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The Influence of Ecological Science on American Law: An Introduction in Symposium, Ecology and the Law (with A. Dan Tarlock)

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THE INFLUENCE OF ECOLOGICAL SCIENCE ON AMERICAN LAW: AN INTRODUCTION

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INTRODUCTION

This symposium explores how changing paradigms in ecology have influenced environmental law and policy, and how the current paradigm may influence laws and regulatory programs built on an earlier paradigm. Environmental law is a joint product of economics, ethics and science, but science is the driving force. Science—primarily ecology and toxicology—gives content to ethics and economics.

Ecology is a well-recognized branch of biological science that deals with the interrelationship between living things and their environment. One of ecology's primary contributions to modern environmental law has been to show how an action that impacted one species of plant or animal might indirectly impact many other species, e.g., eagles died from eating fish that ate worms that ate DDT. In the early days of the environmental movement, the ecologists' work was popularized as "everything is related to everything else." This led to the common perception that any human modification of the environment was likely to be harmful in some direct or indirect way.

Environmental law frequently relied on ecology as interpreted by scientist-philosophers and those who read these popularizers. Current environmental law, however, rests on a simple ecological paradigm which the science has now rejected and replaced with a more complex, open-ended model. The idea that "Nature knows best: leave her alone" fit with the secular-spiritual preservation movement which transformed itself into environmentalism in the 1960s. "Leave her alone" principles derive from classic ecological theories which posited equilibrium as the highest state of natural systems and viewed ecosystems as inherently fragile and thus vulnerable to human degradation. Ecology was an attractive basis for law because it was thought to yield

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scientific laws which could form the basis for the intense regulation of land and resource use.

In recent years, classic ecology has been challenged by newer ecological theories which have potentially significant implications for environmental regulation. These new theories vary, but they tend to see the environment as in a process of constant change rather than in search of a stable end-state. Environmental law is just beginning to adapt to the new paradigm.

As environmental law adapts to changing ecological theories, it is useful to review the influence of ecological science on American law in its historical context. Contrary to popular opinion, ecology was not invented in the 1960s. Ecology has been recognized as an important branch of biological science for just over a century. Throughout that time, ecology has continually affected the way that legal theory and legal institutions have developed.

This introduction sets the stage for the scientific and legal analysis of the new paradigm by a distinguished group of scientists and lawyers by summarizing the history of ecology's influence on law. We review four periods during the last century when new ecological ideas were becoming established. In each period, the current thinking in ecology provided support for changes in public policy and legal institutions. A review of the impact of past changes in ecological thinking may shed light on the ways in which today's "new paradigm" in ecological science will affect environmental law.

Part I of the article looks at the Progressive era and the influence of ecology on the jurisprudence of that period through the work of the ecologist-turned-lawyer, Roscoe Pound. Part II focuses on the concepts of succession, climax and equilibrium developed by Frederic Clements and their influence on American land planning programs in the 1920s and 1930s. Part III examines the role of the leading British ecologist, Sir Arthur Tansley, in replacing the end-state organismic theories of Clements with a more complex theory of the ecosystem. Part IV traces the development of Eugene Odum's theory of the ecosystem as a mechanical system tending toward harmony and order, its adoption as the scientific basis for modern environmental law, and its subsequent replacement by a chaos-theory driven, non-equilibrium paradigm.

I. ECOLOGY IN THE PROGRESSIVE ERA: AN ENGINE OF SOCIAL AND SCIENTIFIC PROGRESS

The social sciences in the late nineteenth century were heavily influenced by the physical sciences, especially Darwin's theory of evolution.[1] Social Darwinism was the term used to characterize the application of Darwin's theories of adaptation and fitness to human affairs.[2] One of the most prominent Social Darwinists, Yale sociologist William Graham Sumner, coined the earthy epigram that symbolized the period: "[R]oot, hog or die!"[3] To the Social Darwinists, Darwin's concept of the survival of the fittest meant that those human individuals who became successful must be reflecting innate characteristics of fitness—a theory that had a natural appeal to many of those who had achieved success.[4]

Sumner and his colleagues believed that human society was inherently competitive because all living things were inherently competitive. Some scientists, however, questioned whether the biological evidence supported such an individualistic viewpoint: It had long been noted that certain plants and animals often formed mutually interdependent associations. The field of ecology took its place in the natural sciences out of the study of those interrelationships.[5]

Ecology was recognized as a legitimate field of the biological sciences in 1893,[6] and even before it was formally recognized, it was beginning to affect the intellectual climate beyond the boundaries of biology.[7] In the era of new world exploration, biology had emphasized the classification of the many specimens of plants and animals brought back from places newly discovered by European science.[8] Too often the specimen was removed from its natural context and had to be classified almost exclusively by its physical characteristics as observed in the museum.[9] As biologists found new bases of operations

1. *See, e.g.*, PETER J. BOWLER, EVOLUTION: THE HISTORY OF AN IDEA 187-237 (1983).
2. RICHARD HOFSTADTER, SOCIAL DARWINISM IN AMERICAN THOUGHT (1955).
3. BOWLER, *supra* note 1, at 287.
4. *See* Herbert Hovenkamp, *Evolutionary Models in Jurisprudence*, 64 TEX. L. REV. 645 (1985).
5. DONALD WORSTER, NATURE'S ECONOMY: A HISTORY OF ECOLOGICAL IDEAS 194 (1985).
6. ROBERT P. MCINTOSH, THE BACKGROUND OF ECOLOGY 294 (1985).
7. WORSTER, *supra* note 5, at 133-40.
8. FREDERIC E. CLEMENTS, RESEARCH METHODS IN ECOLOGY 3 (1905). Biology was dominated by Linnaean taxonomy with its emphasis on physiology rather than interaction. WORSTER, *supra* note 5, at 31-39. The effect of Linnaeus on the development of ecology in Sweden is discussed in THOMAS SÖDERQVIST, THE ECOLOGISTS 18-20 (1986).
9. MCINTOSH, *supra* note 6, at 41-42; CLEMENTS, *supra* note 8, at 13.

outside older urban centers, which provided a better opportunity to observe species in their native surroundings, they increasingly recognized the need to study the interaction of plants and animals with their surroundings and with each other. The science of ecology developed accordingly.[10]

As the nineteenth century neared its end, the study of ecology began to permeate the biology departments of American universities.[11] In the 1890s, the University of Nebraska, perched on the prairie, became a pioneer in the development of plant ecology under the leadership of Charles Bessey.[12] Two of his top students, Roscoe Pound and Frederic Clements, went on to become very influential figures in the application of ecology to American society.[13]

Roscoe Pound had the most immediate influence on the legal system because of his switch from the study of biology to the study, practice and teaching of law. He obtained his Ph.D. in botany from Nebraska in 1897 on the basis of his extensive work with fungi and lichens, having already written (in cooperation with Clements) *The Phytogeography of Nebraska,* a path-breaking work in ecology.[14] Pound was later to become a famous legal scholar. His jurisprudential theories reflected his ecological training, which impressed on him two important principles that would influence him throughout his life and, in turn, influence the law of today's regulatory state. First, *empiricism*: scientific thought did not proceed by deductive reasoning from abstract principles, but from careful study of actual facts.[15] Second, *interdependence*: individual organisms could not be adequately understood, except in the context of their physical surroundings.[16]

10. WORSTER, *supra* note 5, at 197.

11. MCINTOSH, *supra* note 6, at 41-42; WORSTER, *supra* note 5, at 206. For an analysis of ecological study in continental Europe during this period, see ANNA BRAMWELL, ECOLOGY IN THE 20TH CENTURY (1989).

12. RONALD C. TOBEY, SAVING THE PRAIRIES 38-45 (1981).

13. *See infra* text accompanying notes 14-97.

14. ROSCOE POUND & FREDERIC E. CLEMENTS, THE PHYTOGEOGRAPHY OF NEBRASKA (1st ed. 1897). The work on the book was substantially complete at the time Pound received his doctorate in 1897, but the plates of the original book were accidentally destroyed, so a second and revised edition was published in 1900. ROSCOE POUND & FREDERIC E. CLEMENTS, THE PHYTOGEOGRAPHY OF NEBRASKA (2d ed. 1900). *See generally* DAVID WIGDOR, ROSCOE POUND: PHILOSOPHER OF LAW 55-58 (1974).

15. Empirical research was seen as the foundation of all nineteenth century science. WORSTER, *supra* note 5, at 130.

16. The European ecologists, such as Drude and Warming, emphasized the mutual interdependence of all elements of the natural environment. WORSTER, *supra* note 5, at 199-202. Pound read many languages and studied Drude and Warming in German. WIGDOR, *supra* note 14, at 55.

