WHAT *ARE* SLUGS GOOD FOR? ECOSYSTEM SERVICES AND THE CONSERVATION OF BIODIVERSITY

DALE D. GOBLE*

I. INTRODUCTION

> *The concept of "ecosystem services" was conceived as a tool for conserving biodiversity. Ecosystems, the argument goes, provide services that would be far more costly if we sought to provide them through engineered approaches; valuing the benefits that nature confers will help society more consciously evaluate the environmental tradeoffs between alternative actions. Given this objective, ecosystem services can be characterized as a "surrogate" for biodiversity—a step that makes explicit the assumption that, if we conserve ecosystem services, we will conserve biodiversity. It is this assumption that is the focus of this article. Surrogates are employed when it is difficult, expensive, or impossible to measure something. An examination of the concept of biodiversity demonstrates that it is such a something. Are ecosystem ser-*

* Margaret Wilson Schimke Distinguished Professor of Law, University of Idaho. My thanks to Gretchen Daily, Holly Doremus, Bryan Norton, J.B. Ruhl, J. Michael Scott for their helpful comments, and the participants at the Symposium on The Law and Policy of Ecosystem Services organized by J.B and Jim Salzman at Florida State University College of Law -- it was a model of what such events should be. They all are, of course, absolved of any responsibility.

> *vices a suitable surrogate for biodiversity? A preliminary review suggests two problems. First, the spatial and temporal scales of biodiversity and ecosystem services differ substantially. Second, the utilitarian valuation that is implicit in the term "services" and explicit in the attempt to monetize that value also undercuts the usefulness of ecosystem services as a surrogate because it appears likely that there will always be a more "efficient" way to provide any specific service. Ultimately, whether ecosystem services are a suitable surrogate for biodiversity depends upon whether biodiversity has value beyond utility.*

What *are* slugs good for? They aren't tasty like cows or corn. They can't be bottled in garlic oil and sold as faux escargot. Slugs are neither charismatic[1] nor megafauna. Slugs are just icky.

Slugs do, however, serve a role in the ecosystems they inhabit. They are decomposers, chewing up leaves, feces, and other detritus and helping to recycle the nutrients back into the soil.[2] Slugs thus contribute to what has become known as "ecosystem services." In Gretchen Daily's frequently cited definition, ecosystem services are "the conditions and processes through which natural ecosystems . . . sustain and fulfill human life."[3] The service to which slugs contribute is replenishing soil fertility.

In defining ecosystem services, Daily noted that the concept had been born from the conclusion "that society is poorly equipped to evaluate environmental tradeoffs, and that the . . . continued resolution [of these tradeoffs] on the sole basis of the social, economic, and political forces prevailing today threatens environmental, economic, and political security."[4] The goal was to foster

1. In the reverse psychology of such matters, the native slug of the Pacific Northwest, the banana slug, is the school mascot of the University of California, Santa Cruz. The species was not, however, chosen to grace the "tails" side of the new Washington state design for the quarter; the salmon was chosen instead. Richard Roessler, *In Search for Identity, Toss Goes to Fish,* THE SPOKESMAN-REVIEW, May 5, 2006, at 1A.

2. *See generally* ROBERT E. RICKLEFS, ECOLOGY 239-40 (3d ed. 1990).

3. Gretchen C. Daily, *Introduction: What are Ecosystem Services?, in* NATURE'S SERVICES 1, 3 (Gretchen C. Daily ed., 1997) [hereinafter NATURE'S SERVICES]. The same definition with a more expansive discussion can be found in Gretchen C. Daily et al., *Ecosystem Services: Benefits Supplied to Human Societies by Natural Ecosystems,* 2 ISSUES IN ECOLOGY 2 (1997), *available at* http://www.esa.org/science_resources/issues/FileEnglish/issue2.pdf; *see also* GEOFFREY HEAL, NATURE AND THE MARKETPLACE 1-3 (2000); Shahid Naeem, *Ecosystem Consequences of Biodiversity Loss: The Evolution of a Paradigm,* 83 ECOLOGY 1537, 1540 (2002); NATIONAL RESEARCH COUNCIL COMMITTEE ON ASSESSING AND VALUING THE SERVICES OF AQUATIC AND RELATED TERRESTRIAL ECOSYSTEMS, VALUING ECOSYSTEM SERVICES 1 (2005) [hereinafter cited as NRC AQUATIC COMMITTEE].

4. NATURE'S SERVICES, *supra* note 3, at 2. For an earlier statement of the problem, see Gretchen C. Daily et al., *Managing the Earth's Life Support Systems: The Game, the*

better understanding of the value of biodiversity by "characteriz[ing] the ways in which the earth's natural ecosystems confer benefits on humanity."[5] Ecosystem services are thus offered as a tool for conserving biodiversity. Specifically, valuing the benefits that nature confers will increase awareness and encourage conserving "natural ecosystems." As Geoff Heal noted, "Most of the services provided by natural ecosystems are dependent on adequate and appropriate biodiversity. So in selling any of these services we are obtaining an economic return on biodiversity."[6]

Since advocates of ecosystem services argue (at least in part) that the concept of ecosystem services will lead to the conservation of biodiversity, the concept can be characterized as a surrogate for biodiversity. Characterizing the relationship between ecosystem services and biodiversity as a surrogacy makes the conservation objective explicit, and it is the connection between ecosystem services and biodiversity that is the focus of this article. It is sufficient to note that, if the conservation of ecosystem services (the "surrogate") is to conserve biodiversity (the "target"), the services must be correlated to biodiversity so that changes in the services mirror changes in biodiversity. That is, if markets for ecosystem services are to conserve biodiversity then the service must be dependent upon biodiversity so that a reduction in biodiversity reduces the value of the service and thus provides a direct and immediate incentive to the decisionmaker to cease the destructive actions. Stated from the opposite perspective, if there is no necessary correlation between ecosystem services and biodiversity then there is no reason to assume that conserving ecosystem services will conserve biodiversity.

Examining the relationship between ecosystem services and biodiversity as a formal surrogacy relationship facilitates a more analytical examination and brings the issues into sharper relief. Does the concept of ecosystem services work as a surrogate for biodiversity? Can the concept be used to distinguish between good and bad policy choices? Will markets for these services provide incentives that foster choices that conserve biodiversity? Untangling these questions requires not only an examination of the concepts of biodiversity and ecosystem services, but also the idea of

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Players, and Getting Everyone to Play, 6 ECOLOGICAL APPLICATIONS 19 (1996). For amplification on the themes, see Gretchen C. Daily, *Countryside Biogeography and the Provisions of Ecosystem Services, in* NATURE AND HUMAN SOCIETY 104 (Peter H. Raven & Tania Williams eds., 1997).

5. NATURE'S SERVICES, *supra* note 3, at 2.

6. HEAL, *supra* note 3, at 106. Daily also makes the point implicitly. *See* Gretchen C. Daily, *Introduction: What are Ecosystem Services?, in* NATURE'S SERVICES 1, *supra* note 3, at 1-4.

surrogacy that ties them together.

II. THE CONCEPT OF BIODIVERSITY

Biodiversity has proven notoriously difficult to define or measure.[7] The National Research Council's Committee on the Noneconomic and Economic Value of Biodiversity began a chapter titled "What Is Biodiversity?" by noting that:

> The word *biodiversity* is used in many ways. Economists and ecologists, ranchers and gardeners, mayors and miners all view biodiversity from different perspectives. When people discuss biodiversity, they often use it as a surrogate for "wild places" or "abundance of species" or even "large, furry mammals." Yet from the viewpoint of those engaged in biodiversity-related sciences—such as population biology, ecology, systematics, evolution, and genetics—biodiversity has a specific meaning: "the variety and variability of biological organisms."[8]

Although the variety-and-variability definition is more specific than "wild places," it is only slightly so—the Committee itself spent twenty-three more pages amplifying the definition.[9] A con-

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7. This term was coined in the run-up to the National Forum on BioDiversity that was held in Washington, D.C. at the end of September 1986. Walter G. Rosen created the neologism by compressing the term "biological diversity." *See* DAVID TAKACS, THE IDEA OF BIODIVERSITY 34-40 (1996). The term quickly assumed an independent identity: "In 1988, *biodiversity* did not appear as a keyword in *Biological Abstracts,* and *biological diversity* appeared once. In 1993, *biodiversity* appeared seventy-two times, and *biological diversity* nineteen times." *Id.* at 39 (citation omitted) (emphasis in original). *See generally* Bryan Norton, *Toward a Policy-Relevant Definition of Biodiversity, in* 2 THE ENDANGERED SPECIES ACT AT THIRTY: CONSERVING BIODIVERSITY IN HUMAN-DOMINATED LANDSCAPES 49 (J. Michael Scott, et al. eds., 2006).

8. NATIONAL RESEARCH COUNCIL COMMITTEE ON NONECONOMIC AND ECONOMIC VALUE OF BIODIVERSITY, PERSPECTIVES ON BIODIVERSITY 20 (1999) [hereinafter cited as NRC BIODIVERSITY COMMITTEE]. The Committee's definition tracks the definition given by the congressional Office of Technology Assessment:

> Biological diversity refers to the variety and variability among living organisms and the ecological complexes in which they occur. Diversity can be defined as the number of different items and their relative frequency. For biological diversity, these items are organized at many levels, ranging from complete ecosystems to the chemical structures that are the molecular basis of heredity. Thus, the term encompasses different ecosystems, species, genes, and their relative abundance.

U.S. CONGRESS, OFF. OF TECH. ASSESSMENT, TECHNOLOGIES TO MAINTAIN BIOLOGICAL DIVERSITY box I-A, at 3 (1987) [hereinafter OTA].

9. NRC BIODIVERSITY COMMITTEE, *supra* note 8, at 20-42.

temporaneous discussion compiled nine additional variations on the variety-and-variability definition[10] and more continue to be drafted:

> Biodiversity is the variety of life. The concept of biodiversity includes the entire biological hierarchy from molecules to ecosystems, or the entire taxonomic hierarchy from alleles to kingdoms, all the logical classes in between (individuals, genotypes, populations, species, etc.), and all of the different members of all those classes. It also includes the diversity of living interactions and processes at all these levels of organization.[11]

E.O. Wilson captured the difficulty when he commented "it is, in one sense, everything."[12]

These variations on the theme of variety are descriptively powerful because they share a pervasive, intuitive understanding that nature is diverse. But this intuitive understanding masks complex questions concerning what variety and variability is crucial. Is it the uniqueness of each specimen or the variety and variability of a population, a subspecies, or a species? Should the focus instead be on assemblages of species such as communities, ecosystems, and landscapes? If answers to these questions are forthcoming they only produce more questions. For example, how is the variety and variability to be measured? Is it even measurable? As one mathematical ecologist has noted, "diversity is rather like an optical illusion. The more it is looked at, the less clearly defined it appears to be and viewing it from different angles can lead to different perceptions of what is involved."[13]

The lack of clarity substantiates Bryan Norton's conclusion that there can be no single "objective scientific definition" of biodiversity in the sense that there is a standard for measuring it.[14]

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10. Kevin J. Gaston, *What Is Biodiversity?, in* BIODIVERSITY 1, 1-2 & table 1.1 (1996).

