Exploiting Invertebrate Intimacy

Author: Lowenberger, Carl

Source: BioScience, 58(3) : 270-271

Published By: American Institute of Biological Sciences

URL: https://doi.org/10.1641/B580314

Oceans of Peril and Hope

The Unnatural History of the Sea. Callum Roberts. Island Press, Washington, DC, 2007. 456 pp., illus. $28.00 (ISBN 9781597261029 cloth).

A flurry of reports over the last decade has brought overfishing to the fore of scientific awareness and policy debate. Yet the scope and magnitude of fisheries-induced changes on the world's oceans remain poorly understood and underappreciated, in large measure because of the lack of rigorously obtained scientific data from earlier times, an intellectual myopia caused by regional or taxon-specific interests, and a psychological phenomenon known as "shifting baselines": the tendency for people to define pristine nature as nature the way they first saw it, not the way it was in the beginning. *The Unnatural History of the Sea* offers a larger and longer-term perspective on whaling, sealing, and fishing, tracing the significant impacts of these activities back a millennium or more in Europe, and hundreds of years elsewhere, as European adventurers became competent seafarers and began probing the world's oceans.

The recognition of long-standing human impacts on marine species and ecosystems is not new—witness Mark Kurlansky's nonfictional bestseller *Cod* or Jeremy Jackson and colleagues' *Historical Overfishing and the Recent Collapse of Coastal Ecosystems. The Unnatural History of the Sea* is nonetheless groundbreaking in that it draws together accounts of remarkable change in various species and in most of the world's major marine ecosystems over the sweep of recorded history. Some readers will no doubt quibble with the book's various details, and a few may take strong exception to its essential conclusions, arguing that proper documentation is lacking and that the picture painted is therefore alarmist and extreme. In my mind, however, the book makes a forceful case, supported by diverse evidence from various species and ecosystems, that modern oceans have been so vastly altered by the overexploitation of whales, seals, and fishes as to be barely recognizable semblances of their preexploitation states.

The book is organized into three sections. The first is a view of the more ancient past, including depictions of the abundance of various fish and marine mammal populations in early Renaissance Europe or at the time of their discovery elsewhere by European explorers, and explanations of the historical events that led to these discoveries. As scientific data of present-day standards are lacking from early times, the measures of abundance are instead obtained from the written narratives of early adventurers—ship captains, privateers, and various government officials. Such accounts are necessarily of mixed quality and sometimes-uncertain reliability, depending on the whims, motivations, objectivity, and integrity of those who wrote them. Despite these shortcomings, it is difficult to imagine that reports of such richness, recounted independently by so many sources from so many places, do not fairly portray the oceans as the early fishers saw them.

The book's second section focuses on the modern era of industrial exploitation, a period extending from roughly the early to mid-19th century to the present. The author takes us from a time of widespread belief in an inexhaustible sea through the declines of such sundry species and ecosystems as the great whales, European coastal and shelf fisheries, Atlantic cod, eastern North American estuaries, coral reefs, and, most recently, the remote open ocean and deep sea. The historic narratives that accompany these first two sections provide fascinating insight into the recent history of the oceans and interesting new perspectives on important figures from the history of science. For example, many readers will no doubt be surprised to learn that Thomas Huxley's powerful intellect and force of personality came to bear not only in championing Darwin but also in denying 19th-century concerns over the destructive effects of bottom trawling.

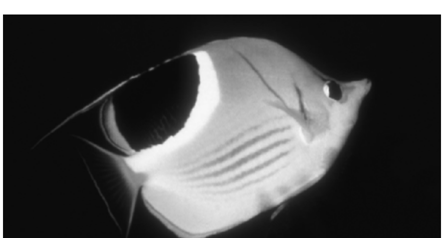
No matter how much you think you know about fisheries and the state of our oceans, this book will leave you with a renewed appreciation for what has been lost through the exploitation of living marine resources, a heightened awareness of the present state of the oceans, a sense of urgency for the need for action, and a feeling of some hope in the proposed solutions.

