ANNEX 4

REPORT OF THE SECOND MEETING OF THE WORKRING GROUP ON KRILL

(Leningrad, USSR, 27 August to 3 September 1990)

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INTRODUCTION

The Second Meeting of the Working Group on Krill (WG-Krill) was held at the Fishery Exhibition Building in Leningrad, USSR from 27 August to 3 September 1990. The Meeting was chaired by the Convener, Mr D.G.M. Miller (South Africa).

2. The Convener welcomed delegates and outlined the Working Group's Terms of Reference and the meeting objectives. The meeting objectives were set out in paragraphs 2.35 and 5.21 of SC-CAMLR-VIII covering a requirement to review information on krill abundance and distribution, to liaise with the CCAMLR Ecosystem Monitoring Program with respect to assessing and monitoring the effects of changes of krill abundance on predators, and to consider procedures to evaluate the impact on krill stocks of current and future levels of harvesting.

3. The Working Group was also asked to address three specific questions by the Commission through the Scientific Committee (see CCAMLR-VIII, paragraph 50).

(i) What is the biomass and potential yield of krill in Subarea 48.3?

(ii) What are the possible management measures, including limits, that might be necessary on krill catches in the subarea which would maintain ecological relationships with dependent and related populations, including:

(a) the protection of dependent predators; and

(b) the protection of young and larval fish?

(iii) If these questions cannot be answered, what new information is required and how soon could it be obtained?

4. A Provisional Agenda distributed prior to the Meeting was considered by the Working Group. The Working Group felt that, whilst there was a lot of detail to cover in the Agenda,

and some overlap was expected in discussion of some items, the work program as set out would provide the opportunity to cover the meeting's objectives.

5. The amended Agenda was adopted (Appendix A). A List of Participants (Appendix B) and a List of Meeting Documents (Appendix C) are attached.

6. The following rapporteurs were responsible for preparing the Report of the Meeting: Drs D. Butterworth (South Africa), M. Basson (UK), S. Nicol (Australia), K. Kerry (Australia), E. Murphy (UK), J. Watkins (UK), D. Powell (Secretariat) and D. Agnew (Secretariat).

ORGANISATION OF WORK

7. To facilitate deliberations concerning certain technical aspects, the Working Group agreed that these be referred to specialist sub-groups for detailed discussions. Ideally the reports of these sub-groups would have been rediscussed by the Working Group as a whole, but this was not possible because of pressure of time and business. Accordingly it was decided to include in this Report those conclusions of the sub-groups which were agreed by the Working Group. However, any reservations that the Working Group had concerning the views expressed in sub-groups would also be recorded.

DEVELOPMENT OF APPROACHES TO MANAGING THE KRILL FISHERY

Identification of Needs

8. In discussion of approaches to the conservation of marine living resources at its meeting in 1988, the Commission sought the Scientific Committee's advice on:

> 'operational definitions for depletion and target levels for recovery of depleted species', and
>
> 'the ability of the CCAMLR Ecosystem Monitoring Program to detect changes in ecological relationships and to recognise effects of simple dependencies between species including distinguishing between natural fluctuations and those induced by fisheries'.

9. Following its consideration of these issues and papers on the subject submitted to the 1989 Meeting of the Scientific Committee (SC-CAMLR-VIII/BG/56, SC-CAMLR-VIII/BG/17, SC-CAMLR-VIII/9) it was agreed that the specialist working groups should consider the Commission's questions and the broader issue of the development of approaches to conservation.

10. The Working Group noted the relationship between this requirement and its fourth Term of Reference.

11. The Working Group was also required to address three specific questions in relation to Subarea 48.3, as detailed in paragraph 3 above. In dealing with the question of approaches to management, it was agreed to focus discussions on this subarea, noting nevertheless that the management approaches and considerations arising in such discussions also would be pertinent to the krill fishery in other subareas.

AVAILABLE INFORMATION

12. In order to identify specific needs with respect to the development of approaches to managing the krill fishery, the Working Group reviewed the relevant and available information. This included papers distributed at the Meeting dealing with topics outlined in paragraph 2.11 of the Scientific Committee's last report (SC-CAMLR-VIII) in addition to new information. The papers and topics considered were: commercial krill fisheries catches and the distribution of fishing activities in the Convention Area (SC-CAMLR-VIII/BG/11, 21, WG-Krill-90/16, 19), the collection and analysis of data from krill fisheries vessels and in krill fishing grounds (SC-CAMLR-VIII/BG/4, 5, 7, 10, 23, WG-Krill-90/6, 11, 25, 26, 27), the operating of fishing vessels with respect to krill distribution, biology, behaviour and catchability (SC-CAMLR-VIII/BG/9, 23, WG-Krill-90/22), analyses of fine-scale krill catch data reported to the Commission (SC-CAMLR-VIII/BG/43, 44, WG-Krill-90/8, 9, 10), estimation of krill biomass in selected subareas (SC-CAMLR-VIII/BG/4, 5, 7, 10, WG-Krill-90/7, 15, 17, 18, 20, 21, 23, 24), the determination of the acoustic target strength of krill (SC-CAMLR-VIII/BG/30, WG-Krill-90/12, 13, 28, 29, papers by Foote *et al*., 1990) and a variety of aspects of krill biology in general (SC-CAMLR-VIII/BG/22, 24, WG-Krill-90/5) including particularly the potential for identifying separate krill 'stocks' (SC-CAMLR-VIII/BG/7, 10, 21, 28, WG-Krill-90/8, 9, 16, 18, 19). With respect to the actual development of a management procedure for the krill fishery, due account was taken of paragraphs 7.10, 7.17 and 7.18 of SC-CAMLR-VIII and two papers specifically addressing

this issue (SC-CAMLR-VIII/BG/17 and WG-Krill-90/14). The detail of papers considered in depth by the Working Group are set out where appropriate below.

Stock Identification

13. Paper SC-CAMLR-VIII/BG/21 addressed this matter for the region of the Antarctic Peninsula and related waters. In introducing the paper Dr V. Spiridonov (USSR) stated that a functional approach, based on water circulation patterns, pointed to the existence of two sub-populations of krill in the Weddell Sea and the Bellingshausen Sea, with a transition zone between the two in the vicinity of the Bransfield Strait. This division would not imply genetic separation.

14. It was pointed out that the position of the transition zone varies over time, and also that most of the catch in Subarea 48.1 comes from the vicinity of the transition zone so that it would be difficult to allocate the catch between the two sub-populations.

15. Dr I. Everson (UK) commented that catch distribution patterns derived from fine-scale data revealed that krill fishing concentrated in the outer parts of the slope shelf areas, and showed that fishing moved from Subarea 48.3 in winter to Subarea 48.2 in summer which might be related to the sea-ice position. Prof. T. Lubimova (USSR) questioned the validity of these data which indicated fishing in areas to the southeast of South Georgia during summer, because she doubted that fishing had been undertaken in such areas. It was clarified that fishing activity occurred on the outer parts of the shelf and slope areas. It was pointed out by Dr Agnew that fishing in this area during summer had only been reported for 1987/88, the first year of reporting of such data, and recording errors might well be present, since the 1988/89 data did not show fishing in these areas. It was noted that these data shed little light on the stock identity problem, because different catch positions were likely to be related to high krill concentration areas within a stock, and not necessarily to different stocks.

Abundance Estimation

16. A sub-group, convened by Dr R. Hewitt (USA) was given the task of discussing the problems associated with the use of acoustics to estimate biomass and specifically to discuss recent work on krill acoustic target strength.

17. Members of the sub-group were Drs Everson, K. Foote (Norway), Hewitt, S. Kasatkina (USSR), Kerry, V. Tesler (USSR) and Watkins. The following papers were

reviewed and discussed: WG-Krill-90/13; 28; 29; SC-CAMLR-VIII/BG/30; Everson *et al*., 1990; Foote *et al*., 1990; Foote, 1990. During the discussion, references were made to additional published works, Foote *et al*., 1990; BIOMASS, 1986.

18. Two types of method are currently used to assess the spatial distribution and abundance of krill: acoustics and direct sampling methods. The principal advantages of acoustics relative to direct sampling methods are that a much larger portion of potential krill habitat is sampled per-unit-survey time and problems of net selectivity and catchability are avoided. Principal disadvantages include undersampling krill in the upper 10 metres of the water column and possibly undersampling dispersed krill (as suggested by positive net catches where no krill have been detected acoustically).

19. Further development is required of standardised procedures for the conduct of acoustic surveys for krill. These would include specification of:

- the krill target strength relationship used to convert integrated echo return to krill biomass;

- statistical procedures for summarising the data, preparing distribution maps, and estimating total abundance and its variance; and

- guidelines for survey design and direct sampling requirements.

20. The sub-group focused most of its discussion on the specification of krill target strength. Substantial progress has been made in the last two years on defining the target strength of krill by researchers in Australia, Japan, Norway, South Africa, UK, USA and USSR. Some of this work is published, some is in the form of reports and working papers, and some of it is in progress. Most have shown either an increasing dependence of krill target strength on acoustic frequency or lower krill target strength than that previously used to scale echo returns of krill to biomass (BIOMASS, 1986), or both.

21. It was acknowledged that some uncertainty in the measurement of target strength may be introduced by:

(i) differences in the orientation of animals in the experiments with the orientation of animals in the wild (although data were presented that show that average tilt angle and its variance for animals used in the experiments of Foote *et al*. (1990) was consistent with published observations of animals in the wild);

(ii) animal density effects (although this was shown to account for only 6% of the variation in target strength in the experiments of Foote *et al*. (1990); and

(iii) possible day-night differences in target strength.

These uncertainties do not appear to change the qualitative conclusions.

22. It was recognised that krill target strength may vary not only as a function of animal size but also condition. This is due to changes in specific density of the animal and speed of sound through the animal corresponding to changes in physiological condition.

23. It was agreed that:

(i) acoustic surveys are an efficient means of determining krill distribution and abundance provided that systems are correctly and frequently calibrated;

(ii) the values of krill target strength reported to date vary over a range of approximately 10 dB. This implies a 10-fold range of estimated krill biomass. In the absence of a more thorough review of technical issues, discrepancies between reported values of krill target strength may be best resolved in technical literature. Accordingly, it is recommended that Members encourage the publication of on-going work with sufficient detail so as to judge its technical merit. It is further recommended that a workshop on krill target strength be convened as soon as possible with the following terms of reference:

(a) technically review published and unpublished work on the specification of krill target strength; and

(b) recommend a krill target strength relationship to be used in acoustic surveys of krill;

(iii) additional experiments designed to measure krill target strength under controlled conditions should be conducted and, in particular, such experiments should include observations on the orientation of the observed krill. In this regard, Prof. Lubimova informed the Working Group that the Soviet Union was interested in cooperating in krill surveys and target strength measurements;

(iv) additional measurements of the density and speed of sound through individual krill should be made over a wide range of krill sizes, and stages of reproductive maturity, gut fullness, and moult cycle; and

(v) suggestions for appropriate survey designs, methods for summarising survey data, and procedures for estimating biomass and its variance should be developed and submitted to the CCAMLR WG-Krill. In this regard, the current ICES initiative to develop a standard method for estimating biomass and its variance from line-transect measurements of animal density was noted.

