

Report of WG-EMM

5.1 In its discussions leading to an ecosystem assessment, WG-EMM considered trends in harvested species, dependent species and the environment and interactions between them. Trends in harvested species were discussed under Agenda Item 4, and trends in dependent species under Agenda Item 3.

Environment

5.2 The Scientific Committee noted that, in order to obtain a better understanding of krill flux, a practical index of current flow is required (Annex 4, paragraph 5.2).

5.3 Sea-surface temperature (SST) is widely seen as being an important environmental variable. SST data have been included on the CCAMLR database and a preliminary index of SST has been developed by WG-EMM. The Scientific Committee noted that further consideration of an SST index would be possible only after interactions in the ecosystem had been studied (Annex 4, paragraph 5.6). Data on bathymetry are also considered important for an understanding of both ecological and fishery interactions (Annex 4, paragraphs 5.11 to 5.13).

5.4 The Scientific Committee noted that some progress had been made on incorporation of sea-ice information into assessments, but further consideration of this topic is needed (Annex 5, paragraphs 5.7 and 5.14 to 5.22). Consideration has also been given to water circulation with respect to SST, bathymetry, and sea-ice (Annex 4, paragraphs 5.23 to 5.27).

5.5 Information had been provided to WG-EMM which indicated that an increase in mean temperature has been taking place over the past decade and the implications of this for krill were discussed (Annex 4, paragraphs 5.28 to 5.31). The Scientific Committee noted the view of WG-EMM that a better understanding of interactions within the system would be obtained by encouraging a more active participation by physical oceanographers who have a particular interest in helping to solve biological problems.

By-catch of Fish in the Krill Fishery

5.6 WG-EMM has reviewed new data and analyses by Japanese scientists of by-catches of fish in the krill fishery (Annex 4, paragraphs 6.1 to 6.3). It recommended that these data, augmented by length composition data for the most abundant species, should be incorporated into the comprehensive review of fish by-catches being undertaken by a correspondence group under the coordination of the Science Officer, Dr E. Sabourenkov. It has also requested that by-catch studies be extended to cover seasons other than the austral summer.

5.7 The Scientific Committee welcomed the provision of the new data and analyses, noting with gratitude that further data, including historical Russian data from krill surveys, have also been provided to WG-FSA (Annex 4, paragraphs 5.8 to 5.12). It endorsed the recommendations of WG-EMM on fish by-catch studies and looked forward to receiving the final report of the correspondence group.

Interactions between Harvested Species and the Environment

5.8 When attempting to relate krill distribution and recruitment to environmental variables, WG-EMM had identified a need to establish the degree of linkage between major concentrations of krill, to determine the size of areas in which similar variation takes place, and to establish to what extent observed variation could be explained by changes in krill production within an area, as opposed to movement of krill from area to area (Annex 4, paragraph 6.9). The Scientific Committee endorsed WG-EMM's conclusion that the implications of these points with respect to the size of management areas used by CCAMLR should be considered.

5.9 The Scientific Committee noted WG-EMM's discussion of the extent of variation in krill recruitment and its underlying causes. It endorsed the conclusion that the next step should be to derive an absolute recruitment index. It noted that further work was needed on the interpretation of recruitment indices and their relationship with sea-ice and other environmental variables (Annex 4, paragraphs 6.10 to 6.21).

5.10 The present krill yield model is based on the assumption that there is no temporal trend in krill recruitment. Evidence has been provided to WG-EMM which indicates that there may have been a decline in krill recruitment and abundance in Subarea 48.1 and possibly other subareas, arising from environmental changes. In the event that significant real trends are demonstrated, the Scientific Committee recognised that further development of the krill yield model may be required. It also

noted that refinements of the krill yield model to account for environmental effects on krill growth and mortality need to be considered (Annex 4, paragraphs 6.22 to 6.24).

Interactions between Harvested Species and the Krill Fishery

5.11 The Scientific Committee noted that analysis of haul-by-haul data from the krill fishery indicated that in Areas 48 and 58, the fishery was concentrated at locations which appear to be associated with environmental features, such as topographically induced eddies. The Scientific Committee endorsed the conclusion of WG-EMM that the provision of haul-by-haul data will improve our understanding of factors responsible for the local aggregation of krill (Annex 4, paragraph 6.25).