11. Sahotra Sarkar & Chris Margules, *Operationalizing Biodiversity for Conservation Planning,* 27 J. BIOSCIENCE 299, 299 (2002). *See also, e.g.,* Kent H. Redford & Brian D. Richter, *Conservation of Biodiversity in a World of Use,* 13 CONSERVATION BIOLOGY 1246, 1247 (1999) ("the natural variety and variability among living organisms, the ecological complexes in which they naturally occur, and the ways in which they interact with each other and with the physical environment.").

12. E.O. Wilson, *Introduction, in* BIODIVERSITY II at 1, 1 (Marjorie L. Reaka-Kudla et al. eds. 1988).

13. ANNE E. MAGURRAN, ECOLOGICAL DIVERSITY AND ITS MEASUREMENT 1 (1988).

14. Bryan G. Norton, *On What We Should Save: The Role of Culture in Determining Conservation Targets, in* SYSTEMATICS AND CONSERVATION EVALUATION 23, 25-29 (P. Forey et al. eds. 1994).

Definitions and measures are tools that have utility to the extent that they help us navigate the world and not because they result from any "correspondence to prior realities."[15] The difficulty with the consensus, variety-and-variability definition is that it cannot be applied in the day-to-day universe where choices are constrained by limited resources. Since we can't protect every specimen—or even every place of biological interest—how can we decide what should be conserved?[16] There have been several suggestions for clarifying the concept of biodiversity so that it can be used as a guide for conservation decisions by focusing on either three hierarchical levels (genes, species, and ecosystems),[17] five biospatial levels (genes, populations, species, assemblages such as communities, and landscapes or ecosystems),[18] three nested scales (alpha, beta, and gamma diversity),[19] or three ecosystem attributes (composition, structure, and functions).[20] These approaches not only raise their own concerns,[21] but also demonstrate the importance of context. Michael Soule, for example, offered the five biospatial levels to call attention to "the biological and social contexts of conservation actions, particularly how both biogeography and political geography dictate different conservation tactics."[22] Reed Noss, on the other hand, focused on the three ecosystem attributes because he was seeking a method for selecting "indicators of biodiversity

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15. Norton, *supra* note 7.

16. *See, e.g.,* Justin Garson et al., *Birds as Surrogates for Biodiversity: An Analysis of a Data Set from Southern Quebec,* 27 J. BIOSCIENCE 347 (2002). This issue is often discussed as a question of reserve planning. *See, e.g.,* Craig R. Groves et al., *Planning for Biodiversity Conservation: Putting Conservation Science into Practice,* 52 BIOSCI. 499 (2002); C.R. Margules & R.L. Pressey, *Systematic Conservation Planning,* 405 NATURE 243 (2000); Mark W. Schwartz, *Choosing the Appropriate Scale of Reserves for Conservation,* 30 ANNUAL REV. ECOLOGY & SYSTEMATICS 83 (1999).

17. ELLIOTT A. NORSE ET AL., CONSERVING BIOLOGICAL DIVERSITY IN OUR NATIONAL FORESTS 2-3 (1986); OTA, *supra* note 8, box I-A, at 3; NRC BIODIVERSITY COMMITTEE, *supra* note 8, at 2-3; ORGANISATION FOR ECONOMIC CO-OPERATION & DEVELOPMENT, SAVING BIOLOGICAL DIVERSITY 19-23 (1996) [hereinafter OECD].

18. Michael E. Soule, *Conservation: Tactics for a Constant Crisis,* 253 SCI. 744 (1991).

19. *See* NRC BIODIVERSITY COMMITTEE, *supra* note 8, at 23-24, 26-30; BRYAN G. NORTON, WHY PRESERVE NATURAL VARIETY? 31-34 (1987); R.H. MacArthur, *Patterns of Species Diversity*, 40 BIOLOGICAL REV. 510 (1965); ROBERT H. WHITTAKER, COMMUNITIES AND ECOSYSTEMS (1970); R.H. Whittaker, *Evolution and Measurement of Species Diversity*, 21 TAXON 213 (1972).

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

21. One difficulty that these approaches share is that many of the categories they employ are characterized by very blurry edges. Even the concept of "species"—the fundamental taxonomic unit of all biological classification—has proved remarkably resistant to clarity and unanimity. As the twentieth century's leading taxonomist and historian of biology noted, "There is probably no other concept in biology that has remained so consistently controversial as the species concept." ERNST MAYER, THE GROWTH OF BIOLOGICAL THOUGHT 251 (1982). This is perhaps less surprising when it is recalled that evolution is, after all, about continuums.

22. Soule, *supra* note 18, at 744.

for use in environmental inventory, monitoring, and assessment programs."[23] The difference between Soule's and Noss's approach reflects not only their differing objectives but also the impossibility of using a single metric to measure something that is "everything"—we can at best measure only parts of the irreducibly complex whole that we call biodiversity.[24]

The lack of clarity on what we mean by biodiversity is important not because there is some true definition waiting to be discovered, but because it reveals substantial uncertainties in our understanding of an important conservation objective. Our inability to define biodiversity means we cannot be sure that our conservation management is effective at conserving what we need to conserve to conserve biodiversity. In a political universe of constrained choices and the competing interest of the moment, such concerns quickly become political liabilities.[25] This difficulty reflects recurrent problems associated with attempting to measure and describe complex systems—a difficulty that has elsewhere led to the use of surrogates that can be measured.

III. ECOSYSTEMS, THEIR COMPOSITION, STRUCTURE, AND FUNCTION

Ecosystem services is neither a scientific concept nor something that is (at least in theory) measurable, like the number of species in an ecosystem or the pathways that carbon moves through that ecosystem, because the term "services" brings values into the question. Therefore, before examining the concept of ecosystem services, it is useful to examine the science behind the concept.

Ecosystems are generally described as an assemblage of organisms and the abiotic environment with which and within which the organisms interact:

> [a] community has a close-linked, interacting relation to environment, as climate and soil affect the

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23. Noss, *supra* note 20, at 356.

24. For example, Landres and his colleagues note in their discussion of indicator species that ecological criteria for selecting indicators may be either species-based or community-based depending upon whether a particular species or the quality of the community is of concern. The "types of data needed under each approach are different and, generally, cannot be substituted for one another." Peter B. Landres et al., *Ecological Uses of Vertebrate Indicator Species: A Critique*, 2 CONSERVATION BIOLOGY 316, 320 (1988).

25. For a description of how real-world complexity can be translated into ideological warfare see Joel Achenbach, *The Tempest*, WASH. POST, May 28, 2006, at W8, *available at* http://www.washingtonpost.com/wp-dyn/content/article/2006/05/23/AR2006052301305_5.html (describing how the ambiguities of global climate change are manipulated by skeptics to undermine science).

> community and the community affects the soil and its own internal climate or microclimate, as energy and matter are taken from [the] environment to run the community's living function and form its substance, transferred from one organism to another in the community, and released back to [the] environment. A community and its environment treated together as a functional system of complementary relationships, and transfer and circulation of energy and matter, is an *ecosystem*.[26]

Ecologists who study ecosystems generally focus on the contributions of the interdependent parts of the system to its overall function by examining interactions such as the transformation of energy and the cycling of elements within an ecosystem.[27]

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26. WHITTAKER, *supra* note 19, at 1. *See also* NATURE'S SERVICES, *supra* note 3, at 2 ("An ecosystem is the set of organisms living in an area, their physical environment, and the interactions between them."); GENE E. LIKENS, THE ECOSYSTEM APPROACH: ITS USE AND ABUSE 9 (1992) ("a spatially explicit unit of the Earth that includes all of the organisms, along with all components of the abiotic environment within its boundaries"); NRC AQUATIC COMMITTEE, *supra* note 3, at 7; OECD, *supra* note 17, box 2, at 23 ("the plants, animals, microorganisms and physical environment of any given place, and the complex relationships linking them into a functional system"); ROBERT E. RICKLEFS, THE ECONOMY OF NATURE 3 (4th ed. 1997) ("Assemblages of organisms together with their physical and chemical environments"). From its inception, the concept has been focused on the interaction between the living and nonliving components of the biosphere. *See* A.G. Tansley, *The Use and Abuse of Vegetational Concepts and Terms,* 16 ECOLOGY 284, 299 (1935) ("Though the organisms may claim our primary interest, when we are trying to think fundamentally we cannot separate them from their special environment, with which they form one physical system.").

Our understanding of these interactions has changed as it has become increasingly apparent that ecosystems are not equilibrium systems - there is no "balance of nature." That is, ecosystems are not "static entities in equilibrium," but rather "complex systems that are dynamic and unpredictable across time and space." Tabatha J. Wallington et al., *Implications of Current Ecological Thinking for Biodiversity Conservation: A Review of the Salient Issues*, 10 ECOLOGY & SOC'Y (2005), *available at* http://www.ecologyandsociety.org/vol10/iss1/art15. Ecosystems, in other words, are historically contingent: they evolve over time as the biotic alters the abiotic and is in turn altered by the new environment. LIKENS, *supra*, at 10. At a global scale, for example, life has transformed this planet into a place that is hospitable to the life that has co-evolved with the changing abiotic environment that life itself has modified. One example is oxygen. Although early life was anaerobic, it produced oxygen as a waste product which (as the amount of oxygen in the atmosphere increased) provided a competitive advantage for organisms that could tolerate oxygen. *E.g.,* VLADIMIR N. BASHKIN, MODERN BIOGEOCHEMISTRY 24-27 (2002); RICKLEFS, ECOLOGY, *supra* note 2, at 33; *see generally* PETER WESTBROEK, LIFE AS A GEOLOGICAL FORCE (1991); Naeem, *supra* note 3, at 1540. Human impacts have come to play an increasingly dominant role. *See, e.g.,* Peter M. Vitousek et al., *Human Domination of Earth's Ecosystems,* 277 SCI. 494 (1997). Ecologists have come to recognize that current "natural" ecosystems are at least human-influenced. *See, e.g.,* Jesse Bellemare et al., *Legacies of the Agricultural Past in the Forested Present: An Assessment of Historical Land-Use Effects on Rich Mesic Forests*, 29 J. BIOGEOGRAPHY 1401 (2002); David Foster et al., *The Importance of Land-Use Legacies to Ecology and Conservation*, 53 BIOSCI. 77 (2003); Tansley, *supra* note 26, at 303-04. Simply removing the disturbance is thus no guarantee that the system will return to its previous status.