24. A sub-group, convened by Dr V. Siegel (EEC), was tasked with expanding and updating the table of net characteristics presented in the Report of the First Meeting of WG-Krill (SC-CAMLR-VIII, Annex 5). The updated version is presented here as Table 1.

25. Paper WG-Krill-90/23 was introduced containing results of investigations from surveys conducted during the austral summer over the period 1984 to 88 in the area from the South Shetland Islands to the South Georgia area. The paper considers krill distribution and its relationship to primary production and environmental factors. Inferences from these surveys suggest that krill do not consume more than 4 to 5% of primary production per day during the austral summer.

26. Paper WG-Krill-90/25 was introduced by Dr V. Latogursky (USSR). The paper comments on the work done by observers on-board krill fishing vessels during November 1989 to February 1990, northwest of Coronation Island (see paragraph 121).

27. Paper WG-Krill-90/17 presents biomass estimates from acoustic surveys, as well as descriptions of the characteristics of krill distribution patterns in the Indian Ocean sector (Statistical Area 58).

28. It was pointed out that since Japanese fishing vessels have operated in the Indian Ocean sector in the past, additional information may be available from this source. Dr M. Naganobu (Japan) confirmed that these data exist. Data from survey vessels have been collected and are being analysed.

29. Paper WG-Krill-90/18 presents results of investigations on krill distribution and abundance in the Enderby-Wilkes Subarea (58.4) over the period 1985/86 to 1988/89. Data are from commercial surveys. Biomass estimates of commercial aggregations and maps of

krill distribution are given. It was felt that it would be useful to have the bottom topography indicated on maps or charts that illustrate the distributional characteristics of krill.

30. Paper WG-Krill-90/22 presents results of studies into the catchability of midwater trawls and possible approaches for assessing the amount of krill that escape the trawl. It is shown that catchability depends both on the characteristics of krill local scale distribution and trawl parameters (e.g., speed of trawling and angle of attack of set net). The agreement between estimates of catchabilities from hydroacoustic data and estimates calculated according to probability/statistical theory of fishing trawls was emphasised.

31. Paper WG-Krill-90/20 shows that the estimation of krill biomass depends on characteristics of krill distribution which varies considerably over time because of its dependence on the biological state of the animals. The author, Dr Kasatkina, referring to SC-CAMLR-VIII/BG/10, pointed out that, from the results of WG-Krill-90/20 and data on actual fishing effort, it is possible to estimate fishing intensity and initial biomass of krill at the beginning of the fishing period.

32. Guidelines on the accumulation and processing of the information, used in their estimates, have been developed by AtlantNIRO. A booklet containing guidelines was presented to the Working Group and it was agreed that it would be advisable to consider them at its next meeting. The Soviet Delegation was asked to submit this material in English.

33. These results suggest that it will be necessary to consider local distributional characteristics of krill when estimating density from trawl survey data.

34. Biomass estimates presented in tabled papers, as well as estimates from previous studies are presented in Tables 2.1 to 2.3. It was pointed out that these were estimates of the biomass in the region concerned at a point of time, averaged over the usually short period of the survey. These are termed ‘instantaneous’ estimates. Because of immigration and emigration of krill from this region over a year, ‘instantaneous’ biomass differs from the ‘effective total’ biomass, which is the biomass of all krill, which are in the region at some time during the year. It is the ‘effective total’ biomass which is pertinent to the assessment of the harvest which can be taken from the region.

35. It was recognised that not all estimates in the tables are comparable. With respect to estimates of biomass for the South Georgia region (Subarea 48.3) surveys took place at different times of the year and the areas covered differed. There is a need for standardisation of survey design and methods.

36. The importance of not only presenting biomass estimates, but also including estimates of variance and detailed descriptions of the survey and analytical methods used was emphasised. In some cases estimates of biomass from survey data were obtained by means of contouring. It was considered important to include an explicit description of the method used, since different contouring procedures can lead to very different results, and the drawing of contours can often be subjective. A further problem is the difficulty of obtaining estimates of the coefficients of variance for the biomass estimates.

37. It was pointed out by Dr Foote that statistical techniques for estimating biomass and associated variance from survey data are available. These techniques make explicit use of observed information on spatial structure, hence their generic name ‘spatial statistical techniques’ (see also paragraphs 12 to 13). Work of the kind described in SC-CAMLR-VIII/BG/10 may be especially useful in this regard.

38. The Meeting felt that, in the light of problems associated with surveys of krill, greater precision would be achieved by coordinated surveys using standardised techniques and methodologies.

39. It was noted that the peak of the krill fishery at South Georgia is during the winter months (March to June) and that there is very little fishing during the summer months when krill are spawning. Dr P. Fedulov (USSR) explained that this redistribution of fishing effort is aimed at allowing the local krill population to reaccumulate and at avoiding interference with the feeding of breeding seabirds.

40. It was felt that a better understanding of the rates of movement (immigration and emigration) of krill into and out of Subarea 48.3 was necessary in order to derive appropriate estimates of effective total biomass in that region. It was, however, pointed out that it may be very difficult to estimate these rates of movement in practice.

41. The comments made with respect to biomass estimates for the South Georgia region apply equally to estimates for other regions. It was emphasised that the estimates should be interpreted with caution.

42. In some cases coefficients of variation (or likely ranges) for biomass estimates were included in Table 2.1 and it was noted that estimates of biomass appeared to have large variances in these cases. The need to identify the component of the total variance attributable to sampling was emphasised.

Estimation of Potential Yield

43. No specific estimates of potential yield for any subarea (or combination of subareas) had been made in any of the papers presented to the Meeting. This matter is discussed further in paragraphs 63 to 80.

Identification of Demographic Parameters

44. The following demographic parameters and variables were identified as of importance for modelling exercises related to krill management:

(i) natural mortality, **M** (related to production/biomass ratio);

(ii) age at maturity;

(iii) stock-recruit relationship parameters;

(iv) the extent of variability about the stock-recruit relationship;

(v) length-weight relationship parameters;

(vi) weight-at-age (in turn requiring estimates of critical parameters of the krill growth curve);

(vii) immigration and emigration rates; and

(viii) distributional parameters for krill aggregations (e.g., concentration size, swarm radii and swarm spacing).

45. **M** is inversely related to the longevity of the individuals in a population. There is an increasing body of opinion that the life-span of krill extends to at least four to five years. While this information alone does not provide a unique estimate of **M**, it is helpful in indicating a likely order of magnitude. It was noted that **M** is likely to vary in space and time and is also likely to depend on the age of the krill. However, larval mortality is not of concern for management, as it is an estimate of **M** which is typical of that for the ages susceptible for the fishery which is required.

46. Miller and Hampton (1989) summarised available estimates of **M** for krill to be found in the literature. These covered a wide range from 0.6 to 5.5. Due to pressure of time, it was not possible to critically review the bases for these various estimates during the Meeting. It was recommended that a review be carried out prior to the next meeting of the Working Group.

47. It was suggested that efforts be made to estimate **M** from the length distribution of catches, on the assumption that these were being taken from near-unexploited populations. To reduce a major source of bias in estimating the length distribution for the population, it was suggested that hauls to obtain such information be carried out at night to minimise net avoidance problems. It was further suggested that the forthcoming BIOMASS Krill Biology Workshop be requested to investigate whether the data collected during various BIOMASS surveys could be used to provide estimates of **M**.

48. A body of literature on the age (or length) at sexual maturity exists (e.g., see review by Miller and Hampton, 1989). The relationship between these two parameters is complicated by possible maturity regression after spawning.

49. In a table contained in Morris *et al*. (1988) details of existing evaluations of length-weight relationship parameters are provided. These are of particular importance in converting acoustic target strength length relationships to weight in the estimation of biomass. It was emphasised that full details must be provided for any additions to this table, as results can be very sensitive to the conditions under which measurements are made.

50. Data from future surveys should also be used to provide further estimates of the demographic parameters listed above (paragraph 44).

51. The previous meeting of the Working Group had identified the need for more information on krill swarm distribution parameters. Paper SC-CAMLR-VIII-BG/10, Tables 2.2 and 2.3 and WG-Krill-90/20 provided a valuable summary of further information in this regard, and would be most helpful in refining concepts of krill distributional patterns.

52. Mr I. Wojcik (Poland) recalled that at the Sixth Meeting of CCAMLR (SC-CAMLR-VI, paragraph 16.5), the Polish representative advised that the Plankton Sorting and Identification Centre in Szczecin, Poland offers low-cost services in sorting and identification of zooplankton samples. He suggested that this offer might be of interest to the Working Group in the context of standardisation of the analysis of data from the krill fishery.

This would, however, first necessitate that the Working Group specify the parameters to be measured very clearly.

REVIEW OF POSSIBLE APPROACHES

53. Paper WG-Krill-90/14 discussed factors to consider in developing procedures for the management of krill. The paper stressed the importance of identifying 'subsidiary' management objectives which would supplement the broad, general objectives of the Convention in ways which would allow an objective assessment of the state of the stocks with respect to these general objectives. Therefore 'subsidiary' objectives need to be set out in terms of quantities that can be reliably estimated. Their form may change with improved assessment methods and knowledge about krill and the fisheries. This means that there would usually be a strong link between the formulation of 'subsidiary' objectives and the types of assessment methods used. The paper also discussed the advantages and disadvantages of a number of possible approaches to krill management. A workplan for analysing the likely performance of potential management procedures was outlined.

54. Prof. Lubimova commented that the paper was of a general nature and she had difficulty in relating its contents to the problems at hand. A number of Members considered that it provided a valuable starting point in the development of a management approach, and that it illustrated the importance of integrating research and management considerations if the evolution of this management approach to krill is to proceed effectively.

55. Paper SC-CAMLR-VIII/BG/17 discussed the process of developing a feedback operational management procedure for krill. The paper suggested that the structure of a management procedure and its development involved four components, not necessarily in order of priority:

(i) a basis for assessing the status of the krill resource in the region concerned;

(ii) an algorithm for specifying appropriate levels of regulatory mechanisms (such as a catch control law) as a function of the results of such assessment;

(iii) a basis for the simulation testing of the performance of the management procedure ((i) and (ii) above); and

(iv) an operational definition of CCAMLR Article II to provide criteria against which performance could be assessed.

The word ‘operational’ implies ‘in terms of quantities which can be measured or estimated from field observations’. An ‘operational definition’ is synonymous with the ‘subsidiary objectives’ discussed in WG-Krill-90/14 (see paragraph 53 above).

56. An illustrative example was given for krill in Subareas 48.1, 48.2 and 48.3. Assessment was based on the CPUE ‘Composite Index’. The rate of increase of TACs was limited after an initial catch ceiling was reached. An operating model of krill dynamics for simulation testing purposes was set out. Finally an operational definition of Article II taking implicit account of the effect of harvesting on dependent and related species was suggested. A video illustrating how a similar management procedure was being developed for the International Whaling Commission was shown.

57. In response to questions, the author of SC-CAMLR-VIII/BG/17 (Dr Butterworth) stated that, in the absence of ground truth data for krill dynamics, the simulation testing was based on the best available estimates for the parameters describing these dynamics, but that it was also essential to test that performance did not degrade markedly if such estimates were varied across plausible ranges corresponding to current levels of uncertainty. Further, he stated that it was quite possible to extend the krill dynamics model used for testing purposes to incorporate spatial effects and related predator populations.

