

Southern Ocean ecology: the BIOMASS perspective

Edited by

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Glossary of acronyms

AAAS	American Association for the Advancement of Science
AABW	Antarctic Bottom Water
ACC	Antarctic Circumpolar Current
ACMRR	Advisory Committee on Marine Resources Research
ADBEX	Antarctic Division BIOMASS Experiment
AZ	Antarctic Zone
BAS	British Antarctic Survey
BIOMASS	Biological Investigations of Marine Antarctic Systems and Stocks
BOFS	Biogeochemical Ocean Flux Study
BSBBW	Bransfield Strait Basin Bottom Water
BWPFE	BIOMASS Working Party on Fish Ecology
CCAMLR	Commission for (<i>or</i> Convention on) the Conservation of Antarctic Marine Living Resources
CCSZ	Coastal and Continental Shelf Zone
CDW	Circumpolar Deep Water
CPUE	catch per unit effort
CSW	Continental Shelf Water
DEE	Daily Energy Expenditure
DMS	dimethylsulphide
DMSP	β -dimethylsulphoniopropionate
DOM	dissolved organic matter
EASIZ	Ecology of the Antarctic Sea-Ice Zone
EEZ	Exclusive Economic Zone
ENSO	El Niño – Southern Oscillation
EPOS	European <i>Polarstern</i> Study
FAP	fluorescent age pigment
FIBEX	First International BIOMASS Experiment
FRAM	Fine Resolution Antarctic Model
GEOSECS	Geochemical Ocean Sections Study
GLOBEC	Global Ocean Ecosystem Dynamics Programme

GOSEAC	Group of Specialists on Environment and Conservation
HNLC	high-nutrient, low-chlorophyll (waters)
IABO	International Association for Biological Oceanography
ICES	International Council for the Exploration of the Sea
IFZ	Ice-Free Zone
IGBP	International Geosphere–Biosphere Programme
IGY	International Geophysical Year (1956–7)
IOC	Intergovernmental Oceanographic Organization
ICSU	International Council of Scientific Unions
ISAS	International Survey of Antarctic Seabirds
IUCN	International Union for the Conservation of Nature
IWC	International Whaling Commission
IWSOE	International Weddell Sea Oceanographic Expedition
JARE	Japanese Antarctic Research Expedition
JGOFS	Joint Global Ocean Flux Study
LOICZ	Land–Ocean Interactions in the Coastal Zone
LME	large marine ecosystem
MIZ	Marginal Ice Zone
MVBS	mean volume backscattering strength
NMDS	non-metric multidimensional ordination
NOAA	National Oceanic and Atmospheric Administration
PF	Polar Front
PFZ	Polar Frontal Zone
POM	particulate organic matter
POOZ	Permanently Open Ocean Zone
PPIZ	Permanent Pack-Ice Zone
PSU	Practical Salinity Unit
RACER	Research on Antarctic Coastal Ecosystem Rates
SACW	South Atlantic Central Water
SAF	Sub-Antarctic Front
SAZ	Sub-Antarctic Zone
SCAR	Scientific Committee on Antarctic Research
SC-CAMLR	Scientific Committee for the Conservation of Antarctic Marine Living Resources
SC-CCAMLR	Scientific Committee of the Commission for the Conservation of Antarctic Marine Living Resources
SCOR	Scientific Committee on Oceanic Research
SIBEX	Second International BIOMASS Experiment
SIBW	South Indian Basin Bottom Water
SIZ	Seasonal Ice Zone
SL	standard length
SPIZ	Seasonal Pack-Ice Zone
STF	Subtropical Front
SSW	Summer Surface Water
SW	Surface Water <i>or</i> Shelf Water
TAAF	Terres Australes et Antarctiques Francaises
UML	upper mixed layer
UNCLOS	United Nations Convention on the Law of the Sea
WCRP	World Climate Research Programme
WDW	Warm Deep Water
WEBW	Weddell–Enderby Basin Bottom Water

WG-CEMP	Working Group for the CCAMLR Ecosystem Monitoring Programme
WG-FSA	Working Group on Fish Stock Assessment
WG-Krill	Working Group on Krill
WOCE	World Ocean Circulation Experiment
WSC	Weddell–Scotia Confluence
WW	Winter Water

Foreword

The BIOMASS Colloquium, held in Bremerhaven, Germany, in September 1991, was the culmination of the major programme of Biological Investigations on Marine Antarctic Systems and Stocks, formulated in 1976, and directed to improving understanding of the ecology of the vast Southern Ocean. The origins of the programme lie in the establishment, in 1972, of a Subcommittee of the SCAR Working Group on Biology, on Marine Living Resources of the Southern Ocean. In 1975 this Subcommittee was upgraded by SCAR to a Group of Specialists on Living Resources of the Southern Ocean, which was later renamed the SCAR Group of Specialists on Southern Ocean Ecosystems and their Living Resources, in co-sponsorship with SCOR (as Working Group 54), IABO and ACMRR.

