Protecting Ecological Integrity: An Urgent Societal Goal

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I. INTRODUCTION

Unbridled population growth and technological expansion threaten the integrity of the biosphere and, thus, our welfare.[1] The threat is not new. Human history documents numerous civilizations that developed and prospered by exploiting natural resources.[2] Their populations grew until the resource base could no longer support them; eventually, those civilizations fell. The mysterious collapse of the Easter Island society, for example, has been traced to "environmental degradation brought on by deforestation."[3] Populations less geographically constrained than Easter Island's have often delayed the inevitable by expanding to other regions.[4] Today, however, environmental degradation is global in scope and exploitable frontiers no longer exist.[5] In a very real sense, twentieth-century Earth is like the Easter Island society of the mid-sixteenth century.

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1. *See generally* WORLDWATCH INST., STATE OF THE WORLD: 1992 (1992); Brian J. Huntley et al., *A Sustainable Biosphere: The Global Imperative*, 20 ECOLOGY INT'L 6 (1991); Jane Lubchenko et al., *The Sustainable Biosphere Initiative: An Ecological Research Agenda*, 72 ECOLOGY 371 (1991).
2. *See* ALFRED W. CROSBY, ECOLOGICAL IMPERIALISM: THE BIOLOGICAL EXPANSION OF EUROPE: 900-1900 (1986); CLIVE PONTING, A GREEN HISTORY OF THE WORLD (1991).
3. PONTING, *supra* note 2, at 5. The population of Easter Island peaked in 1550 and went into decline a half century later. *Id.*
4. *Id.* at 117.
5. *See* GLOBAL WARMING AND BIOLOGICAL DIVERSITY (Robert L. Peters & Thomas E. Lovejoy eds., 1992); AL GORE, EARTH IN THE BALANCE: ECOLOGY AND THE HUMAN SPIRIT (1992); NATIONAL RESEARCH COUNCIL, GLOBAL ENVIRONMENTAL CHANGE: UNDERSTANDING THE HUMAN DIMENSIONS (Paul C. Stern et al. eds., 1992); STEPHEN H. SCHNEIDER, GLOBAL WARMING: ARE WE ENTERING THE GREENHOUSE CENTURY? (1989).

Human ability to change the world outpaces the capacity of biological systems to respond to those changes. As a result, we are accumulating an environmental deficit without adequately evaluating its consequences.[6] Unfortunately, many societal leaders have not acknowledged the lessons of history which call for this assessment. Human actions have unintentionally resulted in overharvest of forest and marine resources, soil and water resource depletion, widespread chemical contamination, biodiversity reduction, ozone depletion, and global climate change.[7] Collectively, these phenomena have caused progressive biotic impoverishment — a systematic reduction in our planet's ability to support living systems.[8] Since continued impoverishment arguably presents the greatest long-term threat to humanity, we must understand contemporary environmental problems as a crisis of sustainability.[9] Such realization calls for better tools to evaluate the status of the Earth's biological resources, as well as concerted educational efforts to make effective use of those tools. We have perhaps fifty years to alter our course in ways that will ensure a sustainable future.[10] The question is, "Are we up to the task?"

This paper begins by defining ecological health or integrity. Using water resources as a case study, it then contends that policymakers need new methods to assess the current condition of Earth's life support systems. Finally, the paper concludes by arguing that an ecological integrity ethic is essential to protecting the sustainability of human society.

II. DEFINING ECOLOGICAL INTEGRITY

A society ignores threats to its health or well-being only at its peril. In order to protect itself, however, it must first recognize exactly what constitutes health. We commonly think of health in only two dimensions: corporeal and economic. Historically, human beings primarily interacted with the environment as individuals and, typically, on relatively small spatial and temporal scales. Disease, accidents, and predatory acts comprised the primary threats to individuals. Medicine developed with the goal of curing diseased or injured individuals, and as medical practice improved, so did the quality of

6. *See* F. Herbert Bormann, *The Global Environmental Deficit*, 40 BIOSCIENCE 74 (1990) (discussing environmental deficits, which accrue when consumption rates that exceed annual growth or regeneration rates degrade natural resources).

