ANNEX 6

REPORT OF THE *AD HOC* WORKSHOP ON KRILL CPUE

INTRODUCTION

1. The Working Group met on 21, 22 and 29 August 1985. Dr W. Ranke (GDR) had been appointed Convenor of the group. In his absence Dr I. Everson (UK) chaired the meeting for the first two days and Mr D. Miller (South Africa) acted as rapporteur.

2. Having briefly reviewed the background to the meeting, the Chairman proposed an agenda (see Appendix I) which was subsequently adopted by the meeting (see Appendix II for list of participants).

3. A number of documents were available to the meeting and these are listed in Appendix III.

REVIEW OF PURPOSE OF THE MEETING

4. The purpose of the meeting was reviewed. The aims of the group were, briefly:

   (a) To identify the measures of fishing effort that are suitable for the monitoring of krill abundance by the catch-per-unit-effort (CPUE) method, and the methods of analysing effort data in order to produce indices of abundance.

   (b) To describe research projects that will improve the quality of krill abundance estimates by the CPUE method.

USE OF CPUE DATA

Basic Description of CPUE Theory

5. Dr J. Gulland (CCAMLR invited expert) briefly described the underlying theory behind the use of the CPUE method for the estimation of commercial fish abundance. He identified three types of fisheries operations and highlighted differences in the characteristics of CPUE data so collected.

6. The three fisheries types identified were demersal trawl fishery, whaling and purse seine fishing. These differ in the relative importance given when computing or collecting

data on fishing effort to the time spent actually fishing, and the time spent searching. Bottom trawl fisheries are characterised by more or less continuous fishing whilst whaling involves a high proportion of searching relative to catching time. Purse seining involves a combination of the two strategies.

7. The group recognised that the assumption of random distribution of krill fishing activities was not necessarily a pre-requisite of the fishery although it simplified the basic principles of CPUE application. It follows that an inverse linear relationship cannot be assumed between krill abundance and fishing effort for a wide distributional area and for essentially localised fishing activity. The krill fishery is therefore likely to reflect a combination of operations varying between searching and continuous fishing in areas of good catches as in a demersal fishery.

Fishing Effort and the Krill Fishery

Description of fishing strategies

8. Japanese and Soviet methods of krill exploitation differ. Dr Y. Shimadzu briefly summarised the Japanese fishing operation as set out in Documents 4–6 and Document 9. He highlighted differences in single catcher boat and in mother-ship type operations, indicating associated variations in the catch-per-haul data. The Japanese fishing operation also depends on the type of krill targeted and this in turn directly affects fishing time. When large krill are being fished, haultime is reduced to improve the quality of the catch. The Japanese krill fishery appears similar at least during the peak fishing season to a demersal trawl operation, for which catch-per-unit-fishing time is quite readily used as an index of density. For this operation fishing appears to be more or less continuous, with little or no between-haul searching. The length of haul is adjusted to the catch rate, so that catch per haul would not reflect changes in density. The catch per hour or per minute would not be so affected. The group therefore recognised that in the Japanese fishery catch-per-unit-fishing time would appear to provide a useful index of local density in the immediate vicinity (i.e. of the order of perhaps 1–5 km around the vessel’s track although judging by the daily operational area of catcher boats in mothership type operations, this area may be much larger – possibly as much as 50 km). Difficulties occur when attempting to expand to provide abundance indices for larger areas in the absence of search-time or inter-krill-concentration distance.

9. The Soviet fisheries strategy is very different from that of the Japanese. As described in Documents 7 and 8, it relies on advice from fisheries research vessels to locate fishing

vessels in areas of high krill abundance. At present, problems with processing the catch set the level of fishing effort and little data is available from actual fishing operations. The group appreciated that research vessel survey data would be likely to provide fisheries independent estimates of krill abundance.

Measures of Abundance for Large Areas

10. While the catch-per-unit-fishing time in operations such as the Japanese mid-season fishery do provide information on krill density over an area much larger than the path swept by the net (perhaps dimensions of 1–-5 km upwards – Item 8 and Document 4) (or possibly areas of 1° latitude by 5° longitude in those areas where fishing has been distributed over such an area); problems still exist in using catch/effort data to provide measures of abundance over larger areas such as ‘fishing’ areas or areas occupied by a biological stock. The key questions are found in the ratio of the overall density to local density in the selected areas, or, what is nearly but not quite the same thing, the proportion that high density areas (sufficiently high to support a fishery) occupy of the total distributional area of the stock. The second question is best answered when information on the searching carried out by the fishing fleets is available and from which the average distance between high-density patches may be deduced. On this point, the tactics of the Soviet and Japanese fleets are different, and data from the two types of operation may require different methods of analysis in order to produce useful indices of abundance.