The book's final section makes two forceful arguments—first, that fisheries have now penetrated the deepest and most remote parts of the ocean, thus exhausting stocks nearly everywhere and driving living marine resources far below any reasonable conception of sustainability; and second, that a fundamentally different approach to fisheries management and ocean conservation will be needed to fix the problem. Although there will be grousing over the details, I doubt that many would disagree with the first of these arguments. In marshaling support for his second argument, Roberts reminds the reader that traditional fisheries management has repeatedly failed, and points out that even greatly reducing fishing will be insufficient to restore habitats that have been damaged or transformed by bottom trawling. His proposed solution is to manage ocean resources around a global network of marine reserves and protected areas. Such a radical departure from the status quo is bound to stir controversy—the stakes are high, and radical change from traditional views is always slow in coming. Regardless of where one stands on fisheries management, this book provides a great service to society by forcing the issues into the arena of public visibility and debate.

The Unnatural History of the Ocean is essential reading for everyone with an interest in the ocean, and I highly recommend it to anyone with a general desire to learn more about the world. You will be captivated by the graceful prose, intriguing historical vignettes, and startling revelations. No matter how much you think you know about fisheries and the state of our oceans, this book will leave you with a renewed appreciation for what has been lost through the exploitation of living marine resources, a heightened awareness of the present state of the oceans, a sense of urgency for the need for action, and a feeling of some hope in the proposed solutions. My only disappointment is over the author's failure to consider whether any of this matters very much, given the world's limited capacity for food production and the closely related question of how we are to feed the large and growing human population in a sustainable way. In fairness, the same criticism could be leveled against most other modern agendas and proposals for conservation action. Nonetheless, this book's underlying messages are certain to become part of the language of the future. Read it and consider these messages or be left behind.

JAMES ESTES
James Estes (e-mail: jestes@ucsc.edu) is a marine biologist at the Center for Ocean Health with the University of California–Santa Cruz.

doi:10.1641/B580313
Include this information when citing this material.



EXPLOITING INVERTEBRATE INTIMACY

Big Fleas Have Little Fleas: How Discoveries of Invertebrate Diseases Are Advancing Modern Science. Elizabeth W. Davidson. University of Arizona Press, Tucson, 2006. 208 pp., illus. $17.95 (ISBN 9780816525447 paper).

The field of invertebrate immunity and pathology goes back to the beginning of the 1900s. In *Big Fleas Have Little Fleas: How Discoveries of Invertebrate Diseases A Are Advancing Modern Science,* Elizabeth W. Davidson approaches the discovery of invertebrate pathogens and their effects on pest invertebrate hosts from the perspective of "usefulness," giving an account of how we have used and exploited these pathogenic microorganisms for our own purposes.

Davidson, a professor at Arizona State University, begins the book with a description of silkworm diseases, moving into the development and understanding of "germ theory" to explain infectious disease, a major concept in its own right. She then discusses the discovery of *Bacillus thuringiensis* (Bt) as a lethal agent for lepidopteran larvae (caterpillars), and the effort to develop this bacterium as a biological control agent. *Bacillus thuringiensis* is no longer merely an odd microbe; its genes have been copied and cloned into other organisms to create transgenic plants resistant to feeding by lepidopteran pests, and its use in agriculture is massive.

Although Bt toxicity is largely limited to the Lepidoptera, Davidson describes a related bacterium, *Bacillus thuringiensis israeliensis* (Bti), that is toxic to dipteran larvae. Bti, and to a lesser extent *Bacillus sphaericus,* became the major microbial insecticides used to reduce populations of mosquito and black fly larvae, an intervention that has undoubtedly saved the lives of millions of people who would have contracted malaria and onchocerciasis and alleviated the suffering of many more. These products continue to be the foundation of antimosquito and anti–black fly programs throughout the world.

