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QUESTION OF ANTARCTICA

State of the environment in Antarctica

Report of the Secretary-General

CONTENTS

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ABBREVIATIONS

ACSE	Antarctic Coastal and Shelf Ecosystem
ADDS	Antarctic Data Directory System
AGONET	Antarctic Geospace Observatory Network
AMD	Antarctic Master Directory
ANTIME	Antarctic Ice Margin Evolution
ANTOSTRAT	Antarctic Offshore Acoustic Stratigraphy
APIS	Antarctic Pack-ice Seals
ASMA	Antarctic Specially Managed Area
ASOC	Antarctic and Southern Ocean Coalition
ASPA	Antarctic Specially Protected Area
ASPECT	Antarctic Sea-ice Processes, Ecosystems and Climate
BIOTAS	Biological Investigations of Terrestrial Antarctic Systems
CCAMLR	Commission for the Conservation of Antarctic Marine Living Resources
CEMP	CCAMLR Ecosystem Monitoring Programme
CEP	Committee for Environmental Protection
CFC	Chlorofluorocarbon
CLIVAR	Climate Variability and Predictability
COMNAP	Council of Managers of National Antarctic Programmes
EASIZ	Ecology of the Antarctic Sea-ice Zone
ENSO	El Niño/Southern Oscillation
FROST	First Regional Observing Study of the Troposphere
GAW	Global Atmosphere Watch
GCTE	Global Change and Terrestrial Ecosystems
GESAMP	Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection
GIPME	Global Investigation of Pollution in the Marine Environment
GLOBEC	Global Ocean Ecosystems Dynamics Research
GLOCHANT	Global Change and the Antarctic
GOOS	Global Ocean Observing System

GOS	Global Observing System
GRID	Global Resource Information Database
GTS	Global Telecommunications System
IAATO	International Association of Antarctica Tour Operators
ICAIR	International Centre for Antarctic Information and Research
ICSU	International Council of Scientific Unions
IGBP	International Geosphere-Biosphere Programme
IHDP	International Human Dimensions of Global Environmental Change Programme
IOC	Intergovernmental Oceanographic Commission
IPCC	Intergovernmental Panel on Climate Change
ISMASS	Antarctic Ice Sheet Mass Balance and Sea-Level Contributions
IWC	International Whaling Commission
JGOFS	Joint Global Ocean Flux Study
LOICZ	Land-Ocean Interactions in the Coastal Zone
PICE	Palaeoenvironmental Records from Antarctic Ice Cores
SCAR	Scientific Committee on Antarctic Research
SCOR	Scientific Committee on Oceanic Research
SO-GLOBEC	Southern Ocean - Global Ocean Ecosystems Dynamics Research
SO-JGOFS	Southern Ocean - Joint Global Ocean Flux Study
START	System for Analysis, Research and Training
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
WCRP	World Climate Research Programme
WMO	World Meteorological Organization
WOCE	World Ocean Circulation Experiment
WWW	World Weather Watch

I. INTRODUCTION

1. The present report has been prepared in response to General Assembly resolution 49/80 of 15 December 1994 on the question of Antarctica and, in particular, to paragraph 2 of that resolution, in which the Assembly calls for a report on the information supplied by the Antarctic Treaty Consultative Parties on their activities in Antarctica to be submitted to the General Assembly at its fifty-first session. 1/

2. The report also updates previous reports to the General Assembly on the state of the environment in Antarctica in accordance with General Assembly resolutions 38/77 of 15 December 1983, 39/152 of 17 December 1984, 40/156 A and B of 16 December 1985, 41/88 A and B of 4 December 1986, 42/46 A and B of 30 November 1987, 43/83 A and B of 7 December 1988, 44/124 A and B of 15 December 1989, 45/78 A and B of 12 December 1990, 46/41 A of 6 December 1991, 47/57 of 9 December 1992 and 48/80 of 16 December 1993.

3. Information has been drawn from the final report of the Nineteenth Antarctic Treaty Consultative Meeting which took place at Seoul from 8 to 19 May 1995, and from information submitted at the Twentieth Meeting, which took place at Utrecht, the Netherlands, from 29 April to 10 May 1996. Reports on activities in the Antarctic have also been received from the World Meteorological Organization, the Intergovernmental Oceanographic Commission (IOC), of the United Nations Educational, Scientific and Cultural Organization (UNESCO), the Department of Public Information, the Division of Ocean Affairs and Law of the Sea and the World Bank.

II. THE ROLE OF ANTARCTICA IN THE GLOBAL ENVIRONMENTAL SYSTEM

4. Antarctica is the coldest, highest, driest, windiest, remotest and cleanest of continents. It is surrounded by one of the world's largest and stormiest oceans (figure I). Antarctica offers outstanding scientific opportunities and is the world's last great wilderness. These scientific and environmental values are of high priority for protection. The region comprises approximately one tenth of the Earth's land surface. The ice sheet rises to over 4,000 metres. The continent is around 14 million km^2, of which 0.33 per cent is ice-free. 2/ Winter sea ice doubles the ice-covered size of Antarctica, and this fluctuation is the largest seasonal physical process on Earth.

5. Antarctica and the Southern Ocean play a critical role in the global environmental system. 3/, 4/, 5/ Major processes of interaction between the atmosphere, oceans, ice, and biota affect the entire global system through feedbacks, biogeochemical cycles, circulation patterns, transport of energy and pollutants, and changes in ice mass balance. 6/

Figure I. Antarctica and the Southern Ocean:
location map

6. The importance of Antarctica in the global environmental system was recognized in the consensus text of chapter 17 of Agenda 21, in which it was agreed that the region was of immense value for the conduct of research essential to understanding the global environment. It was also agreed that States carrying out such research should, as provided for in article III of the Antarctic Treaty, continue to (a) ensure that data and information resulting from such research are freely available to the international community; and (b) enhance access of the international scientific community and specialized agencies of the United Nations to such data and information, including the encouragement of periodic seminars and symposia.

7. The Protocol on Environmental Protection to the Antarctic Treaty (the Madrid Protocol), adopted in 1991 by States Parties to the Antarctic Treaty, designated Antarctica as a "natural reserve, devoted to peace and science" with the objective of "comprehensive protection of the Antarctic environment and dependent and associated ecosystems". 7/ In article 3, the Protocol explicitly

required as follows: "The protection of the Antarctic environment and dependent and associated ecosystems and the intrinsic value of Antarctica, including its wilderness and aesthetic values and its value as an area for the conduct of scientific research, in particular research essential to understanding the global environment, shall be fundamental considerations in the planning and conduct of all activities in the Antarctic Treaty area".

III. ACTIVITIES OF THE ANTARCTIC TREATY SYSTEM AND INTERNATIONAL BODIES

A. The Protocol on Environmental Protection to the Antarctic Treaty

8. The Madrid Protocol was adopted by 26 States Parties to the Antarctic Treaty in 1991. As at 1 August 1996, instruments of ratification had been deposited by 22 of the States that were party to its negotiation: ratification by Finland, Japan, the Russian Federation and the United States of America is required for the agreement to enter into full international legal effect.

9. The Madrid Protocol comprises general provisions such as objectives, principles, and the institutional workings of the instrument; a schedule on arbitration and dispute settlement; annex I, on environmental impact assessment; annex II, on conservation of Antarctic fauna and flora; annex III, on waste disposal and waste management; annex IV, on prevention of marine pollution; and annex V, on area protection and management.

10. The guiding principles in article 3 require environmental protection, including the protection of biological, intrinsic, wilderness, aesthetic and scientific values, to be fundamental considerations when planning the conduct of all activities in Antarctica (by States party to the agreement).

11. Article 7 of the Madrid Protocol prohibits mineral resource activities, other than scientific research. Article 8 requires that all activities in Antarctica receive prior assessment for their possible impact. Article 11 creates a Committee for Environmental Protection, with responsibility for advising on environmental matters in Antarctica.

12. States Parties to the Antarctic Treaty have initiated discussion towards agreement on a further annex to the Madrid Protocol on liability for environmental damage. Drafts of the proposed annex have been under development for several years, and technical issues are being worked through within the framework of the Antarctic Treaty.