11. In other cases (e.g. whaling) theoretical studies, including simulation modelling, have proved valuable in determining the best methods of approach. The group therefore strongly recommended that a consultant, be appointed, or some other suitable arrangement be made, to study methods of applying search time and CPUE data to the estimation of krill abundance over larger areas.

12. A range of relationships between CPUE and overall krill density are possible. In order to explore this range, and in particular, to identify the type of effort data which will give the strongest relationship between CPUE and abundance, a simulation study will be required. The following broad terms of reference are proposed:

(a) Develop a simulation model of a krill population capable of generating a range of spatial patterns of krill distribution and krill population dynamics;

(b) Develop a model of fishing with the capacity to simulate a range of fishing strategies;

(c) Combine models (a) and (b) to explore the relationship between various measures of CPUE with changes in simulated krill abundance;

(d) In addition, examine how catch and effort data may be combined with independent survey data, based on hydroacoustic methods or research trawls, in order to obtain an index of abundance applicable to larger areas.

13. The aim of the study is exploratory, and hence, both parts of the model should be able to simulate a wide range of possible behaviours. Data from the BIOMASS programme would assist in the development of a spatial model for krill. Changes in the character of krill aggregations with local krill density may give an indication of some possible models for variation in aggregation behaviour with krill stock abundance. In addition, there are several statistical methods which might be applied depending on the nature of the observations being made. In general, the objective would be to derive the appropriate probability density functions describing the frequency, size and type of krill aggregates using the so called 'kernel' method or other appropriate statistical procedures. Comparison of the probability density functions for different times and different areas might be indicative of changes in the krill population. As the 'kernel' method is a relatively new statistical technique, some participants felt that there are likely to be problems in applying the technique to the krill fishery. The group drew notice to the forthcoming ICES meeting in London in October, 1985 when the method will be discussed in some more detail.

14. Data provided to the Working Group by Japanese scientists (along the lines proposed in Appendix IV) should provide sufficient data for input into a model for one class of fishery in which fishing is carried out more or less independently by each vessel. However, further information, both qualitative and quantitative, is required for the USSR fisheries, particularly with respect to the role of fisheries research vessels in directing the fishing fleet to krill concentrations and the time budgets of a range of fishing vessels.

15. A budget to cover appropriate work should be made available to initiate the simulation study. It is likely that the money involved would be around the cost of one year's consultancy time. A preliminary report will be required at the 1986 meeting of SC-CAMLR with a final report being submitted to the 1987 meeting.

Data Requirements and Proposals for Data Submission

16. The group reviewed the type of data required to implement CPUE analyses to determine krill abundance. It recognised that such analyses are most effective in a very small area and only provide very local estimates of krill abundance.

17. Three types of catch and effort data to be collected by fishing operations in order to obtain a measure of krill density or abundance have been discussed on a number of occasions. The group reviewed the data list compiled by the Woods Hole meeting of the CCAMLR *ad hoc* Working Group on Data Collection and Handling. It agreed that only minor modifications were necessary, principally concerning data of interest for other purposes and not essential for providing density or abundance indices. The revised list is given in Appendix IV.

18. The group noted that volumes of data were likely to be large for some countries' operations and that questions had been raised whether difficulties of interpretation, and therefore the potentially reduced value of the data justified the effort and expense of compiling large data sets. Examination of detailed Japanese data resolved some, but not all, of the doubts expressed concerning the value of detailed data.

19. The group further believed that many of the remaining doubts about whether or not varying details of data concerning fishing operations listed in Appendix IV and time-budget information were useful, would be resolved by specific analyses proposed in Paragraph 12. It is therefore essential that countries possessing such data should make a representative sample (e.g. covering the operation of one fleet for two seasons) available. At the same time the meeting believed that all countries should make every effort to collect data listed in Appendix IV as a matter of routine.

20. In terms of abundance estimation, the group appreciated the important role that independent fisheries research vessels may play. Wherever possible, data collected by fisheries research vessels should be integrated with catch data from fishing fleets. Such data are especially important in terms of the Soviet fishery where both research vessel and fishery data are collected routinely. The group requested that Soviet data of this nature be made available.

21. Furthermore, the group appreciated the valuable contribution made by the BIOMASS acoustic surveys to the collection of distributional and abundance information on krill over a wide geographic area. It <u>strongly recommended</u> that further analysis of this data be

encouraged, particularly in terms of the spatial distribution of krill swarms and their probability of occurrence.

22. The group considered that catch and effort data should continue to be collected in accordance with current national practice. Specific proposals on the reporting format should only be made in the light of the results from the proposed simulation exercise (Item 12).