7. Lubchenko, *supra* note 1, at 384.

8. *See* THE EARTH IN TRANSITION: PATTERNS AND PROCESSES OF BIOTIC IMPOVERISHMENT (George M. Woodwell ed., 1990) [hereinafter EARTH IN TRANSITION]; George M. Woodwell, *On Causes of Biotic Impoverishment*, 70 ECOLOGY 14 (1989).

9. *See generally* DAVID W. ORR, ECOLOGICAL LITERACY: EDUCATION AND THE TRANSITION TO A POSTMODERN WORLD (1992).

10. Sandra Postel, *Denial in the Decisive Decade*, *in* STATE OF THE WORLD: 1992, *supra* note 1, at 8.

life. However, medicine's focus on the individual body led to the unfortunate dissociation of human welfare from its dependence on our planet's life-support systems.

Just as doctors evaluate individuals' physical health, economists assess societies' economic health. Unfortunately, financial gauges focus on geographical areas limited by political boundaries and time periods defined by fiscal years or election campaigns. Furthermore, policymakers usually consider the economy as a system in which exchange values circulate in a closed loop isolated from the natural environment.[11] Because some economists believe the economy is not dependent on anything at all outside itself,[12] they rarely incorporate into their analyses the negative externalities associated with resource depletion. For this reason, financial indicators cannot adequately protect the long-term interests of society, because they foster excessive consumption at the expense of future generations. Both medical and current economic measures of health fail to recognize the inextricable relationship between human welfare and the Earth.

A sustainable society depends upon a life-support system with integrity. Such a system is characterized by stability, realization of inherent potential, capacity for self-repair, and minimal need for external support.[13] Ecological integrity then "refers to the 'holistic health' of the ecosphere or biosphere" in which biophysical processes sustain the lives of species and individuals, and reciprocally, the interactions of life forms sustain the support systems.[14] Our expanding populations and advanced technology threaten our welfare. We must acknowledge and halt this trend by taking account of ecological integrity when we evaluate the well-being of our society.[15]

III. ASSESSING ECOLOGICAL INTEGRITY: THE CASE OF WATER RESOURCES

Progress toward measuring ecological integrity has been most rapid in the area of water resources. A number of states have incorporated reliable

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11. Herman E. Daly, *Elements of Environmental Macroeconomics*, *in* ECOLOGICAL ECONOMICS: THE SCIENCE AND MANAGEMENT OF SUSTAINABILITY 32, 34 (Robert Costanza ed., 1991) [hereinafter ECOLOGICAL ECONOMICS].

12. *Id.*

13. *See* JAMES R. KARR ET AL., ASSESSING BIOLOGICAL INTEGRITY IN RUNNING WATERS: A METHOD AND ITS RATIONALE 6 (Ill. Nat. Hist. Surv. Spec. Pub. 5, 1986) [hereinafter KARR, ASSESSING BIOLOGICAL INTEGRITY]. Biological integrity for streams is defined as the ability to support and maintain "a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of natural habitat of the region." James R. Karr & Daniel R. Dudley, *Ecological Perspective on Water Quality Goals*, 5 ENVTL. MGMT. 55, 56 (1981).

