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TThe Nonequilibrium Paradigm in Ecology and the Partial Unraveling of Environmental Law

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THE NONEQUILIBRIUM PARADIGM IN ECOLOGY AND THE PARTIAL UNRAVELING OF ENVIRONMENTAL LAW

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I. INTRODUCTION: THE FRAGILITY OF MODERN ENVIRONMENTAL LAW

A. The Power of the Equilibrium Paradigm in Ecology

Environmental law derives its political power and legitimacy from science.[1] Ecology and toxicology have identified a wide range of harms

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This Essay reflects two related, long-term interdisciplinary activities in which I have been fortunate to participate. Since 1972 I have served on several National Academy of Sciences (NAS)—National Research Council (NRC) committees and boards dealing with the applications of physical and social science information to environmental regulation. The views expressed in this Essay are entirely my own, but I am grateful to the many scientists and NAS-NRC staff who have educated me in the practice and potential of science. In addition, since 1991 I have assisted my colleague Fred Bosselman, who has been a consultant to the California Resources Agency, to develop a habitat conservation planning process to address endangered species issues in Southern California within the broader framework of biodiversity protection. This experience has provided me with an ongoing education in conservation biology. The same disclaimer applies, but I am ever grateful to Fred for his willingness to share his wisdom and knowledge about environmental and land-use issues with me.

An earlier version of this Essay was given at a workshop at Indiana University, Bloomington on November 19, 1993. I would like to thank Professor Robert Fischman for organizing the workshop and for his many critical and helpful comments, many of which I do not answer to his satisfaction in this Essay. I would also like to thank my former colleagues from Indiana University, Bloomington, especially Lynton K. Caldwell, Department of Political Science, and Professor Daniel E. Willard, School of Environmental and Public Affairs, for sharing their experience and insights with me at the workshop.

1. This is a deliberately provocative statement. It rejects the argument that environmental law is—or should be—grounded in nonanthropocentric "rights of nature." *See* RODERICK NASH, THE RIGHTS OF NATURE: A HISTORY OF ENVIRONMENTAL ETHICS (1989). It also rejects the idea that the extremely difficult scientific problems that permeate environmental law can be avoided *simply* by recasting them as ethical. *See* Donald A. Brown, *After the Earth Summit: The Need to Integrate Environmental Ethics into Environmental Science and Law*, 2 DICK. J. ENVTL. L. & POL'Y 1, 17 (1992). Of course, there is no constitutional requirement that environmental regulation be based on scientific understanding, and there are nonscientific justifications for environmental regulation. However, science has driven the environmental movement by identifying problems and solutions and by establishing the legitimacy of intensive regulation of human activity. It will continue to do so for the future. *See* Alfred C.

potentially caused by human activities—such as waste discharges, energy production, and land use and development—but science has also provided strategies to remedy these harms. Driven by these two sciences, environmental law is now subdividing into two broad fields: pollution risk remediation and biodiversity protection.[2] This Essay focuses on the relationship between the nonequilibrium paradigm, which dominates ecology, and the accepted scientific rationales for legal strategies, which prevent or mitigate human disturbance of land and water ecosystems to protect and promote biodiversity.

Ecology provides a justification for a wide range of prohibitions on human activities that alter "natural" land and water systems and, along with toxicology, form much of current pollution control regulation. Legislators, regulators, resource managers, and lawyers have derived a powerful and general lesson from ecology: Let nature be. The ur-text is Aldo Leopold's summary of his ecologically based land ethic: "A thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community. It is wrong when it tends otherwise."[3] This land ethic has gradually replaced the progressive conservation movement's ethic of multiple use as the dominant natural resource management strategy,[4] although there are intense pockets of resistance, especially in the western United States.

The underlying ecological justification for the land ethic is the equilibrium paradigm or, as it is crudely and popularly called, the balance of nature. Legislatures and lawyers enthusiastically embraced this paradigm because it seemed to be a neutral universal organizing principle potentially applicable to the use and management of all natural resources. Modern environmental law's contributions to the legal system, which are based on this paradigm, include the National Environmental Policy Act of 1969 (NEPA),[5] the Endangered Species Act of 1973 (ESA),[6] the Wilderness Act of 1964,[7] and parts of the Clean Water Act,[8]

Aman, Jr., *The Earth as Eggshell Victim: A Global Perspective on Domestic Regulation*, 102 YALE L.J. 2107, 2114-22 (1993). For a further discussion of the relationship between science and ethics, see *infra* notes 64-66 and accompanying text.

2. Donald T. Hornstein, *Lessons from Federal Pesticide Regulation on the Paradigms and Politics of Environmental Law Reform*, 10 YALE J. ON REG. 369, 380-83 (1993).

3. ALDO LEOPOLD, A SAND COUNTY ALMANAC 224-25 (1949).

4. For a good case study of this evolution, see DAVID LEWIS FELDMAN, WATER RESOURCES MANAGEMENT: IN SEARCH OF AN ENVIRONMENTAL ETHIC (1991).

5. 42 U.S.C.A. §§ 4321-4370d (West 1985 & Supp. 1993).

6. 16 U.S.C. §§ 1531-1544 (1988 & Supp. IV 1992).

7. 16 U.S.C. §§ 1131-1136 (1988 & Supp. IV 1992).

8. Pub. L. No. 95-217, 91 Stat. 1566 (1977) (codified as amended at 33 U.S.C.A. §§ 1251-1387 (West 1986 & Supp. 1993)).

such as section 404. Twenty-five years after this paradigm was incorporated into law, it—and thus the basis for the core of biodiversity protection law—is now unraveling. In the twenty-five years since it has been enshrined in environmental law, the equilibrium paradigm has been rejected in ecology and replaced with a complex, stochastic nonequilibrium one.[9]

Environmental law is just beginning to address this paradigm shift. The implications are profound and potentially impact environmental law on many levels from the basic question of its legitimacy to the modification of existing biodiversity protection strategies and the application of basic legal doctrines to biodiversity management. Part I of this Essay argues that the scientific implications of the paradigm shift are crucial to the continued legitimacy of environmental law. Science, not ethics, is the ultimate source of environmental law's legitimacy given its continuing contingent state and the need to harmonize its objectives with the individualistic Western legal tradition that promoted radically different values from those of environmentalism.[10] Part II traces the principal scientific ideas behind the equilibrium and nonequilibrium paradigms, and examines the implications of this shift for environmental science and the relationship between the legal system's demands for useable regulatory science and the production of science under the current culture. Part III applies the paradigm shift to one of the central principles of fairness embedded in our legal system—the finality of resource allocation and management decisions—to illustrate the tension between the new paradigm and existing environmental management strategies.

B. *A Short History of Environmentalism and Environmental Law*

The importance of the paradigm shift for the future of environmental law must be examined in the context of the history of environmentalism. Perhaps the most interesting of the many paradoxes of environmental law is its ability to sustain itself in the face of a contingent legitimacy.[11] Environmental law and environmentalism celebrated their twenty-fifth anniversary in 1993. The central story is the staying power

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9. *See, e.g.*, Judy L. Meyer, *Changing Concepts of System Management*, *in* WATER SCIENCE & TECHNOLOGY BD., NATIONAL RESEARCH COUNCIL, SUSTAINING OUR WATER RESOURCES 78 (1993).

10. The tension between private property and environmentalism is explored in Joseph L. Sax, *Property Rights and the Economy of Nature: Understanding* Lucas v. South Carolina Coastal Council, 45 STAN. L. REV. 1433 (1993).

