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R. Bargagli

Antarctic Ecosystems

Environmental Contamination, Climate Change, and Human Impact

With 50 Figures and 18 Tables

Springer

Professor Dr. Roberto Bargagli
University of Siena
Department of Environmental Sciences
Via P.A. Mattioli, 4
53100 Siena
Italy

email: bargagli@unisi.it

Cover illustration: A view of an iceberg in the Ross Sea from an ice-free area on Prior Island (northern Victoria Land, Antarctica)

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To Guido and Pietro,
the grandchildren born when I was writing this book,
wishing them a world where man will be reconciled with the environment

Preface

The picture of Antarctica as the remotest continent and the symbol of the last great wilderness and pristine environment on Earth has changed considerably in the last two decades. Environmental problems such as the recurring appearance of the "ozone hole" and the break-up of Antarctic Peninsula ice shelves have shown that Antarctica is inextricably linked to global atmospheric, oceanographic and climatic processes, and is therefore exposed to the impact of human activities in the rest of the world. Possible effects of global warming on the stability of ice sheets and the consequent rise in sea level are stimulating interest in this continent. There is also an increased awareness that near-pristine Antarctic ice, marine sediments and biota are archives of climatic and evolutionary history, providing essential data for a global baseline against which to monitor global changes. Although Antarctica is perceived as the last unspoiled region of the Earth and as a symbol of global conservation, its environment is not pristine, especially near scientific stations or areas affected by accidental oil spills. The application of the Protocol on Environmental Protection to the Antarctic Treaty is helping to significantly reduce the impact of human activities in Antarctica and the Southern Ocean. However, most persistent contaminants in the Antarctic environment originate from anthropogenic sources in the Southern Hemisphere and the rest of the world, rather than from local sources.

The Scientific Committee on Antarctic Research (SCAR) favours the implementation of coordinated national and international Antarctic research programmes on global-scale processes. However, the rapid development of analytical techniques and remote-sensing technology requires continuous updating of results which are dispersed in many journals. This book presents an overview of available data on environmental contaminants in Antarctica in order to evaluate whether current levels represent (on a local scale) a threat to the sustainability of ecosystems and whether climate change and probable future increases in atmospheric contaminant inputs from other continents of the Southern Hemisphere may compromise the scientific value of the near-pristine Antarctic environment. The idea for this overview and the discussion

of possible interactions between climate change and spatio-temporal patterns of contaminant deposition in Antarctica arose during the preparation of two reviews of trace metal distribution in Antarctic ecosystems (Bargagli 2000, 2001; Review of Environmental Contamination and Toxicology 166:129–173; 171:53–110). I myself was surprised by the vast amount of literature data on concentrations of persistent contaminants in a number of environmental matrices, by the adoption of unreliable sampling and analytical procedures, and by widespread misconceptions about the functioning of Antarctic ecosystems and/or the sensitivity of Antarctic organisms to heavy metals. Although it has been known since the 1990s that concentrations of Cd, Hg and other potentially toxic elements in some species of Antarctic organisms are naturally higher than in related species from polluted environments of the Northern Hemisphere, some researchers still use Antarctic data on Cd and other elements as global reference values.

In contrast to multi-author books, which often examine a few issues in great depth, this book aims to provide an overview of the Antarctic environment, the functioning of terrestrial and aquatic ecosystems, and the occurrence and cycling of persistent contaminants. Attempts were made to interpret possible interactions between predicted climate change and pathways of persistent atmospheric contaminants from anthropogenic sources in the Southern Hemisphere, and to provide suggestions for large-scale, long-term environmental monitoring of different regions of Antarctica and the Southern Ocean. It is very difficult to give an overview of interactions between climatic and environmental factors, and of the possible impact of climate changes and human activities in Antarctica and the rest of the world on Antarctic ecosystems. In recent years there has been an extraordinary development of models on future trends in air temperature, atmospheric precipitation, sea-ice cover and deposition patterns of a growing number of persistent contaminants in polar regions. The publication of this book in *Ecological Studies* continues the series initiated by Beyer and Bölter (eds) with *Geoecology of Antarctic Ice-Free Coastal Landscapes*, and is indicative of the general, growing interest in Antarctic ecosystems. Although this book reflects the state of the art at the time of writing, many new data will likely become available in the near future.

