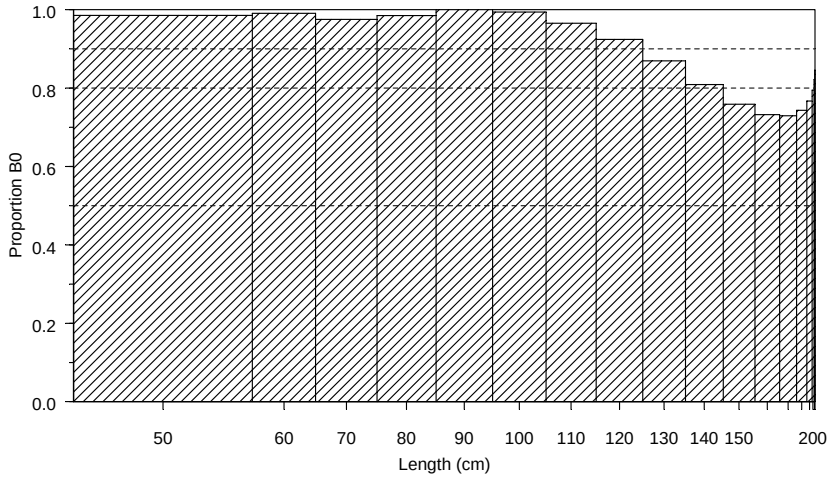
Table 4: Proportional subdivision of recent krill catches and krill biomass from the CCAMLR 2000 Survey among the 15 SSMUs in Statistical Areas 48.1–48.3. Subdivisions of the historical catches are derived from SSMU-specific catches for the last five fishing seasons (see WG-EMM-09/6, Table 8). Subdivisions of krill biomass are from Hill et al. (2007). Pelagic SSMUs are highlighted in bold type, and the total subdivision to these SSMUs is reported in the row marked 'pelagic'. The total subdivision to coastal SSMUs is reported in the row marked 'coastal'. Totals are also provided by Subarea. Antarctic Peninsula (AP) SSMUs: Pelagic Area (APPA); Bransfield Strait East (APBSE); Bransfield Strait West (APBSW); Drake Passage East (APDPE); Drake PassageWest (APDPW); Antarctic Peninsula West (APW); Antarctic Peninsula East (APE); Elephant Island (APEI). South Orkney Islands (SO) SSMUs: Pelagic Area (SOPA); North East (SONE); South East (SOSE); West (SOW). South Georgia (SG) SSMUs: Pelagic Area (SGPA); East (SGE); West (SGW).

Subarea	SSMU	Proportion of catch	Proportion of biomass
48.1	**APPA**	**0.0006**	**0.0729**
	APBSE	0.0387	0.0160
	APBSW	0.0254	0.0122
	APDPE	0.0250	0.0091
	APDPW	0.1038	0.0088
	APW	0.0009	0.0204
	APE	0.0000	0.0341
	APEI	0.0188	0.0205
48.2	**SOPA**	**0.0036**	**0.3058**
	SONE	0.0099	0.0238
	SOSE	0.0003	0.0347
	SOW	0.4448	0.0361
48.3	**SGPA**	**0.0004**	**0.3475**
	SGE	0.1933	0.0326
	SGW	0.1343	0.0255
48.1		0.2132	0.1940
48.2		0.4587	0.4004
48.3		0.3281	0.4056
Pelagic		**0.0047**	**0.7262**
Coastal		0.9953	0.2738

Table 5: Parameters indicating krill availability with indicative availability dates derived (where possible and indicated *) from the CEMP standard methods.