11. I have explored this theme at greater length in A. Dan Tarlock, *Environmental Law, but Not Environmental Protection*, *in* NATURAL RESOURCES POLICY AND LAW: TRENDS AND DIRECTIONS 162 (Lawrence J. MacDonnell & Sarah F. Bates eds., 1993). For further

and political appeal of a hastily assembled movement built on half-articulated and contradictory scientific and ethical principles. A quarter century after environmentalism burst onto the national political agenda in the wake of the fading anti-Vietnam War movement, the idea that government should play a strong role in preventing and remedying environmental degradation enjoys widespread, if regionally uneven, political support. However, the "sustainability" of the movement remains in doubt. The core message of environmentalism is that there are limits to human use and abuse of resources. However, this idea has not yet been systematically adopted as a societal organizing principle, in substantial part because the scientific predictions of serious harm have been harder to prove than originally anticipated.

The Reagan Administration's efforts to balance the costs of environmental regulation against the benefits in the name of efficiency largely failed. Despite its political success, however, both the legitimacy of environmental protection and the means chosen to achieve it remain the subject of intense debate. Much of environmental law is either trivial or ephemeral and therefore is vulnerable to being uprooted and eroded by political pressures. This statement may seem inconsistent when compared to the high level of political support environmentalism enjoys. However, this statement is consistent with recent public opinion polls showing high general levels of support for environmental protection but more mixed responses when cost and other economic considerations are factored into the questions.[12]

The uneasiness with current environmental law is widespread both with those opposed and committed to the basic idea of environmental protection, although the dissatisfactions are, of course, different. Many environmentalists argue that the inadequate level of environmental protection is a function of inadequate enforcement incentives in dense congressional programs.[13] Opponents of environmental regulation generally argue that much environmental protection cannot be justified in cost-benefit terms or more fundamentally, continue to adhere to the classic Western credo that the earth is ours to exploit.[14] However, I think that

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discussion, see WALTER A. ROSENBAUM, ENVIRONMENTAL POLITICS AND POLICY 1-31 (2d ed. 1991).

12. A telling example is the increasing resistance to continued improvements in air quality in Southern California. *See* Robert Reinhold, *Hard Times Dilute Enthusiasm for Clean-Air Laws*, N.Y. TIMES, Nov. 26, 1993, at A1.

13. *See, e.g.*, Howard Latin, *Regulatory Failure, Administrative Incentives, and the New Clean Air Act*, 21 ENVTL. L. 1647 (1991).

14. For a recent exposition of these objections, see George Resiman, *The Toxicity of Environmentalism*, FREEMAN, Sept. 1992, at 336.

the reasons lie in the nature of environmentalism itself. In my judgment, the deeper problem with modern environmentalism, and thus environmental law, lies in the ease with which environmentalism achieved its current success. The rapid growth of environmental law created the illusion that society was in fact responding to real environmental protection needs and failed to lay a sufficient foundation for future challenges. The rapid and, in retrospect, premature embrace of the predictive power of ecology played a substantial role in this process.

II. Ecology as Interpreted by Lawyers

A. *Equilibrium Theory Circa 1969*

Environmental law took its basic principles from three disciplines: economics, engineering, and ecology. Each has made important and related contributions, but ecology remains the foundation of environmental law because it informed society about the adverse consequences of a wide range of human activity. Welfare economics's theory of externalities provided an explanation of environmental costs, such as pollution, and a justification for government intervention to limit emissions and other human activity. Engineering contributed the idea of technology-forcing performance standards to mandate pollution reduction levels. Each theory significantly contributed to environmentalism but ecology is *primes internus*. It provided the basic rationale for all environmental protection: Leave nature alone. Later, philosophers purported to raise a complex and controversial scientific theory to a Kantian and non-homocentric ethic.[15] However, this effort has at best only reinforced science's claim that there are important utilitarian reasons to worry about the magnitude of human-caused ecosystem disturbance and to limit harmful activities to keep these systems "productive."

In the late 1960s the perceived teachings of ecology were incorporated into environmental law and management.[16] The adoption of ecology as the defining norm of environmentalism and environmental law bears close examination because of dramatic changes in ecology since then. The application of science to natural resource management has a

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15. *See, e.g.*, J. Baird Callicott, In Defense of the Land Ethic (1989).

16. Frank B. Golley, A History of the Ecosystem in Ecology: More Than the Sum of Its Parts 3 (1993). Professor Golley argues that the environmental movement seized on the concept of an ecosystem because it provided both a rational explanation of nature and moral management imperatives and ecologists papered over known problems of theory and method as they "passively accepted the buzzing activity." *Id.*

long and troubled history in this country.[17] In 1968, however, ecology offered the hope of coherent and rational resource management that had eluded society in the past. Three individuals—a wildlife manager, Aldo Leopold; the leading ecologist of the post-World War II generation, Eugene Odum; and a political scientist, Lynton K. Caldwell—played leading roles in the popularization of ecological ideas. Professor Caldwell's creative contribution, NEPA, is the most enduring legal application of ecology.[18] NEPA was the first piece of federal legislation to raise ecology to star status. It introduced the concept of environmental assessment, which along with risk assessment, remains one of the few innovative operational ideas of environmental law.

In the late 1960s ecology was an underfunded, low-status science, but one with great appeal to policy makers. The most attractive idea was the theory of general equilibrium at both the population and ecosystem level.[19] The ecologist Tansley had crystallized the concept of "relatively stable dynamic equilibrium" in 1935,[20] and Aldo Leopold had popularized it in his posthumous *A Sand County Almanac*.[21] In turn, these ideas drew on the image of a balanced nature, which was central to both the Christian and Enlightenment world views.[22] For example, the idea of the balance of nature radically disturbed by human intervention was the message of Rachel Carson's indictment of chemical pesticides, *Silent Spring*,[23] perhaps the book most responsible for the environmental movement.[24] For the nonscientist seeking wisdom in the late 1960s, ecologist

17. *See* WILLIAM L. GRAF, WILDERNESS PRESERVATION AND THE SAGEBRUSH REBELLIONS (1990).

18. *See* ROBERT V. PERCIVAL ET AL., ENVIRONMENTAL REGULATION: LAW, SCIENCE, AND POLICY 1082-83 (1992).

19. In an interesting paper, the late Kenneth Boulding identified the concept of a general equilibrium as one of the five similarities between ecology and economics. *See* Kenneth E. Boulding, *Economics and Ecology*, *in* FUTURE ENVIRONMENTS OF NORTH AMERICA 225, 226-27 (F. Fraser Darling & John P. Milton eds., 1966).

20. A.G. Tansley, *The Use and Abuse of Vegetational Concepts and Terms*, 16 ECOLOGY 284 (1935).

21. LEOPOLD, *supra* note 3.

22. *See* DANIEL B. BOTKIN, DISCORDANT HARMONIES: A NEW ECOLOGY FOR THE TWENTY-FIRST CENTURY (1990). The late Charles J. Meyers traced the influence of this idea on environmental law in his 1974 Addison C. Harris lectures at Indiana University, Bloomington. Charles J. Meyers, *An Introduction to Environmental Thought: Some Sources and Some Criticisms*, 50 IND. L.J. 426 (1975).