13. In the interim of the Madrid Protocol entering into force, States Parties to the Antarctic Treaty have agreed to implement voluntarily the provisions of the agreement as it was adopted in 1991, as far as practicable. Many countries have enacted national legislation making Madrid Protocol provisions binding on their nationals prior to the agreement coming into international legal effect.

B. Convention for the Conservation of Antarctic Seals

14. The United Kingdom of Great Britain and Northern Ireland, as Depository Government for the Convention for the Conservation of Antarctic Seals, reported on the numbers of seals captured or killed in the Convention area (the seas south of 60° S) by States Parties to the Convention for the six species of Antarctic seal for the period May 1995 to April 1996. 8/ Data reported showed no seals of any species killed, and 101 Antarctic fur seals (*Arctocephalus gazella*) captured and released (by Chile). Two States (Australia and the United States) reported their data for the previous year, while two further States (Poland and the Russian Federation) did not report. There is at present no known commercial sealing taking place in Antarctica.

C. Convention on the Conservation of Antarctic Marine Living Resources

15. The Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) reported on fisheries in the Convention area by States Parties to the Convention for the 1994/95 and 1995/96 seasons. 9/ These data and management measures, together with additional information from CCAMLR sources, are summarized in chapter IV, section C, of this report.

16. Rules for the CCAMLR System of Inspection were changed to allow inspectors to board all ships presumed to have been fishing in the Convention area, rather than just those observed fishing. This measure is expected to increase the effectiveness of inspections and enforcement.

17. CCAMLR reported that its Working Group on Ecosystem Monitoring and Management had developed the first strategy for an ecosystem assessment model for Antarctica.

18. The CCAMLR Scientific Committee maintains close coordination with the Scientific Committee on Antarctic Research (SCAR) programmes, in particular Antarctic Pack-ice Seals (APIS), Ecology of the Antarctic Sea-ice Zone (EASIZ) and Global Change and the Antarctic (GLOCHANT), as well as International Geosphere-Biosphere Programme (IGBP) projects such as Southern Ocean - Global Ocean Ecosystems Dynamics Research (SO-GLOBEC).

19. CCAMLR continues to keep under review initiatives by the United Nations and the Food and Agriculture Organization of the United Nations on high seas fisheries, in particular, the flagging of vessels on the high seas, the International Code of Conduct for Responsible Fishing, and the Agreement for the Implementation of Provisions of the United Nations Convention on the Law of the Sea of 10 December 1982 relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks.

D. International Convention for the Regulation of Whaling

20. A recent agreement within the International Convention for the Regulation of Whaling of 1946 is of special relevance to Antarctica. A Southern Ocean Whale Sanctuary was established by the International Whaling Commission (IWC) in 1994; it has a northern boundary that is a circumpolar line between 40° S and 60° S. Japan voted against the sanctuary and entered an objection to it with respect to Antarctic Minke whale stocks.

21. Article VIII of the Convention allows contracting Governments to grant special permits to its nationals to kill, take and treat whales for scientific research. Under this provision, Japan killed 440 Antarctic Minke whales in the 1995/96 season and plans to kill the same number in the 1996/97 season for research. At the 48th annual meeting of IWC held in June 1996, a resolution passed by a majority requested Japan to refrain from issuing a special permit for the take of southern hemisphere Minke whales, particularly within the sanctuary, and restructure its research programme to achieve its objectives by non-lethal means.

22. Because of considerable uncertainty over the numbers of whales of different species and in different geographical stocks, IWC decided in 1989 that it would be better not to give whale population numbers except for those species/stocks for which there was statistical certainty. IWC has made estimates for southern hemisphere stocks for only Minke and Blue whales based on its international research cruises (table 1).

Table 1. Estimates of population sizes for large cetacean species in the Southern Hemisphere (rounded to third significant figure of upper confidence limit)

	Estimate of southern hemisphere population size		
Species	Years	Number	95 per cent confidence interval
Blue	1982/83-1988/89	460	450
Minke	1985/86-1990/91	760 000	510 000-1 140 000

Source: Data provided by the International Whaling Commission, Cambridge, United Kingdom, 14 August 1996.

23. In 1996, IWC broadened the scope of its monitoring programme with the introduction of the Southern Ocean Whale and Ecosystem Research Programme (SOWER), which will include research into the effects of environmental change on cetaceans. Other research programmes in the Southern Ocean include acoustic monitoring of Blue whales, preparation for comprehensive assessment of Humpback whales, and a review of population estimates for Southern Right whales. IWC also aims to improve collaboration with organizations working on related issues

in the Southern Ocean, such as CCAMLR, SCAR, SO-GLOBEC, IOC and the Intergovernmental Panel on Climate Change (IPCC).

E. Scientific research in Antarctica and the protection of the Antarctic environment

1. SCAR Global Change Programme 10/

24. A SCAR Global Change Programme Office was established in 1995/96 at the Cooperative Research Centre for the Antarctic and Southern Ocean Environment in Hobart, Australia. The office will build linkages between SCAR programmes with global change components and the core projects of international programmes such as IGBP and the World Climate Research Programme (WCRP). The objective is to ensure that the Antarctic is represented in and compatible with the global scale programmes. A memorandum of understanding between SCAR and the System for Analysis, Research and Training (START) of IGBP, WCRP and the International Human Dimensions of Global Environmental Change Programme (IHDP) is in preparation.

25. The SCAR global change programme is coordinated through its Group of Specialists on Global Change and the Antarctic (GLOCHANT) assisted by the Programme Office. GLOCHANT has identified two research priorities: the role of sea-ice processes in the physical climate system and in biogeochemical cycles; and the physical and dynamical processes controlling the Antarctic ice sheet.

26. GLOCHANT has focused its present programme on two major themes through scientific task groups: "Palaeoenvironmental Records from Antarctic Ice Cores (PICE)" and "Antarctic Ice Sheet Mass Balance and Sea-level Contributions (ISMASS)". PICE is sponsored jointly by the global changes programme of IGBP. The ISMASS programme is extending research being undertaken by national programmes measuring components of ice-sheet mass balance. Remote sensing is the principal method, but ground-truth data are also being collected. A major aim is to determine the ice-mass flux outward from the ice-sheet across the grounding line into the ocean. PICE is developing a bipolar strategy for deep ice-coring. A third programme, Antarctic Ice Margin Evolution (ANTIME), is planned to coordinate research on the Antarctic sedimentary record.

27. GLOCHANT is now developing a science plan for a programme on Antarctic Sea-ice Processes, Ecosystems and Climate (ASPECT), which is close to completion. ASPECT will focus on the interrelationships between the physical processes controlling the atmosphere and ocean interaction, through the development and maintenance of sea-ice cover, and Southern Ocean sea-ice biota and primary production, and their role in global biogeochemical cycling. ASPECT has potential linkages to the IGBP Southern Ocean - Joint Global Ocean Flux Study (SO-JGOFS), SO-GLOBEC and the WCRP core projects on Climate Variability and Predictability (CLIVAR).

28. SCAR has other programmes related to global change that are the responsibility of other SCAR groups of specialists or working groups. The most important are the Ecology of the Antarctic Sea-ice Zone (EASIZ) and the Biological Investigations of Terrestrial Antarctic Systems (BIOTAS). EASIZ has

potential links to three of the IGBP core projects: Land Ocean Interactions in the Coastal Zone (LOICZ); Southern Ocean - Joint Global Ocean Flux Study (SO-JGOFS); and SO-GLOBEC. BIOTAS has a potential direct link with Focus 4, on Ecological Complexity, of the Global Change and Terrestrial Ecosystems (GCTE) project of IGBP.

2. Science in the Antarctic

(a) Atmospheric and solar-terrestrial sciences

29. Monitoring of Antarctic ozone levels continues from both ground-based stations and satellites (see chap. IV, sect. E).