The emphasis on empirical study was an outgrowth of the work that Pound and Clements performed on the botanical survey of Nebraska.[17] In the course of their field work throughout the state, they realized that many of their preconceptions about the composition of plant communities were mistaken. Casual observers had typically characterized plant communities by assuming that the showiest and most easily observable species were dominant, but systematic study often revealed that less noticeable species were actually more significant.[18] Pound and Clements pioneered the development of the "quadrat" method of documenting vegetation patterns by the use of painstaking counts of individual organisms in randomly selected sample areas.[19] The method that they helped develop is still in use today to describe ecosystems and their components.[20]

The second key principle of Pound's ecological thinking, the recognition of the interdependence of organisms, was a product of his extensive study of fungi and lichen. Like other early ecologists, Pound was becoming increasingly aware of the extent to which many species of plants and animals lived in symbiotic relationships with each other.[21] Lichen were the epitome of interdependence: they consisted of an alga and a fungus living together as if they were a single organism and often so dependent on each other that neither could survive in the wild without the other.[22] In one of his first botanical articles, *Symbiosis and Mutualism*, Pound discussed the wide range of symbiotic behavior of plants, ranging from the pure parasitism of the mistletoe to the mutualism of the lichen.[23] He pointed out the difficulty of determining the extent to which symbiotic behavior was beneficial or

17. TOBEY, *supra* note 12, at 57-70. *See* WIGDOR, *supra* note 14, at 56-57.

18. TOBEY, *supra* note 12, at 69-70; MCINTOSH, *supra* note 6, at 133-34; FRANK B. GOLLEY, A HISTORY OF THE ECOSYSTEM CONCEPT IN ECOLOGY 19-22 (1993).

19. Roscoe Pound & Frederic E. Clements, *A Method of Determining the Abundance of Secondary Species*, 2 MINN. BOTANICAL STUD. 19 (1898).

20. "Within a decade of its invention, the quadrat method had been developed by the Nebraska scientists into the main method of scientific ecology." TOBEY, *supra* note 12, at 70. It has, of course, been supplemented today by more complex forms of multivariate analysis. MCINTOSH, *supra* note 6, at 144-45.

21. The idea of interdependence was not novel. Robert McIntosh notes:

> [t]he somewhat waggish current statement about ecology as being everything connected to everything else was specifically stated by Richard Bradley in 1721: "All Bodies have some Dependance upon one another; and . . . every distinct Part of Nature's works is necessary for the Support of the rest; and . . . if any one was wanting all the rest must consequently be out of Order."

MCINTOSH, *supra* note 6, at 69-70.

22. WORSTER, *supra* note 5, at 199-200.

23. Roscoe Pound, *Symbiosis and Mutualism*, 27 AM. NATURALIST 509 (1893).

harmful to the host species without an understanding of the overall context in which the plants lived.[24]

By the late nineteenth century, ecological ideas of empiricism and interdependence were beginning to influence scholars in other fields. The English botanist, Patrick Geddes, was writing about the implications of ecology for city planning.[25] Lester Frank Ward, a biologist turned sociologist, was an influential opponent of the Social Darwinists' emphasis on individualism.[26] Edward Alsworth Ross, who taught at the University of Nebraska while Pound was there, was a prominent sociologist who admired Ward's ideas.[27] Ward and Ross emphasized the need to view society as a complex institution with its own interests,[28] and they believed that humanity was evolving from the narrow self-interest of earlier periods toward a collective reorganization of society through governmental institutions.[29]

By the time the University of Nebraska awarded Roscoe Pound his Ph.D. in botany, he was already mastering a very different field—law. He began the active practice of law in 1890, became a professor of law at the University of Nebraska in 1899, and dean in 1903.[30] His legal scholarship soon attracted national attention, and he moved quickly to the law schools of Northwestern, Chicago and eventually Harvard, where he served as dean from 1916 to 1936.[31]

Pound was very interested in sociology and discussed it frequently with Ross.[32] Pound saw in sociology the science for which he had been searching vainly in the law, and he found in the sociology of

24. *Id.* at 519.

25. PATRICK GEDDES, CHAPTERS IN MODERN BOTANY (1893). *See* PHILIP BOARDMAN, PATRICK GEDDES: MAKER OF THE FUTURE 132-35 (1944); Charles C. Adams, *Patrick Geddes—Botanist and Human Ecologist,* 26 ECOLOGY 103 (1945) (reviewing BOARDMAN, *supra*); Helen Meller, *Cities and Evolution: Patrick Geddes as an International Prophet of Town Planning Before 1914, in* THE RISE OF MODERN URBAN PLANNING, 1800-1914, at 199 (Anthony Sutcliffe ed., 1980). *See also* BRAMWELL, *supra* note 11, at 77-81.

26. DOROTHY ROSS, THE ORIGINS OF AMERICAN SOCIAL SCIENCE 88-94 (1991). For a discussion of Ward's influence on Pound, see Hovenkamp, *supra* note 4, at 672-83. Among the other noteworthy followers of Ward was Howard Washington Odum, a sociologist whose Institute for Research in Social Science at Chapel Hill was a prototype of such institutes. ROBERT C. BANNISTER, SOCIOLOGY AND SCIENTISM: THE AMERICAN QUEST FOR OBJECTIVITY, 1880-1940, at 10 (1987). Odum was to make his own indirect contribution to ecology by fathering Howard T. and Eugene Odum, prominent ecologists discussed *infra* at Part IV. *See* Peter J. Taylor, *Technocratic Optimism, H.T. Odum, and the Partial Transformation of Ecological Metaphor After World War II,* 21 J. HIST. BIOLOGY 213, 223-24 (1988).

27. *See* JULIUS WEINBERG, EDWARD ALSWORTH ROSS AND THE SOCIOLOGY OF PROGRESSIVISM 31, 136 (1972).

28. ROSS, *supra* note 26, at 91-92, 230-40.

29. *Id.* at 230-50.

30. WIGDOR, *supra* note 14, at 69-103.

31. *See id.* at 133-254.

32. *See* EDWARD A. ROSS, SEVENTY YEARS OF IT: AN AUTOBIOGRAPHY 89 (1936).

Ward and Ross the scientific emphasis on empirical research and interdependence that he had discovered in ecology.[33] This blending of law and sociology allowed Roscoe Pound to become the leading theoretician of the Progressive movement,[34] whose theories provided the underpinning for natural resources conservation and, though rarely acknowledged, for the modern environmental movement.[35]

Pound was perceived as a brash but eloquent young critic of the legal establishment.[36] He criticized the legal profession for relying on the old "law in books" while ignoring the fact of social change.[37] He proposed a new sociological jurisprudence which would use the law as a tool for social engineering and would encourage legislation to remedy the ills of society.[38] This would be the "law in action."[39] He was especially critical of the Social Darwinists for their emphasis on the rights of the individual at the expense of the needs of society as a whole.[40] He argued that society was an interdependent whole that was greater than the mere aggregation of the individuals that made up its parts.[41] He urged the courts to be receptive to social legislation and to the factual context of social problems.[42]

The two main themes of Pound's early writings on sociological jurisprudence, empiricism, and interdependence, were an extension of the ideas that grew out of his early work in ecology.[43] Too many legal scholars, he argued, were like the physiological taxonomists who

33. WIGDOR, *supra* note 14, at 112-13. *See, e.g.,* Roscoe Pound, *The Scope and Purpose of Sociological Jurisprudence*, 25 HARV. L. REV. 489, 506-07 (1912) (discussing Ward).

34. JAMES E. HERGET, AMERICAN JURISPRUDENCE, 1870-1970, at 164-75 (1990); MORTON J. HORWITZ, THE TRANSFORMATION OF AMERICAN LAW, 1870-1960: THE CRISIS OF LEGAL ORTHODOXY 217-18 (1992).

35. *See* Richard D. Alexander, *Biology and Law, in* LAW, BIOLOGY AND CULTURE 200 (Margaret Gruter & Paul Bohannon eds., 2d ed. 1993).

36. WIGDOR, *supra* note 14, at 133-35. His early legal writings were crisp and pointed, much different in style from the heavy prose of his later works. *See id.* at 285.