27. *E.g.,* RICKLEFS, ECONOMY OF NATURE, *supra* note 26, at 190-94.

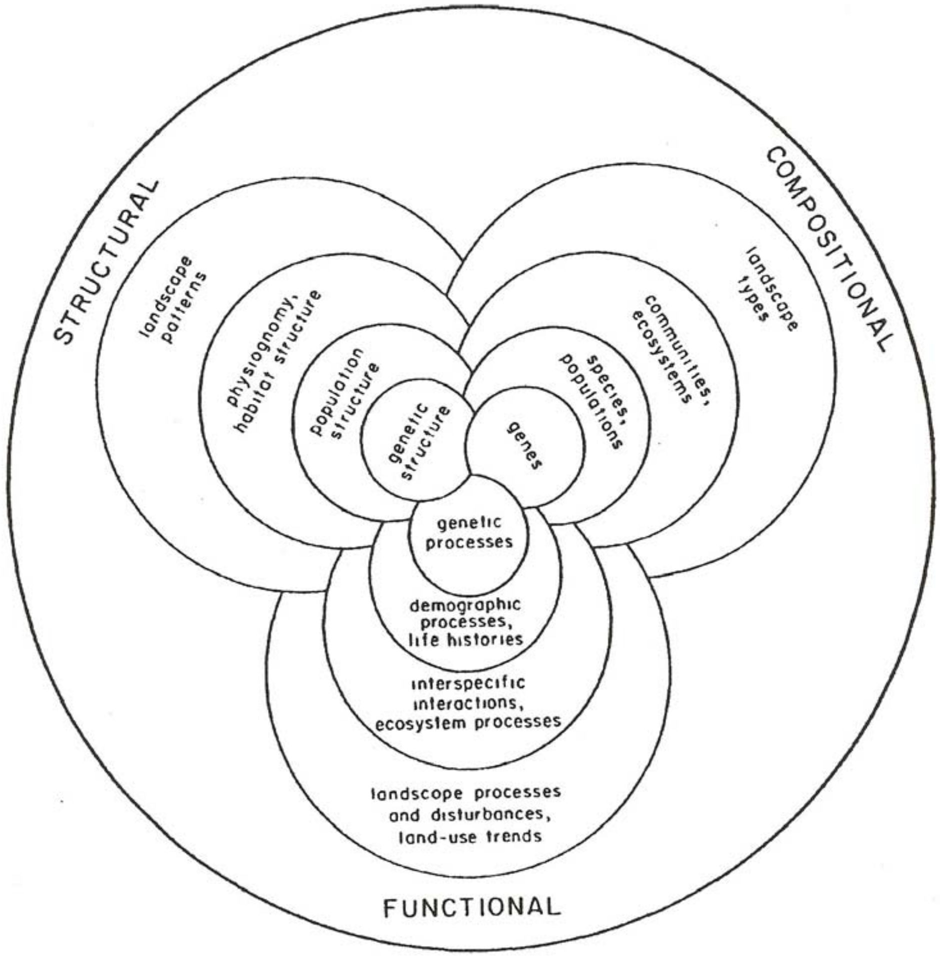

Figure 1.

Ecosystems are characterized by their *composition*, *structure*, and *function* (see figure 1).[28] Ecosystem *composition* refers to the array of organisms in the ecosystem. It includes not only lists of species, but also their relative abundance. The composition of the Pacific Northwest rainforest, for example, includes both banana slugs and Pacific yew.

28. JERRY F. FRANKLIN ET AL., ECOLOGICAL CHARACTERISTICS OF OLD-GROWTH DOUGLAS-FIR FORESTS 2 (
1981); Jerry F. Franklin, *Structural and Functional Diversity in Temperate Forests*, *in* BIODIVERSITY 166, 169-71 (E.O. Wilson & Frances M. Peter eds., 1988); Noss, *supra* note 20, at 356-57. The NRC Aquatic Committee disregards the compositional component, presumably because it is focused on ecosystem services, which are tied to the other two characteristics. NRC AQUATIC COMMITTEE, *supra* note 3, box 3-1, at 60.

Ecosystem *structure* refers to the physical organization or spatial arrangement of the components of the system. Structure thus encompasses both the physical organization (standing dead trees and fallen logs, for example) and biological principles (the relationship between a primary producer, such as the yew, and a decomposer, such as the slug) that organize the relationships among these components.

Ecosystem *function* is the ecological and evolutionary processes that take place as a result of the interactions among the biotic and abiotic components of the ecosystem.[29] For example, primary production and decomposition are ecosystem functions. The yew demonstrates this interaction with the abiotic environment: as a primary producer, the plant relies upon solar energy to fuel photosynthesis that combines atmospheric carbon with water and a wide variety of other chemical elements (e.g.*,* nitrogen, potassium, and sulphur) from the environment (often dissolved in water) that allows the plant to produce new compounds such as amino acids, proteins and the carbohydrate glucose. Primary producers are resources for herbivores, predators, parasites, bacteria, and (ultimately) decomposers such as the banana slug.[30]

Describing the *composition* and *structure* of an ecosystem is complex, but relatively straightforward; describing ecosystem *function* is more difficult because it must be inferred from the observed structure and "there is no explicit and invariant link between structure and function."[31] The problem is further complicated by the fact that the function of any specific ecosystem "is dependent not only on its composition, but also on linkages to surrounding systems and the impact of stressors."[32] For example, two wetlands with the same potential to sequester pollutants, modify nutrient loads, etc., are not identical if one is in an urban setting and the

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29. There is some linguistic ambiguity on the term "ecosystem function." de Groot, for example, separates ecosystem composition into ecosystem structures and ecosystem processes; the structures and processes in turn give rise to ecosystem functions, defined as "the capacity of natural processes and components to provide goods and services that satisfy human needs, directly or indirectly." (citation omitted). Ecosystem functions, in turn, produce goods and services. Rudolf S. de Groot et al., *A Typology for the Classification, Description and Valuation of Ecosystem Functions, Goods and Services,* 41 ECOLOGICAL ECON. 393, 394 (2002). It is not clear that the additional layer of complexity brings additional clarity. This Article follows the NRC Aquatic Committee and uses the terms as defined in the text: ecosystem structure means components, while ecosystem function means processes. The interaction of structure and function produce both goods (ecosystem structural components that are tangible commodities) and services (structural components and functions that are useful but not tangible commodities).

30. *E.g.,* RICKLEFS, ECOLOGY *supra* note 2, at 53-57; *see also* A.R. Main, *The Role of Diversity in Ecosystem Function: An Overview, in* BIODIVERSITY IN MEDITERRANEAN ECOSYSTEMS IN AUSTRALIA 77, 78-79 (Richard J. Hobbs ed., 1992).

31. NRC AQUATIC COMMITTEE, *supra* note 3, at 76.

32. *Id.*

other in a wilderness area because different surroundings create different opportunities.[33]

Much of the conservation effort over the past several decades has focused on ecosystem composition. Implementation of the Endangered Species Act,[34] for example, at least initially emphasized species. Conservation of structural and functional diversity has lagged because it runs counter to our culture's drive to reap the economic benefits that flow from simplifying ecosystems.[35] Ecosystem services, as you will recall, is an attempt to change the dynamics of such decision-making by valuing unaltered ecosystems.

IV. ECOSYSTEM GOODS AND SERVICES

Ecosystem composition and function are scientific descriptions of the relationships that operate within ecosystems. As such, they are (as far as is possible) value-free. Ecosystems can also be described in utilitarian, value-laden terms as providing *goods* and *services*. The relation between ecosystem composition and function, on the one hand, and ecosystem goods and services, on the other, is complicated at least in part because of this shift from description to prescription. There is no simple correlation between ecosystem composition and function, on the one hand, and ecosystem goods and services, on the other hand. Furthermore, the goods produced by an ecosystem are also dependent upon the services provided by that ecosystem. The yew that produces Taxol®,[36] for example, is dependent upon the banana slug for nutrient recycling.[37]

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33. *Id.* at 59; *see also id.* at 76-77.

34. 16 U.S.C. §§ 1531-44 (2000). If the ESA were only a species act, zoos and seed banks would be sufficient to satisfy its goals. Thus, the importance of the Act's statement of purpose: "The purposes of this Act are to provide a means whereby the ecosystems upon which endangered species and threatened species depend may be conserved." § 1531(b). *See also* § 1532(16) (expansive definition of "species").

35. *See* Franklin, *supra* note 28, at 169-71. For an examination of the most common simplification see Donald Worster, *Transformations of the Earth: Toward an Agroecological Perspective in History,* 76 J. AM. HIST. 1087 (1990).

36. "Taxol" is the trade name for an anticancer agent synthesized from the Pacific yew. *See* American Chemical Society, The Pacific Yew, http://acswebcontent.acs.org/landmarks/landmarks/taxol/yew.html (last visited June 23, 2007); Sarah A. Laird & Kerry ten Kate, *Linking Biodiversity Prospecting and Forest Conservation, in* SELLING FOREST ENVIRONMENTAL SERVICES 151, 164 box 9.3 (Stefano Pagiola et al. eds., 2002); *New Source of Cancer Drug Spares Yew Tree,* N.Y. TIMES, Jan. 31, 1993, *available at* http://query.nytimes.com/gst/fullpage.html?sec=health&res=9F0CE7DE1331F932A05752C0A965958260.

37. This may be the meaning of a curious aspect of Daily's definition of ecosystem services. She begins with the statements that ecosystems provide three types of services:

(1) maintenance of biodiversity and the output of ecosystem goods, (2) provision of basic life-support functions, and (3) provision of intangible aesthetic and cultural benefits. NATURE'S SERVICES, *supra* note 3, at 3. The first item on this list raises questions about the relation-

Ecosystem goods are familiar. They are the tangible bits of ecosystem composition that are commodities—the bauxite, timber, fish, Taxol®, and all the other "natural resources."[38] Although banana slugs are structural components of the Pacific rainforest ecosystem, they are not goods—at least until someone can re-conceive and package them as marketable commodities. In other words, goods are compositional elements of ecosystems, but not all compositional components are goods.

