

Ocean: Reflections on a Century of Exploration

By Wolf H. Berger, with contributions by E.N. Shor, University of California Press, 2009, 519 pages, ISBN 978-0-520-24778-9, Hardcover, \$59.95 US.

REVIEWED BY PETER WADHAMS

I will always remember my first visit to Scripps Institution of Oceanography to see Walter Munk. It was a November lunchtime when I arrived at a sun-drenched Institute of Geophysics and Planetary Physics (IGPP), perched on its cliff overlooking the Pacific Ocean. Walter was sitting in his bathing shorts at the picnic table outside the IGPP entrance. In the background, groups of younger oceanographers passed by carrying surfboards. I had just arrived from a cold, rainy, miserable Cambridge, England, and I gazed at the scene with amazement possibly tinged with censoriousness. Seeing my expression, Walter smiled and said, "You don't have to suffer to do good science!" I would like to suggest this as the official motto of Scripps.

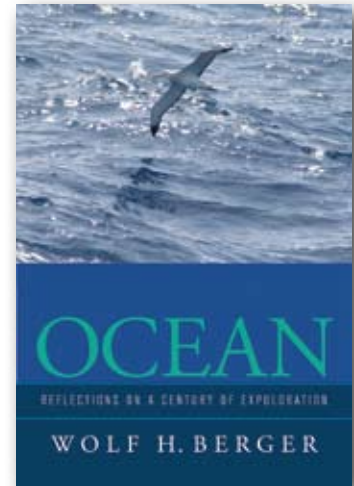
To write a survey of oceanography based mainly on work done by Scripps could be taken as presumptuous, for this is what Wolf Berger has done in his book *Ocean*. But of course it is not, for much of the history of oceanography since 1903 is the history of Scripps. It has always attracted the best oceanographers because it combines a formidable research ethic with a setting in one of the most beautiful places in the world. In fact, one sometimes feels that there are only two types of oceanographers: those who work at Scripps and those who

haven't been able to get a job there. So Berger's bias can be excused.

His survey is set at a fairly elementary level, rather like those introductory textbooks of the 1960s that sit on the bookshelves of older oceanographers, but it says much for the rate of progress of oceanography that it takes him 519 pages to give even a basic account (although I learned much from it). A lot of the growth since those heady 1960s days comes from marine geophysics and marine biology. The revolution in Earth sciences from plate tectonics, the role of geothermal vents, and the discovery of cyanobacteria show how ocean science has massively expanded at both ends of the size scale.

Berger begins with a brief history of oceanography, then he gives "A Portrait of the Ocean Planet," a survey of the ocean and its properties, in 28 pages. Fourteen more chapters then follow on more specialized topics that are treated in the same clear, simple, and entertaining manner. "Life at the Edge of a Fertile Sea" deals with the coastal and intertidal zone, especially of California, giving some recent insights to update the immortal work of Ricketts and Calvin, *Between Pacific Tides*, first published in 1939. "Of Coral Reefs and Atolls" covers the tragic story of damaged and ruined reefs, showing how difficult it now is to find a pristine reef anywhere.

"The Zen of the Beach" ranges widely, from the origin and fate of beaches, drawing on the work of Scripps scientist D.L. Inman, to the sources of swell, drawing on the work of Walter Munk, and the history of sea-level rise.



"Unravelling the Gulf Stream Puzzles" starts with the origin and structure of the Gulf Stream, but goes on to consider the dynamics of ocean current systems in general, paying generous tribute to the work of Henry Stommel of the Woods Hole Oceanographic Institution (WHOI), Scripps' deadly rival, as well as to that of Walter Munk. This warm current flowing north is then contrasted with a cold current running south, in "Sardines and the California Current." This chapter begins with the famous collapse of the sardine fishery but goes on to deal with upwelling processes and El Niño.

"Meadows and Deserts of the Sea" deals with ocean productivity and the food web in the sea. "Of Whales and Sharks and Giant Squid," coauthored with E.N. Shor, is a fascinating account of the largest creatures in the sea. The authors are commendably courageous in giving space to the evidence for sea serpents and other possible giant creatures, referring to the work of Ed Bousfield and Paul LeBlond in analyzing sightings of a creature they named *Cadborosaurus* off Vancouver Island. "The Deep, the Cold, the Dark" deals with life in the unlit depths of the

ocean, from midwater fish with photophores down to the benthos. "Seeing in the Dark" introduces acoustic oceanography, starting with sounds created by fish themselves, and moving on to the deep scattering layer and to seismic refraction and reflection methods for investigating the seabed. Acoustic thermometry of the ocean is described, but the more general technique of ocean acoustic tomography, invented by Walter Munk and Carl Wunsch of MIT, is not. This omits a development important to Scripps (and WHOI), and also a unifying trend in oceanography. Munk has drawn attention to the way in which acoustic oceanography and "normal" physical oceanography developed independently, for different purposes, and with different ways of defining and looking at the physical nature of the ocean. Each has much to learn from the other, and it is time to unify the two views.