30. The First Regional Observing Study of the Troposphere (FROST) programme is yielding coordinated synoptic observations of the Antarctic troposphere for the first time and these are being used to compare weather prediction schemes over the Antarctic continent. Data indicate a general reliability of forecasting but have also shown variable forecasts from different sources. The programme has highlighted the paucity of observing stations in the Pacific sector of Antarctica.

31. The Antarctic Geospace Observatory Network (AGONET) yields geomagnetic and ionospheric data from observatories of more than seven countries, fed into a database hosted by Italy. Particular study is being made of the solar wind.

(b) Biological sciences

32. The SCAR Group of Specialists on Seals has developed a five-year programme of research in its Antarctic Pack-ice Seals (APIS) Programme. APIS aims to promote studies of Antarctic pack-ice seal populations and the role they play in the Antarctic ecosystem. To date, 41 research projects involving scientists from 18 countries have been identified under APIS. There is a proposal to carry out a major circumpolar survey of Antarctic pack-ice seals in the 1998/99 field season.

33. The BIOTAS Programme held its first international expedition in the Ross Sea sector of Antarctica during the 1995/96 season. The main aims of the expedition were to examine the change in ecosystem abundance from the rich coastal regions of the continent to the simple endolithic communities at the edge of the polar plateau, and to gather baseline data for long-term research into the effects of climate change, with special reference to global warming and increased ultraviolet radiation. Future research will clarify the mechanisms used by different species for dealing with climatic stresses such as desiccation, temperature fluctuation and ultraviolet radiation.

34. The EASIZ programme of the Group of Specialists on Southern Ocean Ecology aims to improve understanding of the structure and dynamics of the Antarctic Coastal and Shelf Ecosystem (ACSE), the most complex and productive ecosystem in Antarctica, and likely to be the one most sensitive to global environmental change. The unique character of EASIZ is its coherent approach to the ecology of the coastal and shelf marine ecosystem, integrating work on the ice,

water-column and benthic subsystems. It will form a potentially major input to the GLOCHANT programme, interface easily with SO-JGOFS and SO-GLOBEC and relate closely to the IGBP LOICZ programme.

35. The first field data under the programme were collected during the 1995/96 austral summer season. In particular, there was an EASIZ-dedicated cruise by MV Polarstern in the Weddell Sea in January and February 1996. A dedicated cruise has also been scheduled for the 1996/97 season, and a timetable of workshops and symposia has been proposed.

(c) Earth sciences

36. The Cape Roberts Project is a multinational project being coordinated by New Zealand and involving Australia, Germany, Italy, the United Kingdom and the United States, that aims to recover 1,500 m of drill core from sedimentary strata beneath the sea floor in the south-western corner of the Ross Sea. The project will address two main themes: the early glacial history of the Antarctic and its role in determining global sea-level changes; and the timing of rifting of the Antarctic continent in order to help understand the formation of the Transantarctic Mountains and the Ross Sea.

37. A workshop was held in Cambridge, United Kingdom, in May 1995 to review evidence for the existence of a subglacial lake beneath the inland ice sheet at the deep ice-core drilling site at Vostok Station. The workshop considered the research that needed to be undertaken before any decision was taken on penetrating the lake to sample water and underlying sediments. It was agreed that the current ice-core drilling at Vostok Station should proceed but terminate at least 25 m above the ice-water interface, and should not penetrate the water, and that additional geophysical surveys should be performed. If the existence of a large water body can be confirmed, then studies must be made to find techniques for accessing and sampling the water and sediments beneath with minimum contamination of this environment.

F. Antarctic data management

38. Over recent years, as Antarctic databases have grown in number, size and significance, consideration has been given within the Antarctic Treaty system to improving the comparability and accessibility of Antarctic scientific data. It was concluded that the most important immediate need was for an Antarctic Data Directory System (ADDS), a key component of which will be the Antarctic Master Directory (AMD). The Master Directory will hold records consolidated from contributing national Antarctic data centres describing data holdings. It is being operated under the auspices of SCAR and the Council of Managers of National Antarctic Programmes (COMNAP) by the International Centre for Antarctic Information and Research (ICAIR) at Christchurch, New Zealand, and is funded at present by a consortium of Antarctic programmes from France, Italy, New Zealand and the United States. As host to UNEP/GRID-Christchurch (see para. 53 below), ICAIR is well placed to coordinate and make these directories available into the United Nations system in fulfilment of Agenda 21 (chaps. 17 and 40) objectives.

G. International organizations

1. World Meteorological Organization

39. The principal objectives of WMO in Antarctica are to (a) coordinate the operation of World Weather Watch (WWW) to meet global needs and Antarctic requirements, including monitoring of climate change and of the environment; and (b) to collaborate with other international programmes in Antarctica to ensure a coordinated and cost-effective scientific and technical programme. In this regard, WMO cooperates with a wide range of relevant organizations, including the Antarctic Treaty Consultative Meeting, SCAR, COMNAP, the Scientific Committee on Oceanic Research (SCOR), the United Nations Environment Programme (UNEP) and IOC.

40. The Antarctic is an important component of the Global Observing System (GOS), and is an area of increasing interest. The operation of GOS and transmission of data via the Global Telecommunications System (GTS) are an essential part of WWW. The synoptic observation network currently consists of 37 land-based stations operated by 15 countries. There are additionally over 50 automatic weather stations operated by Australia, the United States and other countries. WMO noted that economic constraints appeared to be affecting the willingness of countries to maintain costly facilities in Antarctica, which might threaten the continuity of some stations with valuable long-term climatic records. The provision of high-quality meteorological services in Antarctica is dependent on a good network of observations and on improvements to numerical forecast models, which the SCAR FROST programme, referred to above, is designed to address.

41. WMO has noted deficiencies in the synoptic network over Antarctica, including the absence of surface observations over most of west Antarctica, the decreasing number of upper-air stations, and the delays of insertion of data into GTS. WMO views it as a priority to maintain implementation of the synoptic network in Antarctica on the basis of the programmes initiated by Antarctic Treaty Parties. Data and space-based imagery should continue to be made available for use in analysis, forecasting, sea-ice information and storm-warning services.

42. A number of countries plan to establish additional weather observation stations on the Antarctic ice cap, which promises to improve the observing network greatly. AGONET, mentioned earlier, will include meteorological sensors at its planned 12 sites spread over the Antarctic interior, which may be able to provide data via GTS.

43. Data collection using drifting buoys is being employed increasingly by a number of countries (Australia, Finland, Germany, Japan, the United Kingdom and the United States) in an International Programme for Antarctic Buoys, which has deployed a number of buoys south of 55° S, including the Antarctic sea-ice zone.

44. Some Antarctic stations monitor trace gas constituents such as carbon dioxide and ozone as part of the Global Atmosphere Watch (GAW). WMO encourages members to expand observations to include ozone-related chemical species. Additional observations are needed to monitor the intensity of solar

UV-radiation. Links are maintained between WMO and the secretariats of the United Nations Framework Convention on Climate Change, the Montreal Protocol on Substances that Deplete the Ozone Layer and the Vienna Convention for the Protection of the Ozone Layer.

45. WMO has prepared a Catalogue on Antarctic Climate Data which will be made available to ADDS being prepared by SCAR and COMNAP. This will improve the accessibility of Antarctic meteorological data.

2. Intergovernmental Oceanographic Commission

46. IOC is a functionally autonomous body within UNESCO that promotes marine scientific investigations and related ocean services with a view to learning more about the nature and resources of the oceans and coastal areas, including the Antarctic region. IOC has a Regional Committee for the Southern Ocean; its sixth session was to be held in September 1996 along with its second Southern Ocean Forum, and it addresses a variety of issues, including pollution and the human impact. IOC is strengthening international research programmes in cooperation with other organizations (the International Council of Scientific Unions (ICSU)/SCOR/SCAR, CCAMLR, IWC, WMO, UNEP) to improve ocean observations and data exchange in the Southern Ocean. IOC aims to meet the requirements of Agenda 21 (chapter 17), the United Nations Framework Convention on Climate Change, the Convention on Biological Diversity and the Madrid Protocol.