58. Dr Naganobu stated that he considered the implementation of limitations on the krill fishery to be premature. He argued that current catch levels were much less than biomass estimates, so could not seriously affect the resource. He also expressed reservations about the use of CPUE-related indices as a basis for assessing resource status and setting catch limits, and suggested that thorough survey procedures were needed to extend knowledge.

59. Prof. Lubimova also expressed strong reservations about the use of CPUE-related indices as a basis for assessing resource status. She drew attention to paragraph 86(a) of the Report of the Workshop on the Krill CPUE Simulation Study (SC-CAMLR-VIII, Annex 4) which stated that the ability to detect decreases in krill abundance from CPUE data is relatively limited. She questioned whether the approach suggested was the best way to proceed and stressed the need for methods to have a biological basis, in particular to take krill distribution features into account. She emphasised the need for more biological data, but agreed that modelling studies could assist in identifying the most critical gaps in present knowledge.

60. The view was expressed by Dr Butterworth and Dr W. de la Mare (Australia) that it was essential to begin the development of a management procedure immediately, so that an

agreed and reliable approach was in place at whatever time limitations to an expanding fishery might become required. It was also pointed out that assessment and catch limits did not have to be based on CPUE data; the example in SC-CAMLR-VIII/BG/17 using such data was intended only as an illustration of the overall approach, and survey data (for example) could equally well be used as the basis for assessment. It was noted that the absence of restrictions as suggested by Dr Naganobu also constituted a form of management procedure.

61. It was agreed that it would be helpful to structure discussion under the headings set out in paragraph 55 above. In regard to heading (iv) of that paragraph, it was agreed that it would not be possible to suggest detailed operational definitions of Article II in the time available to the Meeting. However, four general concepts on which such definitions might be based were developed:

(i) aim to keep the krill biomass at a level higher than might be the case if only single-species harvesting considerations were of concern;

(ii) given that krill dynamics have a stochastic component, focus on the lowest biomass that might occur over a future period, rather than the mean biomass at the end of that period as might be the case in a single-species context;

(iii) ensure that any reduction of food to predators which may arise because of krill harvesting is not such that land-breeding predators with restricted foraging ranges are disproportionately affected in comparison with predators present in pelagic habitats; and

(iv) examine what level of krill escapement would be sufficient to meet the reasonable requirements of krill predators. It was agreed that the Working Group for the CCAMLR Ecosystem Monitoring Program (WG-CEMP) be asked to consider this aspect.

62. Representatives were asked to provide suggested operational definitions of Article II on the basis of these concepts (and further such concepts which they might wish to suggest) in writing in time for consideration at the next appropriate meeting.

DEVELOPMENT OF APPROACHES AND FUTURE DATA REQUIREMENTS

Potential Yield from Subarea 48.3

63. Some Members suggested that a possible initial approach to the determination of appropriate yields from krill populations might be to use the formula:

$$Y = \lambda M B_{\circ}$$

where **Y** is the annual yield,
M is the natural mortality,
$\mathbf{B_{\circ}}$ is an estimate of the effective total biomass of the population prior to exploitation, and
λ is a numerical factor which depends on the age-at-first capture, growth curve parameters, and the extent of recruitment variability, and is typically less than 0.5.

Beddington and Cooke (1983) provide tables for the value of λ for combinations of these last mentioned parameters.

64. Prof. Lubimova expressed the following serious reservations in relation to the use of this formula for calculation of an annual yield of krill:

- $\mathbf{B_{\circ}}$, population biomass, is taken to be an initial population biomass. The calculations at this meeting were performed using instantaneous estimates of biomass. These data are not compatible because they are obtained by different methods for different areas and years (see paragraphs 34 and 35);

- the formula does not take into account the process of krill emigration and immigration, in particular in Subarea 48.3, which is considered to be an area which demonstrates ‘sterile outflux of krill’; and

- the available scientific data do not provide reliable and representative values of natural mortality of krill for the different areas under consideration.

65. The reservations mentioned above preclude the calculation of an annual yield of krill using the suggested formula. However, this formula, if modified to account for processes of

krill emigration and immigration, may be used as one of the possible approaches for krill fishery management and for the collection of information such as that requested by the Scientific Committee (SC-CAMLR-VIII, paragraph 50(c)).

66. Dr Naganobu expressed his support for the view expressed by Prof. Lubimova. He believed that the data used to calculate the biomass of krill in Subarea 48.3 were unreliable for this purpose and that more precise surveys in Subarea 48.3 were required. The krill fishery is an important industrial activity for the countries concerned and its regulation must be based on reliable data.

67. The Members who suggested that the formula in paragraph 63 could be used, considered that the reservations in paragraphs 64 to 66 had already been addressed in detail of their views, which are recorded in paragraphs 68 to 79.

68. The tables for λ referenced above in paragraph 63 were not available at the meeting. In any case, it was pointed out that they were based on a von Bertalanffy growth curve, and the values might change for the seasonably fluctuating growth shown by krill. Drs Butterworth and Basson volunteered to repeat the calculations of Beddington and Cooke for the next meeting, taking account of this last factor. It was agreed that they should do this for a range of plausible values for pertinent parameters. Results should be provided for a set of values for **M** of 0.3 and larger.

69. It was recognised that such calculations were appropriate for single-species fishery considerations so that the resultant value for λ would need to be reduced by some amount to take account of the requirements of Article II relating to dependent and related species (see also paragraph 56).

70. It was also recognised that a catch limit alone might not be an adequate future management measure if most of the catch taken in a restricted area which was also an important foraging area for land-based predators.

71. The Meeting had been asked by the Scientific Committee to advise on the potential yield of krill in Subarea 48.3. It was suggested that the crude formula:

$$Y = 0.5 \, M \, B_o$$

might provide a basis to guide the discussion. It was agreed to focus on the smallest recorded estimate of **M** of 0.6 (Brinton and Townsend, 1984) for this purpose.

72. Table 2.2 provides a set of estimates of the biomass of krill within Subarea 48.3. The average of these estimates which pertain to the March to June period (for which estimates are the most comparable) is some 600 thousand tonnes. It should be noted that these estimates refer to different areas as discussed in paragraphs 34 and 35. Use of this figure for $\mathbf{B}_{\circ}$ in the formula in the preceding paragraph assumes that the krill fishery has not already depleted the effective total biomass substantially below its average level prior to exploitation.

73. It was pointed out that this is an instantaneous estimate, and does not take into account that the total biomass of the population does not only include that occurring instantaneously in the South Georgia vicinity (the region to which the estimates of the preceding paragraph apply), but must also incorporate immigration and emigration of krill from this vicinity during the course of a year (see also paragraph 34).

74. There was considerable debate on the likely extent of adult krill transport throughout the South Georgia vicinity. Hydrographic information is available but this is not sufficient to allow transport rates to be estimated; such information as there was, indicated that these rates vary greatly over time.

75. Observations of a krill patch north of South Georgia (Dr Everson, personal communication) had shown that this dispersed after five days. The extent of the observed reduction of krill density could not have been occasioned by the fishery or predators. This suggested a lower bound of some five days on the residence time of krill in the area, while the associated upper bound would be one year. The corresponding limits for effective total biomass are 44 and 0.6 million tonnes respectively.

76. Annual consumption of krill by predators located at South Georgia (to be updated) is estimated to be 9 million tonnes (SC-CAMLR-VIII/BG/15). This consumption estimate corresponds approximately to the product $\mathbf{M}\ \mathbf{B}_{\circ}$, and suggests that one or both of the lower bounds $\mathbf{M}$=0.6 and $\mathbf{B}_{\circ}$=0.6 million tonnes must be too low.

77. Taken together, these figures and the crude formula in paragraph 71 above suggest a potential annual yield for krill in Subarea 48.3 in the range 0.2 to 13 million tonnes.

78. The low end of this range is similar to recent annual catches of some 0.2 million tonnes from Subarea 48.3. However, many qualifications must be stressed in regard to these yield estimates. On the negative side:

(i) **M** may well be smaller than the 0.6 used in the calculations above;

(ii) the work of Beddington and Cooke (1983) suggests that the value $\lambda=0.5$ used in the formula in paragraph 63 is too high;

(iii) the formula is derived from single-species considerations, and the result it provides should be reduced to some extent to allow for the requirements of dependent and related species; and

(iv) the modification of the biomass estimate to allow for krill transport through the area takes no account of the fact that such krill has probably immigrated from adjoining subareas which are also subject to exploitation.

79. On the positive side:

(i) **M** may well be larger than the 0.6 used for the calculations above;

(ii) the available instantaneous biomass estimates for Subarea 48.3 are negatively biased because of transport factors;

(iii) the estimate of krill consumption by predators in the subarea supports these indications of negative bias in the lower bound for the krill potential yield; and

(iv) the estimates for yield are negatively biased by the extent to which the krill fishery may already have depleted the effective total biomass below its average level prior to exploitation.

80. The very wide range for the crude yield estimate in paragraph 77 above is indicative of considerable uncertainty and lack of key information. However, the approach used does serve to focus attention on areas where further work is urgently needed:

(i) estimation of **M** from available and new data on length composition and age information (see paragraphs 45 and 46);

(ii) continued surveys of the South Georgia vicinity to provide absolute biomass estimates (with associated estimates of survey sampling variance) in a standardised manner;

(iii) empirical and theoretical (hydrodynamic) studies to estimate the typical retention time for krill in this vicinity, to be able to relate instantaneous biomass estimates to effective annual levels; and

(iv) refinement of the crude formula $Y = 0.5\ M\ B_o$ (see paragraph 65).

Effects of Krill Catches on Young and Larval Fish

81. The Commission had also sought advice on management measures for the krill fishery in Subarea 48.3 which would contribute to the protection of young and larval fish. Dr Foote drew attention to initiatives in net design in his country, which addressed such problems. In one study, on shrimp separator trawls, fish were deflected out of the codend, and shrimp alone, without admixture of larger animals, were caught. The quality of these shrimp was superior to that of shrimp caught in conventional shrimp trawls without separator grids. In a second study, large fish were retained in the trawl, and smaller animals allowed to escape by passing through a similar separator grid. (Contact persons for these studies are B. Isaksen, Institute of Marine Research, Bergen, and R.B. Larsen, Norwegian College of Fisheries Science, Tromsö.) It was agreed that the Commission's attention should be drawn to these developments, and it was suggested that experiments with such nets should be carried out for the krill fishery to test their effectiveness in reducing the proportion of young and larval fish captured.

Other Considerations

82. Earlier in the Meeting, reservations had been expressed by Prof. Lubimova and Dr Naganobu about the reliability of attempts at the previous workshop to develop a composite CPUE-related measure to provide a time series indexing krill biomass. A time series of a relative index of abundance (at least) is an essential requirement for the management of a marine resource. Accordingly the question was posed whether regular research surveys (independent of the fishery) were feasible for krill. If not, this would imply that high priority should be given to resolving outstanding problems in using CPUE data.

