Taking the Mystery out of Natural Resource Policy

Author: SCHAEFER, MARK

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Taking the Mystery out of Natural Resource Policy

The Policy Process: A Practical Guide for Natural Resource Professionals. Tim W. Clark. Yale University Press, New Haven, CT, 2002. 215 pp. $35.00 (ISBN 0300090110 cloth).

How is natural resource policy made? "It is a riddle wrapped in a mystery inside an enigma." Some years ago, Winston Churchill's famous quote about Russian foreign policy went through my mind as I sat in a meeting in the Old Executive Office Building listening to a heated discussion about science and policy with respect to dam operations and their impacts on salmon. After reading Tim Clark's book about the policy process, I thought back to that meeting and wondered if the course of our discussion might have changed had all the participants had an opportunity to read *The Policy Process.* The question is, as they say, academic, but I would like to believe it would have.

Tim Clark has been a keen observer of the natural resource policy process for many years. And to his credit, much of what he has seen has not been from the vantage of a desk in the rarefied atmosphere of the Yale University School of Forestry and Environmental Studies but from direct observation and participation in policy discussions throughout the country. In fact, much of his perceptive thinking about policy stems from his experiences in the Greater Yellowstone ecosystem, home of some of the most complex and challenging natural resource issues in the United States, if not the world.

Clark is to be credited for rationally explaining what often appears to be an irrational process. The book is a must-read for students, observers, and practitioners of natural resource policy. Those who make natural resource decisions, whether they represent government, nonprofit organizations, or corporations, should be required to demonstrate a working knowledge of the fundamentals described in the first two chapters of his book. Considerable time is wasted in natural resource policy discussions because of a lack of awareness of how and why human behavior and values drive these discussions. Contrary to the idealized model of science-based policymaking, the process is a messy, nonlinear undertaking often driven more by preconceptions and misconceptions than by science. Clark correctly points out that we must have a "sound understanding of how not only natural systems but also human systems function." His book reflects this critical observation.

After reviewing the fundamentals, Clark examines the elements of the decisionmaking and problem-solving processes in chapters 3, 4, and 5 and then turns in chapter 6 to a perceptive discussion of the way professionals can guide and participate in these processes. Clark states that professionals must "use knowledge and skills to aid other participants in finding common ground." They are in a position to transcend the special interests of stakeholders and therefore "explicitly establish and maintain an observational standpoint for themselves that serves the common interest." It is the responsibility of policy professionals to "formulate problems, focus inquiry...and carry out orderly problem-solving tasks." The important role of policy professionals in catalyzing the resolution of natural resource issues is increasingly recognized by natural resource decisionmakers.

That policymaking is more a social than a scientific process is perhaps the single most significant reason why scientists struggle with it. Schooled in a search for truth that begins with the formulation of a hypothesis, scientists who enter the realm of policymaking often find it to be at odds with all they have learned about the logic of problem solving. Nonetheless, there is an interesting—and necessary—alliance between the policy process and the scientific method. In chapter 6, Clark describes the connections and tensions between the positivism of science and the pragmatism of policymaking. Positivism is grounded in empirical research. The answers to a problem lie in the logical discovery of facts. Clark points out that professionals tend to draw on positivism "automatically and unconsciously," because it is the approach to problem solving taught in higher education. Yet policymaking is a pragmatic activity that focuses not only on scientific fact but also on uncertainty and ambiguity. Often there is no one solution to a problem. Typically, there are multiple viable "solutions." The policymaking process involves trying to understand the implications of taking one path versus another. It requires a willingness to learn along the way and adapt the management approach to accommodate new information. This is the basis for the concept of adaptive management that is increasingly being employed in the natural resources arena.

Clark touches on adaptive management and the ideas of C. S. Holling and others, but he does not give them the degree of attention that I believe they deserve in a book on this subject. Holling points to the value of a broad "systems view" of problems, the importance of integrated science, and the need to maintain flexibility in natural resource management, as more is learned about a system through scientific discovery. Logically, a chapter on adaptive management and its practical application could have fit well toward the end of the book. The two concluding chapters in the book, chapters 7 and 8, are dedicated to an analysis of the policy process and the range of methods that can be employed to address an issue, including the incorporation of rights, ethics, and values. These chapters will be particularly helpful to those seeking practical approaches to applying the principles described earlier in the book. A future edition could also include a discussion of the way powerful new geographic information and decision-support tools are aiding the policymaking process by making it easier to identify, organize, and make use of scientific data.

