Biological Extinction: New Perspectives

The rapidly increasing human pressure on the biosphere is pushing biodiversity into the sixth mass extinction event in the history of life on Earth. The organisms being exterminated are integral working parts of our planet's life support system, and their loss is permanent. Like climate change, this irreversible loss has potentially devastating consequences for humanity. As we come to recognise the many ways in which we depend on nature, this can pave the way for a new ethic that acknowledges the importance of co-existence between humans and other species. *Biological Extinction* features chapters contributed by leading thinkers in diverse fields of knowledge and practice, including biology, economics, geology, archaeology, demography, and architecture. Drawing on examples from various socio-ecological systems, the book offers new perspectives on the urgent issue of biological extinction, proposing novel solutions to the problems that we face.

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CAMBRIDGE
UNIVERSITY PRESS

CAMBRIDGE
UNIVERSITY PRESS

University Printing House, Cambridge CB2 8BS, United Kingdom

One Liberty Plaza, 20th Floor, New York, NY 10006, USA

477 Williamstown Road, Port Melbourne, VIC 3207, Australia

314–321, 3rd Floor, Plot 3, Splendor Forum, Jasola District Centre,
New Delhi – 110025, India

79 Anson Road, #06–04/06, Singapore 079906

Cambridge University Press is part of the University of Cambridge.

It furthers the University's mission by disseminating knowledge in the pursuit of education, learning, and research at the highest international levels of excellence.

www.cambridge.org
Information on this title: www.cambridge.org/9781108482288
DOI: 10.1017/9781108668675

First published 2019

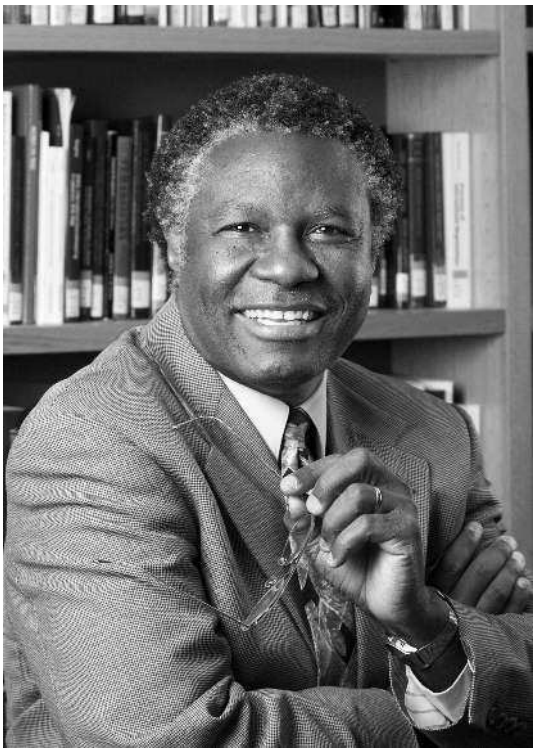
Printed in the United Kingdom by TJ International Ltd. Padstow Cornwall

A catalogue record for this publication is available from the British Library.

Library of Congress Cataloging-in-Publication Data
Names: Dasgupta, Partha, editor. | Raven, Peter H., editor. | McIvor, A., editor.
Title: Biological extinction : new perspectives / edited by Partha S. Dasgupta (University of Cambridge), Peter H. Raven (Missouri Botanical Garden), Anna L. McIvor (University of Cambridge).
Description: Cambridge ; New York, NY : Cambridge University Press, 2019. | Includes bibliographical references and index.
Identifiers: LCCN 2019008003 | ISBN 9781108482288 (alk. paper)
Subjects: LCSH: Extinction (Biology) | Evolution (Biology) | Adaptation (Biology)
Classification: LCC QH78 .B56 2019 | DDC 576.8/4–dc23
LC record available at https://lccn.loc.gov/2019008003

ISBN 978-1-108-48228-8 Hardback
ISBN 978-1-108-71181-4 Paperback

To the memory of our friend and colleague Calestous Juma.
His life provides inspiration and gives hope to us all.



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Preface

On our 4.5-billion-year-old planet, life is perhaps as much as 3.7 billion years old, photosynthesis and multi-cellularity (appearing dozens of times independently) around 3.0 billion years old, and plants, animals and fungi emerged onto land perhaps 480 million years ago. Forests appeared around 370 million years ago, and the origin of modern groups such as mammals, birds, reptiles and land plants appeared subsequently about 200 million years ago. The geological record shows that there have been five major extinction events in the past, the first of them about 542 million years ago; the record suggests that 99 per cent of the species that ever lived (perhaps 5 billion of them?) have become extinct. The last major extinction event occurred about 66 million years ago, at the end of the Cretaceous Period, and in general, the number of species on Earth and the complexity of their communities have increased steadily since then until near the present.