83. It was noted that local surveys in limited areas would in any case be required to provide information on prey availability to krill-dependent predators (see paragraphs 91).

84. It was appreciated that the krill fishery management problem involved difficulties of stock definition and immigration/emigration that were more severe than encountered in many other fisheries, but that these complications did not obviate the need for monitoring biomass, preferably by means of absolute measures, but otherwise using relative measures.

85. It was suggested that if full-scale regular research surveys were impractical, it might be possible to adapt fishing procedures to provide a reliable index of relative abundance. For example, fishing vessels might carry out limited fishing at pre-determined grid positions before commencing their regular pattern of activities.

86. The desirability of making use of on-board observers to obtain more reliable data from fishing operations was stressed (see paragraph 121). Dr V. Marín (Chile) emphasised that data collection procedures should be designed to facilitate the testing of pre-specified hypotheses, in contrast to attempting to collect every possible item of information; this was to ensure cost-effectiveness.

KRILL MONITORING AND WORKING GROUP FOR THE CCAMLR ECOSYSTEM MONITORING PROGRAM (WG-CEMP)

87. The Scientific Committee at its Eighth Meeting (SC-CAMLR-VIII, paragraph 5.21) requested that WG-Krill, in consultation with WG-CEMP as necessary:

(i) develop appropriate designs for prey monitoring surveys for the Integrated Study Regions and their vicinities;

(ii) prepare standard methods for the technical aspects of such prey surveys;

(iii) review the relevant environmental data required in the context (i.e. in terms of the spatial and temporal scales involved) of CEMP's requirements for prey monitoring; and

(iv) develop operational plans for collaborative and cooperative integrated surveys, with particular emphasis on the Integrated Study Regions.

88. Various papers (SC-CAMLR-VI-BG/8, SC-CAMLR-VII-BG/7, SC-CAMLR-VIII/9, SC-CAMLR-VII-BG/5, 10, 12, 13, 15, 31, 32, WG-CEMP-90/11,12, 14, WG-Krill-90/8, 9, 10 and 20) were identified as being pertinent to discussions on the above.

89. The Convener of WG-CEMP, Dr J. Bengtson (USA), was invited to describe the CEMP and in particular, the need for surveys of krill distribution and biomass in relation to specific predators. Dr Bengtson noted that CEMP monitoring, in keeping with its objectives (SC-CAMLR-VI, Annex 4, paragraph 8), comprises three elements: namely, the monitoring of selected predator parameters, the monitoring of prey (principally krill) and the monitoring of important environmental variables. The monitoring of prey and the environment was necessary to facilitate interpretation of the possible cause(s) of any change in selected predator parameters. Standard Methods for the monitoring of predators had been produced and good progress had been made in the implementation of the predator monitoring program. It is now essential that monitoring of prey commence as soon as possible.

90. At its First Meeting WG-Krill had noted WG-CEMP's requirements with respect to prey monitoring but requested (SC-CAMLR-VIII, Annex 5, paragraph 93) additional information on important characteristics of predators that need to be taken into account in krill surveys. This information was subsequently provided by CEMP (SC-CAMLR-VIII, Annex 7, Tables 4 and 5). Details of approximate spatial and temporal scales relevant to monitoring approved predator parameters at land-based sites were provided in WG-CEMP-90/12 and are summarised in Table 3 of this Report.

91. It was noted that, in relation to certain parameters (e.g., adult arrival weight, breeding population size and age-specific survival) predator foraging ranges may cover entire CCAMLR subareas and that long integration periods in terms of prey acquisition were involved. Other parameters entail integration periods that are shorter and foraging areas that are relatively localised. Considering the current level of understanding of krill distribution in space and time, correlating changes in predator parameters having long integration periods with prey abundance would require the latter to be monitored over both the predator's entire foraging area and integration period. It was considered that it would be impractical to expect this amount of prey survey effort to be available. Accordingly the Working Group agreed that, as an initial approach, it would be most practical to develop a krill survey strategy to be implemented during a period of two to two-and-a-half months (particularly during mid-December to late February) within a radius of approximately 100 km of land-based monitoring sites and to a water depth of 150 m.

92. The Working Group agreed that acoustic surveys offer the most practical approach to assessing krill availability at the temporal and spatial scales detailed above. Associated net sampling is also necessary to identify acoustic targets and to sample them accordingly.

93. Although it was recognised that absolute biomass estimates are preferred for prey monitoring as part of CEMP, relative biomass information for the December to February integration period and from year to year would be still very valuable. However, further consideration must be given to the following:

(i) the degree of precision required in the estimates of krill biomass related to the predator parameters having the appropriate integration period identified in paragraphs 90 and 91;

(ii) the compilation of data on areal distribution of krill; and

(iii) the methods of calculating relationships between survey design, associated survey effort and the expected precision of estimates.

A specific recommendation for developing (ii) and (iii) above is given in paragraphs 97 to 100.

94. The precision and accuracy of krill biomass estimates which can be undertaken at present have not yet been determined and it is not possible to specify a survey design in terms of the number of transects for a given area and the number of times that surveys should be repeated within the specified integration period.

95. The Working Group also noted additional constraints on surveys including the need to survey close inshore, and to take diurnal vertical migration of krill into account possibly by limiting acoustic surveys to daylight hours (see paragraph 100).

96. Dr Everson convened a small *ad hoc* group to consider matters related to the general problems of survey design as well as the statistical combination of line transect measurements of animal density to estimate biomass over a region and provide an associated variance estimate. Drs Agnew, Butterworth, Everson, Foote, Fedulov, Spiridonov and Murphy participated in the group.

97. Noting similar work being carried out within ICES, and on the basis of the *ad hoc* group's discussions, it is recommended that a small sub-group be charged to do the following:

(i) examine the problem of estimating krill biomass from acoustic measurements of density along line transects;

(ii) describe specific statistical techniques that can be used to derive estimates of biomass and associated variance;

(iii) describe how such estimates can be applied to various krill distributions, both assumed and observed;

(iv) meet for three days immediately prior to the next WG-Krill meeting in order to discuss and evaluate items (i) to (iii); and

(v) prepare a report to WG-Krill for consideration along with recommendation of specific standard techniques to be used by Members to describe krill distribution and estimate biomass from acoustic surveys.

98. Dr Everson agreed to convene the sub-group during the intersessional period and to coordinate its activities through correspondence and keep all other Members of the Working Group informed.

99. As predator monitoring is presently being undertaken in a number of areas it was suggested that, until detailed survey specifications are developed, Members wishing to determine krill distribution and biomass should adopt the approach set out in paragraph 100 below.

100. The Working Group considered SC-CAMLR-VI/BG/8 and used this as a basis for the development of interim guidelines for survey design. Surveys should be conducted by spacing as many transects as possible evenly over the study area. If possible, transects should be repeated several times during the two to two-and-a-half-month integration period. Given that krill may undertake diurnal migration, animals may be found close to the surface at night and consequently out of range of hull-mounted transducers. It is therefore suggested that surveys be conducted during a period of six to eight hours either side of solar noon. The remainder of the diurnal cycle could then be used to obtain relevant environmental data or to carry out more detailed investigations of areas of high krill abundance in the surface layer using nets. Acoustic surveys should be conducted using a frequency of at least 120 kHz and net hauls should be taken at approximately three-hourly intervals to identify acoustic targets etc.

101. Dr Fedulov indicated that it would be important to improve understanding of environmental processes associated with krill distribution and biomass parameters. In particular, he considered that attention should be focused on transport of Weddell Sea waters

to South Georgia, mixing of water from different origins in the Bransfield Strait, current flow along the Antarctic Peninsula, seasonal and interannual variability in ice edge position, atmospheric phenomena and perhaps some other major processes. Since these processes may greatly affect krill transport and distribution patterns, they should be primarily subjected to environmental monitoring.

102. Acoustic survey data may be presented in a number of ways. These include:

(i) density along line transects integrated over the water column and averaged over set distance intervals;

(ii) density along line transects integrated within selected water depth intervals and averaged over set transect intervals;

(iii) mean depth of swarm layers;

(iv) depth of the upper surface of swarms;

(v) length and thickness of swarms;

(vi) distance between swarms; and

(vii) within-swarm parameters from ping-by-ping analyses.

It is suggested the WG-CEMP consider which of these or other parameters would be most suitable for its purposes. Some details for the application of such parameters are provided in SC-CAMLR-VIII-BG/10.

103. It was noted that parameters such as those identified in paragraph 102 may vary during the course of a season. For instance, recent replicate surveys near Elephant Island conducted by the USA showed a five-fold increase in krill biomass (WG-Krill-90/11). It is clear therefore that replicate surveys should be carried out, and that the frequency of replication will depend on the precision required as well as any underlying structure in the dynamics of the krill concentration being considered. In addition, any identified changes in foraging range and behaviour of the predators including those changes related to specific stages in the breeding cycle should also be taken into account.

104. Since the spatial and temporal integration requirements influence the design of acoustic surveys, it is recommended that WG-CEMP provide advice on the changes in predator foraging range, behaviour and diet likely to occur during predator breeding cycles.

105. Attention was drawn to the environmental data required in terms of the spatial and temporal scales of krill monitoring desired by CEMP. In this context various papers were tabled (WG-CEMP-90/4, 11, 19 and WG-Krill-90/30).

106. At the 1989 Meeting of WG-Krill and at the 1989 Meeting of the Scientific Committee (SC-CAMLR-VIII, paragraph 5.21) information was requested on the possible application of satellite data for monitoring those environmental parameters most likely to influence krill biomass and distribution especially at the scales identified as practical in paragraph 91 above. WG-Krill-90/30 addressed this need. Table 4 lists the types and characteristics of satellites which the Working Group considered would be useful sources of data for monitoring krill. Dr Marín also reported that a cooperative program for a satellite network over the Antarctic was being developed by the FRG and Chile.

107. It was noted that satellite data would be useful for detecting hydrographic features, particularly with respect to large-scale processes such as fronts and gyres. Satellite information might also be of use in characterising surface water features associated with the movement of krill in and out of a particular area.

108. The Working Group agreed that information available from satellites concerning sea surface colour, sea surface temperature, sea surface altimetry and ice cover would contribute greatly in the delineation of gross hydrographic features such as fronts and gyres and also primary production.

109. A number of international programs are currently concentrating on large-scale hydrographic processes (see paragraph 28). For this reason finer resolution hydrographic information is unlikely to become available unless specific programs are developed. Despite the hydrographic complexity of important areas where krill concentrations may be found, such as the South Orkneys and the Antarctic Peninsula, information on large-scale processes influencing water dynamics in such areas was nevertheless considered to be useful.

110. It was agreed that direct measurements of currents (e.g., by Doppler current profiling) are preferred to geostrophic measurements in coastal areas. Physical and chemical water properties, to be used for identification of water masses, may be best obtained through direct

sampling. Sea ice position, cover and movement can be best determined by analysis of satellite imagery. Environmental data requirements for interpretation of krill surveys undertaken for CEMP are summarised in Table 5.

111. Progress was noted in the development of operational plans for collaborative and cooperative monitoring surveys in the Integrated Study Region as suggested by the Scientific Committee (SC-CAMLR-VIII, paragraph 5.21(d)). The Secretariat was requested to compile a list of all proposed joint surveys from the Reports of Members' Activities.