A keystone species of the Antarctic marine ecosystem is a small shrimp-like organism called krill (*Euphausia superba*), potentially a major human food source that may provide an important supply of protein for the future. Krill are crucial to the Antarctic pelagic food chain, providing food for the higher species including whales, seals, penguins, fishes and squid.

The BIOMASS Programme was a major collaborative effort of scientists from many nations; one of its main objectives was to provide an adequate body of knowledge for the wise management of the living resources of the Southern Ocean surrounding the continent of Antarctica. It grew out of the scientific

community's concern for maintaining the underlying ecological relationships between the living organisms in this ocean. The BIOMASS Programme facilitated the achievement of an international convention – the 1980 Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR) – as part of the Antarctic Treaty System. It has been an important source of information for the Scientific Committee of CCAMLR; the BIOMASS investigators were commissioned to produce two key reports for CCAMLR, on the *Biology and Status of Exploited Antarctic Fish Stocks*, and on the *Biology and Ecology of the Antarctic Krill*, both published as BIOMASS Scientific Series 6 and 9, respectively.

BIOMASS was one of the first international collaborations of scientists attempting to provide information for the formulation and application of multispecies management policies, before an ecosystem is seriously threatened or destroyed by commercial exploitation. Because of the immensity of the circumpolar Southern Ocean – some fifty million square kilometres – and its participating membership of eleven countries, the programme was truly international in character.

The overall programme initiated, promoted and drew together marine scientific studies by the participating nations. Scientists standardized methodology, planned programmes, exchanged information in workshops, coordinated the work of joint expeditions and made provision for data archiving and

management by setting up the BIOMASS Data Centre. Two multiship, multinational cruises – FIBEX and SIBEX (First and Second International BIOMASS Experiments) – took place in 1981 and 1984–5. Some 32 international workshops were held around the world. The BIOMASS Programme also led to an impressive number of publications, including many valuable contributions in scientific journals, in addition to 68 Reports in the BIOMASS Report Series, 23 BIOMASS Handbooks, 10 volumes in the BIOMASS Scientific Series, and 25 issues of the BIOMASS Newsletter. The Programme transformed knowledge of the ecology and oceanography of the Southern Ocean, but has also had an impact on scientific research far beyond that region.

In the process the BIOMASS Programme trained and encouraged many young scientists from a variety of nations, disciplines and backgrounds, bringing them together in workshops, as invited participants in the Group of Specialists' meetings, and at the Colloquium.

The administrative costs of this major programme extending over fifteen years totalled less than US\$600 000, that is less than \$40 000 a year, contributed predominantly by the Antarctic Operating Agencies, but also by the International Council of Scientific Unions (ICSU) and its Scientific Committees on Antarctic (SCAR) and Oceanic (SCOR) Research. The leadership of this intensive and

extensive international programme was in the hands of Professor S. Z. El-Sayed (with a tiny Secretariat at Texas A&M University) and the members of the BIOMASS Executive, to whom, and to the many Chairmen, Convenors and contributing scientists, we offer our appreciation and thanks.

In this volume, arising from the contributions to the BIOMASS Colloquium, some of the many accomplishments of the Programme are described, including aspects of physical oceanography; estimates of krill stocks, advances in krill biology, physiology and biochemistry; contributions to the knowledge of organisms at higher trophic levels, particularly fish and birds; and the operation and achievements of the BIOMASS Data Centre. There was remarkable unanimity among those attending the Colloquium that the BIOMASS Programme had been a resounding success and that related programmes, such as the International Geosphere–Biosphere Programme (IGBP) and its core programme the Joint Global Ocean Flux Study (JGOFS), now under way, as well as others now being planned (e.g. the Global Ocean Ecosystem Dynamics Programme, GLOBEC), could build on the BIOMASS data and experience. SCAR and SCOR are proud to have been closely involved in this success story.