CEMP method	Parameter	Species	Location	Indicative availability date
A6	Penguin breeding success	Adélie	South Orkney and South Shetland Islands	06-Feb*
		Chinstrap	South Orkney and South Shetland Islands	01-Mar*
		Gentoo	South Orkney and South Shetland Islands	01-Feb
		Gentoo	South Georgia	01-Feb
		Macaroni	South Georgia	25-Feb*
A7	Penguin fledging mass	Adélie	South Orkney Islands	06-Feb*
		Adélie	South Shetland Islands	25-Jan*
		Chinstrap	South Orkney Islands	01-Mar*
		Chinstrap	South Shetland Islands	25-Feb*
		Gentoo	South Georgia	23-Feb*
		Macaroni	South Georgia	25-Feb*
A8	Penguin chick diet	Adélie	South Orkney and South Shetland Islands	01-Feb*
		Chinstrap	South Orkney and South Shetland Islands	01-Mar*
		Gentoo	South Georgia	15-Mar*
		Macaroni	South Georgia	01-Mar*
B2	Flying seabird breeding success	Black-browed albatross	All	16 April OR the date when all birds have fledged*
-	Krill acoustic density estimate	Krill	South Georgia	01-Feb
		Krill	South Shetland Islands	01-Feb
-	Mackerel icefish diet	Mackerel icefish	South Georgia	01-Mar
-	Weaning mass	Fur seal	South Georgia	01-Jan
-	Pup survival	Fur seal	South Georgia	01-Jan
-	Early diet	Fur seal	South Shetland Islands	01-Feb
C1	Foraging trip duration	Fur seal	South Shetland Islands	01-May
		Fur seal	South Georgia	01-May

(a) End of 2007



(b) End of the projection period (2042)

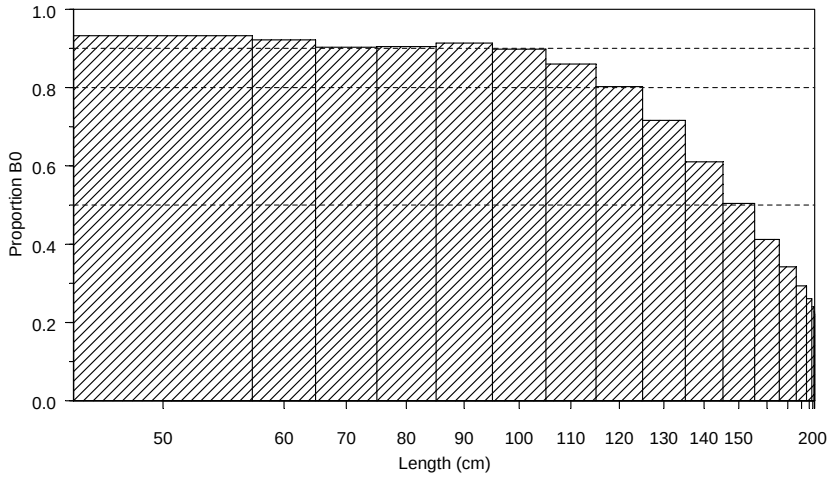


Figure 1: Estimated median relative abundance by size class from the 2007 assessment for *Dissostichus* spp. in Subarea 88.1. Relative abundance is determined as the ratio of the abundance in the size class in the year relative to the initial (B_0) abundance. Bar widths are proportional to the relative abundance of each size class in the population.

