ANNEX 4

REPORT OF THE WORKING GROUP ON ECOSYSTEM MONITORING AND MANAGEMENT

(Siena, Italy, 24 July to 3 August 1995)

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INTRODUCTION

Opening of the Meeting

1.1 The meeting of the Working Group on Ecosystem Monitoring and Management (WG-EMM) was held at the University of Siena, Italy from 24 July to 3 August 1995.

1.2 Prof. Piero Tosi, Chancellor of the University of Siena, opened the meeting and welcomed participants to Siena. On behalf of the Working Group the Convener, Dr I. Everson (UK), thanked Prof. Tosi and Prof. Silvano Focardi for the invitation to hold the meeting in Siena and for the substantial work which had been performed in pre-meeting arrangements.

1.3 The Convener expressed his satisfaction that 16 Members were represented by 43 participants, and that evidence of a high level of interest in the work of WG-EMM was shown by the submission of 90 papers, the largest number ever submitted to a CCAMLR Working Group. The list of participants is given in Appendix A and the list of papers in Appendix B.

1.4 He welcomed representation and the provision of information on CEMP-related programs from New Zealand for the first time. The Working Group regretted the continuing failure of France and Germany to send scientists and data from their active CEMP-related research programs on dependent species.

Adoption of the Agenda

1.5 The Provisional Agenda was introduced and discussed. A number of changes were made to the order of subitems within Item 5, and a new item 'Interactions Between Environmental Variables and Harvested/Dependent Species' included. A number of subitems were added to Item 6. The Agenda, as amended, was adopted (Appendix C).

AIMS AND OBJECTIVES

Historical Perspective of CCAMLR Ecosystem Monitoring

2.1 The Convener introduced WG-EMM-95/30 which presented an overview of the objectives and progress of ecosystem monitoring by CCAMLR. He reminded the meeting that the Scientific Committee's initiation of work towards an ecosystem approach to management arose directly out of Article II of the CCAMLR Convention which can be summarised as harvesting of individual species should be set at a level that does not adversely affect the target species, depleted populations should be allowed to rebuild and harvesting should not adversely affect dependent species.

2.2 The Working Group recognised that from the outset the Scientific Committee had agreed that the complexity of the Antarctic ecosystem was such that attempts should not be made to manage the ecosystem as a whole. Rather, management should be directed at a number of well-defined ecosystem components. It also recognised that a primary aim of all studies within the framework of ecosystem monitoring and management must be the provision of advice regarding harvested species.

2.3 WG-EMM-95/30 detailed the considerable progress that has been made in understanding both harvested and dependent species, their interactions, the nature of harvesting and the influences of environment on the Antarctic ecosystem. A substantial time series of information has been collected by the Working Groups on Krill (WG-Krill) and CEMP (WG-CEMP) since this work began in the mid-1980s. It has resulted in a highly improved understanding of ecosystem components although, with a few exceptions, these have generally been investigated in isolation from other components. In 1991, the Scientific Committee considered that enough detail was known about the individual components to enable the initiation of a process of integrating this information into an ecosystem management approach, and held the first joint meeting of WG-Krill and WG-CEMP in Viña del Mar, Chile in August 1992 to do this. The process culminated with the establishment of WG-EMM in 1994.

2.4 The Working Group agreed that many of the topics identified at the first joint meeting (SC-CAMLR-XI, Annex 7) as being critical to a management-oriented understanding of the key components of the Antarctic ecosystem were still important, and many had only been partially addressed since that meeting. It agreed to consider these further at the present meeting (see paragraphs below).

Objectives of WG-EMM

2.5 The Working Group considered that it was appropriate, at this first meeting of WG-EMM, to review its objectives in terms of ecosystem assessment.

2.6 The terms of reference for the Working Group were set out in SC-CAMLR-XIII, paragraphs 7.41 to 7.43. The Working Group agreed that a useful synthesis of these terms of reference was:

(i) to provide advice on an ecosystem assessment combining information from dependent and harvested species and the environment; and

(ii) to use this assessment to provide advice on management.

2.7 Such an approach requires consideration of a fundamental question.

(Q1) What constitutes an 'ecosystem assessment'?

2.8 In order to understand how to approach this primary question the Working Group agreed that it might be considered as a series of secondary questions:

(Q2) (i) What are the elements of an ecosystem assessment?
(ii) How do we make the assessment?
(iii) How do we improve the assessment?
(iv) How do we use the results from the assessment in formulating management advice?

2.9 The Working Group also agreed that in order to address these secondary questions a strategic model or plan would be required.

2.10 However, it was recognised that until the strategic plan was developed and answers to secondary questions obtained, it would be necessary to agree about the mechanism by which management advice would continue to be provided to the Scientific Committee.

2.11 As a first step towards answering question Q1, a schematic diagram of the Antarctic ecosystem was drawn up (Figure 1), which relates to how ecosystem assessment had been defined at previous meetings.

What is an Ecosystem Assessment?

2.12 At the second joint meeting of WG-Krill and WG-CEMP (Cape Town, South Africa, 1994), the Convener of WG-CEMP provided a description of what WG-CEMP understood its tasks to be in relation to ecosystem assessment. These were to determine annually the magnitude, direction and significance of trends in each of the predator populations being monitored; to evaluate annually these data by species, site and region; to consider conclusions in the light of relevant information on prey and the environment; and to formulate appropriate advice to the Scientific Committee (SC-CAMLR-XIII, Annex 7, paragraph 5.1).

2.13 The Working Group agreed that although reference to a dependent species-oriented assessment in the above paragraph had been appropriate for WG-CEMP, the emphasis on harvested species should be increased so as to reflect the broader needs of WG-EMM. Accordingly, the Working Group agreed that an ecosystem assessment consists of:

Part 1: an analysis of the status of key biotic components of the ecosystem; and

Part 2: a prediction of the likely consequences of alternative management actions for the future status of these components.

2.14 The Working Group considered the definition of 'status' (as in paragraph 2.13) that is used in single-species fishery assessments, and how this definition might be applied to ecosystem assessment.

2.15 In terms of ecosystem assessment, 'status' would need to include not only the points necessary for a single-species assessment, which are:

- current abundance and productivity of the harvested species, with abundance related to some level prior to the onset of exploitation; and

- if possible, the relationships (links) between these quantities and the state of the environment;

but also points related to dependent species which may be summarised as:

- current abundance of dependent species (usually expressed as breeding population size or an index thereof) in relation to previous values, where possible in conjunction with data on current and recent adult survival and recruitment rates.

2.16 Although it was recognised that in many instances the data would not allow the provision of precise management advice, it was understood that management actions considered under Part 2 (paragraph 2.13) would include the concept of a precautionary approach in the absence of certainty; a principle already applied in CCAMLR management regimes.

2.17 An evaluation of the status of biotic components in an ecosystem assessment will depend upon an adequate understanding of the components and links in Figure 1. Further, a successful predictive ability will require a good understanding of current and past ecosystem dynamics and how they are likely to change in the future. The Working Group agreed that an important adjunct to the ecosystem assessment process would be a continual review of the information required to understand the system sufficiently to make effective assessments. This review would include reappraisal of, *inter alia*, the taxa considered as key species within the dependent and harvested components, spatial and temporal aspects, and the most appropriate parameters to measure.

2.18 In the past, the method employed by WG-CEMP to describe the status of various component species, together with associated environmental parameters, was to use a set of site-based tables (SC-CAMLR-XIII, Annex 6, Table 2). The Working Group acknowledged that even though WG-CEMP had been unable to construct these tables with quantitative data as it had intended (SC-CAMLR-XII, Annex 6, paragraph 6.37), the tables had still provided an extremely valuable qualitative assessment of current status. It was agreed that the general form of these tables should be retained and that the new presentation should aim to increase the ability to investigate species and subarea-based trends.

2.19 It was recognised, however, that the parameters given in the tables provided information about different components of the system over different spatio-temporal scales. No single parameter could provide a complete description of the status of the ecosystem. The objective of Part 1 of an effective assessment (paragraph 2.13) would therefore be to examine how such information could be integrated into a form most appropriate for reliable execution of Part 2 of that paragraph.

2.20 Currently, some 14 parameters for dependent species and four environmental parameters are assessed and reviewed annually by CCAMLR, based on the data in the CEMP database. A number of time series of parameter values could also be developed from information on harvested species. Figure 2 shows how these and other parameters could provide information on the components and links of Figure 1.

2.21 The development of a framework for the evaluation of ecosystem status was considered to be fundamental to the aims of the Working Group. It was recognised that estimation of sets of parameters to fully describe the various components and links of the system may well be limited by current data availability and the difficulty of collecting the data which might be specified in the future. (As an example, reliable time series of dependent species survival rates are rare and difficult to obtain.) Nevertheless, work should be continued on ascertaining what might be achievable with more limited data.

Organisation of the Meeting

2.22 The Working Group examined its agenda with reference to Figure 1 and was able to identify agenda items addressing either one component or one or more links between components. It agreed that, in general terms, items which addressed the evaluation of a component were often technical and could be discussed in partial isolation from other components. They were, therefore, assigned to subgroups for detailed discussion.

2.23 Items which addressed links and strategic modelling/planning should not generally be addressed in isolation. These are best discussed by the whole Working Group, using both the reports of the subgroups and other information where necessary. However, it was recognised that some topics related to the linkage of components do, in part, require detailed technical consideration by subgroups prior to consideration by the full Working Group.

2.24 Responsibility for the organisation and compilation of the Working Group's report was, as far as possible, spread through the Working Group's membership to ensure an even distribution of workload and in the interests of a more efficient consideration of specific items.

2.25 The Convener reminded the Working Group that the first joint meeting had identified a number of items which it considered should be studied further to advance work on ecosystem monitoring and management (SC-CAMLR-XI, Annex 8, paragraphs 1 to 13). Although some had been addressed since 1992, topics 1 to 5 of the Report of the First Joint Meeting of WG-Krill and WG-CEMP (SC-CAMLR-XI, Annex 8) were considered to be still pertinent to the work of the group at this time. Topics 9 and 10 (CEMP experimental approach, feedback mechanisms for management advice) were considered to be questions at the level of the strategic model (i.e., they are investigations of the performance of the model, not of its components) and therefore require substantial development of the strategic model before they can be adequately addressed. The Working Group assigned topics 1 to 5 to the components or links of Figure 1:

1: Krill escapement: Fishery/dependent species link (fishery component operating through the impact on harvested species).

2: Functional relationships between krill and predators: Dependent species/harvested species link.

3: Krill biomass versus availability: Environment/harvested species link.

4: Refining functional relationships: Dependent species/harvested species/environment link.

5: Considering predator demands in subarea allocation of catch limits: Dependent species/harvested species/fisheries links.

2.26 The report was prepared by Dr D. Agnew (Secretariat), Drs I. Boyd and J. Croxall (UK), Dr W. de la Mare (Australia), Dr P. Fedoulov (Russia), Prof. B. Fernholm (Sweden), Dr R. Hewitt (USA), Mr T. Ichii (Japan), Dr K. Kerry (Australia), Dr G. Kirkwood (UK), Dr K.-H. Kock (Germany), Dr F. Mehlum (Norway), Dr D. Miller (South Africa), Dr E. Murphy (UK), Dr S. Nicol (Australia), Dr P. Penhale (USA), Dr E. Sabourenkov (Secretariat), Dr W. Trivelpiece (USA) and Dr J. Watkins (UK).

All members of the Working Group contributed to the various appendices. The Convener expressed his appreciation to Working Group members for their contributions.

DATA

Krill Catches in 1994/95

3.1 In the 1994/95 season krill catches in the Convention Area were reported by three Members: Japan (60 304 tonnes), Poland (6 287 tonnes) and Ukraine (51 325 tonnes). Chile and Russia, both of whom fished for krill in previous seasons, reported no krill fishing activities in 1994/95. All catch reports were submitted on a monthly basis as required.

3.2 The total reported catch of krill was 117 916 tonnes. This represents an increase in comparison to catches of 88 776 tonnes in 1993/94 and 83 818 tonnes in 1992/93. Catches reported by Japan and Poland were of the same order as previous seasons. The increase was due to an increase in the catch reported by Ukraine from 8 708 tonnes in 1993/94 to 51 325 tonnes in 1994/95.

3.3 The Working Group noted that no plans for expanding krill fishing were reported by Ukraine at the Commission meeting in 1994.

3.4 All catches reported by Ukraine were taken in Area 48 between January and June 1995, with catches being roughly equally distributed between Subareas 48.1, 48.2 and 48.3.

3.5 The greater part, 4 510 tonnes, of the krill catch reported by Poland was made in Subarea 48.2. Additional catches were reported from Subareas 48.1 and 48.3.

3.6 Japanese catches were mainly taken in Subareas 48.1, 48.2 and 48.3. During the season, the area of operation moved from Subarea 48.1 (South Shetlands) to 48.2 (South Orkneys) and then to 48.3 (South Georgia) in advance of the northward movement of the ice-edge.

3.7 A catch of 1 264 tonnes of krill was reported by Japan in Division 58.4.1 (Wilkes Land, Indian Ocean sector) in January/February 1995.

3.8 The Japanese krill fishery in Subarea 48.1 was concentrated to the north of Livingston Island. Most catches were taken further offshore than in previous seasons. This was because in January/February 1995, krill concentrations were found to be more abundant over the slope than on the shelf itself.

3.9 The Working Group reiterates the importance of continuing a dialogue with fishing nations in order to understand trends in krill fishing and the distribution of catches over the Convention Area (CCAMLR-XII, paragraph 4.5; SC-CAMLR-XIII, paragraph 5.8).

3.10 The Working Group recalled that in previous years it had received reports of krill catches in an area immediately west of Subareas 48.2 and 48.3, FAO Statistical Area 41 (i.e., a catch of 2 506 tonnes by Poland in 1993, and a catch by Russia in 1991/92 (Sushin and Myskov, 1992[1])). It was agreed that for WG-EMM to consider fully the krill component of its ecosystem assessment, continuing information on krill caught outside the Convention Area is most important.

3.11 Last year the Secretariat received from FAO a STATLANT A report that 71 tonnes of krill had been taken in 1993/94 from the Convention Area by a non-Member country, Latvia. Following a request from the Commission, the Secretariat wrote to the Government of Latvia with a request for information about fishing activities of Latvia in the Convention Area. No response has been received as yet.

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[1] Sushin, V.A. and A.S. Myskov. 1992. Location and intensity of the Soviet krill fishery in the Elephant Island area (South Shetland Islands), 1988/89. In: *Selected Scientific Papers, 1992 (SC-CAMLR-SSP/9).* CCAMLR, Hobart, Australia: 305-335.

Scheme of International Scientific Observation

3.12 The first scientific observation program on board a commercial krill fishing trawler under the CCAMLR Scheme of International Scientific Observation was undertaken in 1995. Through a bilateral agreement between the US and Japan, an international scientific observer was placed on board the Japanese trawler, *Chiyo Maru No. 2*, fishing for krill in Division 58.4.1 (Wilkes Land) from 28 January to 22 February 1995 (SC-CAMLR-XIV/BG/10).

3.13 The Working Group noted with satisfaction the large volume of information on catch, effort, and biological data collected from krill catch samples obtained by the observer during fishing operations of the vessel.

3.14 Mr Ichii noted that in addition to the time spent searching for krill swarms, the time between sets of the trawl recorded by the observer was close to the time required to process the krill caught in previous hauls.

3.15 The pilot edition of the *Scientific Observers Manual* (1993) was used for planning the observation program and recording data. Based on experience from using the manual and, in particular, the data forms, the observer suggested that some data forms could be modified to make them easier to use in the field. The Working Group asked the Science Officer to take these suggestions into account in preparing the revised edition of the manual to be submitted for consideration by the Scientific Committee at the forthcoming meeting in 1995.

3.16 The Working Group agreed that the observer's report had provided useful information. It strongly urged Members to implement observation schemes along the lines of the Japanese/US arrangement and in accordance with CCAMLR's Scheme of International Scientific Observation.

3.17 Krill caught by the Japanese vessel fishing in Division 58.4.1 were mostly immature or juvenile specimens and were in all feeding states. There was no evidence that fishing strategy was altered due to the feeding intensity of the krill caught (SC-CAMLR-XIV/BG/10). These observations were explained by Mr T. Kato (Japan) who pointed out that the fishing vessel was not concentrating on catching high quality krill but was aiming to catch a large quantity of krill quickly.

3.18 The Working Group noted that in the past the Scientific Committee had requested information related to the assessment of the mortality of krill passing through trawl meshes during fishing operation (SC-CAMLR-XII, paragraph 2.25). The Working Group recalled that in 1993[2] Dr Yu. Kadilnikov (Russia) had submitted a paper describing a model to test the effects of mesh characteristics on the passage of krill through trawl nets. No further developments have been reported. The Working Group reiterated the Commission's call for information on this topic. It also again urged Dr Kadilnikov to submit the computer code for his model in order for the model to be verified and tested.

Consideration of Commercial Harvesting Strategy

3.19 Fine-scale catch data from 1973/74 to 1993/94 from the Convention Area submitted by Japan from their commercial fishery and augmented by research/experimental fine-scale data from the Soviet Union revealed historical fishing patterns (WG-EMM-95/6).

3.20 In Area 48, krill fishing has consistently been restricted to very localised areas off the South Shetland Islands, the South Orkneys and South Georgia.

3.21 In Area 58, krill fishing has occurred over a much wider area, reflecting the exploratory nature of the fishery in this region in earlier years. Krill harvesting in Area 58 has, in certain years, occurred in waters adjacent to known predator colonies (WG-EMM-95/6).

3.22 Seasonal movements of fishing activity in Area 48 during 1994/95 followed a pattern exhibited in previous years: from the South Shetlands early in summer, to the South Orkneys later in summer and to South Georgia in autumn and winter. This pattern is largely driven by ice conditions (WG-EMM-95/7).

3.23 The single Japanese vessel fishing in Division 58.4.1 during 1994/95 headed south from New Zealand and moved westward along the shelf break until good fishable concentrations were encountered at around 100°E.

3.24 Krill were reported to be scarce in Division 58.4.1 during 1994/95 and those caught were small (mean size: 37.7 mm) (SC-CAMLR-XIV/BG/10) compared to those caught in Area 48 (mean lengths: 40 to 46 mm) (WG-EMM-95/51).

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2 Kadilnikov, Yu.V. 1993. Peak mortality of krill, fished with midwater trawls and feasible criteria of krill trawls ecological safety. Document *WG-Krill-93/34*. CCAMLR, Hobart, Australia.

Biology and Ecology of Harvested and Dependent Species of Particular Relevance to Fisheries Management and CEMP

3.25 A number of papers relevant to this agenda item were tabled.

3.26 Paper WG-EMM-95/54 discussed the distribution of salps at South Shetland Islands in 1990/91 in relation to krill. Krill were found mainly in coastal areas with salps being encountered in greater abundance in oceanic areas offshore. Salp predation of small krill in addition to competition for food between salps and young krill were considered in respect to the relatively low abundance of krill at stations where salps were abundant. The Working Group noted that the effect of predation by salps on small krill may be reduced by delayed krill spawning when salps are abundant.

3.27 Laboratory observations of krill feeding on salps (WG-EMM-95/57) suggest an ecological relationship between krill and salps, indirectly through salps via the microbial loop to krill and directly through feeding by krill on salps.

3.28 The Working Group agreed that although salps may be an important ecosystem component at various times, information on their biology and ecology is still limited. It concluded that there did not appear to be a need to incorporate salps into the Working Group's ecosystem assessments at this time, but urged members to continue investigating the role of salps in the Antarctic marine ecosystem.

HARVESTED SPECIES

4.1 A subgroup was formed to review information and papers presented under Agenda Item 4. The aim was to highlight areas where new information was available that was of specific relevance to Agenda Item 7. Only this latter information is presented in Section 4.

Methods for Estimating Distribution, Standing Stock, Recruitment and Production of Harvested Species

4.2 Thirteen papers were available for discussion under Agenda Item 4(i). The main subject areas covered by the submitted papers were:

- acoustic survey design;
- quantification of errors;

- use of multifrequency techniques for the discrimination of target types; and
- problems identified with echosounder systems.

Survey Design

4.3 Papers WG-EMM-95/34, 38, 43, 71 and 76 related to the topic of survey design. An introduction and overview of some of the issues concerning design and analysis of surveys was provided by Dr K. Foote (Norway).

4.4 Acoustic survey data may be analysed in two basic ways: classic random sampling techniques utilising mean and variance to describe the density distribution of biomass; or geostatistical techniques utilising spatial properties of the data to derive a mean and an estimation of variance. In the absence of spatial structure the estimation of variance will ideally be the same as the sampling variance. It was pointed out that discussion of these points is also to be found in the report of the Workshop on Estimation of Variance in Marine Acoustic Surveys (WG-EMM-95/38).

4.5 With regard to survey design, three general points were raised in the overview by Dr Foote. Firstly, stratification of survey transects may allow an increase in efficiency if there is prior knowledge about the distribution of the species being surveyed. Secondly, in the absence of any knowledge of structure, uniformity of transect spacing will provide maximum information about any large-scale structure. Thirdly, a two-tiered design where a preliminary survey is used to locate areas for stratification of effort during a second survey phase is also effective.

4.6 With regard to potential design for a survey of Area 48 (see also paragraphs 4.59 to 4.67; WG-EMM-95/71), it was accepted that a stratified survey design was the most appropriate one available. It was agreed that in the absence of information about the distribution of krill in the oceanic regions, uniform transect spacings would be the most appropriate.

4.7 The Working Group agreed that previous survey information should be used to define strata within the survey area and that the mean and variance from these surveys could be used to assess the amount of sampling effort required (see WG-EMM-95/71). Any additional information on spatial structure could be used to refine the estimation of effort required.

4.8 The Working Group recommended that further papers on survey design of Area 48 should be prepared during the intersessional period and discussed at the next meeting of WG-EMM.

4.9 A design for an acoustic survey in Division 58.4.1 was tabled (WG-EMM-95/43). While the paper was not considered in detail this year, it was noted that the design was submitted to the last meeting of WG-Krill where it met with favourable review.

Quantification of Errors

4.10 Quantification of errors associated with acoustic surveys (WG-EMM-95/72 and 73) requires consideration of two broad categories of sources of variance and bias:

- those arising from the use of transect sampling (random sampling error); and
- those arising from the application of acoustic methods (measurement error, which contains elements of both systematic and random error).

4.11 Paper WG-EMM-95/76 considered random sampling error in a comparison of geostatistical and random sample survey analyses. The paper described the analysis of three surveys and highlighted problems inherent in the analysis of an extremely aggregated species such as Antarctic krill. The Working Group recognised that there is a large amount of information available outside WG-EMM on the use of random sample and geostatistical approaches to analyse survey data but at present there is no consensus on which approach may produce more efficient estimators[3] of abundance and variance. The Working Group recognised that at this stage there was no need to re-analyse the data used to provide the current estimates of biomass for the management model using geostatistical techniques.

4.12 Measurement error in acoustic surveys of Antarctic krill was considered in WG-EMM-95/72. Systematic and random errors may arise from system calibration, target strength (TS) estimation, diurnal vertical migration and target identification. These components of uncertainty may be different for each survey and as large as (or larger than) sampling error.

Multifrequency Techniques

4.13 Multifrequency acoustic techniques can be used to classify target types under certain conditions, and papers concerned with hardware design (WG-EMM-95/8 and 9) and surveys utilising such techniques were submitted (WG-EMM-95/58, 72, 75 and 87). The Working Group recognised the

[3] A more efficient estimator is one which leads to estimates whose differences from the unknown true value of the quantity of interest are likely to be smaller.

importance of developing such techniques further, and recommended that for future surveys at least two frequencies should be used as an aid in interpreting measurements of volume backscattering.

Echosounder Problems

4.14 Two papers (WG-EMM-95/37 and 73) gave details of some physical and technical problems that have been identified with echosounder systems and may bias biomass estimates. WG-EMM-95/37 described the problems associated with the recognition of single targets in the *in situ* estimations of target strength. WG-EMM-95/73 highlighted some technical problems with a commonly used echosounder. It was emphasised that these problems would not have affected biomass estimates used to calculate the current precautionary catch limits.

Analysis and Results of Studies on Distribution, Standing Stock, Recruitment and Production of Harvested Species

Distribution

4.15 Papers WG-EMM-95/4, 5, 19, 23, 49, 58, 67, 70, 72 and 87 were tabled and important new information was identified as follows.

4.16 The possibility of using predator behaviour to provide information on prey distribution was pursued (WG-EMM-95/23). The behaviour of fur seals at South Georgia suggested that there was overall clumping of prey at the fine-scale level but there was a more even spacing of prey patches at the mesoscale level. The study showed how predator behaviour can provide valuable information on the functional relationship between prey dispersion and predator performance. It also gave some indication of the spatial scales at which studies of predator/prey interactions should be undertaken.

4.17 In general, the scales assumed for the spacing of swarms and patches agreed with those scales identified from acoustic measurements of interswarm distance. Such differences as observed might also arise from assumptions underlying the observational methods (e.g., the extrapolation from the chord length of a swarm detected on a transect to the true size of the swarm in three dimensions). To correspond to the scale of the swarm, the sampling interval in such acoustic studies needs to be around 10 to 15 m.

4.18 A variogram of biomass estimates (g.m^{-2}) from a survey also contains information on spatial structure. This provides an alternative method of analysis of spatial scale which does not require any identification of swarms.

4.19 Some studies (e.g., WG-EMM-95/87) have indicated that predators do not always exploit the highest densities of prey concentration in an area. At present little is known about the methods that predators use to search for krill. However, an understanding of such behaviour requires surveys of krill distribution concurrent with detailed tracking and observation studies of predators. Both sets of studies must be undertaken at the same horizontal and vertical scale. The use of large research vessels was often inappropriate for such studies. The Working Group felt that novel approaches and techniques utilising, for instance, Remotely Operated Vehicles (ROVs) or echosounders mounted on small launches need to be investigated.

4.20 The collection of spatial information from acoustic survey and predator data may assist in deriving a composite index of krill abundance which takes account of distribution and abundance of krill at small scales.

4.21 Paper WG-EMM-95/23 suggested that in years when little krill was available to predators the character of swarms within patches, rather than the overall number of swarms, may change. Such an observation could be investigated through examination of acoustic data at a scale that resolves individual swarms.

4.22 The Working Group concluded that fine-scale studies of krill and predator distribution were important in understanding spatial structure that could be used in the design of surveys at a local scale as well as in the study of predator/prey interactions.

4.23 The presence of a substantial amount of myctophid fish was observed using midwater trawling nets and acoustics beyond the Elephant Island shelf in the 1994/95 season (WG-EMM-95/87). Data from acoustic surveys were used to describe a scattering layer found between 150 and 200 m depth in the day, shallower at night, which may be attributed to these fish (WG-EMM-95/58).

4.24 The importance of the width at the northern boundary of the coastal water mass to consideration of krill flux was recognised. This factor influences the current speed and volume transport in the coastal areas to the north of Elephant Island where krill tend to be abundant (WG-EMM-95/58). When the front existed further south close to Elephant Island, the coastal water mass was relatively narrow and the current speed high, and vice versa. Buoy-tracking observations (WG-EMM-95/49) confirm earlier observations presented at the Workshop on Evaluating Krill Flux Factors (WS-Flux) (SC-CAMLR-XIII, Annex 7, Appendix D) suggesting the existence of a mechanism (oceanic currents) for krill transport from the South Shetland Islands to the South Orkneys and to South Georgia.

4.25 The findings in these papers and of WS-Flux emphasised the need for further consideration of krill flux. It is clear that the amount of krill in an area at any one time will be a function of the standing stock size and the flux. Thus, the fact that krill in a single area are less abundant in one year than another may not be sufficient to conclude that the krill stock size has also decreased. Similarly, differences in krill densities in adjacent areas do not necessarily imply different stock abundances.

4.26 In light of the above, the Working Group encouraged further research on krill flux and other issues associated with the spatial distribution of krill.

Standing Stock

4.27 Papers WG-EMM-95/15, 74 and 75 were tabled and important new information was identified as follows.

4.28 Acoustic surveys indicated that krill density at South Georgia and the South Orkney Islands was extremely low (1.7 and 10.7 $g.m^{-2}$ respectively) in the 1993/94 season, compared with previously published FIBEX density estimates (59.7 and 82.8 $g.m^{-2}$ respectively, WG-EMM-95/75). However, Dr Fedoulov noted that a strong seasonal pattern was apparent in CPUEs of the Russian krill fishing fleet between 1974 and 1990 which suggest seasonal variations in the abundance of krill around South Georgia (WG-EMM-95/69). He emphasised the necessity to describe exactly when in the season density estimates have been made. In response it was noted that there was additional evidence of low krill abundance from the breeding success of land-based predators and prey switching by mackerel icefish, which normally feed on krill. Furthermore, krill abundance was lower in the South Shetland Islands in the 1993/94 season.

4.29 The possibility of a decline in krill abundance from the 1977-83 period (higher mean density with a large range) to the 1985-94 period (lower mean density with a smaller range) was suggested for the Antarctic Peninsula region, based on the 16-year span of net sampling data (WG-EMM-95/15). This matter is discussed further in paragraph 4.43.

Recruitment

4.30 Papers WG-EMM-95/15, 18, 55 and 58 were tabled and important new information was identified as follows.

4.31 In WG-EMM-95/15 it is suggested that recruitment success of krill is related to sea-ice conditions during the preceding winter season, the timing of krill spawning, and the occurrence of dense salp concentrations. The importance of this information for ecosystem assessment and fisheries operations was recognised. Recent poor recruitment from spawning in 1991/92 and 1993/94 seasons was noted, together with probable good recruitment success from spawning in the 1994/95 season.

4.32 Krill size composition in the Bellingshausen Sea (Subarea 88.3), which was one of the lesser-studied regions of the Southern Ocean, was found to be similar to the krill stock composition in the South Shetland region (Subarea 48.1) in the 1993/94 season (WG-EMM-95/18). This finding suggests that the actual krill size composition and the recruitment of krill are similar over a wider spatial scale than just within Subarea 48.1.

Interannual and Within-Season Variability in Distribution, Standing Stock, Recruitment and Production of Harvested Species

4.33 Seven documents were tabled and discussed (WG-EMM-95/15, 18, 23, 53, 55, 58 and 69).

4.34 Paper WG-EMM-95/58 suggested an interannual difference in the timing of peaks of seasonal abundance and in the timing of spawning activity. Peaks of abundance, maturation and spawning in the 1994/95 season occurred earlier than generally observed in the Elephant Island area.

4.35 CPUE data from the Russian krill fishing fleet for the period 1974 to 1990 were used to demonstrate seasonal and interannual variability of krill abundance in Subarea 48.3 (WG-EMM-95/69). Maxima occurred in March, followed by a decline until October. The interannual variation of CPUE was high. As an example, zero CPUEs in both 1978 and 1984 were followed by high CPUEs in 1979 and 1985.

4.36 Large year-to-year variability in krill recruitment around Elephant Island was revealed (WG-EMM-95/15).

4.37 It was noted that in all those papers, attempts were made to seek correlation between krill biological indices and environmental parameters. The results of this were similar in the above-mentioned papers: relationships were indicated between recruitment, krill size indices and sea-ice conditions.

4.38 Paper WG-EMM-95/53 demonstrated the relationship between sea-level air pressure gradients in Drake Passage and krill recruitment variability. Years of high and low pressure differences coincided with the years of good and poor krill recruitment respectively.

Precautionary Catch Limits

Consideration of the Use of the FIBEX Survey for Calculation of B_0

4.39 At last year's meeting, WG-Krill calculated a revised precautionary catch limit of 4.1 million tonnes for krill in Area 48. At the following Scientific Committee meeting, two basic views were expressed. One basic view was that the revised precautionary catch limit of 4.1 million tonnes should replace the existing value of 1.5 million tonnes. An alternative view expressed by some Members was that there was no need to revise the overall precautionary catch limit of 1.5 million tonnes. The Members holding the latter view considered that the catch limit calculated by WG-Krill used an estimate of krill biomass based on data (SC-CAMLR-XIII, paragraph 5.40):

'(i) collected in 1981 and therefore outdated and of no practical use; and
(ii) possibly collected during a year in which the krill biomass was high.'

4.40 The Working Group discussed these two concerns. The calculations of precautionary yield do not assume that the estimate of biomass from a survey has a pre-specified relationship to the median unexploited biomass of the stock. By using information on the variability in recruitment and an estimate of the variance of the krill biomass estimate, the krill model produces statistical distributions of the biomass of krill in the absence of exploitation, and as affected by various levels of exploitation.

4.41 These statistical distributions include all of the possible relationships between the estimated biomass and the true median unexploited biomass that are consistent with the recruitment variability incorporated in the model, as well as with uncertainty in the abundance estimate and demographic parameters. Thus, if the assumptions of the model are not substantially violated, the possibility that the biomass was high in the survey year is taken into account in calculating the precautionary catch limit. One of the assumptions of the model used to date is that the statistical distribution of krill biomass in the absence of exploitation is independent of time. Therefore, as long as this assumption is not violated, it does not matter that the abundance estimate is from data collected in 1981.

Consideration of Recruitment Data for Area 48

4.42 If a reliable time series of estimates of proportional krill recruitment were available, it could be used in the krill model to condition the statistical distribution of unexploited biomass, and thus improve the calculation of the precautionary catch limit.