37. Roscoe Pound, *Law in Books and Law in Action*, 44 AM. L. REV. 12, 20-21 (1910).

38. Roscoe Pound, *The Need of a Sociological Jurisprudence*, 19 GREEN BAG 607, 611-12 (1907).

39. It was only the early work of Pound, which he synthesized in *The Scope and Purpose of Sociological Jurisprudence*, pts. 1-3, 24 HARV. L. REV. 591 (1911), 25 HARV. L. REV. 140, 489 (1912), that influenced the legal system during the progressive era. His later work departed significantly from his earlier ideas. *See infra* note 49.

40. Roscoe Pound, *Do We Need a Philosophy of Law?*, 5 COLUM. L. REV. 339, 344, 346, 352 (1905) [hereinafter *Philosophy of Law*]; Roscoe Pound, *Liberty of Contract*, 18 YALE L.J. 454, 457 (1909) [hereinafter *Liberty of Contract*]; Roscoe Pound, *Enforcement of Law*, 20 GREEN BAG 401, 402 (1908) [hereinafter *Enforcement of Law*]. *See* EDWARD B. MCLEAN, LAW AND CIVILIZATION: THE LEGAL THOUGHT OF ROSCOE POUND 194-202 (1992).

41. What the individual does, Pound wrote, "is quite as much wrought through him by society as wrought by himself alone." *Philosophy of Law, supra* note 40, at 346.

42. Pound, *supra* note 37, at 35-36.

43. *See supra* text accompanying notes 17-24.

never got outside the herbarium and into the field.[44] And because they did not see how interdependent their individual specimens really were, they often overemphasized the importance of the individual and downplayed the role of social interaction.[45]

By 1912, the essential elements of what later scholars have called the "Poundian paradigm" were in place.[46] To the Progressive political movement of that era, the "law in action" embodied many of their goals: For pragmatic scholars and activist lawyers, sociological jurisprudence quickly became a popular label to attach to a range of ongoing reforms.[47] Boston attorney Louis Brandeis used it to justify his successful efforts to persuade appellate courts to consider data on social problems that had not been included in the trial record.[48] And legislators who created administrative agencies with broad regulatory power over business argued that these agencies provided the empirical fact-finding capabilities that Pound said were needed.[49]

Pound the Dean became more conservative than Pound the aspiring professor, but younger legal scholars used his earlier ideas as the basis for the legal realism movement of the 1930s.[50] Although Pound's ideas had changed by then, his early writings embodied the first major impact of ecological science on the legal system.

II.

Frederic Clements did not follow his friend Roscoe Pound into the law but stayed in botany. He went on to become the most famous American ecologist of the first half of the twentieth century.[51] By the 1930s, his theories of ecology had become so embedded in scientific

44. ROSCOE POUND, INTERPRETATIONS OF LEGAL HISTORY 128-29 (1923). *See* E. Victor Walter, *Legal Ecology of Roscoe Pound,* 4 MIAMI L.Q. 178, 185-86 (1950). Pound argued in favor of more empirical research into the way that courts actually operated. *See* PAUL SAYRE, THE LIFE OF ROSCOE POUND 268-69 (1948) (quoting a letter from Pound to Justice Holmes).

45. Pound wrote that sociological jurisprudence was a "movement for putting the human factor in the central place and relegating logic to its true position as an instrument . . . ." *Liberty of Contract, supra* note 40, at 464.

46. HERGET, *supra* note 34, at 147.

47. *See, e.g.,* JOHN W. JOHNSON, AMERICAN LEGAL CULTURE, 1908-1940, at 129-35 (1981).

48. Louis D. Brandeis, *The Living Law,* 10 ILL. L. REV. 461, 464, 470 (1916).

49. *See* DOUGLASS C. NORTH, STRUCTURE AND CHANGE IN ECONOMIC HISTORY 190-98 (1981). By 1940, however, Pound became seriously disillusioned with the administrative state as it had evolved under Roosevelt. HORWITZ, *supra* note 34, at 170-182; WIGDOR, *supra* note 14, at 266-67.

50. WIGDOR, *supra* note 14, at 255-65; HORWITZ, *supra* note 34, at 170-82. During the 1930s, the legal realists turned Yale Law School into the center of cutting-edge legal theory, but in the 1920s under Pound, "the Harvard approach was considered to be the truly 'progressive' one." GERALD GUNTHER, LEARNED HAND: THE MAN AND THE JUDGE 726 n.8 (1994).

51. WORSTER, *supra* note 5, at 209; MCINTOSH, *supra* note 6, at 76-85.

thinking that they reinforced a static concept of the future landscape that became known as end-state planning.[52]

Clements liked to label his theory of ecology as succession, and he wrote extensively about natural processes by which one plant community replaces another in successive waves.[53] But the part of his theory that had the greatest influence on public policy was not succession itself, but his contention that succession eventually would end in a climax state, at which point succession would cease because the landscape had reached its natural condition of equilibrium.[54] Each plant and animal species would then occupy its niche in perpetual harmony.[55] Of course, fire, flood, or other natural event might disrupt such harmony, but in the long run it would not matter because the process of succession would begin again and eventually return to the climax condition.[56]

The idea of climax and equilibrium fell on fertile ground. For centuries, many theologically inclined students of science had inferred a balance of nature, divinely provided until the disrupters of the Garden of Eden bungled things.[57] They argued that humans should search to fit themselves into the framework of natural processes so that a condition of permanent stability could be re-established.[58]

The initial building block of Clements' ecology was the plant community.[59] He thought that each such community functioned as a separate unit in the ecological process.[60] Other biologists of the period, such as Hart Merriam, fostered this idea of separate and independent communities through the popularization of maps showing the separation of the natural world into specific life zones, each

52. *See infra* text accompanying notes 80-84.

53. *See, e.g.*, JOHN E. WEAVER & FREDERIC E. CLEMENTS, PLANT ECOLOGY 60-79 (2d ed. 1938).

54. Frederic E. Clements, *The Nature and Structure of the Climax*, 24 J. ECOLOGY 252, 255-56 (1936).

55. WEAVER & CLEMENTS, *supra* note 53, at 261; MCINTOSH, *supra* note 6, at 104-05; WORSTER, *supra* note 5, at 211.

56. Weaver and Clements exemplify this position:

> While the climax is permanent because of its entire harmony with a stable habitat, the equilibrium is a dynamic one and not static. Superficial adjustments occur with the season, year, or cycle. . . . While change is constantly and universally at work, in the absence of civilized man this is within the fabric of the climax and not destructive of it.

WEAVER & CLEMENTS, *supra* note 53, at 80.

57. WORSTER, *supra* note 5, at 138-43.

58. PETER J. BOWLER, THE NORTON HISTORY OF THE ENVIRONMENTAL SCIENCES 507-09 (1993); WORSTER, *supra* note 5, at 39-53.

59. MCINTOSH, *supra* note 6, at 77-78.

60. *Id.* at 81.

adapted to certain climatic and geographic conditions.[61] As Clements' thinking progressed, he increasingly began to think of such communities and their animal inhabitants as akin to individual organisms that possessed an identity greater than the sum of their parts.[62] Such organismic theories were extremely controversial,[63] but Clements' basic theory of succession and climax dominated American ecology throughout the first half of the twentieth century.[64] The idea of climax coincided nicely with the field observations of those biological scientists who were increasingly taking up residence in the more newly settled regions of the country and who, because they could obtain little historical data about landscape changes in their areas, had to rely on snapshot observations, the value of which would be enhanced if it could be assumed that the natural areas that they observed were representative of a permanent climax condition.[65]

Like Darwinian evolution, Clementsian ecology almost begged to be translated into sociology.[66] Were human communities, like plant communities, passing through succession in a natural process that would end in a stable state of equilibrium? Social scientists seized on this idea almost as readily as they had adapted the Darwinian struggle as their own.[67] Science, they believed, could assist society through

61. KEIR B. STERLING, LAST OF THE NATURALISTS: THE CAREER OF C. HART MERRIAM 270-97 (1974). *See also* WORSTER, *supra* note 5, at 195-96.

62. Clements believed "the community is a complex organism of a wholly different order from the individual plant or animal, but nevertheless an organic entity with functions and structure." FREDERIC E. CLEMENTS, DYNAMICS OF VEGETATION 247 (B.W. Allred & Edith S. Clements eds., 1949). Many, but not all, American specialists in animal ecology supported Clements' theories, and one group at the University of Chicago argued that "ecological interdependence symbolized Nature's overall tendency to evolve in the direction of greater integration, a tendency that was continued by the development of more co-operation in human society." BOWLER, *supra* note 58, at 527-28. *See generally* GREGG MITMAN, THE STATE OF NATURE: ECOLOGY, COMMUNITY AND AMERICAN SOCIAL THOUGHT, 1900-1950 (1992) (discussing the Chicago school of animal ecologists).