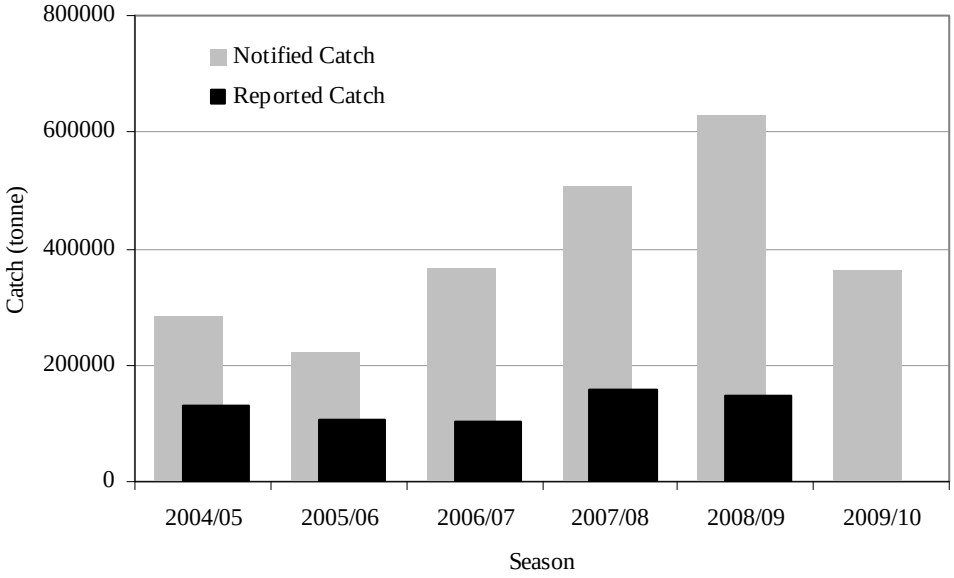


Figure 2: Notified and realised catches in the krill fishery in 2009/10.

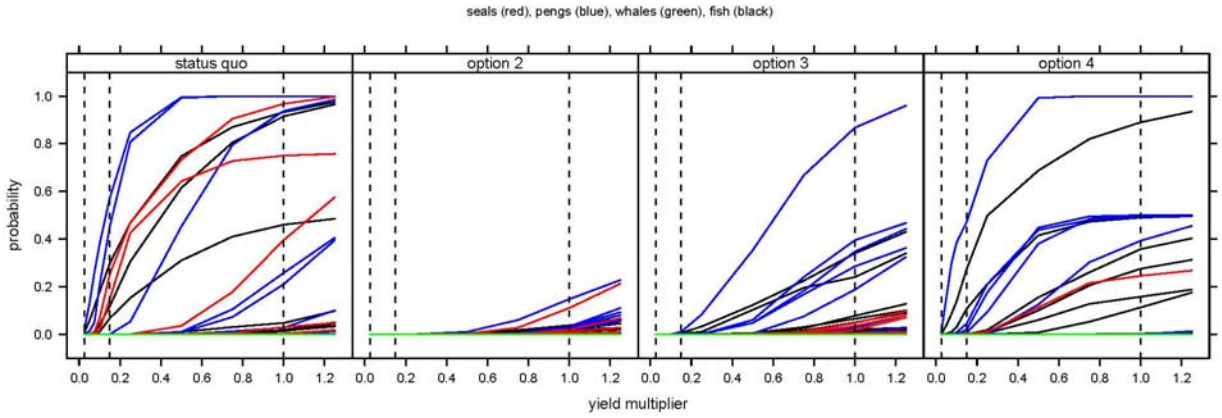


Figure 3*: Effects on predators. Model-averaged, fishing-option-specific probabilities that, at the end of the fishing period, the abundances of predators will be reduced to values less than or equal to 75% of abundances from comparable no-fishing trials. Probabilities are averaged (using equal weights) across parameterisations that are intended to characterize plausible bounds on the flux of krill through the SSMUs and the relationship between foraging success and reproductive success for krill-dependent predators. The x-axis is harvest rate, labelled 'yield multiplier'. Status quo is allocation proportional to the historical distribution of krill catch; Option 2 is the SSMU allocation proportional to predator abundance; Option 3 is the SSMU allocation proportional to the abundance of krill from the CCAMLR-2000 Survey; and Option 4 is the SSMU allocation proportional to predator abundance minus krill abundance. The vertical dotted lines mark yield multiplier values of 0.026 (indicating the harvest rate at recent catch levels), 0.15 (indicating the harvest rate at the present 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.