4.43 Paper WG-EMM-95/15 presented a time series of R_1 recruitment estimates[4] for a portion of Subarea 48.1 from reasonably comparable net haul surveys conducted in most years from 1977 to 1994. In principle, these data could be used to condition the statistical distribution of the unexploited biomass used in the calculation of the precautionary catch limit. The R_1 estimates in WG-EMM-95/15 were not always consistent with related estimates obtained by WG-Krill (SC-CAMLR-XIII, Annex 5, Appendix F). However, the estimates from WG-Krill used data from outside the region analysed in WG-EMM-95/15. The estimates in WG-EMM-95/15 also gave a substantially lower value of average recruitment proportion than was obtained by WG-Krill using all of the available data from the Antarctic at large. However, the estimates in WG-EMM-95/15 were not calculated using the maximum likelihood estimation method used by WG-Krill (de la Mare, 1994[5]). In addition, the calculations involved the exclusion of some observations which the authors had classified as outliers. The Working Group agreed that to be used for input to the krill model, the estimates would need to be recalculated using the maximum likelihood method using the data set including the outliers, for both R_1 and R_2. These recalculations could not be carried out within the time available at the meeting.

4.44 The other difference between the WG-Krill recruitment estimates and those reported in WG-EMM-95/15 lay in the geographical region over which the data had been pooled. The key issue in deciding on the extent of pooling is whether the pooled data will provide a representative sample of the length frequency distributions of the underlying population. This is an issue that must be resolved, not just for this data set, but also for others, such as the extensive length frequency data from predator diet samples.

4.45 Specification of the appropriate degree of pooling in the net haul data was assigned to a subgroup. The results of its deliberations are taken up under Agenda Item 7(vii) (paragraphs 7.107 to 7.118).

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[4] The R_i recruitment rate is the proportion of animals of age *i* in the population in that year.

[5] de la Mare, W.K. 1994. Estimating krill recruitment and its variability. *CCAMLR Science*, Vol. 1: 55-69.

4.46 The hypothesis that recruitment is correlated with the extent of ice cover in the previous year could lead to serial correlation in recruitment if there are trends or cycles in ice cover over time. The krill yield model can be modified to allow for the inclusion of serial correlation in recruitment. The possibility of such serial correlation in existing recruitment data should be investigated.

4.47 At its last meeting, WG-Krill had identified further investigations to be carried out in examining the sensitivity of the krill yield model to possible correlation between natural mortality (M) and von Bertalanffy growth rate (κ). This work has not yet been completed.

4.48 Summarising the preceding discussions, the Working Group indicated that the following areas needed further work.

- Both an index of abundance based on net sampling and a time series of recruitments suggest that 1981 (the year in which B_0 was estimated) may have been a year of high abundance (WG-EMM-95/15).

  Using the time series of proportional recruitments in the model may allow the recalculation of the distribution of unexploited biomass so that this possibility is reflected more explicitly. Commercial length frequency data should be examined to provide qualitative confirmation of any variations in recruitment. Population trajectories obtained from the krill model using the recruitment index can be compared with the net sampling abundance index.

- Recruitments may exhibit serial correlation.

  Time series of recruitments should be analysed for serial correlation.

4.49 The Working Group developed a plan (Appendix D) for completing the analyses in time for its next meeting. A steering group convened by Dr Agnew and consisting of Prof. D. Butterworth (South Africa), Drs de la Mare, Hewitt, V. Loeb (USA) and V. Siegel (Germany) would correspond to complete the required analyses.

4.50 The Working Group agreed to consider revision of the precautionary catch limits as results of these studies become available.

Consideration of Uncertainty in the Variance of B_0

4.51 Paper WG-EMM-95/72 suggested that the variance in the B_0 estimate may have been underestimated because of uncertainty arising in the use of the acoustic gear (paragraph 4.10), and it was suggested that the possibility of any further improvements to the variance estimate of the 1981 survey result should be investigated.

4.52 In relation to possible improvements of the variance estimates for the 1981 survey, concern was expressed that these data had already been subjected to extensive analysis and it was unclear whether high priority should be given to yet further re-analysis.

4.53 The Working Group agreed that the effects of additional uncertainty arising from the random component of measurement errors associated with the use of acoustic gear (paragraph 4.12) could be examined via sensitivity tests carried out at this meeting, using increased values of survey coefficients of variation in the krill yield model.

4.54 Based on the estimates of the additional variability for surveys conducted in the Elephant Island area as cited in WG-EMM-95/72 (additional random error with CV around 23%), runs of the krill yield model with survey CVs increased from the current 30% to 40% were undertaken. Results for a CV of 50% were also computed.

4.55 The results of the runs of the krill yield model are shown in Table 1. The run $\sigma_s = 0.4$ yields the following results, according to the decision rules developed by WG-Krill: (i) γ_1 (the probability that spawning biomass falls below 20% of its pristine level, after 20 years, should not exceed 10%) = 0.140; (ii) γ_2 (median spawning biomass should not fall below 75% of its pristine level after 20 years) = 0.116; and (iii) γ (choose the lower of γ_1 and γ_2) = 0.116.

4.56 In summary, γ_1 was sensitive to the increased survey estimate CV, but γ_2 was not. The final value of γ to be used in determining the precautionary catch limit under the three decision rules currently being used for krill was the lower of the two values that were indicated by the two spawning stock biomass criteria. As it was the median spawning stock biomass criterion (γ_2) that led to the lower value of γ, it followed that the precautionary catch limits from the krill yield model were insensitive to the increased levels of survey estimate CV within the likely range.

4.57 The Working Group agreed that in view of these findings, it was not necessary to attempt re-analysis of the FIBEX data aimed at improving the variance estimate of B_0.

Subdivision of Precautionary Limit

4.58 Given the agreement to consider the revision of the precautionary catch limit calculations for Area 48 at its next meeting, the Working Group was unable to offer further advice on subdivision of the precautionary limit to statistical subareas until the possible revision of the area limit has been considered.

Future Work

4.59 Concerns were raised during discussions under Agenda Item 4(iv) (paragraphs 4.39 to 4.57) concerning the continued use of the FIBEX survey data as an estimate of B_0 in the krill yield model. Although one specific concern about survey variance had been addressed in paragraph 4.6, the Working Group discussed a number of other concerns and examined whether it would be desirable and feasible to conduct a new krill biomass survey of Area 48.

4.60 The Working Group agreed that the question of whether there should be a new biomass survey in Area 48 could be broken down into two related questions: (i) is there a need for a new survey; and (ii) what resources would be necessary to carry out such a survey? Issues regarding survey design were acknowledged to affect the second question and have been addressed in paragraphs 4.3 to 4.9.

4.61 There was agreement that a new hydroacoustic survey of Area 48 would be desirable. The main arguments in favour of a new survey were:

- there were technological and methodological problems associated with the collection and analysis of the FIBEX data;
- there was inadequate survey coverage in Subarea 48.3 during FIBEX;
- there is biotic and abiotic evidence to suggest that there have been changes in the environment of the South Atlantic since the FIBEX survey;
- technology and survey design have advanced substantially since FIBEX; and
- a new survey could be designed specifically with the krill yield model in mind.

4.62 Two papers considered the question of required resources: WG-EMM-95/71, which described a time budget for a survey of Area 48 and WG-EMM-95/43, which described a time budget for the survey of Division 58.4.1 planned for the 1995/96 season.

4.63 Paper WG-EMM-95/71 set out a stratified random design having four strata: the South Shetlands area, the South Orkneys area, the South Georgia area and one stratum in the oceanic area not contained in the other areas. The strata were selected on the basis of historical patterns of krill fishing, differentiating between island and oceanic areas, and on strata derived from the FIBEX data.

4.64 FIBEX and AMLR data were used to determine the ship-time required to survey the area at expected levels of CV. Precision improves as survey effort is increased, but gains for effort levels exceeding three ship-months are small. The paper concluded that a single research vessel can achieve reasonable precision (CV < 0.25) by expending one to two months of survey effort.

4.65 In contrast, the FIBEX survey in Area 48 took some 12 months of ship-time.

4.66 Paper WG-EMM-95/43 indicated that the collection of oceanographic data in Division 58.4.1 would add 43% to the ship-time required for the acoustic and associated net sampling survey.

4.67 The Working Group concluded that a new survey of krill in Area 48 could be achieved with a moderate expenditure of ship-time, and therefore encouraged the development of plans for a survey in Area 48.

DEPENDENT SPECIES

Review of Members' Activities

5.1 Members' CEMP-related activities are summarised in SC-CAMLR-XIV/BG/2 Rev. 1. Participants at the present meeting provided brief reports on their recent and current activities as part of CEMP (Appendix E).

Sites

5.2 Members were asked to report on the initiation of CEMP research at new sites and on changes in CEMP research at existing sites.

5.3 Dr E. Franchi (Italy) reported that a joint Italian/Australian biological research program on Adélie penguins began at Edmonson Point, Ross Sea region, during the 1993/94 season (WG-EMM-95/47). Members noted the importance of the initiation of this research.

5.4 Dr P. Wilson (New Zealand) reported on New Zealand research activities in the Ross Sea which are closely related to CEMP goals. Monitoring of the size of some of the southernmost Adélie penguin breeding colonies on Ross Island has been carried out regularly since the 1960s, and for all other colonies in the Ross Sea since 1981.

5.5 Dr Mehlum reported that Norway plans to establish a CEMP site and initiate research on chinstrap penguins, macaroni penguins and fur seals at Bouvet Island during the 1996/97 season. Possible logistic cooperation with South Africa is hoped to improve access to the site.

5.6 Dr Agnew introduced a report from the Norwegian Foundation for Nature Research (NINA) to the Scientific Committee which summarised recent work on Antarctic petrels at Svarthamaren, Dronning Maud Land. The NINA group enquired if it was possible to register the location as a CEMP site.

5.7 The Working Group noted that the work undertaken by the NINA group represented by far the most detailed study yet undertaken on the population dynamics and foraging performance (including body condition) of this species, which is one of those originally selected as a priority for CEMP.

5.8 The Working Group indicated that it would be very happy to accept Svarthamaren as a CEMP monitoring site if so proposed by Norway. It noted that a doctoral thesis on the work, referring to most of the published and in-press papers arising from research at this site, is held in the Secretariat library. It was suggested that the NINA group might consider what data from their study would be suitable for submission to CEMP, in the light of the draft methods proposed in paragraph 5.41.

5.9 Dr Kerry reported that data will be collected on CEMP parameters for Adélie penguins near Casey Station during the 1995/96 season only. This program, as well as a joint French/Australian program at Dumont d'Urville Station, is being conducted in association with a krill survey being conducted by Australia and will provide initial data on predator/prey relationships.

5.10 Dr R. Holt (USA) regretfully reported that the US would be closing the Seal Island CEMP site due to safety considerations. Limited research may be conducted during the 1995/96 season. Other sites will be considered during the next year with the intent of establishing a new site for US research on predator/prey relationships the year after.

5.11 A report on South African research activities indicated that various CEMP methods continued to be utilised in studies of gentoo and rockhopper penguins at Marion Island. Furthermore, the land and marine zones of the Prince Edward Islands (Marion and Prince Edward Islands) are in the process of being proclaimed as a Special Nature Reserve under South African law. This development will heighten the islands' conservation status and will require the continued collection of data likely to be of interest to CEMP.

5.12 It was recommended that other Members conducting research on CEMP indicator species should contribute appropriate data to CCAMLR and in particular to the CEMP database.

5.13 There was no information on the status of the management plan for the Antarctic Specially Managed Area (ASMA) at Admiralty Bay, King George Island. The plan, submitted by Brazil and Poland, had been referred to CCAMLR-XIII, which provided suggestions for consideration.

CEMP Standard Methods

Existing Standard Methods

5.14 Translations of revisions to the standard methods are almost completed and documents will be distributed to Members in the near future. Small changes arising from discussions at this meeting will be incorporated.

5.15 The standard methods were reviewed briefly. Comments were made on procedures only as noted below.

5.16 Method A1 - adult weight on arrival at breeding colony. For Procedure A it was noted that it was not always possible to obtain weight data at the time of first arrival of the birds to breed. Since the weights of birds arriving later are often less than those of the first arrivals, the results are biased. It was suggested that a potential additional procedure under this method would involve either relating weights to a fixed point in the breeding chronology (e.g., egg laying) and/or involve weighing at this time. Dr Trivelpiece indicated that he had collected data on interannual variation in Adélie penguin weights at egg laying and offered to analyse his results, as a potential alternative means of examining variability in early-season condition among Adélies. The results of his analysis will be submitted for inspection by the Working Group at next year's meeting.

5.17 Method A5 - duration of foraging trip. Paper WG-EMM-95/46 suggested that there may be consistent gender differences in foraging trip duration, feeding localities and diet of breeding Adélie penguins at Béchervaise Island, Prydz Bay and Edmonson Point, Ross Sea region. Female penguins tended to make longer foraging trips than males, ranged greater distances more frequently, and consumed larger quantities of krill, especially when their chicks were small. Males tended instead to make shorter journeys to closer foraging grounds during the guard period and fed more extensively on fish throughout chick rearing.

5.18 It was noted that information collected using Method A5 would be advantageously presented in five-day periods and, if possible, related to the mean or median dates of laying and creching and to the sex of the parent bird being studied. This would require modification to the data submission form so that Members could report data in the appropriate way.

5.19 To address this topic it was decided that a subgroup chaired by Dr Kerry and including Drs Agnew, Boyd, Trivelpiece and G. Kooyman (USA) should work intersessionally. The Working Group should present for consideration by a Subgroup on Monitoring Methods and/or next year's meeting of WG-EMM suggestions for improvements to (i) monitoring protocols; (ii) data submission requirements; and (iii) presentation of the data.

5.20 Method A6 - breeding success. It is not necessary to count adults as part of Index A6c and reference to this was deleted from the text of the standard method. It was noted that Procedure C does not reflect breeding success. Instead it records chick fledging success, i.e. chicks fledged per chicks hatched. It was agreed that this information may still be useful and should continue to be reported.

5.21 Method A8 - chick diet. Paper WG-EMM-95/32 provided a detailed method for obtaining stomach samples from penguins by gastric lavage. The Working Group thanked Dr J. Clarke (Australia) for preparing this paper which had been requested by WG-CEMP (SC-CAMLR-XIII, Annex 6, paragraph 4.30).

5.22 The Working Group agreed that the text on gastric lavage of penguins should, with minor modifications, replace the existing text in the standard method under General Procedures - Procedure A, paragraph 3. It noted, however, that although the technique was in common use, several important elements of the technique had been subjected to little if any critical examination. This is especially the case where physiological effects (e.g., of cold versus warm water and/or fresh versus salt water) are involved. Members were therefore requested to report their experiences of using the present technique and also to assess the effects of different methodologies, particularly by using experimental techniques.

5.23 The Working Group noted that there had been two Australian studies on the effects of gastric lavage on the survival of Adélie penguin chicks (Robertson, 1994[6]; Clarke et al., 1994[7]). No evidence was found which showed that the collection of stomach samples once only during chick rearing from one member of a pair of adult Adélie penguins adversely affected the survival or weight at fledging of their chicks. Studies were not conducted on the effects of the collection of more than one sample from the same bird in a season. These findings support the accepted view that gastric lavage is currently the most humane method of procuring samples from Adélie penguins.

5.24 Paper WG-EMM-95/32 suggested that the present method of preparing stomach samples for analysis might not consistently exclude excess water before determining the wet weight of the sample or its components. The Working Group noted the problem and encouraged Members using consistent techniques to specify these in a report to the next meeting so that appropriate advice could be incorporated into the method.

5.25 Paper WG-EMM-95/32 noted that the contents of the first lavage from birds (compared with the remainder of the stomach contents) contained a high proportion of neritic organisms which suggested that these had been obtained opportunistically by birds on their return to the colony from a foraging trip. The paper therefore cautioned against the use of the historical published information for Prydz Bay where the food from a bird was reported from only one lavage without checking if the stomach had been emptied. As a general point the paper suggested that CEMP consider modifying method A8 to report the contents of the first and subsequent lavages separately.

5.26 The Working Group noted that the CEMP methods currently specify the use of lavage until the stomach is empty. The topic of subdividing the stomach sample prior to analysis would require further discussion and should be referred to a Subgroup on Monitoring Methods.

5.27 Paper WG-EMM-95/32 raised the question of whether birds with empty stomachs should be considered when reporting data on diet. Given the observation that in 1994/95 known breeding birds were returning to Béchervaise Island with empty stomachs (WG-EMM-95/33), it was agreed that such birds should be recorded in the comments field on the data reporting sheet. How such data should be incorporated into the calculation of indices should be considered by a Subgroup on Monitoring Methods. The further point raised by the paper that stomach samples should be reported only for known breeding birds with chicks should also be considered. Dr Wilson noted

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6 Robertson, G. 1994. Effects of water-offloading techniques on Adélie penguins. *Journal of Field Ornithology*, 65(3): 376-380.

7 Clarke, J. and K. Kerry. 1994. The effects of monitoring procedures on Adélie penguins. *CCAMLR Science*, Vol. 1: 155-164.

that sampling birds after they were actually observed to return to their chick was the only way to ensure this, but that it was time consuming and not always logistically possible.

Sexing Adélie Penguins

5.28 Details of a method for sexing birds by timing of incubation are provided in Appendix 2.3 of *CEMP Standard Methods*. This method was developed at Béchervaise Island. In WG-EMM-95/45 evidence was presented from Prydz Bay and the Ross Sea region which suggests that this method may be applicable to Adélie penguins at other sites.

New/Potential CEMP Methods

At-sea Behaviour

5.29 At its 1994 meeting, WG-CEMP began the process of developing indices of predator foraging performance based on at-sea behaviour for inclusion in the monitoring program (SC-CAMLR-XIII, Annex 6, paragraphs 4.15 to 4.23). In the intersessional period, draft standard methods of attachment of instruments to penguins (WG-EMM-95/65) and for the measurement of at-sea behaviour (WG-EMM-95/36) were produced by Drs Trivelpiece and Boyd respectively.

5.30 The Working Group approved the general scope and content of these drafts. It noted that the attachment methods text needed critical review by seal biologists and suggested that the draft could also be reviewed by the SCAR Group of Specialists on Seals and the SCAR Bird Biology Subcommittee at their meetings in July 1996. The text on measurement of at-sea behaviour might need modifying once more specific proposals for indices to monitor at-sea behaviour were developed at a proposed workshop (SC-CAMLR-XIII, paragraph 6.20).

5.31 This workshop was scheduled to be held in 1996. However, Dr Boyd, the Convener of the ad hoc subgroup charged with organising the workshop, reported that because the other members of the subgroup had been unable to attend the meeting planned during WG-EMM, no progress had been made with the plans for the workshop, the choice of venue and the terms of reference (beyond those already formulated in SC-CAMLR-XIII, Annex 6, paragraph 4.22).

5.32 The Working Group regretted that progress had not been made on this important topic. In the circumstances it saw little option but to recommend postponing the meeting until 1997, requesting the Scientific Committee to carry forward the appropriate financial provision from the 1996 to the

1997 budget. Dr Boyd was asked to investigate potential venues for the meeting as a matter of priority, to review the terms of reference as appropriate and to consult, via the CCAMLR Secretariat, with potential participants as soon as possible.

Crabeater Seals

5.33 Crabeater seals have been regarded as of primary importance for CEMP since its inception in 1985. However, despite field research on crabeater seals in recent years, no proposals for standard methods (and thereby for the provision of data to CEMP) have been made.

5.34 Therefore, the Working Group welcomed the report (SC-CAMLR-XIV/BG/11) of the SCAR Antarctic Pack Ice Seals (APIS) research project, arising from a planning workshop in Seattle USA, partly funded by CCAMLR. Dr Boyd, a member of the SCAR Group of Specialists on Seals which had planned the project, stated that over the next five years the APIS program aims to promote studies on the status of Antarctic pack-ice seal populations and the role they play in the Antarctic marine ecosystem. By encouraging scientists from various nations and scientific disciplines to share resources, to collaborate on multidisciplinary projects and to identify and utilise centres of specialised analytical expertise, the APIS program seeks to build a cooperative, multinational science program.

5.35 Although concern was expressed that the report of the recent APIS workshop (SC-CAMLR-XIV/BG/11) had little explicit reference to CCAMLR's interest in relevant data on crabeater seals, it was recognised that in previous APIS documents (e.g., SC-CAMLR-XIII/8), explicit reference had been made to the needs of CCAMLR.

5.36 Dr Boyd also noted that it was implicit that aspects of the program will assist substantially in the provision to CCAMLR of advice on the status of Antarctic seals. In addition, APIS intends to produce a number of recommended standard methods for studies which are likely to be applied across research platforms within the Antarctic. The Working Group encouraged the development of these methods and asked that, where appropriate, consideration be given to the development of standard methods which were also of direct relevance to CCAMLR.

5.37 Members should be encouraged to support this important program. The Working Group considered that careful consideration ought be given by APIS to the collection and analysis of data relevant to the aims of CCAMLR in general and of CEMP in particular.

Antarctic Fur Seals

5.38 It was noted above that demographic data for Antarctic fur seals at South Georgia collected by consistent[8] methods from 1984 to 1994 had been submitted by the UK to CCAMLR (WG-EMM-95/26). In order to assist other Members collect, analyse and summarise similar data, it was important that the methodologies in WG-EMM-95/26 be developed in the form of a standard method. Drs Boyd and Croxall offered to undertake this task.

5.39 In addition, the provision in WG-EMM-95/28 and 29 of extensive data on the diet of Antarctic fur seals at South Georgia indicates that it should be possible to develop standard methods for dietary studies of this species. Drs Boyd and Croxall offered to do this task.

5.40 For some time WG-CEMP had been requesting investigation of potential methods of incorporating condition indices into monitoring studies. Dr Boyd presented WG-EMM-95/21, which compared the use of body mass, body mass corrected for length and bioelectrical impedance measurements for assessing body condition (in terms of total body water and total body lipid determined by hydrogen isotope dilution) in adult female Antarctic fur seals. Bioelectrical impedance gave the poorest correlations, whereas body mass alone gave the best ones.

Petrels

5.41 Dr Mehlum introduced WG-EMM-95/86, which described draft standard methods for fulmarine petrels. The draft was a first step in describing standard methods for population size, breeding success and annual survival and recruitment in the Antarctic petrel. The Working Group welcomed this effort and asked that the draft be circulated to relevant experts for comments and passed to a Subgroup on Monitoring Methods for consideration at a future meeting.

5.42 Lic. R. Casaux (Argentina) summarised WG-EMM-95/85, which presents data on the diet (obtained by lavage) of cape petrels at Laurie Island, South Orkney Islands. *Euphausia superba* was the predominant prey species in the samples; uropod, exopodite and telson length were used to estimate body length. The Working Group suggested that this technique and the statistical relationships presented (see also Nicol, 1993[9]) should be included in a draft of standard methods for studying the diet of fulmarine petrels and might be relevant to diet studies of other predator species.

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[8] Consistent refers to the use of the same method throughout the collection of a time series of data where the method may differ from a CEMP standard method or relate to a CEMP parameter for which standard methods have not yet been developed.

[9] Nicol, S. 1993. A comparison of Antarctic petrel (*Thalassoica antarctica*) diets with net samples of Antarctic krill (*Euphausia superba*) taken from the Prydz Bay region. *Polar Biology*, 13: 399-403.

Lic. Casaux agreed to prepare a draft of methods for analysis of petrel diet samples for discussion at the next meeting of WG-EMM and/or a Subgroup on Monitoring Methods.

5.43 Dr Agnew reported that, following the tabling last year of WG-CEMP-94/24 (SC-CAMLR-XIII, Annex 6, paragraph 4.13), Dr J.A. van Franeker (Netherlands) had provided the Secretariat with a copy of his computer program for use in sex-discriminant analysis of seabirds.

Gastric Lavage

5.44 The Working Group noted that recent communication with Dr A. Veit (University of Washington, USA) indicated that he was prepared to provide text relating to the use of lavage for obtaining stomach samples from albatrosses and petrels. The Secretariat was asked to continue the dialogue with a view to having a method available for consideration at the next meeting of WG-EMM.

5.45 Discussion of the use of this gastric lavage technique on penguins is included in paragraphs 5.21 to 5.27.

Diseases and Pollutants

5.46 Last year Drs Kerry and Clarke were asked to prepare procedures for the collection of diagnostic samples if and when an outbreak of disease or a parasitic infestation is observed in a seabird colony (see SC-CAMLR-XIII, paragraph 6.18).

5.47 In response to this request, Dr Kerry presented WG-EMM-95/44 which outlines methods for the collection and preservation of samples in the field for later examination and analysis by veterinary pathologists.

5.48 The Working Group welcomed these instructions and recommended that they be circulated to Members for use in the interim pending a more detailed examination by appropriate specialists in Member countries. The Working Group agreed that comments should be forwarded to Dr Kerry who would prepare a revised document for consideration by a methods subgroup and/or at the next meeting of WG-EMM.

5.49 The Working Group endorsed the recommendation that scientists conducting field studies should consult with veterinary pathologists before going into the field to ensure that, if needed, urgent analysis of samples is possible and that any special sampling requirements of the laboratory can be accommodated. The recommended list of equipment to have on hand in the field was noted.

5.50 WG-CEMP (SC-CAMLR-XIII, Annex 6, paragraph 4.42) had noted that, in the event of an outbreak of disease or increased infestation, there may be interest in whether any contaminant or pollutant contributed to the outbreak and suggested that consultation with Prof. Focardi be undertaken to ensure sample collection procedures for disease include those necessary for post hoc testing for contaminants.

5.51 Dr Franchi, in collaboration with Prof. Focardi, presented details of such collection methods. It was agreed that a revised version of these instructions be appended to WG-EMM-95/44 and circulated for comment as suggested in paragraph 5.53 below.

Conclusions

5.52 In considering these methods, the Working Group agreed that research involving their use has progressed to the point where a detailed revision of all methods should be considered. This review would determine whether they are yielding the precise information required by WG-EMM and whether their usefulness could be improved by modification or by the development of new methods.

5.53 The Working Group therefore suggested that a Subgroup on Monitoring Methods be established to:

(i) circulate the existing proposals for changes to current methods and proposals for new ones, to all Members and to the SCAR Group of Specialists on Seals and Bird Biology Subcommittee for comment and suggestions for improvement;

(ii) invite all Members and the SCAR Group of Specialists on Seals and Bird Biology Subcommittee to suggest new methods (with accompanying documentation wherever possible) relevant to CEMP objectives;

(iii) arrange a meeting to review the responses to (i) and (ii) above; and

(iv) consider developing plans for a comprehensive review of methods.

Indices

Data Submission Review

5.54 Seven Members have so far submitted data to the CEMP database (WG-EMM-95/12 Rev. 1). Argentina submitted data from 1988 to 1990. Additional data from Argentina for the 1993/94 and 1994/95 seasons were delivered to this meeting by courier.

5.55 Australia submits data annually for Béchervaise Island and sporadically for Magnetic Island.

5.56 Brazil submitted data from 1990 to 1992 from Elephant Island but the predator program is in abeyance.

5.57 Chile has submitted data on pup growth from Cape Shirreff for 1993/94 and 1994/95, the latter conforming to the standard method, as stated in WG-EMM-95/77.

5.58 The UK has now completed submission of all historical data (except on diet) on penguins from Bird Island. Annual data submission continues for Bird Island and Signy Island. The tabling of WG-EMM-95/26, which describes the demography of fur seals at South Georgia and provides full quantitative data on birth, mortality and recruitment rates of pups and pregnancy and survival rates of adult females, effectively constitutes submission of these demographic data to CEMP. The methodological details in the paper will need some modifications in order to serve as the text of a standard method (see paragraph 5.38).

5.59 Italy has submitted data for 1995 from the new site at Edmonson Point, Ross Sea. The new activity being conducted there was warmly welcomed by the Working Group, as was the valuable addition to the database, as there has not been any earlier data submitted from this region.

5.60 The continuing absence of Japanese data on Adélie penguin population size for the Syowa station area was noted. Dr M. Naganobu (Japan) offered to make enquiries with colleagues in Japan.

5.61 The USA has submitted data from Anvers Island from 1990 to 1995 and Seal Island from 1988 to 1995. Some data for Seal Island are missing from the database for 1995 because technical difficulties have delayed the submission. Dietary data (A8) are also missing from 1992 and 1993 as they are still being processed. The USA was strongly encouraged to submit historical data from Anvers Island and particularly all the relevant long-term data on numerous penguin parameters from the monitoring site at Admiralty Bay, King George Island.

5.62 Penguin data collected by New Zealand in the Ross Sea following CEMP methods were described by Dr Wilson. Submission of these data to the CCAMLR database was strongly recommended by the Working Group which, together with the new Italian data, would be a valuable addition from a part of the Antarctic continent for which there are no CEMP data.

5.63 The Working Group looked forward to the CCAMLR database receiving data from the planned Norwegian research program at Bouvet Island and, if possible, from the recent studies at Svarthamaren.

5.64 The Working Group requested that data from the South African research program at Marion Island on gentoo penguins (a CEMP indicator species), collected using CEMP Standard Methods, be submitted to the CCAMLR database. This represents an extension to the existing scope of CEMP (because gentoo penguins at Marion Island do not depend primarily on prey species on the current list of those selected by CEMP). Data from rockhopper penguins at Marion Island are not eligible for submission at present because this species is not currently a selected CEMP indicator species.

Data Analysis and Presentation

5.65 It was recalled that in 1994 WG-CEMP encountered a number of problems in the interpretation and presentation of the CEMP indices, which prevented WG-CEMP from making the transition from a qualitative to a quantitative assessment of indices and trends (SC-CAMLR-XIII, Annex 6, paragraphs 5.6, 5.7 and 7.7). It was recommended that the Subgroup on Statistics meet intersessionally to:

(i) confirm that appropriate analytic and statistical methods were being used; and
(ii) improve the presentation of the indices.

Several Members of the subgroup met in Cambridge, UK, in January to consider these problems.

5.66 Dr Agnew presented the report from the meeting of the Subgroup on Statistics (WG-EMM-95/10). New software (using Microsoft Access) had been developed to make the graphical presentations (WG-EMM-95/12 Rev. 1 and 14 Rev. 1) more easily understood. The new data compilation included three parts:

(i) an introduction and summary of all indices by site and species (WG-EMM-95/12 Rev. 1);

(ii) tables of results with associated statistics and indications of statistically significant differences between years for all parameters within sites (WG-EMM-95/13 Rev. 1); and

(iii) figures of indices depicting trends at sites between years (WG-EMM-95/14 Rev. 1).

5.67 It was noted that the graphs should be studied in conjunction with the tables of results, as the scales used in the presentations may tend to imply statistically significant differences where none exist, and vice versa. The Working Group wished to convey their thanks and appreciation to Dr Agnew for his considerable efforts in improving the analyses and presentations in WG-EMM-95/12 Rev. 1 and 14 Rev. 1.

5.68 The Working Group reviewed the predator data and indices for further technical comments relating to analysis and presentation.

5.69 Index A1 - penguin weight at arrival. A suggested improvement would be the production of a frequency distribution, which could be done easily with the new software.

5.70 Index A3 - penguin breeding population size. Two colonies, TO14 and TO16 from Palmer Station (USA), are no longer counted because they are too large to count accurately. They should be deleted from the database.

5.71 Dr Agnew observed that there were instances where colonies being monitored year to year split or coalesced and when this occurred they were given new identification names or codes without the Secretariat being advised. Dr Agnew stressed the importance of reporting population numbers for the same group of penguins each year. Members reporting data were therefore requested to note any changes to the colony structure and names and, where necessary, illustrate such changes with a map or diagram.

5.72 Index A5 - penguin foraging trip duration. The separation of data into brood and creche stage was discussed. It was agreed that this was appropriate and that some of the apparent inter- and intra-annual variation in the data for Adélie penguin relates to different foraging strategies. It was noted that a frequency distribution presentation of the data would be useful for the analysis of this index but would require data to be submitted appropriately.

5.73 Index A8 - chick diet. There were no technical comments on the data analysis and presentations of A8; however, there was a paper submitted (WG-EMM-95/32) with suggested changes to the methods which had been discussed earlier (see paragraphs 5.21 and 5.22).

5.74 Index C1 - fur seal cow foraging trip duration. The graphical presentation of data from Bird Island was mistakenly based on the data from Seal Island; this was corrected during the meeting.

5.75 Index F2 - sea-ice percentage cover. The new methods of presentation were very helpful for examining patterns in these data.

5.76 There were no technical comments offered for indices not addressed in the above section (e.g., A2 , A4, A7, B1 and C2).

Data Interpretation - Ecosystem Assessment

5.77 Tables 2 and 3 were passed out to members who were asked to update their respective data submission summaries and add the 1994/95 data on status and trends to the interannual summaries of parameters at sites. The interpretation of the 1994/95 data was then undertaken.

5.78 Dr Trivelpiece noted that all penguin data for the Antarctic Peninsula area (Subareas 48.1, 48.2 and 48.3) in the 1994/95 season indicated better breeding success but decreased populations compared with 1993/94. In contrast, data from Béchervaise Island in the Prydz Bay region indicated catastrophic breeding results.

5.79 Dr Kerry reported that at Béchervaise Island and the islands within a 5-km radius, all penguin chicks died within three weeks of hatching. Evidence suggested that starvation was the major cause. Foraging trip durations were longer than previous years and birds foraged further afield, up to 170 km (compared with 110 km), and returned with little or no krill. The spatial extent of the absence of krill is not known, but may be limited. Birds at colonies 57 km to the west and 169 km to the east appeared normal for the corresponding stage of the breeding cycle. Full details are provided in WG-EMM-95/33.

