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A Chronological Frame of Reference for Ecological Integrity and Natural Conditions

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ABSTRACT

The concepts of biological integrity, environmental health, and naturalness are increasingly relevant to the management of conservation lands. Biological integrity and environmental health, integrated via the concept of "ecological integrity," imply the recognition of natural conditions. A holistic and adaptable approach to ascertaining natural conditions recognizes geological and evolutionary processes and the role of humans in modifying such processes. For policy purposes, a reasonable frame of reference for natural conditions extends from the beginning of the Medieval Warm Period at approximately 800 A.D. to the advent of the industrial economy approximately 1000 years later. Data sources for ascertaining natural conditions are primarily ethnographic, historic, archeological, and paleontological. This pre-industrial frame of reference for natural conditions acknowledges a fundamental transformation in the relationship of humans to nature corresponding with proliferation of the human economy at the competitive exclusion of nonhuman species in the aggregate. Ecological integrity remains at its highest level in areas where natural conditions have been least compromised, but some level of ecological integrity exists everywhere and may be maintained accordingly. Ultimately, ecological integrity relies on macroeconomic prudence.

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INTRODUCTION

The concepts of integrity, health, and naturalness are used to ascertain appropriate management strategies in national parks, forests, and rangelands.[1] In the United States, the impetus for considering these concepts comes from a variety of federal statutes. An early example is provided by the Clean Water Act of 1972,[2] the objective of which was "to restore and maintain the chemical, physical, and biological integrity of the Nation's waters."[3] The concepts of naturalness and health (environmental and human) featured prominently in the development of the Act,[4] which has had a major effect on federal and state land management.[5]

The National Wildlife Refuge System Improvement Act of 1997 (Improvement Act)[6] represents a more recent legislative application of these concepts. The Improvement Act charges the Secretary of the Interior with a responsibility to address 14 specific policy goals in the process of "administering the [Refuge] System" [7] (Table 1), including to ensure that the "biological integrity, diversity, and environmental health of the System are maintained for the benefit of present and future generations of Americans."[8] The U.S. Fish and Wildlife Service (FWS) has developed a policy for implementing this clause. The policy generally calls for the maintenance of biological integrity, diversity, and environmental health in an integrated fashion by using historic, non-degraded conditions as a frame of reference.[9]

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1. Bruce P. Van Haveren et al., *Restoring the Ecological Integrity of Public Lands*, 52 J. SOIL & WATER CONSERVATION 226, 226-31 (1997).
2. 33 U.S.C. §§ 1251-1387 (2000).
3. *Id.* § 1251(a).
4. *See generally* James R. Karr, *Health, Integrity, and Biological Assessment: The Importance of Measuring Whole Things, in* ECOLOGICAL INTEGRITY: INTEGRATING ENVIRONMENT, CONSERVATION, AND HEALTH 209 (David Pimentel et al. eds., 2000).
5. SUSAN J. BUCK, UNDERSTANDING ENVIRONMENTAL ADMINISTRATION AND LAW xi, 106-07 (2d ed., 1996).
6. Pub. L. No. 105-57, 111 Stat. 1252 (codified as amended at 16 U.S.C. § 668dd (2000)).
7. 16 U.S.C. § 668dd(a)(4) (2000).
8. *Id.* § 668dd(a)(4)(b).
9. Policy on Maintaining the Biological Integrity, Diversity, and Environmental Health of the National Wildlife Refuge System, 66 Fed. Reg. 3810 (Jan. 16, 2001).

Table 1: Condensed, paraphrased directions provided to the Secretary of the Interior in the National Wildlife Refuge System Improvement Act of 1997. The Secretary is mandated to ensure or conduct each of these "in administering the System."

1. conservation of fish, wildlife, and plants, and their habitats
2. maintenance of biological integrity, diversity, and environmental health
3. growth of the System pursuant to various criteria
4. primacy of refuge purposes over mission of the System
5. coordination and cooperation with landowners and states
6. maintenance of water quantity and quality
7. acquisition of necessary water rights consistent with state laws
8. prioritization of compatible wildlife-dependent recreational uses among public uses
9. opportunities for compatible wildlife-dependent recreational use
10. enhanced consideration of priority general public uses over other public uses
11. opportunities for families to experience wildlife-dependent recreation
12. permission for continued uses by other Federal agencies when necessary and prudent
13. collaboration with federal and state agencies during land acquisition and management
14. monitoring of populations of fish, wildlife, and plants

The phrase "ecological integrity" will henceforth be used to refer simultaneously to biological integrity, diversity, and environmental health; thus, the aforementioned clause in the Improvement Act may be referred to as the "ecological integrity clause." The ecological integrity clause has implications that extend far beyond the Refuge System. Interpretation and implementation of the ecological integrity clause will help frame debates over the concepts of biodiversity, biological integrity, environmental health, ecological integrity, and naturalness. The purpose of this article is to help refine these concepts.

BIOLOGICAL INTEGRITY, DIVERSITY, AND ENVIRONMENTAL HEALTH

The concepts of biological integrity, diversity, and environmental health have evolved in the last few decades of the twentieth century.[10] Each is broad with considerable overlap and the meaning of each phrase tends to change with context. The context

10. *See generally* JAMES R. KARR & ELLEN W. CHU, RESTORING LIFE IN RUNNING WATERS: BETTER BIOLOGICAL MONITORING (1998); Karr, *supra* note 4.

comprised by the Improvement Act has implications for concept definition that have not been faced heretofore. Prior authors have not, for example, been forced to consider the three concepts simultaneously for purposes of policy implementation. Rules of logic and canons of statutory construction suggest that each of the three concepts explicated in the ecological integrity clause are to be considered independently *for purposes of definition*.[11] Statutes do not generally use surplus or entirely redundant nouns to mandate a required condition.[12] Logic and cannons of construction imply that no independent element of the ecological integrity clause can subsume the other two. If, alternatively, Congress required the maintenance of "biological integrity, including biological diversity and environmental health," then it would be appropriate to define the concepts in terms of each other.

The importance of policy context in defining such terms was illustrated by an early disagreement about the phrase "biological diversity." For example, Angermeier and Karr stated, "Although some authors (*e.g.*, Noss 1990) explicitly include [biological] processes as components of diversity, we contend that processes are more appropriately considered as components of integrity." [13] Angermeier and Karr were considering several directives, some of which pertained explicitly to integrity (*e.g.*, Clean Water Act) and some of which pertained explicitly to diversity (*e.g.*, Global Biodiversity Protocol). Noss, meanwhile, had not been considering policies and programs beyond those centered on biodiversity (*e.g.*, Endangered Species Act).[14] If Noss had been forced to consider additional policies, he too may have distinguished diversity and integrity by including processes only in the latter.