63. WORSTER, *supra* note 5, at 317-38.

64. GOLLEY, *supra* note 18, at 23-24; MCINTOSH, *supra* note 6, at 82-83. Clements' ideas were less popular in Europe. "From a European perspective it seemed ridiculous to speak of natural climaxes that were inherently superior to any other form of vegetation in the region. Many of the most stable European environments were maintained by constant human activity." BOWLER, *supra* note 58, at 525.

65. FREDERIC E. CLEMENTS, PLANT SUCCESSION 98-99 (1916) ("The progressive invasion typical of succession everywhere produces stabilization . . ." and an "increase of dominance, culminating in a stable climax. . . . Such a climax is permanent because of its entire harmony with a stable habitat."). *See* WORSTER, *supra* note 5, at 197-206; MCINTOSH, *supra* note 6, at 77; GOLLEY, *supra* note 18, at 23-24.

66. WORSTER, *supra* note 5, at 319-24.

67. Organismic theories were not new. Herbert Spencer and some of the Social Darwinists also viewed human society as similar to an organism. STOW PERSONS, AMERICAN MINDS: A HISTORY OF IDEAS 227-28 (1958). And the "technocracy" movement that began in the 1920s was allied with organismic ecology. *See* Taylor, *supra* note 26, at 234-36.

"regional planning, based upon economic analysis" that would prevent those activities that might disrupt the natural equilibria and thereby ensure "a truly sound economic layout of the metropolis."[68] A human ecology movement began to gain adherents in the 1920s.[69] It provided an intellectual rationale for legal systems created to organize human use of land that became popular during this period.[70] If there was a permanent ideal use for every piece of land, the law ought to give that use a protected status and throw up roadblocks to activities that would conflict with that use.[71] This climax condition became equated in the law with the term "highest and best use," which became a key concept in the development of land use law during this period.[72]

The 1920s, in particular, provided conditions quite receptive to an idea based on natural progress toward a stable state. Rapid advances in technology were changing people's lifestyles at an unprecedented

68. Robert M. Haig, *Toward an Understanding of the Metropolis: The Assignment of Activities to Areas in Urban Regions,* 40 Q. J. ECON. 402, 434 (1926). *See also* HARVEY W. ZORBAUGH, THE GOLD COAST AND THE SLUM 272-73 (1929); SEYMOUR I. TOLL, ZONED AMERICAN 195-98 (1969).

69. *See* ROBERT E.L. FARIS, CHICAGO SOCIOLOGY, 1920-1932 (1967); FRED H. MATTHEWS, QUEST FOR AN AMERICAN SOCIOLOGY: ROBERT E. PARK AND THE CHICAGO SCHOOL (1977); AMOS H. HAWLEY, HUMAN ECOLOGY (1986).

70. The human ecologists looked at the city as if it were a living thing. University of Chicago sociologist Robert Ezra Park thought of the city as a "kind of psychophysical mechanism" that "possesses a moral as well as a physical organization" and has a "life quite of its own." Robert E. Park, *The City: Suggestions for the Investigation of Human Behavior in the Urban Environment, in* THE CITY 1, 2-4 (Robert E. Park et al. eds., 1925). He believed that personal tastes and convenience, vocational and economic interests "infallibly tend to segregate and thus to classify the populations of great cities," so that the city "acquires an organization and distribution of population which is neither designed nor controlled." *Id.* at 5. The human ecologists saw urban development as a process by which "a uniform cost type of structure" gradually dominates a neighborhood and eliminates any other types that vary widely from the norm, and they called such neighborhoods "natural areas," borrowing the term from plant ecology. Roderick D. McKenzie, *The Ecological Approach to the Study of the Human Community, in* THE CITY, *supra,* at 77. Another of Park's colleagues, Ernest W. Burgess, delved deeply into biological symbolism in his description of urban growth as a result of "organization and disorganization analogous to the anabolic and katabolic processes of metabolism in the body." Ernest W. Burgess, *The Growth of the City: An Introduction to a Research Project, in* THE CITY, *supra,* at 47, 53. The constant changes taking place he called "mobility," which was "a measure both of expansion and metabolism, susceptible to precise quantitative formulation, so that it may be regarded almost literally as the pulse of the community." *Id.* at 61. This mobility caused the inevitable "invasion" of neighborhoods, just as one plant community invaded another in a process known as succession. *Id. See also* Robert E. Park, *Succession, an Ecological Concept,* 1 AM. SOC. REV. 171 (1936).

71. *See, e.g.,* Olson v. United States, 292 U.S. 246, 255-56 (1934). *See also* Jeremy Paul, *The Hidden Structure of Takings Law,* 64 S. CAL. L. REV. 1395, 1472-73 (1991).

72. *See* JULIUS L. SACKMAN & PATRICK J. ROMAN, NICHOLS' THE LAW OF EMINENT DOMAIN § 12B.12, at 107, 120-28 (3d ed. 1990) ("Evidence may be adduced showing only the naturally adapted uses of the property in its present condition. The owner's actual plans or hopes for the future are completely irrelevant. . . . [I]n determining market value, consideration may be given to the highest and best available use, although property is not so used at the time of the taking. . . .").

pace.[73] The illusion of permanent prosperity and peace led many people to believe that wars and depressions were things of the past.[74] Demographers projected that the need to accommodate high rates of population growth was over, and that the country's total population might even begin to drop as the year 2000 arrived.[75] The Progressive conservationists had achieved enough success that the concern over loss of natural resources was alleviated and the goal of stable and renewable resources seemed realistic.[76]

The idea of national planning to identify future equilibria began in the heady atmosphere of 1920s confidence.[77] President Hoover, who combined an entrepreneur's admiration for private initiative with an engineer's love for big plans, began the process of natural resources planning even before he took office.[78] Wesley Mitchell, the Columbia economist who headed what today we would call Hoover's transition team, called for the development of a technique of balance to keep production and both natural and human resources in equilibrium.[79]

Hoover promoted the idea of zoning, which was perceived at that time as a way of identifying and perpetuating the climax condition of human communities.[80] Throughout the United States, city after city prepared plans that projected a future use of every parcel of land in

73. The increasing availability of automobiles in the 1920s brought about a mass migration of city dwellers to new homes in newly created suburban communities designed to embody a permanent "climax" of idyllic residential life. *See, e.g.*, KENNETH T. JACKSON, CRABGRASS FRONTIER: THE SUBURBANIZATION OF THE UNITED STATES 174-77 (1985); SCOTT DONALDSON, THE SUBURBAN MYTH 35-36 (1969); ROBERT FISHMAN, BOURGEOIS UTOPIAS: THE RISE AND FALL OF SUBURBIA 156-58 (1987).

74. " 'Here stands our country, an example of tranquility at home, a patron of tranquility abroad,' said President Coolidge on March 4, 1925." ROGER BUTTERFIELD, THE AMERICAN PAST 390 (1957).

75. MEL SCOTT, AMERICAN CITY PLANNING SINCE 1890, at 271-72 (1969).

76. CLEMENTS, *supra* note 62, at 254-57. *See generally* STEPHEN FOX, JOHN MUIR AND HIS LEGACY: THE AMERICAN CONSERVATION MOVEMENT 148-82 (1981).

77. Peter L. Abeles, *Planning and Zoning, in* ZONING AND THE AMERICAN DREAM 122, 127 (Charles M. Haar & Jerold S. Kayden eds., 1989); M. CHRISTINE BOYER, DREAMING THE RATIONAL CITY: THE MYTH OF AMERICAN CITY PLANNING 221 (1983).

78. *See* BOYER, *supra* note 77, at 146-47; SCOTT, *supra* note 75, at 273-78. Hoover's view of the role of government reflected many of the same "progressive" ideas that Pound had espoused. HERBERT HOOVER, THE MEMOIRS OF HERBERT HOOVER: THE CABINET AND THE PRESIDENCY, 1920-1933, at 167-68 (1952). Hoover had an interest in conservation that stemmed from a lifelong love of fishing. *See* FOX, *supra* note 76, at 168.