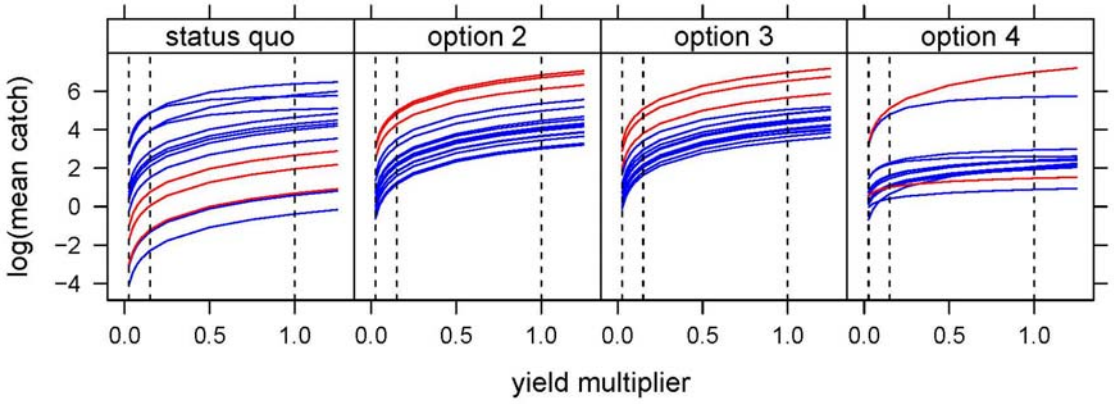


Figure 4*: Effects on the fishery. Model-averaged, fishing-option-specific log of mean catches. The trend lines are SSMU-specific; coastal SSMUs are indicated in blue and pelagic SSMUs are indicated in red. Fishery performance was averaged (using equal weights) across parameterisations that are intended to characterize plausible bounds on the flux of krill through the SSMUs and the relationship between foraging success and reproductive success for krill-dependent predators. 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 implicitly describe initial conditions that would prohibit fishing in many SSMUs. The x-axis is harvest rate, labelled 'yield multiplier'. Status quo is allocation proportional to the historical distribution of krill catch; Option 2 is the SSMU allocation proportional to predator abundance; Option 3 is the SSMU allocation proportional to the abundance of krill from the CCAMLR-2000 Survey; and Option 4 is the SSMU allocation proportional to predator abundance minus krill abundance. The vertical dotted lines mark yield multiplier values of 0.026 (indicating the harvest rate at recent catch levels), 0.15 (indicating the harvest rate at the present 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.