Bacteria were not the only microorganisms being discovered for use in pest control during the 20th century. Davidson explores some of the initial studies on the identification and use of viruses to control caterpillars that cause significant damage to crops and forests. Beetles (Coleoptera) also cause substantial problems in certain crops. To combat beetle pests of palms, scientists identified, characterized, and commercialized viruses lethal to beetles to reduce tree damage to acceptable levels. One virus, first isolated from the rhinocerous beetle of the genus *Oryctes,* was transported around the world for the control of various related pest species. It is sobering to note that relatively few regulations existed at the time to control or regulate the movement of these novel biological control agents, and it might be considered fortunate that beneficial species were apparently not significantly affected.

Insects and other invertebrates have, however, evolved mechanisms to protect themselves against invading pathogens. Davidson helpfully describes the preliminary studies of Metchnikoff on phagocytosis in starfish, immunology in general, and the concept of vaccines, as well as the understanding of innate immunity in both vertebrates and invertebrates. This includes the expression of antibiotic proteins first identified in insects in the 1980s, which has spawned a whole field of studies into innate immunity, the recognition of nonself, and the evolution of immune responses in invertebrates and vertebrates alike. The initial studies of cecropins from Lepidoptera and lysozymes from Diptera have led to similar studies in all classes of organisms.

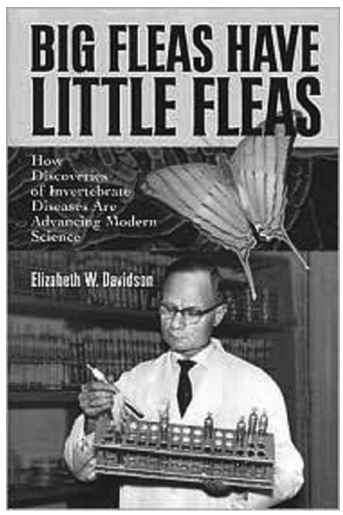
Humans have played a part in the evolutionary stories by moving many pests around the world, often necessitating measures to control those same organisms in their new environments. These pests include insects, their control agents, and organisms that cause illness in cultivated and wild shellfish. Moreover, humans are responsible for transporting human cholera to previously cholera-free regions of the world.

In some cases, pathogens of invertebrates have teamed up to become more efficient killers. Such is the case of a family of nematodes that infects insects. When the nematodes penetrate an insect, they release compounds to inactivate the immune response of the insect, in the process releasing some specific bacteria they have transported with them. The bacteria proliferate once the innate immune response of the insect is knocked down, and the nematode and bacteria reproduce to huge numbers at the insect's expense. When the resources are exhausted, the remaining nematodes feed on some of the bacteria, then millions leave the corpse to look for new potential hosts. This association of nematode and bacteria has been exploited and used in biological control programs to reduce agricultural damage caused by lepidopteran and coleopteran pests to acceptable levels. The biotechnology industry is exploiting the compounds produced by nematodes and bacteria to develop new drugs, all of them possible because of a very successful symbiotic association between two lowly organisms.

Some of the chapters describe the use of bacterial pathogens to reduce pest insect populations that cause losses in human agriculture. It should be noted, however, that beneficial insects such as honeybees have bacterial and viral diseases of their own, which may result in hive death and reductions in agricultural production. Despite hives' innate immune defenses, the loss of colonies or apiaries to bacteria, viruses, or mites is often severe. We still have not found measures to protect hives from these pathogens, and we cannot expect insects we consider beneficial to be exempt from having them.

Fungal diseases of invertebrates also abound, some of which have been developed and exploited to control pests such as the gypsy moth or locusts. Scientists' keen observations of sick insects led to the discovery of these compounds, which are now sprayed from airplanes to control outbreaks of these pest insects. The associations described above are symbiotic, and we have exploited these close linkages to achieve biological control of a problem species. Often, though, humans created the problem in the first place through extensive monocultures or by moving organisms to regions where natural controls are in short supply.