Ecosystem services, on the other hand, are less familiar—in part—because Daily and her colleagues have only recently crafted the concept. Ecosystem services are also less familiar because the physical, biological, and chemical processes at work in ecosystems (the ecosystem functions) are seldom experienced directly (or even seen) by those who benefit from those functions. As processes, they are simply part of the background that is the taken-for-granted world. The decomposition services provided by slugs, for example, is invisible to most people—and when it isn't, it's because slugs are decomposing something of value to humans.[39] Although some services are provided by structural components of ecosys-

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ship of biodiversity to ecosystem services: does biodiversity interact with the abiotic environment to produce the flow of goods and services, or do ecosystem services include biodiversity? That is, is biodiversity a producer of goods and a provider of services or is it an output of ecosystem services? Daily appears to argue that it is an output rather than the provider. What she may mean is suggested in a subsequent discussion of the dynamic, interactive relationship among the parts of ecosystems. Daily and her colleagues wrote, "Biodiversity is generated and maintained in natural ecosystems, where organisms encounter a wide variety of living conditions and chance events that shape their evolution in unique ways." NATURE'S SERVICES, *supra* note 3, at 5. The fact that the biotic and abiotic components of ecosystems are dynamic and interactive does not, however, render biodiversity an ecosystem service; nor does the fact that biodiversity creates biodiversity by rendering services to other species. Rather, it is the interaction of the biotic and abiotic environment that produces not only goods but also the physically observable manifestations of ecosystem functions that have been labeled ecosystem services. If these services are to serve as a surrogate for biodiversity, it seems important to keep the two distinct.

38. Categorizing something as a "resource" is a complex act of social definition that varies among cultures and over time. The anthropologist Eugene Hunn provides a simple example: suckers are a highly valued resource for the indigenous peoples of the Pacific Northwest because the species spawn two months prior to the earliest salmon runs into the basin; they are not, however, resources for Euro-Americans in the region and agencies nominally acting under "multiple-use resource management" systematically extirpate suckers from trout streams. Eugene S. Hunn, *Mobility as a Factor Limiting Resource Use in the Columbia Plateau of North America, in* NORTHWEST LANDS, NORTHWEST PEOPLES 156, 161 (Dale D. Goble & Paul W. Hirt eds., 1999). Bill Cronon's study of New England similarly demonstrates how the Indians and the English perceived the same habitat in dramatically different ways. WILLIAM CRONON, CHANGES IN THE LAND (1983). On the more general question of how societies create "natural resources" by valuing certain elements of their habitat, see WALTER FIREY, MAN, MIND AND LAND 27 (1960); Alexander Spoehr, *Cultural Differences in the Interpretation of Natural Resources, in* MAN'S ROLE IN CHANGING THE FACE OF THE EARTH 93 (William L. Thomas, Jr. ed., 1956); Carolyn Merchant, *The Theoretical Structure of Ecological Revolutions,* 11 ENVTL. REV. 265 (1987); Worster, *supra* note 35.

39. M.L. FLINT, UNIV. OF CAL., PEST NOTES: SNAILS & SLUGS (2003), *available at* http://www.ipm.ucdavis.edu/PDF/PESTNOTES/pnsnailsslugs.pdf.

tems, such as the pollination by animals, the tsunami protection afforded by coral reefs, and the flood risk reduction by wetlands, most ecosystem services are provided by ecosystem functions rather than structure. This array of "services" include:

* purification of air and water
* mitigation of droughts and floods
* generation and preservation of soils and renewal of their fertility
* detoxification and decomposition of wastes
* pollination of crops and natural vegetation
* dispersal of seeds
* cycling and movement of nutrients
* control of the vast majority of potential agricultural pests
* protection of coastal shores from erosion by waves
* protection from the sun's harmful ultraviolet rays
* stabilization of the climate
* moderation of weather extremes and their impacts
* provision of aesthetic beauty and intellectual stimulation that life the human spirit.[40]

Beyond this, and other similar[41] lists, definitions of ecosystem services tend to be overly general. The most frequently cited definition is that provided by Daily: ecosystem services are "the conditions and processes through which natural ecosystems ... sustain and fulfill human life."[42] The authors of the National Research Council report *Valuing Ecosystem Services* note that "the physical, biological, and chemical processes at work in natural ecosystems . . . are seldom experienced directly by users . . . Rather, it is the services provided by ecosystems, such as flood risk reduction and water supply . . . that create value for human users . . . ."[43] The *Millennium Ecosystem Assessment* defined ecosystem services even more generally as "the benefits provided by ecosystems" and lumped goods and services together.[44]

As noted, "ecosystem services" is not a scientific term, but

40. NATURE'S SERVICES, *supra* note 3, at 3-4.

41. The National Research Council Committee's report offers two tables with five different lists. NRC AQUATIC COMMITTEE, *supra* note 3, at 80-81 tbl. 3-2. *See also* Claire Kremen, *Managing Ecosystem Services: What Do We Need to Know about Their Ecology?,* 8 ECOLOGY LETTERS 468, 470 (2005).

42. NATURE'S SERVICES, *supra* note 3, at 3. For the same definition with a more expansive discussion, see id. at 2.

43. NRC AQUATIC COMMITTEE, *supra* note 3, at 1.

44. MILLENNIUM ECOSYSTEM ASSESSMENT, ECOSYSTEMS AND HUMAN WELL-BEING: SYNTHESIS 39 (2005), *available at* http://www.maweb.org/proxy/document.356.aspx; *see also id.* at 40, Box 2.1.

rather a rhetorical approach that draws attention to the value of biodiversity to the public.[45] As such, the value-laden term "services" and the additional, utilitarian definitions perform satisfactorily because they draw attention to a previously little-noted group of benefits that nature provides our species. Ecosystem services thus provide a rhetorical tool for the conservation of nature. The question is whether the concept can provide more than rhetoric.

V. SURROGACY

It is not possible to measure everything. In many situations where it is too difficult or expensive to measure something directly, surrogates are used to provide the missing information.[46] A surrogate (or indicator) is a miners' canary—"an organism whose characteristics (*e.g.,* presence or absence, population density, dispersion, reproductive success) are used as an index of attributes too difficult, inconvenient, or expensive to measure for other species or environmental conditions of interest."[47] Monitoring water quality in drinking water systems, for example, is based in part on the presence of *Escherichia coli* (*E. coli*), a bacteria that is not harmful in itself but which is used to indicate the presence of other potentially harmful organisms because it is found only in human and animal fecal waste.[48] This is the first of two different contexts in which organisms have been used as surrogates: they are used to monitor the presence and effects of pollution.[49]

Organisms are also used as surrogates for changes in ecological factors such as population trends and habitat suitability. Surrogates have a long history in this field, beginning at least with C. Hart Merriam's use of vertebrates to define life zones in 1898.[50]

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45. *See supra* notes 5-6 and accompanying text.

46. Landres et al., *supra* note 24, at 317.

47. *Id. See generally* William A. Thomas, *Indicators of Environmental Quality: An Overview*, *in* INDICATORS OF ENVIRONMENTAL QUALITY 1 (William A. Thomas ed., 1972).

48. *See* Drinking Water Contaminants: Microorganisms, http://www.epa.gov/safewater/contaminants/index.html#micro (last visited June 23, 2007).

49. *See generally* NATIONAL RESEARCH COUNCIL COMMITTEE ON THE APPLICATIONS OF ECOLOGICAL THEORY TO ENVIRONMENTAL PROBLEMS, ECOLOGICAL KNOWLEDGE AND ENVIRONMENTAL. PROBLEM-SOLVING 81 (1986). This use of organisms is well developed. *See, e.g.,* A. JAMES & LILIAN EVISON, BIOLOGICAL INDICATORS OF WATER QUALITY (1979); MARGIT KOVACS, BIOLOGICAL INDICATORS IN ENVIRONMENTAL PROTECTION (1992); WAYNE R. OTT, ENVIRONMENTAL INDICES (1978); L. ELLIOT SHUBERT ED., ALGAE AS ECOLOGICAL INDICATORS (1984); IAN F. SPELLERBERG, MONITORING ECOLOGICAL CHANGE (1991); James R. Newman & R. Kent Schreiber, *Animals as Indicators of Ecosystem Responses to Air Emissions,* 8 ENVTL. MANAGEMENT 309 (1984).

50. C. Hart Merriam, Life Zones and Crop Zones of the United States (1898) (USDA, Division of Biological Survey Bulletin 10). *See also* VICTOR E. SHELFORD, THE ECOLOGY OF NORTH AMERICA (1963).

The use of surrogates has expanded significantly since the enactment of the numerous federal environmental and land-use management statutes of the 1970s. One widely known example is the U.S. Forest Service's reliance upon "management indicator species" to meet its statutory obligation to "provide for diversity of plant and animal communities."[51] Similarly, when the National Research Council sought to assess the U.S. Fish and Wildlife Service's management of listed species in the Klamath River Basin, it relied upon measurements of annual chlorophyll *a* concentrations as a surrogate for algal density during the annual algal blossom.[52]

The most common proposals for reducing the intractable complexity of biodiversity are three potential surrogates:

* *Genetic diversity:* the arguments in support of this alternative focus on the genetic basis of both intra- and inter-specific differences, as well as the fact that this is also the level at which evolutionary pressures operate.[53]
* *Species diversity:* this alternative has been the most common choice—which probably reflects the familiarity of "species" as the fundamental taxonomic unit as well as the relatively more complete documentation of the diversity and distribution of species.[54]
* *Landscape or ecosystem diversity:* those who favor this approach argue that the other alternatives fail to capture the dynamic interactions of communities and thus fail to conserve ecosystem functions. Furthermore, they argue, protecting landscapes will conserve species since landscapes are composed of species.[55]

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51. 16 U.S.C. § 1604(g)(3)(B) (2000). *See generally* Charles F. Wilkinson & H. Michael Anderson, *Land and Resource Planning in the National Forests,* 64 OR. L. REV. 1, 290-309 (1985). The agency's management approach was scientifically controversial. The approach assumed, first, that the surrogates provide a reliable assessment of habitat conditions and, second, that maintaining habitat for the indicator would ensure conditions suitable for other species. Both assumptions are open to dispute. *See* Landres et al., *supra* note 24.

52. *See* NATIONAL RESEARCH COUNCIL COMMITTEE ON ENDANGERED AND THREATENED FISHES IN THE KLAMATH RIVER BASIN, ENDANGERED AND THREATENED FISHES IN THE KLAMATH RIVER BASIN 110-16 (2004).

