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SCAR WORKING GROUP ON BIOLOGY

Report of an informal meeting held in Cambridge, England, 17–18 May 1976

Present: J. Prévost (chairman, Subcommittee on Bird Biology), France; J. Valencia, Chile; K. Kerry, Australia; S. Z. El-Sayed, USA; T. Øritsland, Norway; R. M. Laws, UK; E. M. van Zinderen Bakker, South Africa; W. S. Benninghoff (secretary), USA; W. N. Bonner (chairman, Subcommittee on Conservation), UK.
Observers: G. A. Llano, USA; H. Lorca, Chile.

Subcommittee on Conservation

The report of the Subcommittee on Conservation, which met in Cambridge, 10–12 May 1976, (see also Appendix) was received and considered in the following four parts:

(a) *Classification of Antarctic ecosystems.* The three proposed sections, for marine, terrestrial, and inland waters ecosystems, were discussed and approved for use in connection with matters of biological conservation and protection.

(b) *Review of the adequacy of existing scheduled sites to represent categories of the classification, and recommendation of further sites for scheduling as representative areas.* The group endorsed the subcommittee recommendations and proposed:

Recommendation 1976-BIOL-1, that National Committees consider

(i) Proposing extensions to boundaries of existing Specially Protected Areas (SPA's) so as to include other representative areas at present unscheduled (for example, coastal sites could be extended seaward so as to include the littoral and sub-littoral).

(ii) Identifying areas, particularly inland areas and marine areas of enclosed waters vulnerable to disturbance, which will fill the voids in the classifications proposed.

The group also suggests that it would be appropriate to designate areas Sites of Special Scientific Interest (SSSI's) before upgrading them to SPA's, in order that adequate data on the site may be assembled. This approach would not be appropriate for areas intended for preservation in as undisturbed a state as possible.

The group called attention to the subcommittee's recognition of the importance of the biological time scale in the Antarctic, where ecosystems are continuing to evolve and colonization is taking place, and suggests to National Committees that consideration to be given to routes of dispersal and biogeographical aspects when selecting scheduled sites.

The subcommittee's observation on the need for setting up scheduled sites in the sub-Antarctic islands was noted, as well as the observation that some nations have adequately enforced conservation legislation and have set aside sites, whereas others have no effective control. The Working Group therefore urges:

Recommendation 1976-BIOL-2, that SCAR encourages member nations with sub-Antarctic islands to ensure that representative sites (as defined in the classification matrices of Antarctic ecosystems) are scheduled and that adequate legislation, along the lines of the Agreed Measures for the Conservation of Antarctic Fauna and Flora, for the protection of such sites becomes available.

The subcommittee's recommendation that one or more SPA's should be set up in an Antarctic oasis or dry valley area was accepted, and the group put forward the following:

Recommendation 1976-BIOL-3, that National Committees give further consideration to the establishment of SPA's in oasis and dry valley areas of Antarctica.

At present only Barwick Valley has been recommended to be set aside, and that as an SSSI.

The unusual biological character of the lakes in the McMurdo dry valleys was discussed and it was pointed out that Lake Bonney is the major remaining lake not to have been contaminated to some degree by geological drilling. Therefore, with a view to the future protection of Lake Bonney, the Working Group advanced:

Recommendation 1976-BIOL-4, that the United States National Committee proceed with the preparation of the justification and management plan for designating Lake Bonney as an SSSI, and then submit the proposal for consideration by other National Committees.

(c) *Biological monitoring in Antarctica.* The group endorsed the subcommittee's recommendations, and urged adoption of the following:

Recommendation 1976-BIOL-5, that SCAR encourages a policy of favouring appropriate time-series measurements of biological and environmental phenomena which would serve the objectives of monitoring without deflecting or obstructing the usual project-oriented studies.

Recommendation 1976-BIOL-6, that National Committees include in their annual reports notices of all time-series measurements of phenomena which serve the ends of biological monitoring, and also indicate where the resulting data are published or archived.

The Working Group decided to establish an *ad hoc* Subcommittee on Biological Monitoring in the Antarctic, with the following terms of reference:

1. To advise on biological and environmental monitoring that could be implemented from within existing Antarctic scientific programmes.

2. To recommend further approaches to biological monitoring in the Antarctic with particular regard to the development of time-series measurements of biological and relevant environmental phenomena which will serve the objective of monitoring with minimum deflection or obstruction of the usual project-oriented studies.

3. To advise the Working Group on Biology on how best to co-ordinate existing and future Antarctic monitoring schemes with global schemes.

4. To report on the above topics at the next formal meeting of the Working Group on Biology.

The subcommittee will consist of a chairman and four members, one of whom will be a member of the Working Group on Biology. The members should represent appropriate specialities in biology and should be familiar with the interactions of biology and environmental sciences. The secretary of the Working Group, in consultation with the other members, will select a chairman. The secretary and chairman will then appoint the other four members of the subcommittee.

(d) *Information brochure for support personnel and tourists.* The subcommittee's proposal to prepare such a brochure was approved. The Working Group expected to receive a final draft of the text by 1 August 1977, which it would review and revise as necessary before handing it on to SCAR in January 1978.

The Working Group thanked the chairman for the subcommittee report and advised him that the subcommittee would probably have to meet again shortly before the meetings of XV SCAR in 1978.

Subcommittee on Bird Biology

The Subcommittee on Bird Biology met on 13–14 May 1976 and submitted a report to the Working Group on Biology. The group took the following actions:

(a) *Standardized procedures for observation of birds at sea.* The group endorsed the subcommittee's stand that 'information should be obtained by a co-ordinated international effort using a standardized procedure for observing and recording birds seen, together with data related to ship location, weather, water temperature and the presence of ice'. The group approved the subcommittee's request to circulate to National Committees the document 'Suggested method for observing birds at sea' for comments and consideration for adoption.