The Policy Process will be an important addition to university curricula, for it fills a clear void in the coursework of most graduate students in the sciences. It will be particularly useful to students in science, technology, and society programs, as well as to others with a broad interest in natural resource and environmental issues. As its subtitle accurately states, it is indeed a practical guide, in large part because Clark draws on his own experiences to effectively balance the discussion of theory with real-world examples of natural resource issues. He dissects the policy process into its elements and helps bring logic to what often seems obscure and confusing to the observer. Throughout the book he uses case studies effectively to drive home key points. Lively discussions about issues range from the impacts of ecotourism on mountain gorillas in Rwanda and ozone pollution in Baltimore to park planning in Canada and logging in the American West.

Even those who consider themselves experienced participants in and observers of natural resource policy will find *The Policy Process* an illuminating excursion through the complex human interactions driving the high-stake decisions that determine the quality of our natural resources—and of our own lives.

MARK SCHAEFER
President and CEO
NatureServe
1101 Wilson Blvd.
Arlington, VA 22209

ALL LIFE IS CHEMICAL

Ecological Stoichiometry: The Biology of Elements from Molecules to the Biosphere. Robert Warner Sterner and James J. Elser. Princeton University Press, Princeton, NJ, 2002. 440 pp., illus. $75.00 (ISBN 0691074909 cloth).

Ecology struggles to understand the problems of complex "middle-number" systems. In these systems, the objects of study are too numerous to be treated as individuals (individuals in a population, leaves on a tree, microbes in the soil) but not numerous enough, and existing in too many configurations, for simple statistical models to apply. As a result, much of the theory seeks to reduce the dimensionality of problems and find some axis of variation along which the system's behavior becomes predictable. This approach results in some relatively simple independent variable that is linked to response syndromes that may then be characterized and organized. Examples of this include climate and vegatation pattern (e.g., the Holdridge system, which predicts biogeographic pattern as a consequence of climate) or Rosenzweig's work linking productivity to climate. Other notable examples include succession (where the organizing variable becomes time since disturbance) and the stability–diversity hypothesis. Techniques to reduce the dimensionality of complex systems to the point where they may be understood are characteristic of disciplines studying middle-number systems. Such techniques are widely used in meteorology, fluid dynamics, organic chemistry, and other fields. The development of this type of technique in ecology has been slow, however, because there are so many axes of variation to choose among.

Or perhaps the field did not yet have a theory developed enough to suggest where to look. Sterner and Elser make a strong case that the place to begin looking is in the stoichiometry, or element ratios, of organisms and their environment. Their argument—if I may take the liberty of simplifying its dimensionality—is that organisms are composed of elements, and the ratios of those elements both determine key characteristics of the organism and define its resource requirements from its environment.

The organism-based view links to three other key points. First, evolution clearly acts to affect the element ratios of organisms—few things are more basic than composition—so the stoichiometric theory can link to the theory of evolution. Second, element ratios are a strong and strongly differentiated aspect of the environment, varying with underlying geology, atmospheric deposition, and many other factors. Third, organisms exert some control over the stoichiometry of their environment by consuming and releasing elements in ratios different from those found in their bulk environment. This fact leads to complex feedbacks between environmental and organismal stoichiometry, and, if is a mismatch, can trigger both population and evolutionary responses.

The stoichiometric approach links three aspects of ecology: evolutionary constraints, organismal characteristics, and large-scale ecosystem processes. Sterner and Elser's book is a splendid exposition of the ties among the evolutionary, organismal, and ecosystem levels of organization.

Historically, the stoichiometric approach was first elaborated in marine and aquatic ecology and is associated with the pioneering work of Alfred Redfield (although the authors point to a true origin in Liebig's law of the minimum, which links limiting resources to biological productivity). In the early 1930s, Redfield observed that the ratios of several key elements in marine phytoplankton were identical to the composition of seawater, with both seawater and phytoplankton having (classically) ratios of 1:15:105 between phosphorus, nitrogen, and organic carbon. Redfield's ratios form the basis of marine biogeochemistry, and they led to the realization that much of Earth's geochemistry is controlled by life processes. From Redfield's starting point, studies of ecological stoichiometry have gone in many directions. Sterner and Elser follow these threads in many directions and in many different ecosystems.