5.80 Dr Kerry noted that there was some evidence during spring that emperor penguin chicks at the Auster Colony also may have been affected by a lack of krill. This colony, is located approximately 65 km to the east of Béchervaise Island. At Taylor Colony, approximately 50 km to the west of Béchervaise, healthy chicks were observed when visited in mid-January. It was concluded that the absence of krill was localised to the north and east of Béchervaise Island and that this affected also the presumably krill-dependent prey of emperor penguins.

5.81 Dr Boyd noted that at Bird Island, South Georgia, the 1994/95 season seems to have been characterised by normal krill availability. The reduction of the breeding population of gentoo penguins and Antarctic fur seals at Bird Island, in spite of good indices for reproductive success, probably reflected that breeding success had been exceptionally low in the preceding year. The reduction in the macaroni penguin population (which had sustained average breeding performance in 1993/94 despite having to switch its diet from krill to *Themisto*) also probably reflected the unusual conditions at South Georgia in 1993/94.

5.82 The pattern at Signy, of 1994/95 breeding populations of Adélie and chinstrap penguins significantly reduced from recent levels, may also reflect low food availability (WG-EMM-95/75) and rather poor reproductive performance in 1993/94. Additionally or alternatively, these fluctuations at Signy may reflect the effects of variation in prey availability mediated through ice conditions in the Antarctic Peninsula area (WG-EMM-95/15, 63 and 64).

5.83 Dr Croxall explained that the substantial reduction in the number of black-browed albatrosses breeding at the study site in 1994/95 was due to very late and heavy snow fall preventing the breeding population from nesting. The importance of linking this kind of information to the data appearing in the CCAMLR database was emphasised. The information should be noted both at the time of submission of the data and at the appropriate meeting where the data are discussed.

5.84 Dr Boyd noted that fur seal pup growth indices indicate faster growth at Seal Island than at Bird Island, a matter which merits further investigation. A possible explanation may be that due to the small size of the colony at Seal Island, the same pups are weighed more frequently there. However, Dr Croxall recalled that in the 1970s the Bird Island data values were higher than in more recent years, so that other explanations, perhaps relating to ecological effects of population size, may be involved.

5.85 Dr Trivelpiece noted that the Adélie penguin data from Palmer Station reflected a pattern consistent across all Antarctic Peninsula area sites: good breeding success but reduced population size. Krill size classes (large) and foraging trip durations (long) show significant correlation with ice patterns and krill habitat preferences (WG-EMM-95/64). Dr Holt noted that the overall trend described for the other Antarctic Peninsula sites was evident at Seal Island.

5.86 Dr Franchi reviewed the new Italian data from Edmonson Point that, for the first time, included a complete set of parameters; therefore no trend analysis was possible. The Working Group looked forward to the possibility of following trends in this new area. She also informed the Working Group that ecotoxicological and disease studies were undertaken at the site. The studies are expected to continue for a minimum of three years.

Dependent Species Links with Harvested Species and the Environment

The Overlap Between the Fishery and Foraging by Dependent Species

5.87 The importance of continued investigation and analysis of the nature and significance of overlap between the location of krill fisheries and the foraging areas (and food requirements) of krill-dependent predator species during their breeding season was re-emphasised in SC-CAMLR-XIII, paragraphs 7.8 to 7.16. This interaction is currently assessed during the critical period-distance (CPD), which is currently taken to be a range of 100 km from breeding sites over the period December to March.

5.88 The Data Manager had, as requested, continued to calculate overlap between the location of krill fishing and the predator CPD. The summary of the results of analysis of the 1994 data, together with previous assessments, was presented in WG-EMM-95/41. This paper was presented in a new style and format, consistent with those for the CEMP predator indices. The Working Group thanked the Data Manager for his work and for the much improved presentation.

5.89 It was noted that where the percentage of total catch reported by fine-scale data was less than 50%, these data have not been included in the analysis presented in WG-EMM-95/41. In general, however, more than 75% of the catch was reported at fine scale. Furthermore, considerable historical data had been provided this year by Japan. The Working Group thanked Japan for its great efforts to provide so much valuable data. For the first time results for Division 58.4.2 were included. A similar presentation for Division 58.4.1 was not included because details of the penguin colonies in this area were unavailable at the time.

5.90 The overall picture in Subarea 48.1 was of a progressive reduction in the percentage catch within the CPD from 90 to 100% in the late 1980s to 60 to 70% in recent years, with a reduction in the total catch in the CPD in 1993 and 1994. In Subarea 48.2 there is no clear pattern, but the catch in 1993 and 1994 was much reduced compared with previous years and the percentage of catch in the CPD was less than 20% (compared to 40 to 50% in the previous two years). For Subarea 48.3, catches and overlap in the CPD were very low because the main krill fishery takes place in the winter. In Division 58.4.2 (Prydz Bay region), catches were small but the percentage of catch in the CPD in recent years was high (60 to 80%).

5.91 Mr Ichii explained that one reason for some of the recent reduction in the fishery/dependent species overlap within the CPD in Subareas 48.1 and 48.2 was that more fishing was conducted outside the critical period for predators. This was because of logistic constraints on the timing of the fishery imposed by the need for the vessels involved also to fish in areas adjacent to the Convention Area.

5.92 It was recollected, however, that the existing CPD concept was only one of a suite of potential critical periods for predators. There are clear indications that the March to May period may be equally critical for the survival of fledgling penguins in some regions, and also suggestions that winter (June to September) may be an important time for the survival of adult seals and penguins.

5.93 Mr Ichii pointed out that no account is taken of the size and distribution of colonies in the calculations of the CPD. He also suggested that the CPD ought to be weighted by the distance of the fishery from colonies of different sizes (WG-Joint-94/8 and 17).

5.94 However, it was noted that these issues may be of importance only if there is no flux of krill in the areas under consideration (see SC-CAMLR-XIII, Annex 7, paragraph 4.3).

5.95 Dr Kerry noted that Adélie penguins at Béchervaise Island regularly forage during the entire breeding season between 100 and 120 km from the coast, and that during the past season they had foraged up to 170 km from the coast (WG-EMM-95/46). He suggested, therefore, that the critical distance should be extended to at least 125 km for Division 58.4.2.

5.96 It was agreed that both the concept and the detail of the CPD needs to be critically re-examined in the light of new data on the foraging ranges of predators, fishing grounds and the times of year at which predators are particularly vulnerable. Such a discussion should be a high priority at the next meeting of WG-EMM.

5.97 The Data Manager reported that in 1995 there had been a substantial increase in the catch of krill by Ukraine in Subareas 48.1, 48.2 and 48.3 (see paragraph 3.2). In view of this, it was thought advisable to review the overlap between fisheries and dependent species as soon as possible, and the Data Manager was asked to provide relevant information for this year's meeting of the Scientific Committee.

5.98 As a contribution to the continuing research aimed at assessing potential overlap between predators and the krill fishery in the vicinity of Seal Island, Mr Ichii introduced WG-EMM-95/87. This described the results of assessments of krill and fish abundance (from acoustic surveys) in relation to the foraging journeys of chinstrap penguins and Antarctic fur seals tracked by VHF radio (and satellite tags) during the incubation and early offspring rearing periods. Krill densities were higher over the shelf areas and lower in offshore areas where fish (principally myctophids) were at high density and available at night within the depth foraging range of penguins and fur seals. The individual predators actually tracked, however, travelled to areas well offshore during incubation/early pup rearing (December) and also offshore, albeit closer to Seal Island, in January. The propensity for chinstrap penguins and Antarctic fur seals to travel to offshore areas might reflect that:

(i) krill were present at shallower depths throughout the day, and therefore more easily detected and caught;

(ii) krill tended to be larger in size; or

(iii) myctophids were available to predators at night.

The availability of myctophids was regarded as the key element determining the foraging strategy of predators which incorporated an overnight period into their foraging trip (i.e., all fur seals and some chinstrap penguins).

5.99 The Japanese and US scientists were congratulated for undertaking such a complex, intensive and productive research project. However, it was noted that the key role of myctophids in the foraging strategies of chinstrap penguins and fur seals was, at this stage, simply inferred from data on prey abundance and predator location (and these from very small numbers of individuals) and unsubstantiated by any data on predator diets. Furthermore, existing data on the diet of chinstrap penguins from Seal Island indicate that fish have only comprised more than 1% by mass of the diet in one year (1994: 9%) of the five years for which data are available (WG-EMM-95/13 Rev. 1). All published dietary data for chinstrap penguins from the South Shetland and South Orkney Islands indicate that krill is their main prey (more than 90% by mass); thus, even if myctophids were important in the diet of chinstraps at Seal Island in January 1995, this could, at present, be regarded as a local effect only. Analogies were drawn with the situation at South Georgia from which macaroni penguins and Antarctic fur seals regularly travel through inshore krill concentrations (exploited by species such as gentoo penguin) to shelf-slope and offshore areas (where myctophids are abundant) to feed almost exclusively on krill. Caution was urged in drawing conclusions from the data presented in WG-EMM-95/87, at least until quantitative dietary data from the tracked predators and for the chinstrap penguin and Antarctic fur seal populations at Seal Island in January 1995 are available.

Subarea and Local Consumption

5.100 A key element in the assessment of krill fishery/dependent species interactions is knowledge of the food requirements of predators. WG-CEMP had undertaken considerable work in developing appropriate energy budget models for the main predator groups (phocid seals, fur seals, penguins) and providing estimates of energy and/or krill consumption for some or all of these groups in appropriate areas (SC-CAMLR-XIII, Annex 6, paragraphs 6.3 to 6.6).

5.101 It was also noted that a current proposal relating to potential precautionary measures (e.g., WG-EMM-95/17) is based on estimation of the food requirements of predators. It was recommended, therefore, that a comprehensive compilation of data regarding diets, energy budgets and foraging ranges/areas of top predators in the Convention Area be maintained and updated annually, together with appropriate information on analogous modelling exercises for other ecosystems. Members were requested to make such information available to WG-EMM.

5.102 Paper WG-EMM-95/22 reported new data on activity-specific energetics of gentoo penguins, and WG-EMM-95/28 and 29 provide new quantitative data on summer and winter diet of Antarctic fur seals at South Georgia. Dr Boyd stated that he was currently developing a generic pinniped energy budget model and would be considering the sensitivity of its results to values of demographic variables. Dr Trivelpiece reported that a modelling exercise (WG-EMM-95/66) aimed at developing an energetic model for Adélie penguins, as part of a larger ice/krill/dependent species model, is planned. Papers WG-EMM-95/46 and 87 contained valuable data on foraging ranges of penguins and fur seals.

5.103 Data on actual foraging areas covered by Antarctic fur seals and chinstrap penguins from Seal Island, obtained from shipboard radio telemetry and satellite tracking, are summarised in WG-EMM-95/87 (see also paragraphs 5.98 and 5.99).

Relationships Between Dependent Species and Other Ecosystem Components

Modelling Functional Relationships

5.104 The background to this topic is reviewed in SC-CAMLR-XIII, Annex 7, paragraphs 4.19 to 4.30. At that meeting, specific problems had been highlighted about interpretation of the data used in the models. This resulted in the clarification of several issues relating mainly to whether survival data for predators had been interpreted correctly. The joint meeting had encouraged further development of the models in the light of this new information.

5.105 The Working Group considered WG-EMM-95/39 and 42 which described progress with the development of modelling functional relationships between indices of predator recruitment/survival and krill abundance. Initially, only those aspects relevant to the predator data were discussed.

5.106 In WG-EMM-95/39, substantial progress was reported towards achieving a realistic result from the model for the black-browed albatross. Allowing different juvenile and adult survival rates in the model had led to a substantial improvement in realism. The current model assumes that the population is stable, although this is not the case, as noted in WG-CEMP-94/44, and does not explicitly incorporate data on laying rate.

5.107 Specific steps to be taken in extending the model for black-browed albatross are detailed in Appendix F(a). The most important of these are to re-estimate parameters to reflect the observed decline in the population over the 1976 to 1989 period, rather than to assume that the population is stable, and to incorporate laying rate data within the calculation of fecundity rate.

5.108 Further modelling of Antarctic fur seal functional relationships incorporating the full set of data on survival rates had been less successful because of an additional problem with the data (WG-EMM-95/39). A rate of population increase of +3.4% per annum was the maximum that could be achieved by the model even though there was evidence of an actual increase of +10% per annum. However, it was pointed out that:

(i) there are wide confidence limits on the current annual estimates of both adult female survival and pregnancy rates;

(ii) survival rate will be underestimated by the current methods of measurement in Antarctic fur seals. This is because estimated adult emigration (currently assumed to be negligible) and correction for tag loss rate will be, if anything, on the low side. Further, age-dependent mortality factors are likely to have affected the survival rate of the study population more than that of the South Georgia population as a whole; and

(iii) the rate of increase in the study population (though not in the whole South Georgia population) has decreased throughout the study period (it is currently stable). The study population from which these data are derived is not a closed population and it is not known how representative it is of the whole South Georgia population of Antarctic fur seals. In these circumstances, the current fit given by the model may be much better than the authors of WG-EMM-95/39 thought. Further discussions may now be required to determine the best way to proceed.

5.109 Specific steps for further developing the model for the Antarctic fur seal are listed in Appendix F(b). Because tag-recapture estimates of adult survival rate are biased downwards when used to represent the population as a whole, an additional parameter is to be introduced into the model to adjust these estimates so that the model population is able to achieve the growth rate of some 10% per annum observed in the recent past for the overall population.

5.110 For Adélie penguins (WG-EMM-95/42), a model had been developed which allows for lower adult survival rates in the year of first breeding and the possibility that breeding may be deferred one year if conditions are poor. However, the fit of the model to a time series of annual estimates of breeding population size was unable to reproduce as much interannual variability as the data suggest. As a further development of this model, variable annual adult survival could be incorporated instead of using a fixed value as at present. It was also pointed out that there is interannual variation in sub-adult survival and this may have to be incorporated in the model.

5.111 The planned modifications to the Adélie penguin model of WG-EMM-95/42 are described in Appendix F(c). These include allowance for first breeding to occur over a wider range of ages and for annual variation in the first year survival rate.

5.112 Implementation of the steps outlined in Appendix F(a) and F(b) should allow final calculations for the present form of the krill/dependent species model to be presented at the 1996 meeting of WG-EMM for two species, the black-browed albatross and the Antarctic fur seal. The Adélie penguin modelling exercise is more complex and may therefore require a further iteration at the 1996 meeting before results of possible relevance to management recommendations from this approach become available for this species.

5.113 The Working Group endorsed the future work described above. It noted that this work should at present be confined to the three species mentioned, but encouraged extension of the approach to other species and sites as possible and appropriate. Extension of the approach would depend on the availability of appropriate demographic data and it is important that these contain estimates of the measurement error associated with the empirical estimates of the population parameters.

Krill Selectivity by Predators

5.114 At the 1994 joint meeting, calculations involving the length distributions of krill in predator diet data had been requested because the results of the krill yield estimation model were particularly sensitive to the age-dependence in krill natural mortality (SC-CAMLR-XIII, Annex 7, paragraphs 4.34 and 4.35). In response to this, sets of krill length frequency distributions from minke whale, crabeater and Antarctic fur seal, Adélie, chinstrap, gentoo and macaroni penguin and white-chinned petrel stomach samples had been sent to Prof. Butterworth and Miss R. Thomson (South Africa) for them to attempt to assess the effects of this age dependence.

5.115 The results of an illustrative analysis, using data on minke whales from Mr Ichii, crabeater seals from Dr J. Bengtson (USA), Adélie penguins (Lishman, 1985[10]) and white-chinned petrels (Croxall et al., 1995[11]), are summarised in WG-EMM-95/40. Prof. Butterworth pointed out that most of the krill lengths in the data sets supplied showed that predators were taking a low proportion of krill from age classes <3 years. Since the krill yield model is more sensitive to mortality in the early age classes of krill, which these sets suggest to be poorly represented in the diet of the predators, he questioned whether continuing with this approach was worthwhile. However, questions were raised about the selection of those data sets examined in WG-EMM-95/40. The meeting felt there was evidence from several of the submitted data sets and various other studies (e.g., WG-EMM-95/28, 29 and 64) that krill of <3 years of age (<44 mm) were taken regularly by predators consuming large quantities of krill.

5.116 If krill natural mortality is to be inferred from the length distribution of krill consumed by predators, then further requirements would include: (i) representative data on the length frequencies of krill taken by all major krill predators; and (ii) estimates of the proportion of the total consumption of krill by each species. The Working Group agreed that: (i) for most major predators diet and/or scat samples provide representative data on the length frequency of krill they eat; and (ii) adequate estimates of proportionate krill consumption could be provided. However, concern was expressed about how easy it would be to obtain fully representative length frequency distributions, because of the effects of different spatio-temporal scales of sampling.

5.117 The Working Group noted that concern about the sensitivity of the krill yield model results to age dependence in krill natural mortality had been based on calculations for which natural mortality was changed for krill of ages 0, 1 and 2. However, subsequent practice has been to base estimates of krill recruitment variability and natural mortality on krill length frequency data for age 2 and above only. This means that the yield model results become independent of values assumed for krill natural mortality for ages 0 and 1. Given the difficulties of developing predator dietary data into the form necessary to attempt to estimate age dependence in krill natural mortality, the Working Group agreed that the sensitivity of the krill yield model results to this dependence should be re-examined for ages 2 and above only, prior to possible further analysis of the dietary data.

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[10] Lishman, G.S. 1985. The food and feeding ecology of Adélie and chinstrap penguins at Signy Island, South Orkney Islands. *Journal of Zoology, London*, 205: 245-263.

[11] Croxall, J.P., A.J. Hall, H.J. Hill, A.W. North and P.G. Rodhouse. 1995. The food and feeding ecology of white-chinned petrel *Procellaria aequinoctialis* at South Georgia. *Journal of Zoology, London*, 237.

5.118 In preparation for further work on this topic it will be important to assess biases in krill length frequency data derived from predators. Members able to compare krill length frequency data from net hauls with data derived from predator diet samples taken at times and places similar to the times and places of net hauls were asked to make such information available to the next meeting of WG-EMM.

Other Approaches

5.119 Dr Trivelpiece presented an analysis of the relationship between Adélie penguin fledgling survival (1981 to 1991 cohorts), population changes (1977 to present) and pack-ice cycles (WG-EMM-95/63). The analyses revealed that cohort survival was independent of ice cycles; however, the relatively constant survival rates from 1981 to 1986 (mean 22%, range 20 to 24%) declined significantly to a mean of 10% (range 5 to 14%) for the 1987 to 1991 cohorts. Lagging two years behind this change in cohort survival, the Adélie population at Admiralty Bay declined from approximately 10 000 to 5 000 breeding pairs. Furthermore, analysis of krill length frequency from Adélie diet samples (1974 to present; WG-EMM-95/64) and pack-ice cycles (WG-EMM-95/62) revealed a consistent pattern of relationship between krill length frequencies and pack-ice cycles. These papers suggest that the reduction in the frequency of winters with extensive pack-ice has resulted in a decrease in krill recruitment, and hence biomass, in the region, which in turn has led to changes in the survival, recruitment and population size of Adélie penguins.

5.120 The Working Group recognised the significance of this work and the importance of testing the conclusions and hypotheses therein. Analysis of additional time series of data on krill length frequencies from predators in appropriate areas and of other relevant demographic data for penguins (especially data on chinstrap penguin survival and recruitment rates from Seal Island) was strongly recommended.

5.121 Methods are also being developed to examine indices of variability in the spatial structure of krill swarms from data on the foraging time budgets of Antarctic fur seals (WG-EMM-95/23). This paper concluded that, during 1990/91 at South Georgia, when fur seals seemed to have reduced food availability, there appeared to be no reduction in the frequency at which seals encounter krill swarms but the quality of those swarms as foraging patches for fur seals may have been reduced.

5.122 While welcoming this development, Mr Ichii asked if there were concurrent acoustic data to provide an independent test of the ideas expressed in the paper. Unfortunately there were no such data. Mr Ichii noted that, from his recent experience in work around Seal Island, fur seals appeared to swim continuously through krill swarms rather than feeding on a single swarm for a long period of time, as suggested by Dr Boyd's analysis. In response, Dr Boyd suggested that, because of the small spatio-temporal scales (0.18-0.27 km and 1.3-1.36 km) involved in fur seal feeding, it would be difficult to infer, by casual observation, the precise behaviour of fur seals engaged in travelling and foraging and that one could easily have the impression that animals were travelling continuously.

5.123 Paper WG-EMM-95/75 reported some data from 1993/94 on comparisons of acoustic estimates of the abundance of krill and other zooplankton in the South Georgia and Signy Island areas, which were consistent with available data on predator reproductive performance. Interpretation of these relationships would have been improved by dietary data from penguins at Signy and more detailed data on non-krill zooplankton distribution and abundance at South Georgia, but this could not have been foreseen as a desirable objective at the time the acoustic study was planned.

5.124 It was emphasised that it was important to collect data on distribution and abundance of predators and prey from similar times and places. Data on the population structure of prey from predators as well as on prey populations directly, should also be collected in a similar manner.

Ecosystem Assessment

5.125 The data requirements to develop strategic models for ecosystem assessment were reviewed. For dependent species the only sources of integrated data on population size, adult survival rate, reproductive rate and recruitment are:

Subarea 48.3	-	Antarctic fur seal (South Georgia)
		Black-browed albatross (South Georgia)
Subarea 48.1	-	Adélie and gentoo penguin (King George Island)
Subarea 48.1	-	Adélie penguin (Palmer)
Division 58.4.2	-	Adélie penguin (Béchervaise)

Historical data covering all the above variables are available for Adélie penguins at Cape Crozier and crabeater seals in Subarea 48.1.

5.126 A variety of studies are providing regular or annual time series of data on some or all of: diet (including prey population structure), foraging range and foraging performance and these are listed in Table 4.

Research Relating to Non-krill Harvestable Resources (Scope of CEMP)

5.127 The background to this item is set out in Annex 6 of SC-CAMLR-XIII, paragraphs 9.1 to 9.8, and SC-CAMLR-XIII, paragraphs 6.34 to 6.40.

5.128 In response to the Scientific Committee's request for relevant information and proposals for monitoring and related research initiatives the meeting considered the implications of papers tabled this year and information considered in previous years.

5.129 In the past, these contributions have mainly related to: (i) a need within CEMP to know if CCAMLR intends to undertake monitoring and/or coordinated directed research (e.g., including on dependent species) on *Pleuragramma antarcticum*; (ii) the potential for coordinating the collection, analysis and interpretation of data on interactions between certain fish-eating (and possibly even squid-eating) species and their prey. The main fish-based dependent species/harvested species interactions discussed at the present meeting related to blue-eyed shag, king penguin and Antarctic fur seal.

5.130 Lic. Casaux presented a review of recent Argentinian research investigating in detail the consumption (in terms of number and biomass) of coastal fish species by blue-eyed shags in Subareas 48.1 and 48.2 (WG-EMM-95/78, 79, 81, 82 and 83). The fish species represented in the diet agreed, even in relative importance, with those sampled by means of conventional fishing gear (gill/trammel nets) and included harvested and harvestable species. He also presented a draft of a methodological proposal for monitoring changes in coastal fish populations by analysis of pellets (WG-EMM-95/84). This method could be a very effective means of detecting both short- and long-term variations in fish populations, which should have considerable interest for CCAMLR.

5.131 The Working Group welcomed these developments and noted that the fish consumed by blue-eyed shags include juveniles of species (such as *Notothenia rossii*) which have been harvested in the past and whose current status in Subareas 48.1 and 48.2, where there is currently no commercial fishing, is of much interest to CCAMLR.

5.132 It was noted, however, that it may be important to try to clarify: (i) the sizes/ages of commercially exploitable fish species eaten by shags; and (ii) any biases inherent in the use of shags as sampling agents for these size categories of the fish population.

5.133 For king penguins at South Georgia, WG-EMM-95/27 provides detailed quantitative dietary data for three consecutive summers demonstrating that, like king penguins at all sub-Antarctic islands so far studied, they depend almost exclusively on a diet of myctophids.

5.134 Dietary work on this species, in conjunction with the use of satellite tracking, time-depth recorders (TDRs) and other instruments is already providing much information on the dynamics of interactions between king penguins and their prey (Jouventin et al., 1994[12]). Many of these data could be of relevance to CCAMLR in terms of obtaining information on aspects such as relative abundance and distribution within and between years of a group of fishes which has been subjected to considerable harvesting in some subareas and for which relatively few biological data from the fishery are currently available.

5.135 Papers WG-EMM-95/28 and 29 include the first full quantitative data on the composition (by numbers and biomass) of the fish diet of Antarctic fur seals. In breeding females in three consecutive summers at South Georgia the fish element of the diet was small and mainly comprised ice fish and notothenioids early in the pup-rearing season (December/January) and myctophids later on (February/March). In contrast, the winter diet of male fur seals in two consecutive years at South Georgia contained substantially more fish, mainly consisting of *Champsocephalus gunnari*. The size of the fur seal population and the estimated potential consumption of *C. gunnari* is such that this predation may have a significant influence on the dynamics of the South Georgia stock of *C. gunnari* - which is of considerable interest to CCAMLR as an extensively harvested resource.

5.136 The Working Group suggested that it was becoming increasingly important for CCAMLR to consider fish-based dependent species/harvested species interactions in its deliberations and to consider appropriate mechanisms for coordinating studies and evaluating results.

ENVIRONMENT

General Environmental Analyses

6.1 A number of papers reported on directed studies aimed at understanding particular physical environmental processes or characterising variability.

6.2 Paper WG-EMM-95/16 considered water mass distributions in the Elephant Island area utilising a Conductivity Temperature and Depth probe (CTD) survey. The frontal variability of the

[12] Jouventin, P., D. Capdeville, F. Cuenot-Chaillet and C. Boiteau. 1994. Exploitation of pelagic resources by a non-flying seabird: satellite tracking of the king penguin throughout the breeding cycle. *Marine Ecology Progress Series*, 106: 11-19.

region was highlighted and the Working Group recommended the compilation and analysis of available historical data sets.

6.3 This point was further developed in WG-EMM-95/67 where historical data have been analysed to generate a regional description of the oceanographic regime in the Antarctic Peninsula area allowing consideration of the variability. The importance of Circumpolar Deep Water (CDW) in influencing the production systems of the area was emphasised.

6.4 The value of such a review of historical data was clear and the Working Group considered that the issues of access to such data and the facilitation of analyses should be reviewed.

6.5 Papers WG-EMM-95/61, 62 and 80 report on the analyses of long-term, large-scale climate and sea-ice data sets. These papers emphasise the strong links between the ice, ocean and atmospheric systems. They also highlight that there are important regional differences in the operation of the physical systems as well as strong inter-regional connections. Interannual variability was considered and possible trends or patterns examined. Understanding of the underlying physical processes involved remains incomplete.

6.6 The ecological importance of such variability was recognised and this theme was developed extensively in WG-EMM-95/62. The paper emphasises that the ice/ecosystem link was highly variable in the Antarctic Peninsula region and that the high interannual variability was not spatially consistent in the area.

6.7 One paper (WG-EMM-95/52) developed on aspects discussed at WS-Flux (SC-CAMLR-XIII, Annex 5, Appendix D) last year and reported on the development of a coupled physical-biological numerical model of the Southern Ocean ecosystem. The paper reported on a three-dimensional regional model of the King George Island/Livingston Island area.

Prey-based Analyses of Environmental Data

6.8 Papers WG-EMM-95/4, 19 and 49 reported on aspects of current flow influence on krill distribution, building on information obtained at WS-Flux last year.

6.9 General concepts of krill flux were discussed in WG-EMM-95/19 which emphasised the importance of krill biology when considering the generation of krill distributions using current systems. Paper WG-EMM-95/4 reported on a restricted-area study of short-term changes in the distribution of krill in relation to current flows.

6.10 Paper WG-EMM-95/49 reported on an extensive multidisciplinary study of environment and krill distribution. Aspects of current flows and krill flux were examined using drifting buoys tracked by the ARGOS satellite system. The data emphasised that the South Shetlands area was one of high retention. Transfer of buoys released from the South Shetland area across the Scotia Sea occurred although the tracks followed were highly variable. The time-scale for transfer to the South Georgia vicinity was of the order of 150 to 200 days.

6.11 The execution of a multidisciplinary cruise considering krill flux, reported in paper WG-EMM-95/50, used a wide range of environmental logging systems including CTD, Expendable Bathythermography (XBT), Acoustic Dopler Current Profile (ADCP) and Remotely Operated Vehicle (ROV).

6.12 A number of studies considered interannual variation in krill recruitment. Paper WG-EMM-95/15 used data on ice concentration, duration and other ice indices. Links to surface water temperatures were also considered.

6.13 The Working Group noted the value of such studies and, realising the long-term planning required in developing such studies, emphasised the continued need for such data as highlighted by WS-Flux.

6.14 The correlation between climate and krill recruitment was examined in WG-EMM-95/53. This paper investigated sea-level pressure data as an indication of atmospheric system behaviour. The effect on krill recruitment was considered to operate through links between the atmospheric-ice and ocean systems.

6.15 Krill recruitment and ice cover was also considered in WG-EMM-95/55 which used the extensive Japanese fishery data set for the South Shetland region and linked this to sea-ice extent.

6.16 Aspects of ice/ocean/recruitment relationships were analysed in WG-EMM-95/69 using data from the central Scotia Sea. This paper considered links between CPUE from the Russian fishery data and atmospheric, oceanographic (sea surface temperature (SST)) and sea-ice variables. Links between the physical variables were examined in detail.

6.17 Paper WG-EMM-95/58 reports on the results of a workshop on the temporal changes in the Antarctic Peninsula region. This brought together a range of extensive data sets on both biotic and abiotic components of the ecosystem. The recommendations of the workshop emphasise the importance of good oceanographic data for addressing the question of mesoscale distribution of prey. Data utilised included CTD, nutrient distributions and chlorophyll *a* concentrations. The importance of variability in water mass distributions was emphasised. One transect with five stations on 55°W was occupied six times from early December 1994 to late February 1995 north of Elephant Island. One of the important findings is the north-south movement of the oceanic frontal zone varying about 15 n miles, which might influence the krill flux and distribution. Nutrient depletion was found as the season progressed, probably associated with phytoplankton species succession.

6.18 Paper WG-EMM-95/18 reported on a specific study on the distribution and biological characteristics of krill in the Bellingshausen Sea. These data were discussed in relation to other ecosystem components.

6.19 Paper WG-EMM-95/54 reports on a multidisciplinary study which included analysis of salp and chlorophyll *a* distributions and concentrations in relation to water mass effects.

6.20 An investigation of spatial distributions of krill CPUE (WG-EMM-95/51) emphasised the importance of bathymetry.

6.21 A study from an area outside the CCAMLR region on euphausiid species in Japanese waters (WG-EMM-95/48) was reported. Distributions were linked to current system fluctuations and oceanographic regimes.

Integrated Ecosystem Analyses of Environmental Data

6.22 A number of papers reported on mesoscale studies of predator/prey interactions.

6.23 Paper WG-EMM-95/87 considered penguin foraging and included hydrographic observations. The need for bathymetric data was emphasised.

6.24 Paper WG-EMM-95/60 reported on the AMLR program and emphasises the multidisciplinary nature of the cruises. The paper highlights the effort required to carry out detailed ecosystem analyses of mesoscale variability.

6.25 A proposal for a fully integrated oceanographic/biological program was described in WG-EMM-95/43.

6.26 A number of papers discussed the interannual variability of various aspects of predator biology in relation to environmental variation.

6.27 The effect of environmental variation on pregnancy rates of fur seals in relation to time of year and food availability was discussed in WG-EMM-95/24.

6.28 Papers WG-EMM-95/28 and 29 considered the diet of fur seals and emphasised the potential importance of interannual variability in the pelagic system.

6.29 Paper WG-EMM-95/33 reported on penguin deaths in the vicinity of Mawson and emphasised the need for understanding environmental variation.

6.30 Links between penguin recruitment and environmental variation were examined in paper WG-EMM-95/63. Penguin recruitment was linked to ice-extent data and interannual variability in krill recruitment. Further aspects of this study were developed in WG-EMM-95/64 and 66.

6.31 Paper WG-EMM-95/31 reported on a meeting which considered large baleen whales in the Southern Ocean. Various ecosystem interactions were considered at the meeting and large-scale surveys suggested.

6.32 Paper WG-EMM-95/66 proposes a modelling study developing coupled biological-physical models of the krill/penguin/ice/ocean system as a method for developing understanding of ecosystem operation.

Data Reports

6.33 Papers WG-EMM-95/11 to 14 report the CEMP and other data sets compiled by the Secretariat. Physical data include a range of sea-ice indices for a range of locations.

Consideration of Future Environmental Data Requirements

6.34 Paper WG-EMM-95/20 highlights general aspects of environmental monitoring programs in the Antarctic and aspects of data management.

6.35 The Working Group emphasised that the studies considered here cover a wide range of topics and scales. It considered that carefully focused questions were required to clarify what types of environmental data and analyses were needed to meet the objectives of WG-EMM.

6.36 A proposal for the development of standard transects was discussed. It was noted that various nations were developing standard transects. The Working Group was also reminded that programs such as the World Ocean Circulation Experiment (WOCE) were already undertaking such studies. Links to such programs would need to be considered once the questions on environmental data were clarified.

6.37 The Working Group was reminded that an earlier meeting of WG-CEMP had generated a table identifying the environmental data requirements of that group (SC-CAMLR-V, Annex 6, Table 6). The Working Group recognised that many of the subjects shown in the table had undergone important developments since 1986 and noted that a more detailed scheme had been proposed by Dr Fedoulov.

6.38 A general table was produced which incorporated the information in SC-CAMLR-V, Annex 6, Table 6 and Dr Fedoulov's suggestion (Table 5). It shows some of the measurable variables and methods for the study of oceanic, ice, atmospheric and terrestrial features at different scales. The table can be used to identify the variables and methods available.

