ANNEX 7

REPORT OF THE WORKING GROUP ON STATISTICS, ASSESSMENTS AND MODELLING
(St Petersburg, Russia, 14 to 22 July 2008)

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INTRODUCTION

Opening of the meeting

1.1 The second meeting of WG-SAM was held at Giprorybflot (State Research and Design Institute for the Development and Operation of Fishing Fleet), St Petersburg, Russia, from 14 to 22 July 2008. The meeting was convened by Dr A. Constable (Australia).

1.2 Prof. V. Romanov, General Manager, Giprorybflot, welcomed the participants and provided an overview of the Institute's function. The Institute is a leading research and development centre for the fishing industry, and was directly involved with the construction and operation of the fishing fleet of the former Soviet Union. Giprorybflot's activities span more than 70 years, and include the design of fishing vessels, equipment and processing plants, the development of technical specifications and industry standards, and research in the fields of post-harvest technology, computer science and information systems.

1.3 Dr Constable thanked Prof. Romanov for his warm welcome, and Giprorybflot for hosting the meeting with the support of the State Committee for Fisheries. Dr Constable also welcomed the participants (Appendix A).

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

Adoption of the agenda and organisation of the meeting

1.5 The provisional agenda was discussed and adopted without change (Appendix B).

1.6 Documents submitted to the meeting, and WG-EMM documents referred by the authors for consideration by WG-SAM, are listed in Appendix C. At the request of the Convener, the papers from the WG-EMM Predator Survey Workshop (Hobart, Australia, 16 to 20 June 2008) were submitted to WG-SAM for information and consideration under Item 5.2 (Krill-based food-web models).

1.7 WG-SAM also agreed to consider the technical contents of two papers (WG-EMM-08/30 and 08/44) which had been submitted after the deadline for document submission to WG-SAM.

1.8 WG-SAM's deliberations under the krill-related Items 5.2 (Tools for population, food-web and ecosystem modelling) and 6.3 (Evaluation of management strategies) were led by Dr C. Jones (former Convener of WG-SAM) because of Dr Constable's direct contributions to the development of ecosystem-based management procedures (WG-SAM-08/15 and 08/16).

1.9 The report was prepared by Drs D. Agnew (UK) and A. Brandão (South Africa), Mr A. Dunn (New Zealand), Drs P. Gasyukov (Russia), M. Goebel (USA), S. Hanchet (New Zealand), S. Hill (UK) and R. Hillary (UK), Mr J. Hinke (USA), and Drs C. Jones (USA), S. Kasatkina (Russia), S. Kawaguchi (Australia), D. Middleton (New Zealand), É. Plagányi (South Africa), D. Ramm (Data Manager), K. Reid (Science Officer), C. Reiss (USA), G. Watters (USA) and D. Welsford (Australia).

PARAMETER ESTIMATION

Parameters used in toothfish assessment

2.1 The Working Group considered WG-SAM-08/8 and 08/14 under this agenda item. The Working Group agreed that the details of the discussion of WG-SAM-08/8 be contained under Item 3.2 (paragraphs 3.16 to 3.25) and of WG-SAM-08/14 under Item 5.1 (paragraphs 5.1 to 5.8).

Size and weight data for toothfish in East Antarctica

2.2 Dr V. Bizikov (Russia) presented WG-SAM-08/9 on behalf of the authors, describing a study conducted on *Dissostichus mawsoni* captured SSRU 5841G. The paper described the results of using factory-measured weights of processed individual toothfish, in combination with conversion factors and length–weight relationships, to derive a length frequency for the whole catch (2 000 fish). This differed in some respects, particularly in the numbers of fish between 50 and 90 cm length, with the length frequency measured by the scientific observer (300 fish).

2.3 Given the disparity at the smaller sizes between the measured fish by observers and reconstructed fish lengths, the possibility of whether smaller fish were detected by the observers was raised. In response, it was noted that the rarity of small fish means that they may be missed by observers but are caught in the processed fish, given the higher number of measurements of processed fish.

2.4 The Working Group also considered that the observer data may demonstrate a systematic bias, for instance if scientific samples were obtained from the deeper sections of a longline or if smaller fish are preferentially selected for tagging and therefore removed from length-frequency samples. The Working Group encouraged work by Members to investigate the potential for such biases arising in observer datasets.

2.5 The Working Group further noted that previous work by WG-FSA showed that the length of fish being processed is an important factor to consider when estimating conversion factors (SC-CAMLR-XXI/BG/27), and therefore that conversion factors as a function of size would need to be considered when reconstructing size distributions from processed toothfish.

2.6 The Working Group encouraged Members to submit studies on the effect of fish length on conversion factors from *Dissostichus* spp. fisheries.

2.7 The Working Group also requested that WG-FSA consider the impacts of using reconstructed size distributions in fishery assessments as described above, and requested that TASO consider the feasibility of collecting all individual processed weights from longline vessels throughout the Convention Area.

Seabed areas in Subarea 48.3

2.8 Dr Agnew presented WG-SAM-08/10, describing the development of an updated bathymetric dataset for South Georgia and Shag Rocks, based on the use of bathymetric data arising from multi-beam swath mapping from research vessels, and single-beam echo soundings from fishing and research vessels.

2.9 The Working Group noted that this newly compiled dataset has been used to update seabed area estimates for the shelf <500 m deep, and will be used to refine biomass estimates of demersal fish species from trawl surveys, and to assist with the appropriate depth stratification of such surveys. The revised dataset indicated that point estimates of depth on previous charts were inaccurate, and the seabed areas calculated and used in previous surveys were between 0.9 and 1.33 times the values calculated from the revised dataset.

2.10 The Working Group recommended that Members consider collating bathymetric data to develop updated bathymetric grids for other areas where recent multi-beam data or single-beam echo soundings exist and trawl surveys are conducted.

STOCK AND BIOLOGICAL ASSESSMENT METHODS

Exploratory fisheries in Area 58

3.1 Dr Agnew introduced WG-SAM-08/4 which applied four different approaches to estimating stock size in Divisions 58.4.1 and 58.4.2: comparative CPUE analysis, local depletions, a constant recruitment population model and mark–recapture data. The analysis presented in WG-SAM-08/4 also contributed to understanding other issues of importance to the assessment, such as stock identity and recruitment. However, it was noted that some of the records of *D. eleginoides* in these divisions may be mis-identified *D. mawsoni*.

3.2 The least successful approach used mark–recapture data: very few tags have been returned from this fishery, despite 3 000 releases, suggesting much larger population sizes compared to the other three methods. Clearly, some of the assumptions of the method are not correct; for instance, fish could be moving rapidly away from the SSRUs where they are tagged (two of the four recaptured fish have moved between SSRUs, one travelling 150 km and one 1 690 km after 1 year at liberty), natural and tag-induced mortality rates might be higher than anticipated, fishing may still be too localised to effectively recapture tags, or there may be implementation problems causing the data to be of variable quality.

3.3 The comparative CPUE analysis utilises the fact that some vessels have fished both in the Ross Sea and Divisions 58.4.1/58.4.2. It assumes that catchability by these vessels in both areas is the same, so that standardised CPUE from SSRUs in Division 58.4.1/58.4.2 can be translated into estimated density of toothfish by comparison to the estimated density in the Ross Sea. The depletion analysis utilises local depletions of toothfish in small regions within SSRUs to estimate biomass and density in these regions. Both methods rely on calculations of fishable area within SSRUs to estimate total population biomass.

3.4 WG-SAM encouraged further development of these approaches to explore and characterise the uncertainty in the assessments that could be used by WG-FSA to consider appropriate precautionary catch levels. In particular, uncertainty in CPUE, biomass estimates, fishable area and toothfish density distribution across an SSRU should be characterised.

3.5 The characterisation of uncertainty in fishable area and density distribution will be difficult. WG-SAM-08/4 assumed that the area between 500 and 2 000 m in an SSRU is the fishable area and that the density encountered by the fleet applies evenly across the fishable area of an SSRU. However, in most cases the actual fishing pattern has been restricted to a small part of the fishable area between 800 and 1 800 m, and there is very little information from which to understand the distribution of toothfish density across the entire fishable depth range of an SSRU. It is suspected that toothfish density is not uniform across the area, and is most likely higher in the areas that have been selected by the fleet for fishing.

3.6 WG-SAM-08/5 detailed both a generic methodology of performing stock assessments in situations where data are limited (in terms of age/length structure and numbers of tags released and recaptured) that could form a bridge between the initialisation of data collection and tagging programs, and the point at which these data are usable in terms of an age/length-structured stock assessment. As an example of the potential usefulness of the approach, an initial assessment of *D. eleginoides* in Division 58.4.3a incorporating catch data (legal and IUU estimates) and the available mark and recapture data was undertaken.

3.7 While general support was given for the approach, there was a clear understanding that, when performing assessments on such limited data, care is needed to avoid the potential of errors in key data, such as fish recaptures, having a large influence on the assessment results and any potential catch limits set. With respect to the results for *D. eleginoides* from Division 58.4.3a, it was noted that, even when considering the potential for small errors in the key data, a catch limit of 250 tonnes that is currently set in this area might be too high, given the catch limits coming from the assessment (assuming a contained stock with mixed tagging data) did not exceed 120 tonnes.

3.8 The Working Group agreed that prior uncertainty in the Pella-Tomlinson shape parameter should be considered in future applications of the approach described in WG-SAM-08/5.

3.9 WG-SAM-08/6 presented a simple method by which catch limits and tagging rates (per tonne of fish landed) might be balanced to best achieve a sufficiently accurate abundance estimate from a tagging program. To test the model, the predicted variation in toothfish abundance in Subarea 48.3 was compared between this method and the variation coming from the actual stock assessment. The results were comparable, but demonstrated that the model would likely be a slight underestimator of the predicted CV in abundance. However, it was noted that information on 'additional' variance from the stock assessments could provide a suitable conversion factor with which to account for this apparent underestimation of uncertainty. As a more direct application of the model, initial stock size estimates and tagging rates for toothfish in Subarea 48.4 were used to assess whether the current catch limit (100 tonnes) would give a predicted abundance CV of around 30%, and it was found that this would be likely to achieve a CV of this level.

3.10 The Working Group agreed that an approach to managing new and exploratory fisheries, with these kinds of emerging stock assessment datasets, might be able to be developed by using all three of the approaches detailed in WG-SAM-08/4, 08/5 and 08/6. Relative CPUE analyses might be used to give approximate initial estimates of biomass from which the tagging rate and catch limit can be adjusted. This would enable fishing to proceed and would deliver tagging data that can be used in an initial stock assessment from which the catch limit can be adjusted from a more informed position. Eventually data would be obtained with which a more realistic age/length-structured assessment can be performed. Members were encouraged to submit to WG-FSA further analyses on these approaches, along with discussions on how to account for uncertainty in the orderly development of exploratory fisheries.

Ross Sea toothfish

3.11 Dr Agnew presented WG-SAM-08/7 which analysed tag data from the Ross Sea toothfish fishery. A dataset of all possible combinations of release nation, recapture nation, release year and recapture year for tags released and recaptured in the same SSRUs on the slope of Subarea 88.1 was compiled for the years 2003–2006. Recapture rate was expressed as tags captured/tags released/fish scanned (caught). The paper used regression techniques to determine the effects of release nation and recapture nation on the reported tag-recapture rates.

3.12 There was a large number of combinations of release year, recapture year, SSRU, release nation and recapture nation, with 193 recaptures available for the analysis. The paper noted that fishing had not been consistent enough between nations, locations and over time to allow the analysis to be definitive. In many cases, release or recapture nation effects were not significant. However, in the cases where significant differences existed, recapture rates were usually highest with released and recaptured fish from New Zealand vessels, and there was some evidence for suggesting that recapture rates were highest when the nation releasing and recapturing the tagged fish was the same.

3.13 The Working Group thanked the author for carrying out the analysis and noted that the results supported and extended those reported by New Zealand scientists at WG-FSA-2007 (WG-FSA-07/40). Both analyses suggested that nation effects contributed to the high variability in tag-recapture rates. Dr Hanchet suggested that it might be useful to examine the variability in tag-recapture rates at South Georgia, to determine whether the observed variability in the Ross Sea was consistent with that experienced in other parts of the Convention Area.