14. JAMES A. NASH, LOVING NATURE: ECOLOGICAL INTEGRITY AND CHRISTIAN RESPONSIBILITY 18 (1991).

15. Bryan G. Norton, *Ecological Health and Sustainable Resource Management*, *in* ECOLOGICAL ECONOMICS, *supra* note 11, at 102, 104 [hereinafter Norton, *Ecological Health*]; D.J. Rapport, *What Constitutes Ecosystem Health?*, 33 PERSP. IN BIOLOGY & MED. 120, 137 (1989). *See generally* ECOSYSTEM HEALTH: NEW GOALS FOR ENVIRONMENTAL MANAGEMENT (Robert Costanza et al. eds., 1992) [hereinafter ECOSYSTEM HEALTH].

methods of evaluating water resources from a biological perspective as a central step in decision-making.[16] Those methods can determine whether a resource has been degraded, and if so, the potential causes of that degradation. They may even suggest programs for restoration.[17] Given the intimate relationships between terrestrial and aquatic components of landscapes, policymakers should seek to replicate water resource evaluation methods in the terrestrial setting.[18]

The phrase "biological integrity" was first used in defining the goal of the Water Pollution Control Act Amendments (WPCA) of 1972, which was "to restore and maintain the chemical, physical and biological integrity of the Nation's waters."[19] Yet nearly a decade passed after WPCA's enactment before anyone advocated the use of an ecological integrity perspective to guide water resource protection.[20] Many major legal treatises fail to discuss biological or ecological integrity,[21] or address the concept only briefly.[22]

Federal enforcement of the Clean Water Act has focused on protection of water quality to ensure human health alone, rather than on a more balanced goal of ecological and human health.[23] Consequently, despite expenditures of $473 billion (1986 dollars) since 1970 to build, operate, and administer water pollution control facilities,[24] the quality of water resources continues to decline.[25] Scientific research, regulatory decisions, and policy evaluations during the past decade demonstrate the importance of assessing ecological integrity to the protection of water resources.[26]

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16. *See, e.g.*, OFFICE OF WATER, U.S. ENVTL. PROTECTION AGENCY [U.S. EPA], BIOLOGICAL CRITERIA: STATE DEVELOPMENT AND IMPLEMENTATION EFFORTS vii (U.S. EPA, Pub. No. EPA-440/5-91-003, 1991); OFFICE OF WATER, U.S. EPA, BIOLOGICAL CRITERIA: NATIONAL PROGRAM GUIDANCE FOR SURFACE WATERS (U.S. EPA, Pub. No. EPA-440/5-90-004, 1990) [hereinafter EPA, PROGRAM GUIDANCE].

17. James R. Karr, *Biological Integrity: A Long-Neglected Aspect of Water Resource Management*, 1 ECOLOGICAL APPLICATIONS 66, 67, 79 (1991) For an expansive treatment of the need for restoration of aquatic ecosystems, see NATIONAL RESEARCH COUNCIL, RESTORATION OF AQUATIC ECOSYSTEMS: SCIENCE, TECHNOLOGY, AND PUBLIC POLICY (1992).

18. *See* James R. Karr, *Landscapes and Management for Ecological Integrity*, *in* BIODIVERSITY AND LANDSCAPES: A PARADOX FOR HUMANITY (K. C. Kim & Robert D. Weaver eds., forthcoming 1993) [hereinafter Karr, *Landscapes*].

19. Federal Water Pollution Control Act Amendments of 1972, Pub. L. No. 92-500, § 2, 86 Stat. 816 (codified as amended at 22 U.S.C. § 1251(a) (1992)).

20. *See* Karr & Dudley, *supra* note 13, at 56 (equating chemical, physical, and biological integrity with ecological integrity).

21. *See, e.g.*, ZYGMUNT J. B. PLATER ET AL., ENVIRONMENTAL LAW AND POLICY: A COURSEBOOK ON NATURE, LAW, AND SOCIETY (1992); *see also* MICHAEL BEAN, THE EVOLUTION OF NATIONAL WILDLIFE LAW 1 (1983) (criticizing lack of critical scrutiny of federal wildlife law).

22. WILLIAM GOLDFARB, WATER LAW 172-73 (2d ed. 1988).

23. SCIENCE ADVISORY BD., U.S. EPA, REDUCING RISK: SETTING PRIORITIES AND STRATEGIES FOR ENVIRONMENTAL PROTECTION 17 (U.S. EPA, Pub. No. SAB-EC-90-021, 1990).