23. RACHEL L. CARSON, SILENT SPRING (1962). Most pertinent to this point is chapter 6, "Earth's Green Mantle."

24. In his expansion of his path-breaking contribution to the environmental movement, *A Quiet Crisis*, former Secretary of the Interior Stewart Udall writes that Carson's book "was a masterstroke . . . . It shifted the debate over pesticides into a context where ecological, not economic, values would predominate." STEWART L. UDALL, THE QUIET CRISIS AND THE

Eugene Odum's widely used textbook *Fundamentals of Ecology* provided the most authoritative scientific statement of equilibrium:

> Homeostasis at the organism level is a well known concept in physiology . . . . We find that equilibrium between organisms and environment may also be maintained by factors which resist change in the system as a whole. Much has been written about this "balance of nature" but only with the recent development of good methods for measuring rates of function of whole systems has a beginning been made in the understanding of the mechanisms involved.[25]

In retrospect it is clear that ecology was not ready for its starring role. Odum's theory of ecosystem equilibrium is one of the last gasps of nineteenth-century deterministic science. The theory is a sophisticated and subtle extension of leading twentieth-century ecologist Clements's theory of plant communities as being stable superorganisms because they progress through a series of successional stages leading to a superorganistic permanent climax.[26] In elite science, deterministic theories had already been replaced by probabilistic ones, but the shift came late to biology and even later to ecology.[27] Ecologists reported varying levels of indeterminate results testing the paradigm, but many scientists glossed them over because of an extreme case of "physics-envy."[28] The point for lawyers is that this internal debate was missed in the rush to implement

NEXT GENERATION 200 (1988). For a more detailed review of Carson's contribution to the environmental movement, which reaches the same conclusion, see Linda J. Lear, *Rachel Carson's Silent Spring*, 17 ENVTL. HIST. REV. 23 (1993) (book review).

25. EUGENE P. ODUM, FUNDAMENTALS OF ECOLOGY 25 (2d ed. 1959) (citation omitted).

26. *See* Edward Goldsmith, *Ecological Succession Rehabilitated*, 15 ECOLOGIST 104, 108-09 (1985). The most readable history of modern ecology is DONALD WORSTER, NATURE'S ECONOMY (1977). FRANK B. GOLLEY, A HISTORY OF THE ECOSYSTEM IN ECOLOGY, *supra* note 16, provides an elegant technical history of the science. My colleague Fred Bosselman and I will trace the evolution of ecology's influence on law from Clements to Botkin in a forthcoming article in a symposium on the new ecology to be published in the *Chicago-Kent Law Review*.

27. This shift of ecology from deterministic to probabilistic theories is traced in a pathbreaking paper, Daniel Simberloff, *A Succession of Paradigms in Ecology: Essentialism to Materialism and Probabilism*, *in* CONCEPTUAL ISSUES IN ECOLOGY 63 (Esa Saarinen ed., 1982).

28. J.E. Cohen, *Mathematics as Metaphor*, 172 SCI. 674 (1971). Mark Sagoff, *Ethics, Ecology, and the Environment: Integrating Science and Law*, 56 TENN. L. REV. 77 (1988), is an exhaustive and insightful analysis of the tension between the culture of theoretical science, which seeks universal physical explanations, and that of applied or normative science, which seeks to apply science to a specific objective.

Leopold's dictum to "think like a mountain" in the heady days of the rise of environmentalism.[29]

Ecologists made it easy to ignore the debate, especially in the 1960s when ecology aspired to a be a big, mathematically based science like physics or molecular biology.[30] The profession enthusiastically suggested the regulatory implications of ecology, which represented its ability to deliver the requisite science to balance nature. In a unique Joint House-Senate Colloquium, which laid the foundation for NEPA, the Public Affairs Committee of the Ecological Society of America prophesied that "ecology is ready for rapid growth and development."[31] Moreover, the Committee was not shy about the social utility of the science, noting that "[w]hen a theory of ecosystem emerges, it will be one of the major synthesizing ideas in science, perhaps rivaled only by the theory of evolution through natural selection."[32] Ecology's promise was embraced by Lynton K. Caldwell, a professor of public administration at Indiana University, Bloomington, who became the principal drafter of NEPA. In an influential article published in 1966, Caldwell suggested that qualitative environmental standards could provide the administrative coherence historically lacking in natural resources policy.[33]

B. The Nonequilibrium Paradigm Arrives

Since its incorporation into environmental law and policy, the equilibrium paradigm has undergone a Kuhnian revolution.[34] The equilibrium paradigm was flawed from the start, but until recently many scientists and policy makers believed the problem was the lack of necessary data rather than the paradigm itself. The alternative paradigm was

29. Professor Eric T. Freyfogle of the University of Illinois, Champaign-Urbana, has emerged as one of the most passionate champions of Leopold. *See* Eric T. Freyfogle, *The Land Ethic and Pilgrim Leopold*, 61 U. COLO. L. REV. 217 (1990).

30. One of the manifestations of this ambition was the unfortunate separation of ecology during the 1930s into two camps, the theoretical modelers and the experimental or field researchers. This split is traced in Peter Kareiva, *Renewing the Dialogue between Theory and Experiments in Population Ecology*, *in* PERSPECTIVES IN ECOLOGICAL THEORY 68 (Jonathan Roughgarden et al. eds., 1989).

31. *Joint House Senate Colloquium to Discuss a National Policy for the Environment, Hearing Before the Comm. on Interior and Insular Affairs United States Senate and the Comm. on Science and Astronautics U.S. House of Representatives*, 90th Cong., 2d Sess. 154 (1968).

32. *Id.* at 157.

33. *E.g.*, Lynton K. Caldwell, *Administrative Possibilities for Environmental Control*, *in* FUTURE ENVIRONMENTS OF NORTH AMERICA 648 (F. Fraser Darling & John P. Milton eds., 1966). Professor Caldwell applied his theory to provide the "action-forcing" provisions of NEPA. FREDERICK R. ANDERSON, NEPA IN THE COURTS: A LEGAL ANALYSIS OF THE NATIONAL ENVIRONMENTAL POLICY ACT 6 (1973).

34. *See* THOMAS S. KUHN, THE STRUCTURE OF SCIENTIFIC REVOLUTIONS (1962).

neither clearly articulated nor widely accepted until the 1980s. It has, however, with pockets of resistance, been replaced with the more hard-edged probabilistic theories of nonequilibrium. These theories undermine much of the law's approach to resources management, or in modern terms, biodiversity preservation strategies of classic environmental law. Nonequilibrium ecology rejects the vision of a balance of nature. Further, it rejects the romantic idea that nature should be a place without humans, and returns to the problem posed in Genesis: How should one manage the Garden of Eden after it has been invaded by humans?

In a path-breaking book, Daniel Botkin has "deconstructed" the equilibrium paradigm as a misguided effort to match science to theological and scientific visions of a perfect universe.[35] His basic argument is that the images of nature that have influenced ecology are static when, in fact, the kinds of problems we face require a dynamic view of nature. This view starts from the premises that human action is one of the principal forces operating on ecosystems and that system disturbances are both predictable and random. Ecosystems are patches or collections of conditions that exist for finite periods of time.[36] Further, the accelerating interaction between humans and the natural environment makes it impossible to return to an ideal state of nature.[37] At best, ecosystems can be managed, but not restored or preserved. Management will be a series of calculated risky experiments: "[N]ature moves and changes and involves risks and uncertainties and . . . our own judgments of our actions must be made against this moving target."[38]

Most ecologists now reject any idea of a *balance* of nature, and the nonequilibrium paradigm is now the organizing principle of modern ecology. As one ecologist recently commented, "[t]he idea [of a balance of nature] makes good poetry but bad science."[39] The best evidence of this paradigm shift is a short but extremely influential list of twenty great ecological ideas for the 1990s published by Eugene P. Odum,[40] the distin-

35. BOTKIN, *supra* note 22. Interestingly, the book apparently attracted little attention in the scientific journals when it was first published with the exception of a laudatory review by a physicist. *See* James Trefil, *Discordant Harmonies: A New Ecology for the Twenty-First Century*, 41 BIOSCIENCE 176 (1992) (book review).

