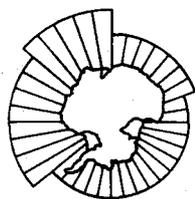


Intergovernmental Oceanographic Commission

Workshop Report No. 50

CCAMLR-IOC Scientific Seminar on Antarctic Ocean Variability and its Influence on Marine Living Resources, particularly Krill (organized in collaboration with SCAR and SCOR) Paris, 2-6 June 1987



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No.	Title	Publishing Body	Languages	No.	Title	Publishing Body	Languages
1	CCOP-IOC, 1974, Metallogenesis, Hydrocarbons and Tectonic Patterns in Eastern Asia (Report of the IDOE Workshop on); Bangkok, Thailand 24-29 September 1973 UNDP (CCOP), 138 pp.	Office of the Project Manager UNDP/CCOP c/o ESCAP Sala Santitham Bangkok 2, Thailand	English	16	Workshop on the Western Pacific, Tokyo, 19-20 February 1979.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French Russian
2	CICAR Ichthyoplankton Workshop, Mexico City, 16-27 July 1974 (Unesco Technical Paper in Marine Sciences, No. 20).	Division of Marine Sciences, Unesco Place de Fontenoy 75700 Paris, France	English (out of stock) Spanish (out of stock)	17	Joint IOC/WMO Workshop on Oceanographic Products and the IGOSS Data Processing and Services System (IDPSS), Moscow, 9-11 April 1979.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
3	Report of the IOC/GFCM/ICSEM International Workshop on Marine Pollution in the Mediterranean, Monte Carlo, 9-14 September 1974.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French Spanish (out of stock)	17	Papers submitted to the Joint IOC/WMO Seminar on Oceanographic Products and the IGOSS Data Processing and Services System, Moscow, 2-6 April 1979.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
4	Report of the Workshop on the Phenomenon known as "El Niño", Guayaquil, Ecuador, 4-12 December 1974.	FAO Via delle Terme di Caracalla 00100 Rome, Italy	English (out of stock) Spanish (out of stock)	18	IOC/Unesco Workshop on Syllabus for Training Marine Technicians, Miami, 22-26 May 1978 (Unesco reports in marine sciences, No. 4)	Division of Marine Sciences, Unesco Place de Fontenoy 75700 Paris, France	English (out of stock) French Spanish (out of stock) Russian
5	IDOE International Workshop on Marine Geology and Geophysics of the Caribbean Region and its Resources, Kingston, Jamaica, 17-22 February 1975.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English (out of stock) Spanish	19	IOC Workshop on Marine Science Syllabus for Secondary Schools, Llantwit Major, Wales, U.K., 5-9 June 1978 (Unesco reports in marine sciences, No. 5).	Division of Marine Sciences, Unesco Place de Fontenoy 75700 Paris, France	English French Spanish Russian Arabic
6	Report of the CCOP/SOPAC-IOC IDOE International Workshop on Geology, Mineral Resources and Geophysics of the South Pacific, Suva, Fiji, 1-6 September 1975.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English	20	Second CCOP-IOC Workshop on IDOE Studies of East Asia Tectonics and Resources, Bandung, Indonesia, 17-21 October 1978.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
7	Report of the Scientific Workshop to Initiate Planning for a Co-operative investigation in the North and Central Western Indian Ocean, organized within the IDOE under the sponsorship of IOC/FAO (IOFC)/Unesco/EAC, Nairobi, Kenya, 25 March-2 April 1976.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French Spanish Russian	21	Second IDOE Symposium on Turbulence in the Ocean, Liège, Belgium, 7-18 May 1979.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French Spanish Russian
8	Joint IOC/FAO (IPFC)/UNEP International Workshop on Marine Pollution in East Asian Waters, Penang, 7-13 April 1976.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English (out of stock)	22	Third IOC/WMO Workshop on Marine Pollution Monitoring, New Delhi, 11-15 February 1980.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French Spanish Russian
9	IOC/CMG/SCOR Second International Workshop on Marine Geoscience, Mauritius, 9-13 August 1976.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French Spanish Russian	23	WESTPAC Workshop on the Marine Geology and Geophysics of the North-West Pacific, Tokyo, 27-31 March 1980.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English Russian
10	IOC/WMO Second Workshop on Marine Pollution (Petroleum) Monitoring, Monaco, 14-18 June 1976.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French Spanish (out of stock) Russian	24	WESTPAC Workshop on Coastal Transport of Pollutants, Tokyo, 27-31 March 1980.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English (out of stock)
11	Report of the IOC/FAO/UNEP International Workshop on Marine Pollution in the Caribbean and Adjacent Regions, Port of Spain Trinidad, 13-17 December 1976.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English Spanish (out of stock)	25	Workshop on the Inter calibration of Sampling Procedures of the IOC/WMO UNEP Pilot Project on Monitoring Background Levels of Selected Pollutants in Open-Ocean Waters, Bermuda, 11-26 January 1980.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English (superseded by IOC Technical Series No. 22)
11 Suppl.	Collected contributions of invited lecturers and authors to the IOC/FAO/UNEP International Workshop on Marine Pollution in the Caribbean and Adjacent Regions, Port of Spain, Trinidad, 13-17 December 1976.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English Spanish	26	IOC Workshop on Coastal Area Management in the Caribbean Region, Mexico City, 24 September-5 October 1979.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English Spanish
12	Report of the IOC/ARIBE Interdisciplinary Workshop on Scientific Programmes in Support of Fisheries Projects, Fort-de-France, Martinique 28 November-2 December 1977.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French Spanish	27	CCOP/SOPAC-IOC Second International Workshop on Geology, Mineral Resources and Geophysics of the South Pacific, Nouméa, New Caledonia, 9-15 October 1980.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
13	Report of the IOC/ARIBE Workshop on Environmental Geology of the Caribbean Coastal Area, Port of Spain, Trinidad, 16-18 January 1978.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English Spanish	28	FAO/IOC Workshop on the effects of environmental variation on the survival of larval pelagic fishes Lima, 20 April-5 May 1980.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
14	IOC/FAO/WHO/UNEP International Workshop on Marine Pollution in the Gulf of Guinea and Adjacent Areas, Abidjan, Ivory Coast, 2-9 May 1978.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French	29	WESTPAC Workshop on Marine biological methodology Tokyo, 9-14 February 1981.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
15	CCPS/FAO/IOC/UNEP International Workshop on Marine Pollution in the South-East Pacific, Santiago de Chile, 6-10 November 1978.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English (out of stock)	30	International Workshop on Marine Pollution in the South-West Atlantic Montevideo, 10-14 November 1980.	IOC, Unesco Place de Fontenoy, 75700 Paris, France	English (out of stock) Spanish
				31	Third International Workshop on Marine Geoscience Heidelberg, 19-24 July 1982	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French Spanish
				32	UNU/IOC/Unesco Workshop on International Co-operation in the Development of Marine Science and the Transfer of Technology in the context of the New Ocean Regime Paris, 27 September - 1 October 1982	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French Spanish

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on Antarctic Ocean Variability
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1. OPENING OF THE SEMINAR

The Convenor of the Seminar, Prof. D. Sahrhage, opened the meeting and welcomed the participants. He noted with satisfaction that many distinguished scientists from a considerable number of countries and representatives of international organizations attended this meeting. Many scientific papers had been prepared and were to be presented during the meeting. He pointed out that:

- (i) the Seminar was sponsored jointly by CCAMLR and IOC as their first joint effort. CCAMLR is the international body entrusted with the conservation of Antarctic marine living resources and the protection of the related ecosystem. The Intergovernmental Oceanographic Commission is deeply engaged in the promotion of oceanographic research, and the Southern Ocean as a most important region for the world's climate and oceans circulations takes a prominent place within its overall programme. The combined efforts of both organizations to bring together biologists, oceanographers and meteorologists to such an interdisciplinary meeting should be highly appreciated. Both organizations, besides providing usual assistance of sponsors, agreed also to provide financial funds to facilitate the later publication of Seminar papers in a book;
- (ii) furthermore co-operation of SCAR and SCOR was obtained. From SCAR it was particularly useful to have the experience and results from the BIOMASS programme with FIBEX and SIBEX. From SCOR its Working Group 74 had prepared an useful report on the General Circulation of the Southern Ocean with recommendations for research which are very pertinent to the discussions of the Seminar;
- (iii) SCOR and IOC provided financial assistance to facilitate the participation of several scientists, particularly from developing countries. This was gratefully acknowledged.

The idea for this Seminar was first developed in May 1984. Following a recommendation by the IOC Programme Group for the Southern Oceans made in March 1983, IOC organized a meeting of experts on oceanography related to the dynamics of the Antarctic ecosystem in Kiel (Federal Republic of Germany) where biologists and oceanographers involved in BIOMASS activities met with the oceanographers of SCOR WG 74, to discuss ways and means for additional physical and chemical observations in the oceanographic research within BIOMASS. It was the time when large changes in the distribution of krill had just been found and the questions arose whether this was possibly the result of changes in the Antarctic water ring. During the Kiel meeting, it was agreed to promote close collaboration between oceanographers, biologists and meteorologists to investigate the Antarctic ocean variability and its influence on the marine living resources, particularly krill. Naturally CCAMLR had much interest in this question too, and thus plans for this Seminar were further developed. Due to the absence of many scientists who worked during 1986 in the Antarctic not only during the summer season but also - for the first time - in large winter expeditions, the Seminar had to be postponed until today. However,

this has perhaps provided more time to obtain results and prepare for the meeting.

Dr. Sahrhage then described the main purpose of the Seminar, which is expected to contribute replying to the following questions:

- What is known on the variability in the Antarctic Ocean circulation systems?
- What are the possible causes for such variations?
- To what extent and how does this ocean variability influence primary production, zooplankton and other organisms?
- To what extent and how does this ocean variability influence krill distribution and abundance?
- What are the effects on krill predators (seals, penguins, fishes)?

It should be clear that these items are related to meso- and large scale variability. The Convenor emphasized that sufficient time should be reserved for extensive discussions on conclusions and on recommendations for future research. This was particularly important and timely since immediately after the Seminar, there would be other meetings and activities to carry proposals further into practical steps:

- CCAMLR Working Group on Ecosystem Monitoring Programme (Dammarie-les-Lys, 10-16 June 1987)
- IOC Regional Committee for the Southern Ocean (Paris, 9-12 June 1987)
- Planning of the World Ocean Circulation Experiment (WOCE) (Paris, 10-11 June 1987).

Finally Prof. Sahrhage expressed thanks to the members of the Steering Group for all their assistance and advice for the benefit of the Seminar. Members are:

Dr. Anatolyi Elizarov (USSR)
Prof. Sayed Z. El-Sayed (BIOMASS/USA)
Dr. Arnold Gordon (USA)
Dr. R. Barry Heywood (UK)
Prof. Jean-Claude Hureau (France)
Dr. Enrique Marschoff (Argentina)
Dr. Worth Nowlin, Jr. (SCOR WG 74/USA)
Dr. Yasuhiko Shimadzu (Japan)

Dr. M. Ruivo, Secretary of IOC, welcomed the participants on behalf of IOC and expressed appreciation to CCAMLR as a co-sponsoring organization and SCAR and SCOR for collaboration and support in the preparation of the Seminar.

He noted that the IOC Executive Council at its Seventeenth Session (1984) when considering recommendations of the Fourth Session of the IOC Programme Group for the Southern Oceans instructed the Secretary to proceed further in strengthening the collaboration with organizations relevant to the SOC region, particularly with SCOR, SCAR and CCAMLR.

The Secretary IOC welcomed this Seminar as a good example of co-operation of many countries and various organizations involved in the studies of the Southern Ocean. Investigations in the Southern Ocean, the water ring around Antarctica, and on its living resources, have been intensified during recent years, both through national activities and through internationally co-ordinated programmes, in particular:

- BIOMASS (Biological Investigations of Marine Antarctic Systems and Stocks), established in 1976 for a period of 10 years under the auspices of SCAR and SCOR.
- Review of the present knowledge on the circulation in the Southern Oceans and recommendations for further research in this field by SCOR Working Group 74.
- Planning of the World Ocean Circulation Experiment (WOCE) by SSG for WOCE, as a joint body of CCCO-JSC (IOC, WMO, SCOR and ICSU) which identifies the Southern Ocean as the focus of the second of three core projects.
- Development by IOC of an Ocean Global Observing System, including GLOSS, IGOSS XBT Ship-of-Opportunity Programme (jointly with WMO), Drifting Buoy Programme, and of oceanographic data and information management.
- Development by IOC, jointly with FAO, of the OSLR Programme.