6.39 The Working Group recognised that the items set out in Table 5 require elaboration, particularly in respect of defining the spatial and temporal scales over which the various environmental processes operate. Dr S. Kim (Republic of Korea) noted in particular that no clear distinction is made between the physical and biotic components of the environment. For example, a detailed breakdown of the ocean processes affecting prey, such as primary productivity, might be considered for inclusion in the table.

Sea-ice

6.40 The Working Group noted that CCAMLR has long recognised the importance of seasonal sea-ice dynamics in the Antarctic marine ecosystem. In particular, information has been sought on the physical and biological properties of sea-ice as these affect key ecosystem components at different times and in different areas.

6.41 Papers tabled at the meeting reported on recent developments in studies aimed at understanding the effects of sea-ice on various biota and the differential responses of such biota to ice dynamics. In this connection, it was recognised that the effects of sea-ice depend on both its character and extent and the rate at which these change through time.

6.42 Developments of particular significance identified by WG-EMM include linkage of sea-ice conditions to krill recruitment (WG-EMM-95/15, 18 and 55), spatial and temporal variability in sea-ice as a function of long-term seasonal climatic changes (WG-EMM-95/61, 62 and 80) and possible effects of sea-ice on predator population dynamics and diet (WG-EMM-95/63 and 64).

6.43 It was noted that the Antarctic Peninsula region is one which shows very large interannual variability and that there has been a strong cyclical signal over some decades. The region also shows an annual cycle characterised by a five-month advance and a seven-month retreat of pack-ice which is the opposite of other regions (WG-EMM-95/52).

6.44 The Working Group agreed that a clear distinction needs to be made between the direct effects and indirect effects arising from variability in sea-ice extent, character and dynamics. Such effects are summarised in the last column of Table 5.

6.45 For example, sea-ice impacts predators directly via habitat availability and indirectly via prey availability.

6.46 For prey, sea-ice affects the over-winter survival of larval krill and affects adult maturation and growth rates. Ice may also provide a refuge for krill as well as a site for seeding the water column with food in early summer.

6.47 In the case of the fishery, the presence of ice directly affects fishing operations with consequent effects on krill and its dependent species.

6.48 The Working Group agreed that in order to facilitate formulation of specific hypotheses on the potential effects of sea-ice on components of the Antarctic marine ecosystem in key areas and to identify the data necessary to test such hypotheses, a small task group should work by correspondence during the forthcoming intersessional period.

6.49 The task group, convened by Dr Miller and consisting of Drs Agnew, Croxall, Holt, Naganobu, Siegel and Trivelpiece, will:

- summarise previous discussions and data requests by CCAMLR on sea-ice and related matters. To a large extent this task will be carried out by the Secretariat;

- identify key hypotheses and areas of research aimed at improving current understanding of the physical and ecological effects of sea-ice in the Antarctic marine ecosystem;

- liaise with other programs focused on sea-ice studies (e.g., EASIZ of SCAR), the cataloguing of currently available data and identification of future data requirements;

- identify key sea-ice properties and processes, including the data necessary to characterise the variability and seasonability of such properties and processes; and

- report to WG-EMM's next meeting on the above.

6.50 The Working Group was reminded of the importance of other oceanographic and atmospheric variables and possible inter-relationships. The Working Group noted that care must be taken in the interpretation of short time-series and in investigating correlations with other variables. The need for carefully focused questions was again emphasised.

ECOSYSTEM ASSESSMENT

By-catch of Fish in the Krill Fishery

7.1 Two papers reported on the by-catch of fish in the krill fishery. One (WG-EMM-95/56) assessed the by-catch in the Japanese krill fishery off the South Shetland Islands (Subarea 48.1) from 30 January to 18 February 1995, the other (SC-CAMLR-XIV/BG/10) the occurrence of fish in commercial krill catches taken by a Japanese trawler off Wilkes Land (Division 58.4.1) from 19 January to 2 March 1995.

7.2 A detailed examination of these papers was prepared for submission to the Working Group on Fish Stock Assessment (WG-FSA).

7.3 The Working Group welcomed the two investigations and encouraged continuation of such studies. However, it noted that the two studies provided only limited information on spatial, seasonal and diurnal differences in fish by-catch. The data were not presented in the standardised manner (i.e., in numbers/weight per tonne/hour) which makes possible comparison between studies, as requested during previous meetings (e.g., SC-CAMLR-XII, Annex 5, paragraphs 7.1 to 7.5; SC-CAMLR-XIII, Annex 4, paragraphs 5.6 and 5.10) and in the *Scientific Observers Manual*. Dr S. Kawaguchi (Japan) informed the Working Group that there is evidence from the study presented in WG-EMM-95/56 that the level of by-catch of mesopelagic fish is higher during the night. The possibility that WG-FSA could provide additional information on periods and areas at which early life stages of fish are at risk from the krill fishery was considered to be remote at present, given the limited information on patterns of spatial, seasonal and diurnal distribution and abundance of larval and juvenile fish.

7.4 The Working Group reiterated requests from previous years by the Scientific Committee and its Working Groups and encouraged Members to conduct more extensive studies on this matter to cover spatial, seasonal and diurnal differences in the occurrence of fish in krill catches to assess when fish are most vulnerable to the krill fishery. It also stated that appropriate statistical procedures be applied to the analysis of such data. Results should be presented in a standardised manner as agreed by the Scientific Committee to facilitate assessment by the Working Groups.

Interactions Amongst Harvested Species, Dependent Species and the Environment

7.5 When reviewing new tabled information on interactions between harvested species and dependent species, and between both of these and the environment, it was clear to the Working Group that the three were inextricably linked. Accordingly, discussions on Agenda Subitems 7(ii) and 7(iv) were combined. The relevant material is in Sections 4, 5 and 6 of this report. To avoid excessive duplication, only a brief summary is given of material already described in those sections, along with appropriate references.

7.6 An initial review of the available material indicated that there was new information available to this meeting on a number of interactions. Discussion on these is grouped under corresponding headings.

Links Between Sea-ice, Krill Abundance and Penguin Breeding Success and Abundance (see paragraphs 5.78, 5.85, 5.119 and 5.120)

7.7 Papers WG-EMM-95/62, 63 and 64 presented analyses that suggested that the reduction in the frequency of winters with extensive pack-ice has resulted in a decrease in krill recruitment and thus biomass in the region. This, in turn, has led to changes in the survival, recruitment and population size of Adélie penguins. All penguin data in the Antarctic Peninsula region indicate that there was better breeding success but decreased breeding population size in the 1994/95 season compared with the 1993/94 season.

7.8 In relation to the latter point, Mr Ichii commented that it was more likely that breeding success was directly related to krill availability at breeding time than was breeding population size. Dr Croxall agreed, stating that breeding population size was likely to integrate krill availability over winter and, in terms of penguin recruitment, probably over several years.

7.9 The Working Group agreed that this work was of particular significance, and it recalled its recommendation (paragraph 5.120) that appropriate additional time series of krill length frequencies from predator stomachs be analysed, along with other relevant demographic data from penguins. On the basis of this work, it should be possible to both make and test predictions based on the hypotheses proposed for environment/harvested species/dependent species interactions.

Penguin Chick Starvation at Béchervaise Island
Linked to Local Food Shortage
(see paragraphs 5.79 and 5.80)

7.10 At Béchervaise Island and surrounding islands, all penguin chicks had died soon after hatching, with evidence suggesting that starvation was the principal cause (see WG-EMM-95/33). Longer foraging trips were also recorded, with birds returning with little or no food. The extent of food scarcity appeared to be limited, since birds at colonies between 50 and 150 km to the west appeared not to be affected.

7.11 It was noted that this major apparent interaction between krill availability and fledgling survival occurred despite there having been no krill fishing in the region over the last five years. That there can be such extreme variations in local krill availability and subsequent effects on dependent species in the absence of fishing has important implications for the interpretation of any apparent effects in areas where there has been fishing activity.

Krill Flux and Other Determinants of Local Krill Abundance
(see paragraphs 4.24 and 4.25)

7.12 Paper WG-EMM-95/58 presented evidence demonstrating the importance of frontal zones to the krill flux process in the coastal areas to the north of Elephant Island. Oceanic currents seem also to be implicated in the transport of krill from the South Shetlands to the South Orkneys and South Georgia.

7.13 Dr Trivelpiece noted that comparisons of krill length frequency distributions in penguin diet samples from Palmer Station (Bellingshausen Sea) and Admiralty Bay (South Shetland Islands) indicated the krill populations of these two regions had different age structures within years (WG-EMM-95/64). The comparisons suggest only slow interchange between the Bellingshausen Sea and the South Shetland Island krill populations. Dr Everson noted that the movement of krill is not necessarily directly along the Antarctic Peninsula; there may be some areas within which they are retained. These differences were linked to a one-year time lag in pack-ice cycles between the areas.

7.14 Dr Naganobu queried whether DNA analyses might be used to determine whether krill concentrations in different areas came from the same stocks. Several members commented that in other bodies (e.g., the IWC), considerable progress had been made in studying stock structure and migration using these techniques.

7.15 Dr Nicol commented that DNA techniques had been tried previously with krill, but DNA samples proved very difficult to extract. Given the rapid advances in this field, he agreed that it may be worthwhile trying again.

Patterns of Breeding Success and Breeding Population Size at Bird Island and Signy Island Linked to Krill and Different Environmental Factors (see paragraphs 4.28, 5.81 and 5.82)

7.16 The 1994/95 season at Bird Island appeared to be one of normal krill availability, corresponding to indices of good reproductive success in gentoo and macaroni penguins and Antarctic fur seals. This contrasts with the 1993/94 season, characterised by very poor krill availability and corresponding reproductive success. The reduced breeding population size of gentoo penguins and Antarctic fur seals at Bird Island in 1994/95 was attributed to events connected with the low reproductive success in 1993/94. Similar, but less pronounced, patterns have been observed at Signy Island, but this might also involve a more direct effect of variation in prey availability influenced by sea-ice conditions in the Antarctic Peninsula region (i.e., a stronger sea-ice-prey link than at Bird Island).

7.17 The hypotheses suggested for Signy and Bird Islands are very important for three reasons. They suggest (i) that the effects on predators can carry over from one year to the next; (ii) that at different sites there can be different functional relationships; (iii) that there can be time lags in the prey response to the environment. All three of these points suggest that interactions between the environment, harvested and dependent species can be very complex, and can occur with different time lags.

7.18 It was noted that there was additional evidence, arising from the low proportion of krill in the diet of icefish, that the 1993/94 season at South Georgia was a very poor one (Kock et al., 1994[13]).

7.19 One difficulty in interpreting the linkage between breeding success, breeding population size and krill availability was that the latest season for which predator data are available and that for which estimates of krill abundance are available are different. This is a problem for a number of subareas.

Low Albatross Breeding Population Size Linked to Snowfall (see paragraph 5.83)

7.20 The numbers of black-browed albatross breeding at South Georgia in 1994/95 was reduced due to a late and heavy snowfall preventing nesting.

7.21 Several members commented that this provided a striking example of a strong environment/dependent species link having a major effect on a dependent species in an area where fishing was taking place. Had for some reason the environmental event not been noticed, the reduced population size could well have been attributed, at least in part, to fishing.

7.22 Dr de la Mare commented that several of the examples of linkages described above emphasise the high degree of variability intrinsic in the system, even in the absence of fishing, and especially at the local scale. The examples also highlighted the potential complexity of the various interactions and the probable presence of time lags in responses. This highlights the need, where possible, to be able to calculate predator-based indices so that they really do reflect the effects of changes in the abundance and availability of krill.

New Models Relevant to Harvested Species/Dependent Species Interactions (see paragraphs 5.104 to 5.118)

7.23 Three papers were presented that developed new models relevant to the interactions between dependent species and harvested species. Paper WG-EMM-95/39 modelled functional relationships between krill and black-browed albatrosses and Antarctic fur seals. Paper WG-EMM-

[13] Kock, K.-H., I. Everson, L. Allcock, G. Parkes, U. Harm, C. Goss, H. Daly, Z. Cielniaszek and J. Szlakowski. 1994. The diet composition and feeding intensity of mackerel icefish (*Champsocephalus gunnari*) at South Georgia in January/February 1994. Document *WG-FSA-94/15*. CCAMLR, Hobart, Australia.

95/42 undertook a similar task for Adélie penguins, while WG-EMM-95/40 addressed the issue of age-dependent mortality in krill by analysing krill length frequencies from predator stomach samples.

7.24 The principles of, and requirements for further work on, the models developed in these papers were discussed in detail under Agenda Subitem 5(v) (paragraphs 5.87 to 5.126) and no further comment will be given here.

Krill Fishery/Dependent Species Interactions

7.25 The Data Manager has provided further data on the overlap between the location of krill fishing and predator CPD. These are given in WG-EMM-95/41. The CPD is taken to be a distance of 100 km from the breeding site over the principal breeding period December to March. These results are discussed under paragraphs 5.88 to 5.91.

7.26 It was recognised that the CPD would be species-dependent, and several members commented that it may be useful to review this matter (paragraph 7.96). Even ignoring species-dependent effects, differing views were expressed as to whether application of the concept of CPD under- or overestimates the extent of overlap between predators and krill fishing (see also paragraphs 5.92 to 5.94).

7.27 In any case, there remains a major problem in that the relationship between overall krill abundance within the CPD and the actual krill availability to predators in that region is complex. There are still few data on this. It is very important that more empirical studies are undertaken.

7.28 Research has continued on assessing the potential overlap between predators and the fishery in the vicinity of Seal Island (WG-EMM-95/87). It was found that krill were in higher densities over the shelf areas than in offshore areas, where acoustic surveys showed that fish (mainly myctophids) were at high density and available at night within predator foraging ranges. See paragraphs 5.98 and 5.99 for further discussion.

7.29 Mr Ichii commented that the results of this research called into question the standard assumption that there is a tight relationship between krill and predators. It may well be that predators will switch prey species from krill to myctophids when the density of krill is low. If so, then low krill abundance does not necessarily lead to deleterious effects on predators.

7.30 Dr Croxall responded by noting that this assumption is based on many years of dietary data. Furthermore:

(i) paper WG-EMM-95/87 contains no data on diets of predators, so consumption of myctophids, let alone prey-switching, is purely inferential;

(ii) the extensive series of published and CEMP data on the diet of chinstrap penguins in Subareas 48.1 and 48.2 have never recorded myctophids at more than 10% by mass of diet;

(iii) changes in predator diet in years of low krill availability are, however, documented to occur in some predators at South Georgia (gentoo penguins take more icefish and *Notothenia* species, macaroni penguins more *Themisto*) but not in others (e.g., Antarctic fur seal, black-browed albatross). None of the prey-switching of these krill-dependent predator species involves myctophids - and this in a subarea where most myctophid fishing in the Convention Area has taken place; and

(iv) more work on predator diet in Subareas 48.1 and 48.2 is to be encouraged because substantial time series of quantitative data are needed to demonstrate the extent to which predators depend on krill.

7.31 In response to a question concerning acoustic discrimination of fish and krill targets, the importance of using multifrequency acoustic methods was emphasised. While it is possible to reliably distinguish krill and myctophid targets during the day (when they are well separated in their depth ranges), this becomes difficult at night even using such techniques.

7.32 Paper WG-EMM-95/23 reports studies of the variability of the spatial structure of krill swarms using data from foraging time budgets of fur seals (see also paragraphs 5.121 and 5.122). The main assumption in this work is that the predator foraging behaviour reflects the spatial structure of the prey. The results suggest that seals forage at the scale of individual krill swarms and also at the scale of groups of swarms (aggregations). The methods in WG-EMM-95/23 may be useful for studying and interpreting functional relationships between predators and krill, and between krill abundance and availability to predators.

7.33 Dr Miller agreed that this study had important implications for how spatial information might be used to obtain a proper index of availability, and for the scale at which predator/prey studies should be conducted in the field.

7.34 Mr Ichii observed that the paper seemed to make the assumption that the principal prey species was krill, even in a poor krill year, and he referred to information from Seal Island reported in WG-EMM-95/87. In response, Dr Boyd commented that at South Georgia, concurrent diet studies had been undertaken and these had shown that the principal species in the diet was indeed krill, even in the poor krill year, as reported in WG-EMM-95/28. This emphasised, in his view, how essential it was to undertake simultaneous studies of diet and at-sea feeding ecology and behaviour.

Approaches to Integration of Harvested Species/Dependent Species/Environment Interactions into Management Advice

7.35 This subitem was discussed under three main headings: strategic modelling; accounting for land-based predators when setting precautionary catch limits; and ecosystem assessment.

Strategic Modelling

7.36 Figure 1 gives a schematic diagram of the components and linkages that together make up the processes involved in ecosystem monitoring and management in the Antarctic. The primary components of the exploited ecosystem are the environment, harvested species, dependent species and the fisheries. The system as a whole is completed by a link between these components and management approaches. The ecosystem assessment is conducted using information on the non-management components and linkages between them.

7.37 As indicated in Section 2, a vital tool in evaluating the procedures involved in an ecosystem assessment and in any system of providing management advice is strategic modelling. The strategic model incorporates the biological and fishery components, the links between them, and the procedures for ecosystem assessment and for the provision of management advice and the resulting management actions.

7.38 The term ‘strategic’ in the phrase ‘strategic modelling’ has been used to describe a number of different things. For the purposes of this report, strategic modelling is distinguished by:

(i) explicit consideration of uncertainties in (a) parameter values and (b) the underlying dynamic processes operating in both the components of the system being modelled and the linkages between them; and

(ii) its primary purpose, which is to allow evaluation of the efficacy of the principal output (management advice) from the procedure being studied (here, ecosystem assessment or ecosystem management). This evaluation should enable identification of the uncertainties in the system that contribute most to inadequate performance in the output, thereby identifying requirements for information which will lead to the greatest improvement in performance.

7.39 In the papers that have so far been presented to the Working Group and its predecessors, no strategic model of the overall system has been attempted. Most progress has been made in a model of a subsystem that links the fishery, the harvested species (krill) and management. This is the so-called krill yield model (Butterworth et al., 1994[14]). Previously this model has mainly been discussed by WG-Krill. As this Working Group has merged the former WG-CEMP and WG-Krill, it was felt useful for an initial presentation to be made by Prof. Butterworth of the principles behind the extensions to the krill yield model designed to allow estimation of functional relationships between harvested and dependent species. These were described in papers WG-EMM-95/39 and 40 by Thomson and Butterworth (see also Butterworth and Thomson, 1995[15]).

7.40 The presentation and subsequent discussion led to a much greater understanding within the Working Group of the models, their assumptions and their properties. A number of important points emerged.

(i) The models have several key assumptions. These are:

(a) the probability distribution of unexploited krill abundance is time invariant. This does not mean that the unexploited krill abundance is constant over time; rather that the annual krill abundances are sampled from the same probability distribution; and

(b) changing krill abundance affects predator fecundity and survival, but not vice versa.

(ii) A clear distinction has to be made between the density of the krill available within the foraging range of a predator and the extent to which it is actually available to the

[14] Butterworth, D.S., G.R. Gluckman, R.B. Thomson, S. Chalis, K. Hiramatsu and D.J. Agnew. 1994. Further computations of the consequences of setting the annual krill catch limit to a fixed fraction of the estimate of krill biomass from a survey. *CCAMLR Science*, Vol. 1: 81-106.

[15] Butterworth, D.S. and R.B. Thomson. 1995. Possible effects of different levels of krill fishing on predators - some initial modelling attempts. *CCAMLR Science*, Vol. 2: (in press).

predator for consumption. This can vary widely between dependent species, sites and seasons.

(iii) As described more fully in paragraphs 4.39 to 4.57, provided the assumption in subparagraph (i)(a) above is satisfied, the models take full account of the known extent of variability in krill recruitment by explicitly using existing krill recruitment estimates. Currently, the link between the environment and krill recruitment is modelled using an empirical probability distribution. Should an explanatory relationship for krill recruitment be established subsequently, e.g. using sea-ice data, this could be incorporated.

(iv) A potential weakness in the models is that, while they operate properly at a regional or krill stock-unit scale, of necessity some of the input data (time series of predator survival and recruitment indices) were estimated on a much more localised spatial scale. This is a potential weakness, since use of small (local) spatial scale data in a regional scale model involves some degree of extrapolation.

(v) One apparently simple way around this is to apply the models uniformly at a local spatial scale. Unfortunately, while doing so apparently resolves the scale problem with the recruitment or predator survival estimates, it introduces probably greater problems because of lack of closure of the krill population and difficulties in properly defining local krill recruitment.

7.41 Several issues arose in the discussion. These were that: (i) the current model of functional relationships between krill harvest and predator response uses only a small part of the predator data which are currently available; (ii) it would be useful to examine the importance of additional precision in several of the input parameters to ensure that attention is given to increasing the precision of measurements that will have the greatest influence on the results of the modelling exercise; and (iii) the scale at which the current model of functional relationships operates is often different to the scale at which predator data are collected.

7.42 Dr Boyd commented that there was an alternative approach, which used foraging and energetics models to treat harvested/dependent species interactions on a purely local scale. He also noted that of all the biological parameters for predators, adult survival rate is one of the most difficult to obtain. This is an important input parameter in the Butterworth-Thomson model. It may be possible to use other predator data, much more widely available than direct estimates of survival rates, in the local scale models being investigated.

7.43 Prof. Butterworth commented that it was possible to use other measures to index predator recruitment and survival rates, but it was necessary to take care to justify the assumed relationships between the indices and the actual rates.

7.44 Dr Boyd further explained that the modelling approach at the local scale should be seen as an alternative to, and not a potential replacement for, the Butterworth-Thomson models. Indeed, there were potential links between the two approaches, since the results from the local models could provide valuable insight and information on the recruitment estimates used in the Butterworth-Thomson model, as well improving knowledge about krill availability.

7.45 The Working Group then attempted to develop further the conceptual framework of the processes contained in Figure 1, and to identify those components and linkages for which models were either currently available or being developed. These are shown in Figures 3 and 4. In view of the importance attached to the scale on which the models operated, separate figures are shown for the models at local and regional scales.

7.46 Figure 3 shows a framework of system processes within which the Working Group discussed the development of a strategic model. Each link in the figure is associated with text describing the type of link. The Working Group emphasised the difference between the two important environment/system links. In the first, the direct effects of environment on the dependent species were of interest, for instance the presence of snow delaying the onset of egg laying, mortality of chicks in very high winds, or the inability of predators to forage because of problems of access to open water. The other environment link, to harvested species, primarily acts by influencing the recruitment of prey or the distribution and availability of prey.

7.47 Figure 4 shows the models that are available for describing certain components and links. For the environmental component there are a number of models (for instance the calculation of geostrophic current velocities and the FRAM model) that have been developed outside CCAMLR. The krill CPUE model (Butterworth, 1988[16]; Mangel, 1988[17]), the krill yield model (Butterworth et al., 1994[18]), the krill recruitment model (de la Mare, 1994[19]), the functional relationships model (Butterworth and Thomson, 1995[20]), the krill spatial model (Mangel et al., 1994[21]) and the fishery

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16 Butterworth, D.S. 1988. Some aspects of the relation between Antarctic krill abundance and CPUE measures in the Japanese krill fishery. In: *Selected Scientific Papers, 1988 (SC-CAMLR-SSP/5)*, Part I. CCAMLR, Hobart, Australia: 109-125.

17 Mangel, M. 1988. Analysis and modelling of the Soviet Southern Ocean krill fleet. In: *Selected Scientific Papers, 1988 (SC-CAMLR-SSP/5)*, Part I. CCAMLR, Hobart, Australia: 127-235.

18 Butterworth, D.S. et al., op. cit., p. 173.

19 de la Mare, W.K. 1994. Modelling krill recruitment. *CCAMLR Science*, Vol. 1: 49-54.

20 Butterworth, D.S. and R.B. Thomson, op. cit., p. 174.

behaviour model (Agnew and Marín, 1994[22]; Agnew, 1994[23]) have all been developed within CCAMLR and address a number of components and links. Further dependent species models are also appropriate, for instance the model of dependent species energetics (Croxall et al., 1985[24]) which was developed further for CCAMLR in 1991 (Croxall, 1991[25]) and the crabeater seal energetics model (Bengtson et al., 1992[26]). Although there are many different scales on which this exercise could be done, the figure is separated into local (within a subarea) and regional (statistical area based) spatial scales, and areas where additional work is required are highlighted.

7.48 In constructing Figure 3 the Working Group paid particular attention to the weights of the arrows (links) between components. It was felt that at both scales, the influence of environment on the fishery and of the fishery on dependent species was low. It was agreed that the influence of the fishery on harvested species was potentially large, while the influence of harvested species on dependent species was large by definition. It was felt that while the availability of harvested species, for instance, had some effect on the fishery, this was not a link of sufficient concern to be given a heavy arrow.

7.49 Because this exercise was done to highlight the strategic modelling, one important link is missing in these diagrams, that between the fishery and management (see Figure 1). It was noted that a model of primary importance to this link is the krill yield model. In Figure 4 this model is represented at the regional level as two components, 'yield model' and 'catch model'. It was recognised that separation of effects into the two scales was not always possible, as for instance where local dependent species dynamics affected the regional populations of those species.

7.50 It is obvious from Figures 3 and 4 that there are components and linkages between them for which no models currently exist. For some linkages, as indicated by the thin lines, this probably is not too much of a problem. However, there are other linkages that are definitely important that have so far received little or no modelling attention.

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21 Mangel, M., A. Stansfield and S. Rumsey. 1994. Progress report on AMLR project 'A modelling study of the population biology of krill, seabirds and marine mammals in the Southern Ocean'. Document *WG-CEMP-94/30*. CCAMLR, Hobart, Australia.

22 Agnew, D.J. and V.H. Marín. 1994. Preliminary model of krill fishery behaviour in Subarea 48.1. *CCAMLR Science*, Vol. 1: 71-79.

23 Agnew, D.J. 1994. Further development of a krill fishery simulation model. Document *WG-Joint-94/4*. CCAMLR, Hobart, Australia.

24 Croxall, J.P., P.A. Prince and C. Ricketts. 1985. Relationships between prey life-cycles and the extent, nature and timing of seal and seabird predation in the Scotia Sea. In: Siegfried, W.R., P.R. Condy and R.M. Laws (Eds). *Antarctic Nutrient Cycles and Food Webs*. Springer-Verlag, Berlin Heidelberg: 516-533.

25 Croxall, J.P. 1991. Estimates of prey requirements for krill predators. Document *WG-CEMP-91/37*. CCAMLR, Hobart, Australia.

26 Bengtson, J.L., T.J. Härkönen and P. Boveng. 1992. Preliminary assessment of the data available for estimating the krill requirements of crabeater seals. Document *WG-CEMP-92/25*. CCAMLR, Hobart, Australia.

7.51 A brief discussion on these aspects was initiated and several useful suggestions were made as to how these gaps might be filled, both in terms of models and of the data required to parametrise them.

7.52 For the regional scale models, Dr Miller noted that there was no model of the fishery component. Given that our primary influence on the system was via the fishery, he believed it important that we learn more about what motivates the behaviour of the fishery. At the very least, this implies that we should maintain the current dialogue with the operators of the fishery on their future intentions.

7.53 Following on from this point, it was emphasised that from the point of view of potential management measures, these can apply only to the fishery operations. Understanding the other components and linkages was essential to identifying the knock-on effects of management actions on the various components, but the appearance of these other components and links in the strategic model does not mean that they can be directly affected by management actions.

7.54 As noted in paragraphs 6.12 to 6.16 and 6.26 to 6.30, several papers were tabled at this meeting presenting evidence in support of a conceptual model linking sea-ice cover with local krill recruitment and subsequent impacts on predator populations. This research opens the possibility for the local-scale strategic models (and potentially also for regional strategic models) of developing explanatory sub-models for the link between the environment and harvested species. These sub-models would require the collection of time series of data on sea-ice cover, SST and krill recruitment. Data on the fine-scale distribution of fishing will also allow the link between the fishery and harvested species to be incorporated into these sub-models.

7.55 For local strategic models, other important factors in the linkage between the environment and harvested species are the forces that drive krill flux between areas and that cause variations in krill availability.

7.56 In relation to krill flux, key factors are water circulation, current systems and frontal zones. Collection of data on these is essential for further investigation of this phenomenon. Another oceanographic feature that may lead to retention of krill in a local area is the presence of eddy systems.

7.57 For local-scale models, more reliable evaluation of krill availability and the extent to which it varies over space and time will require further study of krill vertical migration and swarming behaviour and of predator foraging behaviour in relation to this highly aggregated and patchily distributed prey.

7.58 More generally, the linkage between the environment and harvested species requires the elucidation of the factors that determine the distribution and abundance of the prey. The linkage between the environment and dependent species requires the determination of those factors that affect observations on dependent species that may confound interpretation of interactions between dependent and harvested species (see, for example, paragraph 7.21).

7.59 For regional models, more realistic modelling of the dynamics of dependent species requires clarification of sources of density dependence and of the importance of species other than krill in the diets of the predators. For local models, interpretation of the local dynamics of dependent species is greatly enhanced by the availability of time series of local estimates of predator abundance.

7.60 It was observed that, at least conceptually, the regional models apply at roughly the scale of a statistical area, whereas many of the studies relevant to local models applied at the scale of the foraging area. It is possible, therefore, that there may be a need to develop strategic models that applied at a scale intermediate between the local and regional scale (e.g., at the subarea or Integrated Study Region (ISR) scale).

Taking Account of Land-based Predator Populations When Setting Precautionary Catch Limits

7.61 When introducing WG-EMM-95/17, Dr Everson drew attention to the fact that concerns have regularly been expressed about the potential impact of krill fishing on local predator populations over the last 20 years. Despite the considerable amount of research that has been carried out during that period, this has not yet resulted in management advice directed specifically at these concerns. The aim in WG-EMM-95/17 was to seek methods that would closely integrate the activities of the former WG-CEMP and WG-Krill groups and produce management advice designed to meet the aims of Article 2 of the Convention. The main concern was that, at present, a considerable proportion of any statistical area or subarea precautionary limit could, in principle, be taken in or near the foraging areas of dependent land-based predators during the breeding season.

7.62 As outlined in WG-EMM-95/17, land-based predators on South Georgia were estimated in 1987 to consume on average around 10 million tonnes of krill annually. This implies that at least that amount of krill must pass through South Georgian waters each year, though in practice there must be much more, since account needs also to be taken of the consumption by pelagic predators and of the need to maintain sufficient krill production to support the stock in subsequent seasons. The paper suggested that if a precautionary catch limit was set for an area around South Georgia corresponding to the foraging range of the predators at 10% of the estimated annual land-based predator consumption, then the aims of Article 2 would be met for these predators.

7.63 The factor of 10% was essentially an arbitrary figure representing only a small proportion of the predator food consumption. In WG-EMM-95/17, illustrative areas in which this precautionary catch limit might apply extended to around 125 km from the coastline. Additional limitations were proposed on the timing of catches throughout the year corresponding to the CPDs for the predators.

7.64 The methodology proposed for calculating local precautionary catch limits was illustrated for South Georgia, because all the required information on predator consumption was available for that island. However, the method could be used for other areas, provided the information required could be supplied or collected. It was also noted that further strategic modelling could lead in time to a more biologically realistic implementation of this approach.

7.65 The Working Group had an extended discussion of this paper. The main points that arose are described below.

7.66 Prof. Butterworth welcomed the intent of the paper, but commented that the appropriateness of the proposed 10% factor depended critically on the flux of krill through the waters of South Georgia. If the flux was low, then indeed fishing could cause local depletion and thereby affect predators. However, if the flux was high, then it was unlikely that land-based predators would be affected. He proceeded to illustrate, using results from a mathematical model (Appendix G), that the 10% factor could be too conservative if the flux were sufficiently high.

7.67 Dr de la Mare preferred that, where possible, the existing method based on a proportion of standing stock should be used, but there may be some circumstances where an approach of the kind given in WG-EMM-95/17 would be more practical. He subsequently proposed a modified method for using predator consumption data and estimates of krill flux that would allow an estimate of the instantaneous standing stock around South Georgia to be calculated. This could then be used as input to the existing krill yield model.

7.68 In relation to both these alternative approaches, Dr Boyd observed that predator food consumption was one of the variables that can be estimated with quite high precision. He noted, however, that existing data on krill densities suggested that the turnover of krill around South Georgia could be quite variable both within and between years and over space. It was important that this variability be taken into account in any calculations, rather than just using an average figure. Dr Trivelpiece also emphasised the need to take full account of the distribution and variability of krill recruitment.

7.69 Dr de la Mare commented that, provided the levels of variation in these variables can be quantified, as described in paragraph 4.48, they could be specifically accounted for using the approach of the krill yield model. He noted further, however, that research directed at obtaining the necessary information about levels and variability of krill flux could be very difficult, perhaps exceeding the difficulty of directly obtaining an estimate of the krill standing stock around South Georgia.

7.70 It was suggested that, in view of the krill flux between Subareas 48.1, 48.2 and 48.3, account needed to be taken of krill biomass and catches in Subareas 48.1 and 48.2 when determining precautionary limits for Subarea 48.3. In such circumstances, it may be necessary to apply a pro rata (percentage-based) system for the allocation of local precautionary limits amongst these areas.

7.71 Dr Naganobu thought that the method proposed in WG-EMM-95/17 had potential, but he foresaw problems in applying it as it presently stood. In particular, he queried the extent to which the method could be used in other areas, such as Subareas 48.1 and 48.2, which are characterised by heavy winter sea-ice and much lower predator populations than Subarea 48.3. He also queried how changes in predator populations that occurred for reasons other than fishing would be taken into account. For instance, if the predator populations (and thus consumption) at South Georgia halved or doubled in a year, would the corresponding precautionary limits halve or double respectively?