Fishing Power

23. Changes in fishing power – a larger net, more powerful trawler, changed net design (e.g. as discussed in Document 4) – will affect the catch-per-unit of fishing time on a given density of krill. It is therefore essential to have good records of factors that may affect fishing power (see Appendix IV, Part I). Research into the relation between these parameters and fishing power is encouraged.

Calibration and Verification of CPUE Methods

24. The group agreed that in the future some attempt will have to be made to calibrate the effort-effectiveness of fishing power. In addition, independent verification of the assumed linear relationship between krill abundance as indexed by CPUE and actual abundance requires empirical analysis. Co-operative programmes between research and fishing vessels were once again encouraged.

Krill Behaviour With Respect to CPUE

25. It was agreed that CPUE may change as a result of variability in the catchability of krill caused by behaviour.

26. At present few substantial data are available for determination of cause-effect relationships in krill swarm formation. Few data are available concerning the effects of swarming, seasonal behaviour and diurnal variation on the catchability of krill in terms of fishing operations.

27. The group strongly recommended that research vessel investigations of krill behaviour and catchability be encouraged.

OTHER APPROACHES TO MONITORING KRILL ABUNDANCE

28. The group recognised a number of fisheries independent methods for monitoring krill abundance.

29. Hydroacoustics was seen as the most effective method for direct estimation of krill abundance and distribution. The group took cognisance of some of the problems inherent in the hydroacoustic method and outlined by the BIOMASS Krill Acoustics Working Party. Problems outlined included inadequate krill acoustic target strength information, inadequate insonification of surface waters, dispersal effects and a mismatching between krill consumption by predators and acoustic standing stock estimates. The costs of acoustic surveys would also be a serious consideration for their implementation over an extended area.

30. The group recognised the potential importance of monitoring krill abundance over smaller areas than ‘stock’ or ‘fishing’ areas, particularly when studying the interaction between krill predators (especially those with restricted foraging ranges – e.g. penguins); krill; and krill fishing. For these purposes the catch-per-unit-fishing time might already be a reasonably satisfactory index of local krill density.

FOLLOW-UP TO WORKSHOP

31. A preliminary report on simulation modelling of krill fishing operations (Items 11, 12 and 15) will be required for the Fifth Meeting of SC-CAMLR. The group recognised that the availability of suitable data will be essential for the successful implementation of the simulation modelling exercise. The group appreciated the efforts of the Japanese delegation in supplying such data to the present meeting. It also took note that the USSR may be unable to submit detailed data from commercial krill fishing operations.

APPENDIX I

KRILL CPUE WORKSHOP
AGENDA

1. Review of Purpose of the Meeting

2. Use of CPUE Data

   (a) Basic Theory

   (b) Fishing Effort and the Krill Fishery

   - Description of fishing strategy and breakdown into activities
   - Measures of abundance for large areas
   - Data requirements and proposals for data submission
   - Fishing power
   - Calibration and verification of CPUE methods against several independent methods.

   (c) Krill Behaviour With Respect to CPUE

3. Other Approaches to Monitoring Krill Abundance

4. Follow-up to the Workshop

5. Adoption of the Report

APPENDIX II

LIST OF PARTICIPANTS OF
KRILL CATCH PER UNIT OF EFFORT WORKSHOP
(21–22, 29 AUGUST, 1985)

ARGENTINA	Dr A. Tomo Dr E. Marschoff
AUSTRALIA	Dr K. Kerry Mr W. de la Mare Mr P. Heyward Dr G. Kirkwood
CHILE	Dr A. Mazzei
FRG	Dr K.-H. Kock
GDR	Dr W. Ranke
JAPAN	Dr Y. Shimadzu Dr Y. Watanabe
NORWAY	Dr O. Østvedt
POLAND	Dr W. Slosarczyk
SOUTH AFRICA	Dr D. Miller
USSR	Dr R. Borodin Mr S. Komogortsev
UK	Dr I. Everson Dr J. Beddington
USA	Dr K. Sherman Dr R. Hennemuth

IUCN SPONSORED EXPERT	Dr J. Cooke
INVITED EXPERT	Dr J. Gulland (UK)
SECRETARIAT	Dr D. Powell Mr F. Ralston Dr E. Sabourenkov