A real effort has been made to pass on the wisdom gained from personal research experience in the Ross Sea and Victoria Land environment, probably the regions most cited in this book. The book spans diverse topics such as climatology, meteorology, glaciology, atmospheric chemistry, oceanography, pedology, hydrology, environmental biogeochemistry, and marine and terrestrial biology and ecology. Some areas of research and interest probably received only limited attention. However, an extensive bibliography is included at the end of the book for readers wishing to pursue issues of interest in greater depth. In addition to any deficiencies, there may be some errors

and misconceptions – I would be grateful to colleagues for constructive criticism.

The book was organised in relatively self-contained sections but, due to the interdisciplinary nature of the subject and to interrelations between topics, it was necessary to cross-reference chapters, figures and tables; some repetitions could not be avoided. The first three chapters are devoted to general aspects of the environment in Antarctica and the Southern Ocean – climate trends, glacial systems, and the structure and functioning of terrestrial, freshwater, and marine ecosystems. Early responses of Antarctic ecosystems to climate change and the possible effects of enhanced UV-B radiation on phytoplankton and primary productivity were emphasised. Chapter 4 deals with persistent atmospheric contaminants and their sources in Antarctica and elsewhere in the Southern Hemisphere. Chapter 5 discusses the deposition of atmospheric contaminants and their incorporation into ice, reports available data on chemicals in snow, ice, soils, lakes, and cryptogamic organisms, and suggests some approaches for monitoring atmospheric contaminants around scientific stations. Chapter 6 addresses the chemical composition and biogeochemical cycle of trace elements in Southern Ocean seawater, and discusses local environmental pollution in marine coastal ecosystems near scientific stations, disused whaling stations or in areas affected by accidental oil spills, and effects of pollutants on benthic communities. Chapter 7 gives a comprehensive account of the accumulation of trace metals and persistent organic compounds in Antarctic marine organisms, the transfer of contaminants in pelagic and neritic food chains, and discusses the potential role of the most widespread species of organisms as biomonitors of contaminants and environmental changes. The last chapter discusses the potential impact of human activities in the Southern Hemisphere on the Antarctic climate and environment, and suggests the development of long-term circum-Antarctic monitoring networks. The book concludes with a discussion on the possible role of Antarctic research in implementing the protection of the global environment.

Overall, I would be delighted if this book can serve as a reference for researchers interested in local or large-scale monitoring surveys, management of the Antarctic environment, in climate change and its effects on polar regions. The description of Antarctic ecosystems, their structure and functioning may serve terrestrial and marine ecologists, and conservationists. As the problem of environmental contamination in Antarctic ecosystems is intermeshed with global processes, the book may also be useful to students of atmosphere physics and chemistry, oceanography, and glaciology.

I am grateful to Fabrizio Monaci for preparing all the illustrations, Arabella Palladino for the revision of the English, Otto Lange for constructive review of the manuscript, several colleagues for suggestions, and to co-workers in the Department of Environmental Sciences and the National Antarctic Museum

Felice Ippolito at the University of Siena for their help in collecting and archiving the literature. I am particularly grateful to my wife and entire family for their understanding and patience which enabled me to devote many weekends and the summer holidays to writing this book.