53. Terry L. Erwin, *An Evolutionary Basis for Conservation Strategies,* 253 SCI. 750 (1991); Daniel P. Faith, *Conservation Evaluation and Phylogenetic Diversity,* 61 BIOLOGICAL CONSERVATION 1 (1992); R.I. Vane-Wright et al., *What to Protect? Systematics and the Agony of Choice,* 55 BIOLOGICAL CONSERVATION 235 (1991); Paul H. Williams et al., *Do Conservationists and Molecular Biologists Value Differences Between Organisms in the Same Way?,* 2 BIODIVERSITY LETTERS 67 (1994).

54. *See, e.g.,* M. Philip Nott & Stuart L. Pimm, *The Evaluation of Biodiversity as a Target for Conservation, in* THE ECOLOGICAL BASIS OF CONSERVATION 125 (S.T.A. Pickett et al. eds., 1997).

55. *E.g.,* J. Michael Scott et al., *Species Richness: A Geographic Approach to Protecting*

Each proposal has its own shortcomings. Advocates for species diversity, for example, assume that conservation management actions targeted at species will conserve other taxa (such as subspecies and populations) as well as genetic diversity and ecosystem diversity—a claim that continues to be contested.[56]

To restate this more formally, surrogacy is a relationship between two variables, the surrogate (or indicator) and the target (or objective).[57] When the target (something of interest, such as biodiversity) either cannot be measured directly or economically, measurement of a surrogate may be substituted. The surrogate should meet two criteria: first, it should be relatively simple and economical to measure; and second, it should be correlated to the target so that changes in the surrogate track changes in the target. For our purposes, the issue is the degree of correlation between the proposed surrogate (ecosystem services) and target (biodiversity). Specifically, do changes in an ecosystem's output of services track changes in that ecosystem's diversity?[58]

It is helpful to distinguish between three degrees of correlation.[59] For example, the use of *E. coli* as a surrogate for water quality is a "first-order surrogate." Because it is found only in fecal material, the presence of *E. coli* in a drinking water system indicates that there is substantial probability that the water supply has been contaminated. The proposed genes, species, and landscape surrogates are similar to *E. coli*: measuring the variability of the chosen metric is claimed to be sufficiently correlated to biodiversity-in-general that changes in the surrogate track changes in biodiversity. Translated into a management context, the claim is that management actions that conserve genes or species or landscapes will conserve biodiversity. Although these are disputed correlations, they are nonetheless offered as factual (*i.e.,* measurable)

Future Biological Diversity, 37 BIOSCI. 782 (1987); *see generally* JAREN VERNER ET AL., WILDLIFE 2000 (1986).

56. *E.g.,* Sandy J. Andelman & William F. Fagan, *Umbrellas and Flagships: Efficient Conservation Surrogates or Expensive Mistakes?,* 97 PROC. NAT'L ACAD. SCI. 5954 (2000); D.B. Lindenmayer et al., *The Focal-Species Approach and Landscape Restoration: A Critique,* 16 CONSERVATION BIOLOGY 338, 340 (2002).

57. *See, e.g.,* Sarkar & Margules, *supra* note 11, at 304.

58. Advocates of ecosystem services such as Daily and Heal have not argued that services are a *formal* surrogate for biodiversity. My argument, however, is that, if ecosystem services are to be of value in conserving biodiversity, they must be correlated with that diversity—which is the role of a surrogate. The objective in examining the surrogacy relationship as a formal relationship thus is to expose the implicit issues in whether the ecosystem services can be used to conserve biodiversity.

59. What are here labeled first-order and second-order surrogates, Sarkar and Margules call "true surrogates" (surrogates that represent the target variable) and "estimator surrogates" (surrogates that have true surrogates as their target variable). Sarkar & Margules, *supra* note 11, at 304-05. Sarkar and Margules do not consider what I have denominated "third-order surrogates."

relationships that can in principle be verified or refuted.

A second-order surrogate is offered not as a measure of biodiversity (as is the case with a first-order surrogate) but rather as a measure of a first-order surrogate. Examples are the variety of proposals that rely upon different subsets of species composition such as flagship,[60] umbrella,[61] focal,[62] and keystone[63] species. Proponents of such categories of species have argued that they can be used as a measure of species diversity (the first-order surrogate) and, hence, as conservation management indicators because actions targeted at the subset will meet the conservation needs of other species (and thus of biodiversity-in-general).[64] These proposals are second-order surrogates because they would replace

60. These are charismatic species that often have become the symbol for an entire conservation agenda. The northern spotted owl and the Florida panther are examples. Daniel Simberloff, *Flagships, Umbrellas, and Keystones: Is Single-Species Management Passé in the Landscape Era?,* 83 BIOLOGICAL CONSERVATION 247, 248-50 (1998). *See also* Andelman & Fagan, *supra* note 56.

61. Umbrella species require such large habitat blocks that they are thought likely to shelter other at-risk species as well. Spotted owls and Florida panthers are also umbrella species. *See* Simberloff, *supra* note 60, at 249-50; David Wilcove, *Getting Ahead of the Extinction Curve,* 3 ECOLOGICAL APPLICATIONS 218 (1993).

62. Andelman & Fagan, *supra* note 56; Robert J. Lambeck, *Focal Species: A Multi-Species Umbrella for Nature Conservation,* 11 CONSERVATION BIOLOGY 849 (1997); Lindenmayer et al., *supra* note 56.

63. Keystone species play a disproportionately significant role in shaping the ecosystems in which they are found. Robert T. Paine, *Food Web Complexity and Species Diversity,* 100 AM. NATURALIST 65 (1966). For example, sea otters are keystone species in the nearshore rocky ecosystem of the Pacific coast. The otter preys upon sea urchins, the primary herbivore in the ecosystem. Removal of otters leads to a population explosion of urchins that turn the kelp forests into "deserts" that support far fewer species. *See generally* Paul K. Dayton, *Experimental Studies of Algal Canopy Interactions in a Sea Otter-Dominated Kelp Community at Amchitka Island, Alaska,* 73 FISHERY BULL. 230 (1975); James A. Estes et al., *Sea Otter Predation and Community Organization in the Western Aleutian Islands, Alaska,* 59 ECOLOGY 822 (1978); James A. Estes & John F. Palmisano, *Sea Otters: Their Role in Structuring Nearshore Communities,* 185 SCI. 1058 (1974); L.F. Lowry & J.S. Pearse, *Abalones and Sea Urchins in an Area Inhabited by Sea Otters,* 23 MARINE BIOLOGY 213 (1973); Charles A. Simenstad et al., *Aleuts, Sea Otters, and Alternate Stable-State Communities,* 200 SCI. 403 (1978). Similarly, the foraging behavior of a guild of three desert-dwelling, seed-eating kangaroo rats prevents the establishment of tall perennial and annual grasses but increases the number of seed-eating birds: exclusion of the rats leads to the replacement of desert shrubs and animal species by grassland plants and animals. James H. Brown & Edward J. Teske, *Control of a Desert-Grassland Transition by a Keystone Rodent Guild,* 250 SCI. 1705, 1705 (1990). *See also* J.C. Castilla & L.R. Duran, *Human Exclusion from the Rocky Intertidal Zone of Central Chile: The Effects on Concholepas concholepas (Gastropoda),* 45 OIKOS 391 (1985) (removal of top predator, humans, increased species diversity); John Pastor, et al., *Moose, Microbes, and the Boreal Forest,* 38 BIOSCI. 770 (1988) (moose browsing changes plant community composition and soil microbial processes in boreal forests); W.G. Wharton & K.H. Mann, *Relationship Between Destructive Grazing by the Sea Urchin, Strongylocentrotus droebachiensis, and the Abundance of American Lobster, Homarus americanus, on the Atlantic Coast of Nova Scotia,* 38 CANADIAN J. FISHERIES & AQUATIC SCI. 1339 (1981) (overfishing of lobsters in the northwestern Atlantic altered balance among urchins, kelp, and other marine species).

64. *E.g.,* Andelman & Fagan, *supra* note 56, at 5954; Lindenmayer et al., *supra* note 56, at 340.

measurement of species diversity (the first-order surrogate) with measurement of one or a subset of species.

Other second-order surrogates rely upon vegetation types. The Gap Analysis Program, for example, seeks to conserve biodiversity by mapping land cover (vegetation types) based on satellite imagery.[65] Vegetation is the dominant structural component of ecosystems, providing not only habitat but food for a large variety of animal species—including many inconspicuous (and thus easily overlooked) species. It is, however, a second-order surrogate because the assumption is that land-cover is a reasonably accurate measure of species or landscape diversity (the first order surrogates).

Given the difficulty (if not impossibility) of monitoring and managing biodiversity-in-general, some simplifying measure is necessary—but all of the choices are by definition imperfect. It is the overwhelming complexity of biodiversity that necessitates the reductionistic use of a surrogate to begin with, and because all reductionistic decisions are choices, they pose risks.[66]

Ecosystem services *are* correlated with biodiversity—if only to

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65. *See generally* J. MICHAEL SCOTT ET AL., GAP ANALYSIS: A GEOGRAPHIC APPROACH TO PROTECTION OF BIOLOGICAL DIVERSITY (1993) (Wildlife Monographs No. 123); U.S GEOLOGICAL SURVEY, GAP ANALYSIS PROGRAM HISTORY AND OVERVIEW (2003), *available at* http://www.gap.uidaho.edu/portal/gap_fs2004.pdf; Official Description, http://gapanalysis.nbii.gov/portal/server.pt (follow "About GAP" hyperlink; then follow "official description" hyperlink) (last visited June 23, 2007) (describing the GAP Analysis Program).

66. Reed Noss, for example, offered a possible approach that began with the primary attributes of ecosystems—composition, structure, and function—and crafted a nested, hierarchical scheme that included each element at increasing geographic scales (*see* figure 1). Noss, *supra* note 20. Simberloff's response was that the proposal was "the *reductio ad absurdum* of th[e] confusion of goals" because it required monitoring "virtually *everything*." Simberloff, *supra* note 60, at 248. On the other hand, Peter Landres and his colleagues concluded that most of the ecological criteria that had been suggested for selecting surrogates lacked scientific rigor. As a result, "[u]sing indicators to assess population trends and habitat suitability for other species is inappropriate without confirmatory research"—which they acknowledged was prohibitively expensive. Landres et al., *supra* note 24, at 323.