In the case of the ecological integrity clause, three separate concepts must be considered simultaneously. The most appropriate set of definitions may not, therefore, correspond with definitions derived or used by authors who may have had only one or two of the concepts to consider (*e.g.*, Noss with biological diversity, Angermeier and Karr with biological diversity and biological integrity). The purpose of this section is to refine definitions such that the definition of any does not subsume the definition of either of the other two.

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11. *See generally* WILLIAM D. POPKIN, STATUTES IN COURT: THE HISTORY AND THEORY OF STATUTORY INTERPRETATION (1999).

12. FREDERICK REED DICKERSON, THE INTERPRETATION AND APPLICATION OF STATUTES 11–42 (1975).

13. Paul L. Angermeier & James R. Karr, *Biological Integrity Versus Biological Diversity as Policy Directives: Protecting Biotic Resources*, 44 BIOSCIENCE 690, 692 (1994).

14. *See generally* Reed F. Noss, *Indicators for Monitoring Biodiversity: A Hierarchical Approach*, 4 CONSERVATION BIOLOGY 355 (1990).

Biological Diversity

Meffe and Carroll defined biological diversity, or biodiversity, as "the variety of living organisms considered at all levels, from genetics through species, to higher taxonomic levels, and including the variety of habitats and ecosystems."[15] The FWS definition of biodiversity is slightly more comprehensive: "The variety of life and its processes, including the variety of living organisms, the genetic differences among them, and communities and ecosystems in which they occur."[16] It is conceivable, however, that the "processes" explicated in the FWS definition were implied by Meffe and Carroll. It is conversely conceivable that, if the Improvement Act had been anticipated, the FWS may have concurred with Angermeier and Karr that processes were more relevant to the concept of biological integrity than to the concept of biodiversity per se.

Species richness and diversity have been the most useful indicators of biodiversity, especially for public policy purposes. As Caughley and Gunn noted, "the idea of a species can be grasped intuitively by most people despite debate over the species concept."[17] Genetic diversity is served to an extent by species conservation because species are fundamental units of genetic distinction.[18] Furthermore, while ecosystems are defined in terms of composition, structure, and function,[19] species are entities of composition and contributors to structure and function. In one sense, any ecosystem that hosts an endangered species may be viewed as an endangered ecosystem because ecosystems are defined largely by their species.[20] None of this implies that the maintenance of biodiversity redounds simply to species conservation. The concept of biodiversity conservation via representation of vegetative communities, for example, is scientifically defensible and administratively efficient.[21] However, the nuances of

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15. GARY K. MEFFE ET AL., PRINCIPLES OF CONSERVATION BIOLOGY 559 (1994).

16. U.S. FISH & WILDLIFE SERV., U.S. FISH AND WILDLIFE SERVICE MANUAL, 052 FW 1.12(b), *available at* http://policy.fws.gov/series.html (last visited Oct. 24, 2004).

17. GRAEME CAUGHLEY & ANNE GUNN, CONSERVATION BIOLOGY IN THEORY AND PRACTICE 16 (1996).

18. *See generally* SPECIES: THE UNITS OF BIODIVERSITY (Michael F. Claridge et al. eds., 1997).

19. *See generally* J. Baird Callicott et al., *Current Normative Concepts in Conservation*, 13 CONSERVATION BIOLOGY 22 (1999).

20. *See generally* PRECIOUS HERITAGE: THE STATUS OF BIODIVERSITY IN THE UNITED STATES (Bruce A. Stein et al. eds., 2000).

21. David W. Crumpacker et al., *A Preliminary Assessment of the Status of Major Terrestrial and Wetland Ecosystems on Federal and Indian Lands in the United States*, 2 CONSERVATION BIOLOGY 103 (1988).

conserving diversity at the genetic, community, and ecosystem levels have been addressed by many others and will not be addressed here.

One aspect that has been largely ignored, however, pertains to taxonomic equality, which has been assessed primarily in a sociopolitical sense.[22] Yet differences among taxa in functional genome size, molecular clock speed, phylogenetic distinctiveness, and associated ecological traits have tremendous implications for biodiversity measurement and the prioritization of taxa for conservation.[23] Of these factors, only phylogenetic distinctiveness has been subject to rigorous assessment as a prioritization criterion.[24]

Biological Integrity

As related to conservation biology, "integrity" means "1. the state of being unimpaired, soundness, 2. the quality or condition of being whole or undivided, completeness."[25] Borrowing from Meffe and Carroll's definition of biodiversity, biological integrity means the integrity of living organisms considered at all levels, from genetics through species, to higher taxonomic levels, and including the integrity of habitats and ecosystems.[26] Maintaining unimpaired, sound, whole, undivided, and complete biodiversity amounts to maintaining biological integrity.

Whole, undivided, and complete do not connote supplemented, amplified, or inflated. An appropriate frame of reference is therefore required to make the concept of biological integrity operational. This finding is consistent with Angermeier and Karr's definition of biological integrity, whereby "a system's wholeness, including presence of all

22. *See generally* STEVEN R. KELLERT, THE VALUE OF LIFE: BIOLOGICAL DIVERSITY AND HUMAN SOCIETY (1996); *see also* Brian Czech et al., *Social Construction, Political Power, and the Allocation of Benefits to Endangered Species*, 12 CONSERVATION BIOLOGY 1103 (1998).

23. Brian Czech & Paul R. Krausman, *The Species Concept, Species Prioritization, and the Technical Legitimacy of the Endangered Species Act*, 63 N. AM. WILDLIFE & NAT. RESOURCES CONFERENCE TRANSACTIONS 514, 517-22 (1998). Czech and Krausman argue that species with larger functional genomes, greater phylogenetic distinctiveness, broader niches, and slower molecular clocks should be prioritized for conservation and that these traits are generally associated with larger body size. Using the burning library metaphor for conservation triage, they argue that these types of species are similar to the classic tomes of antiquity: laden with copious information; extensive in coverage; and representing long, laborious investments in authorship.

24. *See, e.g.*, R.I. Vane-Wright et al., *What to Protect – Systematics and the Agony of Choice*, 55 BIOLOGICAL CONSERVATION 235 (1991).