(b) *Proposals for international programmes in bird biology.* The proposals were endorsed by the Working Group, and the subcommittee was urged to proceed with its plans to elicit information from all nations concerning their past and present bird banding programmes and to exchange banding information annually. The subcommittee was advised to pursue the possible uses of satellites for tracking birds.

(c) *Census of avian species.* The Working Group suggested that the subcommittee prepare a more substantive proposal concerning the designation of a year for the census of avian species, and circulate it to National Committees for comments. The subcommittee will report on the results at the next formal meeting of the Working Group.

(d) *Studies of pollution in Antarctic birds.* The group agreed with the subcommittee's recommendation that more attention be given to such studies and suggested that more emphasis be placed on studies of individuals in the populations to determine concentration levels and possible effects.

(e) *Standardization of measurements of birds.* The subcommittee recommended that its members circulate details of currently employed standardization techniques. The Working Group endorsed this suggestion and encouraged the subcommittee to proceed by sending communications to the group's representatives and to appropriate persons engaged in research on Antarctic birds.

(f) *Statement on the summary of birds killed in the Antarctic.* After discussion of the statement and clarification of the fact that Dr R. M. Laws has been collecting and preparing these summaries for publication along with similar reports for seals, the chairman modified the statement to read as follows: 'The subcommittee recommends that the records of birds killed or taken in the Treaty Area continue to be summarized and published together with the data on seals. The subcommittee gratefully acknowledges and accepts the offer of Dr Laws to continue to prepare and publish these reports.' National Committees, and the national representatives to the Working Group are requested to ensure that the reports of birds killed or taken are submitted promptly after each Antarctic summer research season.

The Working Group thanked the chairman for the subcommittee report and advised him that the subcommittee should consider holding its next meeting not later than shortly before XV SCAR.

Information reports

Dr R. M. Laws, convenor, presented a report of recent activity by the Group of Specialists on Seals. The report was accepted with thanks.

Professor E. M. van Zinderen Bakker, convenor of the Group of Specialists on Late Cenozoic Studies, reported on recent activities in connection with the Congress of the International Quaternary Association in Birmingham, England, next year. A one-day symposium for Antarctic papers has been scheduled for 17 August 1977.

Professor S. Z. El-Sayed, convenor of the Group of Specialists on Living Resources of the Southern Ocean, presented a progress report on plans for the International Conference on Living Resources of the Southern Ocean, 17–21 August 1976 at Woods Hole, USA. He also announced the establishment of a group *Newsletter*, the first issue of which had been distributed.

Dr G. A. Llano, editor of the *Proceedings of the Third Symposium on Antarctic Biology*, reported that he had handled 72 papers, comprising 1 509 pages of manuscript text, 393 pages of figures, and 253 pages of tables, not including the record of discussions. The publisher is Clayton Umbach, Gulf Publishing Company, Houston, Texas.

Eighth Antarctic Treaty Consultative Meeting recommendations

Recommendations from the Eighth Antarctic Treaty Consultative Meeting relating to special areas were found to be in agreement with the proposals submitted from the Working Group. The recommendations considered were:

(a) VIII-I. Adoption of Litchfield Island as Specially Protected Area, No 17.

(b) VIII-2. Review of Specially Protected Areas—cancellations of No 6: Cape Crozier (Ross Island), No 10: Byers Peninsula (Livingston Island, South Shetland Islands), and No 12: Fildes Peninsula (King George Island, South Shetland Islands).

(c) VIII-3. Sites of Special Scientific Interest—statement of principles.

(d) VIII-4. Sites of Special Scientific Interest—interim guidelines and annexed plans for the following sites:

Site No 1: Cape Royds, Ross Island
Site No 2: Arrival Heights, Hut Point Peninsula, Ross Island
Site No 3: Barwick Valley, Victoria Land
Site No 4: Cape Crozier, Ross Island
Site No 5: Fildes Peninsula, King George Island, South Shetland Islands
Site No 6: Byers Peninsula, Livingston Island, South Shetland Islands
Site No 7: Haswell Island

(e) VIII-5. Permits for entry to Specially Protected Areas—change of wording in the Agreed Measures for the Conservation of Antarctic Fauna and Flora *from* permission for collection of native mammals, birds, or plants *to* added possibility of permit issued 'for some other compelling scientific purpose'.

Recommendations from the Consultative Meeting relating to the environment were reviewed, namely:

(a) VIII-10. Antarctic marine living resources.

(b) VIII-11. Man's impact on the Antarctic environment—code of conduct and encouragement of detecting and assessing changes.

(c) VIII-13. The Antarctic enviroment—code of conduct for governments.

No points of view were found to diverge from those of the Working Group. All feasible actions for this group to undertake had already been initiated, as discussed earlier in the meeting.

Mineral resources

As an added agenda item for this meeting the Working Group considered the document recently distributed to all National Committees by the SCAR Executive, 'Antarctic resources—effects of mineral exploration: initial response to invitation to SCAR contained in Antarctic Treaty Recommendation VIII-14', and made some comments that have been forwarded to SCAR.

Future meetings

The Working Group on Biology requested SCAR approval to convene its next formal meeting in association with XV SCAR in 1978. It is desired that the subcommittees on conservation and bird biology meet shortly before the formal meeting of the group. The *ad hoc* Subcommittee on Biological Monitoring must meet not later than the period just before the group meeting, if a meeting is required for the conduct of its business. Circumstances may require convening the group or any one of the subcommittees at earlier dates.

APPENDIX I

Extract from the report of the meeting of the Subcommittee on Conservation, Cambridge, 10–12 May 1976

Consideration of a classification of Antarctic and sub-Antarctic terrestrial, freshwater and inshore marine benthic ecosystems

While an elaborate classification might be possible, the objectives and time available indicated the need for a simple, but nevertheless comprehensive, and workable system which would enable a general type classification of ecosystems to be made. The final classification would need to relate to conservation, and so a uniform system for marine, terrestrial and inland water ecosystems might not be appropriate.

