Extinctions

Are we now entering a mass extinction event? What can mass extinctions in Earth's history tell us about the Anthropocene? What do mass extinction events look like, and how does life on Earth recover from them? The fossil record reveals periods when biodiversity exploded, and short intervals when much of life was wiped out. In comparison with these ancient events, today's biotic crisis has not yet reached the level of extinction to be called a mass extinction. But we are certainly in crisis, and current parallels with ancient mass extinction events are profound and deeply worrying. Humanity's actions are applying the same sorts of pressures – on similar scales – that in the past pushed the Earth System out of equilibrium and triggered mass extinction events. Analysis of the fossil record suggests that we still have some time to avert this disaster: *but we must act now*.

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'… a useful and succinct summary of the research into the reality and timing of mass extinctions from the early concepts to recent research – it brought me up-to-date with current thinking on mass extinctions. I admire his 'sceptical' stance: attempting to discriminate what a mass extinction actually *is* – outside the biggest three – is not as easy as has been assumed. The mass extinctions of the past clearly have relevance to the current approaching catastrophe in the Anthropocene, and the careful appraisal of exactly where we are in comparison with previous extinctions will be of great concern to those interested in the 'long view'. I particularly appreciated the focus on the notion of the interconnectedness of Earth systems.'

– Richard Fortey, author of *Life: An Unauthorised Biography* *History* and *Trilobite: Eyewitness to Evolution*

'Despite its sombre title and topic, *Extinctions* is an exuberant road trip through the history of life on Earth, led by a friendly and knowledgeable guide who knows all the locals along the way. Visiting so many ancestral Earthlings and vanished ecosystems is heady – and deeply humbling.'

– Marcia Bjornerud, Lawrence University, author of *Timefulness* and *Reading the Rocks*

'Most of life may well be extinct, because of the huge age of the Earth, but Michael Hannah shows vividly in this book that the 8.7 million species on Earth today are profoundly at risk; the lessons of the fossil record tell us what will surely happen if we continue pushing species after species to the brink.'

– Michael Benton, University of Bristol, author of *Dinosaurs Rediscovered*

'Without death, there can be no change. And, as Michael Hannah makes clear in his engaging new book, mass extinctions on various scales have been key shapers of the world as we know it. Had the dinosaurs not abruptly disappeared, we humans would not be here today. But as Hannah also shows, there is something dreadfully

menacing about the massive species loss and climate change the world is currently experiencing, making his book a balanced yet deeply unsettling account of what humans are unwittingly doing to the world.'

– Ian Tattersall, American Museum of Natural History, co-author of *The Accidental Homo Sapiens*

'An accessible and authoritative guide to the past, present, and future of extinctions. Michael Hannah dives into the fossil record and surveys the great mass extinctions of Earth history, from the death of the dinosaurs to the demise of the woolly mammoth, and explains how they are relevant to understanding the predicament we are in today, and to plotting a better future.

– Steve Brusatte, University of Edinburgh and New York Times/Sunday Times best-selling author of *The Rise and Fall of the Dinosaurs*

'Michael Hannah's book expertly examines the geological record of mass extinction events. It asks us to consider whether we wish to join asteroid strikes and massive volcanic eruptions as causes of mass extinction. Or whether we can change our relationships with the wonderful diversity of life around us to avoid such an ignominious outcome.'

– Mark Williams, University of Leicester

Extinctions

Living and Dying in the Margin of Error

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Kia whakatōmuri te haere whakamua

I walk backwards into the future with my eyes fixed on my past

MĀORI PROVERB

The longer you can look back, the farther you can look forward

WINSTON CHURCHILL

For June

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Preface

To a first approximation all life on Earth is extinct

David Raup

One estimate suggests that there are 8.7 million species alive on the Earth today.[1] In all honesty, this is our current educated best guess at the total biodiversity of the planet. However, if there are 8.7 million species alive on Earth today, approximately 3.7 billion years ago there was one. That single species evolved and flourished and is the ultimate ancestor to all living things today.

The quote above attributed to David Raup reflects a very palaeontological perspective on life. Raup's somewhat depressing conclusion about the amount of life currently on Earth is based on his estimation that of all the species that have ever existed on the planet, over 99% are extinct. In other words, the 8.7 million descendants of that single first species represent less than 1% of the number of species that have evolved and gone extinct since life first appeared on Earth. If we assume (generously) that all species alive today represent exactly 1% of all the species that have ever lived, simple arithmetic suggests that about 870 million species have lived on the Earth at some point in time. The margin of error on the estimate of 8.7 million species currently alive is ±1.3 million, or about 15%. Applying this level of error to my simplistic estimate for all species that have ever existed suggests a margin of error of about ±130 million species, well above the most outlandish estimates of the planet's current level of biodiversity. From the perspective of deep time, we, and every other organism on the planet, are *living and dying in that margin of error.*

[1] This estimate by Camilo Mora and his co-workers (which is not without its critics) is said to be accurate to within ±1.3 million. I chose this estimate because it was (1) fairly recent and (2) well documented.

It's highly likely that most of the millions of species that have gone extinct over the eons of geological time have left no trace of their existence. But some of them – certainly the minority of them – have been preserved in rocks and become part of the fossil record. That record has its limitations, but it has allowed palaeontologists to piece together, often in fine detail, the history of life on Earth. We have recovered fossils of organisms from rocks 3.7 billion years old, some of the earliest living things on the planet. We have fossils that trace the evolution of this early life, and we can watch as it became more complex and diverse, eventually filling the oceans. Through the fossil record we can witness life creeping out of the oceans and onto the land. The record contains fossils of the first flowering plants and a full record of the evolution of whales. In recent years, palaeo-anthropologists have identified an extraordinary array of hominin fossils that, together with genetic data, have triggered a revolution in the understanding of our own evolution. Many of the stunning fossils that have been recovered have captured the public's imagination. It seems as if every child I meet over the age of five knows more about dinosaurs and their extinction than I do.