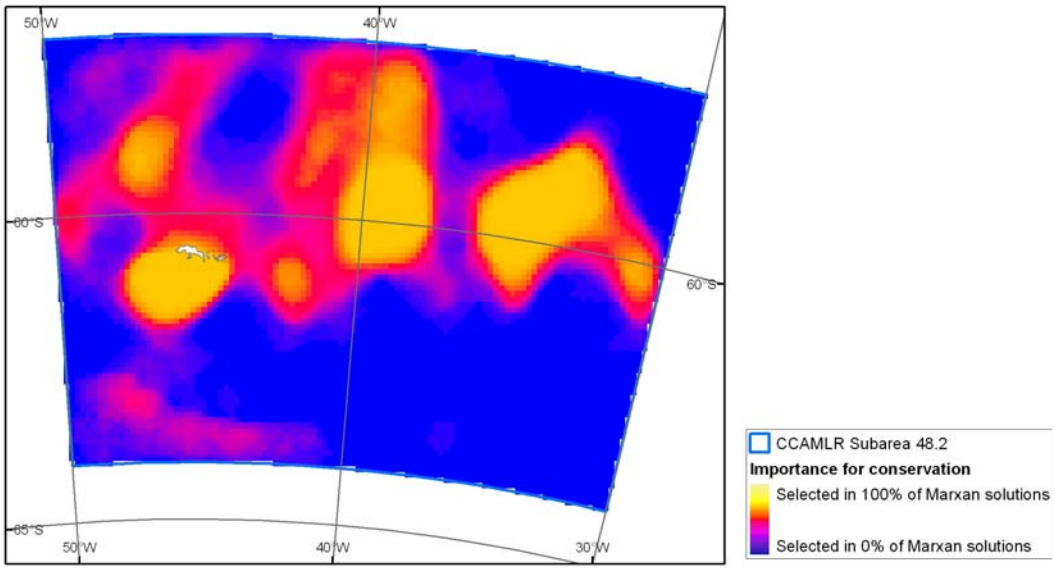


Figure 5*: Output from MARXAN analysis undertaken as part of a systematic conservation planning process for the South Orkney Islands (from WG-EMM-09/22, Figure 4b). Map shows the selection frequency of planning units within Subarea 48.2, when MARXAN analysis was run using input data on albatross and petrel foraging areas, penguin foraging areas, pelagic bioregions, chlorophyll concentration, sea ice concentration, and ocean front buffers (see WG-EMM-09/22 for full description of methods and results). Planning units selected most frequently are considered to have the highest importance for conservation, based on the defined conservation objectives.

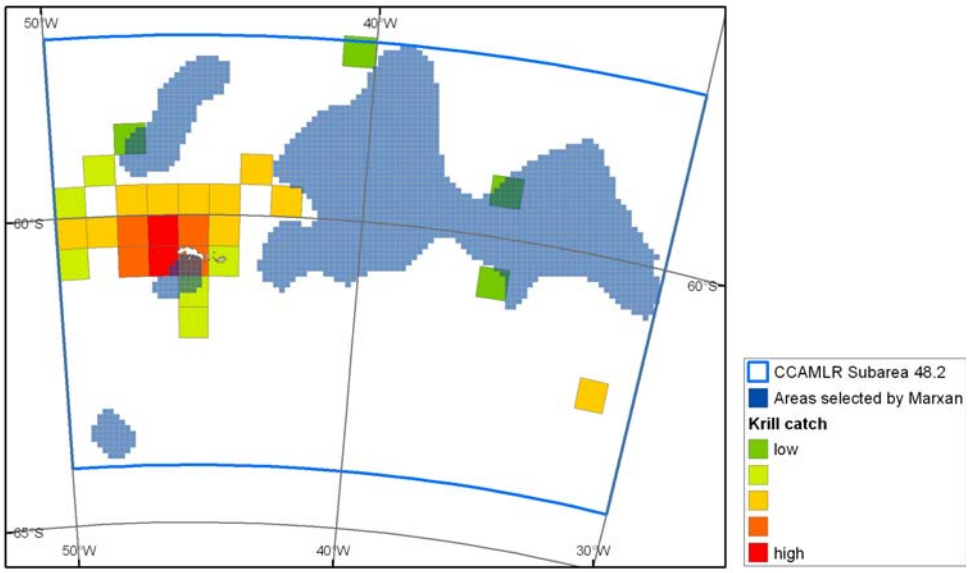


Figure 6*: Output from MARXAN analysis showing areas selected when an additional 'cost' factor was introduced for planning units in which krill fishing occurs (other input data are the same as in Figure 5) (from WG-EMM-09/22, Figure 4c; see WG-EMM-09/22 for full description of methods and results).

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

APPENDIX A

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(Bergen, Norway, 6 to 17 July 2009)

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APPENDIX B

AGENDA

Working Group on Ecosystem Monitoring and Management
(Bergen, Norway, 6 to 17 July 2009)

1. Introduction
   - 1.1 Opening of the meeting
   - 1.2 Adoption of the agenda and appointment of rapporteurs
   - 1.3 Review of requirements for advice and interactions with other working groups

2. Focus Topic: Second Workshop on Fisheries and Ecosystem Models in the Antarctic

3. Ecosystem effects of fishing for krill
   - 3.1 Krill
   - 3.2 Krill-dependent predators
   - 3.3 The krill fishery and scientific observation of the fishery
   - 3.4 Krill surveys and monitoring
   - 3.5 Climate impacts
   - 3.6 Feedback management strategies
   - 3.7 Advice to the Scientific Committee and collaboration with its other working groups

4. Ecosystem effects of fishing for finfish

5. Spatial management to facilitate the conservation of marine biodiversity
   - 5.1 Vulnerable marine ecosystems
   - 5.2 Protected areas
   - 5.3 Harmonisation of approaches (both within CCAMLR and across the Antarctic Treaty System)

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.