APPENDIX III

WORKSHOP ON KRILL CPUE ANALYSES

Hobart, 21–22, 29 August 1985

List of Documents

Krill WG/1985/Doc.1	Workshop on Krill CPUE Annotated Agenda
Doc.2	Krill – Catch Per Unit Effort (J.A. Gulland)
Doc.3	A Note on Relating Krill CPUE Measures to Abundance Trends (Douglas S. Butterworth and Denzil G.M. Miller)
Doc.4	Some Considerations on the Usefulness of CPUE Data from Japanese Krill Fishery in the Antarctic (Yasuhiko Shimadzu and Taro Ichii)
Doc.5	An Updated Information of the Japanese Krill Fishery in the Antarctic (Yasuhiko Shimadzu)
Doc.6	Some Aspects of Repeated Operation on the Same Patch in Japanese Krill Fishery (Taro Ichii)
Doc.7	Agenda
Doc.8	List of Documents
Doc.9	Proposals on the Standardisation of Complex Studies Aimed to the Elaboration of the System of the Biological and Oceanographical Monitoring of the Antarctic Waters (basing on examples of the observation of the XXII expedition of the R/V 'Academic Knipovich' at the section going along 67°E. Commonwealth Bay, March 1984) (R.R. Makarov and V.V. Maslennikov, 1985, USSR National Section, CCAMLR)

Doc.10 Technique of Modelling Quantitative Distribution of Krill Basing on the Oceanographical, Biological and Hydroacoustic data of surveys on the Computer
(R.R. Makarov, et. al, 1985, USSR National Section, CCAMLR)

Doc.11 List of Participants

Doc.12 A Note on the Characteristics of Japanese Operation
(Yasuhiko Shimadzu)

Doc.13 Data Tape Listing (Japanese commercial krill fishing operations)

Other Papers

Report on Post-Fibex Acoustic Workshop, Frankfurt, Federal Republic of Germany, September 1984. (Submitted by SCAR)

The Influence of Schooling Behaviour on CPUE as an Index of Abundance in Rep. Int. Whal. Commn (Special Issue 2), 1980. K. Radway Allen.

Estimating Catchability Coefficients from Catch and Effort Data in Rep. Int. Whal. Commn 33, 1983. J.G. Cooke.

A Rationale for Modifying Effort by Catch, using the Sperm Whale of the North Pacific as an Example in Rep. Int. Whal. Commn (Special Issue 2), 1980. Charles W. Fowler.

Population Assessment of the Antarctic Minke Whale in Rep. Int. Whal. Commn 29, 1979. Seiji Ohsumi.

Basis of Fishing Effort for Minke Whaling in the Antarctic in Rep. Int. Whal. Commn 30, 1980. Yasuhiko Shimadzu.

Bias of the CPUE Using Search Time as Effort Measure in Rep. Int. Whal. Commn 32, 1982. Samuel Zahl.

Correcting the Bias of the CPUE due to a Varying Whale Density in Rep. Int. Whal. Commn 33, 1983. Samuel Zahl.

Adjustments to the CPUE for Antarctic Minke Whaling in Rep. Int. Whal. Commn 34, 1984. Samuel Zahl.

Summary Report of Krill (*Euphausia superba*) Fishing Ground Exploitation in the Antarctic Ocean (1981/1982). National Fisheries Research and Development Agency, Busan, Republic of Korea.

Formation of Antarctic Krill Concentrations in Relation to Hydrodynamic Process and Social Behaviour. Z. Witek, A. Grelowski and J. Kalinowski, ICES, C.M. 1982/L: 59.

Forms of Antarctic Krill Aggregations. J. Kalinowski and Z. Witek, ICES, C.M. 1982/L: 60.

APPENDIX IV

PROPOSALS FOR BASIC DATA COLLECTION

The following list was drawn directly from that detailed on Page 193 of the Report of the Third Meeting of SC-CAMLR.

1. Fishing Power

(a) Description of Vessel

- name of ship
- registration number and port of registration
- ship nationality
- gross register tonnage
- length overall (m)
- maximum shaft power (kW at ... rev/min) or horse power

(b) Description of Gear

- trawl type (according to FAO nomenclature)
- code number for trawl type
- mouth opening or length of bottom rope and length of upper rope (m)
- effective area of mouth (m^2)
- mesh size at mouth (mm stretched)
- mesh size at codend (mm stretched)
- liner mesh size
- underwater acoustic equipment echosounders (types and frequencies), sonar (types and frequencies), netsonde (yes/no).

2. Fishing Information

(a) Tow Information

- date
- position at start of fishing (in degrees and minutes)
- time at start of fishing (in hour and minutes GMT; if local time, indicate the variations from GMT)
- time at end of fishing (before hauling)
- bottom depth (m)
- fishing depth (only if midwater trawl)
- direction of trawling (if the track changed during trawling, give the direction of the longest part of the track)
- towing speed
- comment on gear performance

(b) Catch Records for Each Tow

- estimated total catch (kg)
- approximate species composition (percent of total)
- weight (kg) of krill
- average size of krill (mm) or commercial size categories (e.g. S, M, L).