"Mountains, Trenches, Sunken Islands" moves into Berger's own territory of marine geophysics. This chapter deals with the exciting history of how seafloor spreading was established as a fact and the scramble to discover the arrangement and mode of operation of the tectonic plates that make up Earth's crust and that are most accessible and dynamic under the ocean.

The later chapters bring us into newly developed areas of research where much remains undiscovered and much else is controversial. "The Ocean's Memory of the Ice Ages" deals with the impact of the ice ages on ocean structure, and also the role of the ocean in the descent into, and recovery from, the ice ages. In particular, the unsolved question of the origin of the two-stage recovery from the last ice age, via the Younger Dryas reversion, is

dealt with in detail. "Abyssal Memories" takes us further back into climate history through the results of the Deep-Sea Drilling Project, which was originally managed at Scripps in the 1960s before becoming a Texas A&M responsibility in 1985. The final chapter is highly speculative: "Global Warming and the Ocean" traces out the current controversies relating to the mechanisms of present climate change, and the role of the ocean in the greenhouse effect. As has often happened, a pioneering effort from Scripps can be identified in the 1957 paper of Roger Revelle and Hans Suess on carbon dioxide exchange between the atmosphere and the ocean, showing that the ocean was not in fact capable of absorbing all the additional CO₂ pumped out by human action, but must result in a rise in atmospheric levels. This conclusion led to the Mauna Loa observations, and the rest is modern history.

The epilogue deals with the future, and what we can do to halt the warming and pollution of the ocean and the destruction of its ecosystems. It ends with a plea for public education in Earth sciences, but equally a plea for public education toward environmental stewardship, that is, toward a sense of responsibility for the future of the ocean and the planet. "Without participation of a committed public, scientific knowledge will not translate into political action." This is a call for public action from marine scientists.

As shown above, although the book ends up covering most major topics in oceanography, it is not structured in a didactic way, but each chapter goes on from one starting point and seemingly naturally wends its way through a number of connected topics, like

a stream of consciousness artfully designed to look random. This construction makes the book a pleasure to read, as each chapter looks like a self-contained essay. *Ocean* also contains a useful set of appendices.

One of the delights of the book is the lengthy set of gossipy footnotes to each chapter, which expand on the personalities involved in the work and their interactions, and also direct us to a mass of further books and reading. We learn, for instance, in Chapter 7, that Carl Hubbs, a Scripps ichthyologist, used to take his graduate students on field trips in the 1940s, and forced them to spend the evenings and nights sorting fish while allowing them to cook some of the specimens for dinner. Luckily, he prevented them from eating cabezon, which he suspected of being poisonous, and he and chemist Arne Wick then experimented on cabezon specimens, finding that the roe killed rats and guinea pigs while the flesh was harmless. One of Hubbs' voyages was funded by the actor Errol Flynn, who quickly jumped ship to party in Acapulco while the scientists collected specimens, resulting in a movie called "The Cruise of the Zaca." Dipping in again, in Chapter 11 we learn that a fiendishly dangerous electrical sound source for seismic reflection, called the Rayflex Arcer, was operated safely by the Scripps marine technician Harold Sammuli only because his body was found to have an unusually high resistance to electricity. These historical snippets are absolutely fascinating and humanize the process of oceanography—although ocean science has always seemed the most human of the sciences, the one most closely connected to the enthusiasms and foibles

of the scientists who created it.

Elizabeth N. Shor, the historian at Scripps, is co-author of two of the chapters, on giant creatures and underwater acoustics, but makes her presence felt strongly throughout in supplying historical material to the footnotes sections.

There are bound to be a few errors in such a huge book. I only noticed two: Alfred Russel Wallace (who is given due credit for his role in discovering evolution) spelled his middle name with one “l”, not two, and the voyage of the *Fram*

started in 1893, not 1883.

I thoroughly recommend this book, not only to oceanographers of every kind and age, but also to general readers. It is enormously enjoyable and informative.

Peter Wadhams (*p.wadhams@damtp.cam.ac.uk*) is Professor, Department of Applied Mathematics and Theoretical Physics, University of Cambridge, Cambridge, UK, and Université Pierre et Marie Curie, Laboratoire d’Océanographie, Villefranche-sur-Mer, France.