47. Areas of attention include the role of the ocean in global climate change and variability through the World Ocean Circulation Experiment (WOCE) sponsored by WMO, IOC, ICSU and UNEP; marine pollution through the joint IOC/UNEP/IMO/IAEA Programme on Global Investigation of Pollution in the Marine Environment (GIPME); the role of the ocean in global carbon dioxide balance and studies of ocean ecosystem dynamics, by cooperating with SCOR in the IGBP JGOFS and GLOBEC programmes.

48. IOC is expanding and improving ocean observations and data exchange through increased support of existing operational programmes and the development of the Global Ocean Observing System (GOOS). The System is intended to provide a global framework or system for the gathering, coordination, quality control and distribution of oceanographic data.

3. United Nations

49. The United Nations Department of Public Information has focused on the implementation of the outcomes of Agenda 21, the Rio Declaration on Environment and Development, the Conventions relating to climate change and biodiversity, the Convention to Combat Desertification in Those Countries Experiencing Serious Drought and/or Desertification, the Agreement for the Implementation of Provisions of the United Nations Convention on the Law of the Sea of 10 December 1982 relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks, and the work of the Commission on Sustainable Development. Since 1994, no specific activities have related directly to the state of the environment in Antarctica.

50. The Division for Ocean Affairs and the Law of the Sea in the Office of Legal Affairs is one of eight supporting agencies of the Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP), which is preparing the next global state of the marine environment report under UNEP leadership, to include the polar regions. The GESAMP Working Group on Marine Environment Assessment is starting with a report on land-based activities to be ready by 1998. As results from the GESAMP work are not yet available, data from Strömberg and others were used 11/ in chapter IV of the current report.

4. The World Bank

51. The World Bank published a report in 1995 on the status of marine protected areas worldwide, including Antarctica. 12/ It intends following up on the recommendations in the report, but sites in Antarctica are not at present considered of high priority for attention. The World Bank indicated on 27 June 1996 that it had no immediate plans with regard to environmental activities directed towards Antarctica.

5. UNEP/Global Resource Information Database

52. UNEP has established a Polar Task Force to coordinate its environmental interests in the polar regions.

53. UNEP established a Global Resource Information Database (GRID) node for the Antarctic and Southern Ocean at ICAIR, Christchurch, New Zealand, on 30 May 1996, by an agreement with the Government of New Zealand. To be known as UNEP/GRID-Christchurch, the node was established with assistance from UNEP/GRID-Arendal (Norway) and the two polar centres will coordinate their activities and work in close cooperation.

6. World Conservation Union

54. IUCN has maintained its active interest in Antarctica, sponsoring and organizing four recent international workshops on matters related to the conservation of the Antarctic environment, the first three of which were organized jointly with SCAR. The first, in Paimpont, France, in April 1992, considered issues related to the conservation of sub-Antarctic islands, while the second, in Cambridge, United Kingdom, in June 1992, addressed the development of the Antarctic Protected Area system. The third, in Gorizia, Italy, in April 1993, considered matters related to education and training on environmental matters in Antarctica. The fourth, in Washington, D.C., in September 1996, addressed problems relating to the assessment of cumulative environmental impacts in Antarctica. Reports from the first three workshops have been published. 13/, 14/, 15/

7. Antarctic and Southern Ocean Coalition

55. ASOC is an affiliation of 230 non-governmental organizations with environmental, technical and scientific expertise in Antarctica located in 43 countries. ASOC regularly participates in, and monitors components of, the Antarctic Treaty System. In recent years, ASOC has been particularly active in encouraging States parties to the Antarctic Treaty to ratify and implement rapidly the Madrid Protocol. ASOC provides information to Governments, scientists and the public on matters of environmental importance in Antarctica and publishes a regular newsletter.

H. Environmental monitoring in Antarctica

56. Environmental monitoring is a fundamental element of basic research, environmental management and conservation. 16/ Environmental monitoring in Antarctica has a long history and can be classified as "global" or "local". Many global phenomena, such as gaseous constituents of the atmosphere, have been monitored continuously since 1957, while the presence of pollutants in Antarctic snow and biota has also been analysed. Data on the status and trends of global phenomena provide a necessary baseline against which to assess the contribution of local sources of environmental change. 17/

57. States Parties to the Antarctic Treaty convened the First Meeting of Experts on Environmental Monitoring in Antarctica at Buenos Aires, Argentina, in June 1992. The experts made recommendations, *inter alia*, on the representation of monitoring sites, data management, the need to develop data standards and international coordination. A further workshop was recommended to consider the design of monitoring programmes, data standards and quality assurance, available technologies and data management.

58. SCAR and COMNAP offered to convene the workshop, which was held in two sessions, at Oslo in October 1995 at College Station, Texas, United States, in March 1996. The report 18/ of the workshop is still in draft form and is intended to be finalized for submission to the Antarctic Treaty Consultative Meeting, to be held at Christchurch, New Zealand, in May 1997.

IV. STATE OF THE ANTARCTIC ENVIRONMENT: SYNOPSIS OF SOME RECENT FINDINGS

59. The sections that follow highlight some recent findings for a selection of topics of current interest with regard to the state of the Antarctic environment. This selection is not intended to be comprehensive, but rather illustrative of prominent topics. These sections were reviewed by a range of specialists in the relevant fields.

A. Science and support activities

60. Scientific investigation is the predominant human activity in Antarctica. The number of science and support personnel working in Antarctica each season

provides a crude estimate of the level of this activity. States Parties to the Antarctic Treaty report on the numbers involved in an "Annual exchange of information" required under Antarctic Treaty Consultative Meeting agreements. 19/

61. While these data provide a basic context for the level of scientific activities currently occurring in Antarctica, it is important to note that they generally do not allow a quantification of the total scientific presence in terms of person-days in the region.

62. Since regular activities began, the number of people participating in Antarctic scientific programmes grew steadily up to 1989/90 (figure II). 20/ Associated with an increased number of people participating in Antarctic activities was an increase in both the number of countries represented and the number of operating stations. The United States has the largest Antarctic science programme, comprising approximately 35 per cent of the science and support population in the 1994/95 season.

63. A preliminary assessment of the levels of science and support personnel since 1990 suggests that there has been a reduction in personnel by perhaps around one third. However, data compilation for this section was hampered by variable quality and timeliness in the reporting of activities and in the distribution of this information by States working in Antarctica. Further analysis, perhaps linked to investigation of national investment levels, would be required to draw conclusions from the apparent trend.

Figure II. Levels of science and support activity, 1941/42 to 1989/90

Source: Data from J. C. N. Beltramino, *The Structure and Dynamics of Antarctic Population* (New York, Vantage Press, 1993).

B. Antarctic tourism

64. Antarctica has been a tourist destination for the past 40 years, with more than 60,000 tourists estimated to have visited the area over that time. 21/ Antarctic commercial tourism has undergone a period of accelerated growth in the last decade, both in the number of passengers on ships and, more recently, in overflying aircraft (figure III).

Figure III. Levels of Antarctic tourism activity, 1980/81-1995/96

Sources: (1) Adapted from D. J. Enzenbacher, "Tourists in Antarctica: numbers and trends", Polar Record, vol. 28, No. 164 (1993).

(2) United Kingdom of Great Britain and Northern Ireland, "Recent developments in Antarctic tourism", Information Paper 13, XIX ATCM, Seoul, 8-19 May 1995.

(3) International Association of Antarctic Tour Operators, "Preliminary overview of Antarctic tourism", Information Paper 96, XX ATCM, Utrecht, the Netherlands, 29 April-10 May 1996.

65. "Seaborne" tourists are those visiting Antarctica on commercial cruise vessels and the figures include yachts where data are known. "Air-landing" tourists are those journeying to and from Antarctica by air with a landing, while "Air-overflight" tourists are those who visit Antarctica as a specific destination by air but do not land. Overflights of Antarctica on commercial airline routes are not included in this review because this does not constitute travel to Antarctica as a specific tourist destination. The number of ships shown in figure III does not include yachts.

66. There is growing awareness of the importance of environmental issues arising from Antarctic tourism. 22/ However, research on the effects of Antarctic tourism is still in its infancy and there is still uncertainty over the level of impact arising from tourist visits to Antarctica. 23/ Antarctic Treaty recommendation XVIII-1 provides operational and environmental guidance to tour operators in Antarctica.