Davidson has done a good job of describing the historical context in which these pathogens have been developed as controls. She also portrays the individuals from a range of countries who have worked together in their own symbiotic relationships to solve the problems. It should be noted that many activities of scientists, such as sending live biological material from laboratory to laboratory and continent to continent, are not as simple today as they may have been only a few decades ago.



Big Fleas Have Little Fleas is not an in-depth text for researchers on biochemical methodologies, large-scale production processes, or the biochemistry of pest-control agent interactions. There are many more-specialized texts for their purposes. What Davidson has produced is an overview and a recent history of the development of the "little fleas," or the microbial pathogens, that we have exploited to control the big fleas—the pests that cause us no end of grief, either directly (mosquitoes that transmit parasites) or indirectly (pests that reduce our food supply). As such, this book is valuable for the novice entering the field—it puts some initial discoveries and concepts in perspective. This text also gives the research scientist or agronomist who uses these products regularly a historical context. It describes the chain of events that has allowed us to identify, produce, and exploit specific aspects of these lowly microbes to develop effective microbial agents to control pest populations. There will always be big fleas. This text suggests there will also always be more little fleas that can be exploited for our purposes.

CARL LOWENBERGER
Carl Lowenberger (e-mail: clowenbe@sfu.ca) works in the biology department at Simon Fraser University in Burnaby, British Columbia.

doi:10.1641/B580314
Include this information when citing this material.

EXPLORING THEORETICAL MORPHOSPACES

The Geometry of Evolution: Adaptive Landscapes and Theoretical Morphospaces. George R. McGhee. Cambridge University Press, New York, 2006. 212 pp., illus. $75.00 (ISBN 9780521849425 cloth).

In *The Geometry of Evolution: Adaptive Landscapes and Theoretical Morphospaces,* author George McGhee visualizes evolution by natural selection as a journey across a fitness landscape consisting of hills, mountains, and ravines, in search of some optimal solution for an organism that must adapt to certain environmental conditions. This fascinating metaphor is an interesting approach to studying evolutionary processes, one that leads naturally to the development of mathematical theories about how organisms adapt to a changing environment and how morphogenesis is linked to evolution.

In chapter 2, McGhee discusses the modeling of natural selection in adaptive landscapes, referring to the work of Kauffman (1993, 1995). But McGhee and Kauffman take different approaches. In *The Origins of Order,* Kauffman (1993) presented mathematical models of a fitness landscape, then, on the basis of simulated results, visualized the landscapes in accordance with various parameters. The models discussed by McGhee in chapter 2, however, are not mathematical—they are conceptual models of how an adaptive landscape might look.

In chapter 3, on modeling evolutionary phenomena in adaptive landscapes, McGhee reproduces a fascinating illustration from *Signs of Life: How Complexity Pervades Biology* (Solé and Goodwin 2000) that shows how an adaptive landscape might look for extinct trilobites from the Palaeozoic era. Every peak in the landscape corresponds to some beautiful trilobite morphology. Unfortunately, the landscape is not based on measurements—it is entirely conceptual. Although it is not entirely straightforward to visualize the fitness landscape for extinct trilobites, it would have been instructive for McGhee to show not only conceptual models but also a mathematical model of an adaptive landscape, as Kauffman did in *The Origins of Order*.

Yet when trying to explore the adaptive landscapes of such a mathematical model, many questions need to be answered. Two key ones are, How can the fitness of an individual be determined? and How can the multiparameter spaces of an adaptive landscape be visualized? Exploring these questions is a worthy research endeavor in itself.

In chapter 4, McGhee introduces the concept of theoretical morphospaces, which he defines as *n*-dimensional geometric hyperspaces produced by systematically varying the parameter values of a geometric model of form. The most famous theoretical morphospace is the one constructed for mollusk shells by Raup (1966). In Raup's paper, a range of hypothetical mollusk shell morphologies was visualized as a function of the number of parameters controlling the morphology of the shell. A pioneering publication in many ways, this paper was the first to introduce the concept of morphospaces. In this early application of scientific visualization, the results of a mathematical model were visualized on a computer screen even before the field of computer graphics existed!