25. AMERICAN HERITAGE DICTIONARY OF THE ENGLISH LANGUAGE 983 (3d ed. 1992) [hereinafter AMERICAN HERITAGE DICTIONARY].

26. U.S. FISH & WILDLIFE SERV., *supra* note 16, 052 FW 1.12(b).

appropriate elements and occurrence of all processes at *appropriate* rates."[27]

For wildlife conservation, an appropriate frame of reference for biological integrity is natural conditions. Angermeier considered naturalness an "imperative for biological conservation."[28] Designating natural conditions as the frame of reference for biological integrity is also consistent with the Leopoldian land ethic. Aldo Leopold identified a dichotomy that he called the "A-B cleavage," group A being "quite content to grow trees like cabbages....its ideology is agronomic," while Group B "employs natural species, and manages a natural environment rather than creating an artificial one."[29] Leopold added, "To my mind, Group B feels the stirrings of an ecological conscience."[30] The FWS adheres to this ethic in its ecological integrity policy by defining biological integrity as "[b]iotic composition, structure, and functioning at genetic, organism, and community levels comparable with historic conditions, including the natural biological processes that shape genomes, organisms, and communities."[31]

Environmental Health

"Environment" is a very comprehensive noun, but its two definitions most pertinent to biodiversity conservation are "1. The circumstances or conditions that surround one, surroundings, and, 2. The totality of circumstances surrounding an organism or a group of organisms, especially a. the combination of external physical conditions that affect and influence the growth, development, and survival of organisms...."[32] Health means "1. The overall condition of an organism at a given time, 2. Soundness, especially of body or mind; freedom from disease or abnormality, 3. A condition of optimal well-being: *concerned about the ecological health of the area.*"[33]

Defining health as "the overall condition of an organism" portrays health as falling along a spectrum from poor to good, where good health would correspond with "soundness...freedom from disease

27. Angermeier & Karr, *supra* note 13 (emphasis added).

28. Paul L. Angermeier, *The Natural Imperative for Biological Conservation*, 14 CONSERVATION BIOLOGY 373, 373 (2000).

29. ALDO LEOPOLD, A SAND COUNTY ALMANAC AND SKETCHES HERE AND THERE 221 (Spec. members ed. 1968).

30. *Id.*

31. Policy on Maintaining the Biological Integrity, Diversity, and Environmental Health of the National Wildlife Refuge System, 66 Fed. Reg. 3810, 3818 (Jan. 16, 2001).

32. AMERICAN HERITAGE DICTIONARY, *supra* note 25, at 616.

33. *Id.* at 833.

or abnormality." In other words, one may speak of health as the measure of one's condition no matter how favorable, or alternatively as a state of favorable condition. This creates potential for confusion, which may be obviated by adopting the convention that, when the phrase "environmental health" is used with no preceding adjective, it connotes favorable condition. "Environmental health" would then be used in an unfavorable sense only when qualified by adjectives such as "poor" or "low."

In the ecological professions, the phrase "ecosystem health" is more commonly used than "environmental health," perhaps because the latter was already in common usage in the human health professions.[34] However, "ecosystem" tends to connote biological entities while "environment" tends to connote physical, thus the *American Heritage Dictionary* defines "ecosystem" as "an ecological community *together with its environment*."[35] Meanwhile, "environment," as in the aforementioned definition, refers "especially [to] the combination of *external physical conditions*."[36]

Given that the Improvement Act addresses biological conditions with the terms "biological diversity" and "biological integrity," the statutory mandate of maintaining environmental health may be interpreted as emphasizing the condition of the *abiotic* environment. Thus, environmental health as defined by the FWS is the physical complement to biological integrity: "Composition, structure, and functioning of soil, water, air, and other abiotic features comparable with historic conditions, including the natural abiotic processes that shape the environment."[37]

Not only does the concept of environmental health complement the concept of biological integrity, it does so at the same levels applied to biological integrity. For example, at the genetic level, environmental health may be maintained by preventing contamination that tends to disrupt the reproductive process, damage germ cells, or stimulate

34. Evidence for this may be found by comparing the tables of contents of ECOSYSTEM HEALTH (largely an ecological journal), *at* http://www.ingenta.com/isis/browsing/All Issues/ingenta?journal=pubinfobike://bsc/ehe (last visited Oct. 27, 2004), to the tables of contents of JOURNAL OF ENVIRONMENTAL HEALTH (largely a human health journal), *at* http://www.neha.org/JEH/recent_issues.htm (last visited Oct. 27, 2004).

35. AMERICAN HERITAGE DICTIONARY OF THE ENGLISH LANGUAGE, *supra* note 25, at 583 (emphasis added).

36. *Id.* at 616 (emphasis added).

37. Policy on Maintaining the Biological Integrity, Diversity, and Environmental Health of the National Wildlife Refuge System, 66 Fed. Reg. 3810, 3818 (Jan. 16, 2001).

artificially high rates of mutation.[38] Many such contaminants are detrimental at the organism level as well, constituting carcinogens or otherwise toxic substances.[39]

At the population level, habitat fragmentation is particularly problematic.[40] Fragmentation can result from biological processes (*e.g.*, species invasions), but much of the fragmentation endangering biodiversity is due to physical structures such as dams, roads, and utilities infrastructure.[41]

At the habitat level, physical degradation may have direct consequences for biodiversity conservation. For example, security cover for pronghorn antelope amounts to wide openness so that the erection of structures including fences, power poles, windmills, and towers degrades the environmental health of pronghorn habitat.[42] Space, another habitat component, is negatively affected by the same structures.

At the ecosystem level, physical components, structures, and functions are relevant to environmental health.[43] The major physical components and structures include topography, geological formations, hydrological systems, airsheds, and the elements and compounds comprising each. Physical functions include water cycles, nutrient cycles, and thermal regulation. Environmental health is diminished to the extent that the natural condition of these components, structures, and functions is modified. For example, open pit mining diminishes environmental health by altering topography, liquidating geological deposits, polluting the air, interrupting nutrient cycles, removing thermal cover, and, in some cases, depleting or re-positioning aquifers. Open pit mining therefore degrades environmental health by destroying natural physical components, structures, and functions.

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38. *See generally* THEO COLBORN ET AL., OUR STOLEN FUTURE: ARE WE THREATENING OUR FERTILITY, INTELLIGENCE, AND SURVIVAL? A SCIENTIFIC DETECTIVE STORY (1996).

39. *See generally* ENVIRONMENTAL CONTAMINANTS IN WILDLIFE: INTERPRETING TISSUE CONCENTRATIONS (W. Nelson Beyer et al. eds., 1996).

40. *See generally* METAPOPULATION BIOLOGY: ECOLOGY, GENETICS, AND EVOLUTION (Ilkka Hanski & Michael E. Gilpin eds., 1997).

41. Brian Czech et al., *Economic Associations Among Causes of Species Endangerment in the United States*, 50 BIOSCIENCE 593, 598 (2000).

42. JAMES D. YOAKUM & BART W. O'GARA, ECOLOGY AND MANAGEMENT OF LARGE MAMMALS IN NORTH AMERICA 559 (Stephen Demarais & Paul R. Krausman eds., 2000).