24. WATER POLLUTION CONTROL FEDERATION/WATER QUALITY 2000, CHALLENGES FOR THE FUTURE: INTERIM REPORT 12 (1991).

25. *See infra* text accompanying notes 29-39.

26. *See* Karr, *supra* note 17, at 67; *see also*, U.S. EPA, PROGRAM GUIDANCE, *supra* note 16, at vii; JAMES L. PLAFKIN ET AL., RAPID BIOASSESSMENT PROTOCOLS FOR USE IN STREAMS AND RIVERS:

A. *Current Status of Aquatic Ecological Systems*

Aquatic organisms are seriously threatened. Among North American species, 34%, 65% and 73% of fishes, crayfishes, and unionid mussels, respectively, are classified as rare to extinct.[27] Although the federal government has made large expenditures to improve water quality and to protect fishes under the Endangered Species Act[28] and other recovery efforts, none of the 251 fishes listed as rare in 1979 could be removed from the list in 1989.[29] The freshwater mollusk fauna of the United States, the most diverse in the world, is in steep decline, with twelve mussel species extinct and 20% of the remainder endangered.[30] The threat to aquatic biodiversity is severe, and may exceed the threat to terrestrial biodiversity.[31]

Of the 5.2 million kilometers (3.2 million miles) of streams and rivers in the continental United States, only 2% have sufficiently high quality features to be considered worthy of federal protection.[32] Among rivers longer than 1000 kilometers, only the Yellowstone is not severely altered. The threat to water resources goes beyond the destruction of channels and the extinction of species. Since 1910, Columbia River salmon runs have declined by 75-85%.[33] Since 1945, the Missouri River commercial harvest has declined over

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BENTHIC MACROINVERTEBRATES AND FISH 1-1 (U.S. EPA, Pub. No. EPA-444/4-89-001, 1989); SURFACE WATER SECTION, OHIO ENVTL. PROTECTION AGENCY, BIOLOGICAL CRITERIA FOR THE PROTECTION OF AQUATIC LIFE i (rev. ed. 1988).

27. Larry Master, *The Imperiled Status of North American Aquatic Animals*, BIODIVERSITY NETWORK NEWS (Nature Conservancy), No. 3, 1990, at 1, 2. By comparison, only 11% to 14% of terrestrial vertebrates are classified as rare to extinct. *Id.*

28. 16 U.S.C. § 1531 (1992).

29. Jack E. Williams et al., *Fishes of North America: Endangered, Threatened, and of Special Concern*, FISHERIES, Nov.-Dec. 1989, at 2, 2. Some did, however, become extinct. *Id.*

30. EDWARD O. WILSON, THE DIVERSITY OF LIFE 256-57 (1992).

31. The status of the aquatic biota is symptomatic of a larger biodiversity crisis. *See generally* BIODIVERSITY (Edward O. Wilson & Frances M. Peter eds., 1988); NORMAN MYERS, THE SINKING ARK (1979); WALTER V. REID & KENTON R. MILLER, KEEPING OPTIONS ALIVE: THE SCIENTIFIC BASIS FOR CONSERVING BIODIVERSITY (1989); WORLD RESOURCES INST., GLOBAL BIODIVERSITY STRATEGY: GUIDELINES FOR ACTION TO SAVE, STUDY, AND USE EARTH'S BIOTIC WEALTH SUSTAINABLY AND EQUITABLY (1992). This crisis has captured the attention of scientists, *see* Michael E. Soulé, *Conservation Tactics for a Constant Crisis*, 253 SCIENCE 744 (1991); politicians, *see* James H. Scheuer, *The National Biological Diversity Conservation and Environmental Research Act (H. R. 1268): A New Approach to Save the Environment*, 70 BULL. ECOLOGICAL SOC'Y OF AM. 194 (1989); Gerry E. Studds, *Preserving Biodiversity*, 41 BIOSCIENCE 602 (1991); and the public. The "charismatic megafauna" (warm-blooded animals such as Smokey the Bear, the Giant Panda mascot of the World Wildlife Fund, primates, large cats, elephants, spotted owls, whales, and dolphins) attract the greatest attention. Concern for smaller and more obscure but no less important taxa such as invertebrates and plants is growing. Recently, the focus occasionally has shifted to habitats, with tropical rain forests, old growth forests of the Pacific Northwest, and wetlands attracting particular attention. Because of the extraordinary diversity of species that reside in tropical rain forests, that habitat has, in some sense, become the flagship of efforts to protect biodiversity.