3.14 There were several suggestions for examining and/or improving detection rates. These included the use of PIT tags on a subset of tagged fish, using a rewards system to encourage reporting of tags, and direct experimentation to compare recapture rates from vessels fishing side by side. There was general support for these approaches but it was noted that they could affect the vessel behaviour with respect to reporting rates. The Working Group referred these points for discussion to TASO and WG-FSA.

3.15 The Working Group noted that the current assessment in the Ross Sea used tag data from New Zealand vessels only and agreed that it was important to consider data from other vessels. However, given the strong nation effects in the model, and other possible data quality issues, it was difficult to determine what additional fleets should be included in future assessment runs. It was also noted that such data quality issues were likely to be at the vessel level rather than at the nation or fleet level.

3.16 Dr Gasyukov presented WG-SAM-08/8 which described and compared some properties of the TISVPA model presented in the paper by Drs V. Vasiliev and K. Shust (Russia), and the CASAL model. The paper discussed some of the advantages of the estimation methods of the TISVPA as compared with CASAL. The authors noted that the methods of estimation used in TISVPA were designed to allow robust estimation of parameters using median absolute deviations and winsorisation. The authors noted that these methods can have some advantages over more traditional methods using likelihoods, can be more effective in cases where data are noisy or contain a large number of outliers, and results from the use of such methods may be more robust and less prone to bias. However, the authors also noted that the current implementation of TISVPA had some difficulties combining the various components of the objective function, as is currently done with CASAL.

3.17 The paper proposed to evaluate the TISVPA and CASAL models using parameters used for *D. mawsoni* in the Ross Sea. The authors noted that it would be necessary to either develop an operating model (OM) for *D. mawsoni* in the Ross Sea, or use existing simulation software to simulate datasets with errors arising from various statistical processes. These data could then be used to carry out comparisons of the performance of both models, and to assist the Working Group in understanding the reasons for different estimates of stock size and resulting catch limits from the models. The paper proposed that the Working Group consider development of a new approach that could lead to an agreed assessment method that included both robust estimation methods (TISVPA features) and statistically correct integration of data using likelihoods (CASAL features).

3.18 Dr Gasyukov noted that the CASAL model had been thoroughly tested by New Zealand scientists and WG-FSA, and has been used to assess stocks in both New Zealand and CCAMLR. The TISVPA model has been thoroughly tested by the ICES working groups on stock assessment methods and has been included in the list of available software for use by ICES working groups. Dr Gasyukov also noted that it was important to understand the reasons that the models had given different estimates of stock status when applied to data from the same region.

3.19 Dr Hillary agreed that robustness to data outliers was important in assessments. However, he considered that the concerns noted in the paper related more to normal likelihoods than to the overdispersed multinomial and binomial likelihoods used in CASAL. He also questioned the citation of Hillary and Agnew (2006) as that reference did not provide a method for calculating absolute abundance from tag data.

3.20 The Working Group noted that it was unclear whether the differences in results from the TISVPA and CASAL models arose due to model differences, differences in the input data, differences in the weights given to different datasets, or a combination of these factors.

3.21 Dr Jones noted that in 2007, WG-SAM had given general guidance on the process to be followed in the review of new methods (SC-CAMLR-XXVI, Annex 7, paragraph 6.3). Furthermore, WG-FSA had given specific guidance on the information that would have to be provided for WG-SAM to adequately review the TISVPA method (SC-CAMLR-XXVI, Annex 5, paragraph 4.27):

(i) A full paper detailing the method and its implementation needs to be compiled from existing work and presented to WG-SAM with further consideration of its implementation as discussed in the following points.

(ii) Simulated (theoretical) data need to be developed for a number of fishery–stock scenarios and those data need to be analysed using CASAL and the TISVPA in order to compare how the two methods perform using data from known population and fishery attributes.

(iii) Mathematical and statistical details of how the input data for the TISVPA are generated from the available datasets used in CASAL, including any pooling of the data in space and/or time, need to be provided.

(iv) Descriptions need to be provided on the methods for deriving the CPUE indices, including how the indices are standardised to account for differences and variability between vessels, times of year, location of fishing and so forth.

(v) Descriptions are needed on how uncertainty is treated in both the assessments and evaluation of yield.

3.22 The Working Group agreed that this had not been carried out and, in the absence of the authors, was therefore unable to complete an evaluation of the TISVPA method.

3.23 The Working Group agreed that it was often informative to carry out assessments using alternative models. It recalled that it had previously completed detailed comparisons of CASAL and ASPM assessments of toothfish in Subarea 48.3. In this instance, when the models were provided with identical datasets, the model outputs were very similar. The Working Group noted that it was important that the models were provided with identical data and that the subsequent treatment and fitting of those data within the models was well understood.

3.24 Dr Constable noted that in WG-SAM-08/8 the authors of the TISVPA method had indicated their commitment to the process requested by WG-SAM and should be encouraged to provide the information required for WG-SAM to review the method fully at its next meeting. He also noted that the use of simulated data from an OM was an important aspect of the validation process, and that simCASAL (Bull et al., 2008) could be used for this purpose.

3.25 The Working Group reiterated its advice from last year and recommended that the authors carry out the program of work required for evaluation of the model outlined by WG-FSA.

3.26 Dr Middleton presented WG-SAM-08/13 which developed metrics related to the quality of fishing event, catch and biological sampling data from fishing trips. Application of these metrics to data from the Ross Sea toothfish fishery illustrated the sometimes substantial variation in the quality of data from different trips. A cluster analysis of the metrics identified two groups of trips. Tag-recapture rates from trips classified into one group were consistently and substantially higher than those of the other group.

3.27 It was proposed that these measures could be used in two ways. First, individual metrics may provide useful guidance on the use of particular datasets from trips in an assessment. The Working Group noted that the quality of data required would vary depending on the nature of the analysis, and that the effects of variation in data quality would have to be considered on a case-by-case basis. Second, that a clustering analysis of the measures collectively may also provide an objective basis for the selection of the tagging dataset to be used in a particular assessment.

3.28 Dr Watters noted that the recorded catch diversity may be a useful proxy for the attention given to the scanning for tag recoveries. The Working Group encouraged the further development of the methodology, in conjunction with that of WG-SAM-08/7, to provide a basis for selecting tag datasets for assessments. The Working Group recommended that WG-FSA provide specific guidance on the metrics considered most useful for distinguishing data quality with respect to assessments.

3.29 Dr Constable suggested that rather than eliminating data, it may be possible to include both groups in an assessment as different fisheries. In the first instance, sensitivity tests, using the different datasets separately and combined, could be used to explore the degree to which the assessment might be impacted by these differences. Mr Dunn agreed that this may be feasible in the medium term. Dr Agnew supported further evaluation of the effects of retaining poorer-quality data in assessments. The Working Group agreed that this was a useful approach and recommended that further work be carried out during the intersessional period to identify alternative datasets which could be used in the next assessment of the Ross Sea toothfish fishery.

3.30 The Working Group noted that the methodology would have uses beyond the selection of data for stock assessment. These include the use of fishery data by other working groups, such as WG-EMM, and the performance management and training of observers. The Working Group also considered that a centralised system of data quality assessment by the Secretariat may provide both for rapid feedback on the quality of data from individual trips, and simplify the determination of data quality by other working groups. The Working Group recommended that ad hoc TASO consider the issues raised by the paper.

Management advice

3.31 The Working Group referred suggestions for examining and/or improving detection rates for discussion to ad hoc TASO and WG-FSA (paragraph 3.14).

3.32 The Working Group recommended that WG-FSA provide specific guidance on the metrics considered most useful for distinguishing data quality with respect to assessments (paragraph 3.28).

3.33 The Working Group recommended that ad hoc TASO consider the issues raised by WG-SAM-08/13 on data quality (paragraphs 3.26 to 3.28).

Krill

3.34 Dr Kasatkina presented WG-SAM-08/P1 which outlined proposals on krill survey data processing. The application of an Aitcheson delta distribution is proposed for estimating statistical characteristics of trawl survey catch values including the mean, standard deviation, confidence intervals and probability density function (delta distribution). This involved post-stratifying the survey area to determine strata of equal probability to detect certain values of krill biomass density. Delineation of such strata for specified krill densities should be made using PDFs from survey data. It is suggested that subsequent biomass estimation and summarising through delineated strata will improve accuracy of survey results.

3.35 Dr Kasatkina also presented WG-SAM-08/P2 which further indicated that representative sampling can only be made within areas with statistically homogeneous distributions of marine organisms. The author proposed to include stratifying a forthcoming survey area to provide strata with statistically homogeneous distributions of target species based on data from previous observations, and to allocate sample effort among these strata. This paper recommended minimising error in acoustically derived density estimates using methods of statistical averaging if a random component of error is more than twice its regular component.

3.36 Dr Agnew questioned whether some of the proposals outlined in WG-SAM-08/P1 could be used for analysis of catch data from commercial fisheries. However, the Working Group was unable to interpret the document in order to establish this possibility.

3.37 Since WG-SAM-08/P1 and 08/P2 were presented in Russian, the Working Group encouraged the author to prepare a combined manuscript in English for the next meeting of WG-SAM, with examples of analyses included to allow a comparison of proposed and traditional data processing methods. Comparing data from the traditional method and this method may be useful to try to understand what the advantages of a trawl survey might be and how that might improve on an acoustic survey.

Seals, penguins and flying seabirds

3.38 Dr Goebel reported on the Predator Survey Workshop held in Hobart, Australia, 16 to 20 June 2008. The workshop was convened by Dr C. Southwell (Australia) and was attended by 17 participants. Twelve papers were considered at the workshop covering topics relating to penguins, seals and flying seabirds. The 11 species considered at the workshop were selected based on overall abundance and krill consumption estimated in Croxall et al. (1985): penguins (4), seals (2) and flying seabirds (5). They were reviewed with respect to biology as it pertained to abundance estimates, distribution, uncertainties in estimation procedures and gaps in our current knowledge. The workshop concluded with four categories of recommendations to WG-EMM. These were: immediate (10), short-term intersessional (4), medium-term intersessional (4), and future work (4). Future work included considerations beyond estimating abundance of predators to estimating prey consumption for each species of predator. The full report was available as WG-EMM-08/8.

ADVICE ON METHODS FOR USE IN WORK OF SC-CAMLR

Research designs in exploratory fisheries

4.1 The exploratory research plan for Divisions 58.4.1 and 58.4.2 was designed to concentrate fishing in alternate SSRUs in an attempt to develop a better understanding of the distribution of toothfish in these areas and to develop mark–recapture-based assessments. The first objective has been partially met, but despite almost 3 000 tags having been released, recapture rates are much lower than would be expected and the tag data currently suggest much higher population sizes than any of the alternative methods presented in WG-SAM-08/4. Some of the assumptions in the mark–recapture experiment are clearly not being met (see paragraph 3.2).

4.2 The Working Group therefore advised WG-FSA that, given the current results, the mark–recapture data are unlikely to provide accurate assessments of local abundance or stock size in the short term. Tagging should continue, however, so that if tag mortality and movement parameters are better understood in the future, these data may be utilised in either integrated assessments (such as the CASAL assessments being undertaken in the Ross Sea) or the methods described in WG-SAM-08/5.

4.3 The Working Group advised that WG-FSA could consider providing management advice for Divisions 58.4.1 and 58.4.2 using comparative CPUE and local depletion methods (WG-SAM-08/4) as a basis for developing preliminary assessments in the short term, with the modifications noted in paragraphs 3.4 and 3.5. The Working Group requested that WG-FSA also consider methods to acquire additional information necessary to develop these methods further. This may include defining specific research plans, including set positions and consistent gear configurations for research hauls, to obtain improved information about the density distribution of toothfish across SSRUs and within likely fishing grounds.

4.4 In respect of Division 58.4.3a, WG-SAM recommended that the methods described in WG-SAM-08/5 could be used this year to provide management advice for the *Dissostichus* spp. fishery in this division.