The Seminar was to provide a forum for the presentation of scientific contributions and discussion of results on variations in the water circulation systems of the Antarctic and adjacent oceanic areas, their causes and their influence on the organisms of the Antarctic marine ecosystems. The Seminar was expected to identify and make recommendations for future research needs, and to promote closer co-operation between oceanographers and biologists in this field. The conclusions and recommendations of the Seminar would be submitted to the Fifth Session of the IOC Regional Committee for the Southern Ocean next week.

The Secretary IOC wished to express appreciation to the Seminar Convenor, Dr. D. Sahrhage, and members of the Steering Group, who, with the assistance of the IOC Secretariat, made substantial efforts for the preparation of the Seminar.

Thirty-two scientific papers, prepared by almost 90 scientists (separately or as joint work) from various countries, had been submitted to the Seminar. The Secretary IOC thanked those scientists for their contribution to the international co-operation and to this Seminar, in particular. He expressed hope that the discussion at the Seminar and its recommendations on further studies on Antarctic Ocean variability and its marine living resources will provide a sound scientific basis for the preparation of co-operative projects, to be considered at the Fifth Session of the IOC Regional Committee for the Southern Ocean.

Dr. F.W.C. Baker, Executive Secretary of ICSU, welcomed the participants on behalf of ICSU, and SCAR and SCOR in particular. He wished to point out those activities of SCAR and SCOR which are directly relevant to the topics to be discussed at the Seminar. He noted in particular activities of the Scientific Steering Group for WOCE in planning the World Ocean Circulation Experiment, implementation of the BIOMASS programme co

sponsored by SCAR and SCOR, preparation of the report on the General Circulation of the Southern Ocean by SCOR WG 74, and new initiative of ICSU on the International Geosphere and Biosphere Programme. Dr. Baker wished to express ICSU's appreciation to the Steering Committee and IOC and CCAMLR for their efforts and support in preparing the Seminar.

2. ARRANGEMENTS FOR THE MEETING

The Programme of the Seminar is shown in Annex I.

A List of Scientific Contributions, in alphabetical order by authors, is reproduced in Annex II. Copies of all papers were made available to the participants at the beginning of the Seminar.

Abstracts of the above-mentioned contributions and other presentations made during the Seminar, arranged in sequential order under each major topic of the meeting, follow in Annex III.

The List of Participants is given in Annex IV.

Most of the contributions will be published in a book entitled "Antarctic Ocean and Resources Variability" by Springer Verlag with D. Sahrhage as Editor.

3. MESO/LARGE SCALE VARIABILITY IN THE ENVIRONMENT

Chairman: Dr. A. Gordon
Rapporteur: Mr. H. Van Loon

During the first session an overview of the atmospheric elements at the ocean surface south of 40°S, and information on long-term, interannual and seasonal variability in the atmospheric circulation, and in the ice cover, mainly in the Atlantic sector were provided. In the field of oceanography a review was given of the spatial and temporal variability within the Southern Ocean, supplemented by presentations of results in special areas. The importance of wind-induced variations in the Antarctic water ring became apparent.

The discussion centered mainly on two aspects: what information on the physical environment is needed to unravel the mystery of krill? What are the scales of space and time required for the investigation of variability in space and time?

As regards time, it was stated that it is the interannual change and seasonal abnormality in the weather, ice and hydrographic conditions which is of greatest influence on the marine resources and biological processes. Thus, environmental data for specific years or seasons are of utmost importance. Associated with the apparent lack of stability in the populations, it is obvious that as the amount of data increases so does the observed variability.

There is a lack of time series over long periods for all aspects of the physical environment. Unfortunately, many elements observed on islands are not representative of conditions over the surrounding oceans.

When places for future observations for time series are selected, they should not be protected places dominated by localized variability.

It is important that the same areas be observed consistently over a longer time-span to obtain comparable samples and homogeneous series.

New technologies (drifting buoys, observations from satellites) are promising, but it will be a while till they produce series long enough to yield meaningful statistics. Ships-of-opportunity are comparatively few over the area of interest (Polar Front to coast), and in any event operate almost exclusively during the warmer part of the year.

The following meteorological data are available for variability studies:

- i) Ship's observations in and around the Drake Passage, available in Seewetterant, Hamburg. About 100 000 observations as far back as 1870. All months.
- ii) Whaling ship observations, 1925 - collected in South Africa. Summer only.
- iii) Daily values of sea level pressure at grid points, approximately 25 years. Can be converted into geostrophic winds. All months. Available at the National Centre for Atmospheric Research, Boulder, Colorado.

It was recommended that a network of tide gauges should be supported.

Some observations suggest that the concentration of krill is high after a cold winter. Could sea ice extent be used as an indicator of the coldness of the winter? It should be kept in mind that the character of the winter is not necessarily the same everywhere around Antarctica. A change in the amplitude or phase of the quasi-stationary waves in the atmosphere would, for instance, cause opposite temperature anomalies on either side of the wave.

It was discussed that besides macro- and meso-scale investigations more attention should be given in future to micro-scale experiments. The upper layer dynamics should be studied more closely (vertical and horizontal mixing processes). It was noted that the atmosphere is important for the mixed layer dynamics, and closer interaction between disciplines with collaboration between oceanographers, meteorologists and biologists should be encouraged. However, the sites where oceanographers would like to monitor changes in the physical environment are not necessarily the best ones for the biologists.

In interdisciplinary experiments the scientific problems should first be formulated, theoretical links be established, and then the experiment be designed accordingly.

Influence of El Niño/Southern Oscillation (ENSO) events on the Southern Ocean were found likely but not yet well established. The Southern Oscillation does not consist only of the extreme when anomalously warm water occurs on the Equator in the Pacific and El Niños are found on the Peruvian

coast. The other extreme, with anomalously high pressure at Tahiti/low pressure at Darwin is just as important for the Oscillation. Both extremes have recognizable signals at middle and high latitudes on the Southern Hemisphere. These signals are, however, seasonally dependent (see Monthly Weather Review, February 1987).

4. MESO/LARGE SCALE VARIABILITY IN THE BIOTA (RELATED TO THE ENVIRONMENT)

Chairman: Prof. S. El-Sayed

Rapporteur: Dr. W. Smith

Eleven contributions were made in the second session, which opened with an overview of the seasonal and interannual variabilities in Antarctic phytoplankton with reference to krill distribution. The general picture that emerges is one of great variability of the phytoplankton biomass and primary production between low values typical of oligotrophic waters and high values characteristic of eutrophic regions. The spatial variability (up to two orders of magnitude) tends to overshadow the expression of seasonal differences.

The other 10 contributions covered the gamut of the biota (sea ice microbial community, phytoplankton, zooplankton, krill and micronekton) of the Southern Ocean. Habitats studies included: sea-ice, ice-edge and open waters. Seasonal and interannual variabilities in these biota were discussed against a background of seasonal and annual variations in the physical parameters.

The ranges of temporal and spatial scale over which krill variability occurs were discussed. These are equated with different levels of organizations of the population. The biology of krill was discussed in relation to variation in physical factors, food supply and predation at scales corresponding to individual krill, swarm and aggregations up to the population level. Scales where environmental and krill variability interact were highlighted and discussed within the overall context of the Southern Ocean.

An extensive discussion developed on the results of biological studies in and under the pack-ice. It was reported that biological activity and microbial biomass associated with the sea-ice was found to be equal to or greater than that in the several meters of underlying sea water. Microbial biomass and production were enriched in the ice compared to the water column for all the seasons. Substantial numbers of late furcilia and juvenile krill were observed to be feeding actively in sea-ice microhabitats which were blooming with microalgae. It was hypothesized that (a) sea-ice can be considered as a concentrated source of microbial carbon for zooplankton grazing even in winter, (b) sea-ice may serve as an important nursing ground for larval krill, (c) productivity of the Southern Ocean will be increased when pack-ice production is considered.

The significance of marginal ice zone as site for enhanced primary productivity was emphasized in another presentation. This enhanced productivity appears to be largely controlled by the vertical stability created by low-density meltwater released from the receding pack-ice. A conceptual model was presented which allows the calculation of ice-edge related productivity. The model assumes that an ice-edge phytoplankton bloom occurs when light and vertical water column stability are sufficient to enhance growth. Thus, as the region of enhanced stability moves with the receding ice-edge, a bloom follows. Interannual variations in primary productivity within the marginal ice zone were shown to be substantial. In view of the importance of the marginal ice zone as a site of biological production and its temporal variations, an understanding of the causes of interannual variability of the ice-edge location and of biological processes within marginal ice zones is needed to assess the impact of these time/space variations on the food web of the Southern Ocean.

The discussion then focussed on the recent investigations in the Weddell Sea in winter. These studies have shown the existence of rich flora and fauna. The ice cover provides shelter and food and appears to be a most important area in relation to the survival strategies of the organisms, particularly krill, in winter.

Points made in the discussion included:

- Size classes of krill in ice-edge indicate that both small and large sizes occur and are associated with ice.
- Behaviour of crab-eater seals in the ice indicated that they are harvesting krill from 50-250 m in depth. In addition, they are taking adult krill, not just subadults as reported.
- Information on krill distribution under the ice is needed.
- Ice distribution obviously contributes to the physical variability of the Southern Ocean and that the model suggested (see above) was an appropriate step to understanding how the physical variability was manifested in the biological processes.
- Further studies of the sea-ice zone are encouraged.
- In sea-ice studies, caution should be exercised in extrapolating the results from one season or one region to the entire Southern Ocean, in view of the size of the ocean and the limited data from few locations.
- The significance of remote sensing in phytoplankton studies in marginal ice zone and open water was emphasized, and strong recommendation was made regarding the usefulness of this technique in future studies.

5. KRILL VARIABILITY IN RELATION TO THE ENVIRONMENT

Chairman: Dr. I. Everson
Rapporteur: Dr. J. Priddle

Most of the 11 contributions presented in this session were concerned with the Southwest Atlantic sector, although there were papers covering most areas where krill are found.

A number of discussion points were associated with the presentations.

There was confusion as to underlying stability in the ecosystem with regard to krill, other zooplankton and their predators. This stability or normality must include season-to-season variability.

There is a need to identify whether events characterized as "abnormal" are extremes of continua, or are catastrophic occurrences reflecting unusual conditions.

There are potential problems with comparisons of different sampling methods (e.g. CPUE, nets and acoustics); with the aliasing of finer scale differences; and with overlap of different months when comparing between years.

The commercial fishery provides a large data source which can provide information on total krill density. The effort is, of course, directed at areas thought likely to yield high catches. It does, however, point to areas of consistently high krill catch such as NW of Elephant Island and near Coronation Island (South Orkneys). Further studies are needed to relate CPUE to broader scale distribution of krill.

South Georgia was identified as an area of high variability, Elephant Island was considered one of less dramatic fluctuations.

There is a need to quantify the sources of krill reaching these areas.

Some basic information is not available for krill, such as population variables, ability to migrate actively or not, the proportion dispersed and that aggregated in swarms.

A need was identified for work in "quieter" areas of considered low krill abundance so as to study processes with minimum background noise.

The subsequent discussion opened with a suggested time-scale framework for the consideration of variability. Seasonal variation, identified in the present and previous sessions as a highly significant component, was separated on the one hand from longer interannual variation and on the other from short-term changes. Furthermore it should be noted that the ecosystem has been heavily perturbed due to commercial whaling and thus is likely to experience density dependent effects on krill and, indirectly, on its other predators.

A need was identified to link biological studies to other investigations of physical oceanography and climatology. Possible multidisciplinary studies of the system would need first to identify clearly the hypotheses to be tested. On larger scales, krill can be seen as non-

conservative passive tracers, whose abundance and distribution could be expected to reflect a combination of intrinsic (biological) factors, such as recruitment, and physical factors operating over larger distance scales. It was pointed out that there was a paucity of information to quantify interactions even though a large body of biological and physical data existed. The following deficiencies in our knowledge of krill were highlighted by various speakers and these must clearly receive attention in the approach to problems on this large scale:

- (i) an assessment (or reassessment?) of the spatial heterogeneity of krill distribution on a circumcontinental scale;
- (ii) those aspects of hydrography determining large-scale pattern;
- (iii) details of population structure and recruitment;
- (iv) the importance of the ice-associated ecosystem in relation to krill biology on an oceanic scale;
- (v) effects of predation and competition;
- (vi) basic environmental tolerance and susceptibility to change in conditions both in the vertical and horizontal.

Given these data, a modelling approach could be designed to test hypotheses on biology that are linked to the physics of the Southern Ocean.