36. D.L. Urban et al., *Landscape Ecology*, 37 BIOSCIENCE 119 (1987).

37. The philosophical basis for the new ecology can be found in Bill McKibben's widely read book, which argues the modern mind separates humanity from nature and thus the romantic visions of harmony between humanity and nature are impossible. BILL MCKIBBEN, THE END OF NATURE (1989).

38. *Id.* at 190.

39. Wallace Kaufman, *How Nature Really Works*, AM. FORESTS, Mar.-Apr. 1993, at 17, 18.

40. Eugene P. Odum, *Great Ideas for Ecology for the 1990s*, 42 BIOSCIENCE 542 (1992).

guished ecologist who is most responsible for implanting in the minds of lawyers and policy makers the idea that natural systems tended toward equilibrium if left undisturbed. The first and over-arching great idea states that "an ecosystem is a thermodynamically open, far from equilibrium system."[41] The other ideas are either a specific application of the nonequilibrium principle or policy prescriptions to implement good management, commentary as it were on the first principle.

The nonequilibrium paradigm does not undermine the case for biodiversity protection because it accepts the principal lesson of ecology: Unregulated, humans harm ecosystems and the magnitude of human intervention is often too great. In many instances, it strengthens the scientific case for ecosystem management, while exacerbating the politics of that management. The scale of management is larger and the emphasis is on the maintenance of processes that produced undisturbed systems.[42] This new paradigm can also serve as the basis for the argument that since nature is in flux, human change is just another "flux" to be tolerated. However, ecologists reject this argument because it undermines the functional, historical, and evolutionary limits of nature.[43]

C. The Science of the Nonequilibrium Paradigm

Adherents to the nonequilibrium paradigm have pioneered a sophisticated new applied science, conservation biology, to protect ecosystems from human insults.[44] To date the science has been stimulated by the need to match protected natural habitats with the survival of listed endangered and threatened species. Conservation biology is a regulatory science that seeks to develop scientific standards that can be applied to regulatory criteria and then to develop the management strategies to meet those standards. For example, endangered species protection first requires the determination of an "effective population size" for species viability. After this is calculated, a habitat reserve system must be designed, taking into account existing land use patterns and land uses

41. *Id.* Ironically, Odum cites the third edition of his classic text, EUGENE P. ODUM, BASIC ECOLOGY (3d ed. 1971).

42. For example, one of the major potential lessons of landscape ecology is that states of equilibrium or "an equilibrium mosaic" may be reached on a large scale. R.V. O'Neill et al., *Ecological Systems, in* PERSPECTIVES IN ECOLOGICAL THEORY, *supra* note 30, at 140, 141. The efforts to create a greater Yellowstone ecosystem illustrate the problems of large-scale management across multiple property and public land classification boundaries.

43. Stewart W. Pickett et al., *The New Paradigm in Ecology: Implications for Conservation Biology above the Species Level, in* CONSERVATION BIOLOGY: THE THEORY AND PRACTICE OF NATURE CONSERVATION PRESERVATION AND MANAGEMENT 65 (1992).

44. The leading text is CONSERVATION BIOLOGY: AN EVOLUTIONARY-ECOLOGICAL PERSPECTIVE (M.E. Soule & B.A. Wilcox eds., 1980) [hereinafter CONSERVATION BIOLOGY].

that will preserve the species. Existing laws and the politics of endangered species protection require only that *minimum* necessary habitats be preserved. Not surprisingly, conservation biology is concerned with the relationship between species extinction and habitat fragmentation.[45] The basic objective, as discussed in Part III, is to manage nature to mimic natural systems.[46]

D. Research Priorities

Nonequilibrium ecology increases the pressure of science to produce socially useful research. Successful conservation biology requires the increased production of regulatory science. In brief, regulatory science is scientific research directed to provide useful information for regulators rather than to pursue knowledge for its own sake. The United States Department of Interior's new National Biology Survey illustrates the focused and law-driven nature of regulatory science: "One of the most important uses of the scientific information gathered by the National Partnership [for Biological Survey] will be to assist decision makers in addressing existing biological resource issues and anticipating future ones."[47]

Regulatory science cuts deeply into the culture of science, which promotes independence, disciplinary elegance, and resistance to legal and political control, because it requires that science be useful and accountable. The problem is especially acute for ecology for two reasons. First, ecology has never been a high priority science within the government because it does not directly serve military or foreign policy, including trade objectives.[48] Thus, it is still trying to establish itself as an elite science. There are, however, indications that the government is coming to recognize the need to support more research in this area. The establishment of the National Biological Survey in the Department of Interior to complement the United States Geological Survey is a hopeful sign. Second, much useful ecology is sophisticated, applied, interdisciplinary science. This creates a problem that is much more difficult to address because both the politics of governmental support for environmental science and the culture of disciplinary-rooted science must be changed.

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45. For a good, short review of the early literature, see Bruce A. Wilcox & Dennis D. Murphy, *Conservation Strategy: The Effects of Fragmentation on Extinction*, 125 AM. NATURALIST 879 (1985).

46. *See generally* CONSERVATION BIOLOGY, *supra* note 44.

47. COMMITTEE ON THE FORMATION OF A NAT'L BIOLOGICAL SURVEY, NATIONAL RESEARCH COUNCIL, A BIOLOGICAL SURVEY FOR THE NATION 59 (1993).

48. DAVID DICKSON, THE NEW POLITICS OF SCIENCE (1984).

The political problems are in part a reflection of scientists' resistance to regulatory science. Because regulatory science is applied science, it will be resisted by many elite scientists because it interferes with the traditional research agendas of theoretical scientists. It also differs from previous models of applied science. Often environmental regulations require scientists to answer questions that they consider nonscientific. Thus, prior research data and research designs are generally not adequate to answer the question posed by legislation. In addition, disciplinary boundaries must be scrambled so that data can be integrated. Integration is the first step toward the production of information on which regulatory decisions can be made. The efforts to develop a unitary scientific definition of "wetlands" is a prime example of this problem. Wetlands must be delineated because federal law distinguishes them from nonwetland or dry land. This is a scientific dilemma for those who see the landscape as a continuous interactive system, because the term is a social construct not a scientific one. Nonetheless, we cannot escape applying science to wetlands delineation.

These tensions are part of the larger constraints of "pure" science characteristic of the post-1960s research context. As science has obtained large amounts of public funds, so has the public interest in its products. The gap between the scientific and political definitions of good research is illustrated by a recent National Academy of Sciences critical evaluation of federal environmental research expenditures.[49] About five billion dollars a year are spent on global climate change and toxic waste disposal research and development projects.[50] Most of the research is first rate but poorly coordinated, and it therefore has a limited effect on national policy.[51] To avoid these problems, science will increasingly be held to two standards: It must be relevant to larger social issues and it must be accountable. The net result of these two constraints is that science must offer credible advice on questions that are not often on the research agendas of the primary producers of knowledge because the questions are not perceived as scientific by researchers.

The ascendancy of regulatory science is also changing the dynamics of the traditional good-versus-bad science debate that has dominated risk assessment.[52] Its impact is illustrated in the breakdown of the traditional

49. COMMITTEE ON ENVTL. RESEARCH, NATIONAL RESEARCH COUNCIL, RESEARCH TO PROTECT, RESTORE, AND MANAGE THE ENVIRONMENT (1993).