The proposed classification is described in three matrices (Tables 1–3). The boxes in the matrices are not exclusive, hence any site set aside as a conservation area might fall into more than one box; the scheme is however comprehensive in that any site can be assigned to a box.

The marine ecosystem

The marine ecosystem, in contrast to those of the land and inland waters, provides a relatively continuous and uniform environment. The chief variables are distance from shore, depth of the water column, ice cover and substrate type. Minor variations of, for example, salinity, temperature, nitrate and phosphate concentration, are of profound biological significance, but usually occur on too small a scale to make site conservation practicable.

The surface waters provide the foundation for the food web of virtually all of the oceanic pelagic system; transfer of energy and nutrients from the marine ecosystem to the terrestrial ecosystem (and thence to the inland waters ecosystem) occurs on a scale which is of great local significance. Hence it is vital that active steps are taken to ensure that the integrity of the marine system is maintained. Since site conservation is impracticable and inadequate in the open sea this must be done by general agreements on ocean use and exploitation. The SCAR/SCOR Group of Specialists on the Living Resources of the Southern Ocean is considering the problem.

The classification proposed (Table 1) is based on those physical features which characterize particular sets of biota. The vertical axis of the matrix is mainly concerned with the presence or

absence of ice, though the special effects of freshwater influence from run-off and geothermal heating are recognized. The importance of enclosed bays, inlets or fiords, and their vulnerability to disturbance are recognized by the inclusion of a special category of 'enclosed waters'. The horizontal axis extends from the open sea to the littoral. Indications of the depths concerned are given, but depth relations are not well understood in the Antarctic. The essential division implied between the shelf zone and the sub-littoral is that in the latter the benthos is sustained mainly by living organisms in the water column above it while in the former only detritus is available. The littoral is defined as extending from the lowest limits of tides to the highest part of the splash-zone, where an interface occurs with the terrestrial system. The littoral is an especially vulnerable zone, but is likely to be included in both marine and terrestrial scheduled sites.

TABLE 1. PHYSICAL FEATURES CHARACTERIZING MARINE ECOSYSTEMS

		BENTHIC					LITTORAL			
	Pelagic neritic	Bathyal > 500 m	Shelf zone (c 500 - 200 m) hard bottom	Shelf zone (c 500 - 200 m) soft bottom	Sub-littoral (c 200 - 0 m) hard bottom	Sub-littoral (c 200 - 0 m) soft bottom	Rock / boulder	Pebble	Sand, mud and/or shell	Ice
Permanent ice		?	?	?						
Seasonal ice		?	?	?						
Absence of ice										X
Fresh water influence	X	X	X	X						
Enclosed water mass		X	X	X						
Geothermal influence										

The terrestrial ecosystem

Each component of the matrix (Table 2) comprises a complex mosaic of habitats and associated biota. Each habitat is characterized by specific within-site variables of which the following are considered the most important:

1. Water availability (including extent and duration of snow cover: partially related to aspect).
2. Stability of substrate.
3. Slope and exposure (= aspect).
4. (a) Rock type
   (b) Nutrient availability (partially related to rock type and partially to marine biotic influences)

(c) Texture of substrate
(d) Fumerole activity.

5. Altitude (linked to environmental characters in matrix headings).

In evaluating the general characteristics for ecosystem studies it was concluded that the only adequate data are those concerning species diversity; it would be valuable to direct future studies to monitoring and ultimately modelling the energetics of the ecosystems and to obtain more detailed information on biomass and net primary and secondary production. Such data are

TABLE 2. TERRESTRIAL ECOSYSTEMS - CLASSIFICATION MATRIX

Environmental variables / Biotic variables	Ice-free rocks and soils (including late snow beds)								Permanent ice		
	Coastal				Inland (> 10 km from shore)						
	adjacent to sea and up to 10 km from shore		above ice shelf		valley		mountain		ice cap / glacier		
	<1 000 m alt	>1 000 m alt	<1 000 m alt	>1 000 m alt	<1 000 m alt	>1 000 m alt	<1 000 m alt	>1 000 m alt	Coastal land / or < 100 m alt	100 - 1000 m alt	>1000 m alt
Vascular plants significant/ locally dominant											
Bryophytes sig/dom											
Lichens sig/dom											
Macrothalloid algae sig/dom			?								
Microbiota sig/dom		?		?		?		?			
Snow algae sig/dom							?				
Sterile	?		?								
Marine faunal enrichment											

available only for a very few areas or specific ecosystems. One possible approach to investigating primary production in relation to climatic diversity would be to study growth and production of one or more moss species which occur in a wide range of habitats throughout the sub-Antarctic–Antarctic region (for example, *Bryum argenteum*).

All Antarctic plant communities can be classified according to Lewis Smith's system[1] (modified as necessary) which he applied to the vegetation of Signy Island and other maritime Antarctic regions. Sterile areas may be of high conservation interest and are therefore included in the matrix; these could consist of such areas as the remote surface of the ice cap, some undisturbed dry valley surfaces and new volcanic deposits. Areas of marine faunal enrichment, where concentrations of birds or seals have greatly increased the available nutrients with their excreta or carcasses, often support characteristic biota and are provided for in the matrix.

[1] LEWIS SMITH, R. I. 1972. Vegetation of the South Orkney Islands with particular reference to Signy Island. *British Antarctic Survey Scientific Reports*, No 68.

The inland water ecosystem

The extreme complexity of the separate and interacting components of communities and their associated environments, which comprise the inland water ecosystems, was recognized and a simple, workable and flexible classification was devised (Table 3).