Discussion of the physical environment looked to a large extent outside the main circumcontinental belt of the Southern Ocean. Speakers questioned how far this could be treated as an isolated system. Consideration should be given to ocean-atmosphere processes of hemispheric or global scale. The possible influence of El Niño/Southern Oscillation (ENSO) events was given as an example, although insufficient data are available at present to assess either mechanisms or their significance.

The discussion progressed to address the suitability of certain sites for studies (primarily shipborne) of processes and their variability. In many respects, this depended on the need to search in a defined environment in which the "signal" of biological phenomena could stand out from "noise". Optimum sites for such focussed studies would obviously be determined by the character of the hypothesis addressed. Practical considerations also influence the choice, both through the need to utilize existing data sets rather than work in "unknown" or data-sparse areas, and the more mundane requirements for logistic support. Whilst it was recognized as important that we build on existing data-sets, it is equally clear that this should not ossify the research approach. A reappraisal of existing data is clearly needed in some cases.

Although most of the discussion dealt with the pelagic ecosystem, it was clear from the data (presented in the previous session) relating to the ice-associated ecosystem as a habitat for krill that this topic must be given major consideration in future. However, formidable problems can be envisaged if this ecosystem is to be integrated satisfactorily with the rest of the Southern Ocean.

Major objectives were identified as follows:

- (i) to gain further understanding of the factors influencing krill distribution and abundance, particularly on large scales;
- (ii) following this, there is a need to characterize and explain changes in the environment, such as circulation pattern or ice-cover, which could influence variability in zooplankton, particularly where this variability is so large to affect predators or impinge upon conservation measures;
- (iii) to assess and identify external processes that affect the Southern Ocean.

6. KRILL VARIABILITY DETECTED FROM PREDATOR STUDIES

Chairman: Dr. Y. Shimadzu
Rapporteur: Dr. J. Bengston

Four papers were delivered concerning the degree to which variability in the marine environment has been revealed by study of natural history patterns in upper trophic level predators. Two contributions reported on the interannual variability of seabird and pinniped reproductive performance and foraging behaviour at South Georgia and the South Orkney Islands. A third paper compared yearly changes in blubber thickness of minke whales in IWC Areas III and IV. The fourth presentation outline some aspects of trophic interactions between krill, squid, and sperm whales. A common theme among the four papers was that predators can provide useful information on the temporal and spatial variability of physical and biological ecosystem interactions. This utility is relevant to development of the CCAMLR Ecosystem Monitoring Programme.

In the discussion following the presentation, it was noted that although the CCAMLR Scientific Committee requires information on various ecosystem components throughout the Antarctic, it is unlikely that it will be possible to extrapolate the results of studies in any one area to the whole system. Instead, although information on the availability of prey to predators in local areas at specific times of the year (e.g., breeding season on land) is not necessarily of the entire ecosystem, such data may be pertinent to CCAMLR on a smaller scale. Because the ecological diversity between geographic areas has been recognized, the CCAMLR Scientific Committee has recommended that monitoring studies be conducted in several areas and on a variety of important species and parameters.

Understanding the relative stability or variability of different areas, and how these features affect ecological interactions, is an important issue. For example, there was some difference of opinion on the extent to which the South Georgia area is more variable than the Elephant Island area, which some have suggested as being a relatively stable system at least in some parts. Similarly, there appear to be differences in the relative stability as reflected by predators' ecology, at sites such as Cape Bird in the Southern Ross Sea and at King George Island in the South Shetland Islands. The extent, to which these differences may be related to the amount of available environmental data (e.g. is the physical environmental data base for the Scotia Arc adequate to conclude that one area is more stable than another?) or to differences in predator biology

(i.e. are certain predators in some areas more capable of switching prey when one resource is scarce?) requires further study.

Information on the seasonal aspects of predators' behaviour and ecology is essential for interpreting changes in indicator parameters in relation to biological and physical factors. We are moving into a new phase of predator studies which will rely heavily on technological advances to keep answer questions of seasonal distribution and movements, activity patterns, and foraging behaviour. In particular, the development of satellite-linked sensors will allow the investigation of predator/prey interactions during predators' pelagic, migratory phases. Such seasonal features are fundamental for both the physical and biological components of the Antarctic marine ecosystems. The extent to which species remain south of the Antarctic Polar Front or migrate north on a seasonal basis is one which deserves further consideration (e.g. differences in the migratory habits of baleen whales and male sperm whales in response to feeding strategies).

These questions still exist on the utility of certain parameters which might be included, in future monitoring studies, it is important to identify the specific questions being asked before recommendations are made to field programmes. For example, it was noted that although the proposal to monitor krill availability using the blubber thickness of minke whales has not yet been fully clarified or evaluated, there was some opinion that this proposal should be given further consideration. It was also noted, however, that use of the blubber thickness parameter appears to have several as yet unresolved technological problems, both in obtaining accurate measurements and in the analysis and interpretation of the data.

The issue of temporal and spatial scale must be carefully considered when evaluating future research activities related to monitoring. For example, parameters as it is measured in predators at land-based sites during the reproductive season (e.g. penguins and fur seals) have limited spatial and temporal scales. In contrast, large, highly mobile predators (e.g. whales) present in the Antarctic outside of their breeding season integrate environmental conditions on considerably different spatial and temporal scales.

7. SYNTHESIS AND CONCLUSIONS

Chairman: Prof. D. Sahrhage
Rapporteur: Dr. R.B. Heywood

The session began with summaries of the sessional discussions presented by the various chairmen.

As the main discussion developed, the Chairman reminded participants that the objective was a set of recommendations which, although having no formal status, could be brought to the attention of two meetings being held during the following weeks:

- IOC Regional Committee for the Southern Ocean
- CCAMLR Ecosystem Monitoring Working Group

through which decisions to be taken at intergovernmental level could perhaps be influenced. The recommendations of this meeting should seek to identify and promote areas of research suitable for close collaboration between meteorologists, physical oceanographers and biologists.

It was agreed to structure the discussion by considering variability and its influence at levels of descending scale, and that these scales should be carefully defined in the report of the meeting. The order taken was:

- i) Planetary scale - changes in the World Ocean System, and changes in the Southern Ocean
- ii) Large scale - changes within specific areas of the Southern Ocean
- iii) Mesoscale - changes within specific features such as the marginal ice zone, frontal zones, eddies and krill patches

It soon became clear that there was an urgent need for a literature search across the disciplines - many phenomena were already being studied and papers had already been published. There was also an urgent need for greater familiarization with on-going programmes, both at national and at international level, and with programmes currently being planned or recommended by Working Groups under the aegis of IOC, SCOR, SCAR and CCAMLR. Studies in the World Climate Research Programme could meet many of the needs of the biologists for environmental data over the next decade. Specifically identified were:

- i) World Ocean Circulation Experiment (WOCE), which included a study of Southern Ocean circulation. Data from instrument packages on drifting buoys, and shipborne studies would lead to a greater understanding of interactions at the atmosphere/ocean interface and the mixed layer.
- ii) Fine Resolution Antarctic Model (FRAM), which would produce an eddy resolving, multi-layered model of water movement with 10 km discrimination.
- iii) Planned research associated with satellite programmes such as ERS1, NROSS, Columbus, etc., which would be studying the atmosphere/ocean interface and the fluid dynamics of the ocean in order to improve the instrumentation of this next generation of satellites.
- iv) Global Sea-Level Observing System (GLOSS), which would also serve to study Southern Ocean circulation.
- v) Various national Southern Ocean Sea Ice projects, in which meteorologists, glaciologists and physical oceanographers were already studying the effects of seasonal formation and decay on weather, waves energy dissipation, surface currents and stability in the upper ocean.

It also became clear that there was a very large amount of data, especially meteorological data, which had yet to be analyzed, and an even larger data set of meteorological and physical oceanography data which could be reworked in interdisciplinary studies with biologists. It was also accepted that the value of the very large data set of commercial CPUE statistics should be examined.

Many areas of biological research were reviewed, and the need for continued research on all aspects of krill biology was recognized. Major topics identified were:

- i) Re-examination of the published patterns for the heterogeneous distribution of krill to determine if any were real, or all artifacts of sampling design.
- ii) Determination of whether there were several natural populations of krill by using more refined genetic and morphological typing techniques.
- iii) Determination of the extent to which krill could be considered as passive particles in Southern Ocean currents before they could be considered as an extra variable in models of circulation such as FRAM.
- iv) Confirming and quantifying the apparent seasonal pattern of krill migration related to life stages, as revealed by work in the Bransfield Strait, and determining if this occurred in other areas of the Southern Ocean.
- v) Investigating the hypothesis that catastrophic changes in local krill concentration were due to changes in distribution and not overall abundance.
- vi) Predator/prey and competitor interactions.
- vii) Swarming and swarm behaviour.
- viii) Influence of eddies and frontal areas on krill distribution and biology.
- ix) Sea-ice ecology, to provide insight into an important community of the marine ecosystem, associated with a major physical feature that has a dramatic impact on a major portion of the Southern Ocean. This was recognized as being particularly vital to complement research traditionally carried out in ice-free areas.

The value of research on top predators was noted. They are long-lived integrators of a wide spectrum of biological and physical features within ecosystems, and over a variety of spatial and temporal scales. Consequently the ecology and behaviour of predators in open ocean and pack-ice areas should form an integral part of studies within the Antarctic marine ecosystem. In view of the difficulties of working within the pack-ice, the use of top predators in investigating aspects of ice-associated krill biology should also be evaluated.

A general point was made that care should be taken to avoid the danger of allowing the research to degenerate merely into monitoring programmes, achieving only retrospective rather than predictive knowledge. Programmes must include elements of research on the dynamic process of the flux of energy and matter through the ecosystem.

In a review of priority sites for research, the value was recognized of the continuity in time and space of the work being carried out by many of the national programmes centered on the Bransfield Strait (including Elephant Island area), Scotia Sea and South Georgia, and in Prydz Bay. The need to obtain data from other areas of the Indian and Pacific Ocean sectors of the Southern Ocean was recognized, but so was the danger of overstretching the resources for research. Again the need for communication between organizations and between nations, and co-ordination of activities was stressed, in order that the achievement of the whole would be greater than the sum of the individual projects. The importance of selecting the most favourable sites for specific projects was recognized. In this context, the Weddell-Scotia Confluence was identified as an area suitable for studies on the influence of eddies on the Southern Ocean ecosystem.

The importance of making full use of advances in such modern equipment and techniques such as:

- satellite sensors
- moored instrument arrays
- drifting buoys
- ships-of-opportunity
- manned and unmanned submersibles
- commercial fishing fleets
- shore-based research facilities
- mathematical modelling

was noted.

8. RECOMMENDATIONS FOR FUTURE RESEARCH

- i) Closer collaboration between meteorologists, physical and biological oceanographers should be promoted at all levels.
- ii) Exchange of information, in particular relevant publications and summary reports with improved lists of activities, cruises, data inventories, etc., should be developed.
- iii) Studies under the World Climate Research Programme are highly welcomed as relevant to meet many of the needs of the biologists. The second core project of the World Ocean Circulation Experiment Programme, a study of the Southern Ocean Circulation, and the associated UK Fine Resolution Antarctic Model (FRAM) were identified as particularly useful.
- iv) The usefulness of long time series data was appreciated. Some areas of the Southern Ocean in the Indian and Pacific Ocean sectors are not yet well covered, and proper long-term data collection should be initiated. Ways and means for data collection should be better specified. It was realized that data from certain positions can often not be extrapolated to wider areas where they were collected on protected places.

- v) Although it is appreciated that mean values of environmental parameters are needed to describe average conditions of atmospheric and oceanographic circulations and processes, it should be stressed that data at smaller temporal scale for definite months and years are required to enable their utilization jointly with biological data in the analysis of interactions in ocean and resources variability.
- vi) In addition to macro- and meso-scale investigations, more micro-scale observations are required in the form of interdisciplinary process studies. Particular attention should be paid to the upper mixed layers and to the vertical stability of the water column.
- vii) Further extensive studies in the pack-ice zone, particularly during the winter season, with close integration of work between meteorologists, oceanographers, glaciologists and biologists are encouraged.
- viii) Ships-of-Opportunity are a suitable means of collecting ground truth data for monitoring positions and variations in the various oceanic fronts (polar front, sub-antarctic front, Weddell/Scotia confluence) and the extent of ice. Improvements are required in the collection and reporting of such data.
- ix) Considerable further progress can be expected from increasing application of modern methods and techniques, like satellites and other remote sensors (aircraft, remotely operated underwater vehicles), drifters, drifting-buoys, moored instruments (current meters, sediment traps), and sea-level measurements with tide gauges.
- x) There appears to be a wealth of historical data, e.g. on atmospheric circulation over the Drake Passage, which have not yet been worked up sufficiently to be of immediate use for the analysis of Antarctic ocean and resources variability. The re-activation and evaluation of such data sets is encouraged.