Interactions between Dependent Species and the Environment

5.12 The Scientific Committee noted WG-EMM's discussions on the relationship between penguin breeding success and local environmental variables, such as sea-ice distribution. It endorsed the request for Members to prepare formats for data submission and to suggest how appropriate indices might be calculated (Annex 4, paragraphs 6.30 to 6.36).

Interactions between Dependent Species and Harvested Species

5.13 The Scientific Committee noted new developments in studies on diet, energy budgets and foraging ranges of birds and marine mammals in the Convention Area (Annex 4, paragraphs 6.38 to 6.42). It endorsed the standing request to Members to monitor and update annually data on these aspects (Annex 4, paragraph 6.37). It also noted that studies on interactions between dependent species and their prey had highlighted the need for precise information on diet, feeding activity and diving behaviour in relation to the types of prey available (Annex 4, paragraphs 6.43 to 6.46).

5.14 Two approaches to modelling the relations between dependent species and prey were discussed by WG-EMM. The first of these investigated the effects of fisheries on krill predators, considering processes at the level of a foraging trip, rather than at the level of population effects. The Scientific Committee noted that this approach would be of particular relevance to ecosystem assessment (Annex 4, paragraphs 6.47 to 6.55). The second approach involved modelling functional relationships between predators and prey. Initial models have been developed for fur seal, black-browed albatross and Adélie penguin. The Scientific Committee endorsed the plans for

further development of these models developed by WG-EMM (Annex 4, paragraphs 6.56 to 6.61 and Appendix F).

5.15 Prof. Moreno welcomed the progress that had been made in understanding the interactions between dependent and harvested species, but queried the apparent absence of studies in which krill-eating fish are treated as dependent species.

5.16 Dr Everson noted that one example of such a study involving *C. gunnari* has been discussed by WG-FSA (Annex 5, paragraphs 4.149 to 4.153). As this work progresses, it may be appropriate for it also to be discussed by WG-EMM.

Overlap between Fisheries and Dependent Species

5.17 For a number of years, the Secretariat has been calculating the critical period-distance (CPD) index. Last year, it was agreed that the derivation and use of this index should be reviewed. This issue had been considered by WG-EMM's Subgroup on Statistics. Four levels at which the analysis of niche overlap may be considered were identified (Annex 4, paragraph 6.63 and Appendix H). The current CPD index is based on a potential overlap model. An alternative approach, which calculates a realised overlap index, is provided by the Agnew and Phegan (1995) model, however, WG-EMM noted that neither the model, nor its parameter values, had been evaluated by the Scientific Committee or its working groups (Annex 4, paragraph 6.72).

5.18 The Scientific Committee noted that this was a particularly complex subject on which considerable further work was needed (Annex 4, paragraphs 6.65 to 6.79). It endorsed the suggestion by WG-EMM that progress could be made intersessionally on the realised overlap index if the Agnew and Phegan model were evaluated critically in terms of its assumptions and the values of parameters used. It agreed that this task should be initiated through the WG-EMM Subgroup on Statistics and also by inviting submissions to the subgroup of additional or alternative values of parameters, including those suitable for extending the generality of the model beyond the Seal Island area (Annex 4, paragraph 6.80).

5.19 In relation to the additional data and analyses that would be needed by the subgroup for the review, the Scientific Committee agreed with the proposal from WG-EMM that the Secretariat should be asked to request data or analyses describing, for all relevant sites and species, (i) monthly estimates of typical diet composition, maximum and modal foraging range and direction, (ii) finer-scale foraging data where possible, and (iii) estimates of the above derived from close and/or similar sites if the information is not available for the specific CEMP site.

5.20 The Scientific Committee noted the expectation of WG-EMM that this process would lead to the development of one or more versions of the realised overlap model. The indices of overlap provided by this approach would be expected ultimately to replace those currently calculated using the potential overlap model. However, the current indices would continue to be calculated for the time being, particularly until implications relating to krill flux are better understood (Annex 4, paragraph 6.82).