Ecosystem-Based Management for the Oceans

Edited by Karen McLeod and Heather Leslie, Island Press, 2009, 392 pages, ISBN 978-1-59726-155-5, Paperback, \$45 US

REVIEWED BY ANDREW FISCHER

By now, there is no mistaking that the oceans are in peril. But, how do we move forward to address the problems and manage our ocean ecosystems for sustainability? How do we create new solutions to resource management challenges that span biological, social, and political disciplines? The compilation *Ecosystem-Based Management for the Oceans*, edited by Karen MacLeod and Heather Leslie, is probably the most comprehensive attempt at addressing these questions.

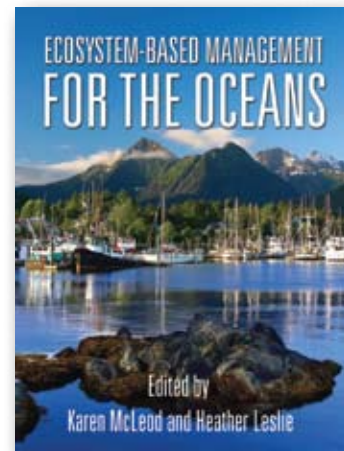
The book is organized into five parts, and each of the 19 chapters is a contribution from a total of more than 40 experts in the fields of marine science and management. Each of the chapters contains black-and-white illustrations

and photographs that support the text, and critical information in each of the chapters is summarized in boxes. The book begins with a foreword by Jane Lubchenco (Administrator, National Oceanic and Atmospheric Administration) and a preface by Anne Guerry (Lead Scientist, National Capital Project’s Marine Initiative) highlighting the interconnectedness and complex relationships among ecology, human interactions, and climate change in the Arctic and Puget Sound ecosystems. They make a compelling case for the urgent need for ecosystem-based management (EBM).

The first part of the volume is titled “Setting the Stage,” and the first two chapters define EBM, provide a guide to the volume, and spell out what resource managers need to implement an EBM approach. Ecosystem-based management is defined as an “integrated approach to management that considers the entire ecosystem, including humans.” The

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basis of this approach is to conserve ecosystems for the long-term delivery of ecosystem services. Another key aspect of the approach espoused by the book is the incorporation of resilience science, or embracing change and how ecosystems respond to myriad human and natural influences. To overcome traditional sector-based management challenges of current ocean management regimes and deliver a robust approach to EBM, Chapter 2 concludes that managers will require, among other things, a comprehensive and clear legal mandate, scientific information that is

cross-sectoral, and a forum for comprehensive ocean planning.

The second part of the book, “A Conceptual Basis for Ecosystem-Based Management,” focuses on key concepts that underpin EBM. Chapter 3 makes a strong case for the ocean as peopled seascapes, or coupled social-ecological systems—systems that integrate people’s institutions and economies, as well as the biophysical aspects. Chapter 4 defines resilience science, and both resilience science and coupled social-ecological systems become key concepts that underpin the remaining chapters of the book. Further conceptual development of EBM in Chapter 5 examines cross-scale ecological interactions. The authors of Chapter 5 suggest that, through examining a simple ecological model of a rocky intertidal community, testable qualitative predictions can be made and incorporated into adaptive EBM management scenarios. In Chapter 6, Lisa Wainger and James Boyd review the economics of natural resource management and economic valuation techniques. They recommend alternative approaches to valuing the long-term functioning of ecosystem services and their increased resilience through methods such as ecological production and ecological demand functions.

The third part of the volume, “Connecting Concepts to Practice,” focuses on implementing EBM. This part looks at four ways to incorporate concepts into the practice of EBM. Chapter 7 examines monitoring and evaluation programs, suggesting that EBM requires an adaptive approach, or a process of learning and change. The monitoring and evaluation of management outcomes or indicators,

in an experimental fashion, should lead to policy refinements that enable management programs to move toward resilience and sustainability. Chapter 8 calls for the incorporation of better nonmarket valuation techniques to determine trade-offs in EBM. Ecosystem services are largely not marketed, and not valuing them properly can lead to inefficient management of coastal and marine ecosystems. Using an example of shrimp aquaculture in Thailand, Chapter 8 further illustrates that the proper valuing of mangrove systems can lead to changes in the current incentives to convert mangroves to shrimp farms. Chapter 9 defines local knowledge (LK) and traditional ecological knowledge (TEK) and discusses the challenges of integrating LK and TEK into western science-based management frameworks. Using the Papahānaumokuākea Marine National Monument and the Olympic Coast National Marine Sanctuary as examples, this chapter shows how LK and TEK have played a role in establishing regulation and management responsibilities in these marine protected areas. Finally, Chapter 10 focuses on the legal and institutional frameworks in the context of EBM. Using the Magnuson-Stevens Act (fisheries) and the Endangered Species Act as examples, the authors show that current legislation contains provisions to permit or require EBM decisions, but, due to the fragmented state of statutory tools in the legislative framework, EBM approaches may not be applied consistently or at all.