Over the past 66 million years, the number of species has grown to an estimated 10–14 million kinds of eukaryotic organisms (those with complex cells) and an unknown but probably much larger number of prokaryotic organisms (archaea and bacteria). The first members of the human evolutionary line split off the African apes about 6–8 million years ago. Our first close relatives, which we call hominids, appear in the fossil record about 2.7 million years ago in Africa. *Homo erectus*, the species most likely to have been the ancestor of our own, migrated out of Africa via the Middle East, starting about 2 million years ago, and apparently gave rise to the Neanderthals and Denisovans in the north. These extinct species were joined about 60,000 years ago by our own species, *Homo sapiens*, which had originated in Africa about 200,000 years ago. *Homo sapiens* spread to Australia soon after their arrival in Eurasia but didn't get to the New World until perhaps 18,000 years ago, and perhaps sooner. By about 30,000 years ago, they had already conquered and killed the other forms of hominids that were

present in the Northern Hemisphere, after interbreeding with Neanderthals and Denisovans when they came into contact with them.

For tens of thousands of years after they reached Eurasia, humans lived as hunter-gatherers. During that period, they began to create artistic works and to make weapons, musical instruments and the like, but since they kept moving in search of food, necessarily carrying their babies with them, there was not much chance for them to develop what we consider civilisation today. Dogs were domesticated in Eurasia likely more than 20,000 years ago, and crops were being cultivated by about 12,000 years ago. Along with domestic animals, these crops provided a major source of storable food, one that could see humans through droughts, winters and other unfavourable times. The numbers of people who could live together in a village, town or city were thereby greatly increased, allowing most aspects of what we consider civilisation to develop in these centres. Human dispersal to Australia occurred long before there was any domestication of plants or animals, a practice that never developed there, while dispersal to the New World occurred after the domestication of dogs (Chihuahuas, to eat). No crops were brought to the New World, and in North and South America, crop agriculture was invented independently.

At the time that crops became important elements for human survival some 10,000 years ago, the world population is estimated to have been about 1 million people, with about 100,000 in Europe. Written language was developed about 5000 years ago as distinctive civilisations developed in different parts of the world. Human populations began to grow rapidly and to overwhelm the capacity of many natural systems through cultivating crops and grazing. It is estimated that at the time of Christ, there may have been 300 million people living globally; now, there are nearly 7.6 billion. Some 10 per cent of the world's ice-free land surface has been converted to crop agriculture, with an additional 20 per cent to grazing, most of it unsustainable, on natural grasslands. It is obvious that many of the kinds of organisms that existed 10,000 years ago have already gone extinct and that we are dealing with a reduced set of the organisms that existed when agriculture was first adopted by our ancestors. What percentage would have been lost during this period is unknown, but for some groups on islands (e.g., Pacific birds), it seems to have been a majority, and on continents, a large percentage also, certainly in areas like the Mediterranean Basin.

Current extinction rates of species in relatively well known groups of organisms have been estimated to be 10–1000 times greater than their average rate (about one extinction per million species per year) over the past several million years. That average rate is called the 'background rate' of extinction. Figures for current extinction rates are reached from field studies and from estimates of declines of specific groups of mammals and birds. The latter are arrived at from empirically drawn relationships between the number of species in a geographical area and the size of the area. The relationships are known to vary substantially among communities and habitats, which is why, as the range shows, there are great uncertainties in the estimates. Despite the uncertainties, the figures put the scale of humanity's impact on the Earth system in perspective and explain why most scientists have come to believe that we are witnessing the start of what has been called the Sixth Extinction, following the five earlier ones that occurred before human activities were adding to the destruction.

In recent years, an enormous body of scientific studies, ranging from those of small-scale ecosystems to those of large-scale systems (biomes), has uncovered causal, positive links between biodiversity and the biosphere's productivity, on which we depend. That we do not inflict irreparable damage to the biosphere through destroying species should now be seen to be our central obligation to our descendants. This is why it is remarkable that there is very little available by way of quantitative data relating humanity's demand for the biosphere's goods and services to the biosphere's ability to meet that demand on a sustainable basis. One, inevitably crude estimate is that some five decades ago, we were using about 70 per cent of the Earth's sustainable capacity, but now, we are using about 175 per cent. Nevertheless, 800 million people are chronically malnourished and 100 million are on the verge of starvation at any one time. How have such imbalances, both among contemporaries and between the present and future generations, come about, and how could they possibly be sustained? The problems wouldn't go away if we had another 75 per cent of the size of the Earth to take care of our needs, but we could at least stop eating into the productive capacity of the Earth progressively as the years go by. With a number of nations markedly better off than others, and the wealthy best off everywhere, those who are better off are draining productivity from poor nations in the form of energy, wood and fuel. So there is no possibility of our improving our