The question of correlation thus becomes a question of risk: do you prefer Type I or Type II errors? Type I errors are false negatives; that is, a failure to detect a significant effect (*e.g.,* a correlation between two events); Type II errors, on the other hand, are false positives, incorrect claims that there is a significant effect. Scientists generally assume that Type I errors are less significant than Type II errors. This preference reflects the standard of lab-bench science where experiments are reproducible: a Type I, false-positive error is likely to lead future research astray, wasting resources; a Type II, false-negative error, on the other hand, may only result in delay. Where experiments can be duplicated, this is a prudent institutional preference. It is, however, a normative choice—both Type I and Type II errors *are* errors and there is no intrinsic reason to prefer one type to the other. Furthermore, in situations where there is more than epistemological risk—in the conservation of biodiversity or at-risk species, for example—the lab-bench preference may be imprudent since Type II errors generally will lead to failing to provide protection—and extinction is irreversible. K.S. Shrader-Frechette & E.D. McCoy, *Statistics, Costs and Rationality in Ecological Inference,* 7 TRENDS IN ECOLOGY & EVOLUTION 96 (1992); Daniel J. McGavey, *Making the Most of the "Best Data Available" in Endangered Species Act Science,* BIOSCI. (forthcoming).

the extent that the services are the product of some aspect of the biodiversity of a parcel. The proposed surrogacy relationship, however, is an unusual one. Proponents of the concept might be understood to be assuming that ecosystem services is a second-order surrogate that provides a measure of a first-order surrogate, ecosystem or landscape diversity. To the extent that ecosystem services depend upon ecosystem composition, structure, and function, it seems analogous to claims that umbrella or keystone species can serve as a second-order surrogate for species diversity. There is, however, a fundamental difference. Ecosystem services, unlike other second-order surrogates such as keystone species or landcover, changes the metric employed in measuring the surrogate: rather than employing a biological measurement (*e.g.,* populations of grizzly bears or old-growth rain forest), ecosystem services employs a utilitarian valuation (value to humans) that is further translated into dollars (*e.g.,* dollars per ton of carbon). That is, the translation of ecosystem function into services and then into dollars involves two value-laden transformations: from a biological function into a claim that something has value to humans and then into a monetization of that value. My concern is not with the *ability* to monetize the "services"—a topic that has attracted significant attention[67]—but rather with the shift between a biological and a non-biological metric to measure the surrogate.

To return to our question: is the concept of ecosystem services sufficiently correlated to biodiversity to serve usefully as a surrogate for biodiversity? There are two types of problems with the surrogacy relationship between ecosystem services and biodiversity. First, the scales (both spatial and temporal) of biodiversity and ecosystem services not only differ substantially but also do so in a consistent pattern that undercuts the surrogacy relationship. Second, the utilitarian valuation that is implicit in the term "services" and explicit in the attempt to monetize that value also militates against the usefulness of ecosystem services as a surrogate: it seems likely that there will always be a more "efficient" way to

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67. Much of the work on ecosystem services has focused on developing methods for determining the economic value of ecosystem services. Daily, for example, has argued that the lack of markets for ecosystem services means that there are no price signals to reflect changes in supply or condition. "This is a major factor driving the . . . conversion [of natural ecosystems] to human-dominated systems . . . ." NATURE'S SERVICES, *supra* note 3, at 2. Several of the chapters in Daily's book address the valuation issue. *See, e.g.,* Lawrence H. Goulder & Donald Kennedy, *Valuing Ecosystem Services: Philosophical Bases and Empirical Methods, in* NATURE'S SERVICES 23 (Gretchen C. Daily ed., 1997); Robert Costanza & Carl Folke, *Valuing Ecosystem Services with Efficiency, Fairness, and Sustainability as Goals, in* NATURE'S SERVICES 49. *See also* NRC AQUATIC COMMITTEE, *supra* note 3; *Symposium,* 20 STAN. ENVTL. L.J. 309-536 (2001); James Salzman, *Creating Markets for Ecosystem Services: Notes from the Field,* 80 N.Y.U. L. REV. 870 (2005).

provide the specific service in question. This limitation is also a consistent problem since there does not appear to be a necessary correlation between services and diversity. Although marketing ecosystem services may benefit some of the biological diversity on a parcel of land, the absence of a necessary correlation between ecosystem services and biodiversity means that the marketing of ecosystem services cannot be expected to conserve all of the biodiversity associated with that parcel—particularly because much of the diversity associated with a parcel surrounds that parcel.

VI. *ECOSYSTEM* SERVICES AND SCALE

Biodiversity varies at both spatial and temporal scales: "patterns of diversity are caused by a variety of ecological and evolutionary processes, historical events, and geographical circumstances."[68] Although these scales are interrelated—increasing the spatial scale, for example, tends to increase the temporal scale of ecological processes (*i.e.,* bigger ecosystems generally change more slowly)—it is useful to examine them separately.

A. Spatial Scale

Spatial scale is a continuum that ranges from the dimensions of subatomic particles to the expanding universe. The spatial scale of biodiversity is more restricted, but still staggering as it ranges from the area used by a single microbe to the biosphere.

Scale plays a fundamental role in ecology because different aspects of biodiversity are present at different scales. Biodiversity, in other words, is nonlinear: it does not vary uniformly with varying scales. The diversity of local ecosystems, for example, is a dynamic interaction between local and regional processes. Local processes such as predation, competitive exclusion, and stochastic events tend to promote local extinction while regional processes such as species formation and dispersal add species to local assemblages. Species diversity at a small scale, in short, is influenced by events at much broader scales.[69] From the opposite perspective, local heterogeneity is generally averaged out at broader scales.[70] Similarly, although manipulation of a few hectares[71] is sufficient

68. Dolph Schluter & Robert E. Ricklefs, *Species Diversity: An Introduction to the Problem, in* SPECIES DIVERSITY IN ECOLOGICAL COMMUNITIES 1, 1 (1993).

69. *E.g.,* Robert E. Ricklefs, *Community Diversity: Relative Roles of Local and Regional Processes,* 235 SCI. 167, 167 (1987).

70. *See generally* J.A. Wiens, *Spatial Scaling in Ecology,* 3 FUNCTIONAL ECOLOGY 385 (1989).

71. A hectare is a unit of area equal to 2.47 acres.

to address questions of how individual shrubsteppe birds utilize habitat, addressing the same questions at a population level would require the manipulation of several square kilometers.[72] Furthermore, different types of processes seem to be dominant at different scales: mechanistic relationships between climate and vegetation that are present at broad scales are overwhelmed by biological processes at finer scales.[73] In part, this reflects the discontinuous, patchiness of habitats at finer scales: the remaining Pacific Northwest rainforest, for example, appears relatively uniform from the window of an airplane, but very patchy when one is trying to navigate off-trail.[74]

The crucial point is that ecosystems are dynamic and contingent upon their spatial context: they are both internally variable as well as open to interactions with other ecosystems across the range of spatial scales.[75] These variations are often nonlinear.

If ecosystem services are to operate as a surrogate for biodiversity, the services must be acquired/managed at biologically relevant spatial scales. This raises questions about the correlation of the scale of land ownership (since legal control will be necessary for market transactions) to the scale at which the desired service is produced. Buying half a wetland, for example, may provide the desired water purification services but fail to protect the biodiversity of the full wetland because it is now an "island" only half its previous size. Furthermore, even purchasing the entire wetland may be insufficient if its context is transformed by residential development.[76] Given the nonlinear variations in biodiversity, our boundaries—be they the Euclidean boundaries of township and section or the explanatory boundaries of patch and ecosystem—

72. *See* John A. Wiens et al., *A Lesson in the Limitations of Field Experiments: Shrubsteppe Birds and Habitat Alteration,* 67 ECOLOGY 365, 374 (1986). A square kilometer is 100 hectares.

73. *See generally id.* at 386.

74. *See generally* CHRIS MASER, FOREST PRIMEVAL (Oregon State University Press 2001).

75. *See generally* Wallington et al., *supra* note 26.

76. *E.g.*, Larry D. Harris, *Edge Effects and Conservation of Biotic Diversity,* 2 CONSERVATION BIOLOGY 330 (1988); Janice M. Lord & David A. Norton, *Scale and the Spatial Concept of Fragmentation,* 4 CONSERVATION BIOLOGY 197 (1990); William D. Newmark, *Legal and Biotic Boundaries of Western North America National Parks: A Problem of Congruence*, 33 BIOLOGICAL CONSERVATION 197 (1985); William D. Newmark, *Extinction of Mammal Populations in Western North American National Parks*, 9 CONSERVATION BIOLOGY 512 (1995); Michael E. Soule & L. Scott Mills, *No Need to Isolate Genetics,* 282 SCI. 1658 (1998); Stanley A. Temple & John R. Cary, *Modeling Dynamics of Habitat-Interior Bird Populations in Fragmented Landscapes,* 2 CONSERVATION BIOLOGY 340 (1988); Ronald L. Westmeier et al., *Tracking the Long-Term Decline and Recovery of an Isolated Population*, 282 SCI. 1695 (1998); Richard Yahner, *Changes in Wildlife Communities Near Edges,* 2 CONSERVATION BIOLOGY 333 (1988). For a popular explanation see DAVID QUAMMEN, THE SONG OF THE DODO (1996).

frequently are not large enough to encompass the necessary spatial scales.[77]

B. Temporal Scale

As with spatial scale, temporal scale of biodiversity is a continuum that ranges from the very brief (the life span of a single microbe) to the all-but inconceivably long (the billions of years since life emerged on the planet). The organisms that are present at any given time at any particular place are a result of processes operating at all of these time scales.[78] Individual Douglas firs in the old-growth Pacific rainforest may be a millennium old having persisted through climatic fluctuations such as the Little Ice Age that contributed to the extinction of the Greenland Norse.[79] They structure a forest that includes many organisms whose lives are measured in hours or days at most.[80] Although individual trees may be ancient, they are part of a dynamic spatially and temporally patchy system: "The landscape consists of a continually changing mosaic of patches in different stages of succession . . . ."[81] As long as disturbances are small relative to the landscape and infrequent relative to recovery times, the landscape will be a shifting mosaic that maintains a relatively stable distribution of organisms.[82] As with spatial scale, however, temporal scale can involve nonlinear changes, particularly when disturbances are too large or too frequent. Ecosystems can flip between multiple, relatively stable conditions.[83]

Stated more generally, ecology is an historical science in which events play out over varying lengths of time and the outcome of random events, resource exploitation, and other disturbances may

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77. *See, e.g.,* Dale D. Goble, *The Property Clause - as if Biodiversity Mattered,* 75 U. COLO. L REV. 1195 (2004); Richard J. Hobbs, *Managing Ecological Systems and Processes, in* ECOLOGICAL SCALE 459, 467-80 (David L. Peterson & V. Thomas Parker eds. 1998).

