The Hadal Zone

Life in the Deepest Oceans

The hadal zone represents one of the last great frontiers in marine science, accounting for 45% of the total ocean depth range. Despite very little research effort since the 1950s, the last 10 years has seen a renaissance in hadal exploration, almost certainly as a result of technological advances that have made this otherwise largely inaccessible frontier a viable subject for research.

Providing an overview of the geology involved in trench formation, the hydrography and food supply, this book details all that is currently known about organisms at hadal depths and linkages to the better known abyssal and bathyal depths. New insights on how, where and what really survives and thrives in the deepest biozone are provided, allowing this region to be considered when dealing with sustainability and conservation issues in the marine environment.

Alan Jamieson is a Senior Lecturer at the University of Aberdeen, based at Oceanlab. His research is focused on the exploration of the hadal zone for biological research. He is the designer and operator of the 'Hadal-Landers' that over the last 7 years have been deployed over 100 times in ultra-deep trenches of the Pacific Ocean.

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Life in the Deepest Oceans

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For Rachel, William and Matthew

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Preface

The hadal zone is an enigmatic ecosystem or rather a cluster of deep ocean trench ecosystems. It is not only one of the most extraordinary, extreme marine environments in terms of high hydrostatic pressure, geological instabilities and low food supply, the hadal zone is also a place where life has been found to thrive at such great depths, despite common perceptions to the contrary. The hadal zone represents one of the last great frontiers in marine science, accounting for 45% of the total ocean depth range, yet it receives little or no mention in contemporary deep-sea biology text books. In the 1950s, the hadal fauna were subject to a great deal of attention as a result of the Soviet *Vitjaz* and Danish *Galathea* biological sampling expeditions, the discovery of the deepest trenches and the first manned submersible dives into the trenches. The decade culminated in the first visit by humans to the deepest place on Earth, the Mariana Trench. Despite the myriad of public attention and the advances in our understanding of hadal biology, ecology and geology, interest appeared to dwindle and very little scientific endeavour occurred through the 1970s, '80s and '90s. In fact, during these decades, the hadal zone's main accolade was as a potential dumping ground for pharmaceutical and radioactive waste materials, driven by the anthropocentric opinion of 'out of sight, out of mind'. Thankfully, this exploitation and perturbation of trench habitats did not become common practice and in recent years there has been a renaissance in hadal exploration, almost certainly as a result of technological advances that have made this otherwise largely inaccessible frontier a viable subject for research. Furthermore, as the current resurgence continues to flourish, it is hoped that the hadal zone will, at long last, be placed equally alongside all other marine ecosystems. We face an uncertain climatic future and thus, the ocean must be understood and maintained in its entirety and not categorised by proximity to the nearest human. It is startling how little is known about the hadal environment and this lack of knowledge renders a limited view of the communities that survive at the greatest depths and endure the highest pressures on Earth.

Officially, the hadal zone occurs in areas where one tectonic plate subducts beneath another; where the topography of the vast abyssal plains suddenly plunges to depths of nearly 11 km below sea level. The hadal zone was named after *Hades*, the name of both the ancient Greek kingdom of the underworld and the god of the underworld himself, *Hades* (brother to Zeus and Poseidon). The hadal zone comprises many disjunct trenches, mostly around the Pacific Rim and these trenches are host to most major taxa, some of which flourish even at the greatest depths (e.g. Holothurians, amphipods,

bivalves, gastropods). The geological setting of the trenches is notoriously unstable, adding another string to the extreme environment bow. The trenches offer up many biological and ecological conundrums, such as why two seemingly isolated trenches, sometimes tens of thousands of kilometres apart, are both home to the same species that do not inhabit the areas in between? Likewise, how were the trenches ever colonised at all, given that the quantity and distribution of surface-derived food supply varies so drastically from the surrounding plains? Also, what happens to the benthic communities following a catastrophic earthquake? Are there seasons, interannular variability or potential for chronobiology? How connected are the hadal communities with each other and to the wider deep-sea communities? We do not know the answers to most of these questions because hadal science is still in its infancy relative to conventional deep-sea research; however, we now have the technological and scientific support required to expand our knowledge of this unique environment.