112. The potential utility of consolidating data derived from prey monitoring surveys was noted, and in this context attention was drawn to facilities such as Geographic Information Systems (GIS) (WG-CEMP-90/4) which would facilitate archiving and analysis of large amounts of data collected from specific areas. Dr R. Holt (USA) agreed to report back to the Working Group on possible applications of GIS with regard to the problem of predator/prey and environmental monitoring.

113. Along with the requirement that fine-scale krill catch data be reported for the Integrated Study Regions (specifically Subareas 48.1, 48.2 and 48.3), it was suggested that even finer scale data (e.g., haul-by-haul) also be reported from areas within 100 km of the shore where land-based predators colonies are found in these subareas. The impracticality of requesting two types of data from the fishery was pointed out and Dr V. Sushin expressed his concern that possible errors existed in the fine-scale data already submitted (see paragraph 15). The Data Manager agreed to investigate any possible errors in the fine-scale data in collaboration with scientists from the USSR.

114. Despite the request from the Scientific Committee (SC-CAMLR-VIII, paragraph 2.39) Dr Sushin indicated that the Soviet krill fishery was not in a position to collect haul-by-haul data and suggested that SC-CAMLR-VIII/BG/10 presents an alternative way of acquiring information of this kind. In this context, the Working Group noted that the presence of observers on Soviet commercial fishing vessels will allow some evaluation of the difficulties of obtaining haul-by-haul data in the future.

115. Although there was support for the experimental analysis of haul-by-haul data from small areas of ecologically interesting areas, it was pointed out that a good reason must be put forward for requesting such data and the desired time and space constraints should be specified. SC-CAMLR-VIII, paragraph 2.46 suggests that reporting of such data should only be specified once appropriate analyses have been identified. WG-Krill felt, however, that

some preliminary analyses of available haul-by-haul data are needed in order to facilitate identification of suitable analyses to be carried out on such data in general.

KRILL RESEARCH OF POTENTIAL USE IN PROVIDING FUTURE ADVICE FOR MANAGEMENT

Identification of Needs

116. The Working Group agreed that many of the aspects associated with the identification of needs for future krill research had already been discussed under Agenda Item 3. Reference should therefore be made to paragraphs 13 to 51 dealing with the need to improve krill stock identification, the assessment of krill abundance in various areas, the estimation of potential yield and the identification of demographic parameters considered to be important in the improvement of knowledge of both krill biology and associated aspects of the operational characteristics of the fishery (e.g., catchability of and selectivity for specific length classes).

Available Information

117. The Working Group discussed recommendations of the First Working Group Meeting and SC-CAMLR-VIII.

118. With regard to paragraphs 2.37 and 2.38 of SC-CAMLR-VIII (review of analyses of both past and currently available acoustic data and the examination of available echo-charts to gather data on krill concentration parameters and aggregation types), WG-Krill noted that consideration of Item 3 of its Agenda addressed these problems. However, it was felt that these analyses were still needed especially with respect to the investigation of the possible underlying causes of the formation and maintenance of fishable concentrations. It was agreed that the results of these analyses along with submissions on data access procedures should be reported to the Working Group's next meeting.

119. Concerning analysis of fine-scale data (SC-CAMLR-VIII, paragraph 2.41), a number of tabled papers specifically addressed this problem: SC-CAMLR-VIII/BG/43; WG-Krill-90/8; 9; 10 and 19. It was recognised that these analyses should be continued in view of a requirement to monitor the fishery activities specifically as these may be confined to relatively restricted areas.

120. The Working Group re-emphasised the importance of the continued evaluation of the potential utility and feasibility of collecting bridge log data, haul-by-haul catch and effort data (including relevant operational details) from commercial fishery and acoustic data from both survey and fishery vessels (SC-CAMLR-VIII, paragraphs 2.39, 2.40 and 2.46). In this connection it was noted that no new information has been provided. The Working Group encouraged the reporting of results of analyses of these data.

121. With regard to the collection of appropriate data aimed at quantifying demographic parameters (SC-CAMLR-VIII, paragraphs 2.40, 2.43 and 2.44), the Working Group noted that the Soviet Union is deploying scientific observers on commercial vessels and providing analysis facilities ashore. In relation to this the Working Group's attention was drawn to a form used by Soviet observers aboard commercial vessels (see WG-Krill-90/25). After some discussion it was agreed that the form be modified to include space for reporting the catch of post-larval and juvenile fish in commercial krill trawls and comments on the behaviour of associated krill predators. A modified version of this form will be prepared by the Secretariat and distributed to Members of the Working Group to provide guidelines for observers on commercial vessels in general. Prof. Lubimova also provided the Secretariat with 'Guidelines for Collecting and Reporting Data on the Occurrence of Juvenile Fish in Krill Trawls' (in Russian) used by observers on Soviet fishing vessels. The Working Group requested that these guidelines be translated.

122. In relation to the problem of incidental catch of post-larval and juvenile fish in krill commercial trawls the WG-Krill recognised that available information is limited and contradictory. In addition the Commission has requested specific advice on the problem in Subarea 48.3 (CCAMLR-VIII, paragraph 50). There was considerable discussion as to whether the by-catch was significant. Therefore the Working Group recommended that information on the amount of fish by-catch by species in the krill fishery (expressed as number and weight of fish) should be collected and reported to CCAMLR for consideration by the Working Group on Fish Stock Assessment.

123. The Working Group had an extensive discussion on the requirement to collect krill length data from commercial hauls (SC-CAMLR-VIII, paragraph 2.43 and 2.44) and papers WG-Krill-90/6, 11 Rev. 1, 26 and 27 were discussed. The Working Group accepted that it was unrealistic to expect the same intensity of sampling from commercial vessels as from scientific vessels. The Working Group concluded that the interim measure which requires the collection of at least 50 krill from one haul per day per vessel should stand until analyses

investigating the level of precision achievable had been carried out. The Working Group accepted that it was necessary to define how such data would be used before it could modify its recommendations concerning changes to the number of krill that should be collected.

124. The Working Group therefore recommended that commercial length frequency data already collected should be analysed either nationally or by the Secretariat, to estimate the level of precision achievable with the present sampling regime.

125. With regard to stock identification, Dr Spiridonov drew attention to work on the occurrence of two species of krill parasites which may have some utility in differentiating between krill populations (Dolzhenkov *et al*., 1987). Dr Nicol drew attention to several new methods for stock identification including mitochondrial DNA and suggested that the investigation of these methods would be a fruitful area for international cooperation. The Working Group recognised that this merited further investigation.

Spatial and Temporal Scales of Assessment

126. The Working Group recognised that an improved understanding of the dynamics of the advection of adult and sub-adult krill in and out of specific areas is crucial to many of the problems fundamental in the assessment of krill distribution and biomass.

Available Techniques and Future Data Requirements

127. It was recognised that given WG-Krill was producing recommendations on data requirements, it would be necessary to address the problems of data management in the near future to ensure optimal and efficient use of such data.

128. The Working Group emphasised that analyses submitted in future should contain sufficient details of methods and techniques (e.g., methods of biomass calculation and estimates of sampling variance) to allow comprehensive assessment by WG-Krill.

129. In view of the need to obtain information on large-scale water mass movement to interpret transport of krill through subareas, the Working Group noted that data pertinent to this were being collected and analysed as part of other international programs (e.g., WOCE, JGOFS). It was agreed that the Convener of WG-Krill should establish formal contact with SCOR to ensure an exchange of information.

130. The problems of estimating the potential yield of krill stocks in subareas of interest and of adequate survey design were addressed earlier in the Meeting. Various activities and tasks have been specified in the paragraphs 80, 100 and 102.

Future Work

131. The discussions at this meeting had identified many areas of importance to the Working Group in assessing the impact of fishing on krill stocks and krill availability to predators. It was felt that although it had been necessary to address this broad range of subjects at the first two meetings, priorities should be decided for the Working Group's work at future meetings.

132. It was agreed that in addition to the continuing requirement to review stock assessment work, attention be focused on the following specific areas:

(i) survey design;
(ii) development of management methods;
(iii) acoustic target strength of krill;
(iv) stock identification; and
(v) krill movement;

and that the highest priority be given to survey design and the development of management methods.

133. The Working Group also felt that at this stage it was essential to be able to plan ahead for the conduct of its work and be able to review progress annually. Various tasks had been referred to the Secretariat, others suggested to Members and some assigned to *ad hoc* groups (e.g., paragraphs 62, 68, 97 and 113) to be undertaken over the next 12 months whose reports should be reviewed at a meeting of the Working Group in 1991.

134. The Scientific Committee had deliberately scheduled and located the meetings of WG-Krill and WG-CEMP in 1990 to facilitate close communication between the two Working Groups. It was agreed that this arrangement had been beneficial and if possible similar arrangements should be made for the 1991 Meetings of the two Working Groups.

135. After considering the list of related meetings planned for 1991, it was agreed that the favoured timing for the meeting of the WG-Krill is in July/August 1991.

136. It was noted that the Scientific Committee at its 1990 Meeting will almost certainly raise matters for inclusion on the agenda of a meeting of WG-Krill in 1991. Nevertheless it was felt that the preparation of a draft agenda at this time, based on the items mentioned in paragraph 2 and the specific tasks referred to various groups throughout the Report, would be a concise means of recording the plans of the Working Group for the ensuing year and would facilitate an early beginning to preparations for the Meeting. The Draft Agenda is attached to this Report (Appendix D).

OTHER BUSINESS

137. Dr Naganobu suggested that available computer network systems should be investigated with a view to improving information flow among CCAMLR Member nations.

ADOPTION OF THE REPORT

138. The Working Group adopted the Report of the Meeting including the following:

ANSWERS TO THE SPECIFIC QUESTIONS RAISED BY THE COMMISSION

139. In answer to the questions posed by the Commission through the Scientific Committee (see paragraph 3 above), the Working Group refers the Scientific Committee and the Commission to the following sections of its Report:

(i) paragraphs 63 to 80 reflect the various opinions expressed. Some Members considered that a range of biomass estimates and potential yield could be provided on a crude basis; paragraphs 75 and 77 respectively reflect their views. Others expressed serious reservations about the biomass estimates and the formula used to calculate annual yield;

(ii) (a) this topic was addressed in general terms under Agenda Item 3(iii). Specific attention is drawn to the concepts developed in paragraph 61;

(b) paragraph 81 reflects suggestions on gear development to alleviate this problem. It is recommended that experiments be carried out on gear modification with a view to reducing the possible mortality of young fish in krill trawls. Paragraph 122 makes recommendations on data collection; and

(iii) requirements for new information are outlined in paragraph 80 and paragraphs 118, 119, 120, 122, 123, 124, 128 and 129. Determination of the time required to obtain sufficient data to provide satisfactory answers to the questions posed would be a substantial exercise which the Working Group was unable to carry out in the time available to it.

CLOSE OF THE MEETING

140. The Convener closed the Meeting and thanked the USSR Ministry of Fisheries for its hospitality in hosting the Meeting. He also thanked the rapporteurs, Secretariat and the Working Group Members for their participation and input.

Table 1: Scientific nets used in the Southern Ocean for krill research.