32. Arthur C. Benke, *A Perspective on America's Vanishing Streams*, 9 J. N. AM. BENTHOLOGICAL SOC'Y 77, 77 (1990).

33. Wesley J. Ebel et al., *The Columbia River: Toward a Holistic Understanding*, *in* PROCEEDINGS OF THE INTERNATIONAL LARGE RIVERS SYMPOSIUM 205, 205 (Douglas P. Dodge ed., 1989) [hereinafter

80%.[34] In 1910, the commercial fish catch of the Illinois River was 10% of the U.S. freshwater catch, second only to the Columbia River, but by the 1980s it had declined to virtually nothing.[35] Thirty-seven states implemented fish consumption bans, restrictions, or advisories by 1989,[36] reflecting concerns about threats to wildlife[37] and human health,[38] as well as the intergenerational consequences of contaminated fish consumption.[39]

As these examples demonstrate, the water resource crisis extends beyond degradation in water quality to the loss of species, loss of the harvestable productivity of aquatic systems, and threats to human health. These water resource examples illustrate the destruction of crucial natural capital and suggest the need to reexamine conventional assessments of the quality of human life.[40]

B. *The Principle and Uses of Biological Monitoring*

To be effective, biological monitors should reflect the multivariate nature of biological systems, signal system stress before severe damage occurs, and mobilize societal concern for environmental degradation.[41] Further, because attributes of biological systems (e.g., species richness, relative abundances of species, production, and trophic dynamics) vary geographically, measures of health or integrity of streams must evaluate biological conditions against regional standards rather than against some universal standard.[42] Well-known

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LARGE RIVERS SYMPOSIUM].

34. Larry W. Hesse et al., *Missouri River Fishery Resources in Relation to Past, Present and Future Stresses*, *in* LARGE RIVERS SYMPOSIUM, *supra* note 33, at 352, 352.

35. James R. Karr et al., *Fish Communities of Midwestern Rivers: A History of Degradation*, 35 BIOSCIENCE 90, 91 (1985).

36. Robert E. Reinert et al., *Risk Assessment, Risk Management and Fish Consumption Advisories in the United States*, FISHERIES, Nov.-Dec. 1991, at 5, 5.

37. *See generally* THEODORA E. COLBORN ET AL., GREAT LAKES, GREAT LEGACY? (1990).

38. *See generally* SEAFOOD SAFETY (Farid E. Ahmed ed., 1991).

39. *See, e.g.*, Joseph L. Jacobson et al., *Effects of* in utero *Exposure to Polychlorinated Biphenyls and Related Contaminants on Cognitive Functioning in Young Children*, J. PEDIATRICS, No. 116, 1990, at 38, 38.

40. Protection of biodiversity is a component of the goal of protecting ecological integrity, but it is not sufficient by itself. A weakness of a narrow focus on biodiversity is the tendency to emphasize the establishment of reserves. Those reserves do not protect sustainability because they ignore the status of lands between the reserves. Protection of minimum viable populations of each species in zoos and reserves will not protect the sustainability of Earth's life support systems. *See generally* PAUL R. EHRLICH & ANNE H. EHRLICH, HEALING THE PLANET: STRATEGIES FOR RESOLVING THE ENVIRONMENTAL CRISIS (1991).