4.5 The Working Group also discussed the value of the 10 tonne toothfish research limits as applied by commercial vessels operating in otherwise closed fisheries. The other use of these limits, to enable research trawl surveys, was not considered.

4.6 Results from WG-FSA-07 (SC-CAMLR-XXVI, Annex 5, paragraphs 5.10 to 5.23) and WG-SAM-08/6 demonstrate that 10 tonne catch levels are not high enough to provide useful mark–recapture estimates of population size, unless tagging rates are very high (more than 10 tags per tonne) and the research operation is persistent, showing commitment to fish in a single area over a number of fishing seasons.

4.7 An alternative use of the 10 tonne research operations is to explore the distribution and density of toothfish in an area. For this to be effective, the vessel’s operational characteristics should be well known, it should set many short lines (5 000 hooks maximum) rather than a few long lines, and the position of lines should be determined to the extent possible in advance to conform to either a fixed position or randomised strategy with clear objectives.

4.8 Tagging at the lower rate of 3 tags tonne^{-1} is potentially useful in such research to advance understanding of toothfish movements rather than in generating estimates of stock size, but there would need to be a large number of tags before the probability of recapture of these tags would be sufficient in such studies.

4.9 Interpreting the data from 10 tonne research operations by new vessels in new areas may be difficult, but data from vessels which have a history of several years of fishing and provision of comprehensive and high-quality data in known (assessed) areas may be more readily interpreted.

Establishing precautionary catch limits in the absence of research in exploratory fisheries

4.10 The Working Group noted the difficulty encountered in using tagging data from the exploratory fisheries to develop assessments in Divisions 58.4.1 and 58.4.2 and other divisions. The Working Group proposed a procedure to be considered by WG-FSA to progress to an assessment in these and similar areas:

(i) In the absence of reliable tagging information, the methods presented in WG-SAM-08/4, utilising comparisons between assessed areas and unassessed areas and local population depletions, with the modifications to incorporate the uncertainty noted above, could be used as a proxy for an initial estimate of population density.

(ii) The method outlined in WG-SAM-08/6 could then be used to decide a suitable tagging rate.

(iii) Once tagging data are available and appropriate assumptions have been met (e.g. assumptions of mixing and overlap in the size and spatial distribution of tagged fish and those targeted routinely by the fishery), the methods presented in WG-SAM-08/5 could be used to refine the assessment until other data time series are of sufficient quality to allow the development of integrated age- or length-based assessment methods.

4.11 However, the Working Group noted that it is important that these approaches capture uncertainty adequately, as, for example, previous attempts to use seabed areas and population densities from Subarea 48.3 had resulted in a higher estimate of yield in the Ross Sea (SC-CAMLR-XIX, Annex 5, Table 32) than that obtained with the subsequent integrated assessment using tag data with the homogenous mixing assumption (SC-CAMLR-XXVI, Annex 5, Appendix I).

Approaches to minimising the effects on assessments of changing fishing practices

4.12 The Working Group recognised that there were two situations in which fishing practices may change:

(i) In the case where change is gradual, this should be monitored and controlled, so that there is sufficient overlap between new and old gear for good estimates to be made of the relative impacts on assessments of the gear change, for instance the relative catchability or selectivity of the gear. In toothfish assessments, this overlap period should be at least five years. More rapid change-over could be achieved if some experimental trials were organised which controlled for different gear effects and increasing capability as vessels learn to use new gear types, rather than having to separate them statistically.

(ii) In the case where change needs to be rapid, such as with the introduction of a new mitigation method, this introduction will usually follow some experimental development of the mitigation method. These experiments should also be used to investigate the effect of the new method on catchability and selectivity, again controlling for as many other gear effects as possible.

Use of BRTs in bioregionalisation

4.13 Dr Hanchet provided an overview of WG-SAM-08/12, which applied a multivariate statistical technique called BRTs as a method of predicting spatial distributions from discontinuous biological data. The method allows fitting complex and scale-dependent relationships between species abundance and environmental data, and is applied to measurements of an abundant zooplankton species (*Oithona similis*) from CPR deployments, taken primarily in East Antarctica, and 13 environmental data layers. The fitted model was then used to predict zooplankton abundance and presence/absence in locations where CPR data were not available.

4.14 The authors concluded that this method was able to successfully detect and define a relationship between long-term broad-scale environmental conditions and observed patterns of biological presence and abundance for *O. similis*. They noted factors that affect the correlation between environmental data and biological distributions, and suggested that larger and longer-lived species, or species with the ability to seek preferred habitat niches, and in environments that exhibit less short- and small-scale spatio–temporal dynamics, are likely to exhibit stronger correlations with environmental data.

4.15 The Working Group generally agreed that the BRT approach is a useful method that can be applied toward bioregionalisation and biogeography, and for ecosystem modelling. However, a number of issues and concerns regarding the utility of this technique, as well as the uncertainty surrounding the extrapolation from local datasets to larger scales, were raised.

4.16 Most Working Group participants agreed that the cross-validation approach used by the authors was appropriate, and some noted that this type of cross-validation approach should be used whenever possible when this type of analysis is attempted, whether or not BRTs alone are used.

4.17 There was some concern regarding the presentation of the uncertainty when extrapolating to larger scales. The Working Group noted the box and whisker plots were useful in this regard, and it was suggested that spatial maps of the residuals might be useful to examine the patterns of bias and uncertainty in the BRT predictions. Further, it was suggested that the variability in the more global datasets that form the layers, which themselves have uncertainty, should also be included in the modelling.

4.18 The Working Group also discussed the efficacy of the environmental overlap statistic, and some members believed that a formal test of the sensitivity of these overlap curves could be useful. Others thought that this information could be inverted and used to predict what the environmental overlap might be. This could then form the basis of a formal statistical test and prediction of the BRT mapping.

4.19 The Working Group encouraged the authors of WG-SAM-08/12 to continue developing this approach and suggested that this could best be pursued through a correspondence group involving statistical experts familiar with BRTs.

Response of white-chinned and grey petrel populations to fisheries and environmental factors

4.20 Ad hoc WG-IMAF had asked for a detailed analysis of petrel population responses to fisheries and environmental factors (SC-CAMLR-XXVI, Annex 6, paragraph I.8(ii)). No papers were submitted on this specific topic; however, WG-SAM-08/P3 introduced a seabird population dynamics model as a potential tool for use by WG-IMAF.

4.21 Mr Dunn gave a presentation of WG-SAM-08/P3, a draft user manual for SeaBird, a generalised age- and/or stage-structured seabird population dynamics modelling package. While the model is still undergoing development, it has been used for the assessment of a Buller's albatross (*Thalassarche bulleri*) population in New Zealand. The software is designed to model seabird populations and assess the effects of fishing on their variability. It was developed to integrate a wide variety of data to generate outputs that could be used to inform management decisions. The model specification is designed for flexibility, allowing a population to be structured on age, life stage, sex or behaviour (e.g. breeder or non-breeder). Interactions with fisheries can be modelled and the user can choose the sequence of events in the model years. Estimation can either be by maximum likelihood or Bayesian.

4.22 SeaBird shares many features with CASAL, in that the model is partitioned into three sections (population, estimation and output), it shares the concept of partitioning within a year (i.e. time steps less than a year), and the command-block format used for input files. Differences between SeaBird and CASAL include: concepts relating to model parameters which are fundamental and explicit in SeaBird but either limited (and implicit) or missing from CASAL; the way SeaBird treats mark–recapture observations, where the sample is not considered random and the main aim is to estimate survival and transition probabilities and not abundance; and finally, the concept of catchability in CASAL is equivalent to visibility in SeaBird.

4.23 Mr Dunn noted that, as SeaBird allowed for a great deal of flexibility in specifying population dynamics, observations and initialisation, modellers would need to exercise caution to ensure that model structure and data inputs were correctly specified. Mr Dunn also noted that the package, manual and source code were available on request and that the authors had offered their assistance if others wished to develop models using SeaBird.

4.24 The Working Group thanked the authors of WG-SAM-08/P3 for this valuable contribution.

Joint CCAMLR-IWC Workshop

4.25 Dr Constable gave a brief summary of the terms of reference and goals for the upcoming Joint CCAMLR-IWC Workshop to be held in Hobart, Australia, from 11 to 15 August 2008 referring to papers submitted for consideration by WG-EMM (WG-SAM-08/14 and 08/15). He emphasised that CCAMLR-IWC welcomed any additional attendees and was open to remote involvement, through correspondence, during the meeting. He stressed the view that the workshop is part of an ongoing process to help the development of models and provide metadata. It is envisaged that one output will be metadata that will be available on the CCAMLR website and available for all CCAMLR modellers.

4.26 Dr R. Holt (USA) expressed a concern that CCAMLR and IWC had different rules of data access and that this would have to be addressed at the workshop.

TOOLS FOR POPULATION, FOOD-WEB AND ECOSYSTEM MODELLING

Dissostichus spp. population models

5.1 Mr Dunn presented WG-SAM-08/14, the development of a spatially explicit, age-structured, statistical, catch-at-age population dynamics model for modelling movement – Spatial Population Model (SPM). SPM is an aggregate movement model suitable for use with large numbers of areas, and is implemented as a discrete time-step state-space model that represents a cohort-based population age structure in a spatially explicit manner. The model is parameterised by both population processes (i.e. ageing, recruitment and mortality), as well as movement processes defined as the product of a set of preference functions that are based on known attributes of spatial location. SPM was designed to be flexible, allow for the estimation of both population and movement parameters based on local or aggregated spatially explicit observations, and optimised for speed of computation.

5.2 A preliminary spatial movement model for *D. mawsoni* in the Ross Sea implemented in SPM was presented. The model was a single-sex model that categorised fish as immature, mature or spawning. Observations included within the model were spatially explicit commercial catch proportions-at-age and CPUE indices. The authors noted that the model results were preliminary, but that the initial outputs were encouraging. The preliminary model captured key aspects of the current understanding of *D. mawsoni* distribution, suggesting immature fish were located in the southern Ross Sea on the continental shelf, mature fish were located on the continental slope, and spawning fish were located on the northern banks of the Ross Sea. The results also suggested that parameterising of movement based on latitude, depth and distance provided a significantly better fit to the observations than a model where depth was ignored.

5.3 Mr Dunn noted that SPM is an estimation model, and allows the use of AIC/BIC or other statistics to compare between models, and that this had the potential to assist in defining plausible movement OMs for evaluating assessment models.

5.4 The Working Group noted that some aspects of the preliminary model should be developed, including the inclusion of spatially explicit tag and maturation-state data, as well as considering the impact of different levels of spatial aggregation. Some consideration could also be given to how regional variability in recruitment, catchability coefficients (q), and other processes may be included within the model. Further, that methods to derive spatially explicit sampling error values and methods to include additional process error will need to be developed.

5.5 The Working Group encouraged further development of SPM, including processes and observation classes to incorporate year-class variability, stock-recruitment relationships, as well as tag–release/recapture and maturation-state observations. The Working Group noted that the implementation of the MCMC algorithm in SPM is only partially complete, and there is some further work on parallelisation algorithms for MCMC that could be investigated. Also, in order to address the assessment model adequacy, SPM needs to be modified to allow simulation of observations from underlying movement parameters.

5.6 Finally, once adequate models for *D. mawsoni* in the Ross Sea have been developed using SPM, the current assessment model (SC-CAMLR-XXVI, Annex 5, Appendix I) should be evaluated within a simulation experiment in order to address current assessment model uncertainties.

5.7 Mr Dunn also described the methods and results from model validation, including implementation checking, development-driven unit tests and comparative software evaluation. Comparative software validation suggested that the processes within SPM replicated results derived from other population models and movement processes implemented in S+/R code.

5.8 The Working Group noted that the use of the unit-testing procedure was a useful development in the context of code development for software developed for use by the scientific working groups, and was an approach that Members could use to allow the Working Group to have some confidence that future developments will maintain the integrity of the underlying software code.