67. The International Association of Antarctica Tour Operators (IAATO) was founded in August 1991 and current membership comprises the majority of companies operating Antarctic tours. During the 1993/94 season, just over 83 per cent of cruise ship passengers travelled aboard ships operated by IAATO members. 24/

Recent developments and trends

68. The number of tourists visiting Antarctica in the 1995/96 season is the highest yet recorded, with increases recorded in both seaborne and air-overflight tourism (figure III). Air-landing tourism caters for a specific adventure-tourist market, and is currently very expensive: the numbers are low and appear static.

69. Antarctic tourist overflights became popular in the 1970s, but ceased after the crash of a DC-10 aircraft on Mt. Erebus (Ross Island) in 1979, killing all 257 passengers and crew. 25/ In the 1994/95 season, Antarctic overflights, departing from Melbourne, Australia, were reintroduced. These were continued in 1995/96 and are again planned for the 1996/97 season. 26/ These flights account for all air-overflight data in figure III. In terms of their potential environmental impact and management, overflights are very different from seaborne and air-landing tourism, owing to their relatively short duration and absence of landings.

70. In the 1995/96 season, a total of 10 tour operators are known to have conducted organized seaborne tours; this compares with 14 operators in 1994/95, the highest number recorded in a season to date. Associated with an increase in the number of tourists is an increase in the number of vessels (figure III), with at least 12 in use each season since 1991/92. 27/ The number of passengers per ship in the 1995/96 season ranged from 13 to 452, the average being 81.5. 28/

71. Most seaborne voyages are concentrated along the Antarctic peninsula during the four-month austral summer, with few landings made in the Weddell Sea and Ross Sea regions. 29/, 30/, 31/ The number of distinct sites at which tourists landed has expanded from 36 in 1989/90 to over 150 in the 1994/95 season, 32/ with probably a comparable number in 1995/96. 33/

72. The types of activities being undertaken have broadened from earlier times, with tourists now engaging in skiing, climbing, camping, sea kayaking, and other activities. Several ships now carry helicopters that can transport tourists to sites previously inaccessible, 34/ and the number of yachts appears to be increasing, with 17 venturing south of 60° S in 1991/92. 35/

73. It is at present difficult to collate complete, consistent statistics on Antarctic tourism. While historically most data have been reported to the United States, which has compiled these data in annual reports to the Antarctic Treaty Consultative Meeting, several operators are now working out of other countries and do not necessarily report to this one point. Argentina 36/ and Australia 37/ also gather and report tour data. Data on yachts are particularly difficult to locate and compile.

74. The Antarctic Treaty Consultative Meeting held at Utrecht, the Netherlands, in May 1996 agreed a prototype standard format for reporting Antarctic tour data, to be trialled in the 1996/97 season with a view to universal adoption at the 1997 Meeting. The format contains fields for data on the principal aspects of tourist activities (for example, operating companies, routes taken, site landings, activities undertaken, tour and landing durations, and impact observed), which, when agreed, should provide the basis for the development of a comprehensive, consistent and accessible international database on Antarctic tourism.

C. Fishing

75. Concern over an unregulated fishery for Antarctic krill, along with past exploitation of fur seals and whales, resulted in the adoption of the Convention on the Conservation of Antarctic Marine Living Resources. The Convention entered into force in 1982 and stringent conservation measures to halt the further decline of fish stocks were implemented by 1989. 38/ Prior to the coming into force of the Convention, many Antarctic fish stocks were overexploited. The conservation measures under the Convention currently include the setting of total allowable catches for targeted species, imposing limits on by-catch of non-target species, measures to prevent incidental mortality of seabirds, and requirements for having scientific observers on some harvesting vessels. 39/

(a) Fishery development

76. Current fishing is focused on Antarctic krill and finfish species. Harvesting of Antarctic finfish species began in 1969/70, with reported annual catches of the Notothenids (*Notothenia rossii* and *N. squamifrons*) and the icefish (*Champsocephalus gunnari*) often exceeding 100,000 tons and peaking at 400,000 tons in 1969/70. More than 3 million tons of finfish were reported to have been caught prior to 1995/96. 40/ However, finfish fisheries have been very low since 1992 (table 2).

77. Krill (targeted species *Euphausia superba*) harvesting began in 1972/73 and over 5 million tons have been taken to date. 41/ The current krill catch is around 90,000 tons a year which, although less than in the peak years of the early 1980s, is still the largest catch in Antarctic waters. An experimental fishery for stone crabs (*Lithodidae*) at South Georgia and Shag Rocks was undertaken by a United States fishing boat in July 1992 (table 2). 42/

Table 2. Total reported fish catches in the region covered by the Commission for the Conservation of Antarctic Marine Living Resources from 1991/92 to 1995/96

	Total reported catch (tons)			
Species	1991/92	1992/93	1993/94	1994/95
Antarctic krill	302 961	88 776	83 962	118 715
Patagonian toothfish	12 497	5 788	5 648	8 889
Mackerel icefish	65	0	28	3 974
Grey rockcod	0	0	0	0
Lanternfish	51 915	0	114	0
Antarctic crabs	0	299	0	0

Source: CCAMLR, Statistical Bulletin 1996 (1986-1995) (Hobart, Australia, CCAMLR, 1996).

(b) Recent trends, threats and initiatives

78. Ecosystem monitoring. CCAMLR maintains an active Working Group on Ecosystem Monitoring and Management. The working group has constructed a framework which will allow information collected from established monitoring programmes to be integrated into management advice. 43/

79. Krill fishery. Krill (Euphausia superba) are the key food for most Antarctic marine birds and mammals, and krill research efforts are central to CCAMLR management. 44/ In recent years, there has been a decline in catches of Antarctic krill (table 2), primarily due to economic factors and driven by a reduction in the Russian Federation and Ukrainian fishing effort for this species. 45/ The current catch is less than 10 per cent of the total allowable catch, which itself is set at 10 per cent of the estimated krill biomass.

80. Seabird mortality. Incidental mortality of seabirds during longline fishing operations has been widely reported as being a significant problem. 46/, 47/, 48/ Mitigation measures adopted by CCAMLR include the setting of longlines only at night, using streamer lines to deter birds from baited hooks, and a prohibition on dumping trash during longline operations. CCAMLR 49/, 50/ has reported a reduction in the by-catch of albatross as a result. However, incidental mortality of white-chinned petrels occurs with night settings 51/ and it is still unknown to what extent albatross populations may be recovering.

81. Marine debris. Management measures have been implemented by CCAMLR to reduce incidental mortality and the impact of marine debris on biota. The use of plastic packaging bands to secure bait boxes on fishing vessels is prohibited and monitoring programmes have detected reductions in debris over the last year. 52/

82. Trawl impact. Most finfishing in the Southern Ocean has been conducted with bottom trawls. 53/ Bottom trawl gear is dragged along the seabed, re-suspending sediments and disturbing the benthos. 54/ Although precise effects on the rich benthic fauna of the Southern Ocean are unknown, it is speculated that trawling could have serious, long-lasting impact owing to the low resilience of the slow-growing communities to disturbance.

83. Illegal fishing. There have been reports of illegal fishing of *D. eleginoides*. The illegal take is believed to equal or exceed the total allowable catch set by CCAMLR, seriously threatening sustainable management of this fishery. 55/ It is not known what effect this level of exploitation is having on fish populations. CCAMLR has introduced a revised scheme of international inspection in an attempt to combat this problem.

84. Squid fishery. The ommastrephid squid (*Martialia hyadesi*) has been recognized by the United Kingdom as having potential for exploitation within the CCAMLR area. 56/ In 1989, a catch of approximately 8,000 tons was taken by the United Kingdom, but no further fishery has taken place.