9. CLOSURE OF THE SEMINAR

At the end of the Seminar, Prof. Sahrhage, the Convenor of the Seminar, thanked all participants, and especially the Chairmen and Rapporteurs of the various sessions, for their active and constructive contributions to the meeting which made the Seminar a success. He expressed again appreciation to the sponsoring organizations, CCAMLR and IOC, and to SCAR and SCOR, for their support. Special thanks were given to the members of the IOC Secretariat for their hard work. Dr. Priddle, on behalf of the participants, thanked the Convenor.

The Convenor then closed the meeting.

ANNEX I

PROGRAMME OF THE SEMINAR

1. OPENING OF THE SEMINAR
2. ARRANGEMENTS FOR THE MEETING
3. MESO/LARGE SCALE VARIABILITY IN THE ENVIRONMENT
4. MESO/LARGE SCALE VARIABILITY IN THE BIOTA (RELATED TO THE ENVIRONMENT)
5. KRILL VARIABILITY IN RELATION TO THE ENVIRONMENT
6. KRILL VARIABILITY DETECTED FROM PREDATOR STUDIES
7. SYNTHESIS AND CONCLUSIONS
8. RECOMMENDATIONS FOR FUTURE RESEARCH
9. CLOSURE OF THE SEMINAR

ANNEX II

LIST OF SCIENTIFIC CONTRIBUTIONS

AINLEY, D.G.; FRASER, W.R.; DALY, K.L.: Effects of pack ice on the composition of micronektonic communities in the Weddell Sea.

BENGSTON, J.L.: Long-term trends in the foraging patterns of female Antarctic fur seals at South Georgia.

BOLTER, M.; v.BODUNGEN, B.; LIEBEZEIT, G.; MEYER, M.: The pelagic ecosystem of the Bransfield Strait, Antarctica: An analysis of microbiological, planktological and chemical characteristics by ordination techniques.

CROXALL, J.P.; McCANN, T.S.; PRINCE, P.A.; ROTHERY, P.: Variation in reproductive performance of sea birds and seals at South Georgia, 1976-1986 and its implication for Southern Ocean monitoring studies.

EL-SAYED, S.Z.: Seasonal and interannual variabilities in Antarctic phytoplankton with reference to krill distribution.

EVERSON, I.: Can we satisfactorily estimate variation in krill abundance?

GORDON, A.L.: Spatial and temporal variability within the Southern Ocean.

HUBOLD, G.; HEMPEL, I.: Zooplankton variability in the Weddell Sea.

KAUFELD, L.: Variability of the atmospheric circulation over the Drake Strait, Scotia Sea and Weddell Sea.

KELLERMAN, A.; KOCK, K.-H.: Patterns of spatial and temporal distribution and their variations in early life stages of Antarctic fish in the Antarctic Peninsula region.

KOTTMEIER, S.T.; SULLIVAN, C.W.: Seasonal, primary, and secondary bacterial productivity in the pack ice as related to krill.

MAKAROV, R.R.; MASLENNYKOV, V.V.; SOLYANKIN, E.V.; SPIRIDONOV, V.A.; YAKOLEV, V.N.: Variability in population density of Antarctic krill in the western Scotia Sea in relation to hydrological conditions.

MARIN, V.: Fine scale variability to two Antarctic copepods north of Elephant Island.

MASLENNYKOV, V.V.; SOLYANKIN, E.V.: Patterns of fluctuation in the hydrological conditions of the Antarctic and their effect on the distribution of Antarctic krill.

MILLER, D.G.M.; MONTEIRO, P.M.: Variability in the physical and biotic environment of the Antarctic krill (*Euphasia superba* Dana), south of Africa: some results and a conceptual appraisal of important interactions.

MURPHY, E.J.; MORRIS, D.J.; WATKINS, J.L.; PRIDDLE, J.: Scales of interaction between Antarctic krill and the environment.

NAGATA, Y.; MICHIDA, Y.; UMIMURA, Y.: Variation of positions and structures of the oceanic fronts in the Indian sector of the Southern Ocean in the period from 1965 to 1986.

NAST, F.; KOCK, K.-H.; SAHRHAGE, D.; STEIN, M.; TIEDTKE, J.E.: Hydrography, krill and fish and their possible relationships around Elephant Island.

NEMOTO, T.; OKIYAMA, M.; IWASAKI, N.; KIKUCHI, T.: The direct and indirect impacts of variable predation on the krill (*Euphasia superba*) by squids and on squids by sperm whales in the Antarctic Ocean.

PRABHU MATONDKAR, S.G.; PANT, A.; PARULEKAR, A.H.: Biological productivity off Queen Maud Land, Antarctica during 1981 to 1986.

PRIDDLE, J.; CROXALL, J.P.; EVERSON, I.; HEYWOOD, R.B.; MURPHY, E.J.; PRINCE, P.A.; SEAR, C.B.: Large-scale fluctuations in distribution and abundance of krill. - A discussion of possible causes.

RAKUSA-SUSZCZEWSKI, S.: Differences in the hydrology, biomass and species distribution of plankton, fishes and birds in the Bransfield Strait and the Drake Passage during FIBEX 1981 and SIBEX 1983/84.

SAHRHAGE, D.: Overview on indications for Antarctic ocean and marine resources variability.

SHIMADZU, Y.: An analysis of yearly change in the blubber thickness of minke whales as an indicator of krill availability.

SIEGEL, V.: A concept of seasonal variation of krill (*Euphasia superba*) distribution and abundance west of the Antarctic Peninsula.

SIEVERS, H.A.; NOWLIN, W.D.: Upper ocean characteristics in the American sector of the Southern Ocean, 39 - 95 W.

SMITH, W.O.; KEENE, N.K.; COMISO, J.C.: Potential interannual variability in primary productivity of the Antarctic marginal ice zone.

STEIN, M.: Variation of geostrophic circulation off the Antarctic Peninsula and in the Scotia Sea, 1975-1985.

VAN LOON, H.; SHEA, D.J.: A survey of the atmospheric elements at the ocean's surface south of 40 S.

VERLENCAR, X.N.; SOMASUNDAR, K.; QASIM, S.Z.: Nutrient anomalies in relation to plankton production in the Indian Sector of the Antarctic Ocean.

WITEK, Z.; KALINOWSKI, J.; GRELOWSKI, A.: Formation of Antarctic krill concentrations in relation to hydrodynamic processes and social behaviour.

WORMUTH, J.H.: Interannual variability in Antarctic zooplankton populations around the tip of the Antarctic Peninsula.

ADDITIONAL SHORT PRESENTATIONS AND ABSTRACTS

HEMPEL, G.: Krill studies in the pack ice of the Weddell Sea (Supplement to the paper by Kottmeier and Sullivan).

HOFMANN, E.; ROSS, R.M.; QUETIN, L.B.: A model of the dynamics of the eggs and larvae of the Antarctic krill, *Euphausia superba*.

FUKUCHI, M.; HATTORI, H.; HOSHIAI, T.: Temporal variation of in-situ chlorophyll a observed by a moored system in Breid Bay, Antarctica.

NOWLIN, W.D.; ZENK, W.: A western slope current in the southern Scotia Sea.

RONG WANG: Structure of swarming and dispersed populations of krill (*Euphausia Superba*) in the waters around South Shetland Islands, January-February 1985.

RONG WANG: Distribution and abundance of krill larvae (*Euphausia Superba*) in the waters around South Shetland Islands, January-February 1985.

ANNEX III

ABSTRACTS OF CONTRIBUTIONS AND PRESENTATIONS

(in sequence as they were given during the meeting
under each major topic)

MESO/LARGE SCALE VARIABILITY IN THE ENVIRONMENT

A SURVEY OF THE ATMOSPHERIC ELEMENTS
AT THE OCEAN'S SURFACE SOUTH OF 40°S

by

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The paper shows the monthly mean and standard deviation of sea level pressure, air temperature, and precipitation at stations south of 35°S and, where relevant, also trends in these elements. It discusses the difference in pressure between station pairs, expressed as geostrophic wind, in terms of the changes of monthly means from year to year. Grid point data of geostrophic wind, in terms of the changes of monthly means from year to year. Grid point data of geostrophic wind supply the material for a discussion of its day-to-day variability.

The annual cycle of the pressure and geostrophic wind, with emphasis on the dominant halfyearly wave, will be outlined in terms of harmonics, and we shall discuss the interannual changes in the annual cycle.

Zonal harmonic waves will be used in a description of the spatial distribution of pressure and its interannual changes.

We shall also briefly outline frequencies of highs, lows, and fronts and show the response of the sea level pressure to the extremes of the Southern Oscillation.

¹ The National Center for Atmospheric Research is sponsored by the National Science Foundation.

VARIABILITY OF THE ATMOSPHERIC CIRCULATION OVER THE DRAKE PASSAGE,
SCOTIA SEA, AND WEDDELL SEA

by

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Grid point values from 50° to 70°S and 0° to 70°W were extracted from monthly charts of global sea level pressure from the last 30 years, which were constructed by the Seewetteramt of Deutscher Wetterdienst.

The data were used to show not only monthly and seasonal mean values but also to calculate zonal and meridional circulation indices to demonstrate the variability of the atmospheric circulation over the Atlantic sector of the Antarctic Ocean. Their anomalies from month to month and year to year and the resulting consequences on atmospheric parameters are discussed.

Finally, different weather situations are presented to describe characteristic synoptical features of this area.

SOME INDICATIONS FOR ENVIRONMENTAL AND KRILL
RESOURCES VARIABILITY IN THE SOUTHERN OCEAN

by

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Indications for long-term and interannual variations in environmental parameters in the Southern Ocean, particularly the Atlantic sector, are described. Trends in the development of average annual air temperatures show considerable changes and so does the extent of the ice cover from year to year. It is attempted to identify years with particularly "warm" or "cold" conditions in the Atlantic sector (South Orkney Islands), and to relate this to variations in the distribution of the krill resources.

SPATIAL AND TEMPORAL VARIABILITY WITHIN THE SOUTHERN OCEAN

by

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The Southern Ocean is not radially symmetric, many circulation and water mass features vary markedly with longitude. This recommends in making generalizations of the ocean dynamics and ventilation for the Southern Ocean. The Antarctic Circumpolar Current (ACC) varies in latitude from a position slightly north of 50°S in the Atlantic sector to near 60°S southeast of New Zealand. At some sites it is marked by jet-like flow, often with a series of current axes, at other sites the flow is more of a diffuse drift. The spatial variability of the ACC is closely linked to bottom topographic features. The ACC displays significant temporal variation, ranging from mesoscale structures of meanders and eddies, to transport variations coupled to changes in the zonal wind stress, to broad regional low frequency variations.

South of the ACC are vast areas of more sluggish flow, many of which are organized into cyclonic circulation gyres. The largest is the Weddell Gyre; smaller gyres are located north and east of the Ross Sea, east of the Kerguelen Plateau. The western boundary current of the Weddell Gyre transports northward well over 50 sv of water. The boundary current may be divided into two parts: a segment flowing along the continental margin which has been altered by thermohaline forcing and a seaward segment which represents the re-circulated waters of the Weddell Gyre (Weddell cold regime, Gordon and Huber, 1984). The "margin" water separates from the continental margin at the northern tip of Antarctic Peninsula feeding the biologically active Weddell-Scotia Confluence zone.

Variation in the strength of the western boundary current and Weddell-Scotia Confluence may be a primary factor in driving variations in the biology of the region. Such variation would be a consequence of large scale wind variations, possibility involving the ACC. Wind induced variations, perhaps coupled to changes in the fresh water balance, would also influence the vertical stability of the water column, the vertical heat flux and the sea ice cover extent. Temporal variation within the Weddell Gyre is evident. The deep and bottom water mass structure displays inter-annual changes, the most dramatic was associated with the Weddel Polynya of the mid-1970's.

The oceanography along the continental margins are also very much dependant on longitude. These variations are related to changes in the geometry of the shelf, the characteristics of the adjacent glacial ice, and on the wind field. At many sites deep reaching convection occurs, though not necessarily to the sea floor at all sites.

UPPER OCEAN CHARACTERISTICS IN THE DRAKE PASSAGE
AND ADJOINING OCEANIC AREAS OF THE SOUTHERN OCEAN, 39°-95°W

by

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A new description based on hydrographic data at various levels (20, 30, 200, 500 and 1000 m) of the upper ocean in Drake Passage and adjoining oceanic areas (50°-70°S and 39°-95°W) is presented. The study is based on observations from 1009 oceanographic stations observed by various ships between 1927 and 1980. Most are summer observations.