Growth in concern for biodiversity in the past decade has on occasion prompted misdirected action in agencies responsible for management of public land. For example, some programs proposed to *increase* biological diversity, such as advocating clear cutting to increase local habitat diversity and thus local biological diversity, are actually likely to *decrease* biological integrity.

41. David W. Schindler, *Detecting Ecosystem Responses to Anthropogenic Stress*, 44 CAN. J. FISHERIES & AQUATIC SCI. 6 (Supp. I, 1987).

42. *See generally* James R. Karr, *Assessment of Biotic Integrity Using Fish Communities*, FISHERIES, Nov.-Dec. 1981, at 21.

examples of geographic variation include the increase in species richness for most taxa with movement toward lower latitudes or downstream within a watershed. Use of multimetric approaches which account for geographic variation for the evaluation of the biological integrity of water resources has proven successful in a variety of contexts.

The most widely used example of such an approach is the Index of Biotic Integrity (IBI).[43] IBI integrates information about biological attributes (metrics) from individual, population, and assemblage levels of organization. The IBI consists of a dozen metrics that are compared to values expected for a relatively undisturbed stream of similar stream size and geographic region. Each metric is rated 5, 3, or 1 depending on whether its condition is comparable to, deviates somewhat from, or deviates strongly from the expected value. Expected values must be set *a priori*. Scores for the metrics are summed to yield an index that ranges from 12 to 60. Regional modifications of the IBI have been very successful as long as the metrics retain the general ecological structure of the original IBI. For example, the Ohio Environmental Protection Agency uses a modified IBI to establish and maintain use designations for water bodies and in support of its non-point source program under Clean Water Act § 319, its water quality inventory reports under Clean Water Act § 305(b), and its NPDES discharge permits.[44]

In short, programs to assess status and trends in ecological integrity should include evaluations relative to regional standards; use indexes that reflect the multivariate nature of biological systems; and evaluate conditions from individual, population, assemblage, and landscape perspectives.[45] The recent development of biological indices and establishment of biocriteria (as complements of the long-established chemical criteria and standards in water resource evaluations) illustrate the value of biological evaluations.[46]

Working with numerous spatial and temporal scales is one of the most difficult components of defining and assessing ecological integrity.[47] The number of variables likely to influence ecological integrity increases as spatial scale increases. Further, the cumulative impacts of human actions complicate development of reliable ecological measures. The difficulties associated with measuring trends include distinguishing between human-induced and natural variation, as well as identifying the human actions responsible for environmental degradation. Nevertheless, as demonstrated by the methods developed

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43. *See generally id.*; KARR, ASSESSING BIOLOGICAL INTEGRITY, *supra* note 13; Karr, *supra* note 17, at 71-80.

44. Daniel R. Dudley, *A State Perspective on Biological Criteria in Regulation, in* BIOLOGICAL CRITERIA: RESEARCH AND REGULATION: PROCEEDINGS OF A SYMPOSIUM 15, 15 (U.S. EPA Pub. No. EPA-440/5-91-005, 1991).

45. *See* Karr, *Biological Integrity*, *supra* note 17, at 80.

46. *See* sources cited in *supra* notes 42 & 43.

47. *See generally* Karr, *Landscapes*, *supra* note 18.

to test aquatic integrity, these difficulties can be overcome.

IV. CHANGING MEASURES OF SOCIETAL WELL-BEING

Scientists and policymakers have made major advances in assessing the biological integrity of running waters,[48] but they have yet to develop integrative tools for direct, rapid, and efficient assessment of other environments.[49] This is a necessary first step in a successful transition to a system with ecological integrity. Still, indicator development alone cannot effect such a transition. We must also modify our conceptions of health to integrate new measures of ecological integrity. In medicine, incorporation of the ecological integrity perspective requires the recognition of tertiary effects of ecological degradation on human beings, such as increased mortality rates or reproductive and immunological impairment. Recognition of those effects will logically lead to expanded efforts to manage health risks through more comprehensive environmental policymaking and preventative health care.