APPENDIX C

LIST OF DOCUMENTS

Working Group on Ecosystem Monitoring and Management
(Bergen, Norway, 6 to 17 July 2009)

WG-EMM-09/1	Draft Preliminary Agenda for the 2009 Meeting of the Working Group on Ecosystem Monitoring and Management (WG-EMM)
WG-EMM-09/2	List of Participants
WG-EMM-09/3	List of Documents
WG-EMM-09/4	Summary of observations aboard krill trawlers operating in the Convention Area Secretariat
WG-EMM-09/5	CEMP Indices: 2009 update Secretariat
WG-EMM-09/6	Krill fishery report: 2009 update Secretariat
WG-EMM-09/7	Summary of notifications for krill fisheries in 2009/10 Secretariat
WG-EMM-09/8	Encounters with vulnerable marine ecosystems in the Convention Area Secretariat
WG-EMM-09/9	Spatial protection and management of Antarctic marine biodiversity S. Grant (United Kingdom)
WG-EMM-09/10	Demographic studies of Antarctic krill in the South Orkney Islands area 2009, fieldwork and preliminary results B.A. Krafft and G. Skaret (Norway)
WG-EMM-09/11	On incidental mortality of Antarctic krill at krill fishery L. Pshenichnov (Ukraine)
WG-EMM-09/12	The risks of not deciding to allocate the precautionary krill catch limit among SSMUs and allowing uncontrolled expansion of the krill fishery up to the trigger level G.M. Watters (USA), S. Hill (United Kingdom), J.T. Hinke (USA) and P. Trathan (United Kingdom)
WG-EMM-09/13	The Ross Sea as a unique evolutionary site J.T. Eastman and D.G. Ainley (USA)

WG-EMM-09/14	Workshop Report – The Ross Sea: Science, Policy and the Public in a Pristine Marine Environment J. Weller and D.G. Ainley (USA)
WG-EMM-09/15	Antarctic toothfish and macrourids are likely important prey of Arnoux's beaked whales in the Ross Sea region R.L. Brownell Jr and D.G. Ainley (USA)
WG-EMM-09/16	The diet of the Antarctic toothfish in the Ross Sea J.T. Eastman and A.L. DeVries (USA)
WG-EMM-09/17	Chinstrap penguins: misunderstood and vulnerable monitors of ecosystem changes in the Scotia Sea region of Antarctica W.Z. Trivelpice, J.T. Hinke, A.K. Miller, C. Reiss, S.G. Trivelpiece and G.M. Watters (USA)
WG-EMM-09/18	Characterising krill fishery dynamics using a random walk model S. Kawaguchi, S. Candy and A. Constable (Australia)
WG-EMM-09/19	Japanese scientific observer activities for krill fishery in CCAMLR Convention Area from 2003/04 to 2007/08 fishing seasons M. Kiyota and T. Iida (Japan)
WG-EMM-09/20	Integrating Count Effort by Seasonally Correcting Animal Population Estimates (ICESCAPE): A method for estimating abundance and its uncertainty from count data using Adélie penguins as a case study J. McKinlay, C. Southwell and R. Trebilco (Australia) (*CCAMLR Science*, submitted)
WG-EMM-09/21	Krill consumption estimates for crabeater seals at the Antarctic Peninsula and the western Weddell Sea with special reference to SSMUs of Area 48.1 J. Forcada and P.N. Trathan (United Kingdom)
WG-EMM-09/22	Towards a system of marine spatial protection for the South Orkney Islands S. Grant, P.N. Trathan, J. Tratalos and J. Silk (United Kingdom)
WG-EMM-09/23	Multiple indicators suggest a strong ecosystem anomaly at South Georgia in 2009 S. Hill, M. Belchier, M. Collins, S. Fielding, E. Murphy, P. Trathan, H. Venables and C. Waluda (United Kingdom)
WG-EMM-09/24	Climate change and the Antarctic marine environment: management implications P.N. Trathan and D. Agnew (United Kingdom)