43. J. Baird Callicott et al., *Current Normative Concepts in Conservation*, 13 CONSERVATION BIOLOGY 22 (1999).

HISTORIC CONDITIONS, NATURALNESS, AND THE ECOLOGICAL IMPACT OF HUMANS

It is logical and consistent with American vernacular to define biological integrity and environmental health in terms of "historic conditions," but the latter phrase must itself be well-defined for purposes of implementation. Accordingly, the FWS defined historic conditions as "[c]omposition, structure, and functioning of ecosystems resulting from natural processes that we believe, based on sound professional judgment, were present prior to substantial human related changes to the landscape."[44] In this section, the phrases "natural processes" and "substantial human related changes" and similar concepts are addressed.

Natural Processes and Substantial Human Related Changes

The phrase "natural processes" invokes the concept of naturalness.[45] The conceptual spectrum typically applied to naturalness has, at one end, everything not influenced by human activities and, at the other, everything including all human activities.[46] By ruling nothing out, however, naturalness becomes indistinguishable from "everything" and therefore becomes a superfluous concept. On the other hand, ruling out all human influence would relegate natural conditions to ancient periods that would offer neither ecological reference value nor pragmatic policy implications. Therefore, the most appropriate and meaningful conceptualization of naturalness lies somewhere between no and all human activity, whereby naturalness diminishes as human activity proliferates.[47]

Those who argue that "human activity" represents a departure from naturalness point to the ecological impact of humans. By and large, it is the *economic* activity of humans that impacts ecosystems.[48] Warfare has been the major exception; yet, compared with the ubiquity of

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44. Policy on Maintaining the Biological Integrity, Diversity, and Environmental Health of the National Wildlife Refuge System, 66 Fed. Reg. 3810, 3818 (Jan. 16, 2001).

45. Jay E. Anderson, *A Conceptual Framework for Evaluating and Quantifying Naturalness*, 5 CONSERVATION BIOLOGY 347, 347-52 (1991).

46. Malcolm L. Hunter, Jr., *Benchmarks for Managing Ecosystems: Are Human Activities Natural?*, 10 CONSERVATION BIOLOGY 695, 695-97 (1996).

47. *See generally* R. EDWARD GRUMBINE, GHOST BEARS: EXPLORING THE BIODIVERSITY CRISIS 239-41 (1992).

48. Czech et al., *supra* note 41, at 593-600.

economic life, the impacts of warfare have been limited.[49] With weapons of mass destruction, warfare now has the potential to exceed the ecological effects of economic activity, but it has also become difficult to distinguish military from economic motives.[50] Religious and other cultural practices have also played a significant ecological role in some societies.[51] However, the exigencies of production and consumption have dominated the lives of humans throughout history and constitute the primary interaction of humans with the natural (or the rest of the natural) world.[52]

The perspective that naturalness falls on a spectrum could readily be supplemented with a threshold level of human influence, below which conditions would be classified for our purposes as natural. For example, prior to the development of Stone Age weapons, hominids lived much as other generalist primate omnivores, and it would be difficult to argue that they were not part of the natural environment even as they began to develop distinctive subsistence toolkits during the Stone Age. During the Mesolithic development of bow-hunting equipment, hunting/gathering societies probably had a greater direct influence (*i.e.*, via predation) on other fauna than did any other vertebrate species.[53] During the Neolithic advent of agriculture, another major human influence was added.[54] Copper, Bronze, and Iron ages corresponded with increasing ecological influence.[55]

All preceding human economy paled in scale and ecological significance, however, to that engendered by industrial technology in the eighteenth and nineteenth centuries. Industrialization was characterized by a rapid increase in economic production and consumption to a level several orders of magnitude higher than pre-industrial levels. This

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49. *See generally* RONDO CAMERON, A CONCISE ECONOMIC HISTORY OF THE WORLD: FROM PALEOLITHIC TIMES TO THE PRESENT (1989).

50. *See* ROBERT M. COLLINS, MORE: THE POLITICS OF ECONOMIC GROWTH IN POSTWAR AMERICA 45-47, 69-77 (2000).

51. *See Religion & Ecology, at* http://hollys7.tripod.com/religionandecology/index.html (last visited Oct. 23, 2004); Catherine Marquette, *Cultural Ecology, at* http://www.indiana.edu/~wanthro/eco.htm (last visited Oct. 23, 2004) (discussing the relationship of religious and other cultural practices and the environment).

52. *See generally* JONATHAN KINGDON, SELF-MADE MAN: HUMAN EVOLUTION FROM EDEN TO EXTINCTION? 166-219 (1993).

53. *See generally* Paul S. Martin, *Prehistoric Overkill: The Global Model, in* QUATERNARY EXTINCTIONS 354 (Paul S. Martin & Richard G. Klein eds., 1984).

54. RONDO CAMERON & LARRY NEAL, A CONCISE ECONOMIC HISTORY OF THE WORLD: FROM PALEOLITHIC TIMES TO THE PRESENT 20-23 (4th ed. 2003).

55. *Id.* at 23-28. For additional details on human impacts during the Iron Age, see, for example, Andreas Lang et al., *Changes in Sediment Flux and Storage Within a Fluvial System: Some Examples from the Rhine Catchment*, 17 HYDROLOGICAL PROCESSES, 3321-34 (2003).

economic transformation constitutes a non-arbitrary, fundamental shift in the relationship of humans to their environment and is therefore a logical selection for an endpoint of natural conditions. As Rees noted, "humanity's drift from a steady state with nature has been accelerating since the Neolithic...and really broke free with the use of fossil fuels and the industrial revolution."[56]

Designating the arrival of industrial economy as the end of natural conditions is particularly appropriate for purposes of biodiversity conservation because economic growth entails the liquidation of natural capital that had comprised nonhuman habitats (Figure 1).[57] Empirical evidence for a conflict between economic growth and biodiversity conservation was provided by Czech et al., who categorized the causes of species endangerment in the United States as economic sectors and noted that "economic growth proceeds at the competitive exclusion of nonhuman species in the aggregate."[58] The Wildlife Society undertook an analysis of economic growth vis-à-vis wildlife conservation and found a "fundamental conflict between economic growth and wildlife conservation."[59] Technological progress could help to lessen the impact of the economy on biodiversity, but it broadens the human niche and exacerbates the challenge to biodiversity conservation if put in the service of economic growth.[60]

The rapid stage of economic growth represented by that portion of the sigmoid growth curve (Figure 1) immediately surrounding the inflection point represents the orders-of-magnitude transformation called industrial "take-off" by economic growth theorists.[61] In the eastern United States, industrialization commenced primarily between 1800 and 1850.[62] While the western states saw few industrial facilities until the late 1800s, their landscapes began to reflect the effects of eastern industrialization far earlier. For example, eastern meat packing plants

56. William E. Rees, *Patch Disturbance, Ecofootprints, and Biological Integrity: Revisiting the Limits to Growth (or Why Industrial Society Is Inherently Unsustainable)*, *in* ECOLOGICAL INTEGRITY: INTEGRATING ENVIRONMENT, CONSERVATION, AND HEALTH 139, 146 (David Pimentel et al. eds., 2000).