79. SCOTT, *supra* note 75, at 273-74.

80. Laurence C. Gerckens, *Historical Development of American City Planning, in* THE PRACTICE OF LOCAL GOVERNMENT PLANNING 21, 39-40 (Frank S. So et al. eds., 1979). *See* RICHARD F. BABCOCK, THE ZONING GAME 116-20 (1966); BOYER, *supra* note 77, at 69, 79, 141, 152-53.

their jurisdiction.[81] Some neighborhoods were seen as climax communities that needed protection, while others were merely in a transitional state where further succession was to be encouraged.[82] Frank Lloyd Wright's Broadacre City typified the idealized and permanent environment toward which Americans were taught to aspire.[83] End-state planners issued the "Plan for the year X" as if once X arrived the process of change would end.[84]

The economic depression that began the thirties extinguished the optimism with which national planning began, but with the election of Franklin Roosevelt in 1932, planning efforts were redoubled.[85] Although unemployment was his most immediate concern, Roosevelt had a lengthy background in conservation and saw a great need for balanced management of natural resources.[86] The first dramatic project of the New Deal, the Civilian Conservation Corps, was in theory an effort to use surplus labor to increase the renewability and stability of natural resources.[87] On a much larger scale, Roosevelt saw regional planning as the way to provide long term stability for entire regions; the Tennessee Valley Authority was to be the prototype that merged the flexibility of the independent corporation with the power of government to create a region in which both the natural and social resources would be managed in equilibrium.[88]

Harold Ickes, who served as Secretary of the Interior during virtually the entire Roosevelt administration, oversaw numerous innova-

81. Charles M. Haar, *The Social Control of Urban Space, in* CITIES AND SPACE: THE FUTURE USE OF URBAN LAND 175, 200 (Lowden Wingo, Jr. ed., 1963) ("Rather than dictating what the planner deems to be desirable—which seems to be a common misconception among the laity—the aim of planning may be to eliminate the inefficiencies of the market mechanism.").

82. NATIONAL COMMISSION ON URBAN PROBLEMS, BUILDING THE AMERICAN CITY 203-04 (1968). *See* DANIEL R. MANDELKER, THE ZONING DILEMMA 59-63 (1971); Abeles, *supra* note 77, at 127.

83. William H. Wilson, *The Ideology, Aesthetics and Politics of the City Beautiful Movement, in* THE RISE OF MODERN URBAN PLANNING, 1800-1914, *supra* note 25, at 165, 185.

84. F. STUART CHAPIN, JR. & EDWARD J. KAISER, URBAN LAND USE PLANNING 91 (3d ed. 1979) ("The land use plan has been the traditional focus of land use planning and . . . presents a future land use pattern as a goal form."). *See also* HARVEY S. PERLOFF, PLANNING THE POST-INDUSTRIAL CITY 182-87 (1980). For more recent critiques of end-state planning, see MELVILLE C. BRANCH, CONTINUOUS CITY PLANNING 41-92 (1981); Carol M. Rose, *Planning and Dealing: Piecemeal Land Controls as a Problem of Local Legitimacy,* 71 CAL. L. REV. 839, 874-98 (1983).

85. SCOTT, *supra* note 75, at 300-11.

86. *See generally* 1, 2 FRANKLIN D. ROOSEVELT & CONSERVATION, 1911-1945 (Edgar B. Nixon ed., 1957) [hereinafter ROOSEVELT & CONSERVATION]. Roosevelt's policies for range and forest land are analyzed in SAMUEL T. DANA & SALLY K. FAIRFAX, FOREST AND RANGE POLICY 142-78 (2d ed. 1980). *See also* FOX, *supra* note 76, at 183-217.

87. ARTHUR M. SCHLESINGER, JR., THE AGE OF ROOSEVELT: THE COMING OF THE NEW DEAL 335-41 (1959).

88. 2 ROOSEVELT & CONSERVATION, *supra* note 86, at 613-15. *See* SCHLESINGER, *supra* note 87, at 319-34.

tions directed toward the stabilization of the nation's resources.[89] The Taylor Grazing Act was intended to correct overuse of the public range lands to ensure that they remained a renewable resource.[90] The National Park Service's role was greatly expanded and large areas of climax forest were designated as primitive areas.[91] And the Natural Resources Planning Board was designed to provide an overall plan for the functioning of the various programs.[92]

The 1930s also brought innovations in the Agriculture Department: The renewability of resources (which today would be called sustainable development) became a key objective of the Forest Service.[93] And as the drought of the period heightened the concern over soil erosion, agricultural scientists searched for ways to perfect the means of agricultural production so that farming areas could achieve the artificial equivalent of a climax state.[94]

Through all of these programs ran the thread of the holistic and almost mystical assumption of the perfectibility of nature that characterized Clementsian ecology.[95] Plans were not thought of as processes for adapting to change, but as visions of an ideal future that, once achieved, would avoid the need for additional change.[96] Like the builders of suburban residential communities or the planners of national parks, scientists of the day tended to emphasize the objective of stability rather than the need for adaptability to ongoing change.[97]

89. *See* FOX, *supra* note 76, at 200-03.

90. *See* WILLIAM L. GRAF, WILDERNESS PRESERVATION AND THE SAGEBRUSH REBELLIONS 141-53 (1990).

91. RONALD A. FORESTA, AMERICA'S NATIONAL PARKS AND THEIR KEEPERS 40-43 (1984). *See also* 1 ROOSEVELT & CONSERVATION, *supra* note 86, at 321-24. On the designation of primitive areas, see DONALD N. BALDWIN, THE QUIET REVOLUTION: GRASS ROOTS OF TODAY'S WILDERNESS PRESERVATION MOVEMENT 203 (1972).

92. 2 ROOSEVELT & CONSERVATION, *supra* note 86, at 323-25. *See* BOYER, *supra* note 77, at 217-25. For insight into the politics surrounding the creation of the board, see HAROLD L. ICKES, THE SECRET DIARY OF HAROLD L. ICKES: THE FIRST THOUSAND DAYS, 1933-1936, at 171-72 (1953).

93. MARION CLAWSON ET AL., LAND FOR THE FUTURE 298 (1960). On the New Deal approach to forestry, see HENRY CLEPPER, PROFESSIONAL FORESTRY IN THE UNITED STATES 147-51 (1971). *See also* J. Douglas Helms, *Walter Lowdermilk's Journey: Forester to Land Conservationist,* 8 ENVTL. REV. 133 (1984).

94. "The ultimate objective of national action" is "a secure land resource, adequate permanently to sustain the national economy. . . ." HUGH H. BENNETT, SOIL CONSERVATION 313 (1939). For the impact of the switch from cattle to wheat in the sand hill region of Clements' home state, see PAUL B. SEARS, DESERTS ON THE MARCH 53-58 (1949). Clements saw the decline of his native state as evidence of the failure to pay attention to the principles of ecology. WORSTER, *supra* note 5, at 235.

95. JOHN PASSMORE, MAN'S RESPONSIBILITY FOR NATURE 173-74 (1974).

96. CLEMENTS, *supra* note 62, at 254-57. *See* SCOTT, *supra* note 75, at 349-52.

97. GOLLEY, *supra* note 18, at 24-26. For example, wildlife was to be protected through the creation of "refuges" that would be "inviolate sanctuaries" forever. Richard J. Fink, *The Na-*

III.

The idea that the plants and animals living in a particular area formed an interdependent community was a dramatic breakthrough at the beginning of the twentieth century when most people had been educated to differentiate elements of the biota only by the place of the individual species on the "great chain of being." By the 1930s, however, some ecologists began to question whether even Clements and the other community ecologists had been thinking on too small a scale. Still, the idea of a stable, functioning system remained.

The concept of an ecosystem as a functioning, holistic, and inherently stable system vulnerable to serious and long-term insults from a wide variety of human activities drives the biodiversity branch of modern environmental law as well as a substantial part of the case against toxic pollutants. This ecosystem focus defined the distinctiveness of ecology as a science and provided a concrete, visible rationale for environmental regulation. The story of the idea's triumph is a fascinating example of the power of paradigms which resonate with deeply held non-scientific values to capture the imagination of scientists. It is also a story of the strengths and weaknesses of tying regulatory justifications and resource management programs to science when the science is still in the theoretical and experimental stage.

The ecosystem paradigm replaced Clements' theory that plant communities were an organism rather than a system of individual plants responding to various stimuli. A British ecologist floated the ecosystem concept as a theory in 1935, and within fifteen years it became an established scientific paradigm.[98] Sir Alfred George Tansley, a distinguished Oxbridge ecologist and longtime friend and follower of Clements, was impressed with the progress of physics at the Cavendish Laboratory in Cambridge and proposed a conception, the ecosystem, to focus the science on a system which permitted nonprogressive vegetational change. "From Tansley's new 'systematic' point of view, systems—not organisms—underwent evolution."[99] An ecosystem was defined as "the whole *system* (in the sense of physics), including not only the organism-complex, but also the whole complex of physical factors forming what we call the environment of the biome—the

tional Wildlife Refuges: Theory, Practice, and Prospect, 18 HARV. ENVTL. L. REV. 1, 13-15 (1994).