Krill-based food-web models

5.9 Three approaches have been developed for krill-based food-web modelling (EPOC, FOOSA and SMOM[1]). The Working Group considered the advances in these models, particularly with respect to their use in evaluating the subdivision of the Area 48 krill catch limit amongst SSMUs, hereafter termed 'SSMU allocation'. The following sections discuss these advances.

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

Tuning models to the calendar of events

5.10 During its 2007 meeting WG-SAM proposed that, in evaluating models, it would be useful to have a calendar of reference points for Area 48. A calendar of events, also endorsed by WG-EMM (SC-CAMLR-XXVI, Annex 4, paragraph 6.45), was developed to provide a set of expectations to be met in models to be used to address the SSMU allocation, particularly regarding recent trends, based on population growth rates and timing of changes, in predator and krill population dynamics for 1970–2007 (SC-CAMLR-XXVI, Annex 7, paragraph 5.24).

5.11 Dr Hill introduced WG-EMM-08/10, which provided a quantitative translation of the calendar into numerical terms suitable for use in the models. This process had two steps. First, for the penguin, seal and whale predator populations, year- and SSMU-specific abundances were estimated from literature sources. Second, the abundance estimates were then back-calculated to 1970 and projected to 2007 using an exponential growth model based on the rates of change reported in the calendar. In the case of whales, growth rates specified in the calendar were updated with recent estimates from the published literature.

5.12 The Working Group noted that the numerical calendar provided in WG-EMM-08/10 gives a common starting point for FOOSA and SMOM, from which comparisons with the expectations of the calendar could proceed. The Working Group agreed that having a common set of starting conditions is useful for model comparison. It acknowledged that only the point estimates provided in WG-EMM-08/10 were used for conditioning FOOSA and SMOM. However, a distinction should be made between using the calendar to provide a common starting point for comparisons of historical trajectories versus using the calendar to provide a set of parameterisations on which future results will be derived.

5.13 The Working Group questioned whether aggregating predators into generic groups was appropriate and how parameters based on generic predators could be interpreted. While the Working Group recognised the need to balance model complexity with the requirement to make progress, it remains unclear whether maintaining generic predator groupings or re-parameterising a disaggregated food web presents a lesser degree of uncertainty in model results. Generally, it was suggested that disaggregating the generic predator groups could increase model complexity (hence uncertainty) due to the larger number of ecological interactions requiring parameterisation. The Working Group noted that the generic group parameters presented in Hill et al. (2007) and used in WG-EMM-08/13 and WG-SAM-08/17 are SSMU specific, i.e. that the composition of the generic predator groups is not the same across all SSMUs. As an alternative to generic predators, Dr Plagányi suggested that OMs with alternative taxonomic resolutions could be constructed. In particular, single indicator species could be represented in the parameterisations. Such OMs could also be included in the reference set for management strategy evaluations.

5.14 The Working Group recalled that the WG-SAM calendar provides no guidance on how fish stocks in the model arena have changed over time (SC-CAMLR-XXVI, Annex 7, paragraph 5.25). Existing data, however, may be useful for updating the calendar to include the general expectations for fish dynamics. The Working Group identified multiple sources of data potentially suitable for inclusion in the calendar, including, *inter alia*, annual AMLR survey acoustic data, CCAMLR-2000 Survey acoustic data and groundfish time-series data from South Georgia.

5.15 With respect to updates to the calendar, the Working Group noted that the forthcoming Joint IWC-CCAMLR Workshop, through the review of available data for input into ecosystem models, may suggest a need for adjusting the calendar generally. The Working Group agreed that such adjustments of the calendar would be welcome, although the need to periodically suspend adjustments to the calendar for the purpose of model development and testing would be essential for progress towards the provisioning of advice on the SSMU allocation.

5.16 Two general concerns on the conditioning of all models to the calendar were noted. First, a question over the degree to which the specified trend in krill biomass is realistic was raised. Dr Constable cautioned that the available data on krill abundance may not support the conclusion for a decline in abundance in Area 48 given the CVs (which are often not reported) surrounding the historical estimates of krill abundance. The Working Group suggested, therefore, that WG-EMM review the evidence for this hypothesised trend. Second, Dr Hillary suggested an alternative method for assessing the degree of correspondence between the calendar and the model outputs. Rather than condition the model to the numerical translation of the calendar reported in WG-EMM-08/10, it might be possible to condition models on the growth rates reported in the calendar starting from the empirical abundance estimates of predators provided in the latter paper.

Updates to FOOSA

5.17 Dr Watters presented the updated version of FOOSA (WG-EMM-08/13). In particular, Dr Watters discussed how the authors have dealt with issues previously noted by WG-SAM-07 regarding model conditioning and validation. New functionality included the potential to link recruitment success of predators to foraging conditions during the winter. To allow for this possibility in the model, a term was included to impose a penalty on recruitment based on the foraging success of predators during the first winter of life, for example, as suggested by the results in Hinke et al. (2007). This formulation is consistent with the requirement in the calendar that the breeding success of penguins not necessarily be related to summer foraging success (SC-CAMLR-XXVI, Annex 7, paragraph 5.24(i)(b)).

5.18 Further, Dr Watters reviewed the base set of four parameterisations used in this version of FOOSA to develop risk-assessment scenarios. These realisations include contrasting movement (*m*) or no-movement (*n*) of krill through the SSMUs, and an assumption of either a stable (*s*) or a linear (*l*) relationship between adult foraging success and the ratio of effective numbers of breeders to the total pool of adults for each population. In all scenarios, a trend (*t*) in krill abundance was used to drive the model.

5.19 The base set of parameters derived from the calendar in WG-EMM-08/10 was developed by tuning the stock-recruitment parameters of predators. The authors discussed how they parameterised the considerable uncertainty surrounding these parameters. Dr Watters also noted that krill and fish parameters were not estimated. Rather, krill recruitment was assumed to be independent of stock size over most of the range of population size and was modelled with no process error. Krill mortality was modelled as a function of predation alone. The calendar also specified that krill abundance exhibited a step-change, and the model conditioning was conducted by assuming a 50% step-change in krill recruitment.

5.20 Following discussion of the model, Dr Watters discussed how to weight the various scenarios in terms of their plausibility. He noted that a method for weighting the scenarios could be based on statistical (e.g. do tuned parameters capture expectations of the calendar) and ecological (e.g. do the tuned parameters result in plausible estimates of predator productivity) criteria. However, they would likely be arbitrary at present. The Working Group agreed that methods for weighting scenarios deserved consideration in the future.

5.21 Ultimately, the Working Group agreed that FOOSA is capable of capturing the expectations of predator populations as specified in the calendar, given krill as a driver of the system. A question arose, however, regarding the ability to predict both the krill and predator dynamics simultaneously. Dr Watters noted that some important future work is under way (see WG-EMM-08/51) to more reliably represent krill dynamics in the model.

5.22 The Working Group further noted that long-term simulations are useful to assess whether model parameters result in viable populations over the long term in the model. Such simulations are useful to provide an internal check of model consistency.

Update of SMOM

5.23 Dr Plagányi presented aspects of work from WG-SAM-08/17 and WG-EMM-08/44. The former paper described an updated version of the Spatial Multi-species Operating Model (SMOM) of krill–predator–fishery dynamics, and the latter paper describes how SMOM was conditioned on the calendar. The presentation focused on efforts to model krill dynamics and fish removals in SMOM and how work to condition SMOM contrasted with similar work to condition FOOSA. A reference set of parameterisations for SMOM was specified from plausible bounds on survival rates for predators. These parameterisations were conditioned to the calendar by tuning a steepness parameter that characterises the sensitivity of predator breeding success to krill abundance (for each combination of survival rates, one steepness parameter was estimated for each of whales, seals, penguins and fish) and by estimating initial (1970) abundances of fish in each SSMU.

5.24 Two models of krill dynamics were considered in applications of SMOM. In the first model, a krill biomass series was specified on the basis of the calendar (i.e. a series that explicitly describes a step-change) and used to drive predator dynamics from the bottom up. This model was relatively easy to condition on the calendar by simply inputting krill biomass as a driving variable. This approach was also used to condition FOOSA on the calendar. In the second model, two sea-surface temperature time series were used to model temporal variations in the intrinsic population growth rates of krill from a group of southern SSMUs (in Subareas 48.1 and 48.2) and a group of northern SSMUs (in Subarea 48.3). This model was also able to be conditioned on the calendar, but a step-change in krill recruitment was nonetheless required. The Working Group agreed that SMOM was capable of reproducing the direction and timing of observed changes in predator abundance in the calendar.

5.25 Historical removals of finfish were explicitly considered in SMOM. This contrasts with the application of FOOSA, which does not currently attempt to account for historical removals of finfish. Historical SSMU-specific catches for generic fish (generic fish are used in the modelling framework to represent a mixture of species, but the implied species composition is assumed to vary among SSMUs) were compiled from information in the *CCAMLR Statistical Bulletins* and are reported in WG-SAM-08/17.

5.26 The Working Group noted two concerns with the methods used to condition SMOM. First, the attempts to model krill growth rates as a function of environmental conditions like temperature were regarded as an important step, but that the current approach was a simplistic implementation and further development was recommended. Second, the Working Group noted that attempts to generate fish dynamics based on fishery catches could be difficult given the generic nature of the fish group currently represented in the models. With respect to the aggregation of the fish group, a question was raised as to whether disaggregation of the fish group would be beneficial.

Implementation of FOOSA in EPOC

5.27 Dr Constable provided an overview of his implementation of FOOSA in EPOC, noting that the result is FOOSA-like rather than a direct implementation (WG-SAM-08/15). He described how a number of the functions were generalised to allow greater flexibility for specifying scenarios that could be explored in evaluating management strategies for krill. This object-oriented implementation provides opportunities for more predators and prey to be included in the food web and to provide flexibility in the number of stages of a predator consuming krill. Some critical differences in model structure include a more general predator recruitment function, to ensure the abundance of predators at which maximum recruitment occurs is able to change with carrying capacity of the predators, and a consumption model for predators, that specifically accounts for potential differences amongst SSMUs in the predator consumption rates within a season. Dr Constable also showed the general implementation of EPOC in its current form.

5.28 The Working Group commented that the FOOSA-like implementation in EPOC includes features that are more complex than those implemented in FOOSA and this complexity may add another layer of uncertainty. Dr Constable noted that, as an operating modelling framework, the features add to the diversity of scenarios that can be explored in management strategy evaluation. As such, it provides the user with the ability to explicitly vary the model parameterisation based on mathematical or ecological considerations or to limit the model to restricted scenarios. It also means that greater transparency in decisions on model structures can be achieved for a broader range of modellers and ecologists because the equations are explicit and provide a template for a wider range of hypotheses to be tested. A useful strategy of incrementally adding features to model simulations was suggested to allow an assessment of the utility of increasing model complexity and to help convey model results. This process also provides ample opportunity to scrutinise whether the modelling framework would require reconditioning based on recent parameter sets. Given the differences between FOOSA and its implementation in EPOC, the Working Group agreed that presentation of a case study developed from the FOOSA-like implementation in EPOC would help to compare it with the other two modelling approaches (FOOSA and SMOM).

Other considerations for SSMU allocation work

5.29 Other specific issues discussed by the Working Group centred on how whale populations could be represented in the models, how parameterisations of fish recruitment might result in stabilising influences that could allow populations to rebound when fishing was stopped in the model, and whether it was important to have the potential of predator groups to recolonise areas where their populations have been reduced to zero. Additionally, the role of krill flux from and into areas outside the SSMUs, the potential for predators to forage outside the SSMUs, and whether environmental forcing was applied to those components of the model were also discussed.

5.30 The Working Group agreed that there was an important difference between modelling frameworks, such as EPOC, and purpose-built models, such as FOOSA and SMOM. It suggested that the FOOSA-like implementation in EPOC was sufficiently different from FOOSA that it should be given a unique name.

5.31 The Working Group noted that the ongoing development of models may result in multiple versions of models that are considered by the working groups of the Scientific Committee at various times during model development. To better manage model development and distribution, it was generally agreed that some formal mechanism be provided to 'version' and archive models as they are updated. Both software and datasets that include parameter formulations should be included in the versioning, and it was thought that the parameter sets, at least, should be provided to the Secretariat.