The fourth section focuses on case studies of marine ecosystem-based management in practice. The case studies, which are largely set in North America, show how EBM is currently

being implemented, and they illustrate some of the successes and failures of its implementation. At the end of each case study, a “key messages” section summarizes its main points. A large aspect of the success of EBM is based on bringing together stakeholders. A case study from Morro Bay, California, exemplifies the utility of integrating EBM concepts through the development of strong networks of resource managers, stakeholders, and scientists who “share information, learn together, deliberate important trade-offs, and engage in collective action.” In the Gulf of Mexico, scientists are involving resource managers and users in long-term research and monitoring to maintain the resilience of the fishing industry. And, of special note, in Chesapeake Bay, integration of social and ecological sectors is being accomplished through a public sentiment index, a method to incorporate the views and engage interested stakeholders in public decision making and policy formulation. A chapter on the Eastern Scotian Shelf Integrated Management Project demonstrates the strengths of implementing EBM through a national-level legislative basis, and there is a short chapter that looks at some examples of national-level implementation from around the world, including Australia and New Zealand. Part 4 concludes with a chapter entitled “State of the Practice” in which the editors provide a brief analysis of the case studies presented. To finish off the volume, Part 5, “Looking Ahead,” addresses a new ethic for the oceans and strategies for moving EBM forward.

Overall, this book is an excellent compilation of theory and practical examples, assembled in a manner that is accessible to all students and

practitioners in either the natural or social sciences. It tackles the truly challenging topic of how to manage the ocean's ecosystem services, and it presents the information in a thorough, succinct, and digestible manner. A book

on this subject, especially of such scope and depth, is long overdue. It will truly serve as a primer for developing a resilience-based approach to the management of the coupled social-ecological systems of the world's oceans.

Andrew Fischer (andy.fischer@utas.edu.au) is a lecturer at the National Centre for Marine Conservation and Resource Sustainability, University of Tasmania, Launceston, Tasmania, Australia.

Cold-Water Corals: The Biology and Geology of Deep-Sea Coral Habitats

By J. Murray Roberts, Andrew Wheeler, André Freiwald, and Stephen Cairns, Cambridge University Press, 2009, ISBN 978-0-521-88485-3, Hardcover, 352 pages, \$125 US

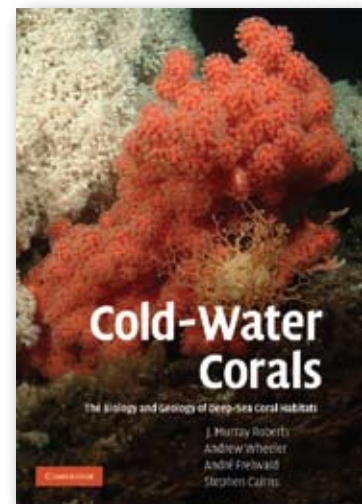
REVIEWED BY SANDRA BROOKE

Cold-Water Corals is the first comprehensive synthesis of one of the most active areas of current deep-sea research. It is a timely contribution to this field, which is experiencing a rapid increase in the number of scientific publications, has been the subject of several directed research programs, and has been the focus of four international conferences to date. The first three authors are recognized authorities on cold-water coral ecosystems in Europe, and the fourth author is a world authority on coral taxonomy. The targeted audience for this book is "professionals and students of marine science." The well-written and easy-to-read format contains numerous topic boxes (12) and case studies (7) that help explain various sections. The book has few typographical errors, a comprehensive index, a fairly complete glossary, and a summary reference section

(relevant to all chapters) that is appropriate to the text. It includes many black and white illustrations, and a 16-page section of color plates.

The text of the book is well organized; its eight chapters follow a logical sequence, and each chapter ends with a useful introduction to the next chapter. Although brief in places, the text is fairly complete. Chapter 1 sets the stage by reviewing the background and history of cold-water coral research and research methods.