98. The scientific story is told in GOLLEY, *supra* note 18.

99. TOBEY, *supra* note 12, at 177.

habitat factors in the widest sense."[100] Succession became a process rather than an end-state.

Tansley's shift from an organism to a system also carried with it the longstanding scientific belief that systems tended toward equilibrium.[101] The idea of a "holistic . . . ecological concept that combined living organisms and the physical environment into a system"[102] was a theory in the grand scientific tradition: it was not based on field observations. Two American ecologists, Ralph Lindeman and Eugene Odum, took the next step and made Tansley's theory operational. In so doing, they paved the way for the shift in environmental discourse from the aesthetic and spiritual to the scientific. The two modes of analysis had long been intertwined,[103] but the case for what we now call ecosystem preservation was primarily made on aesthetic or moral grounds. For example, in a 1930 article, *Wilderness Esthetics,*[104] Robert Marshall, one of the major proponents of wilderness preservation, contrasted the "dynamic beauty" of primitive areas to the static beauty of a Gothic cathedral and argued that "wilderness furnishes perhaps the best opportunity for pure esthetic enjoyment."[105]

The ecosystem concept was made operational in Madison, Wisconsin—a historic center of applied progressivism in the United States. A University of Wisconsin ecologist, Ralph Lindeman, applied the ecosystem concept to the study of a Wisconsin lake and developed the building blocks of modern ecology "such as food webs, food chains, trophic levels, productivity, metabolism, energy flow, and ecological succession."[106] Lindeman posited that if one determined the food habits, feeding coefficients, metabolism and growth of the dominant species in an ecosystem, one could extrapolate to all species, especially rare ones. Lindeman's research has since been criticized as overly simplistic and taxonomic,[107] but the ideas that the trophic func-

100. GOLLEY, *supra* note 18, at 8.

101. TOBEY, *supra* note 12, at 179.

102. GOLLEY, *supra* note 18, at 8.

103. Tansley was equally at home among philosophers and nature writers. A former student of his has observed, "if you scratch a biologist you will find a philosopher." Sir Harry Godwin, *Sir Arthur Tansley: The Man and the Subject,* 65 J. ECOLOGY 1, 23 (1977). More generally, ecology has always had to grapple with the tension between its status as a pure, thus neutral, science and the argument that ecological understanding is value laden and thus ecologists have the right (and perhaps the duty) to apply their insights to law and public policy. *See* MCINTOSH, *supra* note 6, at 308-23.

104. Robert Marshall, *Wilderness Esthetics, reprinted in* A DOCUMENTARY HISTORY OF CONSERVATION IN AMERICA 78 (Robert McHenry & Charles Van Doren eds., 1972).

105. *Id.* at 80.

106. GOLLEY, *supra* note 18, at 76.

107. *Id.* at 77.

tion is central to understanding a system and that all biological events could be reduced to energy flow were a powerful innovation.[108] It greatly influenced post-World War II ecologists[109] such as Eugene Odum who "perfected" and popularized it in the 1950s and 1960s.

IV.

A. Equilibrium Theory Circa 1968

To supplement the spiritual basis of the movement, environmentalism and environmental law quickly borrowed 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' theory of external costs 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 made a major contribution to environmentalism but ecology is *primes internus* because 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 nonhomocentric ethic,[110] but this effort has at best only reinforced science's claim that there are important practical reasons for society to worry about the magnitude of human-caused ecosystem disturbance.

In the late 1960s, the perceived teachings of ecology were quickly and uncritically incorporated into environmental law and management. Modern environmentalism was a visceral reaction to visible and spectacular pollution insults and public works projects that destroyed natural areas. National conservation group opposition to multiple purpose dams in the 1950s paved the way for environmentalism, but the movement lacked a scientific theory or any theory for that matter. It achieved political and popular success on neo-pagan theories that

108. *See* McIntosh, *supra* note 6, at 196-97.

109. *See* Robert E. Cook, *Raymond Lindeman and the Trophic-Dynamic Concept in Ecology*, 198 Science 22 (1977).

110. *E.g.*, J. Baird Callicott, In Defense of the Land Ethic (1989).

nature—at least the landscape of the western part of the United States—was divine.[111]

The adoption of ecology as the ground norm of environmentalism and environmental law bears close examination because of dramatic changes in ecology since its initial incorporation into environmental law. There is a long and troubled history of the application of science to natural resources management in this country,[112] but in 1968 ecology offered the hope of coherent and rational resources management which had eluded society in the past. Four individuals—a wildlife manager, Aldo Leopold, the leading ecologist of the post World War II generation, Eugene Odum, along with his equally distinguished ecologist brother Howard, and political scientist, Lynton K. Caldwell—played leading roles in the popularization of ecological ideas. Professor Caldwell's creative contribution, the National Environmental Policy Act,[113] is the most enduring legal application of ecology. NEPA is the first piece of federal legislation to raise ecology to a star status. The concept of environmental assessment, along with risk assessment, remains one of the few innovative operational ideas of environmental law. It rests on the premise that ecology could provide the rationality to guide administrative action.

In the late 1960s, ecology was an under-funded low status science out of step with the reductionism of biology, 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.[114] Tansley crystallized the concept of "relatively stable dynamic equilibrium" in 1935,[115] and Aldo Leopold popularized it in his posthumous *A Sand County Almanac.*[116] In turn, these ideas drew on the image of balanced nature which was central to both the Christian and Enlightenment world view.[117] For example, the idea of the balance of nature

111. The connection between John Muir's strict Presbyterian upbringing and his subsequent nature worship has been noted by his biographers. *E.g.*, STEPHEN FOX, THE AMERICAN CONSERVATION MOVEMENT: JOHN MUIR AND HIS LEGACY (1981).

112. *See* GRAF, *supra* note 90.

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

114. 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. Kenneth E. Boulding, *Economics and Ecology, in* FUTURE ENVIRONMENTS OF NORTH AMERICA 225, 226 (F. Fraser Darling & John P. Milton eds., 1966).

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

116. ALDO LEOPOLD, A SAND COUNTY ALMANAC AND SKETCHES HERE AND THERE (1949).

117. *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

radically disturbed by human intervention was the message of Rachel Carson's indictment of chemical pesticides, *Silent Spring,*[118] the book perhaps most responsible for the environmental movement.[119]

Interestingly, Roscoe Pound and ecology were once again joined in the late 1960s. Pound's theory of interest recognition helped pave the way for environmentalism to take its place among traditional interests such as the conservation of natural resources. Science was used to define the environmental interest to be protected, although ironically Clements was not the source of the science. Pound's theory of the displacement of rights by interests formed the jurisprudential basis of environmental protection but an ecological underpinning was necessary to make it work. Interest analysis is crucial to environmental protection, because it rests neither on common law nor constitutional rights, but on the theory that the careful study of science can provide rational answers to management problems.

During the New Deal, resource managers slowly realized that there was some trade-off between development and non-development interests. The latter—usually denominated fish and wildlife or aesthetic values—were legitimate interests. However, they were clearly subordinated to maximum economic development of our natural resources for two reasons. The adverse consequences of unlimited development were at best partially understood and thus were easy to discount and it was difficult to measure non-economic interests. Ecology helped to place environmental interests on an equal and sometimes higher position in interest balancing. Ecology was very much part of the optimistic efforts of the physical and social sciences to develop technocrat models of complex systems that would allow society to avoid the irrational horrors of the modern world.[120]

environmental law in his 1975 Addison Harrison lectures at Indiana University, Bloomington. Charles J. Meyers, *An Introduction to Environmental Thought: Some Sources and Some Criticisms,* 50 IND. L.J. 426 (1975).

118. RACHEL CARSON, SILENT SPRING (1962) (especially ch. 6, *Earth's Green Mantle*).

119. In his expansion of his path-breaking contribution to the environmental movement, 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 NEXT GENERATION 200 (1988). For a more detailed review of her contribution to the environmental movement, which reaches the same conclusion, see Linda J. Lear, *Rachael Carson's Silent Spring,* 17 ENVTL. HIST. REV. 23 (1993).