50. *Id.* at 130.

51. *Id.* at 64.

52. See Alon Rosenthal et al., *Legislating Acceptable Cancer Risk from Exposure to Toxic Chemicals*, 19 ECOLOGY L.Q. 269, 348-53 (1992) for a good discussion of the risks of prejudging scientific issues on the "good" science of risk assessment.

model of scientific advice followed by the National Academy of Sciences. To help fight World War I, the National Research Council of the Academy was created between 1916 and 1918 to render "good," peer-validated, scientific and technological advice to the federal government.[53] The National Research Council tried to use the consensus approach to resolve these issues by constituting committees of national or international experts charged with issuing a report that resolved any debates within a discipline about a specific, narrow "scientific" question. Under this model the principal political problem for scientists was ensuring that the right people listened to them and took the proper actions. The literature on science policy has documented failures to listen and speculated about how to prevent them.[54] The hope was that good science would provide objective criteria to make regulatory decisions about issues such as toxic risks.

This model began to break down in the environmental era when scientists were asked to opine on issues with high ranges of uncertainty. There was no consensus about cutting edge scientific issues to report. We now realize that there are two problems with the good-versus-bad science model. First, good science is a political construct that has too often been used to deflect hard questions about the social costs of technology. However, there is a second and more profound problem, which is less a function of abused or sloppy science than of the internal protocols of science. Good science, defined as elegant hypothesis construction and testing, is often inadequate to provide the necessary information and thus, the rational guidance for scientifically sound decision making. The research may be scientifically valid, but it may lack the cross-disciplinary integration and informed speculation needed to be useful to a policy maker.

In short, the whole good-versus-bad science debate is becoming irrelevant. Science is increasingly criticized not because it is bad, but because it provides inadequate guidance to answer questions posed by legislatures and administrators. There are two fundamental reasons for the difficulties of applying science to the issues brought to a board for resolution. The first reason is that the questions are framed as scientific questions when they are actually scientifically informed value judgments. Scientists are pushed to give answers to questions that are framed as posi-

53. *See* THE ORGANIZATION OF KNOWLEDGE IN MODERN AMERICA 1860-1920 (Alexandra Oleson & John Voss eds., 1979).

54. *See* SHEILA JASANOFF, THE FIFTH BRANCH: SCIENCE ADVISERS AS POLICYMAKERS (1990). The usual complaint by scientists and students of science policy is that policy makers do not listen to scientists because the advice undermines the political objectives of a program that the policy maker wishes to pursue for other objectives. Communication between scientific experts and policy makers is an important and continuing problem for the science community.

tive or verifiable, but the questions are normative because a decision must be made before acceptable verification procedures can be followed.[55]

Efforts to make science more accountable offer the potential to use societal resources more efficiently, but they also pose long-term risks to the scientific base of the nation. The experience with accountability in totalitarian regimes must be carefully considered in order to maintain a line between the accountability and the subordination of science to political dogma. The former Soviet Union's replacement of "bourgeois" theories of ecology and genetics with Marxist science reminds us that subordination of science to state objectives can be disastrous. The triumph of Marxist theory over theoretical models tested by careful empirical research led to an unlimited faith in man's ability to transform nature. In the 1920s several ecological research reserves were established, but in the 1930s the research programs were replaced with experiments in acclimatization and Lysenkian genetics.[56]

III. THE LEGAL IMPLICATIONS OF THE NONEQUILIBRIUM PARADIGM

The legal implications of the nonequilibrium paradigm are substantial over space and time.[57] This paradigm shift affects the fundamental justifications for environmental law, the strategies we have used to promote environmental values, the relationship between law and scientific research, and the rules that structure environmental decision making. Environmental law is, to a greater extent than other areas of law, a product of external values not rooted in the environment of human dignity and thus it is difficult to integrate into our legal system. The Constitution, for example, is not a source of environmental rights and duties because the values that environmentalism promotes are not exclusively

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55. Positive science, of course, makes a sharp distinction between fact and value, but this dichotomy is less rigidly accepted by many conservation biologists. *See* Reed F. Noss, *Issues of Scale in Conservation Biology*, *in* CONSERVATION BIOLOGY, *supra* note 44, at 240, 245-48.

56. The history of the triumph of Marxist science over ecological approaches to nature conservation is documented in DOUGLAS R. WEINER, MODELS OF NATURE: ECOLOGY, CONSERVATION, AND CULTURAL REVOLUTION IN SOVIET RUSSIA (1988).

57. For example, the nonequilibrium paradigm as it is being applied to biodiversity protection potentially dissolves the land boundaries that we have built up over centuries and extends the time-scale of management decisions. Public versus private land, national parks versus national forests have no meaning. Under the nonequilibrium paradigm, all natural resources management is an ongoing experiment instead of a series of discrete, final decisions. The net result is to raise the level of uncertainty as a constraint on rational decision making and to extend this uncertainty over a long-time horizon. *See* COMMITTEE ON SCIENTIFIC AND TECHNICAL CRITERIA FOR FED. ACQUISITION OF LANDS FOR CONSERVATION, NATIONAL RESEARCH COUNCIL, SETTING PRIORITIES FOR LAND CONSERVATION 113-38 (1993).

those of the Enlightenment. Environmentalism carries forward the Enlightenment faith in science, but the nonhuman values captured in Aldo Leopold's land ethic flow from the romantic reaction to the end product of the Enlightenment—the French Revolution.

A. *Uncertainty and the Nonequilibrium Paradigm*

The "experimental" nature of the science of nonequilibrium ecology exacerbates the existing problem of making decisions from conditions of extreme uncertainty. The tension between the limits of science to provide information about the magnitude of environmental insults and established standards of causation has been an enduring problem in environmental law. The law has resolved this uncertainty problem in several creative ways. Risk was substituted for cause-in-fact and issues were recast as ethical rather than purely scientific. However, the legitimacy of standards of proof that depart from common-law causation requirements is always contingent and these initial strategies may not work as well in the future. Based, as it is, on probabilistic science, the nonequilibrium paradigm is merely another example of the pervasive problem of scientific uncertainty. However, the time horizons involved in the application of the nonequilibrium paradigm to resource management intensify the existing uncertainty problems, making it more difficult to employ past strategies to navigate around the constraints on environmental management raised by uncertainty.

In the 1970s the federal government began to enact laws to prevent unsafe levels of exposure to toxic chemicals by mandated risk assessments.[58] Risk assessment calls for unavailable information and thus, risk minimization legislation required administrators to make decisions on the frontiers of science under extreme uncertainty. The federal government first enacted laws to control gross forms of air and water pollution but, after the DDT controversy, cancer risk became a proxy for almost all environmental health risks. The net result was that the line between scientific inference and the more rigorous legal standard for cause-in-fact has blurred in the regulatory arena.

When regulators and lawyers began to implement NEPA, the Clean Air Act,[59] the Clean Water Act of 1977,[60] and other environmental statutes, they had to confront what scientists had always known: Most environmental decisions must be made under extremely uncertain conditions.

58. *See* FREDERICK ANDERSON ET AL., ENVIRONMENTAL PROTECTION: LAW AND POLICY 491-519 (2d ed. 1990).
59. 42 U.S.C. §§ 7401-7671q (1988 & Supp. III 1991).
60. 33 U.S.C.A. §§ 1251-1387 (West 1986 & Supp. 1993).

The regulated community seized on the pervasive uncertainty to argue that decisions should wait until "good science" provided conclusive evidence of harm.