78. Hobbs, *supra* note 77, at 472.

79. *E.g.,* JARED DIAMOND, COLLAPSE 219-20 (2005); EUGENE LINDEN, THE WINDS OF CHANGE 1-33 (2006).

80. *See generally* MASER, *supra* note 74.

81. Wallington et al., *supra* note 26. *See generally* DANIEL B. BOTKIN, DISCORDANT HARMONIES (1990); MASER, *supra* note 74.

82. *See* Monica G. Turner, *Landscape Ecology: Living in a Mosaic, in* ECOLOGY 77, 104-06 (Stanley I. Dodson et al. eds., 1998).

83. *See* C.S. Holling et al., *Biodiversity in the Functioning of Ecosystems: An Ecological Synthesis, in* BIODIVERSITY LOSS 44, 48-60 (Charles Perrings et al. eds. 1995); Robert M. May, *Thresholds and Breakpoints in Ecosystems with a Multiplicity of Stable States,* 269 NATURE 471 (1977); Marten Scheffer & Stephen R. Carpenter, *Catastrophic Regime Shifts in Ecosystems: Linking Theory to Observation,* 18 TRENDS ECOLOGY & EVOLUTION 648 (2003). *See also supra* note 63 (discussing the role of keystone species in maintaining alternative stable states)..

be unpredictable.[84] For example, a recent study of the seabed at the North Pole indicated that 55 million years ago the temperature was a balmy seventy-four degrees Fahrenheit—much warmer than climate models had suggested.[85] As one of the lead authors noted, "Something extra happens when you push the world into a warmer world, and we just don't understand what it is."[86] The Arctic Ocean reveals a pervasive—and often incorrect—assumption with which our species views the world: the future will be smooth curve from the present.

As with spatial scale, ecosystem services can operate as a surrogate for biodiversity only if the services are acquired and managed at biologically relevant temporal scales. Natural resource management, however, is dominated by economic and political time scales that are significantly shorter than an ancient Douglas fir. In the United States, for example, politics operates on election cycles of two to six years. As the last dozen presidential elections have demonstrated, it is difficult to maintain a consistent management approach for longer than two to three cycles.[87] Even when a general policy is maintained over lengthy periods from the human perspective, they are frequently too short to conserve biodiversity. For example, the temporal component of *sustained* yield in the multiple-use, sustained-yield paradigm that dominated the twentieth century resource management failed because it approached ecosystems from an engineering perspective that sought to reduce variability (in runs of salmon, for example) and ultimately reduced complexity and resilience of the system, contributing to its collapse.[88] Global climate change offers another obvious

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84. *See, e.g.,* Bellemare et al., *supra* note 26; Foster et al., *supra* note 26; Ricard V. Sole et al., *Self-Similarity of Extinction Statistics in the Fossil Record,* 388 NATURE 764 (1997).

85. Appy Sluijs et al., *Subtropical Arctic Ocean Temperatures during the Palaeocene/Eocene Thermal Maximum,* 441 NATURE 610 (2006); *see also* Kathryn Moran et al., *The Cenozoic Palaeoenvironment of the Arctic Ocean,* 441 NATURE 601 (2006); Henk Brinkhuis et al., *Episodic Fresh Surface Waters in the Eocene Arctic Ocean,* 441 NATURE 606 (2006).

86. Andrew C. Revkin, *Studies Portray Arctic as Sultry in Distant Past,* N.Y. TIMES, June 1, 2006, at A1 (quoting Henk Brinkhuis).

87. *Compare* NRDC: The National Forest Roadless Area Rule, http://www.nrdc.org/land/forests/qroadless.asp (last visited June 23, 2007), *with* Lost in the Woods: Bad Forest Policy Left and Right, http://www.cato.org/dailys/07-21-04.html (last visited June 23, 2007).

88. *See* C.S. Holling, *What Barriers? What Bridges?, in* BARRIERS AND BRIDGES TO THE RENEWAL OF ECOSYSTEMS AND INSTITUTIONS 3, 6-10 (Lance H. Gunderson et al. eds., 1995); C.S. Holling & Gary K. Meffe, *Command and Control and the Pathology of Natural Resource Management,* 10 CONSERVATION BIOLOGY 328 (1996); Gary K. Meffe, *Techno-Arrogance and Halfway Technologies: Salmon Hatcheries on the Pacific Coast of North America,* 6 CONSERVATION BIOLOGY 351 (1992). *See generally* Dale D. Goble, *Salmon in the Columbia Basin: From Abundance to Extinction, in* NORTHWEST LANDS, NORTHWEST PEOPLES 229 (Dale D. Goble & Paul W. Hirt eds. 1999).

example.

The focus on present value and the concomitant discounting of the future that is central to most economic theory also produces a short temporal scale. As Colin Clark argued—and the colloquial "shoot, shovel, and shut-up" demonstrates—the extinction of a species will often be the economically rational choice.[89] Furthermore, the economic perspective informs us that we should not worry about such irreversible events: since resources are fungible (that is, there is always some other resource that can meet the desire) and man-made capital can be substituted for natural capital so there is no absolute scarcity.[90] Stated differently, irreversible changes to ecosystems such as extinction do not prejudice the future because of the substitutability of one resource for another.[91]

The crucial point is that our resource management and market allocation systems have histories measured at most in decades—a period that is far too short to assess their impacts when the systems of concern cycle on centuries and millennia. Given the lag times in such systems our species is likely to ignore or discount gradual changes (such as global climate change) and then be surprised by the major shift that occurs when an unrecognized threshold is crossed.

C. Scale Redux

Ecosystem services thus correlate poorly with both the spatial

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89. Colin W. Clark, *Profit Maximization and the Extinction of Animal Species,* 81 J. POL. ECON. 950 (1973). *See also* Jon H. Goldstein, *The Prospects for Using Market Incentives for Conservation of Biological Diversity, in* THE PRESERVATION AND VALUATION OF BIOLOGICAL RESOURCES 246 (Gordon H. Orians et al. eds., 1990); Roger G. Noll, *Commentary, in* THE PRESERVATION AND VALUATION OF BIOLOGICAL RESOURCES 269 (Gordon H. Orians et al. eds., 1990). As the editor of a collection of essays on conservation through use commented, "[t]he attempt to derive conservation advantage from using wildlife should not be seen as a bold new conservation initiative for it is not proactive at all; it is a concerned response to an existing, and worsening, situation." Melvin Bolton, *Synthesis and Conclusions, in* CONSERVATION AND THE USE OF WILDLIFE RESOURCES 253, 266 (M. Bolton ed. 1997).

90. *E.g.,* Stefan Baumgartner et al., *Relative and Absolute Scarcity of Nature: Assessing the Roles of Economics and Ecology for Biodiversity Conservation,* 59 ECOLOGICAL ECON. 487 (2006); Bryan G. Norton, *Evaluating Ecosystem States: Two Competing Paradigms,* 14 ECOLOGICAL ECON. 113 (1995); Robert M. Solow, *The Economics of Resources or the Resources of Economics,* 64 AM. ECON. REV. PROC. 1 (1974).

91. *E.g.,* Baumgartner, *supra* note 90; Norton, *supra* note 90. Economics is simply irrelevant in realms where such substitutability does not exist. Economists do recognize that some things should be preserved for their "amenity value" -- "It is perfectly okay, it is perfectly logical and rational, to argue for the preservation of a particular species or the preservation of a particular landscape. But it has to be done on its own, for its own sake, because this landscape is intrinsically what we want." Robert M. Solow, *Sustainability: An Economist's Perspective, in* ECONOMICS OF THE ENVIRONMENT 179, 181 (Robert Dorfman & Nancy S. Dorfman eds, 4th ed. 1993). *See also* Robert M. Solow, *On the Intergenerational Allocation of Natural Resources,* 88 SCANDINAVIAN J. ECON. 141 (1986).

and temporal scale of biodiversity. On the one hand, the spatial scale at which the desired service is produced is unlikely to correspond to the scale of land ownership which is both highly fragmented (thus too small) and Euclidean (thus too rectangular). Both characteristics suggest that our boundaries seldom will be large enough or fluid enough to encompass the appropriate scales. Similarly, the temporal scale of ecosystem functions is orders of magnitude greater than the temporal scale of the political and valuation systems that guide natural resource management decision making. Both shortcomings are compounded by the often-nonlinear nature of ecosystem functions at both scales: the history of resource management has been a series of surprises—that there were no more buffalo, passenger pigeons, or salmon.[92]

VII. ECOSYSTEM *SERVICES* AND UTILITY

The description of ecosystem structure and function as goods and services is intrinsically a value statement. To label some elements of an ecosystem a good or a service—the shift from trees to timber and from decomposition to soil fertility—is only to say that some bit of nature is a "resource" because it has utility to our species.

Daily, Heal, and other advocates of ecosystem services frequently refer to the ecosystems that provide the desired services as "natural." In the recurrently cited definition of the concept, Daily wrote that ecosystem services are "the conditions and process through which *natural* ecosystems . . . sustain and fulfill human life."[93] She also is careful to distinguish between natural and human-dominated ecosystems.[94] The biology, however, is less conclusive on this rhetorical dichotomy between natural and human-dominated landscapes—in a world of global climate change where the flesh of polar bears is laced with PCBs, dichotomies dissolve into continuous shades of gray.

Human-dominated ecosystems produce not only "human" goods and services—cows and corn, for example—they also produce "natural" ecosystem services such as carbon sequestration. Although much of the human-dominated landscape is engineered, it nonetheless retains "natural" constituents and functions; the car-

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92. Dale D. Goble, *Three Cases / Four Tales: Commons, Capture, the Public Trust, and Property in Land,* 35 ENVTL. L. 807 (2006).

93. NATURE'S SERVICES, *supra* note 3, at 3 (emphasis added). Similarly, Heal writes: "*Natural* ecosystems are the essential, low-level infrastructure upon which human activities and built systems rest." HEAL, *supra* note 3, at 3 (emphasis added).

94. NATURE'S SERVICES, *supra* note 3, at 2-3. *See also* HEAL, *supra* note 3, at 3-4.

bon sequestration in a suburban ecosystem may be less than in a forest, but the suburb's trees and shrubs also provides this service. Although it is doubtless true that at some point the degradation reaches a point at which the service provided by the ecosystem is so trivial as to be irrelevant (see cartoon), the point is that we face a continuum rather than a dichotomy.