This classification acknowledges the importance of environmental variables, particularly salinity, in influencing the aquatic community structure and composition. Purposely omitted was a comprehensive breakdown of salinity, for example, chloride dominance v sulphates, which have a major influence on the biota of aquatic environments. Similarly, although chemical stratification is indicated with the degree of salinity (fresh, medium, hypersaline) in the upper

TABLE 3. CLASSIFICATION OF ANTARCTIC INLAND WATERS

	LAKES										STREAMS	
	Permanent						Ephemeral					
	Fresh S< 3 g/l		Medium S= 3 - 30 g/l		Hypersaline S> 30 g/l		Ice dammed		Rock or moraine dammed		over ice	over rock
	a	b	a	b	a	b	wholly (melt pools etc)	partly (rock walls)	sea influenced	not sea influenced		
Sterile												
Heterotrophs only												
Primary producers												
(i) Phytoplankton sig or dom												
(ii) Algal felt sig or dom												
(iii) Bryophytes sig or dom												
Herbivores												
Carnivores												

a stratified chemically b not stratified chemically

layer, salinity of the lower layer and reference to thermal stratification has been om itted 'Permanently' is used here to characterize aquatic environments on a human (non-geological) time scale and with year-round liquid water. 'Ephemeral' refers to aquatic bodies frozen sometime during each year, temporary melt pools, streams, sub-surface flow, and certain moist soil habitats derived from snow and glacial melt.

An important feature which characterizes the spectrum of aquatic environments in Antarctica is the development of trophic levels ranging from sterile to carnivore; yet rarely, if ever, does the spectrum include the higher trophic levels developed in most temperate, tropical, and even Arctic aquatic ecosystems.

It is emphasized that the examples of aquatic environments identified from this classification constitute only a partial list from those known. Many different types also exist—for example, geothermally heated lakes. It is hoped that the classification, by its simplicity, will lend itself to categorizing such aquatic environments in the future.

SCAR WORKING GROUP ON GEOLOGY

Report of a meeting held in Sydney, Australia, 19–20 August 1976

Present: C. Craddock (chairman), USA and IUGS; J. C. Dooley, Working Group on Solid Earth Geophysics; O. Gonzalez-Ferran, Chile; P. J. Hugo, South Africa; I. R. McLeod (secretary), Australia; M. G. Ravich, USSR; K. Suwa, Japan.
Observers: V. Bardin, USSR; P. Barker, UK; E. Grew, USA; D. Kinney, USA; R. L. Oliver, Australia; R. J. Tingey, Australia.
Apologies for absence from: J. Nougier, France; T. S. Winsnes, Norway.

Matters arising from previous meeting

The Working Group reaffirmed that annual national reports on geological activities in Antarctica were useful and that their preparation each July should continue in the standard format. Each member is asked to ensure that the existence of these reports be made known as widely as possible in his country.

International Geodynamics Program

Professor Gonzalez-Ferran reported on the activities of the Scotia Arc Study Group of Working Group No 2 of the Inter-Union Commission on Geodynamics. The Working Group on Geology reaffirmed its interest in the Scotia Arc and Scotia Sea region and stressed that efficient use of logistic resources was important because of the difficult working conditions in the region.

Recommendation 1976-G-1. The Working Group, emphasizing the importance of geological and geophysical studies in the region, recommends that international participation in work in the region be encouraged, that information on the potential availability of logistic resources be widely disseminated well in advance, and that participation by local workers in scientific conferences concerning the region be facilitated in accordance with ICG aims.

The group agreed that long-term records of sea levels around the continent were needed for studies of changes in the Antarctic ice sheet and isostatic movements of the continent, and that it was important to begin collecting these data as soon as possible.

Recommendation 1976-G-2. The Working Group, recognizing that long-term records of relative sea levels are needed for studies of isostatic movements of the Antarctic continent and for studies of changes in the ice sheet, recommends that tide gauges be installed at coastal stations as soon as possible.

Antarctic stratigraphic lexicon

The secretary reported that contributions had been received from the United States, Norway, South Africa, USSR, Australia, New Zealand and Chile, and that Dr Nougier had advised him that French expeditions had not introduced any stratigraphic names. Dr Suwa was ascertaining whether Japanese expeditions had introduced any names. The Bureau of Mineral Resources, Australia, had put together the national contributions; this had revealed a number of minor inconsistencies about which the secretary would write to the compilers. It was hoped that the lexicon would be in a form suitable for publication by the end of 1976.

Third Symposium on Antarctic Geology and Geophysics

The chairman outlined progress in planning the symposium to be held in Madison in 1977, and said that the Steering Committee would meet during the International Geological Congress. Expression of interest had been received from 130 people, and about 100 titles had been submitted as potential papers.

CGMW maps of Antarctica

Professor Ravich displayed a 1:5 million geological map of Antarctica which had been compiled by USSR geologists using all available information. The USSR expected to publish the map early in 1977; several copies would be sent to each Working Group member. The group agreed that the USSR geologists who compiled the map had made a valuable contribution to Antarctic geology.

It was decided that the secretary would send photographs of the map to members of the Working Group, who would send their comments and suggestions to Professor Ravich. These comments and the map would be discussed at the Working Group meeting in 1977, with the aim of having a final compilation ready for CGMW by the end of 1977.

The chairman said that he had received a number of comments on the proposed legend for the 1:15 million tectonic map of Antarctica. Several different ways of compiling the map were possible. The Working Group for the Tectonic Map of Antarctica (Professor Craddock, Professor Ravich, Dr Adie and the secretary) now needed to consider how best to proceed, so that general principles and possible legends could be discussed at the next Working Group meeting.

Future geological studies in Antarctica

The Working Group noted the paper on future geological studies prepared by Professor Ravich. It agreed that comments from members should be sent to him, and urged each country to consider the most important research projects for the next five to ten years, so that future programmes could be discussed at the 1977 meeting.

Antarctic mineral resources

The Working Group noted that the paper on mineral exploration which it had prepared at SCAR's request had been included in the SCAR response to Antarctic Treaty Recommendation XIV-14, and that topics bearing on the subject of Antarctic mineral resources would be discussed in conjunction with the forthcoming Symposium on Antarctic Geology and Geophysics. It reaffirmed its readiness to provide advice to SCAR if called upon. It might become necessary, to enable the group to provide appropriate advice, to arrange meetings which could be attended by all group members.