Richard M. Laws
President, SCAR

Jarl-Øve Stromberg
President, SCOR

Preface

This book is the proceedings of the BIOMASS Colloquium held at the Alfred Wegener Institute, Bremerhaven, Germany, in September 1991. It is a record of accomplishments of the international BIOMASS programme during the decade of the 1980s. It traces the historical context and circumstances that led to the establishment in 1972 of the subcommittee on the Marine Living Resources of the Southern Ocean (of the SCAR Working Group on Biology), and the subsequent upgrading, in 1976, of that subcommittee to the SCAR Group of Specialists on Southern Ocean Ecosystems and Their Living Resources. That group was charged with planning, developing and implementing the BIOMASS Programme.

The book consists of 22 peer-reviewed chapters in six sections. The chapters' arrangement follows closely the organizational structure of the Colloquium. The opening chapter gives a short narrative of the history of BIOMASS, which is followed by description of the physical and chemical settings of the two regions of the Southern Ocean that were the main foci of the BIOMASS field work, namely, the Southwest Atlantic Ocean and the Prydz Bay area (in the Indian Sector). This is followed by chapters on the phytoplankton and zooplankton (not including krill). Because of the great attention given to krill research during BIOMASS, the several papers presented at the Colloquium underscore the preoccupation of the BIOMASS investigators with

the Antarctic's keystone organism. The chapters on higher trophic levels, namely fish and birds, document BIOMASS accomplishments in ichthyo- and avifauna research. The interactions among these trophic levels are highlighted in the chapters presented on the subject.

The final chapters are intended as a look to the future. Speakers were asked to respond to the challenge presented by the Convenor, who asked 'Is there life after BIOMASS?' Predictably, the speakers rose to the challenge and provided thought-provoking and stimulating commentaries.

For each of the Colloquium's six sessions, discussants were invited to present their impressions on the papers presented, and to evaluate their strengths and shortcomings. They were later asked to summarize their evaluations, which we are pleased to include under the heading 'Discussant's report' at the end of each section.

As is the case in similar multinational, multidisciplinary programmes whose lifespans extend more than a decade, and in which hundreds of researchers are involved, it is natural to expect that most of the chapters in the book are essentially review papers of the state-of-the-art knowledge in the various disciplines at the end of BIOMASS. This was the charge given beforehand to the authors, all of whom made special effort to comply with that charge.

It is indeed a pleasure to acknowledge with deep gratitude the valuable contributions to this volume

made by the authors and discussants. I am very much indebted to the several reviewers for their diligence and thoroughness, and for making helpful suggestions and thoughtful comments for improvement of the manuscripts.

Grateful acknowledgements should be extended to those members of the BIOMASS community at large, to the members of the SCAR Group of Specialists on Southern Ocean Ecosystems and Their Living Resources, to the Chairmen and members of the BIOMASS Technical Groups, Working Parties and *ad hoc* Groups. Without their interest, enthusiasm and devotion to the cause of BIOMASS, the programme would not have become the reality and the success we believe it was.

Finally, The British Antarctic Survey deserves our appreciation for housing and supporting the operational aspects of the BIOMASS Data Centre. Special thanks are extended to the two main sponsors of BIOMASS, SCAR and SCOR, and to the contributors to the BIOMASS Special Fund, who over the long duration of the programme have given generously to finance almost all aspects related to BIOMASS: its workshops, meetings and publications, including subsidy of the present book.