57. *See generally* Brian Czech, *Economic Growth as the Limiting Factor for Wildlife Conservation*, 28 WILDLIFE SOC'Y BULL. 4 (2000).

58. Czech et al., *supra* note 41, at 593.

59. David L. Trauger et al., *The Relationship of Economic Growth to Wildlife Conservation*, 3 WILDLIFE SOC'Y TECHNICAL REV. 1, 2 (2003).

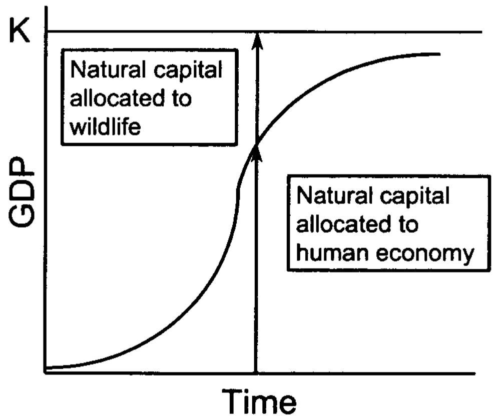
60. *See generally* Brian Czech, *Technological Progress and Biodiversity Conservation: A Dollar Spent, a Dollar Burned*, 17 CONSERVATION BIOLOGY 1455 (2003).

61. W.W. ROSTOW, THEORISTS OF ECONOMIC GROWTH FROM DAVID HUME TO THE PRESENT: WITH A PERSPECTIVE ON THE NEXT CENTURY 434 (1990).

62. *See generally* BUSINESS AND THE AMERICAN ECONOMY, 1776-2001 (Jules Backman ed., 1976).

facilitated high demand for beef and therefore high densities of cattle over much of the Great Plains by the mid-nineteenth century.[63] Therefore, it is helpful to distinguish between an industrial economy per se and an *industrial-aged economy*. The former would be characterized by the presence of industrial capital, while the latter would require only sectoral connection to an industrial economy but would exhibit ecological effects of that industrial economy.

Figure 1: Natural capital (such as soil, water, and timber) reallocated from wildlife to humans in the process of economic growth. As the economy grows, the natural capital comprising wildlife habitat (represented above the sigmoid curve) is liquidated and converted to goods and services in the human economy (represented below the sigmoid curve). K equals economic carrying capacity.



A Frame of Reference for Natural Conditions

While natural conditions may be said to end with industrial-aged economy, we must also consider how far back the frame of reference should extend. To suggest that Pleistocene conditions, for example, would be natural today would be like suggesting that the geological and evolutionary processes that have transpired in the interim have been unnatural. Ruling out Pleistocene and earlier periods leaves the Holocene epoch (the most recent 10,000 years) from which to select a beginning point. However, it would probably also be inappropriate to

63. *See generally* JIMMY M. SKAGGS, PRIME CUT: LIVESTOCK RAISING AND MEATPACKING IN THE UNITED STATES 1607-1983 (1986).

include very early Holocene conditions because of the dramatic ecological transformation that was taking place.[64]

While proximity to the current time is desirable for designating a beginning point because it accounts for evolutionary and other transitional processes, there is a tradeoff. Evolution tends to be "one-way," but many environmental processes are fluctuating or even cyclical. For example, global mean temperatures have fluctuated throughout the Holocene.[65] Temperature is the physical characteristic perhaps most deterministic of other environmental features and ecological communities.[66] If a beginning point is selected too close to the present, a long spectrum of temperature-dependent conditions will not be included in the frame of reference.

Two major climatic cycles occurred during the Holocene. Temperatures increased gradually for most of the first 5000 years, and 5000 B.P. (before present) marked the "Holocene Maximum" when temperatures were about 1°C higher than today's (Figure 2).[67] Temperatures then declined steadily until about 3000 B.P., when they were about 0.5°C lower than today's.[68] Warming ensued and included a relatively pronounced period—the "Medieval Warm Period"—from approximately 800 A.D. to 1300 A.D.[69] This was followed by the "Little Ice Age," which lasted until about 1850 A.D.[70] It has been hypothesized that the Medieval Warm Period-Little Ice Age transition may actually represent one occurrence of an ocean current-driven cycle.[71]

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64. John T. Andrews, *Northern Hemisphere (Laurentide) Deglaciation: Processes and Responses of Ice Sheet/Ocean Interactions*, *in* LATE GLACIAL AND POSTGLACIAL ENVIRONMENTAL CHANGES: QUATERNARY, CARBONIFEROUS-PERMIAN, AND PROTEROZOIC 9, 9-12 (I. Peter Martini ed., 1997).

65. CRAIG D. IDSO, FUTURE CLIMATE AND THE PRECAUTIONARY PRINCIPLE: THE OTHER SIDE OF THE STORY, 8-9 (Ariz. State Univ., Office of Climatology, Climatological Publ'ns Scientific Paper 26, 1997).

66. MICHAEL BEGON ET AL., ECOLOGY: INDIVIDUALS, POPULATIONS AND COMMUNITIES 50-59 (1996).

67. C.K. Folland et al., *Observed Climate Variations and Change*, *in* CLIMATE CHANGE: THE IPCC SCIENTIFIC ASSESSMENT 195, 202 (John Theodore Houghton et al. eds., 1990); *see also* Hugh Anderson & Bernard Walter, *History of Climate Change*, *at* http://vathena.arc.nasa.gov/curric/land/global/climchng.html (last visited Oct. 21, 2004).

68. Anderson & Walter, *supra* note 67.

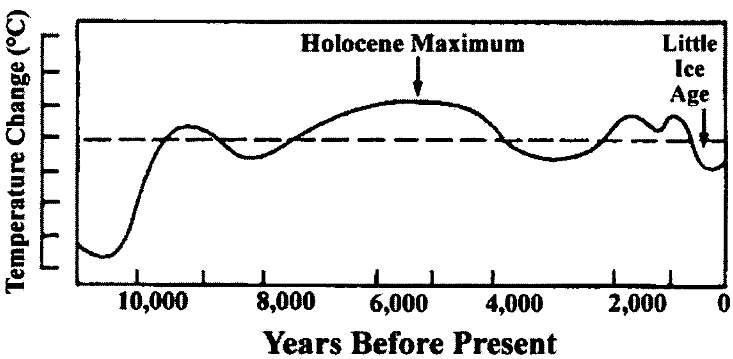
69. CENTER FOR THE STUDY OF CARBON DIOXIDE AND GLOBAL CHANGE, MEDIEVAL WARM PERIOD (NORTH AMERICA)—SUMMARY, *at* http://www.co2science.org/subject/m/summaries/mwpnortham.htm (last visited Oct. 21, 2004).