An empirical ecosystem assessment model

5.32 Dr Constable introduced an empirical ecosystem assessment model described in WG-SAM-08/16 (other aspects of this paper were discussed under Item 6.3). The model is intended to characterise the food web from a statistical perspective and requires fewer assumptions than most other ecosystem models. The model describes krill biomass as a function of fishing mortality and a hierarchical set of error terms that describe different sources of process variation (e.g. independent SSMU and year effects). Fishing mortality can be made to affect the future biomass of krill using an autoregressive term, and density dependence in the krill population can be modelled using a term that compares the current level of abundance to the long-term mean abundance. The model does not explicitly characterise the impacts that predators have on krill, but it is explicit about the impacts that krill availability has on predators. Such impacts are modelled to affect one or more indices of predator performance (e.g. individual CEMP indices or CSIs) using a function that is sufficiently flexible to produce patterns resembling the well-known Holling Types II and III functional feeding responses. Although the model was applied as a simulation model in WG-SAM-08/16, Dr Constable noted that it is intended to be developed as an estimation model.

5.33 The Working Group recognised the novelty of the modelling approach described in WG-SAM-08/16. Usually, ecosystem models have been considered to be most useful as OMs in management strategy evaluation, not as assessment models (e.g. FAO, 2008). Thus, the model described in WG-SAM-08/16 is both unconventional and promising in the sense that it is proposed for use as an assessment model. The Working Group encouraged the authors of the paper to continue pursuing their work in this regard.

5.34 Following its endorsement for continued work with the model described in WG-SAM-08/16, the Working Group suggested that, during this process, the authors consider three additional points. First, the Working Group noted that it was difficult to fully evaluate the model at this meeting because of the breadth of the work presented in the paper and the time available. As such, it was requested that the authors keep the Working Group informed of progress with the modelling approach and provide a completely worked example to the group in the future. Second, the Working Group suggested that the authors consider approaches to re-parameterise and possibly simplify the model. For example, it was suggested that the authors consider a re-parameterisation approach known as hierarchical centering (Gelfand et al., 1995, 1996) and alternative models for density dependence and/or future fishing impacts that are structured as random walks. Finally, the Working Group suggested that it would be useful to generate data (with error) from the model and then try an estimation to see whether the true model parameters can be estimated.

Fish-based food-web models

5.35 No papers were submitted to WG-SAM on fish-based food-web models. However, Dr Hanchet noted that a paper describing an updated carbon-budget trophic ecosystem model of the Ross Sea had been submitted to WG-EMM (WG-EMM-08/42). The authors regard the model as a first step towards investigating ecosystem effects of the fishery for *D. mawsoni*. The paper noted that a future aim of this work is to develop a plausible minimum-realistic model with which to investigate and manage the effects of the *D. mawsoni* fishery on the Ross Sea ecosystem.

Ecosystem models

5.36 There were no additional ecosystem-based modelling approaches presented for consideration by the Working Group. WG-SAM encouraged Members to develop or advance models that may potentially be used toward understanding ecosystem dynamics and consequences of management approaches for Antarctic resources.

Other models

5.37 Mr Dunn gave a presentation of WG-SAM-08/P3, a draft user manual for SeaBird, a package for modelling seabird populations. It was discussed in more detail under Item 4.5. No other papers were presented to the Working Group under this agenda item.

EVALUATION OF MANAGEMENT STRATEGIES

Dissostichus spp.

6.1 Dr Brandão presented WG-SAM-08/11, which described a reference set of four OMs that reflect an 'Optimistic', 'Intermediate', 'Less Pessimistic' and 'Pessimistic' current status for the toothfish resource in the Prince Edward Islands region (Subareas 58.6/58.7). These models are used to investigate the performance of a candidate MP that uses two data sources, the trend in CPUE indices and the mean length of fish in the longline catches, to provide future catch limits, with the primary objective of generating a reasonable probability of securing a catch rate increase, whatever the current resource status. The proposed MP performance is shown to be reasonably robust across a range of sensitivity tests, although it deteriorates in conservation terms if the steepness assumed in the reference set is appreciably lower. The sensitivity tests also indicate that monitoring of future catch-at-length information is necessary to guard against a change in selectivity towards greater catches of older fish.

6.2 The Working Group noted that it would be of interest to compare the performance of the MP with the CCAMLR decision rules. It further suggested that a statistic based on the probability of the final CPUE value being lower than the most recent levels would be very informative.

6.3 The Working Group noted that there is more uncertainty in CPUE projections for the Less Pessimistic scenario than for all other scenarios, and that this needs to be further investigated. One possibility is that the estimated variance for the CPUE indices is much larger for the Less Pessimistic OM than for the other OMs and that this variance is used in generating future CPUE values.

Champsocephalus gunnari

6.4 No papers were received or available to WG-SAM for evaluation of management strategies for *C. gunnari*, and the Working Group did not further consider this topic.

Euphausia superba

Framework for Stage 1 evaluations

6.5 The Working Group recalled that it had previously advised WG-EMM and the Scientific Committee on a staged development of the krill fishery in Area 48 (SC-CAMLR-XXVI, Annex 7, paragraphs 5.7 to 5.51). That advice was subsequently endorsed, including the expectation that further advice on a Stage 1 subdivision of the precautionary catch limit among SSMUs could be delivered, in the form of a risk assessment, this year (SC-CAMLR-XXVI, paragraph 3.36).

6.6 Dr Watters introduced WG-EMM-08/30 which provided a risk assessment purposefully designed to provide advice on strategies for subdividing the precautionary krill catch limit among SSMUs during Stage 1. The risk assessment was conducted with FOOSA, using the reference set of four parameterisations that were conditioned on the calendar

(WG-EMM-08/13). The risk assessment followed the technical guidelines specified by WG-SAM-07 almost exactly with minor additions that include:

(i) the introduction of implementation error by including random errors in the quantities used to compute SSMU-specific catch limits (i.e. the initial estimates of krill biomass and predator demand);

(ii) performance measures for krill that are based on the existing decision rules and are referenced both to pre-exploitation abundance (as stated in the existing decision rules) and to results from comparable no-fishing trials;

(iii) a vector of plausibility weights that are used for model averaging.

6.7 The presentation of work described in WG-EMM-08/30 focused on methodological and technical details and how such details influence the interpretation of results. The results *per se* were not discussed.

6.8 Initially, questions from the Working Group focused on understanding the initial conditions used to set up simulations in the risk assessment. Dr Watters informed the Working Group that the initial conditions were the same throughout the simulations for a given model, i.e. the starting point for risk assessment from each parameter set was fixed. Nevertheless, the tuning process used to develop the set of four reference parameterisations used in the risk assessment, did result in differences in starting points between parameterisations. These four starting points can be considered to come from a distribution of initial conditions, although the between-parameterisation variance in these starting points likely under-represents the true uncertainty in initial conditions. The same set of process errors was used to simulate random variations in krill recruitment and abundance across all four parameterisations in the reference set.

6.9 Dr Agnew noted that predictions from the FOOSA parameterisations with no krill movement indicated that the depletion part of the krill decision rule could be violated (i.e. that, during the fishing period, the krill spawning stock would fall below 20% of the median pre-exploitation spawning stock more than 10% of the time) because those parameter sets implied ongoing downward trends in krill abundance. However, if the risks of violating the krill decision rules are assessed relative to predictions from comparable no-fishing trials, the risk was substantially reduced. The Working Group noted that the Scientific Committee has not recommended whether performance metrics for krill should be referenced to no-fishing trials. Nevertheless, the Working Group agreed that such metrics could be useful for helping evaluate the impacts of fishing when other factors cause trends in the system (paragraph 6.16).

6.10 The discussion summarised in the preceding paragraph prompted further consideration of the assumptions used to derive levels of γ from the krill yield model. The Working Group agreed that WG-EMM, the Scientific Committee and the Commission should be advised that the level of γ (0.093), which is currently agreed and applies to krill in Area 48, was derived under the assumption that, in the future, krill biomass will continue to vary interannually but not trend in response to external factors such as climate change.

6.11 Dr Constable reported on WG-SAM-08/16 in which an ecosystem-based precautionary management procedure for krill fisheries is developed, based on the extensive past experience in CCAMLR. The procedure is based on an empirical ecosystem assessment model, a decision rule for determining local-scale catch limits based on a harvest strategy and a single-species assessment of yield, and a method for implementing the procedure. The decision rule for setting catch limits for a given harvest strategy expresses the target conditions to be achieved and the uncertainties that need to be managed. It is a natural extension of the current precautionary approach of CCAMLR for krill and can utilise existing datasets, including B_0 surveys, local-scale monitoring of krill densities, local-scale monitoring of predator performance, monitoring of predator foraging locations and time series of catches from the fishery.

6.12 Dr Constable noted that this procedure provides a common framework for inserting data, assessment methods and candidate modelling approaches for assessing yield. Consequently, its formalism means that advice on krill harvest strategies can be updated as improvements are made in any component of the procedure, including the provision of data, implementation of new assessment or projection models, or a revision of the decision rule. This framework formalises the decisions that need to be made in dealing with an ensemble of food-web models for providing suitably precautionary advice on how to spatially structure krill fisheries to account for the needs of predators. It provides the primary expectation for managing uncertainty, either by obtaining better estimates of parameters for the projection models and/or by altering the harvest strategy.

6.13 Dr Constable further noted that a preferred harvest strategy, which is initially untenable because of the uncertainties associated with its ecosystem impacts, could become a suitable option if its related uncertainties are reduced. Conceivably, the procedure outlined in WG-SAM-08/16 could be used in a spatially structured feedback management system that can ensure CCAMLR is able to respond to trends in the ecosystem, including those arising from fishing and/or climate change.

6.14 The Working Group noted the breadth of work presented in WG-SAM-08/16 and considered the work in a wide-ranging discussion that included issues relating to:

(i) the definition of terms used by the Working Group. Specifically, the Working Group recommended that the terminology should, as far as possible, be consistent with that of other international fora (e.g. Rademeyer et al., 2007, Appendix 1). Additionally, the report of the Working Group could contain a glossary of the terms once developed;

(ii) the implementation and interpretation of CSIs within the proposed framework of WG-SAM-08/16 (paragraphs 6.26 to 6.30);

(iii) the clarification of how the ecosystem-based management procedure proposed in WG-SAM-08/16 could be used to provide advice on the spatial allocation of krill catch this year by using output from FOOSA and SMOM to construct CSIs (paragraphs 6.26 to 6.30);

(iv) whether decision rules and their associated control parameters should be considered fixed or should evolve over time. The Working Group agreed that an evolution would be necessary, particularly if the Commission requested changes. The Working Group noted that it would be difficult to determine what the values of such control parameters should be in the future (paragraph 6.24);

(v) whether the framework is intended to apply to all predators or just predators whose foraging distributions are limited during particular times in their life histories (e.g. during breeding). The Working Group agreed that the former interpretation was more consistent with Article II of the Convention.

6.15 The foregoing commentary prompted further discussion centred on three specific questions.

6.16 First, the Working Group considered whether the decision rules should be referenced to pre-exploitation states or states predicted from comparable no-fishing trials. In principle, the Working Group agreed that predator performance could be assessed relative to both states, but no agreement was reached on a preference for one or the other. WG-SAM-08/16 proposed a decision rule that is referenced to pre-exploitation states to determine departures from baseline conditions. The alternative is to reference decision rules to a time series of predictions from no-fishing trials (paragraph 6.9) because it is potentially useful to remove trends, transient effects of model parameterisations, climate effects and effects from other dynamical properties not caused by the management strategy being evaluated.

6.17 The Working Group recalled previous work by the Subgroup on Statistics to define VOGONs (values outside the generally observed norm) (SC-CAMLR-XV, Annex 4, Appendix H; SC-CAMLR-XVI, Annex 4, Appendix D, paragraph 2.9) and discussed whether this concept would also be useful for defining reference points in decision rules. The Working Group suggested that the concept of VOGONs and their derivation is useful for defining such reference points. The Working Group agreed that establishing baseline norms should include consideration of variation over a range of time scales.