Sayed Z. El-Sayed
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July 1992

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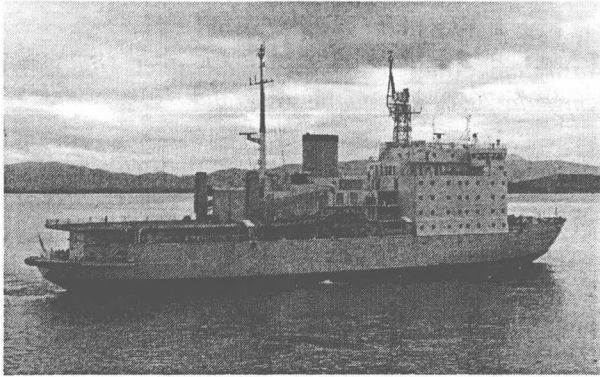
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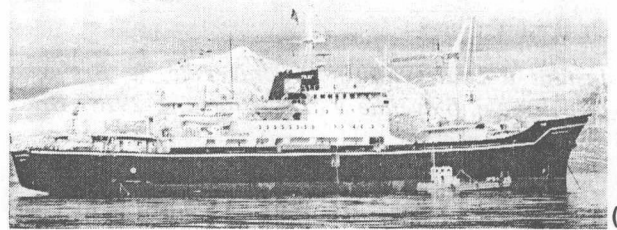
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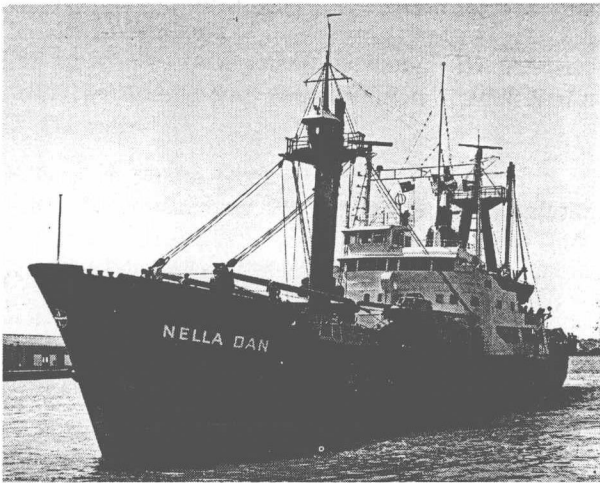
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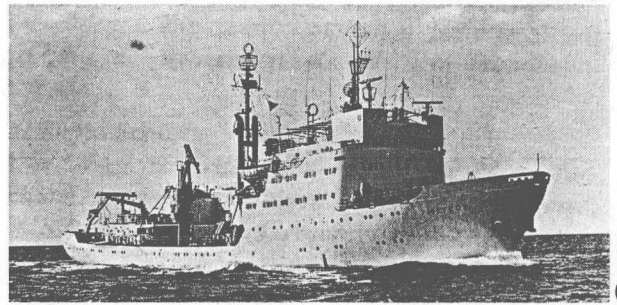
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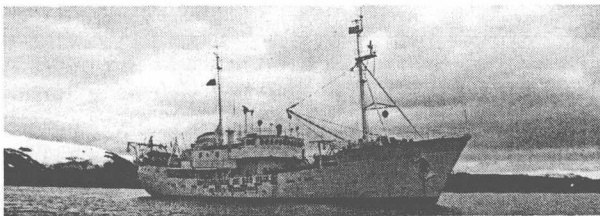
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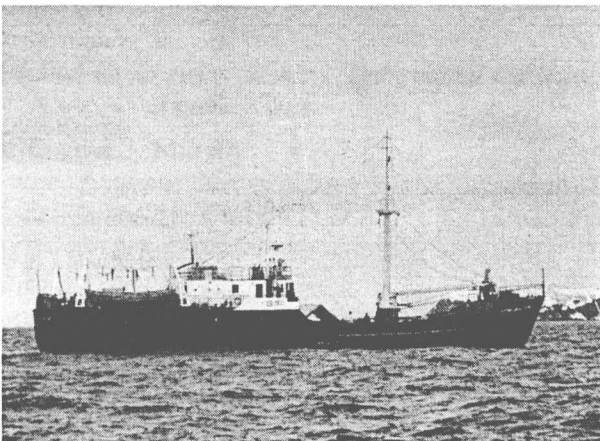
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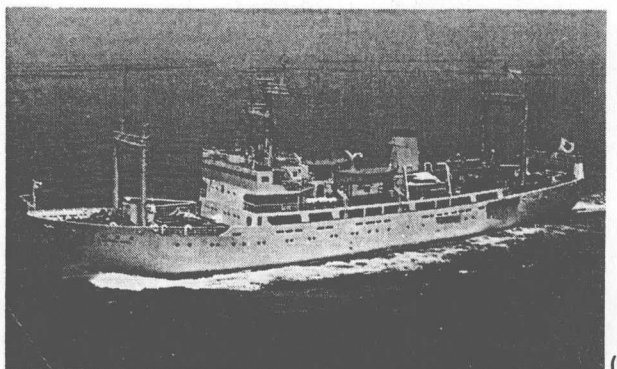
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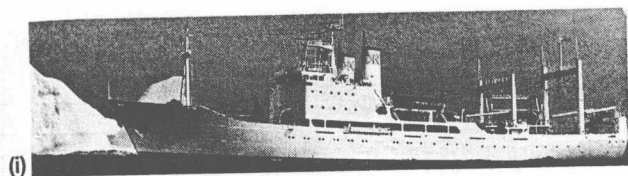
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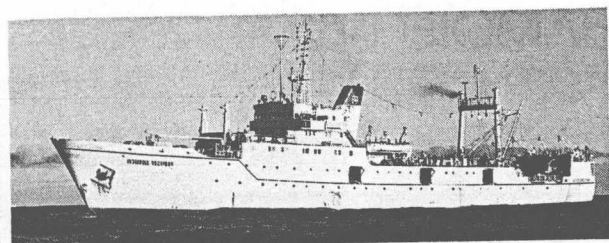
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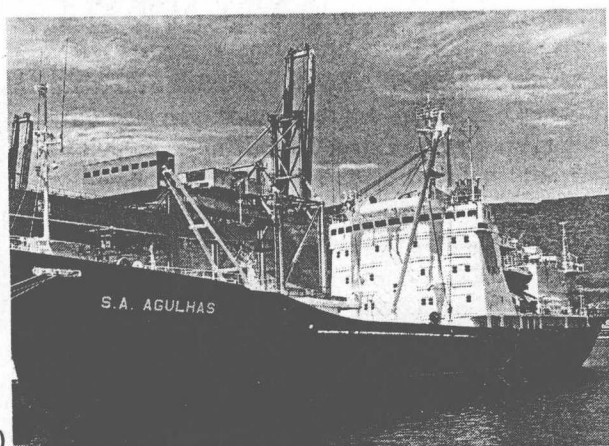
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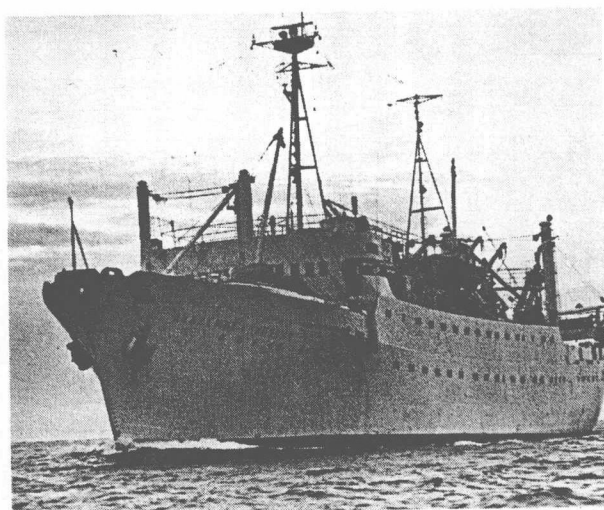
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Contents