70. *See generally* BRIAN M. FAGAN, THE LITTLE ICE AGE: HOW CLIMATE MADE HISTORY 1300-1850 (2000).

71. *See* Wallace S. Broecker et al., *A Possible 20th-Century Slowdown of Southern Ocean Deep Water Formation*, 286 SCI. 1132, 1132 (1999).

In ecological terms, 800 A.D. marks a non-arbitrary and (for policy purposes) appropriate beginning point for natural conditions in North America. By designating 800 A.D. as the beginning point, approximately one millennium is available as a frame of reference for natural conditions; *i.e.*, from the beginning of the Medieval Warm Period until the advent of the industrial-aged economy circa 1800. This millennium includes one pronounced warm period and one pronounced cool period during which the extremes of late Holocene ecology had opportunities to emerge.[72] It encompasses a length of time sufficient for the development of virtually all seral stages likely to be associated with a given area, in a Clementsian sense,[73] or to have hosted a representative sample of successional pathways, the potential for which is suggested by post-Clementsian models of plant community succession.[74] The frame of reference precludes hearkening back to ancient conditions and attempting to restore extinct species and lost ecosystems.

Figure 2: Holocene Temperature Fluctuations



72. *See generally* NEIL ROBERTS, THE HOLOCENE: AN ENVIRONMENTAL HISTORY (2d ed. 1998).

73. FREDERIC E. CLEMENTS, PLANT SUCCESSION: AN ANALYSIS OF THE DEVELOPMENT OF VEGETATION (Carnegie Inst. of Washington Pub. No. 242, 1916).

74. Mark Westoby et al., *Opportunistic Management for Rangelands Not at Equilibrium*, 42 J. RANGE MGMT. 266 (1989).

Reconciling Natural Conditions with Post-Industrial Ecological Change

Conditions having no precedent (*e.g.*, industrially-induced global warming and sea level rise) often suggest that much of an area's ecological integrity has been lost, but unprecedented conditions do not automatically imply the loss of ecological integrity. If natural conditions are those not affected by industrial-aged economy, they may include conditions found prior to the industrial revolution or conditions that would have existed up to the present time if industrialization had not occurred. For example, if paleoecological data indicated that javelina (*Tayassu tajacu*) were expanding their range to the north and west beyond Sonoran Desert communities in recent centuries, one could reasonably infer that the presence of javelina in the Mojave/Sonoran ecotone of northwestern Arizona is natural, even if there were no evidence that javelina existed there in the past. However, the presence of javelina in the Mojave Desert of Nevada would less likely be deemed natural because the Colorado River would have been a barrier to javelina under natural conditions. (Javelina may now cross the river at night via Hoover Dam. They may also cross the river downstream where flows have been drastically reduced by municipal withdrawal.)

Determining Natural Conditions

Information on natural conditions may be historical, ethnographic, archeological, or paleoecological. For purposes of this article, "historical information" means published documents by or about the explorers, soldiers, missionaries, traders, and other early "Americans," typically of European descent. This type of information is available for a relatively small segment of the naturalness frame of reference. Information from a single expedition, for example, represents a "snapshot in time" and not a frame of reference for ecological integrity. Furthermore, many historical descriptions of biota are limited to species deemed worthy of comment at the time.[75] However, some explorers had an eye toward ecological minutiae.[76] There are hundreds of publications

75. *See, e.g.*, THE JOURNALS OF LEWIS AND CLARK (Bernard Devoto ed., 1953).

76. *See, e.g.*, JOHN BAKLESS, THE EYES OF DISCOVERY: THE PAGEANT OF NORTH AMERICA AS SEEN BY THE FIRST EXPLORERS (1961).

that document the presence and natural history of nineteenth century flora and fauna in Montana alone.[77]

Plant ecologists have helped to reconstruct natural conditions at the community level. Comer, for example, used a variety of historical documents to map the vegetative communities of Michigan circa 1800 A.D.[78] Statewide documentation of historical vegetative communities has also been conducted in Minnesota, Wisconsin, Ohio, Illinois, Iowa, and Indiana, and data exist for many smaller areas.[79]

Ethnographic information includes the collective memory of Native Americans to whom information has been passed down through many generations. Some of this has been compiled and published,[80] but usually the investigator obtains the information verbally. For example, Athabascan elders have been interviewed as part of a feasibility study for reintroducing wood bison (*Bison bison athabascae*) in the Yukon Flats of Alaska.[81]

Archaeology is the study of the material remains of human cultures to derive knowledge of prehistoric times. Food, clothing, and shelter were representative of local plant and animal communities in pre-industrial cultures. Therefore, ecological analysis has long been associated with archaeology. For several serendipitous reasons, ecological archaeology is typically concerned with periods of time within the chronological frame of reference for ecological integrity proposed in this article.[82]

The focus of paleoecology is on the non-human world and it recognizes no special relevance of the Holocene. Like archaeology, however, much paleoecology focuses on the late Holocene because more "pieces of the puzzle" are available therefrom. Geological features, fossils, packrat middens, tree rings, fire scars, and pollen cores feature prominently in paleoecology. While detailed biotic assemblages seldom result from paleoecological studies, essential physiographic information

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77. C.J. Knowles & P.R. Knowles, *Presettlement Wildlife and Habitat of Montana: An Overview,* (1995), *available at* http://www.npwrc.usgs.gov/resource/literatr/presettl/presettl.htm#contents (last visited Oct. 23, 2004).

78. Patrick Comer, *Michigan's Vegetation Circa 1800* (1998), *available at* http://www.michigan.gov/dnr/0,1607,7-153-10370_22664-70465--,00.html (last visited Oct. 23, 2004).

79. Telephone Interview with Patrick Comer, Associate Ecologist, Michigan Natural Features Inventory (Feb. 18, 1999).

80. *See, e.g.*, VINE DELORIA, JR., RED EARTH, WHITE LIES: NATIVE AMERICANS AND THE MYTH OF SCIENTIFIC FACT (1995).

81. Brian Czech, *The Feasibility of Reintroducing Wood Bison (Bison Bison Athabascae) to the Yukon Flats of Alaska,* Final Report to the Council of Athabascan Tribal Governments, Fort Yukon, Alaska (1994).

82. Telephone Interview with J. Bryan Mason, Director, Texas A&M Center for Ecological Archaeology (Apr. 14, 1999).

often does. For example, 3800 years of Mono Lake fluctuations during the late Holocene have been described to a level of detail more than adequate for management purposes.[83]

A major advantage to archaeological and paleoecological approaches is that they provide much more data-gathering potential than historical and ethnographic approaches. In many areas, the available historical accounts have long been compiled and oral histories are passing away with elders while the set of archaeological and paleoecological techniques continues to expand. Where information on natural conditions is not available, information from nearby areas that have similar environmental traits at a broad scale may serve as a proxy for natural conditions of the area in question.