The structure of the book is logical, building from an initial conceptual road map chapter. This chapter lays out the foundations of the idea, building strongly on a classic exposition of the role of stoichiometry by Bill Reiners (1986) by illustrating the central role element ratios play in physiology, evolution, and global cycles. The section also introduces the role of homeostasis, as element ratios are interesting only if they are actively controlled to particular levels by homeostatic processes. This section makes the point that element ratios are so central to life and life so pervasive that it takes only a very simple structure of axioms and theorems to deduce that life must have altered the global geochemical cycles from a basic knowledge of the chemical composition of biomolecules. Following this approach, Sterner and Elser conclude that it is stunning "how few steps it takes to get from statements about cellular allocation to statements about the largest spatial and temporal scales relevant to the Earth's biota." While the balance of the book delves into more detailed and less cosmic connections, the intellectual continuity from the thermodynamics of life to the global biogeochemical cycles via the theory of evolution lies at the heart of this approach's appeal.

Following this powerful introduction with its appeal to the unity of ecology, the authors review the chemical composition of life. By reviewing the major classes of biological compounds systematically, they illustrate how both central tendencies and variability in stoichiometry originate in the chemistry of life. This pulls together a combination of very basic biochemistry found in textbooks with some fascinating tidbits. I found it particularly interesting that selection has apparently operated at the finest scales and that enzyme systems designed to capture a particular limiting element tend to have low demand for that element—e.g., the enzymes of the nitrogen fixation pathway are low in nitrogen-rich protein.

The next section, a synthesis of the role of element ratios in regulating autotrophic growth, succeeds in unifying concepts from marine, aquatic, and terrestrial ecology. To my mind, this is the deepest and most authoritative chapter in the book; it should be required reading for all ecologists. The vehicle the authors use is a tour de force. They show the essential similarities between growth of phytoplankton and growth of higher plants by demonstrating the equivalence of the Droop (phytoplankton) and Ågren (land plants) models for growth as a function of nutrient availability.

The authors take an unadvertised second major step in this chapter. By linking nutrients and light, they also illustrate that the stoichiometric theory is complementary to ecological energetics, a theme they expand on in subsequent chapters. The next few chapters deal with the stoichiometry of animals and explore how the stoichiometry of specific organisms affects communities and ecosystems. These chapters are fascinating, and they begin to build the paradigm toward larger scales. They are predominantly concerned with aquatic and marine examples.

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The chapter on the "stoichiometry of consumer-driven nutrient recycling" misses the terrestrial literature associated with McNaughton, Detling, Hobbs, Holland, and Chapin and colleagues on the role of terrestrial herbivores in nutrient recycling almost entirely, providing an opportunity for an enterprising synthesizer to apply Sterner and Elser's ideas in the context of macroscopic animals. Chapters 4, 5, and 6 are largely reviews and lay the groundwork for another breakaway synthesis in chapter 7.

The authors build a predictive basis for modeling species interactions derived from stoichiometric theory. They advance into this area with examples of competition, predation, and mutualism drawn from terrestrial and aquatic settings and then tackle a more general problem. They place the problem of predicting species interaction squarely in the context of complexity theory, showing how multiple stable states, nonlinear transitions, and chaotic behavior can be predicted from simple stoichiometric rules. They also use a sophisticated idea of prediction, clearly arguing that in complex systems, prediction means more than a set of rules for deriving the state of the system at time t from its state at time t–1. Rather, they argue that the first step in prediction is to establish the *types* of behavior that should be expected (thresholds, alternate equilibria, etc.) from the underlying description of the system. This chapter should elevate the discussion of prediction in ecology and lies in a direct line of descent from Robert May's seminal monograph on stability and complexity in model ecosystems (2001).

Chapter 8 returns to the ecosystem level. The return is needed because, the authors note, many of the seminal studies of stoichiometry were done at the ecosystem level. This chapter recaps some exemplary issues at a wide range of time and space scales, from stand-level ecosystem processes to global change. Although this chapter samples only a tiny subset of possible work, it does provide a provocative taxonomy of stoichiometric situations in terms of their dynamical systems properties. This chapter is less an attempt at synthesis and theory than the structurally similar chapters 3 and 7; it is more an opening to the outstanding questions of today's research.