Gear	Advantage	Limitations
Polish German Krill trawls	- large sample size - little to zero net avoidance - deployed on a large number of trawlers = large data set	- net deployment restricted to larger research vessels - net selection for krill > 40 – 45 mm depending on trawl mesh size
RMT 1	(a) relatively simple to handle on most research vessels (b) electronic device enables to have real time net data on e.g. depth of net, filtered water volume (c) opening and closing device for vertical profiles, multiple version of the net available (d) effective on krill larvae sampling	- strong net avoidance of krill - especially uneffective for krill > 35 mm
RMT 8	(e) see (a) to (c) of RMT 1 (f) effective on relative abundance of krill (> 20 mm) for length and development stage compositions (g) working with conducting cable	- net selection for krill > 20 mm - net avoidance in daylight, factor unknown - difficult to handle when no A-frame available on the ship
Bongo	- see (a) and (d) under RMT 1 - two samples at a time	- see RMT 1 - no real time information on depth of net - no opening/closing device
Neuston	- easy to handle on most ships - effective for late krill larvae during certain periods of the season	- impossible to handle during bad weather - restricted to surface sampling
MOCNESS[a] 1 10	- see RMT 1 (b) to (d) - see RMT 8 - working with conducting cables	- see RMT 1 - see RMT 8 - fixed net frame, difficult to handle on smaller vessels, requires large A-frame for deployment
IKMT 6' 12'	- simple to handle on most research vessels - used as a gear for estimation since 1980 (USSR)	(a) unknown net avoidance and size selectivity (b) requires large A-frame for deployment - see IKMT 6' under (a) (c) not very suitable for estimation of concentration density
Discovery net[b]	-	- see Bongo ?
Kaiyo Maru Midwater Trawl KYMT	- see RMT 8 (f)	- see RMT 8 - no opening/closing device
Fixed frame $5m^2$ IKMT (method modified)	- capable of high speed tows (≅ 4 Kt)	- unknown net avoidance and selectivity - requires large A-frame for deployment
BIONESS ($1m^2$)[a]	- see MOCNESS 1	- see MOCNESS 1
ORI net ($1.6\ m^2$)	- opening/closing device - easy to handle on research vessels	- no real time information on depth of net - see RMT 1
Commercial 77.4/202 ($78m^2$)	- used mainly for estimation of density of aggregations and concentrations	- underfishing of juveniles. Hardly suitable for data compilation on size composition of krill.
Samyshev-Yevdokimov trawl, developed jointly by YugNIRO and Scientific Research Association of Commercial Fisheries in Kaliningrad (NPO Promrybolovstva) ($30m^2$)	- used since 1989. Provides for acquisition of data reflecting precisely size composition of catches and krill concentration density. Reduces traumatism of animals entrapped in trawl (as compared with Isaacs-Kidd trawl). Proposed as standard fishing gear for scientific purposes in the USSR.	- is not equipped with opening/locking design. However after 1991 this shortcoming will be eliminated. Sectional system for trawl closing is under development.

[a] not used frequently but may have potential or is under development
[b] out of use except for comparative studies

Table 2.1: Krill biomass estimates derived from papers considered at the 1990 Meeting of WG-Krill: Subarea 48.1.

Area/Subarea		Source	Data Source and Method of Analysis	Area of Survey	Year and Month	Biomass Estimates ('000 t)	Density Estimates (g.m^{-2})
48.1		Nast 1986[a]	Trawl survey SIBEX I and II		Oct/Nov 1983 Nov/Dec 1984 Mar/Apr 1985	723 252 164	10.32 3.60 2.34
48.1	Antarctic Peninsula	SC-CAMLR-VIII/BG/21	Trawl surveys: *Eurica* March 1984 *Argus* December 1984 Analysis by strata	 92 300 km^2 84 600 km^2	 March 1984 December 1984	 1 233±41% 1 708±30%	 13.36 20.19
48.1		To be presented to SC-CAMLR-IX	Trawl survey (contoured, strata) (Saville 77) RV *Meteor* survey	14 310 n miles^2 97 200 n miles^2 78 940 n miles^2 88 230 n miles^2 93 800 n miles^2	February 1982 March 1985 May/June 1986 Nov/Dec 1987 Dec/Jan 1989/90	240 904 52 933 950	4.9±79% 2.7±102% 0.55±165% 3.2±82% 2.7±83%
48.1	Drake Passage	Kalinowski 1982[a]	FIBEX (Poland, Acoustic)		Feb/Mar 1981	1 195.6	8.40
48.1	Drake Passage	Lillo & Guzman 1982[a]	FIBEX (Poland, Acoustic)		Feb/Mar 1981	70.8	9.93
48.1	Bransfield Strait	Kalinowski 1982[a]	FIBEX (Poland, Acoustic)		Feb/Mar 1981	2 271	100.00
48.1	Bransfield Strait	Lillo & Guzman 1982[a]	FIBEX (Poland, Acoustic)		Feb/Mar 1981	448.8	22.26
48.1		Klindt 1986[a]	SIBEX I (FRG, Acoustic)		Oct/Nov 1983	51.7	0.72
			SIBEX II (FRG, Acoustic)		Nov/Dec 1984	379.8	5.48
			SIBEX II (FRG, Acoustic)		Mar/Apr 1985	16.5	0.26
48.1	Drake Passage	Kalinowski *et al.* 1985[a]	SIBEX I, (Poland, Acoustic)		Dec/Jan 1983/84	122.5	1.17
48.1	Bransfield Strait	Kalinowski *et al.* 1985[a]	SIBEX I, (Poland, Acoustic)		Dec/Jan 1983/84	70.6	0.88
48.1	Elephant Island	SC-CAMLR-VIII/BG/10	Acoustic surveys 1984-85	753 n miles^2 1 048 n miles^2	Dec/Jan 1984/85	541[b] 610[b]	209 170
48.1	(48.2, 48.5?) Drake Passage - Scotia Sea	SC-CAMLR-VIII/BG/52	Acoustic (south of 57°S)		1987/88	23 850	-
48.1	Elephant Island	SC-CAMLR-VII/BG/21	Acoustic 120/200 kHz	7 453 n miles^2	1988	260/715[c]	10.19/28.01
48.1	Bransfield Strait (part)	SC-CAMLR-VII/BG/21	Acoustic 120/200 kHz	2 894 n miles^2	1988	39/83[c]	3.94/8.38
48.1	Bransfield Strait	SC-CAMLR-VII/BG/21	Acoustic 120 kHz	7 787 n miles^2	1988	385	14.44
48.1	N. King George Island	SC-CAMLR-VII/BG/21	Acoustic 120 kHz	8 836 n miles^2	1988	309	10.21
48.1		WG-CEMP-90/11	Acoustic Survey 1 Survey 2 Survey 3 Survey 4		Jan/Feb 1990	range 465 (92-838) 1 132 (405-1 858) 2 133 (256-4 009) 2 475 (870-4 080)	

[a] Data from Table 4 of SC-CAMLR-VIII/BG/11
[b] Biomass of commercial aggregations
[c] Results of analyses at 120/200 kHz presented

Table 2.2: Krill biomass estimates derived from papers considered at the 1990 Meeting of WG-Krill: Subareas 48.2, 48.3 and 48.4.

Area/Subarea	Source	Data Source and Method of Analysis	Area of Survey	Year and Month	Biomass Estimates ('000 t)	Density Estimates ($g.m^{-2}$)
48.1 South Orkneys	SC-CAMLR-VIII/BG/10	Acoustic surveys 1984-85	2 002 n miles^2	January 1985	500*	0.251
48.3	WG-Krill-90/19	Commercial(C)/ Research(R) trawl surveys	51 690 km^2 33 370 km^2 12 700 km^2 14 700 km^2 11 700 km^2 48 113 km^2 12 600 km^2 79 120 km^2 2 820 km^2	March 1974 (C) February 1975 (C) June 1981 (C) July 1981 (C) June 1983 (C) October 1984 (C) November 86 (C) February 1988(R) May 1988 (C)	560 906 476 79 54 3.8 607 878 1 402	108.4 28.6 37.9 5.4 4.6 0.1 48.2 10.9 310.0
48.4 South Sandwich Is	WG-Krill-90/21	Trawl survey (biomass rich area treated separately)	90 391 km^2	Mar-Apr 1990 (0-100m layer)	3 385	-

* Biomass of commercial aggregations

Table 2.3: Krill biomass estimates derived from papers considered at the 1990 Meeting of WG-Krill: Subarea 58.4.

Area/Subarea/ Division	Source	Data Source and Method of Analysis	Area of Survey	Year and Month	Biomass Estimates ('000 t)	Density Estimates ($g.m^{-2}$)
58.4.1 Wilkes Land	WG-Krill-90/18	Commercial trawl survey of concentrations		1986-89	[a]	
58.4.2	Miller 1986[b]	SIBEX I net haul data		Mar/Apr 1984	550	3.48
58.4.2 Prydz Bay 48.6 Bouvet Is.	BIOMASS 1986[b]	FIBEX[c], Acoustic	4 512 000 km^2	Feb/Mar 1981	4 512	1.97
58.4.2 Prydz Bay	Miller 1987[b]	SIBEX II[c], Acoustic	1 090 000 km^2	Feb/Mar 1985	124	0.48
58.4.2 Prydz Bay	Higginbottom *et al*. 1988[b]	FIBEX[c], Acoustic	70 000 km^2	Jan/Mar 1981	1 300	1.2
58.4.2 Prydz Bay	Higginbottom *et al*. 1988[b]	ADBEX[c], Acoustic	1 280 000 km^2	Jan/Feb 1984	180	2.7
58.4.1 Prydz Bay 58.4.2	Higginbottom *et al*. 1988[b]	SIBEX II[c], Acoustic		Jan 1985	3 700	2.9
58.4.2	WG-Krill-90/17	Hydroacoustic surveys 1988-90	80 500 km^2 540 000 km^2 760 000 km^2	Jan/Feb 1988 Feb 1989 Jan 1990	3 500±600 12 000±4 000 30 000±10 000	43 75 84

[a] Specific concentrations were surveyed in three 'subareas' between 130° to 150°E, 64° to 66°S. Estimates of biomass for the subarea have not been calculated from this.

[b] Data obtained from SC-CAMLR-VIII/BG/11

[c] Australia, France, Japan, South Africa

Table 3: Aspects of temporal and spatial scales for developing prey surveys in support of CEMP.