Environmentalists, led by the first administrator of the federal Environmental Protection Agency (EPA), William Ruckleshaus, successfully argued that the establishment of a risk of future harm was a legitimate substitute for more traditional scientific and legal standards of cause and effect. The use of what is now known as risk assessment and risk management was also shielded from judicial review by two principles. First, the New Deal-based principle of deference to expertise was applied to scientific uncertainty, despite several efforts to develop a "hard look" theory of review of the scientific evidence.[61] Second, courts have widely endorsed the argument of scientists and engineers that risk assessments must err on the side of loss prevention by the incorporation of wide margins of safety. This has been carried over from toxic substances law to biodiversity protection.[62]

Lawyers have also dealt with uncertainty in a much more problematic way. Risk assessment data usually provides wide, and sometimes meaningless, ranges of risk. To justify the use of risk to limit discharges of toxic chemicals and to preserve ecological integrity, many commentators argue that risk assessment and management are not purely scientific matters but questions of public policy and ethics.[63] Nonequilibrium ecology undermines this effort because it strips away both the pretense of the divine and mechanical. Contrary to much contemporary wisdom that sees environmentalism as grounded in an emerging ethic that attributes rights to nature, I argue that science remains the central explanation and justification for environmentalism.[64] Without the scientific foundation,

61. *See, e.g.*, Marsh v. Oregon Nat'l Resources Council, 490 U.S. 360 (1989). There continue to be occasional instances of the use of a hard look to invalidate risk assessments, primarily under the Occupational Safety and Health Act of 1970, 29 U.S.C. §§ 651-678 (1988 & Supp. IV 1992), which gives OSHA administrators less discretion than EPA administrators to err on the side of risk minimization. *See* AFL-CIO v. OSHA, 965 F.2d 962 (11th Cir. 1992).

62. *See, e.g.*, City of Las Vegas v. Lujan, 891 F.2d 927 (D.C. Cir. 1989).

63. *See, e.g.*, Donald T. Hornstein, *Reclaiming Environmental Law: A Normative Critique of Comparative Risk Analysis*, 92 COLUM. L. REV. 562 (1992); Howard Latin, *Good Science, Bad Regulation, and Toxic Risk Assessment*, 5 YALE J. ON REG. 89 (1988).

64. Mark Sagoff has forcefully advocated the contrary position. *See* MARK SAGOFF, THE ECONOMY OF THE EARTH: PHILOSOPHY, LAW, AND THE ENVIRONMENT (1988). Unlike most lawyers and environmental philosophers, Mr. Sagoff has intensively studied the theory, application, and philosophy of ecology. In one of his most recent articles, *Settling America or The Concept of Place in Environmental Ethics*, 12 J. ENERGY NAT. RESOURCES & ENVTL. L. 349 (1992), he traces the history of wetlands protection, *id.* at 374-77, argues that the early scientific justifications for wetland protection have been refuted, *id.* at 378-79, and concludes "[c]hanging values not changing knowledge motivate and justify efforts to preserve wetlands,"

environmentalism would be the marginal aesthetic movement that it was between the progressive conservation era and the late 1960s. Without science, the central economic concept of externalities would remain an empty shell and the central premise of the environmental ethic, respect for nature, would be equally empty.

This argument does not reject the idea that environmental ethics can be an appropriate, independent source of justification for environmental regulation. In fact, I adopt a central argument of environmental ethics—the need to collapse the modern dichotomy between fact and value[65] in order to develop new resource management principles; however, I apply the collapse in a more cautionary way than have the proponents of the rights of nature. The symbiotic relationship between new information and public perception of the value of resources makes it difficult, if not impossible, to separate fact from value just as modern administrative law recognizes that law and fact are intertwined.[66] Environmentalism represents a profound shift in our world view of our physical surroundings.[67] Through science, simple and sophisticated, we have increasingly come to see natural processes as phenomena to be respected rather than manipulated. This new-found respect can support laws that recognize the value of new resource functions enacted in advance of conclusive scientific evidence. This is the thrust of the newly emerging precautionary principle in international law. However, as long as we value rationality—an open

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id. at 379. My dispute with his reading of history is two-fold: (1) It substitutes a dichotomy for a complex evolution process between changing public perceptions of worth and science; and (2) the survival of ethical justifications unsupported by science is an open question. For a sophisticated analysis of the relationship between science, ethics, and environmentalism, which concludes that to develop a new global ethic, "science can help provide a clearer vision" compared to "any pre-scientific, mythological way of valuing nature," see Holmes Rolston, III, *Science-Based Versus Traditional Ethics*, *in* ETHICS OF ENVIRONMENT AND DEVELOPMENT: GLOBAL CHALLENGE, INTERNATIONAL RESPONSE 64, 71-72 (J. Ronald Engel & Joan Gibb Engel eds., 1990). Donald Worster has also rejected neopaganism in favor of "the superiority of science over superstition" in THE WEALTH OF NATURE 218 (1993).

65. In this century this position has been associated with logical positivism and British empiricism, which has dominated philosophy in English-speaking and Scandinavian countries. Logical positivism, which has been closely linked to twentieth-century science, asserts that propositions have no meaning unless they can be verified. *See* John Passmore, *Logical Positivism*, *in* 5 THE ENCYCLOPEDIA OF PHILOSOPHY 52, 52-57 (1967).

66. For a recent articulation of this symbiotic relationship, which argues as I do that the two should not be artificially separated, see Hannua Tapani Klami et al., *Evidence and Legal Reasoning: On the Intertwinement of the Probable and the Reasonable*, 10 LAW & PHIL. 73 (1991).

67. Professor Eric Freyfogle argues that our changed moral understanding of the natural order now in progress "is one of the most profound changes in human history." Eric T. Freyfogle, *The Moral Psychology of the Environmental Age*, *in* ENVIRONMENTAL FEDERALISM IN THE EUROPEAN UNION AND THE UNITED STATES (John Braden et al. eds., forthcoming 1994).

question with respect to some strains of modern environmentalism—science will continue to serve an important regulating function. The need for some scientific justification, however probabilistic, for environmental regulation is necessary to constrain the potential arbitrariness and unfairness that can result from the substitution of intuition for verification.[68]

Conservation biology can be accommodated within the existing framework of judicial review of science, but it places new strains on the limits of judicial deference to the scientific community. For example, the rules of expert scientific evidence may pose problems for using conservation biology to support regulatory decisions. The law requires some causal link between human behavior and environmental degradation before an individual can be subject to regulation. Although seldom articulated by the courts and commentators, the required link rests on fundamental due process. The rules of evidence and standards of review of scientific evidence assume that preexisting data will be collected and applied to establish cause-in-fact within relatively high confidence levels.

The Supreme Court's recent "junk science" case, *Daubert v. Merrell Dow Pharmaceuticals*,[69] raises the possibility that conservation biology may not be accepted as a basis for a decision. *Daubert* involved the standard for excluding scientific information in products liability litigation and did not discuss the relevance of its analysis to the review of regulatory science. Rule 702 of the Federal Rules of Evidence liberally provides that expert scientific testimony is admissible if it pertains to "scientific . . . knowledge." The issue in the case was whether the rule incorporated the earlier, more restrictive judicial requirement that the science be generally accepted among the relevant peer group.[70] The Court unanimously held that Rule 702 incorporated a general acceptance requirement, but that trial judges had an obligation to apply the methods and procedures of science to screen the reliability of all scientific evidence.[71] "In a case involving scientific evidence, evidentiary reliability will be based on scientific validity."[72]

One sentence in Justice Blackmun's opinion could preclude the use of evidence generated by conservation biology. One of the Court's "key" proposed guidelines for the reliability of scientific evidence is the fal-

68. Freyfogle examines five challenges to utilitarian or anthropocentric environmentalism posed by advocates of the rights of nature. *Id.* These challenges include the argument that utilitarian calculations are impossible to make according to their own terms and the need to substitute intuition for empiricism. *Id.*

69. 113 S. Ct. 2786 (1993).