D. Long-range pollutants

85. Antarctica is the least populated and industrialized continent, with human activities minimal and highly localized. Research has been conducted on the presence and transport of pollutants in Antarctic marine and terrestrial ecosystems. Antarctic case studies can be used to provide a baseline against which to assess both current and future levels of global pollution. 57/

(a) Origin and deposition of long-range pollutants

86. Long-range pollutants in Antarctica originate predominantly from the industrialized areas of the world. 58/ Many such pollutants are transported to Antarctica in the upper atmosphere as vapour, 59/ while others are transported to the Antarctic by ocean currents. Air reaching Antarctica from outside has to pass through the zone of cyclonic storms that surrounds the continent. This acts as a filter, removing some of the particles and reactive gases from the air and depositing them in the Southern Ocean.

87. The transport of atmospheric pollutants between continents is indicated by similarities in the contaminant patterns in Antarctica to those observed in the remainder of the southern hemisphere. 60/ Examples of such pollutants include chlorofluorocarbons (CFCs), responsible for Antarctic ozone depletion (see sect. E below), trace gases such as carbon dioxide and methane, radioactive debris from past atmospheric nuclear bomb tests and accidents, heavy metals and hydrocarbons. 61/, 62/, 63/ Low concentrations of these pollutants (in the ng (nanogram) kg^{-1} range) have sometimes hampered accurate analysis of contamination, and spatial and temporal variability has made it difficult to establish mean values or identify change. 64/

88. Once over Antarctica, pollutants may be deposited within snowflakes, or by direct deposition to the snow surface. The ice preserves a historical record of the atmosphere, with ice-core studies revealing global changes in trace gases,

and some pollutants such as lead. Deposition processes are not well understood, and assumptions that the concentrations seen in snow can be related simply to the concentrations in the air mass are questionable. 65/ The ratio of atmospheric pollution reaching the Antarctic continent to that deposited in the Southern Ocean appears unknown.

89. A range of pollutants indicating intercontinental transport have been identified in Antarctica. Examples of the general trends observed are seen in heavy metals and hydrocarbons.

(b) Heavy metals

90. Heavy metals have received the most attention in studies of pollutants in polar snow and ice. 66/ Studies of heavy metals in Southern Ocean waters and biota are scarce, and suffer from high variability and analytical difficulties. 67/ Lead (Pb) is an example of a heavy metal widely dispersed in the Antarctic environment. It is distributed primarily as a result of its use as tetra-alkyl Pb as an additive to petroleum. Pre-industrial levels were typically 0.3-0.5 ng kg^{-1}, derived from crustal dust and possible volcanic input. 68/ Between 1920 and 1950, lead concentrations varied around a mean of 2.5 ng kg^{-1}, with a clear increase to 6 ng kg^{-1} between 1950 and 1980. 69/ This represents a twelvefold to twentyfold increase in concentration. Subsequent decreases can be linked to increasing usage of lead-reduced fuels. 70/ Isotopic ratios suggest an anthropogenic lead content in Antarctic sea water.

(c) Hydrocarbons

91. Levels of hydrocarbon pollution from anthropogenic activities are very low and localized in Antarctica compared with other areas of the world. Along with low levels of natural biogenic hydrocarbons, this makes the Antarctic an ideal stage on which to measure baselines and assess global hydrocarbon pollution. 71/, 72/ However, it is important to differentiate between global and local sources of pollution, with local outputs having the potential to jeopardize detection of global pollution. 73/, 74/ An example of local hydrocarbon pollution was the release of 600,000 litres of Diesel Fuel Arctic into Arthur Harbour, Antarctic Peninsula in January 1989, from the sinking of the Argentine ship Bahia Paraiso. 75/

92. Chlorinated hydrocarbons have been recorded in Antarctic biota, snow, ice and air. 76/, 77/, 78/ These substances have no known natural source. 79/ Chlorinated hydrocarbon residues are also reported in species of moss and lichen from varying locations. 80/

E. Ozone depletion

93. The discovery of substantial ozone depletion over Antarctica was unexpected and necessitated a major revision to theories of stratospheric chemistry. Although scientists had predicted the possibility of ozone depletion, 81/ the discovery of the ozone "hole" over Antarctica by Farman and others 82/ had not been anticipated. The processes leading to ozone depletion over the polar regions are now broadly understood. Chemical reactions on clouds in the

stratosphere convert chlorine and bromine from inactive reservoir species into forms which catalytically destroy ozone in the presence of sunlight. 83/ Ozone depletion persists until warming of the polar stratosphere removes the stratospheric clouds and causes the breakdown of the polar vortex in early summer.

(a) Development

94. From 1978 to 1987, the ozone "hole" grew, both in depth (total ozone loss in a column) and in area (figure IV). This growth was not linear but seemed to fluctuate with a two-year period influenced by equatorial winds. 84/ Ozone depletion was significantly less in 1988 but in the period 1989-1991 was as large as in 1987. The Antarctic ozone "hole" continued to grow during the early 1990s, although the extremely large "holes" of 1992 and 1993 were due in part to sulfate aerosols from the Mt. Pinatubo eruption which increased the effectiveness of chlorine- and bromine-catalysed ozone destruction. 85/ A record low ozone recording (85 Dobson units) was measured in the spring of 1993. In 1995, the ozone decline started earlier than in any previous year, while the

Figure IV. Antarctic spring ozone minima within the ozone "hole" from 1979 to 1994. The solid filled graph shows the average area of the ozone "hole" (ozone values lower than or equal to 220 Dobson units)

Source: Adapted from J. R. Herman and others, "Meteor-3/TOMS observations of the 1994 ozone hole", Geophysical Research Letters, vol. 22, No. 3 (1995).

rate of decline was the most rapid on record. 86/ Vertical soundings over the South Pole in September and October 1995 showed nearly complete destruction of ozone at altitudes between 15 and 20 km. Total ozone values over Antarctica in September and October 1995 were extremely low, with the minimum values only slightly higher than the record low values observed in 1993.

(b) Implications

95. Increased surface solar ultraviolet-B radiation (UV-B), attributable to the depletion of stratospheric ozone, poses a threat to Antarctic ecosystems. UV-B is detrimental not only for primary terrestrial colonizers such as cyanobacteria and algae, but also for lichens and mosses, higher plants and invertebrates. 87/ Terrestrial colonizers may have protective repair mechanisms, but the long-term effects are not well understood. 88/

96. Evidence has been found of direct effects from an increase in the UV-B radiation in Antarctic waters by comparing phytoplankton productivity both within and outside the "hole" area. One study indicated a 6-12 per cent reduction in phytoplankton productivity in the marginal ice zone. 89/ Karentz and others 90/ concluded that Antarctic marine phytoplankton might have protective repair mechanisms and produce pigment when required. In terms of ecological consequences, McMinn and others 91/ concluded that the displacement of UV-sensitive species by UV-tolerant ones might be more important than a decline in overall productivity. The long-term effects of increased UV on ecosystems are difficult to predict and very little is known at present. 92/

97. Recent scientific findings

(1) The atmospheric growth rates of several major ozone-depleting substances have slowed, demonstrating the expected impact of the Montreal Protocol (1987) and its Amendments and Adjustments.

(2) The conclusion that chlorine and bromine compounds, coupled with surface chemistry on naturally occurring particles in the polar stratosphere, are the cause of polar ozone depletion has been further strengthened. SCAR has noted that other compounds (such as methyl-bromide) in addition to CFCs are now known to destroy ozone.

(3) The 1993 record ozone "hole" was due primarily to a colder than normal stratosphere, a stable polar vortex and volcanic aerosols originating from Mt. Pinatubo.

(4) The maximum area covered by the ozone "hole" is nearing its limiting value set by the low temperature region within the polar vortex.

(5) Peak global ozone losses are expected to occur during the late 1990s.

(6) The link between a decrease in stratospheric ozone and the increase in surface UV radiation has been further strengthened.

(7) Stratospheric ozone losses cause a global mean negative radiative forcing.

F. Sea ice

98. The presence and variability of sea ice around Antarctica constitute one of the most salient characteristics in the southern hemisphere. The dramatic variation in sea-ice coverage, from 4 million km^2 in late summer to almost 20 million km^2 in late winter, more than doubles the effective ice-covered area of the Antarctic continent. 93/ This large seasonal fluctuation affects the exchange of energy, mass and momentum between the ocean and atmosphere and, together with the seasonal fluctuation of Arctic sea ice, plays an important role in global climate.