Though the data are greatly dispersed in time and were collected with different observation techniques, the values of potential temperature, salinity, potential density, dissolved oxygen, nutrients, and geopotential anomalies based on data from individual stations show remarkable coherence, enabling us to produce meaningful horizontal distributions of water characteristics and flow for the region. Frontal positions and distinct water mass zones can be recognized and mapped at the different depth levels. The positions of recognizable fronts must be relatively stable over the period of observations or one could not contour them in this manner.

In general, isopleths parallel the flow patterns, extending almost continuously through Drake Passage. Only in the 20-m and 30-m levels do they appear contorted and patchy due to the effects of local dynamics and other variability which are more pronounced in the near-surface layers.

The isopleths and contours of relative dynamic topography are constricted where the eastward flowing Antarctic Circumpolar Current (ACC) enters Drake Passage and continues to shallow east of the passage; this forces a northward intensification of streamlines within the passage and a deflection to the north once the lateral constriction is passed. There are wavelike patterns associated with some topographic features in the Scotia Sea.

Near-surface characteristics have their largest gradients near the shelves of South America and the Antarctic Peninsula, in response to effects of freshwater runoff from Chile and of ice near Antarctica. By contrast, the gradients at deeper levels are largest in the Subantarctic and Polar Fronts of the ACC, which is found in the northern portions of Drake Passage.

East of the passage the Subantarctic and Polar Fronts turn northward. The first becomes the Falkland Current paralleling the outer edge of the continental shelf. Farther to the east the Polar Front crosses into the Argentine Basin through a gap in the north Scotia Ridge.

Most characteristics within Bransfield Strait differ from those of the surrounding seas. These properties result from local processes in the strait. In their eastward extension they form the Weddell-Scotia Confluence, a zone of low vertical stability which separates the Weddell from the Scotia Seas.

VARIATION OF GEOSTROPHIC CIRCULATION OFF THE ANTARCTIC PENINSULA
AND IN THE SOUTHWEST SCOTIA SEA 1975-1985

by

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Bundesforschungsanstalt für Fischerei, Hamburg
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Based upon the hydrographic data collected by the Federal Republic of Germany during the biological antarctic surveys with FRV "Walther Herwig" and RV "Polarstern" between 1975 and 1985, examples of geostrophic circulation patterns for the region of the Antarctic Peninsula and the adjacent Scotia Sea are discussed. The dynamic topography elucidates the nature of a stationary meander in the vicinity of Elephant Island (South Shetland archipelago) as well as in the western Bransfield Strait. The data indicate the southwestward flow of water west of the Antarctic Peninsula.

VARIATION OF POSITIONS AND STRUCTURES OF THE OCEANIC FRONTS
IN THE INDIAN OCEAN SECTOR OF THE SOUTHERN OCEAN
IN THE PERIOD FROM 1965 TO 1986

by

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³Tokai University, Shimizu
Japan

Oceanographic data obtained in the Japanese Antarctic Research Expedition (JARE) were analyzed. Dating back to 1965 when the icebreaker "Fuji" came into operation (replaced by icebreaker "Shirase" after 1983), two temperature cross-sections are available for each year: from Fremantle to Syowa Station in December and from Syowa Station to Cape Town or Port Louis in February-March. The positions of the oceanic fronts such as the Subtropical Front, the Sub-Antarctic Front, and the Polar Front were read from each cross-section, and their year-to-year variation was investigated.

The nature of the variation is complicated. In some cases, position of a front is unchanged for several years, but water temperature at the frontal surface is considerably changed. The Sub-Antarctic Front sometimes exhibits clear double structure, and the shift of the position may be understood as a weakening of one subfront and a strengthening of the other subfront in some cases. There is some question whether the variation deduced from data taken only once a year can represent true year-to-year variation or shows only various phases of much shorter variations. The results should be checked by comparison with other data, such as the variation of biological productivity, and so on.

A WESTERN SLOPE CURRENT IN THE SOUTHERN SCOTIA SEA

by

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Geological evidences for a deep western boundary current along the Antarctic Peninsula can be found in the literature. Indirect observations showed that discrete branches of this flow enter the Scotia Sea from the Weddell Sea through selected depressions in the South-Sandwich Island Arc, where they turn southwestward towards Drake Passage.

In a synthesis of historical and recent hydrographic data sets, including moored current meter records, we have traced this slope and bottom current on its way from the Powell Basin into the Scotia Sea along the continental slope north of the South Shetland Islands. Hydrographic parameters show the fresher, less saline and oxygenated near-bottom waters to fill the zonal trough and other deep features north of Livingston Island and to continue westward in a narrow tongue along the base of the continental rise at least as far as 65°W. Associated currents demonstrate high directional persistence with negligible speed variations.

It appears worthwhile to discuss the possible impacts of the deep slope current on krill biology. A detailed description of the physical properties of "Westward Slope and Bottom currents in the Southern Scotia Sea" is a press elsewhere (Deep-Sea Research).

MESO/LARGE SCALE VARIABILITY IN THE BIOTA
(RELATED TO THE ENVIRONMENT)

SEASONAL AND INTERANNUAL VARIABILITIES IN ANTARCTIC
PHYTOPLANKTON WITH REFERENCE TO KRILL DISTRIBUTION

by

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The spatial and temporal variabilities in the distribution of Antarctic phytoplankton biomass, based primarily on data collected by the author and other investigators during the past 25 years are summarized. Mesoscale seasonal and interannual variabilities in phytoplankton distribution and abundance in the three best-studied areas of the Southern Ocean (the Drake Passage/Scotia Sea, the Bransfield Strait/Elephant Island and the Ross Sea) are examined. The general picture that emerges is one of great variability of the phytoplankton biomass and primary production between low values typical of oligotrophic waters and high values characteristic of eutrophic regions. This spatial variability (up to two orders of magnitude) tends to overshadow the expression of seasonal differences. Temporal variability in the Drake Passage/Scotia Sea region is clearly discernible at small spatial scales but is easily masked when comparing mean values of chlorophyll and productivity from large areal regions. In the Bransfield Strait/Elephant Island region, order of magnitude differences in chlorophyll a concentrations are noted, depending on the month of sampling. The time of peak phytoplankton abundance varies from year to year. Seasonal variability is much more pronounced than any interannual variability.

Of the several factors thought to cause spatial and temporal variability in Antarctic phytoplankton, three factors, namely, nutrient salts, water column stability, and grazing are discussed. The relationship between phytoplankton and krill remains as one of the vexing problems in Antarctic marine ecosystem studies. Examination of continuous profiles of in vivo fluorescence and acoustically derived estimates of krill biomass reveal a positive correlation between phytoplankton and krill at scales of 2-20 km. This is at variance with the negative correlations usually reported between these two entities on the basis of random, discrete samples separated by much larger distances. For better understanding of phytoplankton/krill interrelationships, future studies must resolve finer spatial scales and include time-course measurements to examine underlying mechanisms.

SCALES OF INTERACTION BETWEEN ANTARCTIC KRILL AND THE ENVIRONMENT

by

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We consider the Southern Ocean ecosystem in a time-space framework, in which hydrodynamic and biological processes are treated as elements in a hierarchy by identifying the temporal and spatial scales of the processes. Those processes which occur at similar scales can interact. A fundamental temporal and spatial scale of response for each group of organisms has been defined using the population growth period. The time and space relationships for hydrodynamic processes, phytoplankton, krill and predators have been compiled and compared. In addition this procedure has also been undertaken for five levels of krill organization: individual, swarm, patch, concentration and population. This has allowed us to examine specific interactions between krill and the environment. The population dynamics of *Euphausia superba* Dana are affected by large scale environmental phenomena such as eddies and frontal systems which may be involved in the formation of concentrations of krill. Interactions between krill and the food supply occur primarily at the swarm level which is the lowest level of organization that can effectively perceive gradients in the food supply in the open ocean. Interactions between krill and a variety of predators take place over a wide range of scales, involving both individual krill and higher levels of organization, thus making krill available as prey items to very different-sized predators. The presence of sea-ice, which is a prominent feature of the Southern Ocean, modifies the scales at which physical and biological interactions can occur. For example, individual krill may be able to perceive gradients in the environment under the ice which they are unable to perceive in the open ocean.

INTERANNUAL VARIABILITY IN ESTIMATED PRIMARY PRODUCTIVITY OF THE ANTARCTIC MARGINAL ICE ZONE

by

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A model is presented which combines data on the spatial variations in ice extent with information on the primary productivity and spatial extent of ice-edge phytoplankton blooms to estimate the interannual fluctuations of primary production in the Southern Ocean. The results indicate that significant interannual variations in productivity of the marginal ice zone can be expected, with variations up to 50% of the mean.

The ice-edge contributes substantially to the carbon cycle of the Southern Ocean; however, it is uncertain that the productivity is immediately utilized by herbivores or whether the biogenic production sinks to sub-euphotic depths.

NUTRIENTS ANOMALIES IN RELATION TO PLANKTON PRODUCTION
IN THE INDIAN OCEAN SECTOR IN THE ANTARCTIC OCEAN

by

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Watermass structure, productivity and nutrient characteristics of the Indian Ocean Sector of the Antarctic waters between 11° and 53°E longitude, based on data collected from 4 cruises during the years 1981 to 1986 are presented. The transition zone between the two frontal zones of Antarctic convergence and Subtropical convergence extends about 5°, latitude (38° to 42°S), in which the Antarctic circumpolar current presumably prevails. Annual shift in position of this frontal zone by 3 to 4 degrees towards north or south suggests that this zone is less sharply marked around Crozet region (52°E longitude). Divergence around 58°S latitude and strong upwelling in the coastal shelf zone bring about surfacing of nutrient rich, relatively warm deep water. Markedly high chlorophyll (Chl. *a*) and primary productivity (PP) values in the coastal ice-edge zone (mean values Chl. *a* $1.72 \pm 1.0 \text{ mg m}^{-3}$, PP $1.27 \pm 1.0 \text{ mg C m}^{-3} \text{ hr}^{-1}$) when compared to those in the oceanic region (mean Chl *a* $0.28 \pm 0.14 \text{ mg m}^{-3}$, PP $0.3 \pm 0.14 \text{ mg C m}^{-3} \text{ hr}^{-1}$) suggest that the coastal waters are more productive. Sharp decrease in the silica concentration from divergence upto convergence indicates higher utilization of this nutrient by Antarctic diatoms.

Positive anomalies of non-conservative parameters like nitrate, phosphate and silicate show that atomic $\Delta \text{N} : \Delta \text{P}$ south of convergence is 10, whereas $\Delta \text{Si}/\Delta \text{N}$ shows two slopes, in the region reflecting the difference in the regeneration rates of silica in subsurface and deep Antarctic waters. $\Delta \text{Si}/\Delta \text{N}$ ratio in the region south of convergence shows five fold increase compared to the region north of it. The changes in the two regions may reflect the difference in the regeneration processes of these nutrients, high $\Delta \text{Si}/\Delta \text{N}$ ratio indicated excess of regeneration of Si in Antarctic subsurface waters.

BIOLOGICAL PRODUCTIVITY OFF QUEEN MAUD LAND, ANTARCTICA DURING 1981 TO 1986

by

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As a part of the yearly Indian Scientific Expeditions to Antarctica from 1981 to 1986 a total of 86 stations were occupied from December to March between the Antarctic convergence and the edge of the ice-

shelf off Dakshin Gangotri (70°05'S, 12°00'E) Queen Maud Land. Samples were taken at discrete depths for the determination of chlorophyll *a*, ATP, primary productivity (¹⁴C technique), zooplankton biomass (IOS net) and krill biomass (bongo net) during these austral summer sampling programmes.

There appears to be a great deal of variation in phytoplankton and zooplankton production from year to year both at the ice-edge and in the region between the ice-edge and the convergence zone. Values as low as 0.009 mg C m⁻³ hr⁻¹ and as high as 10.35 mg C m⁻³ hr⁻¹ were recorded. Zooplankton biomass with associated krill population also displayed a similar trend. These data are presented and discussed.

During 1983-84 summer, 21 stations were taken for zooplankton/krill biomass from 68°30'S and 14°00'E to 20°00'E region from the period 2nd March to 5th March 1984. Biomass varied from 3-309 mg m⁻³. These variations were partly due to phytoplankton patchiness but cannot be fully explained on this or any other single observed biological or chemical parameter.

Phytoplankton biomass measured as Chl *a* is compared to total zooplankton biomass and to the biomass of krill. Estimates of trophic assays are presented.