situation without the widespread adoption of social justice, both as a matter of morality and as a matter of survival. In recent years, the Pontifical Academies have held several colloquia on the subject of social justice, global inequality and deep poverty in the contemporary world. But we haven't addressed the question of whether the Earth system is able to support the demands that humanity has been making on it. The survival of the natural world, and ultimately our survival, depends on our adoption of principles of social justice and sustainability. And sustainability requires care for the biodiversity that supplies the services that enable humanity to live and prosper.

All our food comes directly or indirectly from higher plants, of which there are an estimated 450,000 species. Tens of thousands of these have been cultivated for food at some time by some people, but at present, some 100 of them produce about 90 per cent of our food worldwide, while three kinds of grain, maize, rice and wheat, produce about 60 per cent of the total. We have detailed knowledge of perhaps only one-fifth of the species of plants in the world, and a majority could be gone in nature by the end of the century we entered recently. The same can be said for other groups of organisms, but plants are particularly critical, because we depend on them for many of our medicines, ecosystem services, atmospheric purification, carbon storage and everything that really makes our lives possible.

Even while economists and other social scientists have developed a quantitative grammar for discussing environmental problems, they have in the main neglected to do the same for biodiversity losses. The economics of climate change has advanced to the point where experts are agreed on the ranges in which such ethical parameters as the social rate of discount and the social price of carbon lie. Development economists have arrived at quantitative estimates of income that should be deemed to be the poverty line and have constructed measures of income inequality. But on biodiversity there is nothing comparable. In the absence of the kind of socio-economic reasoning that informs collective decisions affecting other spheres of the social world, direct efforts to preserve biodiversity are the best that is on offer for now. We can continue trying to preserve natural areas, particularly in areas with topographic relief, where the plant and animal inhabitants might have a chance in the face of continued climate change, and we can try to ensure sustainable interactions between the people of given areas and their biodiversity; and we can bring

organisms into domestication, cultivation or seed banks to preserve as many of them as possible while they are still there. Cryopreservation may work well for some of them. All of these methods need to be improved and applied based on a continually improving knowledge of organisms, but they will clearly only succeed in the long run when appropriate social conditions have been put in place and we find substitutions for the destabilising competition and aggression toward one another that we and our ancestors have been practising for tens of thousands of years.

The workshop on Biological Extinction at the Vatican Academy in 2017 was designed to collate our current knowledge of the state of biodiversity and the socio-ecological processes that are reducing it. Governments, international organisations and the public at large are anxious to receive policy advice from experts in technical disciplines. But the processes that are shaping current species extinction are so interwoven and complex, and our understanding still so imperfect, that we have been at pains to concentrate on the science of the subject. With but few exceptions (e.g., the reports on smart villages and smart cities), we have avoided discussing policies that could help reduce humanity's aggregate demand for the biosphere's goods and services. With help and advice from our Chancellor and Presidents, we designed a programme that would offer what we felt would be a rounded perspective on the science of species extinction. And we are most grateful to contributors to the volume not only for creating a lively and informative environment at the workshop itself but also for being attentive to the time schedule we proposed to them for submitting their revised papers. The volume would not have been realised, certainly not within the time frame we have managed, without Dr Anna McIvor, who helped with the editorial process. We are most grateful to them all.

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June 2018

Acknowledgements

The present volume consists of papers presented at a workshop on Biological Extinction, sponsored jointly by the Pontifical Academy of Sciences (PAS) and the Pontifical Academy of Social Sciences (PASS), in Casina Pio IV, Vatican City, 27 February–1 March 2017. We are most grateful to Werner Arber (past President, PAS) and Margaret Archer (President, PASS) for their advice and encouragement in organising the workshop and for participating in it; to the Pontifical Academies, without whose financial support the workshop could not have been held; and to our Chancellor, Bishop Marcelo Sanchez Sorondo, for his advice and help throughout.

We are very grateful to the Centre for the Study of Existential Risk (CSER) at the University of Cambridge for enabling us to invite Dr Anna McIvor to join us in editing the papers for publication.

The usual caveat applies: the opinions expressed in the volume are the authors' own and do not necessarily reflect those of the Pontifical Academies, nor of CSER.