6.18 Second, the Working Group considered whether a decision rule should explicitly address fishery performance (i.e. not be limited to predator performance). WG-SAM-08/16 proposed a decision rule that does not explicitly address fishery performance. However, Dr Constable indicated that WG-SAM-08/16 showed how fishery performance could be used to help choose between different harvest strategies if the resulting options for harvest strategies, including spatial catch limits, have the same level of precaution. For example, fishery performance, along with other commercial, implementation or compliance issues, could result in a lower catch limit being preferred. Thus, metrics of fishery performance are important to accompany the results of calculations used to determine the outcome of a decision rule. The Working Group agreed that it would be possible to explicitly include measures of fishery performance in ecosystem-level decision rules. The Working Group also agreed that these types of decision rules should be investigated. The Working Group noted that the IWC has previously addressed this issue, and it might be worthwhile to review its approach.

6.19 Third, the Working Group considered the manner in which the precautionary approach should be incorporated during various stages of an ecosystem-level decision framework. WG-SAM-08/16 proposed a decision rule wherein the precautionary approach is addressed at the final stage of summarising across models or evaluations (e.g. by taking the 20th percentile of the distribution of harvest rates suggested by an ensemble of results). The Working Group noted that it is difficult to accommodate the precautionary approach in other parts of the decision rule because of the potential biases in projection and assessment models. It also noted that:

(i) models will inevitably have bias, unforeseen or otherwise, that could be in favour of the fishery or the ecosystem;

(ii) precaution needs to be applied in order to achieve the objectives in Article II;

(iii) it would be desirable to have a decision rule that is robust to biases in both directions and satisfies the precautionary approach.

6.20 Dr Plagányi provided an overview of WG-EMM-08/44 that provided a framework for using SMOM and its output to develop appropriate risk metrics from which to develop performance measures. Dr Plagányi presented the following list of factors that should be included in a framework for evaluating MPs:

(i) agreement on broad objectives for the management of the populations in the region under consideration;

(ii) agreement on the data (observations) available which are pertinent to the dynamics of these populations (e.g. WG-EMM-08/10);

(iii) development of a wide range of OMs (e.g. FOOSA, SMOM and EPOC);

(iv) fitting (condition) each of these models to the agreed data;

(v) weighting plausible OMs based on *a priori* considerations and their fit to data;

(vi) specifying statistics in terms of the performances of alternative candidate MPs that are to be assessed and compared;

(vii) agreement on guidelines and/or thresholds that candidate MPs need to meet or achieve to be acceptable in terms of the agreed objectives for management;

(viii) development of candidate MPs;

(ix) testing of candidate MPs based on forward projections over a number of years, of each OM under the management actions output annually by the MP;

(x) comparison of the performance statistics for each candidate MP across all OMs given weighting structure, and selection from amongst the candidates, the MP which best achieves the broad objectives.

6.21 The Working Group agreed it is worthwhile to pursue work that might allow all modelling frameworks to be considered in the provision of management advice. It agreed that the framework introduced by Dr Plagányi could be adapted to suit the purposes of SC-CAMLR to guide future work in subsequent stages and suggested this be considered at a future meeting. In doing so, the Working Group should also compile a table of the progress made with respect to each step.

6.22 The Working Group agreed that if different models suggest different advice it would be important to take additional precaution in setting levels of catch for each SSMU.

6.23 The Working Group agreed that while WG-EMM-08/30 and the outcomes of its deliberations this year could be used to provide advice on a Stage 1 SSMU allocation, WG-EMM should discuss the relative plausibility of each parameterisation in the reference set. WG-EMM-08/30 provided some guidance on plausibility weights that might be assigned to each reference set.

6.24 In considering subsequent work on the SSMU allocation (Stage 2 and beyond), the Working Group noted the following:

(i) the current models and reference sets considered by WG-SAM have a number of assumptions, parameterisations and structures that will need to be updated and/or revised in future work as better scientific evidence becomes available;

(ii) the development of decision rules needs to include consideration of the interpretation of 'the maintenance of ecological relationships' in Article II;

(iii) when decision rules are agreed, judgements will need to be made on the magnitude of control parameters, for example the probability of departure from baseline variation, in order to achieve the appropriate level of precaution.

6.25 The Working Group agreed to inform WG-EMM and the Scientific Committee of the issues that need to be considered in formulating ecosystem-level decision rules. The Working Group further agreed that the framework proposed in WG-SAM-08/16 had covered such issues extensively and should be considered by WG-EMM.

Performance measures

6.26 The Working Group noted that most of the model scenarios result in trends in ecosystem dynamics after the tuning period. It might therefore be appropriate to construct performance measures for biological ecosystem components that make comparisons with norms indicated by no-fishing trials (paragraph 6.16). The Working Group cautioned that comparison to expected future norms increases reliance on model predictions.

6.27 Fish have an important influence on the overall dynamics in current realisations of FOOSA and SMOM, but there has been no conditioning of models on observed fish dynamics due to a paucity of data. There are a number of structural differences in the parameterisation of fish in FOOSA and SMOM which is useful in representing some of the uncertainty associated with this group. Nonetheless, the role of fish in the ecosystem remains an important area of uncertainty. For example, the dynamics of myctophids may be very important in some SSMUs as predators of krill and as prey to higher predators.

6.28 The Working Group noted that, when interpreting results from the models in providing Stage 1 advice, WG-EMM should be aware of the paucity of data on mesopelagic fish in developing generic fish abundances in the calendar.

6.29 The Working Group noted that several questions regarding the development of aggregate performance measures (including CSIs) are worthy of further consideration:

(i) Is there potential to smooth over important detail when aggregating across areas, time periods and populations?

(ii) How can time lags (e.g. between when the effects of fishing occur and when the performance metrics are realised) be dealt with in the development of the aggregate measures?

(iii) Should component measures included in the aggregate measure be weighted?

(iv) How can aggregate measures avoid being confounded by factors not related to the effects of fishing on krill?

6.30 The Working Group agreed to use output from FOOSA for developing an example of CSIs to enable clarification of these questions, based on the output of an ecosystem model (paragraph 6.37).

Risk summaries

6.31 The Working Group reviewed the use of the risk-assessment metrics derived from FOOSA with respect to the scenarios listed in section 5.2 of this report. The discussion focused on the graphical output and, with respect to Article II of the Convention, the decision rules for the allocation of krill. Given that these summaries follow exactly from the specifications made by WG-SAM in 2007, the Working Group endorsed their use.

6.32 Dr Plagányi provided an overview of the modelling work in SMOM to produce risk scenarios that could be compared directly with output from the FOOSA model, as presented in WG-EMM-08/30. Using simulation data, Dr Plagányi examined the probability that predator abundance declines to less than 75% of abundance under a comparable no-fishing scenario across a range of harvest rates for Fishing Options 2, 3 and 4. This scenario was considered most similar to the ‘nst’ scenario presented in Figure 6 of WG-EMM-08/30.

6.33 In comparing the risk assessment plots between the two modelling frameworks, the Working Group was satisfied that there were considerable similarities between the modelling frameworks and , given the scenarios presented.

6.34 Some differences were observed however, and members of the Working Group requested clarification as to whether: (i) such differences were related to structural differences between the modelling approaches, or (ii) the differing results were related to starting parameters and initial conditions. Dr Plagányi noted that some of the difference was related to the implementation of generic fish in the models (paragraph 5.25). Additionally, adult and juvenile survival are handled differently in each model. Technical questions to further clarify the extent of similarities and differences between the models related to the weights given to the relative plausibility of models in the reference set, how implementation error was accounted for, how the subdivision of catch for each of the fishing options was implemented, the relative competitive abilities of predator groups, and the krill movement scenarios. It was acknowledged by the authors of both models and a number of Working Group participants that krill movement is an important component of uncertainty that has been discussed by WG-EMM in past years (SC-CAMLR-XXV, Annex 4). Those discussions specified the contrast of no-movement and movement scenarios presented in WG-EMM-08/30.

6.35 Dr Watters indicated that while it is appropriate to consider the differences between models, the modelling approaches do encompass different structural uncertainties and that such differences can indicate robust results. For example, both models predicted fairly small risks around the trigger level for Fishing Options 2 and 3.

6.36 The Working Group next discussed the types and limits of advice that could be provided to WG-EMM. It agreed that FOOSA and SMOM are valid and that most differences in model output could be adequately understood. On that basis, the Working Group agreed that both modelling approaches could be used to provide an indication of risk for WG-EMM to consider. The Working Group also suggested that resolving the differences in model results might be facilitated if experts in WG-EMM provide an indication of which parameters may need modification in order to align parameter inputs for each model. The Working Group also suggested that ranking the plausibility of models could be a task for WG-EMM.

6.37 Dr Constable provided an overview of his work to use model output from FOOSA to develop CSIs to examine ecosystem performance and to provide indices of risk for various MPs (such as those represented by Fishing Options 2, 3 and 4). Dr Constable suggested that the CSI was an appropriate measure of risk because of a high degree of uncertainty when using the available ecosystem models to assess the effect of fisheries on individual predator populations at the SSMU level. However, the CSI should detect fishery effects by integrating responses of predators across all areas. As indicated in WG-SAM-08/16, the goal of the CSI is to provide a measure of the variation of the ecosystem and how fishing might cause a departure of food-web dynamics from the normal range. The CSI presented to the Working Group thus used the variability in predator dynamics under no-fishing scenarios to define baseline variability. Referencing to a no-fishing scenario helps to remove bias that may be present in the model.

6.38 The results for the CSI presented to the Working Group were based on the recruitment of predators. The recruitment series for each predator was standardised for the age of recruitment so that the recruitment could be directly related to the krill abundance affecting recruitment. It was noted that such an index, like other performance measures, will be sensitive to several factors, including: (i) the degree to which the krill-based system is an open system maintaining a supply of krill over time as represented by the bathtubs in the model; (ii) the degree to which predators forage widely in the system; and (iii) the dependence of predators on krill for reproductive success.

6.39 In his presentation, Dr Constable addressed the issues raised by the Working Group (paragraph 6.29), including:

(i) smoothing-over important detail when aggregating into CSIs – the inclusion of predators that are largely unresponsive to krill abundance will dilute the index. This is important to consider when aggregating across species and/or areas. It is important that the index primarily comprises predators in locations where they respond to krill abundance (see also de la Mare and Constable, 2000);

(ii) lags between the effects of fishing on krill populations and response of predators – WG-SAM-08/16 indicated the need to standardise the time series of predator responses, such as recruitment, so they can be directly related to changes in krill;

(iii) weighting component measures within CSIs – it is difficult to weight individual predator responses using marginal weights. It is easier to adjust the use of CSIs by using binary weights (inclusion or exclusion) to determine what predators should be included and from which areas. Similarly, the degree to which a predator response is summed amongst SSMUs before inclusion in the CSI is a decision that will potentially reduce or enhance the contribution of the predator to the CSI;

(iv) influence of confounding factors – these are less important if predator responses directly relate to krill abundance. Detecting trends in the system would require comparison to baselines in the first part of a time series. However, detection of the effects of fishing may require comparisons of the fishing scenarios to a baseline over the same projection period but with no fishing. Density-dependent effects are unlikely to impact the CSI if the time series of predator response is a summed population response, as recommended in WG-SAM-08/16.

6.40 Dr Constable showed that by calculating the difference in the cumulative distribution functions of CSI values between fished and non-fished trials at the end of the fishing period, the relative difference could provide information about the effect of harvest strategies. He illustrated how the effects of fishing could be observed if setting a critical CSI level at, say, the lower 10th percentile for the CSI in the no-fishing scenario in the last year of the designated fishing period in the fishing scenarios. The probability of being below that critical value at the end of the fishing period could be used as an indicator of the expected effects of fishing in that scenario (WG-SAM-08/16). Plots showing the relationship between the harvest rate (γ) and this probability were shown. These plots provide an indication of the risk of departing from natural variation under each level of fishing for a given fishing and model scenario.