ECOLOGICAL INTEGRITY AS THE INTEGRATION OF BIOLOGICAL INTEGRITY, DIVERSITY, AND ENVIRONMENTAL HEALTH

The independent pursuit of biological integrity, diversity, or environmental health may occur at the expense of the others. For example, maximizing biodiversity often entails the construction of artificial structures (thus compromising environmental health) and can lead to unnatural species assemblages (thus compromising biological integrity). Maximizing biodiversity would tend to result in the maintenance of zoological facilities, not in the maintenance of biological integrity or environmental health.

Because the Improvement Act states that biological integrity, diversity, and environmental health shall each be maintained, and because the maintenance of one may conflict with the maintenance of another, the maintenance of each must be integrated on the Refuge System. The phrase "ecological integrity" is frequently used in such an integrative fashion for purposes of linguistic efficiency. For instance, Miller and Ehnes posited that "[b]iological integrity is the most important component of ecological integrity."[84] Karr and Dudley defined ecological integrity as the "summation of chemical, physical and biological integrity."[85] A recent book title, *Ecological Integrity: Integrating*

83. Scott Stine, *Late Holocene Fluctuations of Mono Lake, Eastern California*, 78 PALEOGEOGRAPHY, PALEOCLIMATOLOGY, PALEOECOLOGY 333, 333-81 (1990).

84. Peter Miller & James W. Ehnes, *Can Canadian Approaches to Sustainable Forest Management Maintain Ecological Integrity?*, *in* ECOLOGICAL INTEGRITY: INTEGRATING ENVIRONMENT, CONSERVATION, AND HEALTH 157, 160 (David Pimentel et al. eds., 2000).

85. James R. Karr & Daniel R. Dudley, *Ecological Perspective on Water Quality Goals*, 5 ENVTL. MGMT. 55, 56 (1981).

Environment, Conservation, and Health, testifies to the integrative propensity of "ecological integrity."[86]

A strong precedent also exists for using the phrase "ecological integrity" in the context of Refuge System policy. The legislative history of the Improvement Act includes three bills from 1992 and 1993 calling for the maintenance of ecological integrity.[87] In addition, two bills from 1995 and 1997 elaborated slightly by calling for the maintenance of biological integrity and environmental health,[88] suggesting that the 1997 phrase "biological integrity, diversity, and environmental health" represents further elaboration of the broader concept of ecological integrity. The FWS requires the development of "Comprehensive Conservation Plans" that "provide long-range guidance and management direction to achieve refuge purposes; help fulfill the National Wildlife Refuge System (Refuge System) mission; maintain and, where appropriate, restore the ecological integrity of each refuge and the Refuge System... and meet other mandates."[89] The FWS also defines ecological integrity as "the integration of biological integrity, natural biological diversity, and environmental health; the replication of natural conditions."[90] The FWS proposed similar wording for purposes of implementing the ecological integrity clause mandate, but retracted the phrase "ecological integrity" in response to concerns voiced during the public comment period.[91]

Whether or not the phrase "ecological integrity" is used by refuge managers, a great deal of their professional judgment will be required to integrate the maintenance of biological integrity, diversity, and environmental health. To some extent, the concepts of biodiversity and biological integrity are reconciled by the definition of biological integrity, which entails natural levels of biodiversity. Integrating biological integrity and environmental health is more problematic and there are no comparative metrics available. In a qualitative sense, however, at least on the Refuge System, biological integrity will generally take precedence consistent with the mission of the FWS (*i.e.*

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86. ECOLOGICAL INTEGRITY: INTEGRATING ENVIRONMENT, CONSERVATION, AND HEALTH (David Pimentel et al. eds., 2000).

87. S. 823, 103d Cong. § 5 (1993); H.R. 833, 103d Cong. § 4 (1993); S. 1862, 102d Cong. § 4 (1992); *see also* ROBERT L. FISCHMAN, THE NATIONAL WILDLIFE REFUGES: COORDINATING A CONSERVATION SYSTEM THROUGH LAW 126 (2003).

88. H.R. 511, 105th Cong. § 5 (1997); H.R. 1675, 104th Cong. § 5 (1995).

89. National Wildlife Refuge System Planning, 65 Fed. Reg. 33,892, 33,910 (May 25, 2000).

90. *Id.* at 33,906.

91. Policy on Maintaining the Biological Integrity, Diversity, and Environmental Health of the National Wildlife Refuge System, 66 Fed. Reg. 3809, 3810 (Jan. 16, 2001).

wildlife conservation).[92] For example, wood duck boxes compromise environmental health, strictly speaking, because they modify the physical structure of natural conditions. However, if a large refuge with forested areas consistently characterized by wood duck nesting cavities under natural conditions has no such habitat due to timber harvesting prior to refuge establishment, then wood duck box installment is appropriate for the purposes of biological integrity.

Management intensity on the Refuge System is another consideration. For example, if the success rate of wood duck boxes is low, prompting the manager to install a plethora of wood duck boxes, a small measure of biological integrity costs a more significant compromise of environmental health. It would be especially imprudent if a high percentage of the wood duck boxes would be used by other species that would then achieve densities higher than those under natural conditions, because then environmental health and biological integrity would be compromised.

Issues of Scale in Maintaining Ecological Integrity

It may not be appropriate to maximize the biodiversity of an area when there is a simultaneous need to maintain both biological integrity and environmental health, especially when issues of geographic scale are considered. When an area is being managed as one unit of a system of conservation lands, for example, it may be more appropriate to focus the management of an area on a narrowly defined target (such as an endangered species, imperiled alliance, or rare seral stage) for purposes of system-level biodiversity. In the jargon of conservation biology, managing for such narrowly defined targets may contribute little to "alpha" diversity and lots to "gamma" diversity.[93]

Furthermore, it may not even be appropriate to maximize ecological integrity (including biological integrity and environmental health) within a particular area because of the simultaneous need to consider conservation needs at ecosystem, regional, national, continental, and global scales. For example, in the Aleutian Islands of Alaska, ecological integrity includes a high density of nesting Aleutian Canada geese. The wintering grounds (primarily in California), however, have been largely usurped by agricultural and other economic developments. Only if areas on the wintering grounds are managed intensively can they support a population of geese high enough to result in relatively natural

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92. *See* U.S. FISH & WILDLIFE SERV., MISSION STATEMENT, *available at* http://www.fws.gov (last visited Oct. 24, 2004).