A general problem with morphospaces is that the underlying mathematical model is based largely on just a description of the organism's form. In the mollusk morphospace, the morphology of the shell is controlled by parameters such as the whorl expansion rate and the translation rate of the shell. The advantage of such a description is that the shell's morphology can easily be captured by a small piece of computer code; the disadvantage is that these parameters do not necessarily have a connection with the developmental process. McGhee's book would have been more interesting with examples of a connection being made between the underlying developmental gene regulatory networks and the form of an organism. There exist among the echinoderms some beautiful examples of how rewiring regulatory networks that control the body plan can result in a sea urchin or a starfish (Davidson 2006).

McGhee states on page 61 that in many cases, creating a mathematical model of growth is not very difficult—it "simply requires a little thought." It is clear that here, McGhee is referring to simple geometrical descriptions of form. To anyone who has ever worked on modeling growth and form (e.g., gene regulation and cell movement), McGhee's statement must sound strange. An interesting topic for his next book might be the construction of morphospaces that are based on physical—or biologically relevant—parameters. In the literature on bacterial colonies, for instance, there are many examples of morphospaces (some with the form of phase diagrams). Kawasaki and colleagues (1997), for example, provided a diagram that shows the morphology of a bacterial colony as a function of two biologically relevant parameters (concentration of nutrient and density of the agar medium).

Regardless of the shortcomings of descriptive and conceptual models, *The Geometry of Evolution* does provide an excellent overview of the role of theoretical morphospaces and adaptive landscapes in models of growth and form. McGhee has made a courageous attempt to develop a mathematical theory connecting models of morphogenesis and evolution, and his book offers an opportunity to learn about the enormous diversity of palaeontological examples of evolution. He has done a very good job in bringing all this material together in one book, and I would recommend *The Geometry of Evolution* to anyone interested in morphogenesis and evolution. Mathematicians and computer scientists in particular will find that the book poses many interesting questions.

[T]he book intrigues, enticing readers to ask new research questions: Can we develop mathematical models of growth and form that are useful for investigating the role of natural selection in evolution? What do these adaptive landscapes look like? Do many possible solutions exist in evolution, or does the evolutionary process converge on a few choice answers?

Visualizing *n*-dimensional parameter spaces and adaptive landscapes is highly relevant to optimization problems and a good example of the challenge of information visualization. Finally, the book intrigues, enticing readers to ask new research questions: Can we develop mathematical models of growth and form that are useful for investigating the role of natural selection in evolution? What do these adaptive landscapes look like? Do many possible solutions exist in evolution, or does the evolutionary process converge on a few choice answers? The reader who is open to such questions will find much here to stimulate reflection and experimentation.

JAAP A. KAANDORP
Jaap A. Kaandorp (e-mail: jaapk@science.uva.nl) is an associate professor in computational biology in the computational science section, Faculty of Science, University of Amsterdam, The Netherlands.

References cited

Davidson EH. 2006. The Regulatory Genome: Gene Regulatory Networks in Development and Evolution. San Diego: Academic Press.

Kauffman SA. 1993. The Origins of Order: Self-organization and Selection in Evolution. New York: Oxford University Press.

———. 1995. At Home in the Universe: The Search for the Laws of Self-organization and Complexity. New York: Oxford University Press.

Kawasaki K, Mochizuki A, Matsushita M, Umeda T, Shigesada N. 1997. Modeling spatio-temporal patterns generated by *Bacillus subtilis*. Journal of Theoretical Biology 188: 177–185.

Raup DM. 1966. Theoretical morphology of the coiled shell. Science 147: 1294–1295.

Solé R, Goodwin B. 2000. Signs of Life: How Complexity Pervades Biology. New York: Basic Books.

doi:10.1641/B580315
Include this information when citing this material.