The global change section was painfully brief for me, as this is my own area of research. The insightful way the authors framed the problems left me wanting to take their text to my own computer and expand it to monograph length, preserving the structure of their argument but filling in the details and ideas from the rapidly expanding literature in this area. I think many readers will have this same urge—to take Sterner and Elser's structure and starting point and then expand their own areas of interest within the paradigm to see how they fit. I think often the fit will be good, and the inevitable instances of lack of fit will lead to further insight.

So who should read this book? This is one of those books that should be well thumbed and on the shelf of every ecologist. It has something to offer to evolutionary, physiological, behavioral, ecosystem, or global ecologists. In its broad perspective, it will inform any reader. The authors are both aquatic ecologists, and the book's depth (sorry) is greater in aquatic coverage than in terrestrial material. The review of issues for "wet" systems is very nearly comprehensive—as might be expected given the role these two authors have played in the field—and the terrestrial material is exemplary. Despite the relative underemphasis on terrestrial systems, any ecologist will find the discussions of terrestrial stoichiometry stimulating and provocative; these discussions may well inspire new investigations.

The approach of building explanation at multiple levels of organization and of building from one level to the next should be inspiring to those tired of debates about reductionism versus holism. The authors move with complete facility from biochemical and evolutionary mechanism to emergent properties of complex dynamical systems. Insights from dynamical systems thinking are sprinkled through the stoichiometric and biogeochemical literature, but Sterner and Elser place those insights at the center of the story, and they show how simple axioms about the composition of biomolecules imply complex systems-level behavior. Buy this book!

DAVID S. SCHIMEL
National Center for Atmospheric Research
Boulder, CO 80305

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EXPLORING EVOLUTION, ECOLOGY, BREEDING, BIOINFORMATICS, AND BIOPRESERVATION

Life at the Limits: Organisms in Extreme Environments. David A. Wharton. Cambridge University Press, Cambridge, United Kingdom. 2002. 320 pp., illus. $25.00 (ISBN 0521782120 cloth).

Life at the Limits was a refreshing reminder of why I became involved in biology research. This 320-page book (with 53 illustrations and four tables) describes organisms found living under extreme environmental conditions and—weaving through themes of the nature of life and its ecology, evolution, and origin—discusses the possibility of extraterrestrial life. These are not esoteric questions; studies of life under extreme conditions brought us creamier ice cream, laundry detergent that works in cold water, and other practical innovations. The author of this imaginative and up-to-date survey is David A. Wharton, an associate professor of the Zoology Department at the University of Otago, New Zealand.

The premise of the book is that all living things, no matter how exotic, have the same basic rules, goals, and equipment, but some organisms have specific strategies to cope with severe environmental stresses. These stresses range from extremes in temperature and water availability and pressure to radiation and toxic chemicals. Not surprisingly, Wharton proclaims that the availability of water, specifically liquid water, is key. Research in a number of laboratories, including mine, suggests that the profound requirement for liquid water is based on the fluidity that it provides. If this is true, then even the single requirement for liquid water could be replaced in other worlds by a chemical that provides the proper capacity for molecular movement under strange (at least to us) conditions of temperature, pressure, and composition.

The book would be a good read for anyone interested in biology, but particularly for those wishing to explore evolution, ecology, breeding, bioinformatics, and biopreservation in a broad or unusual context. Biology teachers could use examples from the text to make class more interesting or to demonstrate a fundamental principle. Strategies to cope with extreme environments might also provide perspectives on gene mining (e.g., the Taq polymerase isolated from organisms in hot springs, which profoundly changed biological research), engineering (e.g., lessons from ants on how to build homes that don't cook in the sun), antibioterrorism (e.g., understanding the weaknesses of tough organisms to help defend against them), and exploration (e.g., what to take to remote places and what to expect). Students of the history of science will find the account of the century-long debate on anhydrobiosis (life without water), from the 1750s to the 1850s, an example of the inextricable link between humans and the science that they do. Although a biology background is not necessary to get the gist of the book, some scientific knowledge would be helpful, since the text can be technical in places. Even so, I would not recommend this book as a reference source or textbook, because it does not directly cite sources, and in some cases it provides only a single perspective on questions that are still being debated in the literature.