(a) Development of Antarctic sea ice

99. Sea ice forms when small randomly oriented ice crystals aggregate into a thin sheet, which then grows downward by the freezing of water onto its base. If there is significant wave action, the ice agglomerates into nearly circular discs or "pancakes" which adhere to each other and raft together forming a continuous consolidated cover up to tens of centimetres thick. 94/ Four factors are dominant in the development of sea ice: oceanic heat flux, or convection currents; atmospheric temperature; wave action; and oceanographic currents. 95/ Of particular importance in the development of Antarctic sea ice (as compared with Arctic sea ice) are the rapid expansion of the ice cover and the formation of "snow-ice" after the ice surface has been flooded by sea water. 96/

(b) Spatial distribution

100. In the austral summer, sea ice is confined primarily to the western Weddell Sea, the southern Bellingshausen and Amundsen Seas and the south-east Ross Sea, with a narrow fringe of ice usually evident around much of the continent. 97/ The winter maximum ice edge extends furthest north in the eastern Weddell Sea, and furthest south in the western Bellingshausen Sea (figure V). Although there is consistency in the seasonal cycle, the magnitudes of the ice extents vary from year to year. Recent research suggests that these fluctuations may be related to the El Niño/Southern Oscillation (ENSO) climate periodicities. 98/

101. Open water occurs within the sea ice as leads and polynyas, where there is intense ocean-atmosphere interaction and significant ice growth and thickening. Leads occur throughout the sea ice and are a consequence of differential ice motion, driven primarily by winds. Polynyas are recurrent zones of open water or low ice concentration observed in the same areas within the sea ice. Some of the largest polynyas occur in the Weddell and Ross Seas, where they result from a combination of oceanographic and atmospheric forcing. Jacobs and Comiso 99/ found that the Ross Sea polynyas were influenced by both upwelling of relatively warm saline water along the continental slope and strong katabatic winds driving off the continent.

Figure V. Seasonal variability of Antarctic sea ice (shaded region) for the period 1973-1992: (a) mean minimum ice coverage, (b) mean maximum ice coverage

Source: Adapted from I. Simmonds and T. H. Jacka, "Relationships between the international variability of Antarctic sea ice and the Southern Oscillation", *Journal of Climate*, vol. 8 (1995).

(c) *Thickness*

102. The Antarctic sea-ice cover is considerably thinner than Arctic sea ice of a similar age. 100/, 101/, 102/, 103/ First-year ice of east Antarctica is typically 0.4-0.6 m thick, 104/ while multi-year ice in the western Weddell Sea - the largest area of perennial ice in Antarctica - is typically 1-3 m thick. 105/ The late winter-ice cover throughout the Pacific sector of the Southern Ocean appears to be thicker (mean 0.9 m) than that in much of the Weddell Sea and the east Antarctic sea ice. 106/

103. *Recent scientific findings*

(1) An analysis of global ice cover between 1978 and 1994 has detected no statistically significant change in Antarctic sea ice, 107/ although interannual variability is high and the time series of synoptic data is relatively short. In the same period, Arctic sea ice appears to have decreased by 5.5 per cent.

(2) Significant reductions in the summer sea-ice cover have been identified in the Bellingshausen/Amundsen Seas in the late 1980s/early 1990s that are consistent with a warming climate west of the Antarctic peninsula. 108/

(3) Parkinson 109/ calculated a "sea-ice season" between 1979 and 1986 which showed increases in the length of the season in the Ross Sea but decreases in the Weddell and Bellingshausen seas.

(4) Antarctic sea-ice coverage shows periodicities that agree well with variations in the ENSO climate periodicities. 110/

G. Ice sheets

104. Over 87 per cent of the Earth's fresh water exists in a frozen state with more than 90 per cent of that ice situated on the Antarctic continent. 111/ The Antarctic ice sheet and floating ice-shelf extensions are a significant element in the global climate system, with high reflection of sunlight combined with its altitude being important influences. The relative size of the ice sheet has a direct effect on global sea level and it is estimated that between 62 and 70 m of sea level equivalent are locked up in this mass of ice. 112/

(a) Mass balance of the Antarctic ice sheet

105. The ice-sheet mass balance is the most relevant and least well-known parameter needed to model the effects of global warming on the Antarctic ice sheet. 113/ The total ice-sheet mass balance is the sum of the net mass balance over the upper surface of the ice sheet (that is, precipitation less melting, sublimation, evaporation and deflation), melt losses at the lower boundary and iceberg calving at the margin. Over the past several thousand years, melting and calving of ice beyond the grounding line of the ice sheet have maintained an approximate balance between accumulation and attrition. 114/ Estimates of the current mass balance are crude, with uncertainties of between 20 and 50 per cent in all budget terms. 115/ The most up-to-date evaluation 116/ suggests that the Antarctic ice sheet is losing mass to the oceans; however, further investigation, particularly into the attrition terms, is required before a reliable statement can be made.

106. The future mass balance of the Antarctic ice sheet has been addressed in several studies. 117/, 118/, 119/ Results suggest that under a warming climate, increased precipitation over the Antarctic ice sheet will lead to greater accumulation, but when atmospheric temperature rises above 5° C of the present day temperature, the Antarctic ice sheet would begin to decline.

(b) Iceberg-calving and ice-shelf melting

107. Calving of icebergs is the largest factor in the attrition of the Antarctic ice sheet. 120/ Recent estimates based on both ship and satellite data suggest iceberg-calving to be only slightly less than the total annual accumulation. 121/ Ice-shelf melting is the other principal element in the attrition of the ice sheet, with approximately 80 per cent of all ice-shelf melting occurring at the base of the circumpolar ice shelves more than 100 km from the ice front. 122/ Recent research has shown that steady ice-shelf retreat has been occurring on the Antarctic peninsula over the past 50 years. 123/, 124/, 125/, 126/ These ice shelves appear to be sensitive indicators of climate change.

(c) Ice-sheet stability

108. The East Antarctic Ice Sheet is a very old and stable feature being grounded primarily above sea level. The "marine-based" West Antarctic Ice Sheet, on the other hand, rests on a bed well below sea level and is believed by many glaciologists to be inherently unstable and prone to collapse. Ice streams - large river-like currents of ice - may be very important to the equilibrium of "marine" ice sheets. 127/ They have the potential to increase the speed of ice-sheet collapse by transporting ice from the interior to the ice-sheet margin at speeds one to two orders of magnitude faster than the general ice flow. Understanding the nature of ice-sheet - stream - shelf transition is crucial to resolving the question of stability of the Antarctic ice sheet.

(d) Effect on sea level

109. The sea level has risen an average of 6 mm $year^{-1}$ since the last glacial maximum (18,000 years BP), 128/ while the best estimate of sea level rise, evaluated for IPCC, over the past 100 years is 1.5 mm yr^{-1}. 129/ The most probable contributions to sea level rise, over the last 100 years, are thermal expansion (0.4 mm yr^{-1}), melting of small ice caps and glaciers (0.4 mm yr^{-1}) and losses from the Greenland ice sheet (0.25 mm yr^{-1}). 130/ This leaves 0.45 mm yr^{-1} of the IPCC 1.5 mm yr^{-1} "best estimate" unaccounted for. If the Antarctic ice sheet is in fact losing mass to the oceans, then only a small fraction of this deficit would need to come from grounded ice to account for the unallocated 0.45 mm yr^{-1} portion of sea level rise.