Method Number	Dates	Integration Period	Foraging Range/Area (km)	Foraging Depth (m)
Prydz Bay Integrated Study Region				
A1	Oct	6-7 months	100s	?
A2	Nov-Dec	7-8 months	?	?
A3	Dec	>1 year		
A4				
A5	Dec-Feb	1-4 days		70-175
A6	Dec-Feb	4 months		
A7	Feb	2 months		
A8	Nov-Feb	14 days		
A9				
Antarctic Peninsula Integrated Study Region				
A1	Oct-Nov	6-7 months	100s	40-120
A2	Oct-Dec	7-8 months	25-50	40-120
A3	Oct-Nov	> 1 year	100s	40-120
A4	Oct-Feb	1 year	100s	40-120
A5	Nov-Feb	2.5 months	25-50	40-120
A6(A)	Jan	1 year	100s	40-120
A6(B/C)	Nov-Jan	2.5 months	25-50	40-120
A7	Jan-Feb	2 months	25-50	40-120
A8	Dec-Feb	5 months	25-50	40-120
A9	Oct-Feb	5 months	25-50	40-120
C1	Dec-Jan	60-70 days	100	25-120
C2	Dec-Mar	80-120 days	100	25-120
South Georgia Integrated Study Region				
A1	Oct-Nov	6-7 months	100s	20-150
A2	Nov-Dec	7-8 months	50-100?	20-150
A3	Nov	1 year	100s	20-150
A4	Oct-Feb	1 year	100s	20-150
A5	Jan-Feb	over 2 months	10-50	20-150
A6	Feb	3 months	10-100	20-150
A7	Feb	2 months	10-50	20-150
A8	Jan-Feb	7 days	10-50	20-150
A9				
C1	Nov-Mar	80-100 days	20-100	30-150
C2(A)	Dec-Mar	110 days	20-100	30-150
C2(B)	Jan-Mar	60 days	20-100	30-150

Table 4: Sources of satellite data that may be useful for monitoring environmental features in Antarctica.

Name of Sensor	Type of Data	Spatial Resolution (m)	Temporal Resolution (days)
NOAA Polar Orbiter	•visible radiance •near infrared •thermal infrared	1 100	< 0.25
Landsat Multispectral Scanner	•visible radiance •near infrared	80	15
Landsat Thematic Mapper	•thermal infrared	30	15
SPOT Multispectral Imager	•visible radiance •near infrared	10-20	10
European Research Satellite-1	•synthetic aperture radar	30	10
Soyuzkarta Panchromatic Imager		6	12*
Soyuzkarta Multispectral Imager	•visible radiance •near infrared	20	12*

* As plotted by the US Geological Survey

Table 5: Environmental data requirements for interpretation of krill surveys undertaken for CEMP.

Feature	Scale		Proposed Methods	Status*
	Spatial	Temporal		
1. WATER				
1.1 Water movements	Macro/Meso	Inter-annual Within season	Direct measurement of currents	M/R
1.2 Physical/chemical properties	Macro/Meso Micro	Inter-annual Within season Weekly	1. Nutrients/tracers 2. Temp., salinity 3. Satellite imagery	M/R M/R M/R
2. ICE				
Sea ice movement, ice edge position, % cover, polynyas	Macro/Meso	Inter-annual Within season	Satellite imagery	M

* Status: M = suitable to monitor now, R = topic currently the subject of research

APPENDIX A

AGENDA FOR THE SECOND MEETING

Working Group on Krill
(Leningrad, USSR, 27 August to 3 September 1990)

1. Welcome

2. Introduction
   (i) Review of the Working Group's Terms of Reference
   (ii) Review of the Meeting Objectives
   (iii) Adoption of the Agenda

3. Development of Approaches to Managing the Krill Fishery
   (i) Identification of Needs
      (a) Working Group's Fourth Term of Reference
      (b) Scientific Committee/Commission Questions (CCAMLR-VIII, paragraph 50)
   (ii) Available Information
      (a) Stock Identification
      (b) Assessment of Abundance
      (c) Estimation of Potential Yield
      (d) Identification of Demographic Parameters
   (iii) Review of Possible Approaches
   (iv) Development of Approaches and Future Data Requirements
   (v) Advice to the Scientific Committee

4. Krill Monitoring and Working Group for the CCAMLR Ecosystem Monitoring Program (WG-CEMP)
   (i) Identification of Needs (SC-CAMLR-VIII, paragraph 5.21)
      (a) Identification of Monitoring Areas
      (b) Development of Suitable Survey Design
      (c) Development of Survey Methods
      (d) Environmental and Krill Monitoring
   (ii) Available Information
   (iii) Spatial and Temporal Scales of Monitoring
   (iv) Techniques of Monitoring

(v) Future Data Requirements
(vi) Advice to the Scientific Committee

5. Krill Research of Potential Use in Providing Future Advice for Management
   (i) Identification of Needs
      (a) Stock Identification
      (b) Assessment of Abundance
      (c) Estimation of Potential Yield
      (d) Identification of Demographic Parameters
   (ii) Available Information (SC-CAMLR-VIII, paragraphs 2.37 to 2.44)
   (iii) Spatial and Temporal Scales of Assessment
   (iv) Available Techniques and Use of Forthcoming Data
   (v) Future Data Requirements
   (vi) Advice to the Scientific Committee

6. Future Work of the Working Group

7. Other Business

8. Adoption of the Report

9. Close of the Meeting.

APPENDIX B

LIST OF PARTICIPANTS

Working Group on Krill
(Leningrad, USSR, 27 August to 3 September 1990)

M. BASSON	Renewable Resources Assessment Group Imperial College of Science and Technology 8, Prince Gardens London SW7 1NA United Kingdom
J. BENGTSON	National Marine Mammal Laboratory National Marine Fisheries Service 7600 Sand Point Way NE Seattle, Washington 98115 USA
V.A. BIBIK	YugNIRO Sverdlov str., 2 Kerch USSR
D. BUTTERWORTH	Department of Applied Mathematics University of Cape Town Rondebosch 7700 South Africa
A. DETKOV	AtlantNIRO 5 Dmitry Donskoy Kaliningrad 236000 USSR
I. EVERSON	British Antarctic Survey High Cross, Madingley Road Cambridge CB3 OET United Kingdom
P.P. FEDULOV	AtlantNIRO 5 Dmitry Donskoy Kaliningrad 236000 USSR

K. FOOTE	Institute of Marine Research PO Box 1870 Nordnes 5024 Bergen Norway
G. GOUSSEV	USSR Ministry of Fisheries Rozsdestvenski Bulvar 12 Moscow 103045 USSR
R. HEWITT	Antarctic Ecosystem Research Group Southwest Fisheries Center PO Box 271 La Jolla, California 92038 USA
R. HOLT	Antarctic Ecosystem Research Group Southwest Fisheries Center PO Box 271 La Jolla, California 92038 USA
S.M. KASATKINA	AtlantNIRO 5 Dmitry Donskoy Kaliningrad 236000 USSR
M. Ya. KAZARNOVSKY	VNIRO 17a V. Krasnoselskaya Moscow 107140 USSR
K. KERRY	Antarctic Division Channel Highway Kingston, Tasmania, 7050 Australia
K. KOBAYASHI	Japan Deep Sea Trawlers Association Tokyo Japan
V.I. LATOGURSKY	AtlantNIRO 5 Dmitry Donskoy Kaliningrad 236000 USSR

L.J. LOPEZ ABELLAN	Centro Oceanográfico de Canarias Instituto Español de Oceanografía Carretera San Andres S/N Santa Cruz de Tenerife Spain
T.G. LUBIMOVA	VNIRO 17a V. Krasnoselskaya Moscow 107140 USSR
R.R. MAKAROV	VNIRO 17a V. Krasnoselskaya Moscow 107140 USSR
W. de la MARE	Centre for Marine and Ecological Research Soerlaan 33 1185 JG Amstelveen The Netherlands
V.H. MARIN	Universidad de Antofagasta Instituto de Investigaciones Oceanológicas Casilla 170 Antofagasta Chile
L.A. MENSHENINA	VNIRO 17a V. Krasnoselskaya Moscow 107140 USSR
D.G.M. MILLER	Sea Fisheries Research Institute Private Bag X2 Roggebaai 8012 South Africa
E. MURPHY	British Antarctic Survey High Cross, Madingley Road Cambridge CB3 OET United Kingdom
M. NAGANOBU	National Research Institute of Far Seas Fisheries 7-1, Orido 5 chome Shimizu-shi, Shizuoka 424 Japan

S. NICOL	Antarctic Division Channel Highway Kingston, Tasmania, 7050 Australia
V.V. PRONIN	USSR Ministry of Fisheries Rozsdestvenski Bulvar 12 Moscow 103045 USSR
V. SAPRONOV	VNIERH Moscow USSR
K.V. SHUST	VNIRO 17a V. Krasnoselskaya Moscow 107140 USSR
V. SIEGEL	EEC Delegate Sea Fisheries Research Institute Palmaille 9 D-2000 Hamburg 50 Federal Republic of Germany
V.N. SPIRIDONOV	Moscow University Moscow USSR
J.O. STRÖMBERG	Kristineberg Marine Biological Station S-450 34 Fiskebäckskil Sweden
V.A. SUSHIN	AtlantNIRO 5 Dmitry Donskoy Kaliningrad 236000 USSR
V.D. TESLER	VNIRO 17a V. Krasnoselskaya Moscow 107140 USSR
J.L. WATKINS	British Antarctic Survey High Cross, Madingley Road Cambridge CB3 OET United Kingdom

I. WOJCIK	Sea Fisheries Institute A1. Zjednoczenia 1 81-345 Gdynia Poland
V.N. YAKOVLEV	YugNIRO Sverdlov str., 2 Kerch USSR

SECRETARIAT:

D. POWELL (Executive Secretary) E. SABOURENKOV (Science Officer) D. AGNEW (Data Manager) G. NICHOLLS (Secretary)	CCAMLR 25 Old Wharf Hobart, Tasmania, 7000 Australia

APPENDIX C

LIST OF DOCUMENTS

Working Group on Krill
(Leningrad, USSR, 27 August to 3 September 1990)

Meeting Documents:

WG-KRILL-90/1	REVISED PROVISIONAL AGENDA
WG-KRILL-90/1 Rev. 1	AGENDA
WG-KRILL-90/2	LIST OF PARTICIPANTS
WG-KRILL-90/3	LIST OF DOCUMENTS
WG-KRILL-90/4	ON INVESTIGATION OF ANNUAL FLUCTUATION OF *EUPHAUSIA SUPERBA* LARVAE A.S. Fedotov and L.L. Menshenina (USSR)
WG-KRILL-90/5	SIZE COMPOSITION IN *EUPHAUSIA SUPERBA*'S MALES AND FEMALES IN THE COURSE OF LIFE CYCLE R.R. Makarov (USSR)
WG-KRILL-90/6	A STANDARDISED SAMPLING PROCEDURE FOR COMMERCIAL KRILL CATCHES S. Nicol (Australia)
WG-KRILL-90/7	UNITED STATES AMLR PROGRAM 1989/90 FIELD SEASON REPORT
WG-KRILL-90/8	FINE-SCALE CATCHES OF KRILL IN SUBAREA 48.1 Secretariat
WG-KRILL-90/9	FINE-SCALE CATCHES OF KRILL IN SUBAREA 48.2 Secretariat
WG-KRILL-90/10	FINE-SCALE CATCHES OF KRILL IN SUBAREA 48.3 Secretariat
WG-KRILL-90/11	HOMOGENEITY OF BODY LENGTH COMPOSITION OF ANTARCTIC KRILL WITHIN THE COMMERCIAL HAUL T. Ichii (Japan)
WG-KRILL-90/11 Rev1	HOMOGENEITY OF BODY LENGTH COMPOSITION OF ANTARCTIC KRILL WITHIN THE COMMERCIAL HAUL T. Ichii (Japan)