Chapter 2 defines cold-water corals taxonomically and ecologically, and discusses their diversity, environmental constraints, and genetic connectivity. An interesting debate related to this field concerns use of the word "reef" and whether the term is appropriate when the structures are not navigational hazards (which is where the word originated). Roberts and co-authors make a strong case in Chapter 2 that from an ecological and biological perspective these cold-water and usually deep-water structures function in a way similar to shallow coral reefs, and, thus, use of the term reef is justified. This chapter does a good job of putting cold-water corals



in a broader perspective so that their importance can be appreciated. One seeming contradiction (or even an error) in this chapter relates to the distribution of the Stylasteridae (p. 42). It is stated that they are "absent from off continental land masses," but then it is noted that they are abundant off Florida (part of the US continental land mass). On p. 45, the same reference (Cairns, 1992b) is used to say that they "rarely occurred off continental land masses." The extensive table listing the 711 valid species (also available in the online appendix) is valuable, but the depth ranges for *Madrepora* and *Lophelia* do not match those in the text.

In Chapter 3, the basic biology of the anthozoa is reviewed, leading off with a treatment of anatomy and morphology. Then follow sections on food supply and

nutrition, growth, ecophysiology, reproduction, and larval biology and dispersal. Chapter 4 presents a geological framework that discusses the theories of initial cold-water coral reef development and the processes by which mounds form over many thousands of years. Chapter 5 on habitats and ecology presents the larger perspective on cold-water coral communities, including a discussion of biodiversity. Some ecologists might take issue with the support for use of the Shannon-Wiener index (p. 143), which has been severely criticized, despite its continued use. Chapter 5 summarizes habitat types and general faunal communities, along with predictive mapping. The paleontology chapter (6) documents the evolutionary history and fossil record of cold-water corals, and it is followed by a chapter on how corals can be used as proxy archives for a variety of measurements of the ocean environment. The final chapter (8) covers anthropogenic impacts to these ecosystems and current management strategies applied to them.

For the most part, figures and tables are clear and support the text. The line drawings of the various coral species are good and clearly show differences among species. Perhaps in future versions it would be useful to have the color plates and illustrations referenced in the index.

Online materials related to the book (www.lophelia.org/coldwatercoralsbook) include access to an appendix (in PDF format) that provides a phylogenetic listing of the 711 currently known species of cold-water corals with their taxonomic synonyms, a gallery of some of the halftone drawings in the book and links to other photographic and video material, a teaching resources section that links to book figures at Cambridge

University Press, a section on reviews of the book, brief biographies of the authors, and information on ordering the book. Although these resources are valuable and lead the reader to other information posted on the Lophelia.org site, it might be more useful if all of the material were in one place instead of among several Web sites. Nevertheless, such material can be easily updated, kept current, and changed with new editions of this book.

Perhaps the most obvious bias in *Cold-Water Corals* is its emphasis on research and issues in the northeastern Atlantic. To some extent, this bias is understandable as this is the area of expertise of most of the authors, and this region has produced most of the research papers. However, noticeably missing was the major review of deep-water corals produced in 2007 for all US waters by the National Oceanic and Atmospheric Administration. One chapter from this report was used (Parrish and Baco, 2007), but others would also seem to contain useful data for this book. In other instances on pages 28 and 31, reference to coral habitats off the southeastern United States and in the Gulf of Mexico is not supported with literature even though such exists. On p. 147, this regional bias is clear in the Norway case study where the area is noted as “globally significant.” While true, it appears to ignore the reference by Paull et al. (2000) that notes there may be over 40,000 coral mounds in one area of the Blake Plateau. Finally, the new huge marine protected area off the southeastern United States that contains abundant deep-sea corals was under development when this book was being written, and it is not mentioned. The authors are urged to

consider adding this information in future revisions.

Overall, the book is a great summary of knowledge on the subject of cold-water corals. The book has a strong conservation message that it backs up with data and logical arguments. It is a good supplement to other texts on deep-sea habitats. The book points out numerous places where data do not exist or are limited and where additional work is needed. It is highly recommended to scientists and students looking for a basic introduction on the topic of cold-water corals.

Sandra Brooke (Sandra.Brooke@mcbi.org) is Director of Coral Conservation, Marine Conservation Biology Institute, Bellevue, WA, USA.

