Review Essay

Valuing Ecosystem Services

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CONTENTS

INTRODUCTION

Beneath the Arizona desert sun on September 26, 1991, amid reporters and flashing cameras, eight men and women entered a huge glass-enclosed structure and sealed shut the outer door. Their 3.15 acre miniature world, called Biosphere II, was designed to re-create the conditions of the earth (modestly named Biosphere I). Built at a cost of over $200 million, Biosphere II boasted a self-sustaining environment complete with rain forest, ocean, marsh, savanna, and desert habitats. The eight "Bionauts" intended to remain inside for two years. Within sixteen months, however, oxygen levels had plummeted thirty-three percent, nitrous oxide levels had increased 160-fold, ants and vines had overrun the vegetation, and nineteen of the twenty-five vertebrate species and all the pollinators had gone extinct. Eden did not last long.[1]

What went wrong? With a multi-million dollar budget, the designers of Biosphere II had sought to re-create the level of basic services that support life itself—services such as purification of air and water, pest control, renewal of soil fertility, climate regulation, polli-

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1. Thomas H. Maugh, *2 Years Inside a Living Lab—Is it Science or a Stunt?*, L.A. TIMES, September 23, 1991, at 1; J. Cohen and D. Tilman, *Biosphere and Biodiversity: the Lessons So Far*, 274 SCIENCE 1150, November 15, 1996; T. Radford, *The Buck Stops Here; How do You Calculate the Real Value of Earth's Life Support System?*, THE GUARDIAN, March 6, 1997, at 6.

nation of crops and vegetation, and waste detoxification and decomposition. Together, these are known as "ecosystem services," taken for granted yet absolutely essential to our existence, as the inhabitants of Biosphere II ruefully learned.[2] Created by the interactions of living organisms with their environment, ecosystem services provide both the conditions and processes that sustain human life. Despite their obvious importance to our well-being, recognition of ecosystem services and the roles they play rarely enters policy debates or public discussion.

The general ignorance of ecosystem services is partly the result of modern society's dissociation between computers, cars and clothing on the one hand and biodiversity, nutrient cycling, and pollination on the other. It is perhaps not surprising that many children, when asked where milk comes from will reply without hesitation, "from the grocery store."[3] The primary reason that ecosystem services are taken for granted, however, is that they are free. We explicitly value and place dollar figures on "ecosystem goods" such as timber and fish. Yet the services underpinning these goods generally have no market value—not because they are worthless, but rather because there is no market to capture and express their value directly.

Although awareness of ecosystem services dates back to Plato, only recently have ecologists and economists begun systematically examining the contribution of ecosystem services to social welfare. An important synthesis, entitled *Nature's Services: Societal Dependence on Natural Ecosystems*, has just been written for the general public. Edited by Stanford biologist Gretchen Daily, the book presents one of the first rigorous attempts to identify the range of ecosystem services and to value objectively the services in dollars. The *New York Times* has hailed the book as "the pioneering efforts of some practical ecologists who are eager to make common cause with economists."[4] The book's findings also provide important insights for environmental law.

As the discussions at the *Ecology Law Quarterly* symposium reprinted in this issue and numerous law review articles clearly demonstrate, ecosystem management has become a familiar part of the environmental law landscape. State and federal agencies do understand its general importance.[5] A number of laws, including the Clean

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2. In addition to those listed above, other ecosystem services include mitigation of floods and droughts, biodiversity, and partial stabilization of climate. NATURE'S SERVICES: SOCIETAL DEPENDANCE ON NATURAL ECOSYSTEMS 3-4 (Gretchen Daily, ed., 1997) [hereinafter NATURE'S SERVICES].

3. Linda C. Puig, *The Udder Side of Education,* The San Diego Union-Tribune, October 18, 1985, at B1.

4. Peter Passell, *Economic Scene,* N.Y. TIMES, March 27, 1997, at D3.

5. EPA's major risk review studies in 1987, Unfinished Business, and 1990, Reducing Risk, both cited habitat alteration and destruction as the agency's highest-priority is-

Water Act, the Endangered Species Act, and the National Forestry Management Act implicitly protect ecosystem services through their habitat protection and planning procedures.[6] Despite these statutes and initiatives, ecosystem protections remain inadequate, as evidenced by EPA's recent high-profile focus on ecosystem protection.[7]

Perhaps the most fundamental policy challenge facing ecosystem protection is that of valuation—how to translate an ecosystem's value into common units for assessment of development alternatives. The tough decisions revolve not around whether protecting ecosystems is a good thing but, rather, how much we should protect and at what cost. For example, how would the flood control and water purification services of a particular forest be diminished by the clearcutting or selective logging of 10%, 20% or 30% of its area? At what point does the ecosystem's net value to humans diminish, and by how much? Can the degradation of these services (in addition to ecosystem goods) be accurately measured? And, if so, how can partial loss of these services be balanced against benefits provided by development or pollution?