6.41 The Working Group agreed that this is an interesting approach and that the relative risk levels could be considered in more detail at WG-EMM.

6.42 There was discussion among Working Group members about how and whether to disaggregate the regional CSI values to the SSMU level, or into predator/prey group levels. Dr Plagányi noted that it will be important to check the predictions of the CSI by working an example of the CSI in reverse to demonstrate that, given a CSI, the Working Group could correctly interpret the underlying ecosystem dynamics on the level of the SSMUs. Dr Constable indicated that initial work in this regard was presented (e.g. de la Mare and Constable, 2000).

6.43 A number of questions were thought to fall under the purview of WG-EMM, including, *inter alia*:

(i) To what degree do the dynamics of generic predators reflect the dynamics of component species, and how can the regional scale of the CSI and the SSMU-scale of management be reconciled?

(ii) To what extent does consideration of an open or closed population of krill influence the outputs of the models providing advice and does the approach to uncertainty adequately address this issue?

6.44 WG-SAM reviewed a number of tools that might be used by WG-EMM to provide guidance regarding the SSMU allocation. These tools include new developments (e.g. CSIs) and implementation of risk methods as outlined by WG-SAM in 2007. WG-SAM recommended that these methods be considered by WG-EMM in formulating advice.

Future work

6.45 The Working Group noted that much of the work in FOOSA, SMOM and EPOC provides a foundation for evaluation of management procedures for krill in subsequent stages of the SSMU allocation work. It encouraged Members to continue this work and present results to WG-SAM and WG-EMM.

OTHER BUSINESS

Revision control

7.1 Mr Dunn described how revision (version) control systems allow the management of multiple revisions of information within a central database. He noted that two modern implementations include CVS (Concurrent Version System) and Subversion, and he gave a demonstration of the revision control system CVS.

7.2 Revision control systems allow organisations and individuals to manage digital documents like software source code, manuals, spreadsheet data or other forms of electronic information in a controlled and future-recoverable manner. Mr Dunn noted that CASAL, SPM and other important software developed in New Zealand for use at SC-CAMLR working groups was maintained within a revision control system.

7.3 The Working Group noted that the use of such systems allowed for a greater degree of transparency in comparing between-code revisions, allowed easy recovery of historical code where issues may arise, and allowed easy checking of who made changes and when those changes were made (see paragraph 5.31).

7.4 The Working Group recommended that WG-FSA and WG-EMM consider how they may use such systems to document and archive their work.

CCAMLR Science

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

7.6 The Working Group recognised that there should be a clear distinction between working group papers and peer-reviewed papers in *CCAMLR Science*. The latter must be made accessible to a broader readership – with greater emphasis on ensuring that the context for the work is clearly described and the consequences/conclusions beyond CCAMLR are provided.

7.7 Dr Reid reminded potential authors to ensure that they have permission to use any data released under the Rules for Access and Use of CCAMLR Data for publication in the public domain. In order to ensure that this is done, there will be a new tick-box on the *CCAMLR Science* manuscript submission form to declare that permission to publish (and to cite working group papers) has been granted.

7.8 Dr Reid invited comments from all working groups on manuscript submission and editorial process of *CCAMLR Science* in order to prepare a paper for this year's meeting of the Scientific Committee.

Paper submission to working group meetings

7.9 The Working Group considered the issue of deadlines for meeting documents and agreed that papers could be accepted after the deadline in exceptional circumstances. Such circumstances include those where the paper(s) contains information of importance to the working group for delivering advice to the Scientific Committee in that year, noting that where Members anticipate the late submission of the paper they should correspond with the convener of the working group to assess the suitability of the paper for the working group.

7.10 In agreeing that flexibility is required with respect to paper submission deadlines, the Working Group noted that such flexibility should not compromise the ability of its members to assess papers prior to the meeting.

7.11 The Working Group noted that there is duplication of information on the document submission forms and the synopsis proformas that are required for papers submitted to working groups. The Secretariat agreed to consider a potential revision to the submission forms prior to the meeting of the Scientific Committee this year.

FUTURE WORK

8.1 The Working Group thanked participants for their innovative contributions, including, *inter alia*:

(i) methodology for data quality assessment (paragraph 3.26);

(ii) assessment approaches for exploratory fisheries in Subarea 58.4 (paragraphs 3.1 to 3.10);

(iii) spatially explicit population dynamics model (paragraph 5.1);

(iv) evaluation of the application of TISVPA (paragraph 3.16);

(v) potential use of BRTs in bioregionalisation, biogeography and modelling (paragraph 4.13);

(vi) a generalised age- and/or stage-structured seabird population dynamics model (paragraph 4.21);

(vii) FOOSA, SMOM and EPOC (paragraph 5.9);

(viii) development of ecosystem-based management procedures (section 5);

(ix) evaluation of management strategies (section 6).

8.2 The Working Group encouraged participants and Members to consider future work relevant to the working groups and the Scientific Committee, noting that items of future work could be submitted to other working groups directly for consideration, including, *inter alia*:

(i) Relevant to WG-FSA –

(a) investigation of the potential for systematic biases arising in observer datasets (paragraph 2.4);

(b) study of the effect of fish length on conversion factors from *Dissostichus* spp. fisheries (paragraph 2.6);

(c) development of updated bathymetric grids for areas other than Subarea 48.3 where recent multi-beam data or single-beam echo soundings exist and trawl surveys are conducted (paragraph 2.10);

(d) development of approaches to estimating stock size and advice on precautionary catch limits in Divisions 58.4.1 and 58.4.2 (paragraphs 3.4 and 3.10);

(e) identify alternative tagging datasets which could be used in the next assessment of the Ross Sea toothfish fishery (paragraph 3.29);

(f) further development of SPM, including processes and observation classes to incorporate year-class variability, stock-recruitment relationships, as well as tag–release/recapture and maturation-state observations (paragraph 5.5);

(g) refine the MP for the Prince Edward Islands region, and compare the performance of the procedure with the CCAMLR decision rules (paragraph 6.2).

(ii) Relevant to WG-EMM –

(a) consider methods for weighting scenarios, based on statistical and ecological criteria (paragraph 5.20);

(b) presentation of a case study developed from the FOOSA-like implementation in EPOC to help compare its performance and outputs with FOOSA and SMOM (paragraph 5.28);

(c) continue the development of FOOSA, SMOM and EPOC (paragraph 6.45);

(d) archive versions of FOOSA, SMOM and EPOC, together with datasets that include parameter formulations, with the Secretariat (paragraphs 5.31 and 7.4).

(iii) General:

(a) consider using the unit-testing procedure in future software developments to assist in checking that the integrity of functions in software code is maintained in future versions (paragraph 5.8).

8.3 The Working Group also:

(i) urged the authors of the TISVPA method (WG-SAM-08/8) to carry out the program of work required for evaluation of the model outlined by WG-FSA (paragraph 3.25);

(ii) encouraged the author of WG-SAM-08/P1 and 08/P2 to prepare a combined manuscript in English for the next meeting of WG-SAM, with examples of analyses (paragraph 3.37);

(iii) encouraged the authors of WG-SAM-08/12 to continue developing the BRT approach and suggested that this could best be pursued through a correspondence group involving statistical experts familiar with BRTs (paragraph 4.19);

(iv) encouraged the development of the novel modelling approach that is intended to characterise the food web from a statistical perspective and that requires fewer assumptions than most other ecosystem models (WG-SAM-08/16) (paragraphs 5.33 and 5.34).

8.4 Dr Gasyukov noted that the implementations of models need to be validated and verified in order to determine that the implementation reflects the mathematical and procedural descriptions provided in submitted papers. This is important for models on which advice is based. He also noted that the models for use in the SSMU allocation have not yet been validated in this way and requested that WG-SAM undertake the validation work required.

8.5 Dr Constable will undertake to assemble a group of interested members of the Working Group during the intersessional period to establish a process for validation based on SC-CAMLR-XXVI, Annex 7, paragraph 8.19, and review progress to date on such a process for existing models. A report will be provided to WG-SAM next year for it to consider how validation work might proceed.

8.6 The Working Group agreed that the work and advice developed during the meeting now requires consideration by the other working groups. The Working Group confirmed the need for flexibility and the maintenance of a relatively open agenda that is annually agreed by the conveners of all working groups and subject to review and agreement by the Scientific Committee (SC-CAMLR-XXVI, Annex 7, paragraph 6.6). It noted, however, that there are many aspects in Item 9 that will require further development of methods in statistics, assessments and modelling, and encouraged Members to submit this work for consideration next year.

ADVICE TO THE SCIENTIFIC COMMITTEE

9.1 Advice of the Working Group for the Scientific Committee and other working groups is summarised below. Generally, the main points are highlighted with reference to appropriate paragraphs with the detail of that advice. Advice on future work arising from the deliberations of the Working Group is also provided under Item 8.

Advice to WG-FSA

9.2 Consider the impacts of using reconstructed size distributions from factory/processing data as described in fishery assessments (paragraph 2.7).

9.3 Stock and biological assessment methods:

(i) develop approaches to assessing new and exploratory fisheries, including consideration of how to account for uncertainty to achieve an orderly development of exploratory fisheries (paragraph 3.10);

(ii) consider ways of examining and/or improving detection rates of tags (including the methods identified in paragraph 3.14);

(iii) provide specific guidance on the metrics considered most useful for distinguishing data quality with respect to assessments (paragraphs 3.28 and 3.30);

(iv) explore the degree to which the assessment of *Dissostichus* spp. in the Ross Sea might be impacted by the use of different sets of tag–recapture data (paragraph 3.29).

9.4 Research design in exploratory fisheries:

(i) tagging should continue in Divisions 58.4.1 and 58.4.2, although mark–recapture data are unlikely to provide accurate assessments of local abundance or stock size in the short term (paragraphs 4.1 and 4.2);

(ii) use comparative CPUE and local depletion as a basis for developing preliminary assessments in Divisions 58.4.1 and 58.4.2, and consider how to further develop these methods (paragraph 4.3);

(iii) use the framework for performing preliminary assessments for exploratory fisheries (WG-SAM-08/5) to provide management advice for the *Dissostichus* spp. fishery in Division 58.4.3a (paragraph 4.4);

(iv) consider the value and requirements for research fishing by longline vessels when fishing within a 10 tonne catch limit (paragraphs 4.6 to 4.9);

(v) consider using the procedure outlined in paragraph 4.10 to develop assessments in exploratory fisheries where difficulty is encountered in using tagging data (paragraph 4.11);

(vi) consider experimental approaches to understand the effects of changing fishing practices on CPUE (paragraph 4.12).

Advice to ac hoc WG-IMAF

9.5 Consider the application of SeaBird for use in modelling populations (WG-SAM-08/P3) (paragraphs 4.20 to 4.24).

Advice to WG-EMM

9.6 FOOSA, SMOM and EPOC:

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

(ii) FOOSA and SMOM are capable of capturing the trends in predator populations as specified in the calendar, given krill as a driver of the system (paragraphs 5.21 and 5.24);

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

(iv) WG-EMM should review the evidence and attendant uncertainty in support of the krill trend represented in the calendar (paragraph 5.16).

9.7 Advice on SSMU allocation:

(i) general advice is provided in paragraphs 6.5 to 6.45;

(ii) FOOSA and SMOM can be used to provide advice on SSMU allocation; however, WG-EMM should discuss the relative plausibility of each scenario (paragraphs 6.5 to 6.45).

Request to TASO

9.8 (i) Consider the feasibility of collecting all individual processed weights from longline vessels throughout the Convention Area (paragraph 2.7).

(ii) Consider ways to improve detection and reporting of tag recaptures (paragraph 3.14).

General advice

9.9 (i) Further develop methodologies to assess data quality (paragraphs 3.28 and 3.30).

(ii) Develop or advance models that may be used towards understanding ecosystem dynamics and consequences of management approaches for Antarctic resources (paragraph 5.36).

(iii) Consider the implementation of revision (version) control systems which allow the management of multiple revisions of programming code, documents and data files within a central database (paragraphs 7.3 and 7.4; see also paragraph 5.31).