<i>Glossary of acronyms</i>	page ix
<i>Foreword</i>	xiii
<i>Preface</i>	xv
<i>Contributors</i>	xvii
History, organization and accomplishments of the BIOMASS Programme <i>S. Z. El-Sayed</i>	1
Antarctic marine environment: physical oceanography	
Antarctic environment – physical oceanography: the Antarctic Peninsula and Southwest Atlantic region of the Southern Ocean <i>M. Stein & R. B. Heywood</i>	11
Physical and chemical oceanography in the vicinity of Prydz Bay, Antarctica <i>N. Smith & P. Tréguer</i>	25
Discussant's Report: Antarctic marine environment – physical oceanography <i>E. Fahrbach</i>	45
Antarctic marine stocks: phytoplankton and zooplankton	
Pattern and variability of phytoplankton biomass in the Antarctic Peninsula region: an assessment of the BIOMASS cruises <i>J. Priddle, F. Brandini, M. Lipski & M. R. Thorley</i>	49
Phytoplankton of the Indian Antarctic Ocean <i>G. Jacques & M. Fukuchi</i>	63
The zooplankton of the Antarctic Peninsula region <i>S. B. Schnack-Schiel & A. Mujica</i>	79
The macrozooplankton communities in the Prydz Bay region, Antarctica <i>G. W. Hosie</i>	93
Discussant's report: Primary production in the Antarctic pelagial – a view from the North <i>E. Sakshaug</i>	125
Antarctic marine stocks: krill	
Krill mesoscale distribution and abundance: results and implications of research during the BIOMASS Programme <i>I. Everson & D. G. M. Miller</i>	129
Krill demography and small-scale processes: a review <i>V. Siegel & J. Kalinowski</i>	145