WG-EMM-09/25	Analysis of krill observer coverage in Subarea 48.3 D.J. Agnew, P. Grove, T. Peatman, R. Burns and C. Edwards (United Kingdom) (*CCAMLR Science*, submitted)
WG-EMM-09/26	Options for using unreplicated ecosystem monitoring data to detect impacts S. Hill, J. Forcada, P. Trathan and C. Waluda (United Kingdom) (*CCAMLR Science*, submitted)
WG-EMM-09/27	Spatial patterns in mackerel icefish diet provides insights into krill abundance and distribution M.A. Collins and C.E. Main (United Kingdom)
WG-EMM-09/28	Development of a new higher predator monitoring program at Cumberland Bay, South Georgia J. Ashburner and M. Belchier (United Kingdom)
WG-EMM-09/29	Analysis of scientific observer data from the Russian krill trawler *Maxim Starostin* in the South Orkney Islands region (Subarea 48.2) during the season 2008/09 D. Sologub (Russia)
WG-EMM-09/30	The research project to digitise historical Soviet krill fishing expedition data L. Pshenichnov and G. Milinevsky (Ukraine)
WG-EMM-09/31	Relevant issues in regards to the management of Antarctic krill fisheries in Area 48 L. Pshenichnov and G. Milinevsky (Ukraine)
WG-EMM-09/32	Detection of vulnerable marine ecosystems in the southern Scotia Arc (CCAMLR Subareas 48.1 and 48.2) through research bottom trawl sampling and underwater imagery S.J. Lockhart and C.D. Jones (USA)
WG-EMM-09/33	Demographic patterns of Antarctic krill (*Euphausia superba*) explain the spatial segregation of baleen whales (Mysticeti) around the South Shetland Islands, Antarctica J.A. Santora, C.S. Reiss, V.J. Loeb and R.R. Veit (USA)
WG-EMM-09/34	Rapid climate change and life history: how plastic is the Adélie penguin? J. Hinke, S. Trivelpiece and W. Trivelpiece (USA)
WG-EMM-09/35	Predicting the vulnerability of benthic, habitat-forming organisms to disturbance using life-history characteristics K. Martin-Smith (Australia)

WG-EMM-09/36	On the stratosphere ozone distribution asymmetry possible impact on krill based ecosystem G. Milinevsky (Ukraine)
WG-EMM-09/37	Southern Ocean Sentinel: Report of the First International Workshop in 2009 A.J. Constable
WG-EMM-09/38	Improving estimates of Adélie penguin breeding population size: developing factors to adjust one-off population counts for availability bias C. Southwell, J. McKinlay, L. Emmerson, R. Trebilco and K. Newbery (Australia) (*CCAMLR Science*, submitted)
WG-EMM-09/39	Update on progress in intersessional work from the Predator Survey Workshop C. Southwell (Australia), J. Forcarda (United Kingdom), M. Goebel, J. Hinke, H. Lynch (USA), P. Lyver (New Zealand), J. McKinlay (Australia), N. Ratcliffe (United Kingdom), D. Ramm, K. Reid (CCAMLR Secretariat), C. Reiss, W. Trivelpiece, S. Trivelpiece (USA) and P. Trathan (United Kingdom)
WG-EMM-09/40	Distribution and abundance of Antarctic toothfish in the Ross Sea S.M. Hanchet, S. Mormede and A. Dunn (New Zealand) (*CCAMLR Science*, submitted)
WG-EMM-09/41	Circulation in the Ross Sea sector of the Southern Ocean: representation in numerical models G.J. Rickard (New Zealand), M. Roberts (United Kingdom), M.J.M. Williams, A. Dunn, M.H. Smith and M. Pinkerton (New Zealand)
WG-EMM-09/42	A balanced model of the food web of the Ross Sea, Antarctica M.H. Pinkerton, J.M. Bradford-Grieve and S.M. Hanchet (New Zealand)
WG-EMM-09/43	Strong effects of environmental conditions on reproductive success of penguins at King George Island J. Hinke, C. Reiss and W. Trivelpiece (USA)
WG-EMM-09/44 Rev. 1	Properties of water dynamics and krill distribution in the South Sandwich Islands subarea S.M. Kasatkina and V.N. Shnar (Russia)
WG-EMM-09/45	Krill density estimates in CCAMLR Subarea 48.6 based on acoustic data collected during January–March 2008 G. Skaret, B.A. Krafft and R. Korneliussen (Norway)