The Working Group noted the paper on mineral exploration prepared by Professor Ravich and agreed that other members should prepare papers, if they thought these would be appropriate, which could form a basis for discussion at the 1977 meeting.

Other business

The group noted that the Working Group on Solid Earth Geophysics was considering holding a formal meeting in conjunction with the Third Symposium on Antarctic Geology and Geophysics to facilitate a joint meeting with this Working Group. From past experience the group believed that a joint meeting would be useful and welcomed the opportunity to hold such a meeting in 1977 in Madison.

The Working Group agreed that the present chairman and secretary should retain office. The question of office-bearers will be considered again at the 1977 meeting of the group.

SCAR/SCOR GROUP ON THE LIVING RESOURCES OF THE SOUTHERN OCEAN (SCOR WORKING GROUP 54)

Report of a meeting held at Woods Hole, USA, 23–24 August 1976

Present: S. Z. El Sayed (chairman); G. Deacon, UK; J. A. Gulland, FAO; G. Hempel, FRG; G. A. Knox, New Zealand; R. M. Laws, UK; T. Nemoto, Japan; G. G. Newman, South Africa; S. Olsen, Norway; D. B. Siniff, USA; A. P. Tomo, Argentina; D. J. Tranter, Australia.

Introduction

The group met in the US National Academy of Sciences Summer Studies Centre in Woods Hole, USA. It was the third meeting of the SCAR Group of Specialists but the first since it became SCAR/SCOR Working Group 54. The meeting was combined with a conference on the Living Resources of the Southern Ocean which was well attended—by 59 scientists—but it was regretted that there was no participation from the USSR.

The chief objective of both the conference and the meeting of the Working Group was to review the present knowledge of the living resources of the Southern Ocean and to develop a proposal for future co-operative studies in this area. Members of the Group of Specialists prepared a draft proposal for an international study of the Living Resources of the Southern Ocean which followed the outline developed at the first meeting of the SCAR Group of Specialists in Cambridge, UK, 6–8 October 1975. A number of background review papers were also delivered at the conference as a basis for discussion. These papers included: 'Physical oceanography of the Southern Ocean: key to understanding its biology' (T. Foster, USA), 'The problems of harvesting and utilization of Antarctic krill' (J. Schärffe, FAO), 'The legal status of the Antarctic' (F. Sollie, Norway), 'Remote sensing of Antarctic living resources' (W. Hovis, USA) and 'Modelling of Antarctic ecosystems' (K. Green, USA).

The growing interest by several countries in marine research in Antarctic waters was reflected by reports and films on Antarctic expeditions in the 1975–76 season carried out by research vessels, commercial factory trawlers and icebreakers of the Federal Republic of Germany, Poland, Japan, France, Argentina and the USA. The results of those expeditions will greatly augment our knowledge of the krill and fish resources of Antarctic waters. The Group of Specialists regretted the lack of up-to-date information on the recent activities of the USSR. The major part of the conference as well as the subsequent sessions o the Group of Specialists were devoted to the discussions on the further development of the proposal for an international co-operative study of the living resources of the Southern Ocean which led to the BIOMASS Programme.

Finally the group noted that it would probably need a further meeting soon after SCOR, SCAR and IOC had considered its report and suggested programme. The proposed changes in its terms of reference, and the increasing activity in Southern Ocean biological research (including work by countries not presently members of SCAR) are likely to make changes and additions to the group's membership desirable, in order to include sufficient range of expertise, and to ensure that the group is informed of all significant research activities. At the same time, it is desirable to keep the group small, and it will be possible in some cases to bring in the required expertise by including appropriate scientists in specialized sub-groups.

Ecosystem studies

An understanding of the trophodynamics of the Southern Ocean ecosystem is vital from the viewpoint of wise resource management and conservation and presents a unique opportunity to contribute to an understanding of ecosystem processes in the ocean. One approach to the understanding of the whole ecosystem is to develop suitable models. The development of a crude whole ecosystem model for Antarctic waters might be feasible now with the present data base and some additional biological data, such as field data on biomass of ecologically important elements of the system and experimental data on transfer rates. A model can serve to organize existing information and to point out areas where additional research is needed. At the same time it can be sufficiently flexible to incorporate further information and insight in the course of its future development.

A model has been constructed of the Ross Sea ecosystem (Green, 1975) which describes the interaction of nutrients, light, ice, phytoplankton, zooplankton and larger animals. The development of a general model of the entire system must be accompanied by other activities, such as development of more detailed sub-models of certain elements of the system. To make full use of the modelling process, it is necessary to bring the model builders together with those concerned with field investigations and experimental studies. A process feedback between model development and field studies will serve to enhance the predictive capabilities of the various models as they are updated, validated and improved. It can also serve to identify information needs and provide some direction for future research. In addition to correspondence there seems a need for meetings of small groups to discuss these matters in detail.

Description of the living resources

A number of compilations and reviews of the main Antarctic living resources were available to the meeting. These included preliminary drafts of reviews of krill, fish and cephalopods prepared by I. Everson as part of the UNDP (FAO) Southern Ocean project, and a review of Antarctic birds by J. Prévost. Extensive reviews of information on marine mammal stocks have been made by scientists for the International Whaling Commission (IWC) and for the Scientific Consultation on Marine Mammals, Bergen, Norway, September 1976.

With a few exceptions, little is known of the biomass and productivity of the living marine resources other than the marine mammals. Though investigations began shortly after the turn of this century, it was not until recent years that studies of the biomass of such resources as fish, crustaceans and seaweeds were made. The discussions on the various living resources aimed at the identification of those aspects of ecology which are of particular importance for an assessment of the magnitude of the resource and the possible consequences of its exploitation; harvesting should be planned and managed on the basis of a knowledge not only of the population dynamics of the resource itself, but also of its interaction with the other parts of the ecosystem.