(iv) Recommend adoption of a common set of terminology consistent with that of other international fora with respect to the evaluation of management procedures (paragraph 6.14).

ADOPTION OF THE REPORT AND CLOSE OF THE MEETING

10.1 The report of the meeting of WG-SAM was adopted.

10.2 Dr Constable thanked all participants for making this such an interesting, challenging and exciting meeting that was characterised by a wide diversity of ideas and contributions that had put the modelling and assessment work on a good footing.

10.3 Dr Constable also thanked all rapporteurs, noting that by working in teams almost all participants had an input into the process which had produced a very concise and accurate report. He also thanked Mrs L. Zaslavskaya for facilitating the meeting and noting especially her flexibility and efficiency in arranging transport. Dr Constable recorded his appreciation of the accommodation made by the Convener of WG-EMM to allow WG-SAM two extra days for its meeting this year, noting that this had allowed substantial progress in the advice that WG-SAM was able to provide to WG-EMM. He also thanked Dr Jones for chairing some particularly complex discussions as well as the Secretariat for its advice, guidance and support.

10.4 Dr Constable noted that while WG-SAM was yet to ‘find its feet’ as a working group, and especially its working relationship with the other working groups, it had made substantial progress this year and that this had been substantially assisted by the effective participation of quantitative experts from all working groups in all areas of the agenda.

10.5 Dr Holt, on behalf of the participants, expressed his appreciation to the Convener and congratulated him on his preparation and leadership, noting particularly his long history of involvement in the development of the Working Group. In response to Dr Constable’s comments about WG-SAM 'finding its feet', Dr Holt noted that he considered that the Working Group had indeed found its feet, but that the challenge now was to determine how big its shoes are.

10.6 The meeting was closed.

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APPENDIX A

LIST OF PARTICIPANTS

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(St Petersburg, Russia, 14 to 22 July 2008)

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APPENDIX B

AGENDA

Working Group on Statistics, Assessments and Modelling
(St Petersburg, Russia, 14 to 22 July 2008)

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

2. Parameter estimation

3. Stock and biological assessment methods

4. Advice on methods for use in work of SC-CAMLR
    - 4.1 Research designs in exploratory fisheries
    - 4.2 Establishing precautionary catch limits in the absence of research in exploratory fisheries
    - 4.3 Approaches to minimise effects on assessments of changing fishing practices
    - 4.4 Use of boosted regression trees in bioregionalisation
    - 4.5 Response of white-chinned and grey petrel populations to fisheries and environmental factors

5. Tools for population, food web and ecosystem modelling
    - 5.1 *Dissostichus* spp. population models
    - 5.2 Krill-based food-web models
    - 5.3 Fish-based food-web models
    - 5.4 Ecosystem models

6. Evaluation of management strategies
    - 6.1 *Dissostichus* spp.
    - 6.2 *Champsocephalus gunnari*
    - 6.3 *Euphausia superba*
        - 6.3.1 MSE framework for Stage 1 evaluation
        - 6.3.2 Performance measures
        - 6.3.3 Risk summaries
        - 6.3.4 Future work

7. Other business
    - 7.1 Procedural steps for multi-year assessments of *Dissostichus* spp.
    - 7.2 Fisheries and Ecosystem Models in the Antarctic (FEMA)
    - 7.3 Bottom fisheries and vulnerable marine ecosystems
    - 7.4 Reporting and archiving validation, verification and assessment work
    - 7.5 *CCAMLR Science*

8. Future work
   8.1 Long-term work plan
   8.2 Other issues

9. Advice to the Scientific Committee
   9.1 WG-EMM
   9.2 WG-FSA
   9.3 Ad hoc WG-IMAF
   9.4 General

10. Adoption of report and close of meeting.

APPENDIX C

LIST OF DOCUMENTS

Working Group on Statistics, Assessments and Modelling
(St Petersburg, Russia, 14 to 22 July 2008)

WG-SAM-08/1	Preliminary Agenda and Annotated Preliminary Agenda for the 2008 Meeting of the Subgroup on Assessment Methods
WG-SAM-08/2	List of participants
WG-SAM-08/3	List of documents
WG-SAM-08/4	Analysis of the potential for an assessment of toothfish stocks in Divisions 58.4.1, 58.4.2 D.J. Agnew, C. Edwards, R. Hillary, R. Mitchell (UK) and L.J. López Abellán (Spain)
WG-SAM-08/5	Exploratory assessment methods for exploratory fisheries: an example case using catch, IUU catch and tagging data for Subarea 58.4.3a R.M Hillary (UK) (*CCAMLR Science*, submitted)
WG-SAM-08/6	Defining tag rates and TACs to obtain suitably precise abundance estimates for new and exploratory fisheries in the CCAMLR Convention Area R.M. Hillary (UK) (*CCAMLR Science*, submitted)
WG-SAM-08/7	Analysis of Ross Sea tagging and recapture rates D.J. Agnew (UK)
WG-SAM-08/8	Towards the balanced stock assessment of Antarctic toothfish in the Ross Sea D. Vasilyev and K. Shust (Russia)
WG-SAM-08/9	Reconstruction of size and weight composition of Antarctic toothfish (*Dissostichus mawsoni*) from the data on processed commercial catches of longliners using conversion factor I. Istomin, K. Shust and V. Tatarnikov (Russia)
WG-SAM-08/10	Revised estimates of the area of the South Georgia and Shag Rocks shelf (CCAMLR Subarea 48.3) M. Belchier and P. Fretwell (UK) (*CCAMLR Science*, submitted)

WG-SAM-08/11	A proposed management procedure for the toothfish (*Dissostichus eleginoides*) resource in the Prince Edward Islands vicinity A. Brandão and D.S. Butterworth (South Africa) (*CCAMLR Science*, submitted)
WG-SAM-08/12	Extrapolating continuous plankton recorder data through the Southern Ocean using boosted regression trees M.H. Pinkerton, A.N.H. Smith (New Zealand), B. Raymond, G. Hosie (Australia) and B. Sharp (New Zealand)
WG-SAM-08/13	Development of a methodology for data quality assessment D.A.J. Middleton and A. Dunn (New Zealand)
WG-SAM-08/14	Development of a spatially explicit age-structured statistical catch-at-age population dynamics model for modelling movement of Antarctic toothfish in the Ross Sea A. Dunn and S. Rasmussen (New Zealand) (*CCAMLR Science*, submitted)
WG-SAM-08/15	Implementation of FOOSA (KPFM) in the EPOC modelling framework to facilitate validation and possible extension of models used in evaluating krill fishery harvest strategies that will minimise risk of localised impacts on krill predators A. Constable (Australia)
WG-SAM-08/16	An ecosystem-based management procedure for krill fisheries: a method for determining spatially-structured catch limits to manage risk of significant localised fisheries impacts on predators A. Constable and S. Candy (Australia) (*CCAMLR Science*, submitted)
WG-SAM-08/17	An updated description and parameterisation of the spatial multi-species operating model (SMOM) É.E. Plagányi and D.S. Butterworth (South Africa)

Other Documents

WG-SAM-08/P1	Resources evaluation of Antarctic krill *Euphausia superba* Dana using areal trawling and hydro-acooustic data L.A. Kovalchuk (Ukraine) (*Ukrainian Antarctic Journal*, 2 (2004): 170–178.)
WG-SAM-08/P2	Methodology of evaluating the aquatic life resources L.A. Kovalchuk (Ukraine) (*Reports of the National Academy of Science of Ukraine*, 12 (2006): 150–157)

WG-SAM-08/P3	SeaBird: Draft User Manual V1.00-2008/06/18 D. Fu and R.I.C.C. Francis (New Zealand) (*Final Fisheries Report to the New Zealand Ministry of Fisheries*)
WG-EMM-PSW-08/4	A population estimate of macaroni penguins (*Eudyptes chrysolophus*) at South Georgia P.N. Trathan (United Kingdom)
WG-EMM-PSW-08/5	The white-chinned petrel (*Procellaria aequinoctialis*) on South Georgia: population size, distribution and global significance A.R. Martin, S. Poncet, C. Barbraud, P. Fretwell and E. Foster (United Kingdom)
WG-EMM-PSW-08/6	Abundance estimates for crabeater, Weddell and leopard seals at the Antarctic Peninsula and in the western Weddell Sea (90°–30°W, 60°–80°S) J. Forcada and P.N. Trathan (United Kingdom)
WG-EMM-PSW-08/7	Spatial and temporal variation in attributes of Adélie penguin breeding populations: implications for uncertainty in estimation of the abundance of breeding penguins from one-off counts C. Southwell, J. McKinlay, R. Pike, D. Wilson, K. Newbery and L. Emmerson (Australia)
WG-EMM-PSW-08/8	Estimating the number of pre- and intermittent breeders associated with the Béchervaise Island Adélie penguin population L. Emmerson and C. Southwell (Australia)
WG-EMM-PSW-08/9	Aspects of population structure, dynamics and demography of relevance to abundance estimation: Adélie penguins L. Emmerson and C. Southwell (Australia)
WG-EMM-PSW-08/10	Flying seabirds in Area 48: a review of population estimates, coverage and potential gaps in survey extent and methods D. Wilson (Australia)
WG-EMM-PSW-08/11	Seasonal estimation of abundance by bootstrapping inexact research data (seabird): a method for assessing abundance and uncertainty from historical count data using Adélie penguins as a case study J.P. McKinlay and C.J. Southwell (Australia)
WG-EMM-PSW-08/12	A brief summary of Adélie penguin count data from east Antarctica C. Southwell and J. McKinlay (Australia)

WG-EMM-PSW-08/13	Incomplete search effort as a potential source of bias in broad-scale estimates of penguin abundance derived from published count data: a case study for Adélie penguins in east Antarctica C. Southwell, D. Smith and A. Bender (Australia)
WG-EMM-PSW-08/14	Antarctic fur seal pup production and population trends in the South Shetland Islands with special reference to sources of error in pup production estimates M.E. Goebel (USA), D.E. Torres C. (Chile), A. Miller, J. Santora, D. Costa (USA) and P. Diaz (Chile)
WG-EMM-PSW-08/15	Timing of clutch initiation in *Pygoscelis* penguins on the Antarctic Peninsula: towards an improved understanding of off-peak census correction factors H.J. Lynch, W.F. Fagan, R. Naveen, S.G. Trivelpiece and W.Z. Trivelpiece (USA)
WG-EMM-08/8	Report of the Predator Survey Workshop (Hobart, Australia, 16 to 20 June 2008)
WG-EMM-08/9	Report from Invited Expert to WG-EMM-PSW-08 R. Fewster
WG-EMM-08/10	Reference observations for validating and tuning operating models for krill fishery management in Area 48 S. Hill (United Kingdom), J. Hinke (USA), É. Plagányi (South Africa) and G. Watters (USA)
WG-EMM-08/11	Proposed small-scale management units for the krill fishery in Subarea 48.4 and around the South Sandwich Islands P.N. Trathan, A.P.R. Cooper and M. Biszczuk (United Kingdom)
WG-EMM-08/12	Allocating the precautionary catch limit for krill amongst the small-scale management units in Area 48: the implications of data uncertainties P.N. Trathan and S.L. Hill (United Kingdom)
WG-EMM-08/13	Developing four plausible parameterisations of FOOSA (a so-called reference set of parameterisations) by conditioning the model on a calendar of events that describes changes in the abundances of krill and their predators in the Scotia Sea G. Watters, J. Hinke (USA) and S. Hill (United Kingdom)
WG-EMM-08/14	Developing models of Antarctic marine ecosystems in support of CCAMLR and IWC A. Constable (Australia)

WG-EMM-08/15	CCAMLR-IWC Workshop to review input data for Antarctic marine ecosystem models: update on progress 2008 A. Constable and N. Gales (Co-conveners)
WG-EMM-08/40	Krill fishery behaviour in the 1999/2000 season S. Kawaguchi (Australia)
WG-EMM-08/44	Conditioning SMOM using the agreed calendar of observed changes in predator and krill abundance: a further step in the development of a management procedure for krill fisheries in Area 48 É.E. Plagányi and D.S. Butterworth (South Africa)