But aside from the spectacular fossils it contains, the fossil record reveals something more fundamental about the history of life itself. It clearly shows that the journey from the one species living 3.7 billion years ago to the 8.7 million species existing on Earth today has been far from straightforward. In fact, the history of the diversity of life on Earth, as revealed in the fossil record, is a turbulent one. There have been periods when the diversity of life simply exploded, with many new species appearing relatively quickly. But there have also been times when the Earth's biota went through periods of great dying: geological instants when huge numbers of species went extinct simultaneously, causing the planet's biodiversity to tumble.

This book aims to show that this tempestuous history of biodiversity is important. Today, humans are warming the planet: the ice sheets are melting, and sea levels are rising. The chemistry of the oceans is changing – they are becoming more acidic, and areas of low

oxygen concentration are spreading. And it's not just that we are changing the climate. To feed and house our ever-expanding population, we are radically changing the way the land is used. Forests are being cut down to make way for agriculture; cities are expanding, reducing the natural habitats that support much of the Earth's biota. As a result, many species have already gone extinct, and many more are under threat. The history revealed in the fossil record offers us a chance to set the current state of the planet into its full historical context. This, in turn, can provide us with lessons that can both help us to understand how we got into our current situation, and offer some guidance about what we might expect in the future, and how we can change it.

Acknowledgements

This book had its genesis many, many years ago when Kim Sterelny – a philosopher of science who seems to be able to produce an erudite book every year – suggested I write a book about mass extinctions. The book you have in front of you does have a lot in it about mass extinctions, but it turned out they were only part of the story I wanted to tell. However, it has taken a long time for me to translate my vague notions of what I wanted to write about into the book you now hold. During that time, I suspect that a lot of my friends, colleagues, and students got heartily sick of hearing me talk about it. They have all been extremely tolerant, and I have to thank them for that. Many of the ideas included here were first tried out on my undergraduate classes. Standing in front of a large class, it was easy to see which ideas were received with enthusiasm and which resulted in almost terminal boredom. If nothing else, the use of cell phones is a great indicator of interest. Interested or not, many of these former students who happen to read the book will probably recognise some of my rubbish jokes (sorry).

Soon after I started writing the book, my confidence faltered, and I almost gave up. Instead, a science writing course offered at Victoria University of Wellington's International Institute of Modern Letters provided a real antidote. I recommend it highly. Course coordinators Ashleigh Young and Rebecca Priestly along with my fellow CREW 352 alumni provided confidence-building encouragement when I needed it the most. They also delivered useful critiques of early drafts of the initial chapters, convincing me that I could write a sustained piece of work that people would want to read. Rebecca Priestly deserves special thanks for introducing me to the amazingly helpful Sam Elworthy at Auckland University Press. Under Sam's careful but firm (very firm when I think about it) guidance, my

collection of not very well linked chapters became the backbone of this book.

Four of my colleagues supported me throughout the writing process: James Crampton, Chris Clowes, Ben Hines, and the astonishing Katie Collins. More than any others, these four put up with me rabbiting on endlessly about mass extinctions, the Anthropocene, and other palaeontological subjects, then convinced me that there was a book in there somewhere. James and Chris deserve special acknowledgement. Together we discussed many of the topics covered here, and they helped me to formulate and sharpen my ideas. They also passed along any scientific papers that they thought would be useful for me, and they usually were. James also allowed me to include many of the topics covered in this book in our joint postgraduate course where I had many of my ideas severely challenged – students can do that. All four read early drafts of the book and provided extremely useful feedback. As is usual, any mistakes that are still included here are my fault, not theirs.

There have been lots of useful discussions about many aspects of early life on Earth, mass extinctions, and ancient levels of diversity over beer and wine during meetings of the Palaeontologists in the Pub group. As well as those listed above, stalwarts included Thomas Cooper, Matt Ryan, Joanna Elliot, Lockie Hobbs, Tom Womack, Sonja Bermudez, Shelby Stoneburner, and Lisa McCarthy. I owe you all a beer.

At Cambridge University Press, Matt Lloyd has been enthusiastic about this project from the very beginning and has weathered my appalling proofreading with good humour. As a result of his geological training, he has also been able to pick up several errors of fact and terminology, which is appreciated. Sarah Lambert provided significant help with the nuts and bolts of assembling the book, from producing the index to obtaining copyright permissions. Lindsay Nightingale did an amazing job of editing the manuscript – saving me from several potentially embarrassing glitches and improving the book considerably.

I'd like to acknowledge Craig Hinton-Taylor, head of the IUCN Red List. He not only granted permission for the use of the list's data in Table 1.1, he also provided me with extra material, and picked up a mistake in my calculations and corrected it!

The translation of the Māori whakataukī (proverb) comes from a paper by Lesley Rameka of the University of Waikato. Although the paper concerned early childhood education, it introduced me to the Māori view of time which sees the past, present and future as intertwined. The past informs both the present and the future: one of the key themes of this book.

My whānau have supported me through all the writes and rewrites that the book has gone through. I need to acknowledge my children, Lachlan and Rebecca, and their partners Hannah and Dan. Thank you all so much. And finally, June, my long-suffering spouse – I cannot thank you enough for your continued support and encouragement. Even when I doubted my own ability to finish the thing, you never faltered. I couldn't have done this without you.

Further Reading

Throughout this book, I have resisted the use of formal scientific referencing because I believe that a reader who is not used to the style would find it distracting. Instead, I have listed at the end the scientific sources I found useful in shaping my thinking on the various topics covered in this book. Most are formal scientific publications, but there are also many books – most of which were written for non-scientific readers.