5.21 Mr Ichii emphasised his view that the current potential overlap index was inappropriate and should be replaced by one based on realised overlap. He noted, however, that a commonsense approach should be taken when identifying realised overlap. In Subarea 48.1, for example, the foraging range of fur seals depends on the distribution of available myctophids, as well as krill. Also, the relative food consumption of the different predators should be taken into account.

5.22 Dr Croxall noted that:

- (i) this was not the consensus view either of the Subgroup on Statistics (see Annex 4, paragraph 6.65) or of WG-EMM (see e.g. Annex 4, paragraph 6.75);
- (ii) the existing formulation of the realised overlap model was, at best, applicable only to penguins in the vicinity of Seal Island and WG-EMM had agreed that it was essential to critically evaluate this model in terms of its assumptions and the parameter values used (Annex 4, paragraph 6.80); and
- (iii) WG-EMM had agreed to try to develop realised overlap models for appropriate combinations of species, sites and areas (Annex 4, paragraph 6.81) but they would need to be based on empirical data on diet and distribution of predators rather than on assertions concerning these.

5.23 The Scientific Committee agreed that ultimately overlap indices would probably be calculated on a site-by-site basis.

Analysis of Data from CEMP Indices

5.24 The Scientific Committee noted that integrated analyses have shown that some CEMP indices may show rather different and more complex responses than those which were previously assumed (Annex 4, paragraphs 6.85 to 6.88). Arising from discussion on an initial multivariate analysis using

data on chinstrap penguin breeding success, krill density and sea-ice extent, a regression model linking breeding success to sea-ice extent was constructed (Annex 4, paragraph 6.90). The Scientific Committee welcomed this approach to the analysis of CEMP data.

5.25 The Scientific Committee agreed that a workshop should be held intersessionally to address uncertainties regarding the relationship between indices of harvested and dependent species at specific sites and also between subareas in Area 48. The main focus would be on examining long time series of data in the area. The terms of reference for the meeting would be:

- (i) identify the extent of between and within-season variation in key indices of the environment, harvested species, and dependent species over past decades;
- (ii) identify coherence in the indices between sites and clarify understanding of the linkages between Subareas 48.1, 48.2 and 48.3;
- (iii) develop working hypotheses; and
- (iv) provide a summary report for consideration by the 1997 meeting of WG-EMM.

The meeting will be held in the USA (local organiser, Dr Holt).

Ecosystem Assessment

5.26 The Scientific Committee welcomed the considerable progress that has been made this year in the analysis of the CEMP indices, particularly the identification of anomalies and trends. It noted, however, that some further work is required, particularly on the treatment of indices which are not normally distributed. It further noted that, because of this, it was not yet possible for WG-EMM to present a table of statistically reliable anomalies. In its place, WG-EMM had developed a table presenting the information as standardised normal deviates for all years. These are set out in Annex 4, Table 4. The Scientific Committee noted that this table is halfway between the previous qualitative subjective presentation of data in last year's report and a future quantitative presentation of anomalies, which is one of the goals of WG-EMM.

5.27 The Scientific Committee joined WG-EMM in congratulating the Secretariat on the new analysis that had been conducted and endorsed the Working Group's recommendation that similar presentations be made in future years. It also agreed that further development should be undertaken by individual research communities with specific experience of individual CEMP sites. It noted that

the full set of raw CEMP data and a table of the indices calculated by the Secretariat, are now available for Members to use in such investigations, in accordance with the rules of access to CCAMLR data.

5.28 Using the information in Annex 4, Table 4 and other indicators contained in papers presented to the meeting, WG-EMM derived an ecosystem assessment for 1995/96. This is given in Annex 4, paragraph 7.2 and is summarised below.

5.29 For Subarea 48.1, there is evidence for a strong 1994/95 krill year class, and predator breeding success was also high. For Subarea 48.2, there are no time series data on prey abundance, but predators experienced a good breeding year. In Subarea 48.3, krill were more abundant than in previous seasons and predators experienced a better-than-average breeding season. Overall in Area 48, there is some coherence between events throughout, with 1995/96 being a cold year with better-than-average krill abundance and predator performance.

