SECOND EDITION

Climate Change

Biological and Human Aspects

JONATHAN COWIE

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Second Edition

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Climate Change
Biological and Human Aspects
Second Edition

The second edition of this acclaimed text has been fully updated and substantially expanded to include the considerable developments (since publication of the first edition) in our understanding of the science of climate change, its impacts on biological and human systems, and developments in climate policy. As well as being completely revised throughout, major updates include:

> Considerable expansion of the sections on climate impacts on early societies in history, and biological impacts;
>
> Updated data and graphs on energy production and consumption;
>
> Completely new chapter sections on: climate thresholds; the Kyoto II conference; Canadian, Australian and New Zealand energy and climate policy;
>
> A new appendix on 'Further thoughts for consideration' to encourage discussion by students and others.

Written in an accessible style, this book provides a broad review of past, present and likely future climate change from the viewpoints of biology, ecology, human ecology and Earth system science. It has been written to speak across disciplines. It will again prove to be invaluable to a wide range of readers, from students in the life sciences who need a brief overview of the basics of climate science, to atmospheric science, geography, geoscience and environmental science students who need to understand the biological and human ecological implications of climate change. It is also a valuable reference text for those involved in environmental monitoring, conservation and policy-making seeking to appreciate the science underpinning climate change and its implications.

The United Nations Environment Programme (UNEP) cited the first edition as one of the top climate change science books of the 21st century.

Jonathan Cowie has spent many years conveying the views of learned societies in the biological sciences to policy-makers, and in science communication (promotion, publishing, and press liaison). His earlier postgraduate studies related to energy and the environment. He is a former Head of Science Policy and Books at the Institute of Biology (UK). He is also author of *Climate and Human Change: Disaster or Opportunity?* (1998).

Praise for this edition:

"A comprehensive review of the science of climate change, the impacts of climate change on biological and human systems, and their interrelatedness. An excellent contribution to the growing recognition that knowledge of biological and human systems is needed to understand climate change."

Gordon Bonan, National Center for Atmospheric Research

"... readers gain an appreciation of the wide-ranging consequences of climate change with many examples and analogies ... it is a book a climate scientist, or any concerned citizen of the world, should read."

Paul A. Dirmeyer, George Mason University

Praise for the First Edition:

"... a fine treatment of global climate change and interactions with biological systems ... everyone is likely to gain a fresh perspective or learn something new."

EOS

"... reader-friendly, quantitative, authoritative, but above all, stimulating; the pages dare you not to turn them over and read further."

The Biologist

"... measured, informative, balanced, scientifically sound, and as up-to-date as a book can possibly be in these days of rapid information accretion."

Bulletin of the British Ecological Society

"There is so much to gain from Cowie's book ... I know of no other source ... that brings together the breadth and depth of material that this book does.... the bottom line is that anyone who wants to understand climate change and its impacts ... should buy this book.... Cowie does a brilliant job of weaving together the evolution of life with the evolution of Earth's climate."

Bioscience

"... an impressive endeavor ... the strength of this contribution is precisely the interdisciplinary approach taken to such a multifaceted challenge."

Global Environmental Politics

In memory of Harry Harrison
Making room

(12th March 1925–15th August 2012)

Acknowledgements for the first edition

I would very much like to thank all those in UK bioscience with whom I have interacted in some way or other on climate-change matters. In particular, I should thank a good number who have been on the various Institute of Biology science committees since the 1990s. This also goes to a score or two of my fellow members of the British Ecological Society and the Geological Society of London. A special thank you goes to those who have alerted (and, as often as not, invited) me to workshops and symposia on climate and energy issues as well as on biosphere science. I have found every one useful in at least one way: many provided a number of new insights and all gave me a reality check. Thank you.

This book also owes a lot to some research bodies. In the UK we are quite bad at making data from tax-payer-funded research publicly available (even for education and policy purposes). This is not so in the USA and so I greatly valued the open access that the National Oceanic and Atmospheric Administration give to their palaeoclimate-related data (which I have used to generate a number of the figures). Interested readers can visit their website at www.ncdc.noaa.gov/oa/ncdc.html. I am also extremely appreciative of the UK Environment Agency's current (2006) Chief Executive, without whom Figure 6.5 [Figure 6.9 in the second edition] simply would not have been presented! Then there are the many who sent paper offprints (e-mailed pdf files). There are too many to mention but be assured all are referenced.