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The Silent Deep: The Discovery, Ecology, and Conservation of the Deep Sea

By Tony Koslow, University of Chicago Press, 270 pages, ISBN 978-0226451251, Hardcover, \$35 US

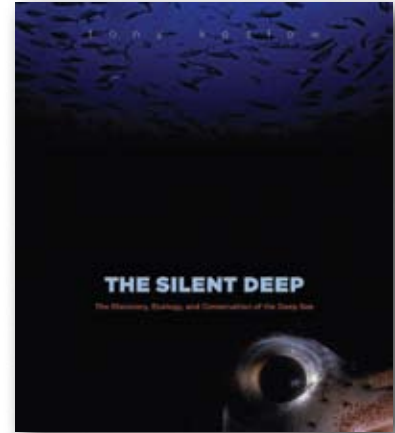
REVIEWED BY TIMOTHY M. SHANK

The deep sea represents one of the last great frontiers on Earth. Although once thought devoid of life, technology has brought the true abundance of deep ocean life into our human consciousness. Koslow's goal in this book is not only to introduce the intertwined explorations of scientific theory and the deep sea, but also to lay bare the facts of what humankind has inflicted on the depths. His vivid and succinct accounts of insults to the deep ocean are presented as freakishly appalling and irresponsible. As with most great frontiers, as Koslow puts it, "we humans devalue what we do not know." Unlike our moon, it remains out of sight for the vast majority of Earth's inhabitants.

Koslow relates the science, use, and future outlook of the deep ocean with an authoritative narrative that is easily understood. He compellingly uses the history of deep-sea exploration and science to demonstrate the human connection to the realms of ecological and evolutionary wonderment and exploitation. Historical science stories and personalities are woven into a fabric where the threads of science push ever forward. These stories are told only as someone with Koslow's experience and style can tell them—interesting, factual narratives that provide his readers, scientist and lay person alike, with

the wonders of the deep sea. He offers fascinating discoveries, ecologies, and evolutionary adaptations simultaneously, but also enumerates the ways humankind has impacted the deep sea and predicts the challenges of future stewardship. While scientists were discovering surprising oases of life at hydrothermal vents, society was concurrently polluting its ocean with chemicals, altering what were once thought to be inexhaustible fisheries through, for example, boat paint that changes the sex characteristics of benthic animals, and climate change that affects whole ecosystems.

The Silent Deep is actually three books in one, and throughout provides new and scholarly insights (even for the expert) as well as stimulating anecdotes. Part 1, "The Early History of Deep-Sea Exploration," presents early paradigms, such as the contention of a deep-sea devoid of life. Part 2, "The Ecology of the Deep Sea," discusses organisms and their ecologies from four major biomes—the fauna of the pelagic twilight zone; the seemingly ubiquitous and diverse "Lilliputian (or very small sized) Fauna" of deep seafloor sediments and muds; chemosynthetic ecosystems hosted by fluids and sediment laden with chemicals issuing from hydrothermal vents, cold seeps, the bones of fallen whales, and cold-water corals; and other invertebrates that dwell on seamounts. Part 3, "The Human Footprint Across the Deep Sea," discusses human activities, including mining, dumping, polluting, and deep-water fisheries activities, along with future conservation



and policy options. Although many of the figures are the standard for such books describing the deep sea, there are 16 plates containing more than 50 vivid images that depict the wide variety of habitats and life forms in the deep sea.

When I began reading this book, I was lead biologist for an international team of scientists on a Swedish icebreaker 4000 m above the deep seafloor using two new autonomous underwater vehicles to explore and sample, for the first time, Arctic hydrothermal vents and to compare their realities with our hypotheses regarding new species and their novel adaptations to the isolated deep Arctic Ocean vents. While remotely recovering hundreds of pounds of sticky mud and finding few if any life forms there, it was clear to me that Koslow not only captured the similar historical activities of the first deep-sea biologists, but he also breathed life into the organic ideas and the formative early exploration of the deep sea. I turned to the final page when I was conducting the first field trials of an exciting, new deep-sea vehicle—a hybrid with both remotely operated and autonomous capabilities, designed to reach the greatest depths on Earth (11,000 meters, which it accomplished in May 2008). The vehicle

employs technological advances new to marine science, such as ceramic spheres to provide buoyancy at pressures close to 16,000 pounds per square inch and a micro-fiber-optic cable the width of a human hair that can transmit multiple video streams along with vehicle sensor and navigation data to scientists aboard ship through a 20-km-long tether. While testing the vehicle's sampling capability, we discovered the anthropogenic legacy of mounds of spent munitions and gunpowder-filled tubes at 500-m depth. Coincident with this find in the Pacific was the discovery of massive damage caused by fisheries trawling on the Corner Rise seamounts in the North Atlantic. These recent experiences made only too real Koslow's major points: that deep-sea science has a storied

history and a legacy of exploration that extends to the current day and that the deep sea remains largely unexplored, although even the most far reaches are not only explorable by humans but have already been negatively impacted by us. He reminds us that we also have the power to steward the future health and use of the deep sea.