Observations at a single station in the polynya from the period December to March in 1983-84 showed a marked day-to-day fluctuation in the primary productivity and phytoplankton biomass. Concomitant krill estimates showed an inverse relationship with time between phytoplankton and zooplankton biomasses. These results are discussed.

Data from oceanic transect stations and a single station in the polynya near the ice-edge at 70°00'S 11°55'E are compared and discussed.

INTERANNUAL VARIABILITY IN ANTARCTIC ZOOPLANKTON POPULATIONS
AROUND THE TIP OF THE ANTARCTIC PENINSULA

by

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Vertically stratified zooplankton samples were taken in the upper 200 m of the water column near Elephant Island in 1981 and 1984 using a 1 m² electronic net and environmental sampling system (MOCNESS). The four dominant copepod species (Calanus propinquus, Calanoides acutus, Metridia gerlachi, and Rhincalanus gigas) were more abundant in 1981 than in 1984 by factors of 101, 807, 20, and 1000 respectively. The salp, Salpa thompsoni, was 10.5 times more abundant in 1984 than in 1981. These changes parallel dramatic changes in krill abundances as evidenced both by the net tows and larger scale acoustic surveys. These conditions appear to have been widespread in the Bransfield Strait and Scotia Sea regions. Possible explanations for this variability will be discussed.

Comparisons of MOCNESS catches with simultaneously collected acoustic data show good qualitative identification of targets and suggest decreased avoidance by krill at low densities.

FINE SCALE VARIABILITY OF TWO ANTARCTIC COPEPODS
NORTH OF ELEPHANT ISLAND

by

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Fine scale variability of Calanoides acutus and Calanus propinquus was studied in surface samples (0-150 m) collected north of Elephant Island (Antarctic Peninsula) during late summer (March-April) 1981, 1984, and 1985. The fine scale spatial distributions of krill and copepods within a krill "super-swarm" in 1981 were also analyzed.

There is a tendency for positive covariation between Calanoides acutus and Calanus propinquus. No evidence was found of spatial exclusion of copepods within the "super-swarm". The results of this analysis suggest that there is no habitat partitioning among species with similar ecological requirements.

ZOOPLANKTON VARIABILITY IN THE WEDDELL SEA

by

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Variability of surface makrozooplankton was studied in the southern branch of the Weddell Gyre. Based on Bongo-net hauls between 200 m and the surface, standardized abundances of frequently occurring zooplankton taxa, including copepods, appendicularians, larval fish Pleuragramma antarcticum, and developmental stages of Euphausia superba, Euphausia crystallorophias, and Thysanoessa macrura were analyzed quantitatively.

Samples were taken over a geographical scale of 400 nautical miles at Vestkapp (73°S/19°W) and Filchner Depression (77°S/40°W). Zooplankton variability between seasons (summer-late winter), and fine scale variability in summer was studied systematically in relation to water mass distribution in a 50 x 50 miles station grid off Vestkapp. Hydrographic conditions were characterized by a steep temperature and salinity gradient over the slope of the continental shelf, indicating westward flow of the coastal current both in summer and late winter.

Temporal variability of zooplankton during 3 weeks in late summer was as high as mesoscale spatial variability over 400 miles. Abundances of larval krill (E. superba) varied 10^3 fold between end of January and mid February. Late winter abundances of 18 zooplankton taxa were 8 to 11 times lower than summer values when compared with mid February and late January, respectively.

The implications of different scales of zooplankton variability for sampling strategies of future monitoring programmes are discussed.

EFFECTS OF PACK ICE ON THE COMPOSITION OF MICRONEKTONIC COMMUNITIES IN THE WEDDELL SEA

by

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Using seabirds as sampling devices on two cruises in the northwestern Weddell Sea, we detected changes in the species or age class composition of micronekton in surface waters. Our micronekton samples represent some of the first ever collected simultaneously in ice-covered and adjacent ice-free waters using the same technique.

The abundance or presence of certain crustacean, fish, and squid species was strongly affected by the presence of ice. Length frequency distributions representing age or sex classes were also affected.

Several faunal schemes proposed for the micronekton of surface waters have been based largely on samples gathered in ice-free waters. Our data indicate that proximity to pack-ice may affect our perception of the composition of micronektonic communities.

PATTERNS OF SPATIAL AND TEMPORAL DISTRIBUTION AND THEIR VARIATION IN EARLY LIFE STAGES OF ANTARCTIC FISH IN THE ANTARCTIC PENINSULA REGION

by

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The Bransfield Strait and adjacent waters are characterized by a high seasonality of ice cover and annual light cycle. Two main water masses of different origins meet and mix in this area which represents the nursery during the early life history of many fish species. Spatial and temporal patterns of distribution of larval and postlarval stages of notothenioid and

myctophid fishes collected during three German and one Anglo-German Joint Antarctic Expeditions between 1977 and 1985 are described. Their variation is analyzed in relation to annual variation in the influence of main water masses and in the spatial and temporal extent of pack ice cover.

SEASONAL PRIMARY AND BACTERIAL PRODUCTIVITY IN THE
PACK-ICE AS RELATED TO KRILL

by

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Biomass and productivity estimates for Southern Ocean pack-ice were made during cruises which took place during the spring (November-December 1983), autumn (March-April 1986), and winter (August-September 1985).

Biological activity and microbial biomass associated with sea ice was equal to or greater than that found in several meters of underlying seawater. Scuba divers photodocumented the underwater structure of the pack-ice, associated microbial communities, and a variety of higher trophic organisms which uses the ice as a substratum, refugium, and site for active foraging.

From these studies we hypothesize:

1. Sea ice can be considered as a concentrated source of microbial carbon for zooplankton grazing, even in the winter.
2. Sea ice may serve as an important nursing ground for larval and juvenile krill.
3. Southern Ocean ecosystem production will be increased when pack-ice production is considered.

KRILL STUDIES IN THE PACK-ICE OF THE WEDDELL SEA
(Supplement to the paper by Kottmeier and Sullivan)

by

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During the Winter Weddell Sea Project in October - December 1986 of RV "Polarstern" the first systematic study of krill in the inner pack-ice of Weddell Sea was carried out by P. Marschall. All along the ship's track from the ice margin of 59°S to south of Halley at 76°S adult and subadult krill was observed on tipped over ice flows and when ice cores were taken. Net hauls yielded rarely some krill from the water column which was

extremely poor in phytoplankton. Krill was seen under the ice at 13 out of 22 dives by a remotely operated underwater vehicle (ROV, Sprint equipped with tv and photocameras). Highest abundance up to more than 50 specimen and 0.2 m^2 was recorded at rugged undersurfaces of the ice and in cavities of melting ice. Krill moved randomly by "walking" and swimming without any swarming behaviour.

Most krill was found actively feeding by scraping off ice algae with the tips of the thoracopods by opening and closing their feeding basket at 2-3 Hz. Loose algae were sucked in by krill hanging underneath the ice and pumping rhythmically with their feeding basket.

Laboratory experiments on board "Polarstern" demonstrated that krill can distinguish between ice flows which are rich or poor in algal growth, clearing rate on glass plates overgrown by ice algae was $0.7 \text{ cm}^2 \cdot \text{sec}^{-1}$.

From the results it can be concluded that the pack-ice provides an important feeding ground to krill, particularly in winter and early spring, when phytoplankton is very scarce. The versatility of krill switching from one habitat and feeding mode to the other might be regarded as one of the keys to its ecological success. Year to year variations in the extent and structure of sea ice may have a significant effect on krill production.

TEMPORAL VARIATION OF IN-SITU CHLOROPHYLL A OBSERVED BY
A MOORED SYSTEM IN BREID BAY, ANTARCTICA

by

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In contrast to a large amount of data on phytoplankton standing crop in the Antarctic Ocean, there is very limited time-series data, which can be useful for analyzing the temporal variability. The moored system was designed for clarifying the long-term as well as fine scale temporal resolution of phytoplankton variation.

The system consists of the continuous measuring-recording buoy for in-situ chlorophyll a, the current meter and the sequentially multiple-sampling sediment trap. The chlorophyll measuring buoy is composed of sensors (in-situ submersible fluorometer, thermistor and pressure transducer), a data logger and a power unit. Two windows of the fluorometer were cleaned hourly by brushing mechanically to remove possible fouling organisms. A set of data (chlorophyll a concentration, water temperature and depth of the buoy) of before and after brushing was sampled hourly. The data logger is capable for three months. The sediment trap can collect 12 discrete samples at a desired sampling interval.

The system was deployed at $70^{\circ}11.54'S$, $24^{\circ}18.68'E$ (water depth 286 m) in the center of Breid Bay, Antarctica. The chlorophyll measuring buoy and the sediment trap were set at 52 m and 120 m depth, respectively, and the current meter was 5 m below the buoy. The mooring experiment lasted for

47 days between 28 December 1985 and 13 February 1986. A total of 1127 sets of time series data was obtained. Brushing mechanism worked successfully, because chlorophyll a concentration measured before and after brushing coincided each other. The sediment trap samples were collected at 3.5 days interval.

Chlorophyll a fluctuated largely between 0.69 - 5.60 $\mu\text{g}/\text{l}$, and it tended to decrease toward early February after a peak in early January. Temperature varied between -1.29 and -1.80°C , being higher in early January and lower toward early February. Depth of the buoy varied in reflection of the tidal rhythm (51.0-54.2 m). High positive correlation between chlorophyll a and temperature persisted and this indicates a possible advective water movement in the Bay, while a low correlation observed might be caused by vertical mixing. Vertical flux of pigment showed a peak in middle January. Sinking of viable phytoplankton cells predominated in the sediment samples. However, the dominancy of faecal pellets (as expressed by volume flux) increased toward early February.

The present system is very effective for the time-series data/sample collections and is applicable for much longer time periods (up to 1 year) not only in coastal waters as a moored system but also in open waters as a drifting system.

KRILL VARIABILITY IN RELATION TO THE ENVIRONMENT

LARGE-SCALE FLUCTUATIONS IN DISTRIBUTION AND ABUNDANCE OF KRILL - A DISCUSSION OF POSSIBLE CAUSES

by

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Some direct information on krill abundance, complemented by data on their predators, suggests that the abundance of krill can vary substantially from year to year in the Scotia Sea near South Georgia and in Bransfield Strait. Despite incomplete knowledge of krill demography, it seems likely that the major cause of these large variations is not due to changes in recruitment or large-scale mortality. More probable mechanisms involve changes in the spatial distribution of krill biomass imposed by physical factors. Changes in distribution would probably be associated with changes in the position of frontal zones and current streams, or with the frequency and character of mesoscale eddies. Whilst the documented spatial scale of such features agrees with the magnitude of observed changes in krill biomass, their likely duration is insufficient to explain changes with time-scale of several months. By contrast, major large-scale changes could be influenced by short-term hydrographic changes which alter physical conditions so as to affect residence time or local distribution of krill. In such cases re-establishing the normal pattern could take longer than with changes in advection and thus agree with the duration of observed biological phenomena. Prolonged southward airflow in the Scotia Sea in two seasons which also exhibited krill paucity could have given rise to hydrographic

changes which released krill from the region, leaving low biomass until replenished by influx of water carrying animals from the Weddell Sea and through Drake Passage.

HYDROGRAPHY, KRILL AND FISH AND THEIR POSSIBLE RELATIONSHIPS
AROUND ELEPHANT ISLAND

by

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Krill, fish and hydrological conditions around Elephant Island were studied with a routine grid programme ("box") in 1977/78, 1983, 1984 and 1985. The hydrological situation was characterized by the presence of Drake Passage water in the north and water of Weddell Sea origin in the south of the box. There is evidence of a stationary meander to the northeast of Elephant Island indicating the indentation of Scotia Sea water masses and Weddell Sea water masses. Krill was most abundant north and northwest of the island. The hydrological regime is thought to be one of the main factors governing the variation in Krill abundance seasonally and annually. More than 40 fish species are present around the island. An attempt was made to correlate the abundance of the most dominant species Notothenia rossii and Champscephalus gunnari with the occurrence of Krill concentrations.

THE PELAGIC ECOSYSTEM OF THE BRANSFIELD STRAIT, ANTARCTICA:
AN ANALYSIS OF MICROBIOLOGICAL, PLANKTOLOGICAL AND
CHEMICAL CHARACTERISTICS BY ORDINATION TECHNIQUES

by

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A data set comprised of biological, chemical, and physical descriptors was treated with a number of statistical techniques, including correlation and cluster analyses. In doing this we aimed to establish reasons for the observed variability - both horizontal and vertical - of planktonic and microbial biomass and activity. Despite an observed zonation in phytoplankton populations, cluster analysis on the complete data set indicates overlap between these zones.