7.72 Mr Ichii raised the issue of whether predator populations were food- or breeding-site limited. If they were food-limited, then an approach based on food consumption may be appropriate, but if they were breeding-site limited, then the food consumption may not be relevant at all.

7.73 Dr Croxall responded that evaluations of most of the main krill-dependent predator species breeding at South Georgia had provided no evidence at present that populations were limited by availability of breeding habitat.

7.74 Mr Ichii suggested that a precautionary catch limit could be unrealistically low if it was based on food consumption by predators whose population sizes are limited by food abundance during the period when food abundance is very low.

7.75 Dr Croxall further commented that, given the difficulties experienced by CCAMLR in suggesting other kinds of precautionary measures in local areas (e.g., closed seasons, closed areas etc. in Subareas 48.1 and 48.2, see WG-EMM-95/17), it appears that the only remaining kind of measure available for use in these situations is a limitation on catches based, in some way, on the food requirements of predators.

7.76 With a view to putting the approach suggested in WG-EMM-95/17 in context with other approaches to determining precautionary limits, Dr Hewitt drew attention to the tradeoff matrix given in Watters and Hewitt, 1992[27]. This rated possible approaches by the likely delay in their implementation and the extent to which they used existing biological data. The ideal was an approach that had a low delay in implementation but made high use of the biological data. In that paper, no approach fitted that description. It is possible that the approach in WG-EMM-95/17 or a development of it may achieve that goal.

7.77 In summary, all members agreed that:

(i) there was a continuing need to ensure that krill catches are not concentrated in small areas and over short periods of time to such an extent that local populations of dependent species may be adversely affected;

(ii) when determining precautionary catch limits and subdividing precautionary limits set for larger areas, as much environmental and biological information as relevant should be used; and

(iii) the approach described in WG-EMM-95/17, which makes use of extensive predator food consumption data, represents a valuable new thrust towards achieving these goals.

7.78 In view of the points raised during the discussions, however, it was agreed that it would not be appropriate to attempt to develop recommendations for precautionary catch limits using this approach at this meeting.

7.79 The remaining discussion focused on identifying further work to be carried out intersessionally so that the topic could be discussed further at next year's meeting.

7.80 A small subgroup was asked to develop further the ideas described by Prof. Butterworth and Dr de la Mare, in order to identify more clearly the work needed to be done. The subgroup developed the plan of work given in Appendix H to investigate precautionary catch limits in time for the next meeting of the Working Group. A steering group consisting of Drs Agnew, Boyd, Prof. Butterworth, Drs Croxall, de la Mare, Everson, Holt and Naganobu and coordinated by Drs Boyd and Everson was appointed.

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[27] Watters, G. and R.P. Hewitt. 1992. Alternative methods for determining subarea or local area catch limits for krill in Statistical Area 48. In: *Selected Scientific Papers, 1992 (SC-CAMLR-SSP/9)*. CCAMLR, Hobart, Australia: 237-249.

Ecosystem Assessment

7.81 As indicated in paragraph 2.13 in this report, the Working Group has agreed that an ecosystem assessment consisted of two parts:

(i) an analysis of the status of key biotic components of the ecosystem; and

(ii) a prediction of the likely consequences of alternative management actions on the future status of these components.

7.82 In working towards this end, Section 4 of this report summarises the current knowledge on the status of the krill populations and the krill fishery. It also examines knowledge of the interactions between harvested and dependent species from the harvested species perspective.

7.83 Section 5 summarises knowledge on the status of dependent species, and on their interactions with harvested species from the dependent species perspective.

7.84 Section 6 examines current knowledge on interactions between dependent and harvested species and the environment.

7.85 This information on interactions (linkages) amongst harvested species and fisheries, dependent species and the environment was further integrated in the discussions on linkages reported in paragraphs 7.5 to 7.20.

7.86 The information in these four sections of the report formed the basis for discussions on an ecosystem assessment. The relevance of the information to the ecosystem components and links identified in Figure 1 is shown in Figure 2.

7.87 The Working Group first noted that Sections 4 and 5 provided substantial information on the current status of both harvested and dependent species and of linkages between them. As a starting point for further discussions, the Working Group then turned to the summary tables (Tables 3.1 to 3.10), which are similar to those previously used by WG-CEMP for dependent species only (see paragraph 2.18).

7.88 For dependent species, only the information in the solid boxes, which has been collected and analysed by the standard methods developed by WG-CEMP, is in the official CCAMLR database. For these parameters, additional quantitative information and analyses are reported in WG-EMM-95/12 to 14. The remaining information on dependent species has been extracted from tabled papers. These data are not in the CCAMLR database and while they have generally been collected using standard methods, it has not been possible to undertake similar analyses of the data in the source papers.

7.89 Shortage of available time at the meeting had prevented completion of the sections of Tables 3.1 to 3.10 dealing with data from the fishery and on environmental variables. A further difficulty facing the Working Group was the qualitative nature of the interpretation of trends. As noted above, while considerable progress has been made during the intersessional period in providing a quantitative assessment of the standard CEMP data, this has not been possible for the remaining data in the tables.

7.90 As a consequence, a number of members expressed the view that it remained very difficult to use the information in these tables to develop an ecosystem assessment. In particular, it was noted that qualitative indices are not necessarily accurate, and they can also disguise trends that would be apparent from quantitative data.

7.91 While acknowledging these points, Dr Hewitt felt that there were some interesting observations that could be made. Referring to the information in paragraphs 4.15 to 4.32, 5.81 to 5.83 and Tables 3.5 to 3.7, it was clear that 1994 was an unusual year at South Georgia, South Shetlands and the Antarctic Peninsula. The abundance of krill was very low in all three subareas in 1994. Predator responses to low krill availability were seen in all three areas, but these were more noticeable at South Georgia than in the Antarctic Peninsula. The reason for this is unknown, but one hypothesis was that it was because South Georgia was downstream of the other areas. In 1995, an estimate of krill abundance was only available for Elephant Island, where it was again low, but the predator breeding success was greater than in 1994.

7.92 In the context of the need, expressed in Part 2 of the description of an ecosystem assessment, to provide predictions of the consequences of alternative management actions (see paragraph 2.13), the Working Group agreed that the current absence of evidence that low krill abundances and subsequent effects on predators were due to krill fishing (i.e., the absence of 'Type I' error) was not alone sufficient to conclude that current levels of catches are not affecting dependent species. This is because the data available do not allow a test of sufficient power to detect such an effect (i.e., the possibility of 'Type II' errors needs to be considered). The Working Group took note of the importance of investigating which information had the greatest potential to enhance the power of tests for such effects, as an aid to the focus of future research.

7.93 Dr Croxall indicated that it was not possible to examine the full 17-year suite of submitted data for South Georgia at the WG-EMM meeting. These data suggest that the incidence of years of low krill availability to predators at South Georgia has been greater in the last decade than in the

1970s and early 1980s. There is no indication that this is due to the fishery, but in order for the fishery not to exacerbate the situation for krill-dependent predator species, there may be a need for the adoption of precautionary measures.

7.94 Discussion then turned to what needed to be done to improve the usefulness of the information in the tables and of their presentation, in terms of an ecosystem assessment.

7.95 The key requirement is to collate time series of quantitative data on both dependent and harvested species that are comparable across years and areas. This has now been done for the standard CEMP data on dependent species, but further re-analysis needs to be done of other data to ensure the necessary comparability.

7.96 The Working Group agreed that the following steps needed to be taken urgently:

(i) request holders of existing data that have been collected using standard protocols to submit time series of such data for inclusion on the CCAMLR database;

(ii) for any data submitted in the future, appropriate quantitative assessments should be undertaken, or where this is not possible, they should be assessed qualitatively in a consistent fashion;

(iii) for existing CEMP time series data, new tables should be produced, as advised by the ad hoc statistics subgroup;

(iv) development of new methods and standard approaches for examining linkages between dependent species, harvested species and the environment;

(v) further development of methods appropriate for conducting an ecosystem assessment; and

(vi) intersessional circulation of the existing table of spatio-temporal scales relevant to all existing parameters of dependent species monitored within CEMP for revision in time for the next meeting. This revision should also include specification of spatial and temporal scales appropriate for potential new monitoring parameters. This exercise may also contribute to possible revisions of CPDs.

7.97 It is essential that progress be made intersessionally on each of these topics, and discussed further at the next meeting on ecosystem assessment.

7.98 Two ad hoc intersessional subgroups already exist to address such issues: one on statistics and one on methods. The Working Group recommends that the membership, convenership and terms of reference of these two subgroups be reviewed. In particular, the Subgroup on Statistics should be expanded to include members with expertise in harvested species and the environment.

7.99 There is a clear need for a meeting of a reconstituted Subgroup on Statistics to meet intersessionally. For the Subgroup on Monitoring Methods, at the very least its intersessional work needs to be more formalised, and it may also be necessary for that subgroup to meet, rather than work by correspondence.

Consideration of Management Measures

7.100 There are currently two conservation measures which address harvesting for krill in the Convention Area: Conservation Measure 32/X which sets a precautionary catch limit of 1.5 million tonnes in Area 48 in any one season; and Conservation Measure 45/XI which sets a precautionary catch limit of 390 000 tonnes in Division 58.4.2 in any one season. Conservation Measure 46/XI, which allocated the 1.5 million tonnes to subareas within Area 48, lapsed at the end of the 1993/94 season and was not replaced.

7.101 At SC-CAMLR-XIII, there was some uncertainty surrounding the use of the 1981 FIBEX survey results as an estimate of B_0. In particular, SC-CAMLR-XIII paragraph 5.40 suggested that:

- the survey was old and therefore of no practical use; and
- that it was possible that it could have been taken in a year when the krill biomass was high.

The Working Group addressed these points in paragraphs 4.39 to 4.41, and concluded that they had no effect on the calculation of potential yield using the model developed by WG-Krill. The Working Group therefore re-affirmed the advice of WG-Krill in 1994, that the current best estimate of B_0 is 35.4 million tonnes for Area 48 and 3.9 million tonnes for Division 58.4.2.

7.102 At its meeting in 1994, the Scientific Committee had extensive discussions on the calculation of precautionary catch limit in Area 48. Two basic views were expressed. One was that a revised precautionary catch limit of 4.1 million tonnes, calculated by multiplying the most recent estimate of γ (0.116) by the unexploited biomass of 35.4 million tonnes estimated from the FIBEX survey should be applied. An alternative view was that there was no need to revise the overall precautionary limit of 1.5 million tonnes (SC-CAMLR-XIII, paragraphs 5.31 to 5.45). The Commission has urged the

Scientific Committee to continue work on providing estimates of potential yield for all areas (CCAMLR-XIII, paragraph 8.6).

7.103 The Working Group investigated a number of refinements to the calculation of a precautionary catch limit (paragraphs 4.42 to 4.47). Investigations of the effect of increased variance in the estimate of B_0 on the results of the yield model (paragraphs 4.48 to 4.56) confirmed that the appropriate value of γ (in the equation Yield = γ B_0) in the absence of any additional information was 0.116. This is identical to that calculated previously by WG-Krill (SC-CAMLR-XIII, paragraphs 5.27 to 5.30).

7.104 For Division 58.4.2, no further data are available which could refine this value of γ. The Working Group therefore advised that the current best estimate of a catch limit in Division 58.4.2 is 450 000 tonnes (B_0 of 3.9 million tonnes combined with a γ of 0.116).

7.105 Data on recruitment which could be used to refine the yield model are available for Area 48. The Working Group agreed that the analyses suggested in paragraphs 4.46 to 4.48, which would incorporate these data, should be performed prior to the next meeting of WG-EMM. This analysis is expected to refine the values used to calculate a precautionary catch limit for Area 48. Accordingly, advice on a precautionary catch limit in Area 48 was postponed until the next meeting of WG-EMM.

7.106 Concerning the subdivision of precautionary catch within Area 48, the Working Group could not offer any further advice until the results of analyses described in paragraphs 4.46 to 4.48 and 7.80 had been examined. The Working Group expected that this would be done at its next meeting.

Extension of the Scope of CEMP

7.107 Last year, in considering the topic of the desirability of expanding CEMP beyond its exclusive focus on the krill-based system (SC-CAMLR-XIII, paragraph 6.34) the Scientific Committee requested Working Groups to consider the topic of appropriate research and monitoring activities on selected predators of certain fish species (SC-CAMLR-XIII, paragraph 6.40).

7.108 *P. antarcticum* has been a CEMP selected species since the start of the program in 1985. However, no proposals for monitoring studies or methods have been brought forward, although several papers on this species as prey have been tabled.

7.109 WG-EMM noted that in these circumstances it seemed inappropriate to propose any coordinated directed research and/or related CEMP monitoring activities on this species.

7.110 However, it was noted that, as was the case last year (SC-CAMLR-XIII, paragraph 6.35(iii)), several Members have programs which include research on predators that regularly eat *P. antarcticum*. Australian research indicates that Adélie penguins breeding at Béchervaise Island (Division 58.4.2) feed on *P. antarcticum* in areas where small-scale commercial harvesting took place in the past. The main foraging range of Adélie penguins, however, is in areas where fishing is known to be difficult due to sea-ice or bottom topography.

7.111 In the Ross Sea, *P. antarcticum* is particularly important in the diet of seals and penguins and is therefore a key component in the local food web. The current enhanced CEMP-related research activity in that area suggests increased opportunities for research on *P. antarcticum* and its trophic interactions.

7.112 The Working Group therefore suggested that Members currently conducting research on *P. antarcticum* should consolidate and review information on this species and its interactions relevant to CEMP and WG-EMM and seek to coordinate this research where feasible. WG-FSA was asked to contribute to this process.

7.113 In reviewing other fish predator/prey interactions, the Working Group recollected information provided in previous years and took particular note of the earlier discussions, summarised in paragraphs 5.127 to 5.135.

7.114 The interactions between Antarctic fur seals and *C. gunnari* at South Georgia (Subarea 48.3) were obviously of substantial potential significance to the management of the *C. gunnari* fishery. The attention of WG-FSA was drawn to the new data now available from predators relevant to this topic and to the importance of the cooperative evaluation of these data by predator and fish biologists.

7.115 Quantitative research on the role of blue-eyed shags as consumers of coastal fish species in Subareas 48.1 and 48.2 had shown that (i) shags consume juveniles of a range of previously-harvested fish species, and (ii) the relative abundance of fish species in shag diets and in net samples is similar. Interactions between shags and certain fish species are thus likely to be of interest to WG-FSA; WG-EMM felt that WG-FSA should consider the proposal for using shags to monitor coastal fish populations (WG-EMM-95/84).

7.116 Research within the Convention Area on predator/prey interactions involving myctophids has increased substantially in recent years. Studies, often conducted year round, of the diet and feeding ecology of king penguins by Sweden at South Georgia (Subarea 48.3), South Africa at Marion

Island (Subarea 58.7), France at Crozet Islands (Subarea 58.6) and Australia at Heard (Division 58.5.2) and Macquarie Islands (adjacent to the Convention Area) have all shown that this species (whose populations are increasing at almost all breeding sites) depends on myctophids (>90% by mass of diet in summer and rarely less than 75% by mass in any winter month). The attention of WG-FSA was drawn to the considerable potential for using coordinated research on diet and feeding ecology of king penguins to monitor the relative abundance of myctophid species and overall changes in myctophid populations.

7.117 Other predators known to consume significant quantities of myctophids include black-browed albatrosses (unpublished UK data) and white-chinned petrels (WG-CEMP-94/14) at South Georgia. Antarctic fur seals at South Georgia also take small quantities of myctophids in February/March (WG-EMM-95/28). Quantitative data on the consumption of myctophids by predators outside Subarea 48.3 are very scarce. There are suggestions, however, that myctophids could sometimes be important in trophic interactions in Subarea 48.1 (WG-EMM-95/87) and further research is encouraged.

7.118 Overall, WG-EMM recommended that the Scientific Committee should discuss interactions between fish and their predators, and especially those between predators and harvestable species, in a more formal way and should consider appropriate mechanisms for coordinating and evaluating research. Links between WG-FSA and scientists working on these predator/prey interactions should be strengthened.

ADVICE TO THE SCIENTIFIC COMMITTEE

Management Advice

8.1 The Working Group recommended that the precautionary catch limit on krill for Division 58.4.2, currently set at 390 000 tonnes in Conservation Measure 45/XI, should be increased to 450 000 tonnes (paragraph 7.104).

8.2 The Working Group could not offer further advice on a precautionary limit in Area 48, or appropriate subdivision within Area 48 in response to the request from CCAMLR-XIII, paragraph 8.6, but anticipated that it would be able to do so at its next meeting following additional analyses.

General Advice with Budgetary/Organisational Implications

Cooperation with Other Groups

- An effective mechanism for consideration of interactions between fish and their predators should be devised (paragraph 7.118).

- CCAMLR should consider co-sponsoring a symposium on krill biology on receipt of a request and proposal from the organising committee (paragraphs 9.4 and 9.5).

- A CCAMLR representative should be nominated to the IWC Workshop on Effects of Climatic Change on Cetaceans (paragraph 9.15).

- CCAMLR should nominate an observer to the SCAR-COMNAP group (paragraph 9.19).

- CCAMLR should nominate an observer to the krill fisheries workshop (Vancouver, Canada, 1995) (paragraph 9.20).

Publications

- Several modifications should be made to the *Scientific Observers Manual* (paragraph 3.15).

- Revisions to the *CEMP Standard Methods* should be distributed (paragraph 5.14).

- A high-quality booklet explaining, in non-specialised language, the ecosystem approach and assessment methods developed by the Working Group, should be considered (paragraph 9.10).

- The work of WG-EMM should be reported to the wider scientific community in a WG-EMM newsletter which would be written by the Convener.

Meetings

- The workshop on proposals for indices to monitor at-sea behaviour, which was to have been held in 1996, should be postponed until 1997. Dr Boyd will pursue its organisation during the intersessional period. The Scientific Committee was requested to adjust its budget accordingly (paragraph 5.32).

- The Subgroup on Statistics should meet to develop methods for presentation of comprehensive quantitative data on dependent and harvested species and data from the fishery and environment to replace the current ordinal presentation of data in Table 3. The subgroup will be expanded to include participants expert in harvested species and environmental data and the Convener, Dr Agnew, was requested to correspond with interested participants and submit a proposal for a meeting in 1996 to the Scientific Committee (paragraphs 7.98 and 7.99).

- The Subgroup on Monitoring Methods may need to meet to consider new methods and revisions to old methods as identified above, preferably immediately prior to the next meeting of WG-EMM. The Secretariat will correspond with interested participants to establish a proposal for such a meeting, to be presented to the Scientific Committee (paragraphs 7.98 and 7.99).

Future Work for WG-EMM

Development of an Ecosystem Assessment

- Further work on defining a strategic approach to ecosystem assessment is encouraged (paragraph 2.9).

- Further development of methods appropriate for conducting an ecosystem assessment is required (paragraph 7.96).

- Assessments should be developed from the current qualitative approach to a quantitative analysis (paragraph 7.96).

Surveys

- A new near-synoptic survey of Area 48 is recommended (paragraph 4.8). Papers considering detailed plans for this survey should be prepared for the next meeting.

- Further examination of errors in acoustic surveys of krill should be conducted (paragraph 4.12).

- The use of multifrequency acoustic techniques in surveying should be examined (paragraph 4.13).
- The report of a survey of Division 58.4.1 to be conducted in early 1996 by Australia should be presented for consideration at the next meeting of WG-EMM.

Data Collection/Analysis Methods

- Members are requested to report their experience with gastric lavage and stomach sample techniques (paragraph 5.22).

- Standard methods for Antarctic fur seal demography and diet studies should be prepared (paragraphs 5.38 and 5.39).

- Draft methods for analysis of petrel diet samples should be prepared (paragraph 5.42).

- Methods for albatross and petrel lavage should be prepared (paragraph 5.44).

- Instructions for the collection and preservation of samples to be taken in the event of disease outbreak should be circulated (paragraph 5.51).

- The Subgroup on Monitoring Methods should circulate for review proposed changes to existing CEMP methods and proposals for new ones (paragraph 5.53).

- More extensive studies on the occurrence of fish in krill catches, particularly assessments of when and where larval fish are most likely to be most vulnerable, should be conducted (paragraph 7.4).

- A table of existing spatio-temporal scales should be circulated for revision during the intersessional period (paragraph 7.96).

Data Submission/Acquisition/Access

- All appropriate data on CEMP indicator species currently held by Members and which have not yet been submitted, including historical data sets, should be compiled and submitted in CCAMLR formats (paragraphs 5.12, 5.61, 5.62, 5.64 and 7.96).

- A bibliography of publications on diets, energy budgets and foraging ranges of dependent species should be maintained by CCAMLR (paragraph 5.101).

- The acquisition of comprehensive bathymetric and SST data should be pursued by the Secretariat.

- CCAMLR should consider developing access to a number of its publicly available data sets via a World Wide Web site (WWW) (paragraph 9.17) .

Modelling/Analysis

- CPD calculations for 1994/95 should be presented by the Secretariat to the Scientific Committee (paragraph 5.97).

- Final calculations of the krill/dependent species model for black-browed albatross and Antarctic fur seal should be completed and presented at the next meeting (paragraph 5.112) together with initial requests for a revised version of the Adélie penguin model.

- Members should compare krill length frequency data from nets and predators (paragraph 5.118) and examine time series of krill length frequencies from predators for information on krill recruitment (paragraph 5.120).

- The relationship between overall krill abundance and actual krill availability to predators within a CPD requires investigation (paragraph 7.27).

- Further work on the sub-models within the conceptual framework of Figures 3 and 4 is encouraged (paragraph 7.50 to 7.54).

Correspondence Groups

- A correspondence subgroup should complete the analysis of recruitment estimates (Dr Agnew (Convener), Prof. Butterworth, Drs de la Mare, Hewitt, Loeb and Siegel) (paragraphs 4.48, 4.49 and Appendix D).

- A correspondence subgroup should consider Method A5 (Drs Agnew, Boyd, Kerry (Convener), Kooyman and Trivelpiece) (paragraph 5.19).

- A correspondence subgroup should consider the development of appropriate sea-ice indices (paragraph 6.49) and the formulation of specific hypotheses on the potential effects of sea-ice on components of the ecosystem (Drs Agnew, Croxall, Holt, Miller (Convener), Naganobu, Siegel and Trivelpiece) (paragraphs 6.48 and 6.49).

- A subgroup will carry out further work on the incorporation of information on predator demand in the calculation of precautionary catch limits and their allocation to subareas (Drs Agnew, Boyd (Co-convener), Butterworth, Croxall, de la Mare, Everson (Co-convener), Holt and Naganobu) (paragraphs 7.77 to 7.80 and Appendix H).

- The group led by Dr Kim whose work resulted in a workshop in Hamburg, Germany (Appendix I), should continue to correspond to coordinate research activities (paragraph 9.8).

OTHER BUSINESS

9.1 Given the many developments in the study of euphausiid biology since the last symposium held in 1982, it was suggested that CCAMLR, SCAR and other interested parties might investigate ways of conducting and jointly sponsoring an international symposium in the near future.

9.2 Such a proposal had been made in the last CCAMLR WG-Krill newsletter circulated in January 1995 by Dr Miller (Convener of WG-Krill) and Dr Watkins (Secretary, SCAR Subcommittee on Krill) (WG-EMM-95/35).

9.3 The Working Group felt that, in general, the practice of conducting scientific symposia would facilitate the consideration of a large volume of scientific information of a broad nature contained in papers submitted to CCAMLR meetings. Because of time constraints, CCAMLR Working Groups are usually only able to discuss matters of direct relevance to CCAMLR, leaving other biological information without detailed consideration.

9.4 The Working Group agreed that there was a need and widespread support for such a symposium. It was also mentioned that the place and timing of the symposium should be decided as early as possible in order to enable potential participants to prepare their contributions and secure funds. It was considered that the symposium could not be convened earlier than in the next two or three years.

9.5 It was agreed that the attention of the Scientific Committee should be drawn to the proposal and to the necessity of establishing a symposium steering committee. Meanwhile, Dr Miller was invited to continue with plans and prepare a proposal for the Scientific Committee.

9.6 Since 1993 a group of CCAMLR Members, under the convenership of Dr Kim, has conducted consultations to coordinate their shipboard research in the vicinity of the South Shetland Islands during in the 1994/95 season and to arrange for collaborative evaluation of survey results.

9.7 Coordinated research surveys were conducted from late November 1994 to late February 1995 by Germany, Japan, Republic of Korea and the USA. Dr Kim informed the Working Group of results obtained by the CCAMLR Workshop 'Temporal changes in marine environments in the Antarctic Peninsula area during the 1994/95 austral summer' held from 16 to 21 July 1995 in Hamburg, Germany (WG-EMM-95/58). A summary of the workshop report is given in Appendix I.

9.8 The Working Group congratulated Dr Kim on this initiative which provided for coordination of research effort of several countries and facilitated collection of valuable data, increasing our knowledge of the area. The Working Group encouraged CCAMLR Members to continue to provide outlines of their future research plans to the Scientific Committee and its Working Groups in order to undertake such coordination in future.

9.9 Dr Kock (Chairman of the Scientific Committee) suggested that the Scientific Committee might consider preparation of a booklet describing CCAMLR approaches to ecosystem monitoring and management including a general description of scientific concepts and mathematical models. Such a booklet would be a useful guide for the CCAMLR community in understanding details of the mathematical models used and the development of the long-term strategy for ecosystem monitoring and management. The booklet would also assist in raising the profile of CCAMLR in international scientific and fisheries management communities.

9.10 The Working Group welcomed the proposal and emphasised that the booklet should highlight ongoing processes in CCAMLR. It referred the proposal for further consideration at the forthcoming meeting of the Scientific Committee.

9.11 The attention of the Working Group was drawn to the report of the 1995 planning meeting of the SCAR APIS research program (SC-CAMLR-XIV/BG/11). Dr Boyd highlighted the common areas of interest between APIS and CCAMLR, particularly as regards the estimation of krill consumption by pack-ice seals. Crabeater seals are probably the most numerous single consumer of krill in the

Antarctic and, since they are already recognised by CCAMLR as a selected indicator species, this program will provide data of direct relevance to the management of krill fisheries.

9.12 The Working Group welcomed recent developments in formalisation of the APIS program. It also noted the link established between CCAMLR and APIS through Dr Boyd.

9.13 The attention of the Working Group was drawn to the recent letter received by Drs Everson and Marín from Dr S. Reilly, Chairman of the IWC Scientific Committee. In this letter Dr Reilly invites CCAMLR scientists to take part in the Workshop on the Effects of Climatic Change on Cetaceans, to be held in March 1996 on Oahu Island, Hawaii.

9.14 The Working Group welcomed the opportunity of further developing cooperation with IWC and considered that CCAMLR scientists may contribute to this workshop on the following two topics:

(i) biological changes in the marine environment which may affect distribution and availability of krill; and

(ii) CCAMLR approach to strategic modelling - a tool to develop management advice in the context of a changing environment.

9.15 Several CCAMLR scientists are likely to participate in the workshop and the Working Group suggested that CCAMLR be officially represented. Dr de la Mare and Mr Ichii agreed to prepare a paper on behalf of the CCAMLR Scientific Committee outlining the CCAMLR approach to the topics in paragraph 9.14.

9.16 The Working Group acknowledged that much of the data collected as a result of initiatives by WG-Krill and WG-CEMP now formed data sets which both CCAMLR and other organisations were finding increasingly useful. For instance, the IWC steering committee for research related to the conservation of large baleen whales in the Southern Ocean (WG-EMM-95/31) examined the catch distributions of krill published in the *Statistical Bulletin* in relation to their investigations of krill as a major prey item for whales. The APIS report (SC-CAMLR-XIV/BG/11) also makes reference to the potential use of CCAMLR data.

9.17 In this connection, the Scientific Committee's attention is drawn to the increasing value of CCAMLR's long-term data sets not only to CCAMLR, but also the international community. It was suggested that some consideration should be given to the possibility of increasing ease of access to these data sets for the CCAMLR community (e.g., CCAMLR home page on the WWW).

9.18 Paper WG-EMM-95/30 drew attention to the involvement of SCAR and COMNAP in monitoring man's impact on the Antarctic environment and recorded the intention to harmonise their activities with any related activities of CCAMLR. The Working Group noted that the introduction of exotic disease into the bird and seal populations was an important concern to CCAMLR. A draft protocol for the collection of samples for diagnosis in the event of a disease outbreak had been developed (WG-EMM-95/44) and was discussed (see paragraphs 5.46 to 5.51).

9.19 Dr Penhale noted that SCAR and COMNAP were holding two related workshops on 'The Role of Environmental Monitoring in Preserving Antarctic Values and Resources' (Oslo, Norway, 17 to 20 October 1995; College Station, Texas, USA, 28 November to 1 December 1995). She understood that SCAR and COMNAP were interested in learning from the CCAMLR experience of developing monitoring protocols and a data management program. Since she would be attending both workshops, she agreed to report the interest of WG-EMM/Scientific Committee to the workshops and to report the outcome of these meetings to WG-EMM/Scientific Committee in 1996.

9.20 Dr Miller drew the Working Group's attention to a workshop on krill fisheries scheduled for the period 13 to 16 November 1995 under the convenership of Dr A. Pitcher at the University of British Columbia in Vancouver. Although various members of WG-EMM have been invited to attend the meeting in their private capacities, given the meeting's potential importance, the Working Group urged that CCAMLR should be represented. Dr Miller undertook to put Dr Pitcher in contact with the Scientific Committee chairman with a view to soliciting the necessary invitation to CCAMLR.

9.21 On a related matter, the Working Group noted that WG-EMM-95/48 had been tabled in response to a request by WG-Krill for information on krill fisheries outside the Convention Area. The Working Group welcomed this paper and recognised that the important information on the Japanese *E. pacifica* fishery which it contained was of particular interest to CCAMLR. In particular, such information described management measures and the ancillary use of environmental data in their formulation. The Working Group recommended that the paper be tabled at the Scientific Committee's next meeting so that the information it contained could be more widely disseminated.

ADOPTION OF THE REPORT

10.1 The report of the first meeting of WG-EMM was adopted.

CLOSE OF THE MEETING

11.1 In closing the meeting, the Convener expressed the sincere thanks of the Working Group to Prof. Focardi and his colleagues in Siena for the substantial amount of work they had done to ensure that the meeting ran smoothly.

11.2 He also thanked participants, section coordinators, all rapporteurs and the Secretariat for their contributions to an extremely successful meeting. The direction of work for this new Working Group (WG-EMM) has been set by this meeting and it has made substantial progress towards its objectives.

11.3 Dr Kock, the Scientific Committee Chairman, congratulated the Convener on a meeting that had taken such important steps forward, and noted that a major part of this was due to the Convener's detailed preparation for the meeting.

11.4 The Convener closed the meeting.

Table 1: Output from the krill yield model, with variance of the survey estimate (σ_s) set at various levels to take account of imprecision additional to that arising from inter-transect variation (paragraph 4.55).

γ	P (B_{sp} < 0.2 in 20 years)			Median B_{sp} after 20 years		
	σ_s = 0.3	σ_s = 0.4	σ_s = 0.5	σ_s = 0.3	σ_s = 0.4	σ_s = 0.5
0	0	0	0	1.00	1.00	1.00
0.1	0.02	0.03	0.04	0.78	0.79	0.79
0.11	0.04	0.05	0.06	0.76	0.77	0.77
0.12	0.05	0.06	0.07	0.74	0.74	0.75
0.13	0.06	0.08	0.09	0.72	0.72	0.73
0.14	0.08	0.10	0.12	0.69	0.70	0.71
0.15	0.10	0.12	0.14	0.67	0.68	0.68
0.16	0.13	0.15	0.17	0.65	0.65	0.66
γ_1	0.149	0.140	0.133			
γ_2				0.116	0.116	0.120

Table 2: Data submission for the 1994/95 season.

Site	Parameter/Species																				
	A1		A2	A3				A5		A6				A7				A8			
	EUC	PYD	PYD	EUC	PYD	PYN	PYP	PYD	PYN	EUC	PYD	PYN	PYP	EUC	PYD	PYN	PYP	EUC	PYD	PYN	PYP
Anvers Is					USA			USA			USA				USA				USA		
Béchervaise Is		AUS	AUS		AUS			AUS			AUS				AUS						
Bird Is	GBR			GBR			GBR			GBR			GBR	GBR			GBR	GBR			GBR
Cape Shirreff																					
Magnetic Is																					
Seal Is																USA					
Signy Is					GBR	GBR	GBR				GBR	GBR	GBR								
Terra Nova			ITA		ITA			ITA			ITA				ITA				ITA		
Hope Bay		ARG	ARG		ARG						ARG				ARG						

Site	Parameter/Species					
	A9			B1, 2	C1	C2
	EUC	PYD	PYN	DIM	SEA	SEA
Anvers Is		USA				
Béchervaise Is		AUS				
Bird Is				GBR	GBR	GBR
Cape Shirreff						CHL
Magnetic Is						
Seal Is	USA		USA			USA
Signy Is						
Terra Nova		ITA				
Hope Bay		ARG				

Species code:

EUC	macaroni penguin
PYD	Adélie penguin
PYN	chinstrap penguin
PYP	gentoo penguin
DIM	black-browed albatross
SEA	fur seal

Country code:

ARG	Argentina
AUS	Australia
CHL	Chile
ITA	Italy
GBR	UK
USA	USA

Table 3: Assessment of predator and prey studies, 1988 to 1995. Predator parameters were obtained from WG-CEMP-94/16 unless otherwise referenced in the tables. Data are given qualitative rankings: High, Medium, Low, Very Low (H, M, L, VL). The symbols +, 0, - indicate changes in parameters between successive years. Foraging duration is expressed as the relative length of foraging trips to sea (S = short, M = medium, L = long, VL = very long). Information within the boxes relates to assessments based on the data, collected in accordance with standard methods and actually submitted to the CEMP database.