The Silent Deep is a unique and wonderful companion to the few other deep-sea textbooks that exist, such as Gage and Tyler's *Deep-Sea Biology: A Natural History of Organisms at the Deep Sea Floor* (1991, Cambridge University Press). However, I know of no other volume of work that so readily describes human impacts on the deep ocean, including the rapid spread and damage of trawling, the buildup of humanity's

toxic pollutants in deepwater life forms, the potential consequences of climate change and ocean acidification, and the future mining of seabed minerals and methane hydrates for hydrocarbons. The public needs to know what is at stake. From a single cigarette butt to megatons of radioactive waste, we have and will continue to impact the deep ocean.

I highly recommend this book for anyone with an interest in deep-sea ecosystems—and the future of our planet.

Tim Shank (tshank@whoi.edu) is Associate Scientist, Biology Department, Woods Hole Oceanographic Institution, Woods Hole, MA, USA. He is involved in several international projects on the biology and genetics of vent, seep, and seamount fauna from around the world.

Enumerating the Sea's Dwindling Bounty

A Review of *World Ocean Census: A Global Survey of Marine Life*

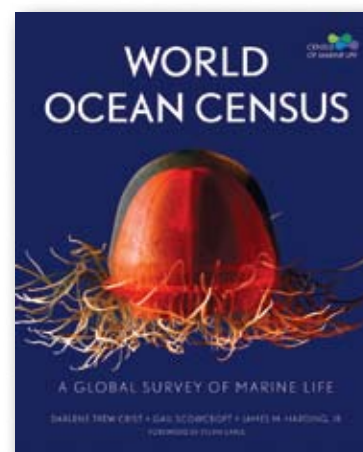
By Darlene Trew Crist, Gail Scowcroft, and James Harding, Jr., Firefly Books, 2009, ISBN 978-1-554-074341, Hardcover, 256 pages, \$40 US

REVIEWED BY CHARLES H. GREENE

During the first decade of the new millennium, a revolutionary approach to studying life in the sea was launched—The Census of Marine Life. Assembling over 2000 ocean scientists from 82 nations, the Census set out to answer three fundamental questions:

- What once lived in the global ocean?
- What is living there now?
- What will live there in the future?

In addressing the above questions, the Census evolved into an unusual mixture of nineteenth-, twentieth-, and twenty-first-century ocean science. Like the *Challenger* expedition of the mid-nineteenth century, the Census placed a strong emphasis on ocean exploration and cataloguing marine biodiversity. At the same time, it pioneered entirely new technologies to study the distribution, abundance, and genetic structure of marine populations as well as the behaviors of individual animals in the wild. It is not an exaggeration to state that over the past decade, the Census has played a fundamental role in transforming the study of life in the sea.



So, what has enabled the Census to play such a transformative role in marine biological research? During a decade in which federal support for such research was modest at best, the Sloan Foundation was able to use its own resources to leverage a large commitment of funding for the Census from

other private sources. Historically, when funding for marine biological research is adequate, scientific creativity and innovation can flourish. In contrast, when funding is scarce, the review process becomes more combative, the proposals become more conservative, and the odds are stacked heavily against truly innovative science. Certainly, the decade-long infusion of over half a billion dollars into marine biological research set the stage for the Census' success.

However, funding alone cannot ensure success. Projects had to be vetted in some sort of review process, and if creativity and innovation were to emerge, risks had to be taken. Did the Census only support the best scientific projects available? Probably not, and it is fair to guess that some would never have survived the peer-review process at traditional funding agencies like the National Science Foundation. Nevertheless, the Census did select themes and support projects that can only be described as game changers. The Future of Marine Animal Populations (FMAP) project was perhaps the most controversial and successful. By supporting conservation-oriented marine ecologists to look into the history of recent fishing practices and project future trends, the Census stirred up a hornet's nest of controversy with fisheries biologists and managers. Remarkably, rather than spinning out of control, this controversy eventually brought both sides to the table and a consensus perspective emerged by the end of the decade (Worm et al., 2009).

Obviously, not all of the Census projects will conclude as gracefully and on such a high note as the FMAP project. Nevertheless, as the Census draws to

a conclusion, it is an appropriate time to assess its accomplishments. *World Ocean Census: A Global Survey of Marine Life* is the first attempt to present these accomplishments in a format that is accessible to a broad audience. With its striking photography and high production standards, the book unfolds as a visual celebration of the Census. Marine biodiversity and the excitement of ocean exploration come alive as the reader thumbs through the pages and marvels at images collected from Census projects throughout the world ocean. As a coffee-table book, *World Ocean Census* succeeds admirably.