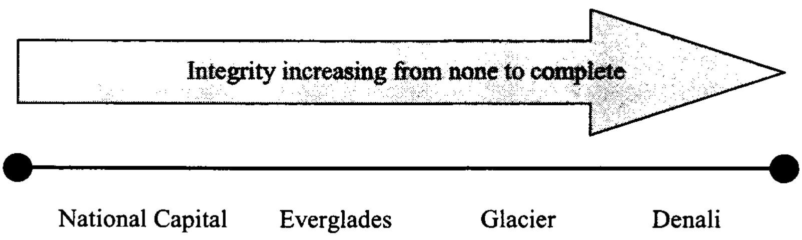
93. MEFFE ET AL., *supra* note 15, at 90.

conditions in the Aleutian Islands. Intensive management includes mechanized crop production, which compromises biological integrity and environmental health. Therefore, compromising some of the ecological integrity of management areas in California is required to maintain the ecological integrity of the Aleutian Islands.

Ecological Integrity as a Relative Concept

Given the amount of global change that has occurred (and is occurring) during the industrial era, no geographic area can be said to retain absolute ecological integrity. However, all areas have some level of ecological integrity remaining, and all contribute to the ecological integrity of the nation as a whole. This concept of relative ecological integrity is illustrated with well-known examples from the National Park System (Figure 3). The National Capital Parks, for example, may not retain as much ecological integrity as Denali National Park. However, they do retain some and contribute to the ecological integrity of the National Park System in ways that cannot be provided by Denali National Park. For example, many species naturally occur in the National Capital Parks that do not naturally occur at Denali.

Figure 3: The Ecological integrity spectrum, with examples from the National Park System



Ecological Integrity, Plant Community Succession, and Wilderness

In many areas, plant and animal communities underwent perpetual succession and remission, driven by natural cycles and disturbances.[94] In some areas, "climax communities" were reached and

94. CLEMENTS, *supra* note 73.

persisted for relatively long periods.[95] In any event, land managers who focus on the maintenance of ecological integrity should manage communities in ways consistent with successional pathways. For example, if one determines that an area was an aspen (*Populus tremuloides*) forest in 1800, one would not be restricted to restoring or maintaining an aspen forest, because aspen forest is a relatively early sere within a variety of successional series. Species succeeding aspen vary by "landtype associations" (classified by soil texture, carbon and nitrogen content, and climatic characteristics), with yellow birch (*Betula lutea*) and sugar maple (*Acer saccharum*) being important in some associations and various pine (*Pinus*) species in others.[96] The manager could therefore maintain aspen forest or a variety of pre- or post-aspen series as indicated by landtype association, and the decision would likely be influenced by objectives other than ecological integrity. Regardless of which seral stages are prioritized, managers concerned with ecological integrity will favor techniques that mimic natural processes.

Alternatively, and especially when not constrained by other objectives, the manager may simply strive to facilitate an entire successional pathway. This approach is especially appropriate when natural disturbance regimes (*e.g.*, fire, flooding, drought) are intact or when such disturbance regimes are relatively predictable and replicable (*e.g.*, a well-established fire cycle that may be mimicked via controlled burning.) Such is most likely to be the case in large wilderness areas, which gives wilderness a special role in the maintenance of ecological integrity.

In designated wilderness there is, however—and in addition to the goal of maintaining natural conditions—the need to avoid manipulative management to the extent possible.[97] This presents a challenge to wilderness managers who, on the one hand, attempt to maintain a natural species assemblage and, on the other, find it hard to do so without employing manipulative techniques. Controversial wildlife management activities have been documented in at least 53 southwestern wilderness areas, for example, and most of the controversy

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95. Martin Büssenschütt & Claudia Pahl-Wostl, *Diversity Patterns in Climax Communities*, 87 OIKOS 531, 537 (1999).

96. George Host & John Pastor, *Modeling Forest Succession Among Ecological Land Units in Northern Minnesota*, 2 CONSERVATION ECOLOGY 15 (1998), *at* http://www.consecol.org/vol2/iss2/art15 (last visited Oct. 24, 2004).

97. David N. Cole, *Ecological Manipulation in Wilderness: An Emerging Management Dilemma*, 2 INT'L J. WILDERNESS, May 1996, at 15, 15-18, *available at* http://ijw.wilderness.net/articles/ecologic.cfm (last visited Oct. 24, 2004).

resulted from the need to balance natural and non-manipulated conditions.[98]

If there was evidence that certain successional pathways were naturally precluded, managers would not attempt to restore those pathways in the service of ecological integrity. For example, if a volcanic eruption in the twelfth century impounded water that flooded a forest, creating a lake in the process, one would not, in the service of ecological integrity, drain the lake to reproduce the forest. Reproducing conditions that naturally ceased to exist would compromise ecological integrity.

CONCLUSION

Biological integrity and environmental health imply the earlier existence of intact, non-degraded, unadulterated conditions. These traits may be characterized as "natural." A non-arbitrary, holistic approach to ascertaining naturalness is one that considers geological and evolutionary processes and the role of humans in modifying such processes. A reasonable frame of reference for policy purposes would begin with the advent of the Medieval Warm Period approximately 800 A.D. and end with industrial-aged economic production approximately 1000 years later. This frame of reference includes warm, cool, and moderate temperature regimes and a relatively comprehensive set of biota. It acknowledges a fundamental transformation in the relationship of humans to nature corresponding with industrialization, concomitant economic "take-off," and the competitive exclusion of nonhuman species in the aggregate. Natural conditions also include those that would have existed presently had industrialization not transpired.

There is a macroeconomic implication of this frame of reference that will become increasingly important for purposes of ecological integrity. The industrial-aged endpoint of natural conditions was not chosen because of the current exigencies of the industrial process such as the use of fossil fuels or the co-production of toxic chemicals (although such rationale also would have merits). The rationale for identifying industrialization as the end-point was based on the dramatic increase in economic scale associated with industrialization, regardless of the means of production, and the fundamental conflict between economic growth and biodiversity conservation.

As more of the landscape is put into economic production, biological integrity, diversity, and environmental health will be

98. Brian Czech & Paul R. Krausman, *Controversial Wildlife Management Issues in Southwestern U.S. Wilderness*, 5 INT'L J. WILDERNESS, Dec. 1999, at 22, 23-26, *available at* http://ijw.wilderness.net/articles/ecologic.cfm (last visited Oct. 24, 2004).

compromised. The challenge to refuge managers is to integrate the three concepts in optimal fashion in pursuit of ecological integrity, but the maintenance of ecological integrity will ultimately depend on the adoption of policies conducive to the establishment of a steady state economy with stabilized (or mildly fluctuating) population times per capita consumption. Conversely, because of the ecological services provided by functioning ecosystems, the maintenance of a healthy economy will ultimately depend upon the maintenance of ecological integrity. The challenge to the polity, then, is to strike the appropriate balance between ecological and economic goals and policies. *Ceteris paribus*, this balance will approximate the optimum size of the human economy.