The results indicate that for an understanding of system dynamics it is necessary not to include only biological parameters. Thus, descriptors of the organic fraction, both absolute and ratios, provide additional necessary information for elucidation of, for example, water mass history. In this context derived parameters appear to be more important than actually obtained data for a comprehensive interpretation of the original data base.

Water masses distinguished by physical parameters cannot necessarily be regarded as being similarly distinct in a biological sense. This stems from for instance vertical transport of euphotic zone produced material into deeper water layers by krill fecal pellets or other particulate organic material.

CAN WE SATISFACTORILY ESTIMATE VARIATION IN KRILL ABUNDANCE?

by

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Knowledge of abundance and rates of change of abundance are basic requirements for fisheries models. Catch per unit of effort (CPUE) has traditionally been used in demersal fisheries assessments as an estimator of abundance. It is less satisfactory for pelagic fisheries. Evidence is given that CPUE estimated from data reported to the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) does not provide a realistic estimate of Krill abundance.

Recognizing that there is a large natural year to year variation in krill abundance it is important that this be quantified and separated from fishery induced variation. The timescale for such information is discussed in the light of the needs of fishery management.

PATTERNS OF FLUCTUATION IN THE HYDROLOGICAL CONDITIONS OF THE ANTARCTIC AND THEIR EFFECT ON THE DISTRIBUTION OF ANTARCTIC KRILL

by

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The variability of hydrological conditions over different time scales in the Antarctic (ranging from climatic fluctuation to periods of several days) results directly or indirectly in changes in the distribution of krill over corresponding space scales (e.g. changes in the area of krill distribution, changes in the northern boundaries of areas with abundant aggregations of krill, and changes in schooling behaviour).

Analyses of the reasonably long-term historical data set of hydrological parameters (e.g. air temperature, barometric pressure at ground level, etc.), collected at several hydrometeorological stations in the Southern Ocean and adjacent areas, have revealed the existence of climatic fluctuations. Two so-called warm and cold climatic "epochs" have been distinguished in the western part of the Atlantic Antarctic by prevailing temperature deviations (below and above 0°C) in the historical set of air temperature records. The cold "epoch" lasted from 1910 to 1950 in the southern part of Scotia Sea and from 1910 to 1959 in the northern part. The cold "epoch" was followed by a warm "epoch", which still exists. The patterns of ice distribution and the thermal regime of the surface waters (which is dependent on the direction of movement of high-latitude modification of water masses, in this case Weddell Sea waters) have been well reflected in the above-mentioned climatic fluctuations. Changes in the advection of high-latitude water masses determine the position of junction with relatively low-latitude water masses of the southern part of the Antarctic Circumpolar Current, i.e. the Secondary Frontal Zone which is a natural boundary of abundant krill occurrence.

The abnormal northern movement of high-latitude modification of water masses results very often in a penetration of Weddell Sea waters into the South Georgia area. In this case the volume of penetrating waters may fluctuate considerably.

The year-to-year and season-to-season variations may have tendencies which are in contrast to the general nature of given "epoch". These variations may result in the redistribution of different modifications of Antarctic waters and in turn influence the formation and stability of eddies which to some extent accompany the Secondary Frontal Zone or occur outside the Zone.

Finally, it is worth mentioning the fine-scale variation (up to daily variation) of the hydrometeorological parameters.

DIFFERENCES IN THE HYDROLOGY, BIOMASS, AND SPECIES DISTRIBUTION OF
PLANKTON, FISHES, AND BIRDS IN THE BRANSFIELD STRAIT AND THE
DRAKE PASSAGE DURING FIBEX 1981 AND SIBEX 1983/84

by

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Bransfield Strait and the Southern Drake Passage were investigated by Polish expeditions in February-March 1981 and in December-January 1983/84. In spite of the earlier 1983/84 season the near surface temperatures in the southern and southwestern part of the research area were either higher than or close to those in the 1981 season. Salinity values were distinctly greater in 1983/84. In the Drake Passage, surface temperatures in 1983/84 were lower and salinity values higher, in accordance with the expected seasonal change. Average net phytoplankton (mesh size ca.

60 μm) dry weight in the Bransfield Strait in 1981 and 1983/84 were 0.4 g/m^2 and 3.5 g/m^2 , and in the Drake Passage 5.3 g/m^2 and 1.6 g/m^2 , respectively.

In 1981 the maximum chlorophyll *a* values were 4.4 mg/m^3 and 332 mg/m^2 in a 1-150 m water column. In 1983/84 the respective maximum values were 11.2 mg/m^3 and 635 mg/m^2 . In both seasons high chlorophyll *a* concentrations were found in the vicinity of Anvers Island, while in the regions of D'Urville Is. and Joinville Is. such high concentrations were observed only in 1983/84.

Distinct differences were found between the distributions of zooplankton during both seasons. In 1983/84 large quantities of Salpae occurred in the region of Elephant Island and in Drake Passage. They were not found in the area under the influence of the Weddell Sea water. The indicator species of the Weddell Sea water were Paralabidocera antarctica, polychaete Rhynchonerella bongraini, and siphonophore Dimophyes antarctica. In 1981 larvae of Euphausia superba were numerous and occurred mainly in the NE region beyond the concentration of krill; in 1983/84 few larvae were found in the eastern part of the Bransfield Strait. Euphausia triacantha occurred farther south in 1983/84 (Anvers Is., West of the Bransfield Strait) than in 1981. In both seasons the population size of E. superba generally diminished from west to east. According to the Polish hydroacoustic data, the krill biomass estimates in Bransfield Strait and Drake Passage in 1981 were 2.3 million tons and 1.2 million tons and in 1983/84 they were 70 thousand tons and 122 thousand tons, respectively. In 1981 juvenile and postlarval stages of 23 species of fishes were found above the shelf of the Antarctic Peninsula. They were mainly represented by Chaenodraco wilsoni, Chionodraco rastropinosus, and Cryodraco antarcticus. In 1983/84 Pleuragramma antarcticum dominated among 13 species observed. The numbers of birds in 1983/84 were more than doubled from 1981.

A CONCEPT OF SEASONAL VARIATION OF KRILL (EUPHAUSIA SUPERBA)
DISTRIBUTION AND ABUNDANCE WEST OF THE ANTARCTIC PENINSULA

by

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Based on data from six expeditions of the Federal Republic of Germany to the Antarctic Peninsula area, covering the months from October to June during 1977 to 1986, an attempt is made to draw a general picture of seasonal variability of krill distribution and abundance.

The following conclusions from these investigations are described: during spring (October/November), in the prespawning season of krill, abundance is low. The population consists mainly of juveniles and subadults. After the retreat of the pack-ice the abundance of all developmental stages increases, starting in the southwestern parts of the area. Later, during the spawning season (mostly in midsummer: January to February), highest values of krill abundance are observed. At that time the krill population is separated into different clusters of developmental

stages. Spawning adults are found near the continental slope or in oceanic waters, while juveniles live in shelf waters. In years of late spawning this situation can be observed until March. Normally, the krill abundance is decreasing in late summer through the month of March. Adult krill migrate back into neritic areas, and oceanic waters off the Antarctic Peninsula are almost free of krill. Because of this migration the spatial summer succession of maturity states is no longer found in autumn, and occurrences of adults, subadults, and juveniles are similar. In late fall and early winter krill are almost restricted to inner shelf waters.

The possible influence of environmental factors on the variability of krill distribution and abundance is discussed.

VARIABILITY IN POPULATION DENSITY OF ANTARCTIC KRILL IN THE
WESTERN SCOTIA SEA IN RELATION TO HYDROLOGICAL CONDITIONS

by

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The variation in abundance of Antarctic krill, which is observed in areas of its aggregation, may be related to two interacting environmental factors: (a) fluctuation in the number of individual subpopulations of krill and (b) variation in hydrological conditions upon which krill distribution is dependent. In general it is hard to assess the effect of each factor separately.

Long-term oceanological observations in the western Scotia Sea, in particular in the area off Mordvinov Island (Elephant Is.), have included surveys covering the entire coastal waters of the Antarctic Peninsula, the Bransfield Strait, and the southern part of Drake Passage as well as the microscale surveys at Elephant Island.

Three or four interacting modifications of the water masses in the area have been identified off Elephant Island. Each modification is characterized by different original densities of krill and by different peculiarities in krill biology. The contribution of each modification to the hydrological structure off Elephant Island varies from year to year due to the pulsating nature of water currents and variability in the direction of the movement of the water masses along the seabed, which have diverse composite structure. Depending on the dominant influence of these modifications of water masses and on the degree of eddy formation and stability, the density of krill population can fluctuate markedly.

The optimal condition for high densities of krill appears to be the combination of stable eddies with intensified influence from the water masses of Weddell Sea origin.

The observed decline in recent years of the penetration of Weddell Sea waters in to the area of Elephant Island as a result of the intensification of the southern branch of the Antarctic Circumpolar Current has resulted in decreased krill density.

The microscale surveys with various time resolution in the area off Elephant Island revealed that krill density may undergo short-term fluctuations as a result of changes in the composition of the adjacent modifications of water masses or as a result of instability in the micro-scale eddies.

Thus, the variation in population density of krill in the area off Elephant Island correlates well with changes in hydrological conditions and, in particular, with the circulation and distribution patterns of the different modifications of the Antarctic water masses.

FORMATION OF ANTARCTIC KRILL CONCENTRATIONS IN RELATION TO HYDRODYNAMIC PROCESSES AND SOCIAL BEHAVIOUR

by

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Distribution of krill concentrations in relation to water circulation is presented in this paper.

It was observed that larger quantities of krill occur in the areas of hydrological fronts, meanders, and current eddies especially in regions characterized by high gradients of current velocity.

It was found, on the basis of hydroacoustic measurements, that krill swarms occurring in their concentration regions are of larger size and are characterized by greater krill quantities than those occurring beyond the limits of such regions.

An attempt is made to present a concept concerning a mechanism of formation of krill concentrations in areas of meanders and current eddies. According to this concept, the mechanical factors (currents) cause the permanent inflow of animals to the regions of concentration, and at the same time behavioral factors (specific reactions to the turbulent water flow, and the instinct of shoal formation) make krill stay and congregate in such regions.

A MODEL OF THE DYNAMICS OF THE EGGS AND LARVAE OF THE
ANTARCTIC KRILL, EUPHAUSIA SUPERBA

by

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A mathematical model composed of a system of nine coupled equations is used to describe the development of the Antarctic krill (Euphausia superba) from the single cell egg stage to the calyptopis I larval stage. The model demonstrates how sink rate changes as the eggs develop and how ascent rate changes with larval growth. Formulations for the development of the eggs and larvae, which are based upon laboratory and field measurements, allow these processes to be expressed as functions of age within a stage, time, and temperature. The developmental stage determined from the model for a given temperature regime is used to estimate the appropriate egg sink rate or larval ascent rate. The variability of these rates has implications for the vertical distributions of the krill eggs and larvae in the field. Furthermore, the resultant simulations are used to investigate how environmental variability, such as differing temperature regimes, can affect the development and distribution of krill eggs and larvae. A second model, solved simultaneously, calculates carbon loss due to respiration for each developmental stage as a function of temperature. This model is used to estimate the total carbon energy reserves remaining when the calyptopis I larvae reach the surface. Variations in the carbon reserves which results from environmental factors is also discussed.

VARIABILITY IN THE PHYSICAL AND BIOTIC ENVIRONMENT OF THE ANTARCTIC KRILL
(EUPHAUSIA SUPERBA DANA), SOUTH OF AFRICA: SOME RESULTS
AND A CONCEPTUAL APPRAISAL OF IMPORTANT INTERACTIONS

by

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Data from recent research (particularly the First International BIOMASS Experiment) south of Africa are used to describe the scale of variability in the distribution of hydrographic conservative properties and primary production. These are examined in relation to quantifiable variations in krill (Euphausia superba Dana) density obtained from hydro-acoustic records. The results so obtained are integrated with currently available information in order to qualify understanding of mechanistic interactions between physical processes (especially turbulence in near-

surface waters), primary production and krill. A simple conceptual model is presented to describe interactive elements and suggestions for future studies are made.

STRUCTURE OF SWARMING AND DISPERSED POPULATIONS OF KRILL
(EUPHAUSIA SUPERBA) IN THE WATERS AROUND SOUTH SHETLAND ISLANDS
JANUARY-FEBRUARY 1985

by

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Through the waters around South Shetland Islands and in the northern part of Bellingshausen Sea during 20 January - 12 February 1985 the RV Xiangyanghong 10 made extensive IKMT (Isaacs-Kidd midwater trawl) collections of krill from both swarming and dispersed populations. Length-frequency distribution and sexual maturity stages composition are studied.