110. Drewry and Morris, 131/ however, stress that the present contribution of the Antarctic ice sheet to sea level rise cannot be reliably estimated by treating the continent as a single unit. Accumulation and ablation rates vary depending on several factors, including the nature of the ice sheet, the surrounding topography and ice dynamics. Of particular importance is the topography beneath the ice sheet which may introduce thresholds of stability and instability causing a stepped response to climate change. 132/

111. Recent scientific findings

(1) Long-term warming trends on the Antarctic peninsula are so large that they appear to be statistically significant. 133/, 134/

(2) Five northerly ice shelves on the Antarctic peninsula have retreated dramatically over the past 50 years, perhaps in response to atmospheric warming. 135/

(3) The recent dramatic collapse of the Larsen Ice Shelf, Antarctic peninsula, implies that after an ice shelf retreats beyond a critical limit it may collapse rapidly. 136/

(4) Catastrophic collapse of the West Antarctic Ice Sheet is not supported by recent three-dimensional numerical models. 137/

V. CONCLUDING REMARKS

A. Environmental issues

112. Antarctic tourism is a growing industry, with the number of sites being visited, as well as the range of types of activity, increasing dramatically. The long-term environmental impacts of tourism activity in Antarctica remain largely unknown, and there are difficulties in distinguishing natural from human-induced change because of the short periods for which environmental impact data have been collected.

113. Current fishing levels are below total allowable catch levels set by CCAMLR, but many fisheries, including krill, are still attracting commercial interest. Problems have been experienced with bird by-catch in longline fisheries, and also with illegal fishing within the CCAMLR area. CCAMLR is attempting to address these problems. It is important to have accurate knowledge of the biology and ecology of the marine ecosystem to allow for informed management decisions leading to a sustainable fishery, which is the focus of CCAMLR.

114. Pollutants originating in the industrial and populated areas of the world are transported to Antarctica by atmospheric and oceanic circulations. Levels in Antarctica are still, however, generally extremely low, except at a few localized sites. Antarctica is thus an ideal stage on which to base monitoring activities for long-range pollutants, due to minimal, localized human activity. It is important that this scientific value of Antarctica is not destroyed through local sources of contamination.

115. A substantial Antarctic ozone "hole" is expected to occur each austral spring for many more decades because stratospheric chlorine and bromine abundances will only approach the pre-ozone "hole" levels (late-1970s) very slowly during the next century. The ozone layer is anticipated to be most affected by human-influenced perturbations and susceptible to natural variations in the period around the year 1998, when peak stratospheric chlorine and bromine abundances are expected to occur. It is only because of the restrictions in the Vienna Convention for the Protection of the Ozone Layer and the Montreal Protocol on Substances that Deplete the Ozone Layer controlling chlorine and bromine emissions that the Antarctic ozone "hole" can be expected to disappear.

116. Sea ice is a very important environmental parameter in the Antarctic, the large seasonal cycle having a significant effect on the exchange of energy, mass and momentum between the ocean and atmosphere. Research using satellite data has shown that the length of the sea-ice season and maximum ice extents have fluctuated throughout the 1970s and 1980s. Evaluations of global ice-cover variations have thus far detected no overall significant change in Antarctic ice cover, although that in the Bellingshausen/Amundsen Seas appears to be responding to a regional climate warming. There are, however, insufficient systematic, spatially distributed data sets available to determine the seasonal and regional variability of the ice and snow thickness, distribution and growth processes.

117. The mass balance of the Antarctic ice sheet should be an important variable for global climate models. However, uncertainties in the accumulation and attrition components, as well as spatial variations in ice-sheet characteristics, make estimation of the total mass balance unreliable at present. The principal immediate effect of climate warming on the mass balance of the Antarctic ice sheet is expected to be an increase in precipitation and consequently accumulation. The marine-based West Antarctic Ice Sheet is considered by many glaciologists to be vulnerable to global warming and sea level rise; however, whether it is currently retreating, in equilibrium or advancing again is not clear. Increasing atmospheric temperature and contemporary ice-shelf retreat on the Antarctic peninsula over the past 50 years suggests that this region is a sensitive indicator of climate change.

B. A comprehensive state of the Antarctic environment report

118. It has not been possible in this report to make a comprehensive synthesis and review of all literature for the purpose of presenting this summary of the state of the Antarctic environment. Such a comprehensive report has yet to be written.

119. Chapter 17 of Agenda 21 reached consensus among Governments to enhance access of the international scientific community and specialized agencies of the United Nations to such data arising from scientific research relevant to understanding of the global environment. While not stated explicitly as such in this text, much of the data of global concern are related to the state of the Antarctic environment, prominent examples of which are data on ozone depletion, climate change and distributions of various pollutants.

120. Imperatives to prepare a state of the Antarctic environment report also issue from the Protocol on Environmental Protection to the Antarctic Treaty. Most specifically, the Madrid Protocol, in article 12 (j), calls for the Committee for Environmental Protection to report to Antarctic Treaty Consultative Meetings on the state of the Antarctic environment.

121. At the Twentieth Antarctic Treaty Consultative Meeting, it was suggested that SCAR consider and provide advice on the matter of preparation of a state of the Antarctic environment report. At the SCAR meeting held in Cambridge, United Kingdom, in August 1996, the production of a state of the Antarctic environment report was discussed. It was considered both appropriate and essential that SCAR should support efforts in concert with other interested parties to produce an authoritative assessment of this key region. SCAR expects to appoint a small steering committee in the very near future to initiate discussions with other organizations on the scope and content of such a report. SCAR will report back on these discussions to the 1997 Meeting.

122. Such a report would for the first time draw together a wide variety of data dispersed throughout the Antarctic literature and environmental databases worldwide, into an accessible and easily interpreted form. Second, it would play an important function in informing all members of the global community about Antarctica.

123. There would be practical benefit from the preparation of a state of the Antarctic environment report. The relevant scientific and technical agencies of the United Nations stand willing to assist towards the goal of issuing such a report, and to contribute in a practical way to meeting goals agreed under chapter 17 of Agenda 21 and the common interests of both States Parties to the Antarctic Treaty and non-Antarctic Treaty States.

Notes

1/ This report has been prepared on behalf of the Secretary-General by the United Nations Environment Programme with the assistance of the International Centre for Antarctic Information and Research, Christchurch, New Zealand, under the UNEP Global Resource Information Database programme.

2/ Fox, A. J. and A. P. R. Cooper. "Measured properties of the Antarctic ice sheet derived from the SCAR Antarctic digital database", Polar Record, vol. 30, No. 174 (1994), p. 204.

3/ Scientific Committee on Antarctic Research. The role of Antarctica in global change: scientific priorities for the International Geosphere-Biosphere Programme (IGBP) (Cambridge, SCAR, 1989), p. 5.

4/ Harris, C. M. and B. Stonehouse, eds. Antarctica and global climatic change (London, Belhaven Press, 1991).

5/ Drewry, D. J., R. M. Laws and J. A. Pyle. Antarctica and Environmental Change (Oxford, Clarendon Press, 1993).

6/ Weller, G. "Antarctica and the detection of environmental change", in Antarctica and Environmental Change. Drewry, D. J., R. M. Laws and J. A. Pyle, eds. (Oxford, Clarendon Press, 1993), p. 1.

7/ Protocol on Environmental Protection to the Antarctic Treaty (full text published by the Scientific Committee on Antarctic Research, 1993).

8/ Report submitted to the XX Antarctic Treaty Consultative Meeting (ATCM) by the Depository Government for the Convention for the Conservation of Antarctic Seals (United Kingdom). Working Paper 7, XX ATCM; Utrecht, the Netherlands, 29 April-10 May 1996.

9/ Report submitted to the XX ATCM by the Commission for the Conservation of Antarctic Marine Living Resources. Information Paper 103, XX ATCM, Utrecht, the Netherlands, 29 April-10 May 1996.

10/ The information in this and the following section is summarized from Information Papers 69, 71 and 72 submitted by SCAR to the XX ATCM, Utrecht, the Netherlands, 29 April-10 May 1996.

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15/ Dingwall, P. and D. Walton. Opportunities for Antarctic environmental education and training. Conservation of the Southern Polar Regions 3. Proceedings of the SCAR/IUCN Workshop on Environmental Education and Training, Gorizia, Italy, 26-29 April 1993 (Gland, IUCN, 1996).

16/ Draft report of SCAR and COMNAP on the Workshops on Environmental Monitoring in Antarctica, Oslo, 17-20 October 1995, and College Station, Texas, 25-29 March 1996, p. 3.

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