Marine mammals and birds

The conference and the Group of Specialists concentrated on certain biological aspects which are of particular importance regarding the present role of marine mammals in the Antarctic ecosystem, and on the changes which have taken place since the depletion of the whale stocks and the cessation of sealing. Abundance estimates of seals are fairly reliable and their biology is relatively well known except for rarer species (particularly the Ross Seal). Crabeater Seals are by far the most abundant of all seal species in the world; their diet consists almost exclusively of krill. Most of the other species have a mixed diet consisting of krill, fish and squids.

Table 1 compares the present abundance and krill consumption of whales with those occurring before whaling began. As a consequence of whaling, total biomass of baleen whales and their annual consumption of krill decreased to about one-sixth and one-fifth, respectively, of the original figures. There are indications of increased body growth rates, earlier maturation and increases in pregnancy rates in Blue, Fin and Sei whales as well as in Crabeater Seals.

TABLE 1. BALEEN WHALES IN THE ANTARCTIC

(Rounded figures of initial stocks and their Antarctic food consumption; present figures given in brackets)

	Stock (thousands)		Mean weight (tonnes)		Biomass (millions tonnes)		Krill consumption (millions tonnes)	
Fin	400	(84)	50	(48)	20	(4)	81	(16)
Blue	200	(10)	88	(83)	18	(0.8)	72	(3)
Sei	75	(40)	18	(17)	1.4	(0.7)	6	(3)
Humpback	100	(3)	27	(26)	2.7	(0.01)	11	(0.3)
Minke	200	(200)	7	(7)	1.4	(1.4)	10	(10)
Total	975	(337)			43	(7)	180	(33)

For the first time an attempt has been made to make a global assessment of the bird population of the Southern Ocean. Penguins comprise 99 per cent of the biomass of Antarctic avifauna with Adélie Penguins largely dominating in the pack ice zone; in the sub-Antarctic 83 per cent of the biomass consists of penguins—petrels and albatrosses making up much of the rest. The total biomass of all birds in the Southern Ocean is estimated to be nearly 200 million individuals, but there are considerable differences in accuracy of the censuses of the various populations. It is also estimated that the food consumption of the bird population is about 40 million tonnes of food per year, 54 per cent of which is taken in the sub-Antarctic region. 86 per cent of all the food of the Southern Ocean birds is eaten by penguins. It consists principally of euphausiids; only a few concentrate their diets on fish or squids. Albatrosses apparently feed heavily on pelagic squids. The petrels differ very much in size (0.04—4 kg) and in food, ranging from micro-zooplankton to larger fish and squids. Food consumption is by far the highest in the vicinity of the Antarctic and sub-Antarctic islands and along the continental coast. Penguins may not have profited greatly from the decrease in whales as competitors for krill. It has been suggested that penguin populations are more strongly affected by the availability of food in the winter and nesting sites than the availability of krill in the summer.

In former times, whales were by far the largest group of consumers of Antarctic krill. Presently, whales and sea birds seem to be similar in their yearly consumption of krill, and seals consume about twice as much as either. The consumption figures for birds are less reliable than for seals and whales.

Fish

A dozen species of fish, mainly Nototheniids, are presently exploited or are likely to become attractive for exploitation in the near future. All of them are demersal and live on the narrow shelves and banks of the Antarctic and sub-Antarctic islands and on parts of the continental shelf. The systematic inventory of the Antarctic ichthyofauna seems to be almost complete and some physiological work has been carried out. In certain species of Nototheniids growth rate is not particularly slow and some information indicates that their food often consists mainly of krill. No reliable figures on abundance, stock density and distribution can be provided for any of the Antarctic fish. Amongst pelagic fishes only Myctophids are relatively frequent in Antarctic waters. They seem to be krill eaters too. Nothing is known about their population dynamics.

Cephalopods

Squids are frequently found in the catches of pelagic trawls taken north of the Antarctic Convergence; they are extremely rare in the samples taken further south. However, this might be due to the fact that most of the southern catches are taken in near-surface layers. There are large numbers of squids recorded in the stomachs of Sperm Whales, seals and birds, particularly in the vicinity of the Convergence and north of it. Further studies on the stomach contents of these predator species and the use of multiple types of collecting gear, as well as good records on the deposits of squid beaks at the sea bed, are needed to substantiate the belief that cephalopods constitute as large a resource in the Southern Ocean as they do in other parts of the world ocean. Without reliable data on squid abundance, species composition and life history, no estimate is possible on the potential resource, or on the role of squids as consumers of krill. The stocks of octopus in the Antarctic do not appear to be large.

Benthic invertebrates

So far there is little indication of large resources of decapod crustacea and bivalves south of the Antarctic Convergence. The continental shelf is possibly too deep to sustain large stocks of macrobenthos. Records in the Palmer archipelago and the Scotia Arc are limited. They indicate the presence of scallops and mytilids but give little indication of substantial stocks of shrimps and prawns. Benthic bivalves and crustaceans are far more important around the northernmost islands where rock lobsters, and particularly lithodids and spider crabs, seem to be abundant. Apart from the resource aspect, benthic studies should be encouraged as important contributions to the understanding of the function of the Antarctic ecosystem; for instance, recent observations made at shore bases showed that krill is consumed by ophiuroids.

Krill

The discussions of krill concentrated on *Euphausia superba*, which is by far the most important species of Antarctic euphausiid. Other species play a major role only at the edge of the Antarctic continent and in the area north of the Antarctic Convergence. In certain areas other planktonic crustacea—amphipods, for example—are abundant and may be grazed upon by large consumers.