Furthermore, the utility of ecosystem function and process is captured (to the extent that it is captured) only in the output of services. The focus on market-driven services means that only the biodiversity needed to produce the specific service will be valued in transactions for that service. Carbon sequestration is currently a hot market—the 2006 Super Bowl, for example, proudly claimed to be "carbon neutral."[95] There are several non-profit and for-profit companies currently offering carbon neutrality generally as a mix of sources such as fuel efficiency, alternative energy sources, and carbon sequestration through planting trees.[96] The website for one of the non-profit organizations captures the crucial point when it when it quotes an attorney for the Natural Resources Defense Council: "the [Climate] Trust is the largest buyer [of offsets] with an environmental . . . as opposed to corporate cost minimization."[97] The attorney's point, of course, is that cost-minimization comes at an environmental cost.

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95. Marc C. Trexler & Laura H. Kosloff, *Selling Carbon Neutrality,* 23 ENVTL. F. 34, 35 (2006). If recycling is too complex or you can't imagine giving up your Hummer, then you can buy an environmental indulgence in the form of trees in Kentucky or wind energy in Washington. *E.g.,* Christine Larson, *A New Way to Ask, "How Green Is my Conscience?,"* N.Y. TIMES, June 25, 2006, at 3.6; Anthony DePalma, *Gas Guzzlers Find the Price of Forgiveness,* N.Y. TIMES, Apr. 22, 2006, at A1.

96. *See, e.g.,* The Climate Trust, http://www.climatetrust.org/index.php (last visited June 23, 2007); Carbonfund, http://www.carbonfund.org/site/ (last visited June 23, 2007); The CarbonNeutral Company, http://www.carbonneutral.com (last visited June 23, 2007).

97. About the Climate Trust, http://www.climatetrust.org/about_us.php (visited June 23, 2007). For discussions of individual sequestration projects see Climate Trust Projects: Deschutes Riparian Restoration, http://www.climatetrust.org/offset_deschutes.php (last visited June 23, 2007); Climate Trust Projects: Preservation of a Native Northwest Forest, http://www.climatetrust.org/offset_native.php (last visited June 23, 2007); Climate Care, Uganda: Helping Climate and Primate, http://www.climatecare.org/projects/countries/uganda (last visited June 23, 2007).

The limited data available suggests that this is what is occurring. As a group of advocates noted in an editorial in *Science*, the degree to which biodiversity and ecosystem services coincide "depend[s] on complex, and at present little-understood, interactions between biodiversity and resultant ecosystem services."[98] The most detailed examination of these interactions is a study that examined six ecosystem services in the central coast ecoregion of California.[99] Chan and his colleagues concluded that "[t]he average correlation between biodiversity and [ecosystem] services is low."[100]

A similar conclusion was reached in an examination of the

98. Patricia Balvanera et al., *Conserving Biodiversity and Ecosystem Services,* 291 SCI. 2047 (2001).

99. Kai M. Chan et al., *Conservation Planning for Ecosystem Services,* 4 PLOS BIOLOGY 2138, 2138 (2006), *available at* http://www.plosbiology.org. The services evaluated in the study were carbon sequestration, crop pollination, flood control, forage production, outdoor recreation, and water provision. *Id.* at 2139.

100. *Id.* at 2144-45.

common approach to carbon sequestration, monoculture tree plantations.[101] A review of some 504 plantations revealed that the higher productivity and biomass of these plantations in relation to diverse forests generally required additional water and fertilizers and produced increased soil acidity.[102] The authors of the article urged greater regulation of carbon sequestration services to protect ecosystem functions—hardly a promising conclusion given the touted benefits of market-based approaches. Although they did not examine biological diversity, it seems probable that biodiversity also was reduced in plantation forests (even ignoring the loss of plant diversity).

Ultimately, the utilitarianism that dominates the services discourse undercuts the claim that it will preserve natural ecosystems. If the value of nature is that it has utility as a source of services, then it can almost certainly be improved upon. It should hardly be surprising that there is little correlation between services and diversity since ecosystem services mimic other resource management strategies that have sought to implement the utilitarian vision—genetically modified poplars sequester far more carbon far more rapidly than diverse, non-engineered forests.[103] Strategies such as multiple-use, sustained-yield have also generally resulted in simplified ecosystems and a loss of biodiversity.[104] There is no apparent reason to assume that the utilitarian perspective embedded in ecosystem services will yield different results—with utility as our guide ecosystem services becomes multiple-use, sustained-yield (version 2.0).

At bottom, this should not be unexpected. Economics and ecology embody strikingly different understandings of nature. Economists view nature (and hence biodiversity) as a storehouse of products (resources). This reflects an axiomatic proposition of economic theory: no resource (product) is irreplaceable because a variety of products can satisfy any desire. Scarcity, on this view, is relative (some products are more expensive because they are scarcer), linear (the transition between sources of satisfaction will be smooth[105]), and choice-based. Ecologists, on the other hand, are

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101. *E.g.,* Robert B. Jackson et al., *Trading Water for Carbon with Biological Carbon Sequestration,* 310 SCI. 1944, 1944 (2005); Jeffery A. Wright et al., *Latin American Forest Plantations: Opportunities for Carbon Sequestration, Economic Development, and Financial Returns,* J. FORESTRY, Sept. 2000, at 20, 21-23. *See also* S. Pacala & R. Socolow, *Stabilization Wedges: Solving the Climate Problem for the Next 50 Years with Current Technologies,* 305 SCI. 968, 970 table 1 (2004).

102. Jackson et al., *supra* note 101.

103. *See* Jackson et al., *supra* note 101; Wright et al., *supra* note 101, at 22.

104. *See, e.g.,* Dale D. Goble, *Salmon in the Columbia Basin: From Abundance to Extinction, in* NORTHWEST LANDS, *supra* note 88, at 243-52; Worster, *supra* note 35.

105. *E.g.,* Robert M. Solow, *The Economics of Resources or the Resources of Economics,*

concerned with the function and integrity of the ecosystem which is often absolute (extinction is not reversible), nonlinear (recall the multiple relatively stable points[106]), and unconcerned with human desires.[107]

VIII. SOME CAUTIONARY CONCLUSIONS

My argument has been that, if markets for ecosystem services are to conserve biodiversity-in-general then ecosystem services must coincide with biodiversity. One way to evaluate this coincidence is to examine the fidelity of ecosystem services as a surrogate for biodiversity. That is: ecosystem services must be correlated to biodiversity so that marketing an ecosystem's services *necessarily* conserves that ecosystem's diversity. The evidence suggests two problems that make this correlation unlikely. The first is the differing spatial and temporal scales of services and biodiversity. The second is the utilitarianism embedded in the concept of services. The combination of the two make the necessary correlation between services and the full complement of diversity unlikely.

The problem is that many ecosystem structural components—such as banana slugs—have no apparent utility to our species. Thus, there is no reason not to simplify ecosystems—and thus to reduce biodiversity—as long as the total output of goods and services from that ecosystem at the present moment is maximized.[108] As Aldo Leopold wrote in *The Land Ethic*, "One basic weakness in a conservation system based wholly on economic motives is that most members of the land community have no economic value."[109]

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supra note 90, at 3.

106. *See supra* note 82.

107. As one overview noted:

> It may well be that natural systems are not so very fragile: they are, after all, complex adaptive systems that will probably change and become new systems in the face of environmental stresses. What *is* fragile, however, is the maintenance of the services on which humans depend. There is no reason to expect systems to be robust in protecting those services—recall that they permit our survival but do not exist by virtue of permitting it.

SIMON A. LEVIN, FRAGILE DOMINION 15 (1999).

108. The posited correlation between stability and diversity remains contested and uncertain. *See, e.g.,* F. Stuart Chapin III et al., *Consequences of Changing Biodiversity,* 405 NATURE 234 (2000); C.S. Holling et al., *Biodiversity in the Functioning of Ecosystems: An Ecological Synthesis, in* BIODIVERSITY LOSS 44, 48-54 (Charles Perrings et al. eds. 1995); Naeem, *supra* note 3; Garry Peterson et al., *Ecological Resilience, Biodiversity, and Scale,* 1 ECOSYSTEMS 6 (1998); Wallington et al., *supra* note 26.

109. ALDO LEOPOLD, *The Land Ethic, in* A SAND COUNTY ALMANAC AND SKETCHES HERE AND THERE 201, 210 (1949). As Harold Morowitz noted, "The answer to 'How much is

As a result, what we value as a good or service is less than the whole diversity of any place.

Ultimately, the issue is one of value—that slippery term that is central to both economics and ethics. If we value biodiversity only for its utility, then parts of the whole are without value; the banana slug is good for nothing. On such a view, ecosystem services are a good surrogate to the extent that they can be easily observed. If, however, biodiversity is or should be valued for reasons that go beyond utility—if "[a] thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community," in Leopold's phrase[110]—then the concept of ecosystem services is a surrogate that is potentially dangerously misleading.

My argument might seem to demand too much, to be jousting with a straw man. After all, ecosystem services have been offered as a tool to facilitate the conservation of biological diversity, not as a surrogate for that diversity. My purpose, however, is to introduce a note of caution: by itself, the conservation of ecosystem services is unlikely to conserve biodiversity writ large.[111] This is not to say that ecosystem services may not be beneficial in conserving some of the biodiversity on a particular parcel—only that it is unlikely to be a magic bullet in conserving biological diversity.[112] As is often the case, win-win scenarios are broadly appealing but often involve self-deception.[113] Although the relationship between ecosystem services and biodiversity is biologically attenuated, the concept has always owed more to rhetoric than to biology. As Bryan Norton has noted, communicating in the political and social arenas to politicians and the public requires attention to rhetoric.[114] To the extent that it has rhetorical power in convincing the public that biodiversity should be conserved because it has value to out species, the concept itself has utility.

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a species worth?' is 'What kind of world do you want to live in?'" Harold J. Morowitz, *Balancing Species Preservation and Economic Considerations,* 253 SCI. 752, 754 (1991). *See also* David Ehrenfeld, *The Conservation Dilemma, in* THE ARROGANCE OF HUMANISM 176 (1978).

110. LEOPOLD, *supra* note 109, at 224-25.

111. Chan et al., *supra* note 99, at 2148, 2150.

112. *Id.* at 2150.

113. William H. Rodgers, Jr., *The Myth of Win-Win: Misdiagnosis in the Business of Reassembling Nature,* 42 ARIZ. L. REV. 297 (2000). *See generally* KAREN A. CERULO, NEVER SAW IT COMING (2006); DOMINIC D.P. JOHNSON, OVERCONFIDENCE AND WAR (2004). *Cf.*Andrew C. Revkin*, Carbon Neutral is Hip, But Is It Green?,* N.Y. TIMES, Apr. 29, 2007, § 4 (Week in Review), at 1 ("An environmental movement that's just about perfect for consumers").

114. Norton, *supra* note 7, at 57-58.