Policymakers must also reexamine conventional economic measures and acknowledge "that the human economy is supported by an array of services supplied free by natural ecosystems."[50] Modern economics incorporates a number of powerful biases that operate against protection of ecological integrity and, thus, against a sustainable society.[51] These include artificially low discount rates on natural resources and narrow definitions of capital stock that improperly assume free substitutability of ecological services;[52] property regimes that create perverse incentives for excessive consumption;[53] an

48. *See* sources cited *supra* note 43.

49. *See* OFFICE OF RESEARCH AND DEV., U.S. EPA, ENVIRONMENTAL MONITORING AND ASSESSMENT PROGRAM: ECOLOGICAL INDICATORS (U.S. EPA, Pub. No. EPA/600/3-90/060, 1990).

50. *See* EHRLICH & EHRLICH, *supra* note 40, at 3.

51. *See* Colin Clark, *Economic Biases Against Sustainable Development*, *in* ECOLOGICAL ECONOMICS, *supra* note 11, at 319, 321.

52. Because conventional definitions of capital stock do not include such long-term assets as biotic, soil, water, and air resources, which form the basis for all ecosystems, national accounts may "create the illusion of income development, when in fact national wealth is being destroyed." ROBERT REPPETTO ET AL., ACCOUNTS OVERDUE: NATURAL RESOURCE DEPRECIATION IN COSTA RICA 2 (1991). In Costa Rica, for example, inadequate economic indicators gave the appearance of growth over the past two decades, while annual depreciation of the country's fisheries, soils, and forests averaged five percent of gross domestic product, or more than one third of gross capital formation. Clearly, Costa Rica cannot sustain its rapid economic growth if it continues to deplete critical environmental capital. *Id.* at 1-6.

For a discussion of threats to Earth's stock of arable land, see Larry B. Stammer, *U.N. Study: 10 Percent of Soil Badly Damaged*, SEATTLE TIMES, Mar. 25, 1992, at A4; WORLD RESOURCES INST., WORLD RESOURCES: 1992-93, at 113 (1992) (estimating that 22 million acres have been permanently destroyed by overgrazing, deforestation, and unsustainable agricultural practices); George M. Woodwell & Richard A. Houghton, *The Experimental Impoverishment of Natural Communities: Effects of Ionizing Radiation on Plant Communities, 1961-1976*, *in* EARTH IN TRANSITION, *supra* note 8, at 9, 9 (discussing soil impoverishment in India); *cf.* PONTING, *supra* note 2, at 117 (examining European expansion driven by population and resource pressures); HERMAN E. DALY & JOHN B. COBB, JR., FOR THE COMMON GOOD: REDIRECTING THE ECONOMY TOWARD COMMUNITY, THE ENVIRONMENT, AND A SUSTAINABLE FUTURE 155 (1989) (making analogy between environment and goose that lays golden eggs).

53. *See* Clark, *supra* note 51, at 321; *see generally* Garret Hardin, *The Tragedy of the Commons*, 162

approach toward scientific uncertainty that justifies irresponsible inaction toward the environment;[54] and a macroeconomic theory that fails to consider the marginal costs of growth.[55] As the 1992 U.N. Conference on Environment and Development illustrated, the integration of environmental goals into economic systems presents no easy task.[56] Successful integration of ecological integrity into social conceptions of economic health will require a new ethic — an ecological integrity ethic.[57]

Two main schools of thought have driven human actions toward the environment during the twentieth century: Gifford Pinchot's utilitarian "resource conservation ethic" and John Muir's spiritual "preservation ethic."[58] Pinchot argued that natural resources should be harvested so as to provide the greatest good for the greatest number of people for the longest period of time. Muir instead suggested that spiritual needs take precedence over material needs, urging designation of wilderness areas to fulfill spiritual needs. These two approaches have established an artificial and counterproductive dichotomy between maximum extraction and maximum protection. The transition to an environmentally sustainable future requires that we perceive our ability to control our destiny differently.