In spite of the extensive work on the distribution and life history of krill carried out during and soon after the main whaling period, there are still major gaps in our knowledge. Areas, depth and intensity of spawning are poorly known. It was suggested that major spawning takes place under the ice on the continental shelf and shelf break and/or in the open ocean. The vertical distribution and horizontal transport of early larval stages from egg to first calyptopis has been described by Marr's hypothesis of development ascent (1962). This has to be confirmed and placed on a more quantitative basis in both time and space (in the light of data on water transport at the relevant depths). There is still much dispute on growth rate of krill, whether krill reaches an age of a little more than two years or almost four years, and whether each female spawns only once in her life-time. Experimental work in enclosures and tanks may help to answer these questions. Furthermore, it is not yet known whether *Euphausia superba* consists of one genetically uniform circumpolar stock or, more likely, of a number of more or less self-sustaining units which differ genetically and in population parameters. Present data show that krill of all stages found in the eastern Weddell drift appear to be expatriates. No mechanism has been determined by which these are returned as eggs or adults to the eastward drift zone.

The present size and annual production of the krill population of the Southern Ocean is unknown except within broad limits. Crude guesses have been based on estimates of primary productivity, ecological efficiency, and the role of krill relative to other herbivores in the region. Recent observations indicate that average primary production of the Southern Ocean is lower than assumed and that other herbivores make up a major part of zooplankton at least in certain regions. Estimates of food consumption of the virgin whale stocks are of the order of 200 million

tonnes. While these figures are relatively reliable, the share taken by other predators such as small cetaceans, seals, birds, squids and benthic invertebrates remains largely unknown. Furthermore, we do not know enough of the recent changes in the abundance of those predators to produce estimates of an accuracy which goes beyond the statement that krill production has been of the order of several hundreds of million tonnes prior to depletion of the Antarctic baleen whales. It is not known to what extent man might replace whales in the exploitation and regulation of krill production.

Recent observations on geographical distribution of krill in the Antarctic have mainly confirmed the earlier work by Marr, Mackintosh and others. Modern pelagic trawls and acoustic devices indicate that krill concentrations may be found at greater depths than have been previously reported. Although micronekton sampling suggests the presence of single krill outside major swarms, the numerical importance of these 'individualists' is not known. In general, structure, migration, dynamics and continuity of krill swarms is poorly understood.

Seaweeds

The littoral zones of the Antarctic archipelago and the sub-Antarctic islands are the habitat of large populations of macrophytes such as red algae, agarophytes and particularly large brown kelps. For example, average figures of standing stock of 5–10 kg/m^2 have been recorded for large beds of *Macrocystis* and of *Durvillea* off Kerguelen Island.

In summer, large concentrations of smaller algae develop along the Antarctic continent. At the conference, the potential importance of the algae as a resource for industrial, chemical and pharmaceutical use was stressed, together with its ecological importance as a habitat, a source of detritus and a producer of dissolved organic substances. An increase in research on Antarctic and sub-Antarctic seaweed is desirable.

Resource utilization

Marine mammals

Whales were the main resource to be harvested between 1930 and 1960, with annual production in the range 1.5 to 2 million tonnes (with a peak of nearly 3 million tonnes in one season). The sustainable harvest, if all stocks were maintained at their most productive level, would be of the same order. Right, Blue and Humpback whales are very scarce, and now receive complete protection. The combination of low predicted rates of increase, the relatively short period of protection in the case of Blue and Humpback whales, and the lack of even moderately precise estimates of absolute or relative abundance have made it impossible to determine whether or not they are recovering as predicted. The other large whales (Fin, Sei, Minke and Sperm) have been depleted to less and varying extents. The management policies of IWC are now in accord with scientific recommendations

Elephant and Fur seals were heavily exploited in the 18th and 19th centuries. Annual catches are believed to have been in excess of some hundreds of thousand animals in some years. Since the cessation of large scale scaling, these stocks have increased, some extremely rapidly, in the past 50 years. The true Antarctic seals have never been harvested on a significant scale, and though consideration has been given to possible exploitation, it does not seem likely to occur in the near future.

Fish

Large scale harvesting, principally by USSR vessels, has occurred in the last ten years around the sub-Antarctic islands. Peak catches have been 400 000 tonnes in 1970 in the south Atlantic (probably mainly around South Georgia) and 200 000 tonnes in 1971 in the southern Indian Ocean (probably mainly around Kerguelen). While the available data do not allow detailed

assessment, the subsequent decline in catches suggests that the stocks have been affected by the fishery. Catches of Southern Poutassou, or Blue Whiting have increased from 8 000 tonnes in 1970 to 48 000 tonnes in 1973. The exact area of fishing is not known, though the principal grounds appear to be around New Zealand and in the Scotia Sea. No significant fish catches appear to have been taken around the Antarctic continent.

Large crustacea

Though these are not abundant, their high price has allowed the development of fisheries around several of the sub-Antarctic islands. Total production of rock lobsters has been some 1 500 tonnes annually, which seems to be almost equal to the maximum productivity of the stocks. Management measures have been introduced into most of the fisheries. Interest has been expressed in varous species of crab, but no fishery has developed apart from those around South America.

Cephalopods

Though the resource is believed to be large, the group had no evidence to suggest that significant squid harvesting would start in the Antarctic or sub-Antarctic in the near future.

Krill

Extensive studies have been made on the practicability of krill harvesting, and several thousand tonnes have already been taken. The technological difficulties of locating and catching krill have been overcome to the extent that krill could be caught in large quantities (perhaps several hundred tonnes per vessel per day) provided that the fishing operations did not have to be interrupted to handle and process the catch. The development of a process to produce, at reasonable cost, a krill product that would find a wide market still presents formidable technological problems. For the present, therefore, the prospects are of only small-scale krill harvesting.

Conservation

In addition to the harvesting of whales and seals, for which there are arrangements for conservation through existing international conventions (IWC and the Seal Convention), substantial exploitation of fish in the sub-Antarctic has begun and the large-scale harvesting of krill appears to be a reasonable possibility in the not too distant future. Arrangements should be made as soon as possible to ensure the conservation and rational utilization of these important resources. The group recommended that SCAR should draw the attention of the parties concerned to the need for such arrangements, which should include the collection and reporting of information (especially from commercial operations), scientific studies (especially the assessment of the state of stocks), and agreement on specific management measures and their implementation.