WG-EMM-09/46	Area protection afforded to Cape Shirreff through CCAMLR and the Antarctic Treaty P.A. Penhale (USA) and V. Vallejos Marchant (Chile)
WG-EMM-09/47	Krill catches indicate the impact of the El-Niño – Southern Oscillation related processes on the distribution of krill biomass between subareas of the Atlantic sector of Antarctic Vassily Spiridonov (Russia)

Other Documents

WG-EMM-09/P1	An apparent decrease in the prevalence of 'Ross Sea killer whales' in the southern Ross Sea D.G. Ainley, G. Ballard and S. Olmastroni (*Aquat. Mamm.*, in press)
WG-EMM-09/P2	The importance of Antarctic toothfish as prey of Weddell seals in the Ross Sea: a review D.G. Ainley and D.B. Siniff (*Ant. Sci.*, in press)
WG-EMM-09/P3	A history of the exploitation of the Ross Sea, Antarctica D.G. Ainley (*Polar Rec.*, in press)
WG-EMM-09/P4	Impacts of cetaceans on the structure of Southern Ocean food webs D. Ainley, G. Ballard, L.K. Blight, S. Ackley, S.D. Emslie, A. Lescroël, S. Olmastroni, S.E. Townsend, C.T. Tynan, P. Wilson and E. Woehler (*Mar. Mamm. Sci.*, in press)
WG-EMM-09/P5	Quantifying movement behaviour of vessels in the Antarctic krill fishery S. Kawaguchi and S.G. Candy (*CCAMLR Science*, Vol. 16 (2009): 131–148)
WG-EMM-09/P6	Direct effects of climate change on the Antarctic krill fishery S. Kawaguchi, S. Nicol and A.J. Press (*Fisheries Manag. Ecol.*, in press)
WG-EMM-09/P7	Population assessments of gentoo penguins (*Pygoscelis papua*) breeding at an important Antarctic tourist site, Goudier Island, Port Lockroy, Palmer Archipelago, Antarctica P.N. Trathan, J. Forcada, R. Atkinson, R.H. Downie and J.R. Shears (*Biol. Cons.*, 141 (2008): 3019–3028)

WG-EMM-09/P8	Modeling predation by transient leopard seals for an ecosystem-based management of Southern Ocean fisheries J. Forcada, D. Malone, J.A. Royle and I.J. Staniland (*Ecol. Model.*, 220 (2009): 1513–1521)
WG-EMM-09/P9	Penguin responses to climate change in the Southern Ocean J. Forcada and P.N. Trathan (*Glob. Change Biol.*, 15 (2009):1618–1630, doi: 10.1111/j.1365-2486.2009.01909.x)
WG-EMM-09/P10	The risk to fishery performance associated with spatially resolved management of Antarctic krill (*Euphausia superba*) harvesting S. Hill, P. Trathan and D. Agnew (*ICES J. Mar. Sci*., doi:10.1093/icesjms/fsp172)