5.30 In Division 58.4.2, following the total failure of breeding Adélie penguins at Béchervaise Island, which occurred as a result of a local krill shortage, most breeders returned in 1996 although breeding success was a little lower than normal. No information on prey abundance was available. In Division 58.4.1, a krill survey discovered higher krill abundance in the western portion of the subarea than in the eastern portion, although no other historical surveys were available to enable an assessment to be made of the relative abundance of krill in the 1996 season.

5.31 In Subarea 88.1, predator performance in the Ross Sea was at an average level in 1996.

Strategic Modelling

5.32 The Scientific Committee noted that WG-EMM had further considered the conceptual framework developed last year (Annex 4, paragraphs 7.34 to 7.42). At present, most effort by WG-EMM is devoted to improving the understanding of the processes and linkages between harvested species, dependent species, the environment and the fishery. It endorsed WG-EMM's view that its ultimate aim should be to develop effective mechanisms for management of the ecosystem, as envisaged in the CCAMLR Convention.

5.33 In light of discussions concerning Annex 4, paragraphs 7.24 to 7.30, Dr K. Shust (Russia) noted that the large figure given in WG-EMM-96/66 for krill consumption by fur seals and penguins in Subarea 48.3 indicates that all previous calculations produced significant underestimates of krill biomass in the subarea, and that the fishery removed an infinitesimal part of the total stock. On the

other hand, if the figures for potential krill consumption by South Georgia fur seals are correct, then the increase in abundance of this predator over the last few years in Subarea 48.3 and the possible impact of this on other krill consumers are cause for concern.

5.34 In this regard, Dr Shust proposed that the abundance dynamics of South Georgia fur seals be studied thoroughly and, if the population is indeed increasing very rapidly, that the possibility of controlling the numbers of this predator be discussed together with specialists from SCAR and specialists on Antarctic fur seals.

5.35 Dr M. Naganobu (Japan) agreed that further study of this issue was needed and proposed that it should be discussed at the next WG-EMM meeting.

Ecosystem Implications of Proposals for New Fisheries

5.36 Consideration by WG-EMM of the ecosystem implications of proposals for new fisheries is discussed under Agenda Item 8. The Scientific Committee agreed, however, that WG-EMM should further consider the ecosystem components related to squid at its next meeting (Annex 4, paragraph 7.54).

Future Work

5.37 The Scientific Committee was pleased to note that a number of tasks identified at previous meetings of WG-EMM had been completed (Annex 4, paragraph 7.57). It noted that further work was needed on other tasks previously identified, as listed in Annex 4, paragraph 7.58, and it also noted the additional tasks identified during the most recent meeting of WG-EMM (Annex 4, paragraph 7.59).

5.38 The Scientific Committee recommended that the Subgroup on Statistics should meet during the intersessional period with the following terms of reference:

- (i) development of indices of at-sea behaviour and methods of deriving them via analysis of sample datasets;
- (ii) further review of identification of anomalies in CEMP indices;
- (iii) methods for dealing with missing values in multiple datasets; and

- (iv) critical evaluation of the assumptions and parameter values of the Agnew and Phegan (1995) model of realised overlap.

5.39 The Scientific Committee endorsed the appreciation shown by WG-EMM to Dr Agnew for his major contribution to the work of WG-EMM. It also joined WG-EMM in thanking Norway for hosting the meeting.

Data Requirements

5.40 The Scientific Committee endorsed the following conclusions of WG-EMM in relation to data requirements:

- (i) the continued collection and analysis of time budget data from the krill fishery is encouraged (Annex 4, paragraph 2.11);
- (ii) because of their utility, the submission of haul-by-haul data from the krill fishery should continue to be encouraged (Annex 4, paragraphs 3.28 and 3.29); and
- (iii) studies on the occurrence of fish in krill catches should continue in accordance with the recommended methods (Annex 4, paragraph 6.1).

Advice to the Commission

5.41 Advice to the Commission in relation to precautionary catch limits for krill is given in paragraph 4.27.