The very common bimodal structure in L-F distribution was not found. Juveniles of one or two years old were quite scarce. They were not found in populations north of South Shetland Islands, and only 10-15% in Bransfield Strait. Monomodal structure was the only structure in our samples.

By means of Percent Similarity Indices of L-F structure and sexual stages composition the populations studied can be clustered into three groups occupying different hydrographic areas. Group A occupying the slope waters north of South Shetland Is. and in Bellingshausen Sea has the largest average body length (47.0 mm), the highest percentage of adults (94.5%) and the highest percentage of gravid and spent individuals (35.8%) in females. No juveniles were found in populations of this group. Populations of group B occur principally in the shelf water around South Shetland Is. and consist of 62.3% adults, 27.6% subadults and 10.1% juveniles. The percentage of gravid and spent females is 30.5%. Group C occupies the southern part of Bellingshausen Sea and water near the tip of Antarctic Peninsula - the coldest area in our research. The average body length is the smallest (40.6 mm) in three clustering groups. The populations here consist of only 21.8% adults, 62.6% subadults and 15.6% juveniles. No gravid and spent females are present.

The L-F structure and sexual stages composition of sequential samples within a large swarm north-east of King George Island showed no evidence of shift in population structure.

DISTRIBUTION AND ABUNDANCE OF KRILL LARVAE
(EUPHAUSIA SUPERBA) IN THE WATERS AROUND SOUTH SHETLAND ISLANDS
JANUARY-FEBRUARY 1985

by

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During the First Chinese Antarctic Expedition zooplankton samples were collected at each of the oceanography stations in the waters around South Shetland Islands from 20 January to 12 February 1985 by vertical tows of a 80 cm diameter conical net from 200 m to surface. Three deep tows were performed in slope water north of South Shetland Is. and in the basin of Bransfield Strait with a closing net. Eggs and larvae of Euphausia superba in zooplankton samples were identified and counted.

There are nine records of eggs from 27 stations. Most catches are of small number and restricted within the near-shore area south of S.S. Is. The largest number (1500/1000 cubic meter) was found in the outer side of Smith Island.

No Nauplius was found. The earliest stage we found is Metanauplius, which only occur in two of three deep tows. The distribution of Calyptopsis I-III and Furcilia I-II are quite similar. They were found mainly in three areas: 1) near-shore water along the south coast of S.S. Is.; 2) slope water north of Smith Island; 3) Gerlache Strait. In a station close to the north entrance of Gerlache Strait all the developmental stages throughout Calyptopsis I to Furcilia IV were found.

KRILL VARIABILITY DETECTED FROM PREDATORS STUDIES

VARIATION IN REPRODUCTIVE PERFORMANCE OF SEABIRDS AND SEALS
AT SOUTH GEORGIA, 1976-1986 AND ITS IMPLICATIONS FOR SOUTHERN OCEAN
MONITORING STUDIES

by

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Aspects of the reproductive performance of three species of albatross, two species of penguin, and of Antarctic fur seals, recorded annually at Bird Island, South Georgia over the last decade (and similar data for two other penguin species at Signy Island) are summarized and reviewed.

Breeding success of the wandering albatross (which breeds in winter and eats fish and squid) has fluctuated little, although population size has declined gradually but significantly. The other species at South

Georgia, which breed in summer and for which krill forms a significant proportion of their diet, have shown major fluctuations in some or all of: breeding population size, breeding success, foraging trip duration and offspring growth rate. 1977/78 and 1983/84 were summers of particularly poor reproductive performance by almost all species. Difficulties in provisioning offspring were mainly responsible; circumstantial evidence relating this to reduced availability of krill is discussed.

Detailed comparisons between normal and abnormal years are made of a range of parameters of albatross, penguin and fur seal biology. The results are reviewed in terms of their suitability for detecting changes in the marine environment that may relate to prey availability and thus be influenced by commercial harvesting.

LONG-TERM TRENDS IN THE FORAGING PATTERNS OF
FEMALE ANTARCTIC FUR SEALS AT SOUTH GEORGIA

by

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During their annual four-month period of lactation and pup rearing, female Antarctic fur seals (Arctocephalus gazella) undertake a series of feeding trips to sea to replenish their energy reserves. Female fur seals at South Georgia may make as many as 20 of these trips, during which time they prey principally on Antarctic krill (Euphausia superba). The number of feeding trips that a female makes during her lactation period is apparently related to the relative availability of local food resources. Therefore, information on the inter-annual variability of feeding behaviour over relatively long periods will be valuable in designing future monitoring programmes that investigate prey and predators simultaneously.

Experimental work utilizing tetracycline-marked teeth has demonstrated that the at-sea/suckling cycles of females are reflected as suckling/starving layers in the teeth of their pups. Therefore, by microscopically examining the fine structure of the dentine laid down in individuals' teeth as pups, it is possible to estimate the number of feeding trips made by their mothers during the four months following their birth. Analysis of a collection of 500 fur seal teeth from Bird Island, South Georgia, has provided information on the mean number of feeding trips made annually by lactating females from 1956 to 1981. The long-term trends and variability of the number of feeding trips is discussed in relation to potential changes in krill availability. Fluctuations in the numbers of feeding trips provides insight into the inter-annual variability of ocean resources over a 25 year period at South Georgia.

AN ANALYSIS OF YEARLY CHANGE IN THE BLUBBER THICKNESS OF MINKE WHALES
AS AN INDICATOR OF KRILL AVAILABILITY

by

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Data on blubber thickness measured on 26,751 minke whales caught in the IWC Areas III and IV (0°-130°E) by Japanese expeditions from 1971/72 to 1984/85 seasons were analyzed. The absolute thickness increases slowly in November and December and then accelerates in January and February. Absolute thickness increases with body length while relative thickness decreases. The relative thickness in a pregnant female to foetus length showed a convex increase ($\text{Log}Y=0.83284-0.83186 \text{ Log}X$, December; $\text{Log}Y=0.89796-0.83924 \text{ Log}X$, February. Y: blubber thickness of the pregnant female in cm. L: body length of foetus in cm).

Statistically significant yearly changes in the mean thickness in December and in February were detected some subsequent seasons, which was supported by a positive significant correlation between thickness in February and that in December in the same year, i.e. the beginning of the successive season.

The amount of gain in the blubber thickness during December and February in the same season showed a considerable yearly variability. A strong positive correlation between males and females ($r=0.986$) revealed the phenomenon common to both sexes. Thus it was suggested that yearly variability in food availability (krill) in the Antarctic waters exists on a considerably large scale.

Since information is not quite sufficient for interpretation of the above yearly variability, a further investigation in the historical conditions should be conducted to pursue the possibility of monitoring krill availability through this physiological condition measurement.

DIRECT AND INDIRECT IMPACTS OF PREDATION ON KRILL
(EUPHAUSIA SUPERBA) BY SQUIDS AND ON SQUIDS BY SPERM WHALES
IN THE ANTARCTIC OCEAN

by

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The major food chain in the Antarctic Ocean has been considered the shortest one: phytoplankton ---> krill ---> baleen whales. International BIOMASS programme work within the past ten years has revealed many pathways of food chains around krill in the Antarctic, one of which is the squids and sperm whales complex.

About ten species of moderate sized squids have been collected in BIOMASS studies in the Antarctic, among which four species: Kondakovia longimana, Moroteuthis knipovitchi, Brachioteuthis picta, and Galiteuthis antarctica are dominant in the co-current species of krill in the big midwater trawl.

The seasonal variation of vertical distribution of krill swarms also is considered to induce the different vertical distribution of smaller K. longimana feeding on krill, but the larger K. longimana and M. knipovitchi are considered generally to distribute in deeper waters, where they do not feed on krill only.

The feeding impact of sperm whales on these squids varies according to their migration to the southern waters and the decrease of their stock in recent years. The dynamic analysis of energy flow already showed that the strong impact on krill is observed by the increase of squids. The probable annual and seasonal variability of krill swarms in size and abundance effects the predators' distribution, but the feeding impact of squids also affects the abundance and distribution of krill. The intensity of feeding of squids and sperm whale on squids has been discussed as the probable cause of krill variability in the Antarctic ecosystem.

ANNEX IV

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No.	Title	Publishing Body	Languages	No.	Title	Publishing Body	Languages
32 Suppl.	Papers submitted to the UNU/IOC/Unesco Workshop on International Co-operation in the Development of Marine Science and the Transfer of Technology in the Context of the New Ocean Regime Paris, 27 September-1 October 1982	IOC, Unesco Place de Fontenoy 75700 Paris, France	English	41	First Workshop of Participants in the Joint FAO/IOC/WHO/IAEA/UNEP Project on Monitoring of Pollution in the Marine Environment of the West and Central African Region (WACAF/2) Dakar, Senegal, 28 October - 1 November 1985	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
33	Workshop on the IREP Component of the IOC Programme on Ocean Science in Relation to Living Resources (OSLR) Halifax, 26-30 September 1983	IOC, Unesco Place de Fontenoy 75700 Paris, France	English	42	IOC/UNEP Intercalibration Workshop on Dissolved/Dispersed Hydrocarbons in Seawater Bermuda, USA, 3-14 December 1984 (in press)	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
34	IOC Workshop on Regional Co-operation in Marine Science in the Central Eastern Atlantic (Western Africa) Tenerife 12-17 December 1983	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French Spanish	43	IOC Workshop on the Results of MEDALPEX and Future Oceanographic Programmes in the Western Mediterranean Venice, Italy, 23-25 October 1985	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
35	CCOP/SOPAC-IOC-UNU Workshop on Basic Geo-scientific Marine Research Required for Assessment of Minerals and Hydrocarbons in the South Pacific Suva, Fiji, 3-7 October 1983	IOC, Unesco Place de Fontenoy 75700 Paris, France	English	44	IOC/FAO Workshop on Recruitment in Tropical Coastal Demersal Communities Ciudad del Carmen, Campeche, Mexico, 21-25 April 1986	IOC, Unesco Place de Fontenoy 75700 Paris, France	English Spanish
36	IOC/FAO Workshop on the Improved Uses of Research Vessels Lisbon, 28 May - 2 June 1984	IOC, Unesco Place de Fontenoy 75700 Paris, France	English	45	IOCARIBE Workshop on Physical Oceanography and Climate Cartagena, Colombia, 19-22 August 1986	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
36 Suppl.	Papers submitted to the IOC-FAO Workshop on Improved Uses of Research Vessels Lisbon, 28 May-2 June 1984	IOC, Unesco Place de Fontenoy 75700 Paris, France	English	46	Reunión de Trabajo para Desarrollo del Programa «Ciencia Oceanica en Relación a los Recursos No vivos en la Región del Atlantico Sudoccidental» Porto Alegre, Brazil 7-11 de Abril de 1986 (in press)	IOC, Unesco Place de Fontenoy 75700 Paris, France	Spanish
37	IOC/Unesco Workshop on Regional Co-operation in Marine Science in the Central Indian Ocean and Adjacent Seas and Gulfs Colombo, 8-13 July 1985	IOC, Unesco Place de Fontenoy 75700 Paris, France	English	47	IOC Symposium on Marine Science in the Western Pacific: The Indo-Pacific Convergence Townsville, 1-6 December 1986 (in press)	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
38	IOC/ROPME/UNEP Symposium on Fate and Fluxes of Oil Pollutants in the Kuwait Action Plan Region Basrah, Iraq, 8-12 January 1984	IOC, Unesco Place de Fontenoy 75700 Paris, France	English	48	IOCARIBE Mini-Symposium for the Regional Development of the IOC-UN (OETB) Programme on "Ocean Science in Relation to Non-Living Resources (OSNLR)"	IOC, Unesco Place de Fontenoy 75700 Paris, France	English Spanish
39	CCOP (SOPAC)-IOC-IFREMER-ORSTOM Workshop on the Uses of Submersibles and Remotely Operated Vehicles in the South Pacific Suva, Fiji, 24-29 September 1985	IOC, Unesco Place de Fontenoy 75700 Paris, France	English	49	AGU-IOC-WMO-CPPS Chapman Conference: An International Symposium on "El Niño" Guayaquil, Ecuador, 27-31 October 1986	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
40	IOC Workshop on the Technical Aspects of Tsunami Analyses, Prediction and Communications Sidney, B.C., Canada, 29-31 July 1985 (in press)	IOC, Unesco Place de Fontenoy 75700 Paris, France	English	50	CCAMLR-IOC Scientific Seminar on Antarctic Ocean Variability and its Influence on Marine Living Resources, particularly Krill (organized in collaboration with SCAR and SCOR) Paris, France, 2-6 June 1987	IOC, Unesco Place de Fontenoy 75700 Paris, France	English