Krill energetics: seasonal and environmental aspects of the physiology of <i>Euphausia superba</i> L. B. Quetin, R. M. Ross & A. Clarke	165
Discussant's report: Evaluation of BIOMASS contribution to krill research D. G. M. Miller	185
Antarctic marine stocks: fish and birds	
The contribution of the BIOMASS Programme to Antarctic fish biology A. Kellermann & A. W. North	191
Studies on fish of the Indian Ocean sector of the Southern Ocean during the BIOMASS Programme R. Williams & G. Duhamel	211
Marine ornithology in the southern Drake Passage and Bransfield Strait during the BIOMASS Programme G. L. Hunt Jr, J. P. Croxall & P. N. Trathan	231
Consumption of Antarctic krill (<i>Euphausia superba</i>) by seabirds during summer in the Prydz Bay region, Antarctica J. Cooper & E. J. Woehler	247
Discussant's Report: Antarctic marine stocks – fish and birds J.-C. Hureau	261
Antarctic marine systems	
Interactions at the base of the Antarctic food web H. J. Marchant & E. J. Murphy	267
Trophic relationships and trends in population size and reproductive parameters in Antarctic high-level predators K.-H. Kock & Y. Shimadzu	287
The history of the BIOMASS Data Centre and lessons learned during its lifetime M. R. Thorley & P. N. Trathan	313
Discussant's Report: Antarctic marine systems R. M. Laws	323
Future developments	
The potential contribution of the BIOMASS Programme to global change research, especially the JGOFS core project of IGBP J. Priddie, M. R. Thorley & P. N. Trathan	331
BIOMASS–CCAMLR relations: past, present and future J. P. Croxall	339
BIOMASS in relation to the sea-ice zone G. Hubold	355
The Antarctic marine ecosystem in global perspective K. Sherman	363
Discussant's Report: The legacy of BIOMASS G. Hempel	377
Critical appraisal of the BIOMASS Programme G. E. Fogg	383
Index	391

History, organization and accomplishments of the BIOMASS Programme

S. Z. EL-SAYED

Background and history of the BIOMASS Programme

IN JULY 1968, on the occasion of holding the Second SCAR Biology Symposium at Scott Polar Research Institute, Cambridge, U.K., two of the Symposium's fourteen sessions dealt with plankton and the pelagic resources of the Southern Ocean. It was obvious from the six krill review papers presented (mostly by Russian scientists) that little was known of the biology, ecology and population dynamics of what was perceived as one of the most significant creatures in the Antarctic marine ecosystem. A few in the audience took note of this deficiency in our knowledge, not only with regard to krill, but also the Southern Ocean ecosystem as a whole. This lack of knowledge spurred a group of U.S. scientists to organize in 1972 the first multidisciplinary oceanographic cruise on board the USNS *Eltanin*. The objective of the cruise was to study the structure and function of the Ross Sea ecosystem (El-Sayed, 1973).

Between the time the SCAR Symposium was held and the *Eltanin* Cruise 51 was under way, the krill fishery was still in its infancy, though showing every sign of potential expansion. On the other hand, the harvest of other Antarctic marine living resources (e.g. finfish) was in full swing (Kock & Shimadzu, this volume). It was then that concern over the need for proper management and conservation of these

resources was voiced by members of the scientific community and national and international agencies and organizations. The concern of scientists for the conservation of Antarctic marine living resources, and in particular krill, stemmed from the fact that despite past research activities, notably those of the *Discovery* Investigations in the late 1920s and 1930s, there was no adequate information on the stocks of these resources. However, effective conservation and management depended upon a continuing flow of data and information regarding these stocks.

In this regard, one has to recall that in the early 1970s a fierce debate was raging between the preservationists and the scientific community. On one hand, the preservationists perceived development in the Antarctic as a potential threat to the ecosystem, or the manifestation of the 'boom and bust' syndrome which has occurred throughout much of the world fisheries during the past several decades. The scientific community, on the other hand, has a vested interest in the Antarctic in that it would like to retain this almost 'pristine ecosystem' as an exclusive 'test tube environment' for future study. Beyond these publicly discussed issues are the peripheral ones associated with the balance of power in the Antarctic jurisdictional matters, and the potential relationship between utilization of living resources and the non-living resources (oil and minerals) of the Antarctic continent and its continental shelf.