3.1 Site: Anvers Is, Subarea 48.1

Year	Adélie				Krill				Environment		
	Breeding Population Size/Change (A3)	Breeding Success (A6)	Fledging Mass (A7)	Foraging Trip (A5)	Catch		CPUE	Biomass	Snow	Sea-ice	Ocean
					100-km radius	Subarea					
1988		-									
1989		-									
1990		L	L	M							
1991		L	M	L							
1992	H (First census)	H	H	L							
1993	L --	M	H	S							
1994	L - or 0	M	L	M							
1995	L --	H	L	M							

3.2 Site: Cape Shirreff, Livingston Is, Subarea 48.1

Year	Antarctic Fur Seal[1]			Chinstrap[2]		Krill			
	Breeding Population Size/Change	Breeding Success	Pup Growth Rate (C2)	Breeding Population Size/Change (A3)	Breeding Success (A6)	Catch		CPUE	Biomass
						100-km radius	Subarea		
1988	L	M							
1989									
1990		L							
1991	M +	H		?					
1992	H +	H		0					
1993	H +	H		0					
1994	H +	H	+[3]	-					
1995	L +	H	H	+					

Year	Environment		
	Snow	Sea-ice	Ocean
1988			
1989			
1990			
1991	H		
1992	M	+Brash	
1993	L	iceberg	
1994	L	-	
1995	H	+ iceberg	

1 WG-CEMP-92/53; WG-CEMP-94/28; WG-EMM-95/77
2 *Boletín Antártico Chileno*, Vol. 11 (1): 12-14
3 Submitted data comprise only two sets of weighings

3.3 Site: Admiralty Bay, King George Is, Subarea 48.1

Year	Gentoo		Adélie		Chinstrap		Krill				Environment		
	Breeding Population Size/Change (A3)	Breeding Success (A6)	Breeding Population Size/Change (A3)	Breeding Success (A6)	Breeding Population Size/Change (A3)	Breeding Success (A6)	Catch		CPUE	Biomass	Snow	Sea-ice	Ocean
							100-km radius	Subarea					
1988	M -	M	H +	M	L -	M							
1989	M +	H	H +	H	M +	H							
1990	M -	M	M -	M	M -	L							
1991	L --	M	L --	L	L --	L							
1992	H ++	H	L +	H	M +	H							
1993	H +	H	L -	M	M +	M							
1994	H - or 0	M	L +	H	M +	M							
1995	H 0	H	L -	H	L -	H							

(This summary table was constructed without reviewing the actual data and may contain source errors)

3.4 Site: Ardley Island and Stranger Point combined, King George Island, Subarea 48.1. Esperanza data used for 1991 for Stranger Point.

Year	Adélie[1] - Ardley		Chinstrap[2] - Ardley		Adélie[3] - Stranger		Krill				Environment		
	Breeding Population Size/Change (A3)	Breeding Success (A6)	Breeding Population Size/Change (A3)	Breeding Success (A6)	Breeding Population Size/Change (A3)	Breeding Success (A6)	Catch		CPUE	Biomass	Snow	Sea-ice	Ocean
							100-km radius	Subarea					
1988	H	H	M	M	L -	H							
1989	H	M	M	H	L -	H							
1990	M	L	H	L	M -	M							
1991	L	M	L	M	M -	L							
1992	M	?	L	M	? +	?							
1993	M	L	L	M									
1994	H +	M	L +	M									

1 WG-Krill-92/21; WG-CEMP-92/54; Valencia, unpublished data

2 WG-CEMP-92/54; Valencia, unpublished data

3 WG-CEMP-92/6; WG-CEMP-92/45
Note: 1991 data from Esperanza

3.5 Site: Seal Island, Elephant Island, Subarea 48.1

Year	Chinstrap[1]				Antarctic Fur Seal[2]				Krill[3]				Environment		
	Breeding Population Size/Change (A3)	Breeding Success (A6)	Fledging Mass (A7)	Foraging Trip (A5)	Pups Born Number/ Change	Foraging Trip	Pup Growth Rate (C2)	Weight at Age	Catch		CPUE	Biomass g/m^2	Snow	Sea-ice	Ocean
									100-km radius	Subarea					
1988	M ?	M	H	S	M +	M	M	H							
1989	L -	L	H	L	VL -	?	H	L							
1990	H +	H	M	L	M +	M	L	L				58.6			
1991	M -	L	L	M	L -	L	H	L				26.3			
1992	H +	M	M	M	M +	M	M	H				45.4			
1993	H -	M	M	S	M 0	L	M	M				111.4[4]			
1994		M	L	M	M 0	M	M	H				8.8			
1995			M		M 0		M	M				10-15			

[1] Data are from the CCAMLR Data Centre and WG-CEMP-90/21, 91/11, 91/33, 92/17 and 93/27

[2] Data are from the CCAMLR Data Centre and WG-CEMP-89/21, 90/34, 90/41, 91/11, 92/17 and 93/27

[3] Data from document WG-Joint-94/9 [4] Value may be artificially high due to difficulty differentiating between echo signals from salps and krill

3.6 Site: Signy Is, South Orkneys, Subarea 48.2

Year	Adélie		Chinstrap		Gentoo		Krill				Environment		
	Breeding Population Size/Change (A3)	Breeding Success (A6)	Breeding Population Size/Change (A3)	Breeding Success (A6)	Breeding Population Size/Change (A3)	Breeding Success (A6)	Catch		CPUE	Biomass	Snow	Sea-ice[1]	Ocean
							100-km radius	Subarea					
1988	H +	M	L -	H	H ++	H						H	
1989	H 0	L-M	L 0	H	H +	H						H	
1990	M -	L-M	M +	L	H +	L						L	
1991	L --	M	L -	H	M -	H						M	
1992	M +	M-H	L-M +	H	M -	H						H	
1993	M 0	H	M 0	H	H +	M						?	
1994	M +	L	M +	L	H +	L						?	
1995	L - -	M	L - -	M	H +	M							

[1] Murphy *et al*., (in press)

3.7 Site: Bird Island, South Georgia, Subarea 48.3

Year	Gentoo					Macaroni						Black-browed Albatross			
	Breeding Population Size/Change (A3)	Breeding Success (A6)	Krill in Diet (A8)	Meal Size (A8)	Fledging Mass (A5)	Breeding Population Size/Change (A3)	Breeding Success (A6)	Krill in Diet (A8)	Meal Size (A8)	Arrival Mass (A1)	Fledging Mass (A5)	Breeding Population Size/Change (B1)	Breeding Success (B2)	Adult Survival (B3)	Growth Rate[1]
1988	M -	M	M	H		M -	L	-	-			L - - -	VL	M	-
1989	H ++	M	H	M-H	M	H +	H	M	M	M	H	M ++	M	L	H
1990	H -	L-M	M	M	H	M -	H	M	M	H	M	M 0	M	VL	L
1991	L - -	VL	L	L	L	M -	H	L	L	L	M	L-M -	VL	M	M
1992	M +	H	M	M	H	M 0	M	H	H	M	H	L -	M	?	H
1993	M 0	H	H	M-L	M	M 0	M-H	H	M	M	M	L +	H	?	H
1994	L-M -	VL	VL	VL	L	L-M -	M	VL	L	M	L	L -	VL	?	?
1995	L - -	L-M	M	H	L-M	L - -	M	M	L	M	L	VL - -	VL	?	?

Year	Krill				Environment		
	Catch		CPUE	Biomass	Snow[2]	Sea-ice[3]	Ocean
	100-km radius	Subarea					
1988					H	H	
1989					M	M	
1990					M	L	
1991					M	L	
1992					H	M-H	
1993					M	L-M	
1994					M	?	
1995					H		

1 P.A. Prince, unpublished data

2 Black-browed albatross only

3 Lunn *et al*., 1993 (WG-CEMP-93/10)

3.8 Site: Bird Island, South Georgia, Subarea 48.3

Year	Antarctic Fur Seal[1]										
	Pups Born Number/ Change[1]		Birth Mass[2]	Perinatal Period[2]	Foraging Trip (C1)	Pup Growth Rate (C2)	Wean Mass[2]	Breeding Success[1]	Pregnancy Rate[3]	Survival Rate[3]	Recruitment Rate[3]
1988	H	-	H	M	S	M	M	M	L-M	M	M
1989	H	-	H	M	M	M	H	M	L	H	M
1990	H	+	H	M	S	L-M	M	M	M-H	M	VL
1991	L	- -	L	S	VL	M	M	H	L-M	M	L
1992	L-M	+	M	M	M	M	M-H	L	M	H	M
1993	H	+	M	M	M-L	M-H	M-H	M	H	M-H	L
1994	M	-	M	?	VVL	M	L	VL	H	?	?
1995	L-M	-	M	?	M	L - M	M	M	?	?	?

Year	Krill				Environment		
	Catch		CPUE	Biomass	Snow	Sea-ice[1]	Ocean
	100-km radius	Subarea					
1988						H	
1989						M	
1990						L	
1991						L	
1992						M-L	
1993						M-L	
1994						?	
1995							

1 Boyd *et al*., 1995 (WG-EMM-95/26) and BAS unpublished data

2 Data from Lunn and Boyd, 1993 (WG-CEMP-92/41), Lunn *et al*., 1993 (WG-CEMP-93/9), Boyd, unpublished data

3 Boyd *et al*., 1995 (WG-EMM-95/26)

3.9 Site: Béchervaise Island, Mawson, Division 58.4.2

Year	Adélie							Krill				Environment		
	Arrival Mass (A1)	Incubation Shift (A2)		Breeding Population Size/change (A3)	Breeding Success (A6)	Fledge Mass (A7)	Krill in Diet (A8)	Catch		CPUE	Biomass	Snow	Sea-Ice	Ocean
		1st	2nd					100-km radius	Subarea					
1991		Start		Start	Start		Start					L	M	
1992	Start	0	0	+[1]	0	Start	0					L	M	
1993	0	-	-	-	0	-	0					Ma	M	
1994		-	-	+	0	+	0					L	L	
1995	0	0		0	Nil	Nil	VL					L	H	

[1] *Proc. Nat. Inst. Polar Res.*, 6 (1993)
0 = no change

1995 Note: No chicks fledged. All died during guard phase.

Snow: L = little snow or none; Ma = medium snow during pre-egg stage; Mb = medium snow during chick fledging; H = snow in colony for most of the season

Ice: H = fast ice continuous to horizon late January; M = open water to horizon mid-January; L = late December

3.10 Site: Edmonson Point, Ross Sea region, Subarea 88.2.

Year	Adélie					
	Incubation Shift (A2)	Breeding Population Size/Change (A3)	Foraging Trip Duration (A5)	Breeding Success (A6)	Fledge Mass (A7)	Krill in Diet (A8)
1994	-	start	-	-	-	-
1995	start	0	start	start	start	start

0 = no change
WG-EMM-95/47

Table 4: Time series of data concerning foraging performance, diet and foraging range of predators. Indices referred to in the table are:

a. Chick/pup survival
b. Chick/pup growth
c. Foraging trip duration
d. Parental condition
e. Foraging location
   e.(i) Area/range
   e.(ii) Depth

f. Diet
   f.(i) Meal size
   f.(ii) Meal frequency
   f.(iii) Meal composition
      f.(iii).a Krill length
      f.(iii).b Fish age/size
      f.(iii).c Squid size

Species	Location	Country/Operator	Index	Time Series
Antarctic fur seal	Bird Island	UK	a, b, c, d (pup birth mass)	1984-1995
			e.(i)	1995
			e.(ii)	1988-1995
			f.(iii).a, f.(iii).b	1991-1995
	Seal Island	USA/AMLR	a, b, c, d, e.(i), e.(ii)	1988-1995
Black-browed albatross	Bird Island	UK	a	1976-1995
			b, c	1976-1977, 1980, 1989-1995
			d	1994-1995
			e.(i)	1993-1994
			e.(ii)	1994-1995
			f.(iii).a, f.(iii).b, f.(iii).c	1976-1977, 1980, 1985, 1988, 1994
			f.(i), f.(ii)	1976-1977, 1980, 1990-1995
Gentoo penguin	Bird Island	UK	a	1976-1995
			b	5y in 1977-88; 1989 -1995
			c, d (mass at arrival)	1986-1989
			e.(i) (range)	1986-1988
			e.(ii)	1986-1988
			f.(i)	5y in 1977-88; 1989-1995
			f.(ii)	1977; 1986-1988
			f.(iii).a	5y in 1977-88; 1989-1995
			f.(iii).b	1986-1988; 1990-1995
			f.(iii).c	1990-1995
	Admiralty Bay	USA/NSF	a	1977, 1981-1995
			b	1977, 1981-1982
			d (adult mass)	1981-1995
			e.(i)	1989-1992, 1994
			f.(i), f.(ii), f.(iii).a	1977-1982, 1987-1995
			f.(iii).b	1987-1995

Table 4 (continued)

Species	Location	Country/Operator	Index	Time Series
Macaroni penguin	Bird Island	UK	a	1977-1995
			b	1977, 1980, 1986 -1995
			c	1977
			d (mass at arrival)	1977, 1989-1995
			e.(i) (range)	1989, 1993
			e.(ii)	1989, 1993
			f.(i)	5y 1977-1988, 1990-1995
			f.(ii)	1977
			f.(iii).a	5y 1977-1988, 1990-1995
Adélie penguin	Béchervaise Island	Australia	a, b, c, d (various derived indices), e.(i), e.(ii), f.(i), f.(ii), f.(iii).a, f.(iii).b	1991-1995
	Admiralty Bay	USA/NSF	a	1977, 1981-1995
			b	1977, 1981-1982
			c	1981-1982, 1987-1995
			d (adult mass)	1981-1995
			e.(ii)	1989-1992
			f.(i), f.(ii), f.(iii).a	1977-1982, 1987-1975
			f.(iii).b	1987-1995
	Terra Nova Bay (Edmonson Point)	Italy	a, b, c, d (various derived indices), e.(i), e.(ii), f.(i), f(ii), f.(iii).a, f.(iii).b, f.(iii).c	1995
	Palmer Station	USA/AMLR/NSF	a, b, c	1990-1995
			f.(i), f.(ii), f.(iii), a, b, c	1987-1995
Chinstrap penguin	Admiralty Bay	USA/NSF	a	1977, 1981-1995
			b	1977, 1981-1982
			d (adult mass)	1981-1995
			c	1989-1992
			e.(i)	1977-1982, 1987-1995
			f.(i), f.(ii), f.(iii).a, f.(iii).b	1987-1995
	Seal Island	USA/AMLR	a, b, c, d, e.(i), e.(ii)	1988-1995

Table 5: Environmental variables considered important to an ecosystem assessment. The rows are not aligned to imply specific relationships between columns.

Medium	Features	Variables	Methods	Examples	Comments
Ocean	Global circulation Regional circulation Fronts Topographic interactions Eddies	Water mass distribution Physical properties (temperature, salinity, density, etc.) Nutrient fields Current velocity field Eddy field Wave height Light attenuation	Standard transects and grids Current measurements (current meters, buoys, ADCP, drifters, geostrophic) Satellite (SST) Model data Bathymetric data Sound velocity, sea level, tide	East wind drift Weddell gyre Weddell-Scotia confluence Shelf circulation Circumpolar deep water in the Peninsula region	Affects prey biology, distribution, and transport. Affects predator foraging capabilities, e.g. through changes in wave height, water column light attenuation.
Ice	Interannual/seasonal sea-ice development Global Regional Local Ice-edge processes Polynya and leads	Ice area - global/regional Ice edge position Ice dynamics Rate of change Concentration Type/thickness Floe size Albedo Ice Colour Optical properties Melting stages	Satellite Field - ship/station Ground truthing Ice coring Light measurements for optical properties Snow cover thickness	Interannual variability in maximum extent in the Peninsula region Regional connections; Bellingshausen - Peninsula - Weddell Longterm change Ecology of MIZ	Refugia Overwintering - possible link to recruitment strength? Prey redistribution? Access for predators to prey. Suitability as breeding sites. Affects fishery operations (ice cover).

Table 5 (continued)

Medium	Features	Variables	Methods	Examples	Comments
Atmosphere	Global climate Regional Weather systems Katabatic winds	Pressure gradients Wind stress field Cloud cover Precipitation Temperature, humidity, etc. Irradiance	Satellites, e.g. scatterometer, cloud cover, irradiance, UV Field measurements - meteorological observations - ground truthing	Weather system - frequency in the Peninsula region - tracks in Scotia Sea Global change Wind stress effects on water column structure	Indirect effect on marine life? (except UV?) Direct effect on predators. Flight tracks. Foraging strategies. Breeding success?
Terrestrial	Topography Geology Habitat suitability Vegetation cover Glacier	Snow cover Breeding site suitability - height - wind direction - substrate Vegetation Access Glacial retreat	Satellite + field measurements Aerial photography Field observations for ground truthing and direct measurements	Seasonal variability Site availability for population expansion?	Availability of nesting sites. Penguin population changes.

Good characterisation of bathymetry is required.

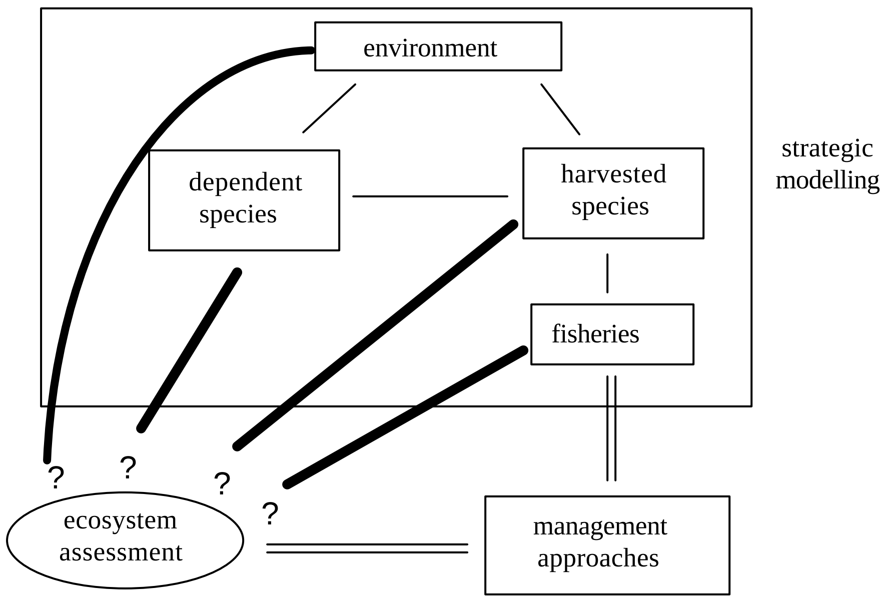

Figure 1: Schematic diagram of the processes involved in ecosystem monitoring and management. The basic ecosystem COMPONENTS are Environment, Dependent Species, Harvested Species and Fisheries. They interact via ecosystem LINKS (thin lines). They also all have an as yet undefined relationship (thick lines) with an 'ecosystem assessment' which incorporates ecosystem monitoring. Strategic modelling is the process whereby the links between components, and between components and the ecosystem assessment are evaluated. The final step in the scheme is the evaluation of management approaches, and the determination of its links with the ecosystem assessment (double lines).

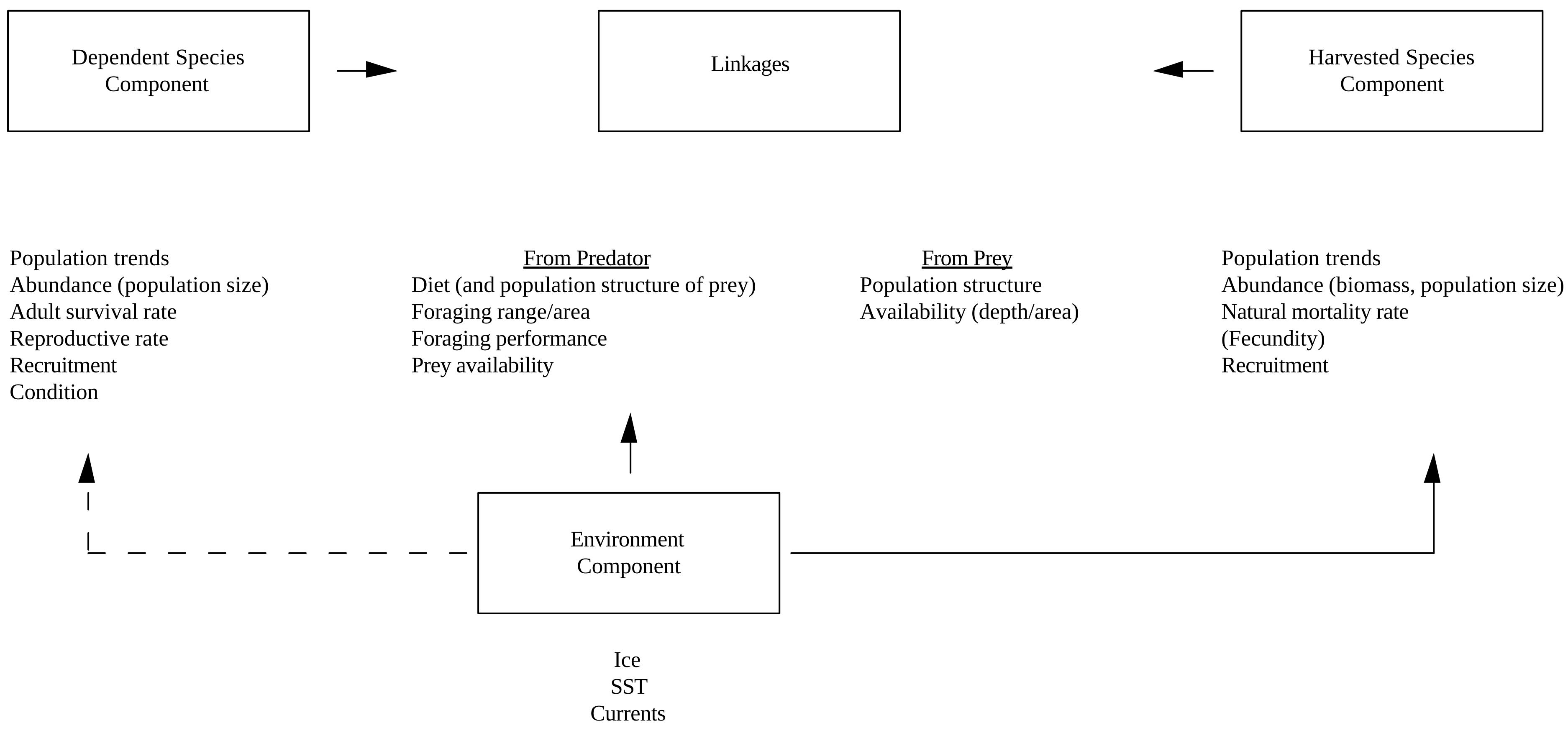

Figure 2: Relevance of various ecosystem parameters to the components and links identified in Figure 1.

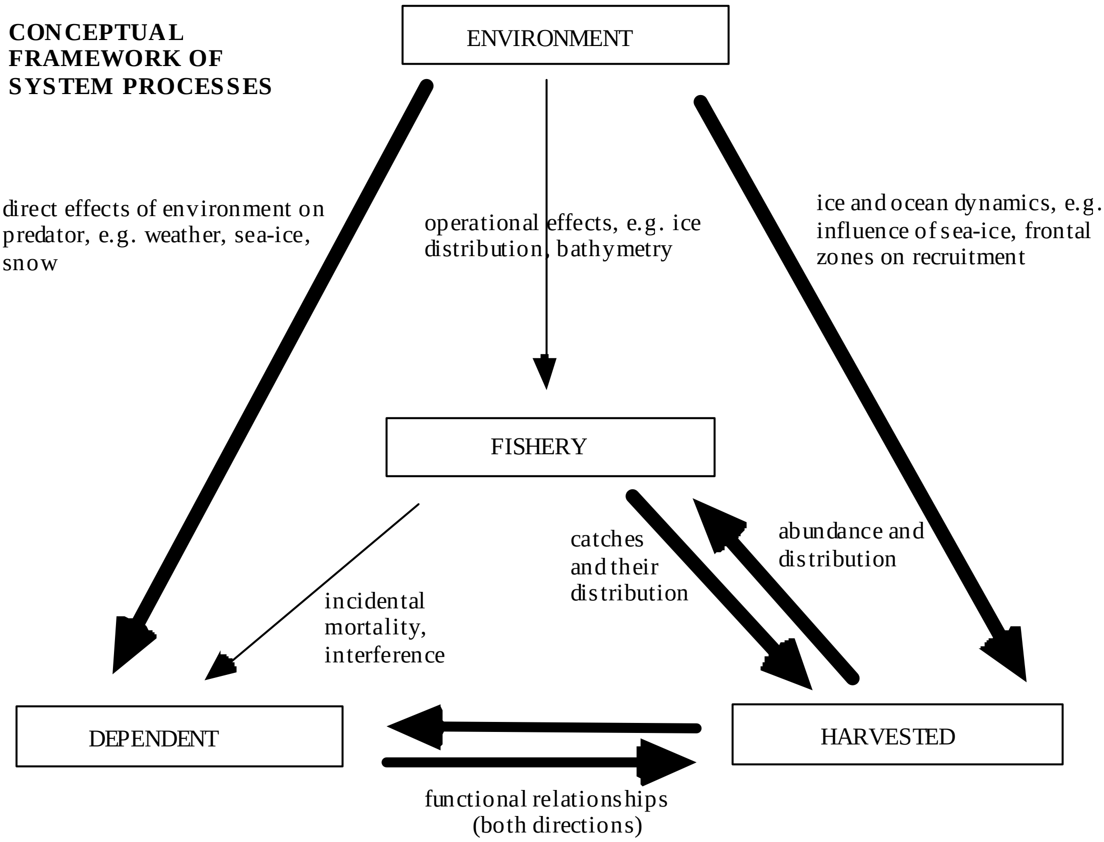

Figure 3: Conceptual framework of system processes. This figure describes the first step in a strategic modelling exercise and demonstrates the relationships between ecosystem components. The direction of arrows indicates the effect of one component on another, and the thickness of an arrow indicates the perceived importance of that link.

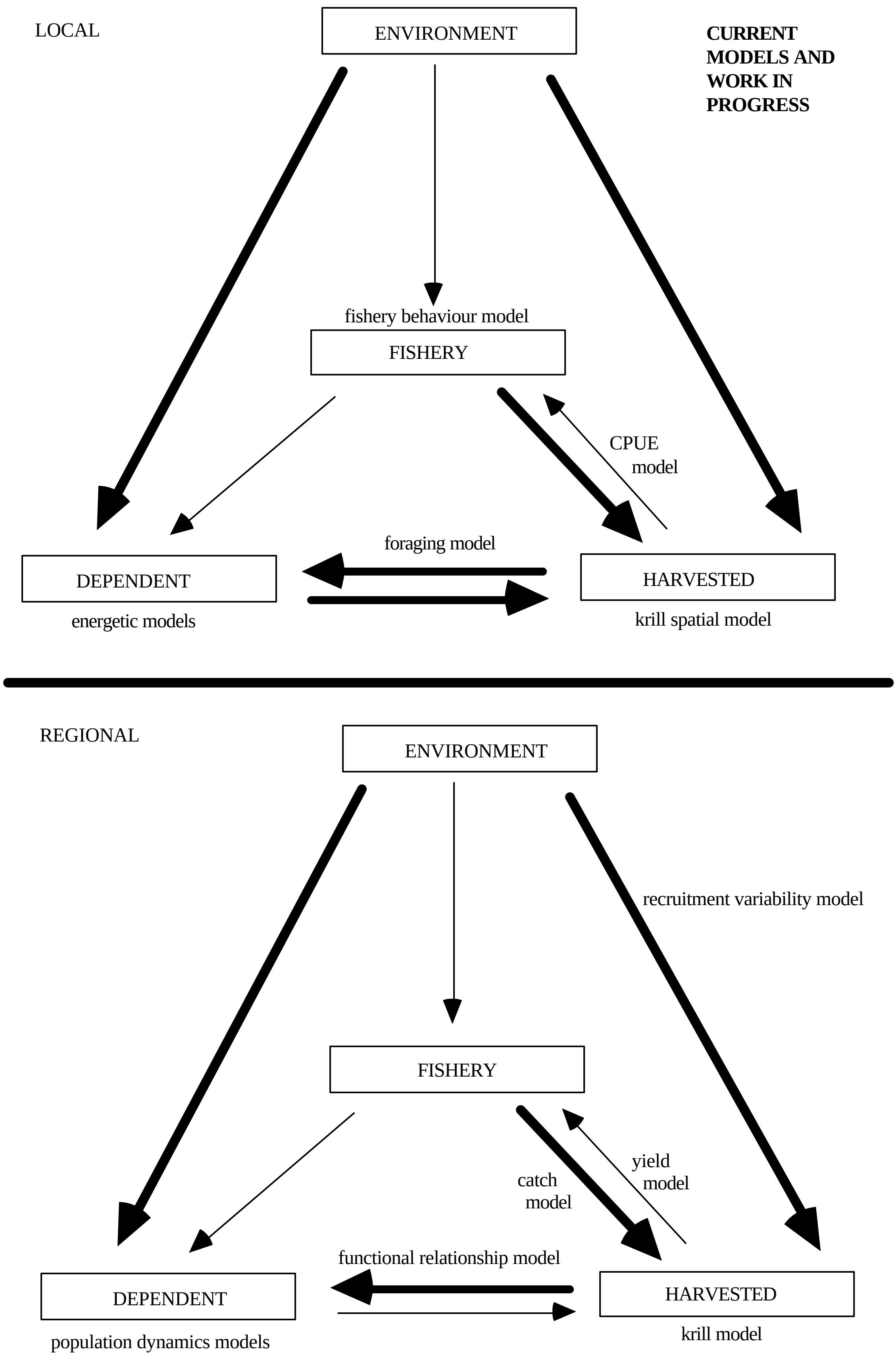

Figure 4: Current models and work in progress. Models are either associated with the components (in which case the models describe the relationships between parts of the ecosystem which are within component boxes) or with links.

LIST OF PARTICIPANTS

Working Group on Ecosystem Monitoring and Management
(Siena, Italy, 24 July to 3 August 1995)

AZZALI, Massimo (Dr)	C.M.R.-I.R.PE.M. Molo Mandracchio 60100 Ancona Italy
BERGSTRÖM, Bo (Dr)	Kristinebergs Marine Research Station S-450 34 Fiskebäckskil Sweden bobe@kmf.guse
BOYD, Ian (Dr)	British Antarctic Survey High Cross, Madingley Road Cambridge CB3 OET United Kingdom ilbo@pcmail.nerc-bas.ac.uk
BUTTERWORTH, Doug (Prof.)	Department of Applied Mathematics University of Cape Town Rondebosch 7700 South Africa dll@maths.uct.ac.za
CASAUX, Ricardo (Lic.)	Dirección Nacional del Antártico Cerrito 1248 1010 Buenos Aires Argentina
CROXALL, John (Dr)	British Antarctic Survey High Cross, Madingley Road Cambridge CB3 OET United Kingdom
DE LA MARE, William (Dr)	Australian Antarctic Division Channel Highway Kingston Tas. 7050 Australia bill_de@antdiv.gov.au

DEMER, David (Dr)

US AMLR Program
Southwest Fisheries Science Center
PO Box 271
La Jolla, Ca. 92038
USA
ddemer@ucsd.edu

EVERSON, Inigo (Dr)

Convener, WG-EMM
British Antarctic Survey
High Cross, Madingley Road
Cambridge CB3 OET
United Kingdom
iev@pcmail.nerc-bas.ac.uk

FEDOULOV, Pavel (Dr)

Via Lago Terrione, 45a
00165 Roma
Italy

FERNHOLM, Bo (Dr)

Swedish Museum of Natural History
S-104 05 Stockholm
Sweden
ve-bo@nrm.se

FOCARDI, Silvano (Prof.)