70. *Id.* at 2793-94 (discussing Frye v. United States, 293 F. 1013-14 (D.C. Cir. 1923)).

71. *Id.* at 2795.

72. *Id.* at 2795 n.9.

sifiability of the hypothesis upon which the scientific conclusion is based.[73] For example, it is difficult to meet this standard in the design of endangered species reserves. As leading conservation biologists involved in the initial design of Northern spotted owl reserves observe, reserve design is based on population models supported "by inferences drawn from research results and hypotheses not falsified by specific tests."[74] In the initial stages of the application of conservation biology, only general hypotheses may be falsified. Specific decisions will be based on the application of models; testing and falsifiability will come later.[75]

B. Adaptive Management: The Theory

The major institutional change necessitated by the nonequilibrium paradigm is the need to apply adaptive management to biodiversity protection. Students of organizational behavior have always counseled the need for feedback loops to reassess policy as new information accumulates; however, this has never been taken seriously in environmental law and policy. We favor management consistent with the core idea of the rule of law—consistent application of fixed rules to yield a single, final decision. Our environmental laws accept a scientific premise and then require its continued application regardless of subsequent research findings and thinking. For example, the Clean Water Act of 1977 requires that all coastal sewage discharges receive secondary treatment,[76] although there is considerable evidence that this may not always be necessary to achieve environmental objectives.[77] Adaptive management, in contrast, is premised on the assumption that management strategies should change in response to new scientific information. All resource management is an ongoing experiment.

Adaptive management is the end product of a fundamental shift in natural resources management. At the turn of the century, the progressive conservation movement promoted scientific management.[78] For example, until the 1960s, it was assumed that large-scale, multiple-purpose

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73. *Id.* at 2796.

74. Dennis D. Murphy & Barry R. Noon, *Integrating Scientific Methods with Habitat Conservation Planning: Reserve Design for Northern Spotted Owls*, 2 ECOLOGICAL APPLICATIONS 30, 36 (1992); *see also* Dennis D. Murphy & Barry R. Noon, *Coping with Uncertainty in Wildlife Biology*, 55 J. WILDLIFE MGMT. 773 (1991).

75. *See* Murphy & Noon, *supra* note 74.

76. 33 U.S.C.A. § 1311(b)(1)(B) (West Supp. 1988). The waiver provision, § 1311(h), expired in 1988.

77. COMMITTEE ON WASTEWATER MGMT. FOR COASTAL URBAN AREAS, NATIONAL RESEARCH COUNCIL, MANAGING WASTEWATER IN COASTAL URBAN AREAS (1993).

78. Martin Reuss, *Coping with Uncertainty: Social Scientists, Engineers, and Federal Water Resources Planning*, 32 NAT. RESOURCES J. 101 (1992).

water resources projects were essential to the economic well being of the nation. Water management meant planning and operating these projects by fixed operating rules to maximize uses—irrigation, hydropower generation, municipal and industrial supply, and flood control. This assumption eroded in the face of the environmental movement.[79] The result is that water resource management rests on some principles that no longer hold true. We rely less on permanent structural solutions and more on adaptive management of existing physical and seminatural systems.

A recent National Research Council-National Academy of Sciences study captures the essence of adaptive management:

> Adaptive planning and management involve a decision making process based on trial, monitoring, and feedback. Rather than developing a fixed goal and an inflexible plan to achieve the goal, adaptive management recognizes the imperfect knowledge of interdependencies existing within and among natural and social systems, which requires plans to be modified as technical knowledge improves . . . .[80]

C. *Adaptive Management: Finality Unraveled*

The idea that all management is an ongoing experiment poses a profound challenge to our legal system because it undermines a core principle of procedural and substantive fairness: finality.[81] We follow Hume and Bentham and seek to confirm settled expectations unless there is a compelling overriding reason, usually one grounded in constitutionally protected norms such as free expression or racial equality. Once a decision is rendered, we expect parties to forever abide by the outcome. Finality takes many forms. Sometimes, it is represented by express doctrines and legislation, such as res judicata, statutes of limitation, and the doctrine of vested rights. On other occasions, finality is implicit. For example, the premise behind an environmental impact statement is that once environmental damage has been fully disclosed, a one-time decision can be made on the merits of the activity, and even if the activity will irrevocably alter the environment, the decision is legitimate and final.

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79. FELDMAN, *supra* note 4.

80. COMMITTEE ON RESTORATION OF AQUATIC ECOSYSTEMS, NATIONAL RESEARCH COUNCIL, RESTORATION OF AQUATIC ECOSYSTEMS: SCIENCE, TECHNOLOGY, AND PUBLIC POLICY 357 (1992).

81. For an insightful case study of the problems that adaptive management poses for "settled" management systems, see John M. Volkman & Willis E. McConnaha, *Through a Glass, Darkly: Columbia River Salmon, The Endangered Species Act, and Adaptive Management*, 23 ENVTL. L. 1249 (1993).

Adaptive management cannot, of course, be constantly changing; it is public regulation that must satisfy constitutional requirements of substantive and procedural due process. However, ongoing efforts to apply adaptive management to biodiversity protection illustrate the subtle ways in which the application of adaptive management supported by nonequilibrium ecology undermines settled expectations and increases the risk to those who undertake activities in areas targeted for biodiversity protection. The Federal Endangered Species Act pressures federal agencies and state governments to accommodate species protection with existing activities. Two notable efforts to apply adaptive management are occurring in Southern California and on the Colorado River through the Grand Canyon.

To avoid listing a threatened song bird in Southern California under state and federal endangered species acts, California passed the Natural Community Conservation Planning Act in 1991.[82] This statute provides a framework for voluntary participation of local governments and private landowners in the preparation of natural community conservation plans (NCCP) for the protection of certain habitats.[83] These plans are to be large scale, multispecies equivalents of existing habitat conservation plans authorized under the Endangered Species Act of 1973.[84] To test the program, the state resources agency selected as a pilot project the "coastal sage scrub" terrain of Southern California, a region that had already witnessed a number of troublesome conflicts under the existing endangered species legislation. The objective was to study and resolve conflicts at an early stage in the process by the people with the most expertise in the relevant areas.

To implement the pilot program, the California Resources Agencies selected a Scientific Review Panel of conservation biologists. The panel's mission was to develop guidelines for a workable NCCP for the coastal sage scrub.[85] Much of the recent research on planning methodologies for

82. 1991 Cal. Stat., ch. 765, § 2 (codified at CAL. FISH & GAME CODE §§ 2800-2840 (West Supp. 1994)).

83. The statute authorizes any person or governmental agency to prepare a natural community conservation plan (NCCP) pursuant to an agreement with, and guidelines written by, the Department of Fish and Game. CAL. FISH & GAME CODE §§ 2805, 2810, 2820, 2825 (West Supp. 1994). Plans are drafted to promote the "protection and perpetuation of natural wildlife diversity while allowing compatible and appropriate development and growth." *Id.* § 2805. Once the Department of Fish and Game approves an NCCP, it may authorize developments that may have adverse impacts on listed or candidate species if they are consistent with the NCCP. *Id.* §§ 2810, 2825(c), 2835.