120. Peter J. Taylor develops this analysis in Peter J. Taylor, *Technocratic Optimism, H.T. Odum, and the Partial Transformation of the Ecological Metaphor after World War II,* 21 J. HIST. BIOLOGY 213 (1988). The roots of this optimism lie in the efforts to develop universal social "laws" to match social progress with the economic progress that technology supported by science brought Europe in the 18th and 19th century. The story has been told many times. *See, e.g.,*

Eugene Odum made an important extension of ecosystem theory by providing a general theory of ecosystem development and function.[121] Perhaps more important for the subsequent development of environmental law, he was understandable to an informed lay audience. Odum was the ecologist most read by the small group of social scientists, lawyers and others who developed the first generation of environmental regulation in the unique political environment of the late 1960s and '70s between the end of the anti-war movement and Watergate and the OPEC oil embargo.[122] "Environmentalists seized upon the ecosystem concept as a way to maintain their faith in holism"[123] and to shore up their rapid political success with a universal scientific justification.

For the non-scientist seeking wisdom in the late 1960s, Eugene Odum's widely used and read textbook, *Fundamentals of Ecology,* introduced policy makers and non-scientists to the potential of ecology. Odum's brother, Howard, took Lindeman's trophic level theories and reduced them to mechanical theories, linked to the hard sciences, of how ecosystems function.[124] Eugene used the pyramidal model of the food chain in an ecosystem to develop a powerful theory that ecosystems were greater than the sum of their parts and inevitably progressed to steady states through the processes of climax and succession. Odum's text provided an elegant, scientific neo-Kantian principle upon which environmental regulation and assessment could rest:

> 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.[125]

In retrospect, it is clear that ecology was not ready for its starring role.[126] At the time, however, policy makers accepted the theory un-

GERHARD MASUR, PROPHETS OF YESTERDAY: STUDIES IN EUROPEAN CULTURE, 1890-1914 (1961).

121. In Donald Worster's words, ecosystem development "ends in the happy state of order." Donald Worster, *The Ecology of Order and Chaos, in* THE WEALTH OF NATURE: ENVIRONMENTAL HISTORY AND THE ECOLOGICAL IMAGINATION 156, 160 (1993).

122. *See id.* at 156-61.

123. GOLLEY, *supra* note 18, at 3.

124. "In the ecosystem model, species acted abstractly, like robots." GOLLEY, *supra* note 18, at 106.

125. EUGENE P. ODUM, *in collaboration with* HOWARD T. ODUM, FUNDAMENTALS OF ECOLOGY 25 (2d ed. 1959).

126. For example, little attention was given to the role of mathematical population ecology in Odum's thinking. This problem is central to the science because Odum had long acknowledged

critically. Some ecologists made it easy to ignore the debate especially in the 1960s when they aspired to turn ecology into a big, mathematically based science like physics or molecular biology.[127] The regulatory implications of ecology were enthusiastically suggested by the Ecological Society of America, which represented that ecologists had the ability to deliver the requisite science to balance nature. In a unique Joint House-Senate Colloquium, which laid the foundation for the National Environmental Policy Act of 1969, the Society's public affairs committee prophesied that "ecology is ready for rapid growth and development . . . ."[128] The committee report was also not shy about the social utility of the science. "When 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."[129] The promise of ecology was embraced by a professor of public administration at Indiana University at Bloomington, Lynton K. Caldwell, who became the principal drafter of the National Environmental Policy Act. In a series of influential articles in the 1960s,[130] he suggested that qualitative environmental standards could provide the administrative coherence historically lacking in natural resources policy.

We can now more clearly understand that Odum's theory of ecosystem equilibrium is one of the last gasps of 19th century deterministic science and was more descriptive than integrative. It was a sophisticated and nuanced extension of Clements' theory of plant communities as stable superorganisms as the consequence of a series of successional stages leading to a superorganistic permanent climax.[131] In elite science, deterministic theories had already been replaced by probabilistic ones but the shift came late to biology and

the tension between this branch of ecology's reductionist approach and his holistic theory of the ecosystem. *See* MCINTOSH, *supra* note 6, at 200-01.

127. One manifestation of this ambition was the unfortunate separation of ecology into two camps, the theoretical modelers and the experimental or field researchers, beginning in the 1930s. Peter Kareiva traces this split in Peter Kareiva, *Reviewing the Dialogue between Theory and Experiments in Population Ecology, in* PERSPECTIVES IN ECOLOGICAL THEORY 68 (Jonathan Roughgarden et al. eds., 1989).

128. *Joint House Senate Colloquium to Discuss A National Policy for the Environment: Hearing Before the Senate Comm. on Interior and Insular Affairs and the Comm. on Science and Astronautics*, 90th Cong., 2d Sess. 154 (1968).

129. *Id.* at 157.

130. *E.g.*, Lynton K. Caldwell, *Administrative Possibilities for Environmental Control, in* FUTURE ENVIRONMENTS OF NORTH AMERICA, *supra* note 114, at 648.

131. *See* Edward Goldsmith, *Ecological Succession Rehabilitated,* 15 ECOLOGIST 104, 108-09 (1985). The most readable history of modern ecology is WORSTER, *supra* note 5.

even later to ecology.[132] Ecologists reported varying levels of indeterminate results testing the paradigm, but many scientists glossed over them because of an extreme case of "physics-envy."[133] The point for lawyers is that this internal debate was missed in the rush to implement Leopold's dictum to "think like a mountain" in the heady days of the rise of environmentalism.[134]

After the equilibrium paradigm was incorporated into environmental law and policy, the science of ecology grew exponentially. Ambitious theoretical models were developed to explain how ecosystems functioned and large-scale field tests were funded. The ecosystem remained the organizing unit which generated much useful scientific knowledge, but the science did not develop the generalizable, predictive information demanded by the environmental regulatory programs put in place in the 1970s.[135] Cracks in Odum's steady-state theories began to appear.[136] However, once the basic structure of environmental regulation was put in place in the 1970s, little attention was paid to the problems that the discipline was experiencing moving from theory to scientifically and socially useful information. The acceptance of risk as a basis for regulating toxic substances made it easy to justify regulation in advance of scientific knowledge.[137]

Environmental regulation transformed ecology from a science to a moral vision of nature. After 1968, ecological-driven environmentalism fundamentally changed the way in which the world is viewed and the standards by which human action is judged. It raised

132. Daniel Simberloff traces this shift of ecology from deterministic to probabilistic theories in his path-breaking paper Daniel Simberloff, *A Succession of Paradigms in Ecology: Essentialism to Materialism and Probabilism, in* CONCEPTUAL ISSUES IN ECOLOGY 63 (Esa Saarinen ed., 1982).

133. Joel E. Cohen, *Mathematics as Metaphor,* 172 SCIENCE 674 (1971) (reviewing ROBERT ROSEN, DYNAMICAL SYSTEM THEORY IN BIOLOGY (1970)). 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.

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

135. *See* MCINTOSH, *supra* note 6, at 193-241, for a survey of the effort to develop systems ecology in the 1960s and 70s.

136. For example, in the famous Hubbard Brook study, which developed the biomass accumulation model, the researchers found that "data showed that the steady-state or 'mature' (climax) stage of forest development has higher nutrient losses than earlier stages, contrary to the suggested trend that the later or stable stages should have minimum nutrient loss." *Id.* at 207.

137. *See* FREDERICK R. ANDERSON ET AL., ENVIRONMENTAL PROTECTION: LAW AND POLICY 493-556 (1990) for the legal and political history of the partial substitution of risk for proof of cause in fact as a justification for toxic substances regulation.

the idea of ecological rationality to parity with economic rationality and thus fatally wounded the western idea that man had a duty to master nature.[138] In the process, the homestatis paradigm was transformed into an unquestioned and ethical principle. In the meantime, the science of ecology rejected the paradigm, but lawyers and policy makers have only begun to catch-up with post Odum-NEPA ecology.

B. The Non-Equilibrium Paradigm Arrives

Since its incorporation into environmental law and policy, the equilibrium paradigm has undergone a Kuhnian revolution.[139] Equilibrium was flawed from the start but until recently many scientists and policy makers thought that the problem was the lack of necessary data rather than in the paradigm itself. The alternative paradigm was not clearly articulated and widely accepted until the 1980s. With pockets of resistance, the equilibrium paradigm has been replaced with more hard-edged probabilistic theories of non-equilibrium. These theories potentially undermine much of the resources management, or in modern terms, biodiversity preservation strategies of classic environmental law based on the theory that it is enough to isolate ecosystems of human contamination. Once again, ecology is following physics as it owes much to chaos theory. Non-equilibrium ecology rejects the vision of a balance of nature. Change and instability are the new constants. Further, it rejects the Romantic idea that nature should be a place without humans and returns to the problem posed by 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.[140] His basic argument is that the images of nature which have influenced ecology are static when in fact the kinds of problems that we face require a dynamic view of nature, which 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

138. *See* Robert V. Bartlett, *Ecological Rationality: Reason and Environmental Policy,* 8 ENVTL. ETHICS 221 (1986).