The growing threat to a sustainable future demonstrates the need for an "ecological integrity ethic" grounded in the realities of evolutionary and ecological biology, such as that advocated by Aldo Leopold.[59] Leopold "saw the search for such an ethic as one culture's search for a workable, adaptive approach to living with the land,"[60] leading him to believe that "[a] thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community."[61] Such an ecological integrity ethic converges with trends in environmental philosophy and ethics[62] and with scientific knowledge about

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SCIENCE 1243 (1968).

54. *See* Clark, *supra* note 51, at 323; *see also* PAUL R. EHRLICH & ANNE H. EHRLICH, EXTINCTION: THE CAUSES AND CONSEQUENCES OF THE DISAPPEARANCE OF SPECIES xi-xii (1981); Woodwell, *supra* note 8, at 14-15. Scientific uncertainty has delayed action on issues of ozone depletion, biodiversity reduction, soil depletion, and global climate change.

55. *See* Daly, *supra* note 11, at 34. Policymakers should distinguish between economic growth ("quantitative increase in the scale of the physical dimensions of the economy") and economic development ("qualitative improvement in the structure, design, and composition of the physical stocks of wealth"). Herman E. Daly, *Boundless Bull*, ORION, Summer 1991, at 59, 60.

56. *See* Scott Hajost, *The G-7 Must Open the "Door From Rio,"* CHRISTIAN SCI. MON., July 3, 1992, at 19 (arguing that GATT should be structured to integrate environmental and development concerns and to promote sustainable development).

57. *See generally* James R. Karr, *Ecological Integrity: Protecting Earth's Life Support Systems, in* ECOSYSTEM HEALTH, *supra* note 15, at 223, 225 [hereinafter Karr, *Ecological Integrity*].

58. J. Baird Caldicott, *Conservation Ethics and Fishery Management*, FISHERIES, Mar.-Apr. 1991, at 22, 24; *see also* JOHN MUIR, RAMBLES OF A BOTANIST AMONG THE PLANTS AND CLIMATES OF CALIFORNIA (1974); GIFFORD PINCHOT, FIGHT FOR CONSERVATION (1910).

59. Caldicott, *supra* note 58, at 27.

60. BRYAN G. NORTON, TOWARD UNITY AMONG ENVIRONMENTALISTS 58 (1991).

61. ALDO LEOPOLD, A SAND COUNTY ALMANAC AND SKETCHES HERE AND THERE 224-25 (1949).

62. *See, e.g.*, NASH, *supra* note 14; NORTON, *supra* note 60; ORR, *supra* note 9.

the dependence of human society on ecological services provided by planet Earth.[63]

V. CONCLUSION

For centuries, the impacts of human actions were local and temporary. Today, the cumulative and largely irreversible effects of human carelessness are global in scale. The species *Homo sapiens* threatens natural environments, from the deep ocean to the tops of mountains, as well as the stability of the human habitat. Frenzied, uninhibited economic growth is transforming highly productive, self-maintaining ecosystems into barren landscapes. The widespread assumption that this transformation advances human interests compounds the tragedy of biotic impoverishment. Protection of the Earth's biota, including its ecological integrity, must become a societal priority. Our future depends on our ability to reverse the trend of biotic impoverishment. We can achieve a biologically sustainable society only if we integrate new measures of ecological integrity into our existing measures of medical and economic health. Our long-term success depends on an enlightened environmental revolution, a set of scientific, political, and ethical transitions similar to those experienced during the agricultural and industrial revolutions.

63. Karr, *Ecological Integrity*, *supra* note 57, at 225.