84. 16 U.S.C. §§ 1531-1544 (1988 & Supp. IV 1992).

85. *See, e.g.*, Peter F. Brussard, *The Role of Ecology in Biological Conservation*, 1 ECOLOGICAL APPLICATIONS 6 (1991); Michael E. Gilpin & Michael E. Soule, *Minimum Viable Popu-*

habitat protection has concentrated on the design of "reserves," which would be large areas that would be managed to maintain or recreate natural habitat conditions.[86] These methodologies had been used for rare species, such as the desert tortoise and northern spotted owl that occupied large areas of public land desired for uses inconsistent with habitat maintenance. For the coastal sage scrub, however, neither the federal nor the state governments had allocated significant funds for habitat acquisition, and only a small proportion of the remaining habitat was located on public land. Although land acquisiton authority is lacking, the statute authorizes the state to use its permitting authority to enforce approved NCCPs.[87] However, the pilot program contemplated that the actual application of the planning methodology would be undertaken by the local agencies and private coalitions that would prepare the NCCPs pursuant to the scientists' guidelines and thus would be enforced by local government through consistency requirements.[88]

The NCCP process raises serious Fifth Amendment taking issues.[89] However, the planning process with its commitment to adaptive management makes it more difficult for landowners to bring these challenges successfully. During the mapping process, takings challenges are not ripe and completed land-use plans are difficult to challenge on ripeness grounds because they are seldom final.[90] Thus, habitat protection decisions per se will not be ripe for a challenge, and the experimental nature of the process means that map lines are subject to modification as better data is collected. Further, the process may yield sufficient development opportunities, compared to less scientifically based planning, to avoid a takings challenge because the entire tract is not stripped of value.[91]

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lations: Processes of Species Extinction, in CONSERVATION BIOLOGY: THE SCIENCE OF SCARCITY AND DIVERSITY (Michael E. Soule ed., 1986); Reed F. Noss, *Protecting Natural Areas in Fragmented Landscapes,* 7 NAT. AREAS J. 1, 2 (1987); John F. O'Leary & Walter E. Westman, *Regional Disturbance Effects on Herb Succession Patterns in Coastal Sage Scrub,* 15 J. BIOGEOGRAPHY 775 (1988).

86. Michael E. Soule, *Land Use and Wildlife Maintenance: Guidelines for Conserving Wildlife in an Urban Landscape,* 57 J. AM. PLAN. ASS'N 313 (1991).

87. *See* CAL. FISH & GAME CODE §§ 2081, 2825(c), 2835 (West Supp. 1994).

88. *See* DANIEL J. CURTIN, JR., CALIFORNIA LAND USE & PLANNING LAW 19 (13th ed. 1993).

89. *See* A. Dan Tarlock, *Local Protection of Biodiversity: What Is Its Niche?,* 60 U. CHI. L. REV. 555 (1993).

90. For an extreme case, see Southview Assocs. v. Bongartz, 980 F.2d 84 (2d Cir. 1992), *cert. denied,* 113 S. Ct. 1586 (1993).

91. *See* Lucas v. South Carolina Coastal Council, 112 S. Ct. 2886 (1992). The Supreme Court has granted certiorari in Dolan v. City of Tigard, 854 P.2d 437, 444 (Or.) (holding land use regulation does not constitute taking of property under Fifth Amendment if legitimate state interest substantially advanced and owner not denied of economically viable use of land), *cert. granted,* 114 S. Ct. 544 (1993).

A similar experiment is taking place at Glen Canyon Dam on the Colorado River. The dam, which stores water for the benefit of Arizona, California, and Nevada, and generates power to pay for irrigation projects in the Upper Basin, was filled in 1962. The filling altered the flow of the river below the dam through the upper reaches of the Grand Canyon. As a result, sediment deposits that build canyon beaches have been reduced; the river temperature has been lowered, threatening listed indigenous fish; and fluctuating releases of water from the dam due to power demands pose potential hazards for the river rafting industry. Initially, the Bureau of Reclamation and the Western Power Area Administration invoked the complex "law of the river" to resist any modification of the dam to address these postdam changes in the riparian environment.[92] However, political pressures forced the Bureau to study these problems and the accumulated eighty-eight million dollars worth of scientific studies[93] have forced the Departments of Interior and Energy to prepare environmental impact statements for the operation of the dam.

Agency insistence that vested rights preclude any changes in dam management has eroded in the face of mounting evidence that serious environmental problems exist. However, there is also evidence that it may be possible to design altered flow regimes that do not unduly prejudice power consumers. Consequently, the operating agencies have embraced the concept of adaptive management thereby committing the operating agencies to experiment with different flow regimes to balance power demands with environmental protection and safety in the Grand Canyon.[94] Adaptive management is attractive to the agencies in large

92. The "law of the river" is a web of interstate compacts, congressional statutes, and Supreme Court opinions that apportion the river between the two basins and among the seven basin states plus subsequent cases and statutes recognizing protected new interests for Native Americans, the environment, and the like. The river was initially apportioned to promote irrigation and urban development. The federal government has constructed large, multiple-purpose dams and reservoirs, which generate hydroelectricity to pay for themselves, and which subsidize irrigation projects. The "law" precludes some long-term changes in existing allocations, but it does not preclude modification of power generation. *See* Helen Ingram et al., *The Law and Politics of the Operation of Glen Canyon Dam*, *in* WATER SCIENCE AND TECHNOLOGY BD., NATIONAL RESEARCH COUNCIL, COLORADO RIVER ECOLOGY AND DAM MANAGEMENT 10 (1991); A. Dan Tarlock, *Western Water Law, Global Warming and Growth Limitations*, 24 LOY. L.A. L. REV. 979, 992-1001 (1991).

93. The National Academy of Sciences-National Research Council has been critically reviewing the Glen Canyon environmental studies since 1986. For an introduction to the science of measuring and monitoring the environmental impacts of the altered canyon environment see WATER SCIENCE AND TECHNOLOGY BD., NATIONAL RESEARCH COUNCIL, RIVER AND DAM MANAGEMENT: A REVIEW OF THE BUREAU OF RECLAMATION'S GLEN CANYON ENVIRONMENTAL STUDIES (1987).

94. The application of adaptive management can be seen in the draft environmental impact statement for dam operations. BUREAU OF RECLAMATION, U.S. DEP'T OF INTERIOR,

part because it allows flow regimes to be modified by future monitoring, which can provide evidence on the environmental benefits, if any, of these new flows.

IV. CONCLUSION

The first part of a mountain climb is usually the easiest and the rapidity of the ascent may create a false sense that the effort will continue to be easy. A great deal of progress can be made by walking in a straight line. Progress becomes more difficult as the slope increases and the irregularity of landscape requires more sophisticated strategies to continue the ascent. Environmentalism and environmental law are now moving from a gentle to a steep slope. The scientific landscape is beginning to change from a simple, linear landscape to a complex, stochastic one. To balance the legal system's traditional promotion of individual fairness with the continued protection of the environment, it must now adapt to this new landscape, in part, by concepts that provide for the continuous integration of science and policy making. Resource management decisions will continue to be made "under conditions of uncertainty," but we need new strategies to reduce data gaps over time. In the future, we must pay as much attention to the implementation and monitoring of management policies as we do to their formation so that newly collected information can be used to modify policies as necessary. There can never be a final decision in science-based management.

OPERATION OF GLEN CANYON DAM: DRAFT ENVIRONMENTAL IMPACT STATEMENT (1994).