NEW TITLES

Aphids As Crop Pests. Helmut F. van Emden and Richard Harrington, eds. CABI, Cambridge, MA, 2007. 752 pp., illus. $290.00 (ISBN 9780851998190 cloth).

Biology of Turtles. Jeanette Wyneken, Matthew H. Godfrey, and Vincent Bels, eds. CRC Press, Boca Raton, FL, 2007. 408 pp., illus. $149.95 (ISBN 9780849333392 cloth).

Cell Division Control in Plants. Desh Pal S. Verma and Zonglie Hong, eds. Springer, New York, 2008. 427 pp., illus. $209.00 (ISBN 9783540734864 cloth).

Citrus: Genetics, Breeding, and Biotechnology. Iqrar Ahmad Khan, ed. CABI, Cambridge, MA, 2007. 384 pp., illus. $160.00 (ISBN 9780851990194 cloth).

Elwyn Simons: A Search for Origins. John G. Fleagle and Christopher C. Gilbert, eds. Springer, New York, 2008. 480 pp., illus. $139.00 (ISBN 9780387738956 cloth).

Heat Treatments for Postharvest Pest Control: Theory and Practice. Juming Tang, Elizabeth Mitcham, Shaojin Wang, and Susan Lurie, eds. CABI, Cambridge, MA, 2007. 350 pp., illus. $150.00 (ISBN 9781845932527 cloth).

Homalopsid Snakes: Evolution in the Mud. John C. Murphy. Krieger, Melbourne, FL, 2007. 260 pp., illus. $68.50 (ISBN 9781575242591 cloth).

Life in the Valley of Death: The Fight to Save Tigers in a Land of Guns, Gold, and Greed. Alan Rabinowitz. Island Press, Washington, DC, 2007. 260 pp., illus. $25.95 (ISBN 978597261296 cloth).

Mathematics of Evolution and Phylogeny. Olivier Gascuel, ed. Oxford University Press, New York, 2007. 442 pp., illus. $49.95 (ISBN 9780199231348 paper).

Peasants, Farmers, and Scientists: A Chronicle of Tropical Agricultural Science in the Twentieth Century. H. J. W. Mutsaers. Springer, New York, 2007. 645 pp., illus. $129.00 (ISBN 9781402061653 cloth).

A Reef in Time: The Great Barrier Reef from Beginning to End. J. E. N. Veron. Belknap Press, Cambridge, MA, 2008. 304 pp., illus. $35.00 (ISBN 9780674026797 cloth).

The Rise of Animals: Evolution and Diversification of the Kingdom Animalia. Mikhail A. Fedonkin, James G. Gehling, Kathleen Grey, Guy M. Narbonne, and Patricia Vickers-Rich. Johns Hopkins University Press, Baltimore, MD, 2008. 344 pp., illus. $75.00 (ISBN 9780801886799 cloth).

Timber Rattlesnakes in Vermont and New York: Biology, History, and the Fate of an Endangered Species. Jon Furman. University Press of New England, Lebanon, NH, 2008. 228 pp., illus. $24.95 (ISBN 9781584656565 paper).

Understanding Flowers and Flowering: An Integrated Approach. Beverley Glover. Oxford University Press, New York, 2007. 252 pp., illus. $65.00 (ISBN 9780198565963 paper).

Understanding New, Resurgent, and Resistant Diseases: How Man and Globalization Create and Spread Illness. Kurt Link. Praeger, Westport, CT, 2007. 200 pp., illus. $44.95 (ISBN 9780275991265 cloth).

The Welfare of Cattle. Jeffrey Rushen, Anne Marie de Passillé, Marina A. G. von Keyserlingk, and Daniel M. Weary. Springer, New York, 2008. 320 pp., illus. $169.00 (ISBN 9781402065576 cloth).

What Bugged the Dinosaurs? Insects, Disease, and Death in the Cretaceous. George Poinar Jr. and Roberta Poinar. Princeton University Press, Princeton, NJ, 2008. 296 pp., illus. $29.95 (ISBN 9780691124315 cloth).