WG-KRILL-90/12	Withdrawn
WG-KRILL-90/13	AN EVALUATION OF REDUCED TARGET STRENGTH ESTIMATES REPORTED FOR KRILL *(EUPHAUSIA SUPERBA*) Michael C. Macaulay (USA)
WG-KRILL-90/14	FACTORS TO CONSIDER IN DEVELOPING MANAGEMENT MEASURES FOR KRILL William K. de la Mare (Australia)
WG-KRILL-90/15	COMMENTS ON THE CALCULATION OF THE COMPOSITE INDEX OF KRILL ABUNDANCE V.A. Spiridonov (USSR)
WG-KRILL-90/16	THE DISTRIBUTION PATTERN AND FISHERY FOR THE ANTARCTIC KRILL (*EUPHAUSIA SUPERBA)* OFF THE WILKES LAND AND BALLENY ISLANDS (WITH NOTES ON THE APPLICATION OF CPUE DATA AS INDICES OF KRILL ABUNDANCE) V.N. Dolzhenkov, E.A. Kovalev, V.A. Spiridonov, V.P. Timonin, I.A. Zhigalov (USSR)
WG-KRILL-90/17	CONDITION OF KRILL RESOURCES IN THE STATISTIC REGIONS 58.4.2 AND 58.4.3 IN 1988-1990 FROM THE ACOUSTIC SURVEY DATA V.A. Bibik and V.N. Yakovlev (USSR)
WG-KRILL-90/18	THE CHARACTER OF DISTRIBUTION AND STATE OF THE RESOURCES OF *EUPHAUSIA SUPERBA DANA* IN THE AREA OF THE WILKES LAND (Data for seasons 1985/86-1988/89) V.N. Dolzhenkov and V.P. Timonin (USSR)
WG-KRILL-90/19	THE DISTRIBUTION, BIOMASS AND CHARACTERISTICS OF THE FISHERY FOR *EUPHAUSIA SUPERBA* OFF THE SOUTH GEORGIA ISLAND (SUBAREA 48.3) V.I. Latogursky, R.R. Makarov and L.G. Maklygin (USSR)
WG-KRILL-90/20	CHARACTERISTICS OF DISTRIBUTION OF KRILL AGGREGATIONS IN FISHING GROUNDS OFF CORONATION ISLAND IN 1989-1990 SEASON S.M. Kasatkina and V.I. Latogursky (USSR)
WG-KRILL-90/21	KRILL BIOMASS ASSESSMENT IN STATISTICAL AREA 48 IN AUTUMN 1989-90 FROM THE TSM *ATLANTNIRO* DATA A.C. Fedotov (USSR)

WG-KRILL-90/22 MIDWATER TRAWL CATCHABILITY ON KRILL EXPLOITATION AND POSSIBLE APPROACHES TO KRILL TOTAL EXEMPTION ASSESSMENT
Yu.V. Zimarev, S.M. Kasatkina and Yu.P. Frolov (USSR)

WG-KRILL-90/23 SUMMARY RESULTS OF KRILL INTEGRATED STUDIES IN STATISTICAL AREA 48 CARRIED OUT IN RESEARCH CRUISES OF RV *ARGUS* AND RV *EVRIKA* IN 1984-1988
V.A. Sushin, L.G. Maklygin and S.M. Kasatkina (USSR)
(available in Russian only)

WG-KRILL-90/24 PRELIMINARY RESULTS OF RESEARCH CRUISE OF RV *ATLANTNIRO* TO THE WEST OF THE ATLANTIC OCEAN SECTOR OF THE ANTARCTIC IN MARCH-APRIL 1990
P.P. Fedulov, V.N. Shnar, A.C. Fedotov and I.V. Krasovsky (USSR)
(available in Russian only)

WG-KRILL-90/25 REPORT OF THE SCIENTIFIC OBSERVER ABOARD FISHING VESSEL BMRT *SAPFIR*
V.I. Latogursky (USSR)
(available in Russian only)

WG-KRILL-90/26 HOW MANY KRILL SHOULD WE MEASURE?
Yoshinari Endo (Japan)

WG-KRILL-90/27 ON THE INTENSITY OF SAMPLING KRILL TRAWL CATCHES
D.G.M. Miller (South Africa)

WG-KRILL-90/28 MEASUREMENTS OF DIFFERENCES IN THE TARGET STRENGTH OF ANTARCTIC KRILL (*EUPHAUSIA SUPERBA)* SWARMS AT 38 AND 120 KHZ
I. Hampton (South Africa)

WG-KRILL-90/29 ACOUSTICALLY ESTIMATING KRILL ABUNDANCE IN THE SOUTHERN OCEAN
Charles H. Greene, Sam McClatchie, Peter H. Wiebe and Timothy K. Stanton (USA)

WG-KRILL-90/30 DISCUSSION OF SATELLITE IMAGERY APPLIED TO CAMLR REGIONS
Robert E. Dennis (USA)

Other Documents:

WG-CEMP-90/4 AN APPROACH TO INTEGRATED ANALYSES OF PREDATOR/PREY/ ENVIRONMENTAL DATA
Stephanie N. Sexton and Jane E. Rosenberg (USA)

WG-CEMP-90/11	SURFACE WATER MASSES, PRIMARY PRODUCTION, KRILL DISTRIBUTION AND PREDATOR FORAGING IN THE VICINITY OF ELEPHANT ISLAND DURING THE 1989-90 AUSTRAL SUMMER Anthony F. Amos *et al*. (USA)
WG-CEMP-90/12	TEMPORAL AND SPATIAL SCALES FOR MONITORING CEMP PREDATOR PARAMETERS (WG-CEMP)
SC-CAMLR-VIII/BG/4	PROPOSALS OF STANDARDIZATION OF COMPLEX INVESTIGATIONS AIMED AT CREATION OF A SYSTEM OF BIOLOGO-OCEANOGRAPHIC MONITORING IN THE ANTARCTIC WATER Delegation of USSR
SC-CAMLR-VIII/BG/5	METHODICAL INSTRUCTIONS IN CONSTRUCTION OF A MODEL OF THE QUANTITATIVE DISTRIBUTION OF KRILL BY DATA OBTAINED IN OCEANOGRAPHICAL, BIOLOGICAL AND HYDROACOUSTIC SURVEYS Delegation of USSR
SC-CAMLR-VIII/BG/7	SUMMARISED RESULTS OF AN INTEGRATED FISHERIES SURVEY IN THE 1987/88 SEASON USSR (Available in Russian only)
SC-CAMLR-VIII/BG/9	THE INFLUENCE OF THE SHAPE OF MESHES ON THE SELECTIVE PROPERTIES OF TRAWLS WITH SPECIAL REFERENCE TO ANTARCTIC KRILL Delegation of USSR
SC-CAMLR-VIII/BG/10	ASSESSMENT OF KRILL BIOMASS IN FISHING GROUNDS USING THE DATA ON FISHING INTENSITY AND HYDROACOUSTIC METHOD Delegation of USSR
SC-CAMLR-VIII/BG/11	COMMERCIAL KRILL FISHERIES IN THE ANTARCTIC 1973 – 1988 Delegation of South Africa
SC-CAMLR-VIII/BG/17	TOWARDS AN INITIAL OPERATIONAL MANAGEMENT PROCEDURE FOR THE KRILL FISHERY IN SUBAREAS 48.1, 48.2 AND 48.3 D. Butterworth (South Africa)
SC-CAMLR-VIII/BG/19	THE RELATIONSHIP BETWEEN KRILL (*EUPHAUSIA SUPERBA*) FISHING AREAS IN THE WEST ATLANTIC AND THE SPECIES' CIRCUMPOLAR DISTRIBUTION D. Miller (South Africa)

SC-CAMLR-VIII/BG/21 POPULATION SUBDIVISION AND DISTRIBUTION OF *EUPHAUSIA SUPERBA* IN THE REGION OF THE ANTARCTIC PENINSULA AND ADJACENT WATERS IN RELATION TO FISHERY DEVELOPMENT
Delegation of USSR

SC-CAMLR-VIII/BG/22 GROWTH AND MATURATION OF *EUPHAUSIA SUPERBA* DANA IN NORTHERN AREAS OF ITS DISTRIBUTION RANGE (WITH REFERENCE TO SOUTH GEORGIA AND BOUVET ISLAND AREAS)
Delegation of USSR

SC-CAMLR-VIII/BG/23 ANALYSIS OF OPERATING CONDITIONS OF THE FISHING VESSEL IN RELATION TO THE DISTRIBUTION, BIOLOGICAL STATE AND BEHAVIOUR OF ANTARCTIC KRILL (A CONTRIBUTION TO THE DEVELOPMENT OF SIMULATION MODEL)
Delegation of USSR

SC-CAMLR-VIII/BG/24 DATES OF SPAWNING OF ANTARCTIC EUPHAUSIIDS
Delegation of USSR

SC-CAMLR-VIII/BG/28 CPUES AND BODY LENGTH OF ANTARCTIC KRILL DURING 1986/87 SEASON IN THE FISHING GROUND NORTHWEST OF ELEPHANT ISLAND
Delegation of Japan

SC-CAMLR-VIII/BG/29 COMPARISON OF BODY LENGTH OF ANTARCTIC KRILL COLLECTED BY A TRAWL NET AND *KAIYO MARU* MIDWATER TRAWL
Delegation of Japan

SC-CAMLR-VIII/BG/30 TARGET STRENGTH ESTIMATION OF ANTARCTIC KRILL, *EUPHAUSIA SUPERBA* BY COOPERATIVE EXPERIMENTS WITH COMMERCIAL TRAWLERS
Delegation of Japan

SC-CAMLR-VIII/BG/31 DISTRIBUTION OF ANTARCTIC KRILL CONCENTRATIONS EXPLOITED BY JAPANESE KRILL TRAWLERS AND MINKE WHALES
Delegation of Japan

SC-CAMLR-VIII/BG/43 KRILL FISHING, ANALYSIS OF FINE-SCALE DATA REPORTED TO CCAMLR
Delegation of United Kingdom

SC-CAMLR-VIII/BG/44 THE FINE-SCALE DISTRIBUTION OF KRILL IN AREA 48 DURING 1987 AND 1988
Secretariat

SC-CAMLR-VIII/BG/52 THE FIFTH ANTARCTIC OCEAN SURVEY CRUISE OF JFA RV *KAIYO MARU* SUMMARY OF RESULTS
Delegation of Japan

SC-CAMLR-VI/BG/8 PREY MONITORING SURVEYS
Delegation of United Kingdom

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FOOTE K.G., I. EVERSON, J.L. WATKINS, and D.G. BONE. 1990. Target strengths of Antarctic krill (*Euphausia superba*) at 38 and 120 kHz. *J. Acoust. Soc. Am*. 87(1): 16-24.

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APPENDIX D

DRAFT AGENDA FOR THE THIRD MEETING

Working Group on Krill

1. Opening of the Meeting
2. Matters Referred by the Scientific Committee
3. Development of Approaches to Managing the Krill Fishery
4. Krill Survey Methods
5. Stock Identification
6. Acoustic Target Strength of Krill
7. Krill Movement
8. Krill Biomass and Distribution
9. Coordination with CEMP
10. Other Business
11. Adoption of the Report
12. Close of the Meeting.