Proposed scientific programme

Objectives

An integrated and well co-ordinated Biological Investigation of Marine Antarctic Systems and Stocks (BIOMASS) is proposed. In broad terms the objectives of BIOMASS are:

1. To provide data and information for the conservation and wise management of the living resources of the Southern Ocean.
2. To improve our understanding of the complex ecosystem on which the resources depend, and to understand the flow of energy through the system.

To achieve these objectives it will be necessary to promote an in-depth study of the individual components of the marine ecosystem, as well as to study the entire system as an integrated

whole. For reasons of resource management and basic ecological science, attention will be focussed on those particular components that offer actual or potential opportunities for commercial harvest.

For each of these resources (krill, squids, fish, marine mammals, lobsters, birds and seaweeds) the main objectives will be to assess:

(i) Standing stock and production
(ii) Basic parameters important in the dynamics of the population (for example, growth, mortality, reproduction)
(iii) Trophic relationships (feeding and predation)
(iv) General biological and ecological characteristics, especially those needed to elucidate the preceding points.

The emphasis given to each line of study will differ for each class of resource, and the BIOMASS programme outlines the detailed objectives for the different resources. The programme also aims to develop a general and theoretical understanding of the system as a whole, including the construction of models describing part or the whole of the ecosystem.

Implementation

Between the period of *Discovery* investigations in the 1930's and the recent work on krill, which has been mainly directed towards studying the possibilities of commercial harvesting of krill, biological research in the open waters of the Southern Ocean had been grossly neglected. Greatly increased research efforts are now required, and should involve the close international co-ordination of activities on board research vessels operating in Antarctic waters, and at shore stations.

Specific activities proposed for biological research vessels include observations of key processes, at times and places at present poorly sampled, and wide-ranging surveys using acoustic and other instruments. Most of the other vessels operating in the Southern Ocean (supply vessels, research vessels carrying out physical oceanography or other studies, and commercial and exploratory fishing vessels) can provide platforms for useful observations, especially those that do not interfere with the ship's main objectives. As a minimum, information resulting from exploratory and commercial fishing vessels must include catch and effort statistics in sufficient detail, sample size, and other biological characteristics of the animals caught.

The principal role of shore stations will be to provide information on the near-shore ecosystem, including long time-series of year-round observations at fixed positions. The possibilities of using remote sensing techniques from aircraft or satellites in order to supplement and extend ship-board or shore-based investigations will be closely studied. Analysis of the information collected in the field will be mainly the responsibility of participating institutions; however, arrangements will be made for the central compilation of some types of data.

International co-ordination and co-operation

There exists a number of international organizations which have expressed interest in the resources of the Southern Ocean; several of these have biological programmes of one kind or another. The success of BIOMASS will depend on the establishment of effective planning and co-ordination machinery. The group studied the present structure of international co-operation which is outlined in the BIOMASS proposal. Recommendations regarding the international planning and co-ordination of BIOMASS are summarized below. While the scientific planning should be done by a non-governmental SCAR/SCOR Group of Specialists, the co-ordination of BIOMASS should be carried out by an international group for BIOMASS under IOC, whose exact status will need to be determined by IOC.

SUMMARY OF RECOMMENDATIONS OF SCAR/SCOR GROUP ON LIVING RESOURCES OF THE SOUTHERN OCEAN

1. That SCAR and SCOR approve the following amended terms of reference for the Group of Specialists on the Living Resources of the Southern Ocean (SCOR WG 54).
   (a) To encourage and stimulate investigations of the trophodynamics of the Antarctic marine ecosystem and the ecology and population dynamics of organisms at different trophic levels.
   (b) To keep under review the current state of knowledge concerning the Antarctic marine ecosystem from the viewpoint of structure, biomass of organisms, dynamic processes at different trophic levels, and prospects and consequences of exploitation of the marine living resources of the Southern Ocean.
   (c) To advise SCAR and SCOR and through them other international organizations on scientific matters related to the study of the ecosystem and the living resources of the Southern Ocean, and in particular to respond to relevant recommendations of the Antarctic Treaty Consultative Meetings and IOC.
   (d) To act as the international scientific planning group for BIOMASS.
   (e) To recommend standardized methods, techniques and data research for biological investigations in the Southern Ocean.
2. That IOC undertakes the international co-ordination of BIOMASS.
3. That IOC requests countries carrying out research in the Southern Ocean to provide details of proposed cruise tracks and scheduled researches, which would be made available to the Group of Specialists.
4. That SCAR requests the National Agencies operating supply ships to institute a circum-Antarctic programme of underway observations of surface temperature, salinity, chlorophyll and underway collection of records of XBT and biological echo traces.
5. That SCAR collaborates with FAO in drawing the attention of all parties engaged in the exploration and exploitation of living resources of the Southern Ocean to the need for detailed catch and effort statistics to be submitted to FAO.
6. That SCAR informs FAO of its approval of the proposed northward movement of the boundary lines between statistical areas in the Atlantic and Indian oceans, and that in the interim period before the new regions are formally approved by all interested parties, countries should be requested to distinguish separately, when reporting to FAO, the catches taken (a) in the south Atlantic in the area bounded by 50° to 60°S in 20° to 50°W and 55° to 60°S in 50° to 60°W, and (b) in the Indian Ocean between 40° and 50°S in 30° to 80°E.
7. That SCAR and SCOR should agree as soon as possible on the publication of selected documents submitted as working material for the Woods Hole meetings.

References

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ACRONYMS

CGMW Commission for the Geological Map of the World
ICG Inter-Union Commission on Geodynamics
IOC Intergovernmental Oceanographic Commission
IUGS International Union of Geological Sciences
UNDP United Nations Development Program