Siena, September 2004 *Roberto Bargagli*

Contents

List of Acronyms and Abbreviations

ACC	Antarctic Circumpolar Current
AChE	Acethylcholinesterase
AEON	Antarctic Environmental Officers Network
ALH84001	Mars meteorite found on December 1984 at Allan Hills, Victoria Land
AMAP	Arctic Monitoring and Assessment Programme
AMIEREZ	Antarctic Marine Ice Ecosystem Research at the Ice Edge Zone
ANARE	Australian National Antarctic Research Expedition
ANL	Argonne National Laboratory
APF	Antarctic Polar Front
ASMA	Antarctic Special Managed Area
ASPA	Antarctic Specially Protected Area
ATCPs	Antarctic Treaty Consultative Parties
ATS	Antarctic Treaty System
BAS	British Antarctic Survey
BIOMASS	Biological Investigations of Antarctic Systems and Stocks
BIOTAS	Biological Investigations of Terrestrial Antarctic System
BROD	Benzyloxyresurfin-*O*-deethylase
CCAMLR	Commission for Conservation of Antarctic Marine Living Resources
CEC	Cation Exchange Capacity
CEMP	CCAMLR Ecosystem Monitoring Programme
CFCs	Chlorofluorocarbons
CHLS	the sum of *cis*-chlordane, *trans*-chlordane, *cis*-nanochlor, *trans*-nanochlor
COMNAP	Council of Managers of National Antarctic Programme
CRAMRA	Convention on the Regulation of Antarctic Mineral Resources Activities
CS-EASIZ	Coast and Shelf-Ecology of the Antarctic Sea-Ice Zone
DDT	Dichlorodiphenyltrichloroethane
DFs	Dibenzofurans

DMHg	Dimethylmercury
DMS	Dimethylsulphide
DMSP	Dimethylsulphoniopropionate
DPASV	Differential Pulse Anodic Stripping Voltammetry
ENSO	El Niño–Southern Oscillation Phenomenon
EPA	Environmental Protection Agency
EPICA	European Project for Ice Coring in Antarctica
EROD	Ethoxyresurfin-*O*-deethylase activity
GCTE	Global Change and Terrestrial Ecosystems
GLOBEC	Global Ocean Ecosystem Dynamics Research
GLOCHANT	Global Change and the Antarctic
GWPs	Global Warming Potentials
HCB	Hexachlorobenzene
HCHs	Hexachlorocyclohexanes
HNLC	High Nutrient Low Chlorophyll (waters)
ICP-MS	Inductively Coupled Plasma-Mass Spectrometry
IGAC	International Global Atmospheric Chemistry
IGBP	International Geosphere–Biosphere Program
IGY	International Geophysical Year
IPCC	Intergovernmental Panel on Climate Change
ITASE	International Trans-Antarctic Scientific Expedition
IUCN	International Union for the Conservation of Nature
IWC	International Whaling Commission
JGOFS	Joint Global Ocean Flux Study
LEAFS	Laser Excited Atomic Fluorescence Spectrometry
LTER	Long-Term Ecological Research
MAA	Mycosporine-Like Amino Acids
MeHg	Methylmercury
NAS	National Academy of Science
NASA	National Aeronautical and Space Administration
NGO	Non-Governmental Organization
NMHCs	Non-Methane Hydrocarbons
NOAA	National Oceanic and Atmospheric Administration
NSF	National Science Foundation
PAGES	Past Global Environmental Changes
PAHs	Polycyclic Aromatic Hydrocarbons
PASC	Polar Atmospheric Snow Chemistry
PAR	Photosynthetic Active Radiation
PCBs	Polychlorinated Biphenyls
PCDDs	Polychlorinated Dibenzo-*p*-dioxins
PCDFs	Polychlorinated Dibenzofurans
PCFs	Perfluorcarbons
PCTs	Polychlorinated Terpenyls
PNRA	Italian National Antarctic Research Programme

POPs	Persistent Organic Pollutants
RiSCC	Regional Sensitivity to Climate Change
ROS	Reactive Oxygen Species
SCAR	Scientific Committee on Antarctic Research
SDS	Sodium Dodecyl Sulphate
SRES	Special Report on Emission Scenarios (commissioned by the IPCC)
UCDW	Upper Circumpolar Deep Water
UKMO	United Kingdom Meteorological Office
UNEP	United Nations Environmental Programme
USAP	United States Antarctic Program
UV	Ultraviolet
UV-B	Ultraviolet B radiation
VAI	Volcanic Aerosol Index
VOCs	Volatile Organic Compounds
WG-PACA	Working Group on Physics and Chemistry of the Atmosphere
WHO	World Health Organization
WMO	World Meteorological Organization