Dipartimento di Biologia Ambientale
Universita di Siena
Via delle Cerchia 3
53100 Siena
Italy
focardi@unisi.it

FOOTE, Kenneth (Dr)

Institute of Marine Research
PO Box 1870 Nordnes
N-5024 Bergen
Norway

FRANCHI, Enrica (Dr)

Dipartimento di Biologia Ambientale
Universita di Siena
Via delle Cerchia 3
53100 Siena
Italy
franchi@unisi.it

GUGLIELMO, Lillo (Prof.)
Dipartimento di Biologia Animale Ed
Ecologia Marina
Contrada Sperone, 31
Universita di Messina
98040 Messina
Italy

HEWITT, Roger (Dr)
US AMLR Program
Southwest Fisheries Science Center
PO Box 271
La Jolla, Ca. 92038
USA
rhewitt@ucsd.edu

HOLT, Rennie (Dr)
US AMLR Program
Southwest Fisheries Science Center
PO Box 271
La Jolla, Ca. 92038
USA
rholt@ucsd.edu

ICHII, Taro (Mr)
National Research Institute of Far Seas Fisheries
Orido 5-7-1, Shimizu
Shizuoka 424
Japan
ichii@enyo.affrc.go.jp

KATO, Tomonobu (Mr)
Japan Deep Sea Trawlers Association
Ogawacho-Yasuda Building, No. 601
3-6 Kanda-Ogawacho
Chiyoda-ku
Tokyo 101
Japan

KAWAGUCHI, So (Dr)
National Research Institute of Far Seas Fisheries
Orido 5-7-1, Shimizu
Shizuoka 424
Japan
kawaso@enyo.affrc.go.jp

KERRY, Knowles (Dr)
Australian Antarctic Division
Channel Highway
Kingston Tas. 7050
Australia
knowle_ker@antdiv.gov.au

KIM, Suam (Dr)	Korea Ocean Research and Development Institute Ansan PO Box 29 Seoul 425-600 Republic of Korea suamkim@sari.kordi.re.kr
KIRKWOOD, Geoff (Dr)	Renewable Resources Assessment Group Imperial College 8, Prince's Gardens London SW7 1NA United Kingdom g.kirkwood@ic.ac.uk
KOCK, Karl-Hermann (Dr)	Chairman, Scientific Committee Bundesforschungsanstalt für Fischerei Institut für Seefischerei Palmaille 9 D-22767 Hamburg Germany 100565.1223@compuserve.com
KOOYMAN, Gerald (Dr)	Scholander Hall, 0204 UCSD La Jolla, Ca. 92093 USA gkooyman@ucsd.edu
LAWLESS, Ruth (Dr)	Australian Antarctic Division Channel Highway Kingston Tas. 7050 Australia ruth_law@antdiv.gov.au
LOEB, Valerie (Dr)	Moss Landing Marine Laboratories PO Box 450 Moss Landing, Ca. 95039 USA loeb@cmlml.calstate.edu
LOPEZ ABELLAN, Luis (Mr)	Centro Oceanográfico de Canarias Instituto Español de Oceanografía Apartado de Correos 1373 Santa Cruz de Tenerife lla@ca.ieo.es

MEHLUM, Fridtjof (Dr)	Norwegian Polar Institute PO Box 5072 Majorstua N-0301 Oslo Norway mehlum@npolar.no
MILLER, Denzil (Dr)	Sea Fisheries Research Institute Private Bag X2 Roggebaai 8012 South Africa dmiller@sfri.sfri.ac.za
MURPHY, Eugene (Dr)	British Antarctic Survey High Cross, Madingley Road Cambridge CB3 OET United Kingdom e.murphy@bas.ac.uk
NAGANOBU, Mikio (Dr)	National Research Institute of Far Seas Fisheries Orido 5-7-1, Shimizu Shizuoka 424 Japan naganobu@ss.enyo.affrc.go.jp
NICOL, Steve (Dr)	Australian Antarctic Division Channel Highway Kingston Tas. 7050 Australia stephe_nic@antdiv.gov.au
ØRITSLAND, Torger (Dr)	Marine Mammals Division Institute of Marine Research PO Box 1870 Nordnes N-5024 Bergen Norway
PENHALE, Polly (Dr)	National Science Foundation Office of Polar Progams 4201 Wilson Blvd Arlington, Va. 22230 USA ppenhale@nsf.gov

PHAN VAN NGAN (Prof.)	Instituto Oceanográfico Universidade de São Paulo Cidade Universitária Butantã 05508 São Paulo Brazil
SAINO, Nicola (Dr)	Dip. Biologia Universita di Milano Via Celonia 26 I-20133 Milano Italy
SIEGEL, Volker (Dr)	Bundesforschungsanstalt für Fischerei Institut für Seefischerei Palmaille 9 D-22767 Hamburg Germany 100565.1223@compuserv.com
THOMSON, Robyn (Miss)	Department of Applied Mathematics University of Cape Town Rondebosch 7700 South Africa robin@maths.uct.ac.za
TORRES, Daniel (Prof.)	Instituto Antártico Chileno Luis Thayer Ojeda 814, Correo 9 Santiago Chile inach@cec.uchile.cl
TRIVELPIECE, Wayne (Dr)	Department of Biology Montana State University Bozeman, Mt. 59715 USA ubiwt@msu.oscs.montana.edu
WATKINS, Jon (Dr)	British Antarctic Survey High Cross, Madingley Road Cambridge CB3 OET United Kingdom j.watkins@bas.ac.uk
WILSON, Peter (Dr)	Manaaki Whenua - Landcare Research Private Bag 6 Nelson New Zealand wilsonpr@landcare.cri.nz

SECRETARIAT:

Esteban DE SALAS (Executive Secretary)	CCAMLR
David AGNEW (Data Manager)	25 Old Wharf
Eugene SABOURENKOV (Science Officer)	Hobart Tasmania 7000
Genevieve NAYLOR (Secretary)	Australia
Rosalie MARAZAS (Secretary)	

LIST OF DOCUMENTS

Working Group on Ecosystem Monitoring and Management
(Siena, Italy, 24 July to 3 August 1995)

WG-EMM-95/1	PROVISIONAL AGENDA AND PROVISIONAL ANNOTATED AGENDA FOR THE FIRST MEETING OF THE WORKING GROUP ON ECOSYSTEM MONITORING AND MANAGEMENT (WG-EMM)
WG-EMM-95/2	LIST OF PARTICIPANTS
WG-EMM-95/3	LIST OF DOCUMENTS
WG-EMM-95/4	KRILL DISTRIBUTION VARIABILITY AND FISHERY CONDITIONS WITHIN THE LOCAL GROUND OF SUBAREA 48.3 IN JUNE 1991 S.M. Kasatkina (Russia)
WG-EMM-95/5	GROWTH OF KRILL AROUND THE SOUTH ORKNEY ISLANDS IN 1989/90 V.I. Latogursky (Russia)
WG-EMM-95/6	SUMMARY OF FINE-SCALE CATCHES OF KRILL: 1973/74 TO 1993/94 Secretariat
WG-EMM-95/7	FINE-SCALE CATCHES OF KRILL IN THE CONVENTION AREA: 1993/94 SEASON Secretariat
WG-EMM-95/8	COMPARISON OF EQUAL-AREA CYLINDRICAL AND CIRCULAR PISTON TRANSDUCERS Kenneth G. Foote (Norway)
WG-EMM-95/9	PERFORMANCE OF AN ACOUSTIC SONDE DESIGN Kenneth G. Foote (Norway)
WG-EMM-95/10	DEVELOPMENTS IN THE CALCULATION OF CEMP INDICES 1995 Data Manager
WG-EMM-95/11	CALCULATION OF INDICES OF SEA-ICE CONCENTRATION USING DIGITAL IMAGES FROM THE NATIONAL SNOW AND ICE DATA CENTRE D.J. Agnew (Secretariat)
WG-EMM-95/12 Rev. 1	INDEX PART 1: INTRODUCTION TO THE CEMP INDICES 1995 Data Manager

WG-EMM-95/13 Rev. 1 INDEX PART 2: CEMP INDICES: TABLES OF RESULTS 1995
Data Manager

WG-EMM-95/14 Rev. 1 INDEX PART 3: CEMP INDICES: FIGURES 1995
Data Manager

WG-EMM-95/15 RECRUITMENT OF ANTARCTIC KRILL (*EUPHAUSIA SUPERBA*) AND POSSIBLE CAUSES FOR ITS VARIABILITY
V. Siegel (Germany) and V. Loeb (USA)

WG-EMM-95/16 HYDROGRAPHIC CONDITIONS AROUND ELEPHANT ISLAND DURING AUSTRAL SPRING 1994
Manfred Stein (Germany)

WG-EMM-95/17 SOME THOUGHTS ON PRECAUTIONARY MEASURES FOR THE KRILL FISHERY
Inigo Everson (UK)

WG-EMM-95/18 PRELIMINARY RESULTS ON THE COMPOSITION AND ABUNDANCE OF THE KRILL STOCK IN THE SOUTHERN BELLINGSHAUSEN SEA (ANTARCTIC, CCAMLR SUBAREA 88.3)
V. Siegel (Germany)

WG-EMM-95/19 ON THE EXAMINING OF KRILL FLUX
R. Makarov (Russia)

WG-EMM-95/20 THE ORGANISATION OF ENVIRONMENTAL MONITORING IN ANTARCTICA
Submitted by SCAR to the XVIIIth ATCM

WG-EMM-95/21 INDICES OF BODY CONDITION AND BODY COMPOSITION IN FEMALE ANTARCTIC FUR SEALS (*ARCTOCEPHALUS GAZELLA*)
John P.Y. Arnould (UK)

WG-EMM-95/22 HEART RATE AND OXYGEN CONSUMPTION OF EXERCISING GENTOO PENGUINS
R.M. Bevan, A.J. Woakes, P.J. Butler and J.P. Croxall (UK)

WG-EMM-95/23 TEMPORAL SCALES OF FORAGING IN A MARINE PREDATOR: IMPLICATIONS FOR INTERPRETING THE DISTRIBUTION OF PREY
I.L. Boyd (UK)

WG-EMM-95/24 INDIVIDUAL VARIATION IN THE DURATION OF PREGNANCY AND BIRTH DATE IN ANTARCTIC FUR SEALS: THE ROLE OF ENVIRONMENT, AGE AND FETAL SEX
I.L. Boyd (UK)

WG-EMM-95/25	SWIMMING SPEED AND ALLOCATION OF TIME DURING THE DIVE CYCLE OF ANTARCTIC FUR SEALS I.L. Boyd, K. Reid and R.M. Bevan (UK)
WG-EMM-95/26	POPULATION DEMOGRAPHY OF ANTARCTIC FUR SEALS: THE COSTS OF REPRODUCTION AND IMPLICATIONS FOR LIFE-HISTORIES I.L. Boyd, J.P. Croxall, N.J. Lunn and K. Reid (UK)
WG-EMM-95/27	DIET OF THE KING PENGUIN *APTENODYTES PATAGONICA* DURING THREE SUMMERS AT SOUTH GEORGIA C.O. Olsson (Sweden) and A.W. North (UK)
WG-EMM-95/28	THE DIET OF ANTARCTIC FUR SEALS *ARCTOCEPHALUS GAZELLA* DURING THE BREEDING SEASON AT SOUTH GEORGIA Keith Reid and John P.Y. Arnould (UK)
WG-EMM-95/29	THE DIET OF ANTARCTIC FUR SEALS *ARCTOCEPHALUS GAZELLA* DURING WINTER AT SOUTH GEORGIA Keith Reid (UK)
WG-EMM-95/30	ECOSYSTEM MONITORING AND MANAGEMENT, PAST, PRESENT AND FUTURE Inigo Everson (UK)
WG-EMM-95/31	REPORT OF THE STEERING COMMITTEE FOR RESEARCH RELATED TO CONSERVATION OF LARGE BALEEN WHALES IN THE SOUTHERN OCEANS (TOKYO, JAPAN, 7-10 MARCH 1995)
WG-EMM-95/32	STOMACH FLUSHING OF ADELIE PENGUINS (CEMP METHOD A8) Judy Clarke (Australia)
WG-EMM-95/33	ADELIE PENGUIN CHICK DEATHS INVESTIGATED K. Kerry, J. Clarke, H. Gardner, R. Murphy, F. Hume and P. Hodum (Australia)
WG-EMM-95/34	TRANSECT SPACING FOR ACOUSTIC SURVEYS Inigo Everson (UK)
WG-EMM-95/35	CCAMLR WG-KRILL NEWSLETTER Denzil Miller (Convener WG-Krill) John Watkins (Secretary SCAR Sub-committee on Krill)
WG-EMM-95/36	DRAFT STANDARD METHODS FOR THE COLLECTION OF DATA ABOUT AT-SEA BEHAVIOUR Ian Boyd (UK)
WG-EMM-95/37	WORKSHOP *IN SITU* ESTIMATION OF FISH TARGET STRENGTH Delegation of South Africa

WG-EMM-95/38	WORKSHOP ON ESTIMATION OF VARIANCE IN MARINE ACOUSTIC SURVEYS Delegation of South Africa
WG-EMM-95/39	ON THE CONSEQUENCES OF DIFFERENTIATING BETWEEN ADULT AND SUB-ADULT SURVIVAL RATES IN THE KRILL-PREDATORS MODEL R.B. Thomson and D.S. Butterworth (South Africa)
WG-EMM-95/40	CAN THE LENGTH COMPOSITION OF KRILL IN PREDATOR DIETS PROVIDE INFORMATION ON THE AGE-DEPENDENCE OF KRILL NATURAL MORTALITY? R.B. Thomson and D.S. Butterworth (South Africa)
WG-EMM-95/41	KRILL CATCH WITHIN 100 KM OF PREDATOR COLONIES FROM DECEMBER TO MARCH (THE CRITICAL PERIOD-DISTANCE) Data Manager
WG-EMM-95/42	ON THE ESTIMATION OF SOME DEMOGRAPHIC PARAMETERS FOR ADELIE PENGUINS R.B. Thomson and D.S. Butterworth (South Africa)
WG-EMM-95/43	A HYDROACOUSTIC SURVEY OF ANTARCTIC KRILL POPULATIONS IN CCAMLR DIVISION 58.4.1 Stephen Nicol (Australia)
WG-EMM-95/44	PROTOCOLS FOR TAKING SAMPLES FOR PATHOLOGICAL ANALYSIS IN THE EVENT OF DISEASE BEING SUSPECTED AMONG MONITORED SPECIES K. Kerry, J. Clarke, D. Obendorf (Australia) and J. Cooper (South Africa)
WG-EMM-95/45	DETERMINING SEX OF ADELIE PENGUINS FROM TIMING OF INCUBATION SHIFT K.R. Kerry and J. Clarke (Australia) and E. Franchi (Italy)
WG-EMM-95/46	DRAFT: DIFFERENCES IN THE FORAGING STRATEGIES OF MALE AND FEMALE ADELIE PENGUINS Judy Clarke and Knowles Kerry (Australia) and Enrica Franchi (Italy)
WG-EMM-95/47	ADELIE PENGUIN MONITORING PROGRAM AT EDMONSON POINT, ROSS SEA REGION E. Franchi (Italy), J. Clarke, R. Lawless and K. Kerry (Australia) and S. Focardi (Italy)
WG-EMM-95/48	EUPHAUSIID FISHERY IN THE JAPANESE WATERS Yoshinari Endo (Japan)
WG-EMM-95/49	CHARACTERISTICS OF WATER FLOWS IN AREAS FOR ANTARCTIC KRILL CONCENTRATIONS NEAR THE SOUTH SHETLAND ISLANDS T. Ichii and M. Naganobu (Japan)

WG-EMM-95/50	AN OUTLINE OF THE ANTARCTIC RESEARCH CRUISE BY THE JAPANESE RV *KAIYO MARU* AROUND THE SOUTH SHETLAND ISLANDS IN 1994/95 M. Naganobu, T. Ichii, S. Kawaguchi, T. Ogishima and Y. Takao (Japan)
WG-EMM-95/51	CPUES AND BODY LENGTH OF ANTARCTIC KRILL DURING 1993/94 SEASON IN THE FISHING GROUNDS AROUND THE SOUTH SHETLAND ISLANDS S. Kawaguchi, T. Ichii and M. Naganobu (Japan)
WG-EMM-95/52	NUMERICAL MODEL OF ECOSYSTEM INCLUDING *EUPHAUSIA SUPERBA* DANA AS A KEY SPECIES IN THE ANTARCTIC OCEAN Michio J. Kishi and Mikio Naganobu (Japan)
WG-EMM-95/53	COINCIDENCE BETWEEN CLIMATE FLUCTUATIONS AND VARIABILITY IN THE ANTARCTIC KRILL (*EUPHAUSIA SUPERBA*) RECRUITMENT M. Naganobu, K. Kutsuwada and Y. Sasai (Japan)
WG-EMM-95/54	DISTRIBUTION OF SALPS NEAR THE SOUTH SHETLAND ISLANDS DURING AUSTRAL SUMMER, 1990/1991 WITH SPECIAL REFERENCE TO KRILL DISTRIBUTION Jun Nishikawa, Mikio Naganobu, Taro Ichii, Haruto Ishii, Makoto Terazaki and Kouichi Kawaguchi (Japan)
WG-EMM-95/55	RELATIONSHIP BETWEEN RECRUITMENT OF THE ANTARCTIC KRILL AND THE DEGREE OF ICE COVER NEAR THE SOUTH SHETLAND ISLANDS So Kawaguchi and Mikio Satake (Japan)
WG-EMM-95/56	FISHES INCIDENTALLY CAUGHT BY JAPANESE ANTARCTIC KRILL COMMERCIAL FISHERY TO THE NORTH OF THE SOUTH SHETLAND ISLANDS DURING THE 1994/95 AUSTRAL SUMMER Tetsuo Iwami (Japan)
WG-EMM-95/57	FEEDING BEHAVIOUR OF ANTARCTIC KRILL ON SALPS S. Kawaguchi and Y. Takahashi (Japan)
WG-EMM-95/58	REPORT OF THE CCAMLR WORKSHOP 'TEMPORAL CHANGES IN MARINE ENVIRONMENTS IN THE ANTARCTIC PENINSULA AREA DURING THE 1994/95 AUSTRAL SUMMER' (HAMBURG 17 TO 21 JULY 1995) Delegations of Germany, Japan, Korea, USA and UK
WG-EMM-95/59	COMPARING A MODEL OF KRILL POPULATION DYNAMICS AND RECRUITMENT DATA Marc Mangel (USA)
WG-EMM-95/60	AMLR 1994/95 FIELD SEASON REPORT - OBJECTIVES, ACCOMPLISHMENTS AND TENTATIVE CONCLUSIONS Delegation of USA

WG-EMM-95/61	CLIMATE VARIABILITY IN THE WESTERN ANTARCTIC PENINSULA REGION Raymond C. Smith, Sharon E. Stammerjohn and Karen S. Baker (USA)
WG-EMM-95/62	SPATIAL AND TEMPORAL VARIABILITY IN WEST ANTARCTIC SEA ICE COVERAGE S.E. Stammerjohn and R. C. Smith (USA)
WG-EMM-95/63	CHANGES IN ADELIE PENGUIN RECRUITMENT: CORRELATIONS TO KRILL BIOMASS ESTIMATES AND IMPLICATIONS FOR FISHERIES MANAGEMENT IN THE SOUTHERN OCEAN Wayne Z. Trivelpiece and Susan G. Trivelpiece (USA)
WG-EMM-95/64	VARIABILITY IN SEA ICE COVERAGE AND LONG-TERM CHANGE IN THE DIETS OF ADELIE PENGUINS: IMPLICATIONS FOR SOUTHERN OCEAN ECOSYSTEM STUDIES William R. Fraser and Wayne Z. Trivelpiece (USA)
WG-EMM-95/65	DRAFT TERMS OF REFERENCE FOR A POSSIBLE WORKSHOP ON TIME DEPTH RECORDERS (TDRs) TO BE CONVENED IN COOPERATION WITH THE CCAMLR WORKING GROUP ON ECOSYSTEM MONITORING AND MANAGEMENT Delegation of USA
WG-EMM-95/66	KRILL-ICE-PENGUIN INTERACTIONS: A MODELLING STUDY Eileen Hofmann and Wayne Z. Trivelpiece (USA)
WG-EMM-95/67	WATER MASS DISTRIBUTION AND CIRCULATION WEST OF THE ANTARCTIC PENINSULA AND INCLUDING BRANSFIELD STRAIT Eileen E. Hofmann, John M. Klinck, Cathy M. Lascara and David A. Smith (USA)
WG-EMM-95/68	DYNAMIC MODEL OF KRILL *EUPHAUSIA SUPERBA* SWARM Massimo Azzali and Janusz Kalinowski (Italy)
WG-EMM-95/69	ENVIRONMENT-KRILL INTERACTIONS IN THE SOUTH GEORGIA MARINE SYSTEM P.P. Fedulov and K.E. Shulgovsky (Ukraine) and C. Symon (UK)
WG-EMM-95/70	UNCERTAINTY IN STANDARD SPHERE CALIBRATIONS David A. Demer and Roger P. Hewitt (USA)
WG-EMM-95/71	ACOUSTIC SURVEY DESIGN TO ESTIMATE KRILL BIOMASS IN SUBAREAS 48.1, 48.2 AND 48.3 George Watters and Roger P. Hewitt (USA)
WG-EMM-95/72	UNCERTAINTY IN ACOUSTIC SURVEYS OF ANTARCTIC KRILL David A. Demer (USA)

WG-EMM-95/73 A SUMMARY OF SOFTWARE ANOMALIES ENCOUNTERED WITH THE SIMRAD EK500 SYSTEM
J.L. Watkins, A.S. Brierley, A.W.A. Murray and C. Goss (UK)

WG-EMM-95/74 AN ACOUSTIC ESTIMATION OF KRILL DENSITIES TO THE NORTH OF SOUTH GEORGIA IN JANUARY 1994
Andrew S. Brierley and Jonathan L. Watkins (UK)

WG-EMM-95/75 A COMPARISON OF ACOUSTIC TARGETS AT SOUTH GEORGIA AND THE SOUTH ORKNEY ISLANDS DURING A SEASON OF PROFOUND KRILL SCARCITY
Andrew S. Brierley and Jonathan L. Watkins (UK)

WG-EMM-95/76 A COMPARISON OF GEOSTATISTICAL AND RANDOM SAMPLE SURVEY ANALYSES OF ANTARCTIC KRILL ACOUSTIC DATA
A.W.A. Murray (UK)

WG-EMM-95/77 REPORT OF CEMP ACTIVITIES CARRIED OUT IN CAPE SHIRREFF DURING THE ANTARCTIC SEASON 1994/95
D. Torres (Chile)

WG-EMM-95/78 VARIATION IN THE DIET OF THE BLUE-EYED SHAG *PHALACROCORAX ATRICEPS* THROUGHOUT THE BREEDING SEASON AT HALF-MOON ISLAND, SOUTH SHETLAND ISLANDS
R. Casaux and E. Barrera-Oro (Argentina)

WG-EMM-95/79 COMPARISON OF THE DIET OF THE BLUE-EYED SHAG *PHALACROCORAX ATRICEPS* BY THE ANALYSIS OF PELLETS AND STOMACH CONTENTS
R. Casaux, M. Favero, N. Coria and P. Silva (Argentina)

WG-EMM-95/80 TEMPORAL VARIATION IN ANTARCTIC SEA-ICE: ANALYSIS OF A LONG-TERM FAST-ICE RECORD FROM THE SOUTH ORKNEY ISLANDS
Eugene J. Murphy, Andrew Clarke, Carolyn Symon and Julian Priddle (UK)

WG-EMM-95/81 THE DIET OF THE BLUE-EYED SHAG *PHALACROCORAX ATRICEPS* AT LAURIE ISLAND, SOUTH ORKNEY ISLANDS, AS REFLECTED BY THE ANALYSIS OF STOMACH CONTENTS COLLECTED THROUGHOUT THE BREEDING SEASON
R. Casaux, N. Coria and E. Barrera-Oro (Argentina)

WG-EMM-95/82 THE DIET OF THE BLUE-EYED SHAG *PHALACROCORAX ATRICEPS* DURING SUMMER AT NELSON ISLAND, ANTARCTICA: TEMPORAL VARIATIONS AND CONSUMPTION RATES
M. Favero, R. Casaux, P. Silva, E. Barrera-Oro and N. Coria (Argentina)

WG-EMM-95/83	NEW CORRECTIONS FACTORS FOR THE QUANTIFICATION OF FISH REPRESENTED IN PELLETS OF THE BLUE-EYED SHAG *PHALACROCORAX ATRICEPS* R. Casaux, E. Barrera-Oro, M. Favero and P. Silva (Argentina)
WG-EMM-95/84	A METHODOLOGICAL PROPOSAL TO MONITOR CHANGES IN COASTAL FISH POPULATIONS BY THE ANALYSIS OF PELLETS OF THE BLUE-EYED SHAG *PHALACROCORAX ATRICEPS* R. Casaux and E. Barrera-Oro (Argentina)
WG-EMM-95/85	DIET OF CAPE PETREL, *DAPTION CAPENSE*, DURING LATE INCUBATION AND CHICK REARING PERIOD, AT LAURIE ISLAND, SOUTH ORKNEY ISLANDS, ANTARCTICA G.E. Soave, N.R. Coria and D. Montalti (Argentina)
WG-EMM-95/86	DRAFT STANDARD METHODS FOR FULMARINE PETRELS A) ANTARCTIC PETREL Fridtjof Mehlum (Norway) and Jan A. van Franeker (The Netherlands)
WG-EMM-95/87	IMPORTANCE OF MYCTOPHID FISH DISTRIBUTIONS FOR FORMATION OF FORAGING AREAS OF CHINSTRAP PENGUINS AND ANTARCTIC FUR SEALS AT SEAL ISLAND T. Ichii, T. Takao, N. Baba (Japan), J.L. Bengtson, P. Boveng, J.K. Jansen, L. M. Hiruki, W.R. Meyer, M.F. Cameron (USA), M. Naganobu, S. Kawaguchi and T. Ogishima (Japan)

OTHER DOCUMENTS

SC-CAMLR-XIV/BG/2	DRAFT CEMP TABLES 1 TO 3
SC-CAMLR-XIV/BG/10	FINAL REPORT OF SCIENTIFIC OBSERVATIONS OF COMMERCIAL KRILL HARVEST ABOARD THE JAPANESE FISHING VESSEL *CHIYO MARU NO. 2*, 19 JANUARY 1995 - 2 MARCH 1995
SC-CAMLR-XIV/BG/11	REPORT OF THE 1995 APIS PROGRAM PLANNING MEETING

AGENDA

Working Group on Ecosystem Monitoring and Management
(Siena, Italy, 24 July to 3 August 1995)

1. Introduction
   (i) Opening of the Meeting
   (ii) Organisation of the Meeting and Adoption of the Agenda

2. Aims and Objectives of WG-EMM

3. Data
   (i) Fisheries
      (a) Catches, Status and Trends
      (b) Observer Scheme
      (c) Other Information
   (ii) Surveys on Harvested Species
   (iii) Dependent Species
   (iv) Environment
   (v) Biology and Ecology of Harvested and Dependent Species of Particular Relevance to Fisheries Management and CEMP

4. Harvested Species
   (i) Methods for Estimating Distribution, Standing Stock, Recruitment and Production of Harvested Species
   (ii) Analysis and Results of Studies on Distribution, Standing Stock, Recruitment and Production of Harvested Species
   (iii) Interannual and Within-Season Variability in Distribution, Standing Stock, Recruitment and Production of Harvested Species
   (iv) Estimation of Potential Yield
   (v) Consideration of Harvesting Strategy in Commercial Operations
   (vi) Subdivision of Precautionary Limit
   (vii) Future Work

5. Dependent Species

- (i) Background
  - (a) Members' Reports
- (ii) Sites
- (iii) Methods
  - (a) Existing
  - (b) New/Potential
    - (i) At-sea Behaviour
    - (ii) Petrels
    - (iii) Crabeater Seals
    - (iv) Lavage
    - (v) Disease
  - (c) Research Relevant to Existing and/or Potential Methods
  - (d) Human Impact
- (iv) Indices (CEMP Data)
  - (a) Data Submission Review
    - (i) Historical
    - (ii) Current
  - (b) Data Presentation
    - (i) Report of Subgroup Meeting (Cambridge)
  - (c) Data Analysis
  - (d) Data Interpretation
- (v) Predator/Prey/Environment Linkages
  - (a) Subarea and Local Consumption and Fishery/Predator Overlap
    - (i) Energy Budgets
    - (ii) Foraging Range/Area/Depth
  - (b) Functional Relationships Between Predator/Prey/Environment
    - (i) Butterworth Model
      - (a) Survival and Reproductive Rates
      - (b) Krill Length Frequency
    - (ii) Other Approaches
  - (c) Other Relevant Research
- (vi) Research Relevant to Non-krill Harvestable Resources

6. Environment
   - (i) Identification of Key Variables
   - (ii) Availability of Data
     - (a) Variability
     - (b) Process Understanding
     - (c) Future Requirements
   - (iii) Environmental Data Required for the Understanding of Other Ecosystem Components

7. Ecosystem Assessment
   - (i) By-catch of Fish in the Krill Fishery
   - (ii) Interactions Between Harvested and Dependent Species
   - (iii) Krill Fishery/Dependent Species Interactions
   - (iv) Environment ∅ Harvested Species/Dependent Species Interactions
   - (v) Approaches to the Integration of Harvested Species/Dependent Species/ Environment Interactions into Management Advice
   - (vi) Consideration of Possible Management Measures
   - (vii) Extension of the Scope of CEMP
   - (viii) Future Work

8. Advice to the Scientific Committee
   - (i) General Advice
   - (ii) Management Advice
   - (iii) Future Work

9. Other Business

10. Adoption of the Report

11. Close of the Meeting.

REPORT OF THE SUBGROUP FOR THE RE-ANALYSIS OF RECRUITMENT AND ABUNDANCE INDICES FOR ELEPHANT ISLAND

The subgroup developed specifications for re-analysis of the net haul survey data presented in WG-EMM-95/15 using the methods employed by WG-Krill at its last meeting. The subgroup agreed that the following analyses should be undertaken.

> Prepare a review of the information available about the distribution of krill by age in and around the study area as an aid to interpreting the results of analysis. This should include a review of available information about krill movements into and out of the study area, and, to the extent possible, where and for how long krill may be retained in the area.
>
> Analysis of recruitment proportions using the maximum likelihood method (de la Mare, 1994[1]) for both 1+ and 2+ recruitment proportions.
>
> Analysis of net haul abundance estimates using the delta distribution estimators (Pennington, 1983[2]; de la Mare, 1994[1]).
>
> Analysis of the 1+ and 2+ recruitment proportions for possible serial correlation.

2. For producing a time series of annual recruitment proportions from the Elephant Island surveys, the analyses will be split by month and pooled after analysis using inverse variance weighting. Where one or more of the separate surveys show zero recruitment, i.e. empty classes over the range of lengths for recruits, the raw data should be pooled before analysis, so as to avoid averaging with an infinite weight.

3. The complete net haul data from wide-area surveys in 1985, 1987 and 1989 should also be analysed for recruitment proportions and densities.

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[1] de la Mare, W.K. 1994. Estimating krill recruitment and its variability. *CCAMLR Science*, Vol. 1: 55-69.

[2] Pennington, M. 1983. Efficient estimators of abundance for fish and plankton surveys. *Biometrics*, 39: 281-286.

4. It is recommended that the Working Group establish a steering group to coordinate the analysis and develop the methodology to be employed in incorporating the recruitment indices into the krill yield model. The steering group should include at least Dr Agnew, Prof. Butterworth, Drs de la Mare, Hewitt, Loeb and Siegel.

5. Dr De la Mare will make available the most recent version of the maximum likelihood program, complete with user notes, to Drs Siegel and Loeb as soon as possible after the meeting (early September).

6. Drs Siegel and Loeb will circulate the results of the review of krill distribution and the re-analyses before January 1996 to members of the steering group. Dr De la Mare will estimate the autocorrelation coefficients and possible trends from the analyses. The steering group will provide such comments as it believes to be necessary in interpreting the results, and make the results available to members of the Scientific Committee and WG-EMM. The steering group will, by correspondence, determine the next steps to be taken to take the results into account in calculating precautionary catch limits for Area 48, and arrange for preliminary calculations to be completed in time for the next meeting of WG-EMM.

REPORTS OF MEMBERS' ACTIVITIES RELATING TO CEMP

This appendix contains descriptions of Members' activities in relation to CEMP that were submitted to this meeting by participants (Argentina, Australia, Chile, Italy, Japan, New Zealand, Norway, South Africa, Sweden, UK and USA).

2. In February and March 1995, Argentina conducted a research cruise around the South Georgia and South Orkney Islands as well as in the waters of the Weddell/Scotia confluence. The first leg of the cruise was focused on a fish survey and the second on a krill survey. During the krill survey, acoustic data using a Simrad EK500 echosounder as well as net samples were collected. The data from both surveys will be available to CCAMLR-XIV. A similar cruise is planned for the next season.

3. Studies on the use of shag dietary data to monitor changes in coastal fish populations at Duthoit Point and Half-moon Island were continued, in the South Shetland Islands and at Pirie Peninsula at Laurie Island in the South Orkney Islands. Next season, the study area will be extended to include Harmony Point, Nelson Island.

4. Several parameters of Adélie penguins were measured in accordance with CEMP Standard Methods at Stranger Point, Hope Bay and Laurie Island. For the next season it is planned to continue this routine.

5. The diet of the cape petrel at Laurie Island has been studied as part of bird monitoring studies. This line of work will be continued.

6. Australia continued its CEMP monitoring program at Béchervaise Island using automated means supplemented by manual observations. The 1994/95 season was unusual in that all chicks died in the guard phase. Studies reported in WG-EMM-95/33 suggested that these deaths were due to starvation. Disease has not been implicated and no fishing has occurred in the foraging region over the past five years. Plans for the 1995/96 season include further investigations of this phenomenon in addition to routine monitoring at Béchervaise Island.

7. Australia will also conduct monitoring studies during the 1995/96 season only at Casey and probably Dumont d'Urville in collaboration with France. These studies are being

undertaken in conjunction with the extensive krill survey to be conducted by Australia in Division 58.4.1 (WG-EMM-95/43). Satellite tracking combined with TDRs will be used to determine foraging range/depth at all sites.

8. During the Antarctic season 1994/95 the Instituto Antártico Chileno carried out a census including weighing pups in the *Arctocephalus gazella* breeding colony at the CEMP site, Cape Shirreff and San Telmo Islands.

9. Counts from this season (15 841 animals) and all previous seasons were tabled (WG-EMM-95/77). Pups were weighed using CEMP Standard Method C2.B. On each occasion 50 individuals of each sex were measured.