One might argue that ecosystem services cannot be evaluated, but this is clearly incorrect. We implicitly assess the value of these services every time we choose to protect or degrade the environment. The fundamental question is whether our implicit valuation of ecosystem services is accurate, and if not, what should be done about it. In-

sues. One of Reducing Risk's main conclusions was that "EPA should be as concerned about protecting ecosystems as it is about protecting human health." EPA, REDUCING RISK: SETTING PRIORITIES AND STRATEGIES FOR ENVIRONMENTAL PROTECTION (1990).

6. EPA's implementing regulations of the Clean Water Act's section 404 wetlands permit program prohibit discharge of dredge or fill material if there is a practicable alternative that "would have less adverse impact on the aquatic ecosystem." 40 CFR § 230.10(a). *See also,* 40 CFR § 230.10(c)(3) (prohibiting pollutant discharges which harm "aquatic ecosystem diversity, productivity and stability . . . [through the] loss of the capacity of a wetland to assimilate nutrients, purify water, or reduce wave energy.") Section 7 of the Endangered Species Act prohibits adverse modification of critical habitat as, effectively, does section 9's regulatory definition of "take." *See* James Salzman, *Evolution and Application of Critical Habitat Under the Endangered Species Act*, 14 HARV. ENTL. L. REV. 311, 315, 328 (1992). The National Forest Management Act's detailed planning requirements mandate protection of biological diversity as well as protection of soil, slope and other watershed conditions. 16 U.S.C. § 1604(g)(3)(B), (E)(i).

7. The EPA's Ecosystem Protection Workgroup sent a memo to Administrator Carol Browner in March, 1994, noting that "[b]ecause EPA has concentrated on issuing permits, establishing pollutant limits, and setting national standards, the Agency has not paid enough attention to the overall environmental health of specific ecosystems. In short, EPA has been "program-driven" rather than "place-driven." Recently, we have realized that, even if we had perfect compliance with all our authorities, we could not assure the reversal of disturbing environmental trends. We must collaborate with other federal, state, and local agencies, as well as private partners to reverse those trends and achieve our ultimate goal of healthy, sustainable ecosystems that provide us with food, shelter, clean air, clean water and a multitude of other goods and services. We therefore should move toward a goal of ecosystem protection." EPA, TOWARD A PLACE-DRIVEN APPROACH: THE EDGEWATER CONSENSUS ON AN EPA STRATEGY FOR ECOSYSTEM PROTECTION (1994).

deed, studies such as *Nature's Services* indicate that our valuations are grossly and systematically understated. This essay explores the importance—and the challenges—of integrating ecosystem services research with the law. The potential is exciting, for a focus on ecosystem services would significantly change the way we understand and apply environmental law.

I
ECOSYSTEM SERVICES

Nature's Services addresses two basic questions: what services do natural ecosystems provide society, and what is a first approximation of their monetary value? Separate chapters describe the range of services and physical benefits provided by climate, biodiversity, soil, pollinators, pest control, the major biomes (oceans, freshwater, forests, and grasslands), and offer case studies of ecosystem services whose values are particularly well-known. The authors do not attempt to measure non-use values such as aesthetic or existence values, arguing that such work has already been done elsewhere. Instead, the authors determine lower-bound estimates of monetary value, using replacement costs where possible. Such information, it is hoped, will provide a basis for better incorporation of ecosystem services in decisionmaking.

The chapter on soil provides a useful example of the book's specific findings. More than a clump of dirt, soil is a complex matrix of organic and inorganic constituents transformed by numerous tiny organisms. The level of biological activity within soil is staggering. Under a square meter of pasture soil in Denmark, scientists identified over 50,000 worms, 48,000 small insects, and ten million nematodes. This living soil provides six ecosystem services: buffering and moderation of the hydrological cycle (so precipitation may be soaked up and metered out rather than rushing off the land in flash floods); physical support for plants; retention and delivery of nutrients to plants; disposal of wastes and dead organic matter; renewal of soil fertility; and regulation of the major element cycles. What are these services worth in the aggregate?

Take, for example, soil's service of providing nitrogen to plants. Nitrogen is supplied to plants through both nitrogen-fixing organisms and recycling of nutrients in the soil. As mentioned above, the authors rely primarily on replacement costs to estimate the value of ecosystem services. If nitrogen were provided by commercial fertilizer rather than natural processes, the lowest-cost estimate for its use on crops in the U.S. would be $45 billion, the figure for all land plants

$320 billion.[8] Most of the services identified in the book, however, such as breaking down dead organic material, are not valued in dollars because no technical substitutes are available.