Wharton makes an insightful effort to define the terms *extreme* and *normal* and to specify what might be considered stressful. Though he tries to be objective by using the "Life Box" concept, which specifies conditions where most species may be expected to exist, it is clearly a struggle for him to avoid anthropocentricity, and he admits near the end of the book that biases may be inevitable. These potential biases are reflected mostly in the choice of environments that are considered extreme; Wharton proposes that extremity is relative, especially in time, space, and creature. He explains that extreme environments may have been the normal condition of early Earth and that extreme organisms may actually be the vestiges of original populations. The possibility that life evolved from what are now considered extreme environments fuels arguments about whether survival strategies are conserved traits or adaptations.

As a stress physiologist, I thought Wharton's discussion of adaptations (or traits) that enable organisms to survive stressful conditions to be further complicated, because he defines these adaptations or traits in an ecological context in which functional differences among strategies are intermingled. He distinguishes between capacity adaptations, which allow organisms to function (i.e., metabolize, grow, reproduce) under harsh conditions, and resistance adaptations, which enable the organism to avoid the harsh conditions—either by changing the environment, by moving away from it, or by going quiescent and waiting for a rainy day (so to speak). In my field, by contrast, organisms that survive stress, either by remaining active or by shutting off metabolism, are considered tolerant of it. The definition of avoidance strategies, and hence the distinction between capacity adaptations and resistance adaptations, is fraught with ambiguity. Avoiding stress by moving or modifying, for example, requires different structures than does surviving the implicit physical disruptions. To complicate matters further, avoidance can also be a capacity adaptation, as is demonstrated by thermal hysteresis proteins, which provide a mechanism to avoid ice growth in cells (the stress) and which also allow polar fishes to swim at subfreezing temperatures without freezing. These functional distinctions are important to humans who wish to make use of the exceptional qualities of extreme organisms.

The issues of time and isolation, which are scattered throughout the text, are not conclusively reconciled. Wharton suggests that the lichens on his slate roof may be several hundred years old. However, it is difficult to tell the actual age of the organisms. Perhaps there are sufficient capacity adaptations for reproduction, and so, while the population has persisted, the organisms are chronologically young. These questions can be posed for many organisms that are believed to be ancient. Thus, we continually return to the ideas of capacity adaptation versus quiescence, and in this context the nature of metabolism must be sorted out. Minor conditions of radiation, isolation, time, and even fire may actually be the true determinants of organisms' ability to colonize and thrive in new places previously devoid of life.

The book may be most enjoyable when read out of sequence, with chapters 1 and 2 covered first, followed by chapters 7 and 8, and finally chapters 3 through 6. This way, the reader would first be exposed to broad concepts of extremity and places on Earth considered to be extreme and then receive a good overview of general strategies for survival and their prevalence among diverse organisms and stresses. Knowing why "extreme biology" is important (chapter 8) provides a good entry into the middle chapters, which give specific details about organism morphology and behaviors that enable organisms to cope. The style of the middle chapters is a departure from the evolutionary or ecological context used in earlier and later chapters. In these middle chapters, discussions about eukaryotes focus mostly on the animal kingdom, and readers with botanical interests may be disappointed by the brief and very general coverage of the remarkable adaptations of plants that endure extreme conditions.

Life at the Limits provides a fascinating account of life, how precarious it is, and also how resilient. Many of the places the author describes are threatened ("the Dead Sea is dying"). Many of the organisms described are at the limit of their tolerance and will perish if the weather gets colder or dry spells become longer. Many other organisms are tough and opportunistic; these may provide benefits to the human community, such as cleaning up toxic wastes, or may become invasive pests. Organisms living at the limits of survivable space and time tell us about how Earth is and was; they also tell us about the possibilities of life outside Earth's atmosphere. Finally, depending on how we care for this planet, these unique organisms may be the harbingers of future Earth.

CHRISTINA WALTERS
Research Leader
Plant Germplasm
Preservation Research
USDA-ARS National Center
for Genetic Resources Preservation
Fort Collins, CO 80521