10. A census of post-breeding colonies of elephant seals at Cape Shirreff was also conducted. A total of 656 elephant seals was counted in 1995 in comparison to 1 375 animals counted in 1994.

11. A total of 251 kg of marine debris was collected in 1995 at Cape Shirreff, after the study baseline was established in 1994. Two specimens of *A. gazella* were recorded entangled, and one of them - a female - was released from the neck collar (piece of net). An exploratory analysis of heavy metals in bones from carcasses of Antarctic fur seals has also been undertaken.

12. A bathymetric chart of waters around Cape Shirreff and the San Telmo Islands CEMP site and SSSI No. 32 was published in September 1994 by the Servicio Hidrográfico y Oceanográfico de la Armada de Chile (SHOA), (SHOA chart No. 14301, scale 1:15 000). A copy of this chart has been submitted to the CCAMLR Secretariat.

13. During the 1994/95 season a joint Italy/Australia biological research program on the biology of Adélie penguins was undertaken at Edmonson Point (74°21'S, 165°05'E) in the Ross Sea region. The site, colony layout and breeding chronology were documented.

14. Investigation of diet and foraging activities were carried out using analysis of foraging trip duration and stomach contents combined with satellite tracking and time-depth recordings. Toxicological and disease studies were commenced.

15. As part of the program an automated penguin monitoring system (APMS) was installed to collect data automatically. Data on CEMP parameters A2, A3 and A5 to A9 were submitted. The program will continue in season 1995/96.

16. Japan continues to monitor the annual trends in breeding population size of Adélie penguins near Syowa Station. From this coming season, studies on Adélie penguins will be conducted with an emphasis on predator-ice interaction using new techniques.

17. New Zealand continues its research activities in the Ross Sea which are closely related to CEMP goals. Monitoring of the size of some of the southernmost Adélie penguin breeding colonies on Ross Island has been carried out regularly since the 1960s, and for all other colonies in the Ross Sea since 1981.

18. In 1995 Norway continued studies of Antarctic petrels at Svarthamaren, Dronning Maud Land with logistic support from South Africa.

19. Norway also participated in the survey of pack-ice seals conducted from a US coastguard ice-breaker during February/March 1995.

20. In May 1994, South Africa initiated monitoring of various aspects of the biology of gentoo penguins (*Pygoscelis papua*) and macaroni penguins (*Eudyptes chrysolophus*) at Marion Island (Prince Edward Islands), in accordance with CEMP Standard Methods. Some of the CEMP procedures were also applied to rockhopper penguins (*Eudyptes chrysocome*). Breeding colonies of gentoo penguins were found to be unduly disturbed by some of the more intensive monitoring procedures. To reduce disturbance to this species, information on its breeding success and breeding chronology in 1995/96 will be based on observations made from outside breeding colonies using binoculars.

21. In July 1994, a census indicated that 1 346 pairs of gentoo penguins were breeding at Marion Island. In November 1994, counts were made of 173 077 pairs of rockhopper penguins and 841 pairs of imperial cormorants (*Phalacrocorax atriceps*) breeding at Marion Island. All three of these counts are substantially (25 to 52%) higher than the previously reported figures for breeding populations at Marion Island - 888, 137 652 and 589 pairs respectively (Cooper and Brown, 1990, *S. Afr. J. Antarct. Res.*, 20(2): 40-57).

22. Sweden has no CEMP-related monitoring activity. Basic research on king penguins and elephant seals is undertaken in cooperation with BAS (UK).

23. During March/April 1995 a bottom fauna survey around South Georgia using a ROV (SeaOwl MK II) was undertaken in collaboration with the USA (AMLR program).

24. UK land-based research in support of CEMP is conducted at Signy Island, South Orkney Islands and Bird Island, South Georgia. Parameters measured in 1995 were identical to those recorded in 1992 to 1994 (SC-CAMLR-XI, Annex 7, Appendix D, paragraph 20) and are listed in Table 1 of SC-CAMLR-XIV/BG/2.

25. In addition, the detailed demographic studies on grey-headed and black-browed albatrosses and on Antarctic fur seals were continued, and these now provide annual data on population size, adult survival, juvenile survival (recruitment), breeding frequency and breeding success for albatrosses and age-specific fecundity rate, maternal mass, pup birth mass and breeding success for fur seals.

26. Additional directed research (summarised in Table 2 of SC-CAMLR-XIV/BG/2) is being carried out on:

(i) chick growth, foraging trip duration, meal size and at-sea activity budgets of albatrosses, especially black-browed albatross; and

(ii) aspects of diving performance and at-sea activity and energy budgets in Antarctic fur seals.

27. The UK was represented on a research cruise on a US coastguard icebreaker in February/March 1995. During the cruise, a survey of pack-ice seal distribution and abundance between Adélie Land and the eastern Weddell Sea was carried out. The primary aim was to examine the methodology involved in carrying out surveys of seals in pack-ice and to deploy satellite transmitters on crabeater seals. The survey showed that line transect methods were greatly superior to those using strip transects and that surveys from ships moving through pack-ice can be as effective as helicopter-based surveys. This cruise contributed to the SCAR APIS research program.

28. United States activities in 1994/95 directly related to CEMP consisted of:

(i) land-based predator studies at Seal Island, near Elephant Island, and at Palmer Station, Anvers Island;

(ii) repeated surveys of hydrographic conditions, phytoplankton production, and krill abundance and distribution in the waters surrounding Elephant Island; and,

(iii) cooperative Japanese/US predator/prey interactions study at Elephant Island.

Preliminary reports on activities (i) and (ii) are provided in the AMLR field season report, WG-CEMP-94/37.

29. At Seal Island, monitoring according to CEMP Standard Methods and directed research in support of CEMP objectives were conducted on populations of Antarctic fur seals, chinstrap penguins and macaroni penguins. Field procedures were conducted for Standard Methods A4, A5, A6 (procedures A and C), A7, A8, A9, C1 and C2. In addition, directed research was conducted on foraging ecology and at-sea behaviour of fur seals and penguins, and penguin breeding population size. An automated, land-based system for tracking seals and penguins to determine foraging locations was further developed and tested.

30. Two 30-day cruises were conducted aboard the NOAA ship *Surveyor* from mid-January to mid-March 1995 in the vicinity of the Seal Island CEMP site near Elephant Island. Chlorophyll *a* concentrations, primary production rates, organic carbon concentrations, phytoplankton species compositions, nutrient concentrations, and solar irradiance were measured and mapped. In addition, the distribution and abundance of krill were measured using sampling nets and hydroacoustic instrumentation.

31. During December 1994 and January 1995, a collaborative cruise with Japanese scientists on board the RV *Kaiyo Maru* was conducted near Elephant Island to investigate predator/prey interactions among Antarctic krill and its marine mammal and bird predators. Shipboard surveys of hydrographic conditions, phytoplankton production, krill distribution, abundance and demography were conducted.

32. In support of the NSF's LTER Program an oceanographic cruise was conducted by the NSF ship *Polar Duke* in January 1995. Primary production rates, chlorophyll *a* concentrations, organic carbon concentrations, microbial production rates, nutrient concentrations and irradiance were investigated in an area from Palmer Station to Rothera Station. Krill distributions were measured using nets and acoustic instrumentation. Seabird surveys were conducted and Adélie penguin diet samples were collected in the Palmer Station area.

33. Anticipated CEMP-related field work in 1995/96 will include continued penguin monitoring at Palmer Station. Studies at Seal Island are likely to be suspended because of safety conditions on the island. Various sites suitable for the relocation of the camp will be inspected during the 1995/96 season and a new site will be established in the 1996/97 season. The LTER program will continue to conduct field research similar to that conducted this year. Additionally, there will be an increased focus on modelling studies of value to the LTER, AMLR, to CCAMLR and to GLOBEC.

34. In addition, a collaborative study with Sweden was conducted aboard the RV *Surveyor* during January/February 1995 in waters around South Georgia using a ROV. The study's primary objective was to investigate Antarctic crab abundance and distribution. However, this objective could not be accomplished because of severe sea states and currents; therefore, the secondary objectives were investigated. These were to investigate benthic communities in inshore regions around South Georgia.

EXTENSIONS TO KRILL-PREDATOR MODELLING EXERCISES

(a) Black-browed albatross

(i) Adult survival rate: Annual estimates and associated variance to be taken from Prince et al. (1994)[1].

(ii) Fecundity: Data on annual laying rates and fledging success to be taken from Prince et al. (1994)[1]. The associated precision may be estimated under the assumption of a binomial distribution (as these data pertain to the whole study population).

(iii) Population trend: Sub-adult survival rate to be adjusted so that the model population reflects the observed decline of 31% from 1976 to 1989 (Prince et al., 1994[1]).

(iv) Density dependence: It may be assumed that fecundity alone is responsible for density dependence. As a guide to the possible level of such dependence, an estimated maximum population rate of increase of 5% per annum for the wandering albatross (de la Mare and Kerry, 1994[2]) may be used. A further guide which may be more appropriate is provided by the data on observed maximum rates of increase of black-browed albatrosses at different colonies at Bird Island as set out in Croxall et al., 1994[3].

(v) Age at first laying: This is to be taken as 10 years (a modal value - see Croxall et al., 1994[3]).

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[1] Prince, P.A., P. Rothery, J.P. Croxall and A.G. Wood. 1994. Population dynamics of black-browed and grey-headed albatrosses *Diomedea melanophris* and *D. chrysostoma* at Bird Island, South Georgia. *Ibis*, 136: 50-71.

[2] de la Mare, W.K. and K. Kerry. 1994. Population dynamics of the wandering albatross (*Diomedea exulans*) on Macquarie Island and the effect of mortality from longline fishing. *Polar Biology*, 14(4): 231-241.

[3] Croxall, J.P., I.L. Boyd and P.A. Prince. 1994. Modelling functional relationships between predators and prey. Document *WG-Joint-94/5*. CCAMLR, Hobart, Australia.

(b) Antarctic fur seal

(i) Adult survival rate: The annual estimates provided in Table 1 of Boyd et al. (1995)[4], which also provides estimates of precision, are to be inflated so that the model population can achieve the annual growth rate of some 10% observed in the recent past (Boyd, 1993[5]). These mark-recapture-based estimates are probably biased downwards because of (1) effects of tag loss, (2) emigration of tagged animals and (3) the study colony animals may have a larger average age than those in the overall population.

(ii) Age at first parturition: Results should be computed for values of this age of both three and four years, though three is probably closer to the actual situation.

(iii) Fecundity: This is a combination of pregnancy rate and pup survival rate. Table 1 of Boyd et al. (1995)[4] provides annual estimates of both pregnancy rate (with confidence intervals) and pup survival rate. The precision of pup survival rate may be estimated under the assumption of a binomial distribution (as these data pertain to the whole study colony).

(iv) Sub-adult survival rate: The value of the parameter that relates this to the adult survival rate will be confounded with the value of the parameter which 'inflates' the estimates for the adult rate (see (i) above). As a guide to the region of parameter space to be investigated, the high costs (in survival terms) of reproduction are considered to suggest a sub-adult rate somewhat higher than the adult rate.

(v) Density dependence: There was a population rate increase of 16.8% per annum through the 1960s. This may have been driven by either high adult survival or immigration. Data on age structure from the early 1970s suggest adult female survival may have been greater than through the 1980s. There is also a relationship between adult female survival and an index of food availability, as reported in Boyd et al. (1995)[4]. Therefore, both adult survival rate and fecundity are likely to be responsible for density dependence.

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[4] Boyd, I.L., J.P. Croxall, N.J. Lunn and K. Reid. 1995. Population demography of Antarctic fur seals: the costs of reproduction and implications for life-histories. *Journal of Animal Ecology*, 64: 505-518.

[5] Boyd, I.L. 1993. Pup production and distribution of breeding Antarctic fur seals (*Arctocephalus gazella*) at South Georgia. *Antarctic Science*, 5: 17-24.

Given the uncertainty associated with the various estimates of population rates of increase, a range of values for the maximum annual rate of population increase possible (from 5 to 17%) will be considered. A range of combinations of density dependence on fecundity and on the adult survival rate will also be considered.

(c) Adélie penguin

Fundamental model assumptions

After discussion, the assumptions for this model were recast in the following form.

(i) The population consists of two components:
   (a) non-colony birds aged 0 to 4, which are non-breeding; and
   (b) colony birds aged 2 to 5+.

(ii) Non-colony birds may move to the colony at the start of each year. All 5-year-old birds move. A fraction (λ_y) of the birds aged 2 to 4 also move - this fraction varies from year to year.

(iii) Birds attempting to breed for the first time have a lower fledging success rate because of their inexperience. This rate varies from year to year (τ_y). These are the birds aged 3 to 5 which have just moved to the colony.

(iv) Birds which first move to the colony at age 2 do not breed that year. It is unclear whether such birds gain 'experience' from this process, and therefore whether the experienced (κ_y) or inexperienced (τ_y) fledging rate applies to them when they first breed the following year when aged 3. Calculations are to be attempted for both possibilities.

(v) Experienced (non-first-time) breeders have a yearly varying fledging success rate (κ_y) which exceeds that for the first-time breeders (i.e., $\kappa_y > \tau_y$).

(vi) Survival rates are as follows:

0-year-old non-colony birds:	S^J_y	(i.e., annually varying)
1- to 4-year-old non-colony birds:	S^I	(fixed in time)
first-breeding colony birds:	μS^A	(fixed in time)

non-first breeding colony birds: S^A (fixed in time)

2-year-old non-breeding colony birds: a range of options from S^A to S^I to be investigated (note that when breeding the following year, calculations should include a range of options from μS^A to S^A for the survival rate).

The rationale for the distinctions above is as follows.

The heaviest pre-breeding mortality probably occurs immediately after fledging when the animals struggle to learn to forage for themselves. This is the reason for the distinction between S^J and S^I; as this is the stage most likely to depend on krill availability, S^J is made year-dependent. $S^J_y < S^I$.

S^A is less than S^I because of the penalties of breeding (involving greater energy requirements and exposure to leopard seal predation) and migration to the colony.

There is a further survival rate penalty in the year the first attempt is made to breed (the factor μ) due to inexperience.

<u>Data</u>

The existing data (though some of these have yet to be extracted and coded) for input to and fitting of the model are:

(i) annual estimates of the number of colony birds (available for most years), whose CV is to be taken to be 5%;

(ii) annual estimates of fledging success rates κ_y and τ_y for most years (values missing should be substituted by random sampling with replacement from known (κ_y, τ_y) paired values within the Monte Carlo Bayesian integration process).

<u>Prior distributions for unknown parameters</u>

(i) Non-first-time breeders survival rate, S^A: calculations for a series of fixed values of 0.7, 0.75, 0.8 and 0.85 (based upon the 0.8 estimate of Ainley (1983)[6]).

(ii) First-time breeding survival penalty, μ: From U[0, 1].

[6] Ainley, D.G., R.E. Leresche and W.J.L. Sladen. 1993. *Breeding Biology of the Adélie Penguin*. University of California Press: 1-240.

(iii) Non-colony birds survival rate from age 1, S^I: From U[S^A, 1].

(iv) First year of life survival rate, S_y^J: From U[0, S^A].

(v) Fraction of non-colony birds migrating to colony, λ_y: From U[0, 1].

Subsequent calculations may attempt simple positive correlation relationships between λ_y and S_y^J, as both are likely reflections of local krill availability that year, e.g.:

$\lambda_y = S_y^J / S^A + \in$ where $\in$ from U [-0.1, 0.1]
subject to $0 \leq \lambda_y \leq 1$.

<u>Key outputs for subsequent krill-predator modelling</u>

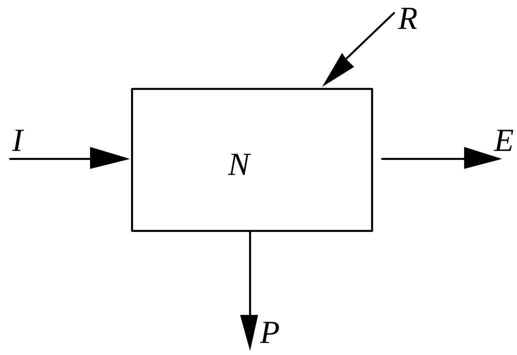
Posterior estimates of a time series for S_y^J (and also λ_y), from which to estimate a functional relationship to krill abundance via the krill yield model.

Further, correlation of the posterior estimates of these two quantities with each other, with κ_y and τ_y, and with environmental indices would be of interest as a basis for testing hypotheses about environmental factors which may (through their impact on krill) influence Adélie penguin demographics.

FURTHER DEVELOPMENT OF THE APPROACH OF BASING A PRECAUTIONARY LIMIT FOR KRILL FISHING IN A REGION ON THE PREDATOR CONSUMPTION IN THAT REGION

D.S. Butterworth

Consider the following schematic representation of krill dynamics in a region in the absence of a krill fishery. The region (*R*) could, for example, be the shaded area around South Georgia in Figure 1 of WG-EMM-95/17.



N is the number of krill in the region at a particular time;
I is the flux of krill (numbers/year) into the region;
E is the flux of krill (numbers/year) out of the region;
P is the consumption of krill (numbers/year) by predators in the region.

Then, in the absence of krill recruitment within the region:

$$\frac{dN}{dt} = I - E - P \tag{1}$$

so that in a steady state:

$$I - E - P = 0 \tag{2}$$

$N = N_u$ (*u* indicating 'unexploited')

Further relationships can be written as follows

$$P = M\,N$$
$$E = \in N \qquad (3)$$
$$T = N_u/I$$

where M = krill natural mortality rate (yr^{-1})
$\in$ = krill (per capita) outflow rate (yr^{-1})
T = krill turnover rate in region R in the absence of exploitation (yr).

Equation (2) can then be written:

$$N_u/T = \in N_u - M\,N_u = 0$$
i.e. $$1/T = \in + M \qquad (4)$$

Now add a krill harvest C (numbers/yr), which is set at a fraction λ^* of the predators' consumption of krill in the absence of exploitation, i.e.:

$$C = \lambda^*\,P_u = \lambda^* M\,N_u.$$

Equations (1) and (2) now become:

$$\frac{dN}{dt} = I - E - P - C \qquad (5)$$
$$I - E - P - C = 0 \quad ; \quad N = N_e \text{ (} e \text{ indicating 'exploitation')}$$

The predators will be affected by a decrease in the density of krill in region R, so that the ratio of interest is N_e/N_u . Now, from equation (5):

$$I - \in N_e - M\,N_e - C = 0$$

so that:

$$N_e = (I - C) / (\in + M) \qquad (6)$$

while from equation (2):

$$N_u = I / (\in + M) \qquad (7)$$

Thus:

$$N_e \; / \; N_u \; = 1 - \frac{C}{\in + M} \left(1 \, / \, N_u\right)$$

but 1 / ($+ M$) = T from equation (2) and $C = \lambda^* M \, N_u$, so eventually:

$$\boxed{N_e \, / \, N_u = 1 - \lambda^* M \, T} \qquad (8)$$

Say we believe that the predators could tolerate an average drop in the krill density of x%. The allowable krill harvest as a fraction of predator consumption (λ^*) is then given by:

$$x/100 = \lambda^* M \, T$$

i.e. $\lambda^* = x/(100 \, M \, T)$ (9)

For example, if we take $x = 10$, $M = 0.7$ yr^{-1} and $T = 0.25$ yr, then a krill harvest as a fraction of predator consumption of $\lambda^* = 0.57$ (57%) would cause a 10% drop in krill density in region R.

Conversely, if λ^* is set to 10%, then the drop in krill abundance is $x = 0.0175$ ($1^3/_4$%).

Questions:

(i) This analysis is entirely in terms of krill NUMBERS - what happens if we change to BIOMASS? Note that strictly then, the growth in mass of individual krill while within region R should also be taken into account. Overall, however, this aspect does not seem likely to affect results markedly, particularly if the predators and fishery have similar selectivity-at-age functions.

(ii) How does M as used here relate to the value customarily taken to reflect the krill natural mortality rate? Since R is a region of higher predator density, the M value to be used here should be somewhat higher than the 'global' value customarily used for krill natural mortality. However, this might be counterbalanced by the fact that the estimate of predator consumption ($P = M \, N_u$) which the calculated λ^* value would multiply may take account only of land-breeding predators. In other words, setting $C = \lambda^* \, P$, we may overestimate λ^* by using too small a value for M in equation (8), but may simultaneously underestimate P by not taking account of pelagic predators.

(iii) If *C* is all concentrated in a small sub-region of region *R*, would this affect conclusions? Yes - IF the predators in the region make particular use of that sub-region AND krill mixing within *R* is slow in relation to the rate of removals from the sub-region.

(iv) What if *C* is taken upstream of region *R*? The inward flux (*I*) would decrease so that krill density within *R* would again fall. The fall might be less than indicated by equation (8), however, as some of the catch *C* would be taken from krill that would otherwise have bypassed region *R* (to the north or south), and therefore not contribute to the diminution of *I*.

REPORT OF THE SUBGROUP FOR CALCULATING PRECAUTIONARY CATCH LIMITS WITHIN SUBAREA 48.3 BASED ON MASS OF KRILL CONSUMED BY PREDATORS

The subgroup considered the modification suggested by Dr de la Mare to the method proposed by Dr Everson in WG-EMM-95/17. The basic modification is to calculate a precautionary catch limit using the krill yield model with an unexploited biomass value derived from predator consumption. The precautionary catch limit is given by:

$$C = \gamma B_o$$

where *g* is the precautionary catch limit as a proportion of biomass, as calculated from the krill yield model. Applying this formula requires an estimate of B_o, which is not available for Subarea 48.3. However, the total krill consumed by land-breeding predators can be used to provide a calculated lower bound on the biomass which would be obtained if a survey were carried out in the area. This is given by the following formula:

$$B_o = \frac{P}{\left(1 - e^{-M}\right)V}$$

where P is the annual consumption of krill by land-breeding predators;
M is the annual rate of krill natural mortality; and
V is the annual turnover of krill in the area (with dimension year^{-1}, i.e. 1/retention time).

2. *g* is calculated using the krill yield model. Applying the method requires estimates of P, M and V. However, the krill yield model also requires an estimate of the variance of B_o, and this could be calculated using the delta method from separate variance estimates for P, M and V. Estimates of M and its variance are already available as a component of the krill yield model, based on the analyses of krill recruitment proportions.

3. The subgroup recommended that the Working Group establish a steering group to coordinate the analyses and develop the methodology for estimating the parameters. The steering group should include at least Drs Agnew, Boyd, Prof. Butterworth, Drs Croxall, de la Mare, Everson, Holt and Naganobu.

4. Land-based predator consumption at South Georgia will be estimated by Drs Boyd and Croxall. They will attempt to provide a variance estimate for this parameter.

5. The subgroup agreed to attempt the application of the method on two geographic scales:

(i) the whole of Subarea 48.3; and
(ii) within the foraging distance of the key krill-dependent predators breeding at South Georgia.

6. Drs Everson and Murphy undertook to provide estimates of retention times at these two scales. At the subarea scale, the subgroup agreed that the FRAM model could be used to calculate an estimate of the water turnover. It may be difficult to assign a variance to this estimate, but it was agreed that consultations among the steering group will take place to consider how this might be attempted. At the smaller scale, the subgroup considered that direct hydrographic calculations would be needed using all available data.

7. The method would be applied initially at the temporal scale of the whole year; if time permitted other scales, including those relating to critical periods, would be investigated.

8. The estimates of P, M and V will be available by the end of June, 1996, so as to allow the re-calculation of g using the krill yield model in time for the next meeting of WG-EMM.

TEMPORAL CHANGES IN MARINE ENVIRONMENTS IN THE ANTARCTIC PENINSULA AREA DURING THE 1994/95 AUSTRAL SUMMER

(Executive Summary of the Report of a Workshop Held at the Institut für Seefischerei, Hamburg, Germany, 16 to 21 July, 1995)

INTRODUCTION

1. At the 1993 meeting of the CCAMLR Scientific Committee and again at the 1994 meeting of the Working Group on Krill (WG-Krill), Dr S. Kim (Republic of Korea) noted that several Members had announced plans to conduct shipboard research in the vicinity of the South Shetland Islands (Figure I.1). Dr Kim further suggested that it would be advantageous to coordinate the planning of such work and to meet afterwards to discuss results.

2. Accordingly, representatives from Germany, Japan, Republic of Korea and the USA met during the 1994 meeting of WG-Krill and agreed to adjust their respective field research plans to include observations at a common set of stations. Five stations were set 15 n miles apart along the 55°W meridian north of Elephant Island (Figure I.1) and corresponded to Stations 60 to 64 on the US AMLR grid which has been occupied twice each austral summer since 1991.

3. The five stations were occupied six times between late November 1994 and late February 1995 during research cruises conducted by Germany, Japan, Republic of Korea and the USA. Observations included CTD profiles, chlorophyll *a* and nutrient concentrations at various depths, net samples of zooplankton, and acoustic transects between stations. In addition, Japan inserted an extra inshore station, the Republic of Korea occupied additional stations along 55°W south of Elephant Island, Germany occupied 77 of the 91 stations in the AMLR grid, and the USA occupied all 91 stations. Table I.1 lists the cruise dates, the dates that the common stations along 55°W were occupied, the survey areas, the types of observations conducted and the equipment used by each Member country.

4. Dr V. Siegel (Germany) volunteered to host a post-season workshop at the Institut für Seefischerei in Hamburg immediately prior to the 1995 meeting of the Working Group on Ecosystem Monitoring and Management (WG-EMM) to discuss results of the field work.

Dr Kim, Dr Siegel, Dr M. Naganobu (Japan), and Dr R. Hewitt (USA) were co-conveners of the workshop entitled ‘Temporal changes in marine environments in the Antarctic Peninsula area during the 1994/95 austral summer’.

5. The workshop was attended by Dr V. Siegel, (Germany), Mr T. Ichii, Drs M. Naganobu and S. Kawaguchi (Japan), Drs S. Kim and Sung Ho Kang (Republic of Korea), Dr I. Everson (UK), Drs D. Demer, R. Hewitt and V. Loeb (USA).

6. The workshop was organized into four subgroups: physical oceanography, phytoplankton and nutrients, zooplankton (including krill demographics), and acoustics. The sub-group reports and recommendations of the workshop for future work are presented in the following paragraphs for consideration by WG-EMM.

7. Of particular note are four conclusions: (i) the north/south position of the oceanic frontal zone north of Elephant Island along 55°W varied by 15 n miles and the relatively narrow northeasterly current associated with this front varied in strength depending on position of the front; (ii) nutrient depletion occurred as the season progressed, probably associated with phytoplankton species succession; (iii) krill spawning during the 1994/95 season was early, extensive and apparently successful; and (iv) taxa other than krill may have caused a substantial portion of the observed acoustic backscattering strength.

Recommendations

8. The causes of the frontal zone movement north of Elephant Island and its influence on the behaviour of organisms should be investigated. The persistent feature of cold water between 75 and 100 m north of Elephant Island should be investigated in relation to zooplankton distribution and primary production.

9. Observations of only chlorophyll *a* concentrations limited the assessment of phytoplankton populations as food reservoirs for krill. We recommend that measurements of the size distribution of cells, carbon biomass, and species composition be made in addition to measurements of chlorophyll *a* concentrations.

10. The factors that control krill recruitment have been described in a conceptual model in WG-EMM-95/15. The 1994/95 field season data analysed during the workshop seem to confirm the first half of the model (early krill spawning, high larval production, low salp density). The second half of the model (recruitment) can be tested during the coming austral summer season 1995/96. We

strongly recommend a survey, or at least a representative sampling program, in the Elephant Island area at that time to provide the essential data to test the prediction made regarding krill recruitment.

11. A two-frequency approach was shown to be useful in delineating size classes and in identifying a previously undescribed acoustic scattering layer. In the future, multiple frequency echosounders and species delineation techniques should be used to apportion the total integrated echo energy to the various scatters. Frequency combinations which include both the Rayleigh and geometric scattering regimes are most powerful when using inversion techniques.

Table I.1: Antarctic 1994/95 cruises conducted by Member countries.

Dates of Entire Cruise (Dates at 55°W Transect)	Country	Observations
26 November - 5 December 1995 (2 December 1995)	Germany	North and south of Elephant Island; water properties, krill/zooplankton; CTD, RMT8 (4 mm) net
30 November - 30 December 1994 (15 - 16 December 1994)	Japan (Leg I)	North of South Shetland Islands; krill/zooplankton, phytoplankton, nutrients; acoustics, CTD, rosette, WP-2 (0.350 mm), KYMT, (3 x 3 m with 3.4 mm mesh), MOCNESS at three stations (0.335 mm mesh), Furuno FQ-72 echosounder
4 - 17 January 1995 (7 - 8 January 1995)	Republic of Korea	Bransfield Strait and northwestern Weddell Sea; krill/zooplankton, phytoplankton, water properties, nutrients; CTD, rosette, Bongo (0.333 mm mesh and 0.505 mm mesh), MOCNESS (0.505 mm mesh)
15 January - 12 February 1995 (18 - 19 January 1995)	Japan (Leg II)	North of South Shetland Islands; krill/zooplankton, phytoplankton, water properties, nutrients; acoustics, CTD, rosette, WP-2 (0.350 mm), MOCNESS (0.335 mm mesh) at six stations
11 January - 4 February 1995 (24 - 25 January 1995)	USA (Leg I)	North and south of Elephant Island; krill/zooplankton, phytoplankton, nutrients; acoustics, CTD, IKMT (1.8 x 1.8 m with 0.505 mm mesh), rosette, Simrad EK-500 echosounder
8 February - 5 March 1995 (18 - 19 February 1995)	USA (Leg II)	North and south of Elephant Island; krill/zooplankton, phytoplankton, nutrients; acoustics, CTD, IKMT (1.8 x 1.8 m with 0.505 mm mesh), rosette, Simrad EK-500 echosounder

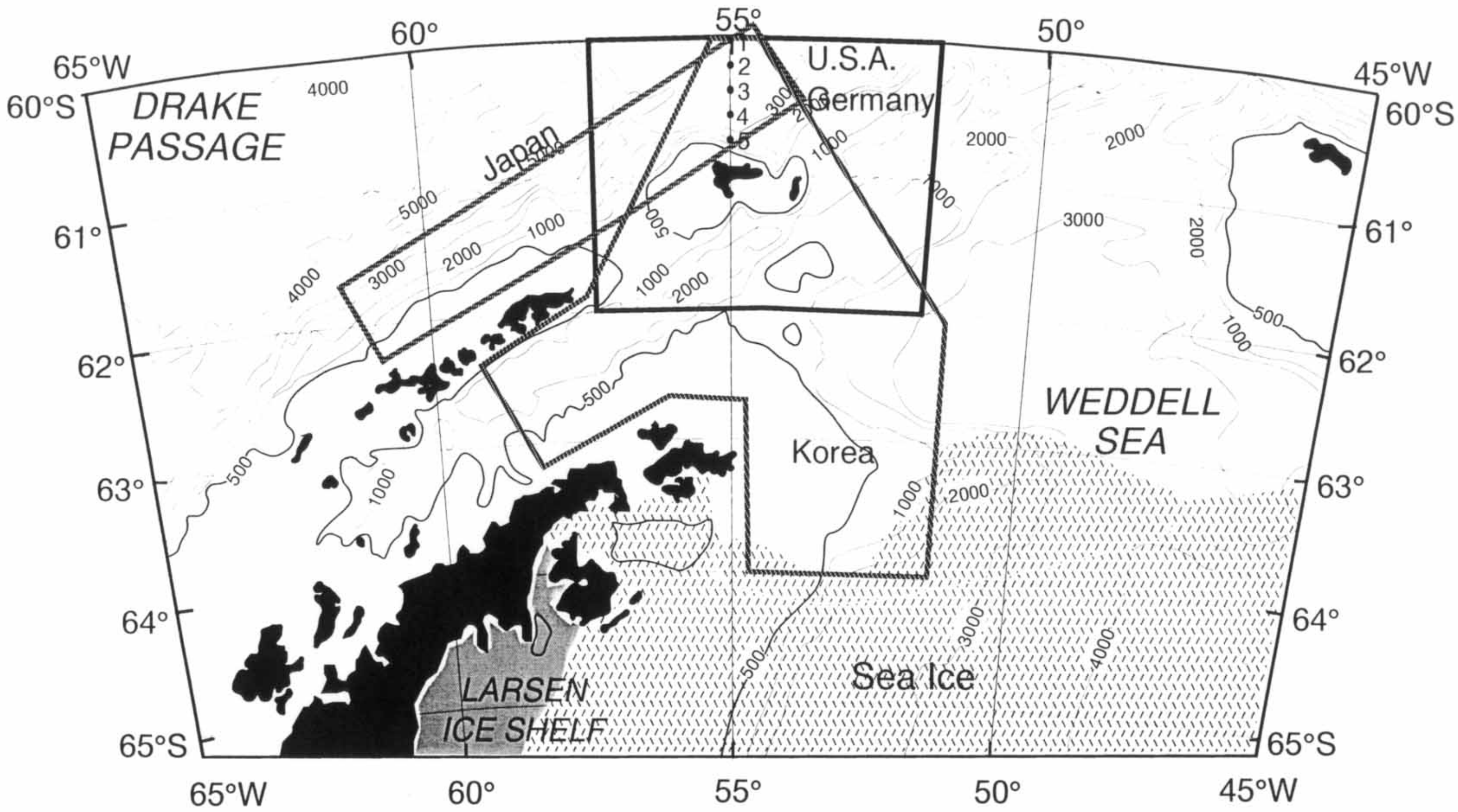


Figure I.1: Survey areas covered by different nations during late November 1994 to late February 1995.