The text of *World Ocean Census* is not consistently up to the standards of its photography. Like the Census itself, the book is organized into three sections focusing on the past, present, and future of life in the sea. Unfortunately, coverage of these topics is uneven, and the quality of the narrative varies considerably from chapter to chapter. The narrative is at its best when it brings to life the personalities of the scientists participating in the Census. I particularly enjoyed Chapter 4 on "Animals as Ocean Observers" and Chapter 8 on "Unraveling the Mysteries of New Life-Forms." Chapter 4 captures the excitement of scientists conducting animal tracking studies and the challenges they face in tagging animals in some of the world's most extreme environments. Chapter 8 is equally engaging, letting the reader share in the thrill of discovery as Census scientists describe the excitement of finding new species.

The narrative hits its low points when it gets caught up in cataloguing technology rather than biodiversity. For example, Chapter 3 on "Expanding the Use of Technology" was very

disappointing. Normally, this topic would be of special interest to me. However, I found the descriptions of a wide variety of technologies in this chapter to be superficial and occasionally misleading. The development and use of state-of-the-art technology has been critical to the success of the Census; nevertheless, I would recommend skipping over this chapter and reading the much more enjoyable Chapter 4. Perhaps an appendix describing the technology in greater detail would have satisfied the more technologically inclined reader without disrupting the flow of the narrative.

Among its many themes, the most memorable message of *World Ocean Census* is that we must explore the ocean and understand its biodiversity before it is too late. This theme is expressed most eloquently in the book's foreword by Sylvia Earle:

The importance of the Census is made urgent because at the same time that more is being learned about the diversity of life in the sea... more is being lost.

However, this statement is not meant to imply that we are simply in a race against the clock to catalogue marine biodiversity before it disappears. Rather, the critical point is that only after we achieve a better appreciation of marine biodiversity can we fully comprehend and address the threats that humanity poses to the ocean environment and its inhabitants. There are several occasions early in the narrative when this message is communicated in a subtle manner. One example is Chapter 5 on "Disappearing Ice Oceans." This chapter has a chilling effect, leaving the reader with haunting images of spectacularly colorful animals living in polar environments that are

gradually disappearing due to some of the most dramatic, climate-induced changes on the planet.

In the final section of the book—“What Will Live in the Ocean?”—all subtlety is cast aside, and the authors forcefully draw attention to the impacts humans are having on marine populations. Chapter 9 on “Forecasting the Future” highlights the threat of extinction from overfishing faced by many large animal populations in the ocean. In addition to the species targeted by fisheries, numerous fish, sea turtle, and marine mammal populations are being driven toward extinction by their incidental capture or entanglement in fishing gear. Despite its overall sobering theme, the chapter ends on an optimistic note, describing how a change in lobster fishing practices can benefit both lobsterman and North Atlantic right whales.

The book’s final chapter, “The Path Forward,” continues the litany of human threats to the ocean and its inhabitants. Ocean acidification, anoxic dead zones, and the *jellification* of marine

ecosystems are each given their due. One can only hope that lay readers fascinated by the book’s earlier focus on marine biodiversity do not become too discouraged reading about how humans are decimating that biodiversity. Like the previous chapter, this one also ends on an optimistic note—concluding that the Census has made a difference and will help humans become better stewards of their ocean planet.

It is worth noting that *World Ocean Census* was written prior to the Census’ completion this year. Therefore, we can anticipate more comprehensive treatments of its scientific findings after the project’s synthesis phase is completed. However, beyond its scientific findings, the Census has other stories that still need to be told. Any endeavor of this size, involving so many people passionate about what they are doing, will lead to compelling stories with elements of comedy and tragedy, failure and triumph. One example emerged during the *Ocean Futures* project. At the height of the controversy this project stirred up, its leader Ransom Myers developed a

brain tumor and passed away after only a few months. His death left his young protégé, Boris Worm, in the crosshairs of the opposition critical of the project’s findings and conclusions. Fortunately, this episode, touched by tragedy, ended in triumph as Worm worked with the opposition to mediate their differences and achieve a critical consensus. Stories from the Census like this one, which convey some of the human drama associated with studying life in the sea, may help capture the public’s imagination and hopefully raise its awareness in time to make a difference. *World Ocean Census* is a start in the right direction, but there are still many stories left to tell.

Charles H. Greene (chg2@cornell.edu) is Director, Ocean Resources and Ecosystems Program, Department of Earth and Atmospheric Sciences, Cornell University, Ithaca, NY, USA.

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