Talking of references, as mentioned in the Introduction, as far as possible I have taken either major reports, many of which are available on the internet, or used high-impact-factor journals that can be found in most university libraries (these in turn cite papers in more specialist publications). However, I have also used a number of World Health Organization (WHO) press releases. This comes from my background in science policy, and the WHO have been sending me these for the best part of two decades. You will not find these in university libraries but fortunately you too can seek these out, at www.who.int/mediacentre/news/en.

A mention also has to go to the friendly and helpful librarians of Imperial College London, whose work really is appreciated. Then there are all those who have facilitated my site and field visits in the UK and abroad, be they to power stations (fossil, hydroelectric and nuclear), sites of special scientific interest (in the literal and not just the UK technical sense of the term) and educational institutions.

A thank you also goes to Peter Tyers for the [first edition's] cover picture. This is the second time he has done this for me, but then he is a good photographer.

Finally I must specifically thank Cambridge University Press and freelance copy editor Nik Prowse for work on the manuscript. I like to think that I have long since

found my feet with words, but any capability for editorial spit and polish has always eluded me. Nik has also greatly helped standardise the referencing and presentation. I therefore really do value good editors (and so should you) and especially those who appreciate those who try to do things a little differently. With luck you will notice.

Acknowledgements for the second edition

In addition to those who kindly helped with the first (2007) edition – as this book firmly builds on that work – I must thank those who helped me develop this updated and expanded second edition. For permission to use figures and data I am appreciative to the following organisations: the Intergovernmental Panel on Climate Change (IPCC), the Earth Science Research at the Laboratory of the National Oceanic and Atmospheric Administration, and the Met Office UK. For permission to reproduce figures (and a photograph), as well as providing advice on data presentation, I am indebted to Timothy Andrews, Gerd Folberth, Jonathan Patz, Pieter Tans and Jim Zachos. A tip of the hat goes to Ian Spellerberg for facilitating some of the contacts for my Australasian sojourn. Here I am most grateful to David Karoly, Rodney Keenan, Ashok Parbhu, Simon Watts and Jez Weston for being generous in affording time and their briefing on climate change impacts and policy in Australia and New Zealand. I have to confess that in this regard I feel somewhat guilty. I had hoped to give more space to climate change and policy matters in these countries. Alas the sheer volume of new science arising in the past 6 years, and the constraints in fitting this into the allocated word count, meant that I could not include nearly as much as I would have liked. Nonetheless I found their briefings most useful, not to mention fascinating, and I hope that my condensing matters down does not do them a disservice.

At this point I must make the obligatory statement that any errors with the science in this book are my own and not those of the above good folk.

I must also thank the Geological Society and British Ecological Society. Of the 'climate surprises' discussed in this book's first edition, the notion that we might at some stage cross a critical transition and climate threshold somewhat analogous to the initial Eocene carbon isotope excursion (CIE) has gained some traction: it was even identified in the IPCC's 2007 Assessment's Working Group I report (pages 442–3 of that work), although it concluded that there was still 'too much uncertainty'. What was needed was a way to bring the current knowledge on this topic together, and so I proposed to the Geological Society the idea of an international symposium on this topic. This suggestion also gained support from the British Ecological Society. In November 2010 a 2-day symposium on past carbon-induced abrupt climate change and how it might inform us regarding future change was held (the first-ever joint event between the British learned societies for geologists and ecologists). There was also an end-of-symposium evening discussion that attracted governmental policy advisors. The outcomes of this symposium have contributed to the discussion in this second edition. Here appreciation goes to my symposium co-convener Anthony Cohen who was invaluable in identifying some of the speakers and in attracting some further sponsorship, as well as Georgina Worrall of the Geological Society who was

the event's organising secretary. Once again, any error in my attempts to convey the science are my own, and not the learned bodies involved or the symposium's speakers.

Finally, as with the first edition, once again I must specifically thank Cambridge University Press staff and freelance copy editor Nik Prowse (www.nikprowse.com) for work on the manuscript. They do what I cannot, and for that I am truly indebted.

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