139. THOMAS S. KUHN, THE STRUCTURE OF SCIENTIFIC REVOLUTIONS (1962).

140. BOTKIN, *supra* note 117. Interestingly, the book seems to have attracted little attention in the scientific journals when it was first published, with the exception of a laudatory review by a physicist. James Trefil, *Natural Changes,* 41 BIOSCIENCE 176 (1991) (reviewing BOTKIN, *supra* note 117).

time.[141] The accelerating interaction between humans and the natural environment makes it impossible to return to an ideal state of nature.[142] At best, ecosystems can be managed rather than restored or preserved, and management will consist of series of calculated risky experiments. "[N]ature moves and changes and involves risks and uncertainties and . . . our judgments of our own actions must be made against this moving image."[143]

As one ecologist recently commented, "The idea [of balance of nature] makes good poetry but bad science."[144] The best evidence of this paradigm shift is a short but extremely influential list, *20 Great Ideas for Ecology for the 1990s*, published in 1992 by no less than Eugene P. Odum,[145] the distinguished ecologist who is more responsible than any other for implanting in the minds of lawyers and policy makers the idea that natural systems tend toward equilibrium if left undisturbed. The first and over-arching great idea states that "an ecosystem is a thermodynamically open, far from equilibrium system."[146] The others are either a specific application of the non-equilibrium principle or policy prescriptions to implement good management—commentary as it were on the first principle. Adherents of the non-equilibrium paradigm have pioneered a sophisticated new applied science, conservation biology, to protect ecosystems from human insults.[147] Conservation biology is a regulatory science, driven mainly by the need to preserve endangered species, which seeks to develop scientific standards that can be applied to regulatory criteria and then to develop on-the-ground management strategies to meet

141. Dean L. Urban et al., *Landscape Ecology*, 37 BIOSCIENCE 119 (1987).

142. The philosophical basis for the new ecology can be found in Bill McKibben's widely read *The End of Nature*, which argues the modern mind separates humanity from nature and thus the romantic visions of harmony between humanity and nature are impossible. BILL T. MCKIBBEN, THE END OF NATURE (1989).

143. BOTKIN, *supra* note 117, at 190.

144. *Quoted in* Wallace Kaufman, *How Nature Really Works*, AMERICAN FORESTS, Mar.-Apr. 1993, at 17, 18.

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

146. *Id.* Ironically, Odum cites the third edition of his classic text, EUGENE P. ODUM, BASIC ECOLOGY (1983).

147. The leading text is CONSERVATION BIOLOGY: AN EVOLUTIONARY-ECOLOGICAL PERSPECTIVE (Michael E. Soulé & Bruce A. Wilcox eds., 1980).

those standards.[148] The basic objective is to manage nature to mimic natural systems.[149]

This symposium addresses the potential impact of the non-equilibrium paradigm for environmental management. A distinguished group of scientists and lawyers discuss the theory and practice of non-equilibrium ecology and its potential legal implications. The basic question underlying all the papers is whether the non-equilibrium paradigm undermines the case for biodiversity protection or whether it both strengthens the case and makes it harder to achieve the objective. The new paradigm is the basis for the argument that since nature is in flux, human change is just another flux to be tolerated, although ecologists reject this argument because it undermines the functional, historical and evolutionary limits of nature.[150]

The Dance of Nature: New Concepts in Ecology, by Professor Judy Meyer of the Institute of Ecology at the University of Georgia, one of the world's most important centers of ecology research, examines the rise of the non-equilibrium paradigm. Landscapes are now viewed as shifting mosaics. The new paradigm does not justify human activity as natural, as some argue; rather it calls for a more sophisticated understanding of how ecosystems function and how they can be managed for environmental values. In *Some Principles of Conservation Biology, As They Apply to Environmental Law,* Reed Noss of the Universities of Idaho and Oregon State takes the non-equilibrium paradigm from theory to practice. A new applied-theoretical science, conservation biology, has emerged in the past fifteen years to maintain biodiversity in complex, often degraded ecosystems. His paper focuses on the principles that the discipline has developed for the design of habitat reserves to give threatened, endangered and stressed species a fighting chance to survive us.

In the third principal paper, *Sustaining ESD in Australia,* Helen Endre-Stacy, Lecturer in Law at Queensland University of Technology, takes a comparative and philosophical look at the potential application of the non-equilibrium paradigm to the management of all resources to promote environmental quality. Environmentalism's ini-

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

149. *See generally* CONSERVATION BIOLOGY: THE THEORY AND PRACTICE OF NATURE CONSERVATION PRESERVATION AND MANAGEMENT (Peggy L. Fiedler & Subodh K. Jain eds., 1992) [hereinafter CONSERVATION BIOLOGY].

150. Steward T.A. Pickett et al., *The New Paradigm in Ecology: Implications for Conservation Biology Above the Species Level, in* CONSERVATION BIOLOGY, *supra* note 149, at 65.

tial objective was to make environmental quality a relative factor to be considered. This battle has now largely been won and the movement's focus has shifted to the assured comprehensive and long-term integration, if not dominance, of this perspective in all resource decision making. The process has been a bitter and messy one because the choices have often been presented as environmental quality *or* economic development. Sustainable development has been floated as an idea to integrate these two choices, and the new ecology can inform both the scientific and philosophical bases of the concept. Using Australia's efforts to use environmentally sustainable development to come to grips with the social costs of its past policies of encouraging a mining and pastoral economy, Endre-Stacy applies the new ecology and postmodern legal theory to raise a number of profound and challenging questions about the future of environmentalism. For example, can western and neo-western legal systems, based on individual claims and the immediate discovery of truth, accommodate what Professor Meyer calls "natural connections in the landscape" and the constant scientific uncertainty promised by the non-equilibrium paradigm? What groups and communities can and should participate in the scientific, political and ethical debates about sustainable development and how should such participation be organized?

Three distinguished professors of environmental law comment on the legal implications of the principal papers by posing a series of hard questions which must be answered before we can use the insights of the new paradigm to better manage the world's resource base. Professor William Rodgers of the University of Washington's comment draws on his recent experience as chair of a National Research Council/National Academy of Sciences committee on federal land acquisition policies. *Adaptation of Environmental Law to the Ecologists' Discovery of Disequilibria* illustrates how the conception of landscapes as shifting mosaics collapses many of the traditional property categories we have used to acquire interests in land. The mosaic image also challenges the longstanding assumption that public land acquisition programs can acquire and maintain islands of ecological integrity free from adverse external influence. Professor Robert Keiter of the University of Utah has worked extensively with the frustrating problems of creating ecosystem management units out of fragmented public and private land patterns and management mandates and draws on that experience to suggest the full implications of conservation biology. *Conservation Biology and the Law: Assessing the Challenges Ahead* discusses the principal legal obstacles to implementing

Reed Noss' argument that biodiversity preservation should be our first land management priority. The comment outlines the powerful ideological and political factors that are currently locked in a battle to establish the ecosystem management concept as the dominant public land management paradigm or to preserve the nineteenth century vision of public lands as an endless commodity cornucopia, and the way in which this struggle manifests itself in litigation and federal land management initiatives. Professor Keiter concludes that both new statutory management mandates and reserve programs as well as the greater use of existing federal and state land management authority are needed to legitimize and to institutionalize the ecosystem management concept.

In the final comment, Professor Christopher Stone of the University of Southern California Law Center draws on his extensive writings in environmental ethics and international environmental law to ask about *Deciphering "Sustainable Development"*. The comment sharply challenges Professor Endre-Stacy's assumption that the sustainable development debates reflect an "intellectual chasm" between environmentalists and developers and argues instead that they reflect a clash of real and perhaps intractable interests, namely the rich and the poor, and that both interests are legitimate and must be accommodated. He proposes an alternative approach based on identifying common interests rather than changing the mode of discourse. Professor Stone finds that some of Endre-Stacy's proposals, such as local participation, promote consensus but that her idea of "unceasing dialogue" needs to be more fully articulated before it can serve as a guide to the promotion of environmental protection and sustainable development in many of the situations he identifies.