There are many aspects of life in the hadal zone that are shared with the wider deep sea, therefore, this book aims to focus specifically on the trenches and the hadal communities therein and should be viewed as a companion resource to other key works. While compiling the information for this book, it became apparent that, despite so many recent developments on the topic, the large amount of sampling undertaken on the Danish and Soviet expeditions of the 1950s, particularly of invertebrates, has not yet been repeated on the same scale. All the data from these expeditions were compiled and documented in the works of the late G.M. Belyaev, from the P.P. Shirshov Institute of Oceanography in Russia, in a book entitled *Deep Ocean Trenches and Their Fauna*. The book was translated into English by the Scripps Institution of Oceanography in the USA and is a fabulous resource and a fantastic compilation of hadal research up until the late 1980s. The intention of this new book is not necessarily to update the work of Belyaev, however, it must be acknowledged that a lot of the information documented in Part III and the updated species list in the Appendix was derived or moderately updated from his work, due to lack of new information on many taxa. The species list in the Appendix and tables throughout are, to the best of my knowledge, correct and I accept any responsibility for errors or reclassifications that may have been missed.

Throughout the book there is also regular mention of 'HADEEP'. HADEEP, the HADal Environments and Education Program are a series of projects that have been running from 2006 to the present. HADEEP was undertaken in collaboration with the University of Aberdeen (UK), the University of Tokyo (Japan) and the National Institute for Water and Atmosphere Research (New Zealand). These projects amassed a large dataset on hadal organisms from many trenches and enabled the compilation of various information databases. Many of these resources are referred to in this book and are referenced to 'HADEEP'. It was during the first HADEEP project that the idea for this book arose.

In terms of organisation, this book is split into four parts, where the first part (History, geology and technology) provides a review of the history of hadal science and exploration (Chapter 1), geography and geology (Chapter 2) and full ocean depth technology (Chapter 3). These three chapters provide an overview of the components that led to the contemporary understanding of hadal science and provide the appropriate background

information for reference in the following sections. Part II (Environmental conditions and physiological adaptations) includes chapters on the hadal environment, hydrostatic pressure and food supply to the trenches. In the hadal zone context, hydrostatic pressure and food supply are independent chapters, given their significance in this environment. Part III (The hadal community) comprises four chapters describing our current understanding of the hadal communities from bacteria to fish (Chapters 7, 8, 9 and 10). The final part, Part IV (Patterns and current perspectives), describes more recent developments in ecology and evolution (Chapter 11) and for the first time, attempts to explore some rudimentary ecology. Chapter 12, Current perspectives, details the interactions between humans and the hadal zone, whether good, bad, present or historical. The Appendix is a species list of all known hadal specimens for reference.

The hadal zone is the subject of many things to different people. For example, it has been the subject of curiosity-quenching exploration, scientific endeavour, a potential source for pharmaceutical prospecting and a source of potentially devastating earthquakes and tsunamis. However, to most people, the hadal zone is a dark, mysterious realm that incites inquisitiveness, fascination and the thirst for exploration. Contrary to long-perceived opinion, we now know that the hadal zone is definitely not a deep, dark area of little importance to the world, where nothing but the weirdest and enigmatic creatures simply eke out an existence.

Future efforts are urgently required to comprehensively sample numerous trenches in order to enable global generalisations about life on Earth. We now live in an age where technology is at a level where very few unexplored frontiers remain, but we can now study these remote and extreme environments beyond simple ‘flag planting’ and try to understand them, maintain them and enjoy them now and in the future. With ever more exploration, visual imagery, experimentation and scientific understanding of these deep environments, it is hoped that the hadal zone will become less ‘alien’ to the world, while still retaining a sense of majesty and wonder.

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