Overall, *Nature's Services* reaches four conclusions. First, the services that ecosystems provide are both wide-ranging and critical. The question, "where would we be without ecosystem services?" is nonsensical, for we simply would not exist without them. Second, as Biosphere II's failure showed, the substitute technologies for most ecosystem services are either prohibitively expensive or non-existent. Massive hydroponic gardening in the absence of soil is at least conceivable, if unfeasible. Substitutes for climate regulation are neither conceivable nor feasible. Third, our overall understanding of ecosystem services—the contributions of individual species, threshold effects, synergies, etc.—is poor. Finally, even taking into account the inevitable imprecision of such valuation exercises, ecosystem services have extraordinarily high values. A recent study in the journal *Nature* estimated their aggregate value at between $16-54 trillion per year.[9] The global GNP is $18 trillion.[10]

Whether such a total estimate is precisely accurate is beside the point. The sheer magnitude of their dollar figures dictates that ecosystem services cannot be treated as merely add-on considerations. Nor can they be shunted aside as soft numbers (as often occurs with scenic beauty or existence value) when assessing the impacts of development or pollution. Tastes may differ over beauty, but they are in universal accord over fertile soil. If the goal of ecologists is to wake people up with big numbers, *Nature's Services* delivers. But are these numbers a convertible currency?

The greatest shortcoming of *Nature's Services*, one openly admitted by its authors, is the macro-scale of the analysis. The fact that pollinators annually provide Americans up to $1.6 billion of service or that soil fertility is worth $45 billion is important to know for general

8. Such measures of value face a number of methodological problems. First, a service's replacement cost may not be the same as its value. As an analogous example, the value of an existing house (in this case the market price) in a run-down neighborhood may be less than the cost of building a replacement house. Hence one may choose not to replace the house—or a certain degraded ecosystem service—in its entirety. Second, as one moves from marginal to total replacement of the service of an ecosystem service, it is unclear where all the commercial nitrogen would come from. Would such large-scale demand for nitrogen drive prices down through new technologies and economies of scale or drive prices up through resource scarcity?

9. R. Costanza et al., *The Value of the World's Ecosystem Services and Natural Capital*, 387 NATURE 253 (1997).

10. *Id.* It is important to note that at a certain level such a figure is meaningless because replacing the world's total natural capital is by definition impossible (for the simple reason that there would be nothing left to replace it with). Hence the true value of the world's natural capital is infinite.

policy direction, but that fact does not help to inform specific land-use or pollution permitting decisions. One cannot divide the $45 billion value of soil fertility by the nation's total agricultural acreage to determine the value of the services of five acres of land threatened by development. Thus, the greatest need for ecosystem service valuation is at the margins. Few policy decisions, thankfully, will involve obliterating an ecosystem service. Rather, policy decisions tend to be incremental. What is the extent of degradation to these services at various points along a continuum of impacts? Given the complexity of ecosystem services, the responses are almost certainly nonlinear.

This problem, the assessment and valuation of services at the margin, is at once the most useful and most difficult challenge for economists and ecologists. *Nature's Services* establishes the range of ecosystem services and their great significance. The next step is to pick up where the book leaves off and identify how ecosystem services should be explicitly considered in real-life decisions, for ecosystem services are rarely, if ever, considered in current agency cost-benefit analyses.

The ideal method to assess development alternatives would be to give local ecosystem services an accurate monetary value. As a complement to the more subjective and controversial non-use measures such as existence and option values,[11] dollar figures for ecosystem services would reflect practical benefits delivered to society. More important, this method would also permit direct comparisons between investments in physical capital and investments in natural capital as well as projections of future costs and benefits. Beyond ensuring wiser development, this method would respond to the regulatory mandates of wetlands mitigation banking, environmental impact statements, and natural resource damages that specifically request such figures.

II
VALUING ECOSYSTEMS

So how does one value an ecosystem? Assume our object of study is a wetland along the banks of the Potomac. The first step lies in defining the ecosystem's contribution to human well-being. An ecosystem may be characterized by its physical features (site-specific characteristics such as landscape context, vegetation type, salinity), its goods (vegetation, fish), its services (nutrient cycling, water retention) or its amenities (recreation, bird-watching). These four aspects may not be complementary. For example, one could manage a wetland for

11. *See* PETER MENELL AND RICHARD STEWART, ENVIRONMENTAL LAW AND POLICY 87 (1994).

cranberry production at the expense of primary productivity and services. Furthermore, the location of the system will be a critical factor of its net utility because location determines the distribution of goods and services. An ecosystem's carbon sequestration and biodiversity will be valuable even if distant from human populations, but its role in pollination and flood control likely will not. Thus two identical ecosystems may have very different values depending on their landscape context.

Economists classify these characteristics using four categories. The most obvious category includes consumable ecosystem goods such as cranberries and crabs that are exchanged in markets and easily priced (direct market uses).[12] Activities such as hiking and fishing (direct non-market uses) as well as more intangible existence and option values (non-market, non-use) are not exchanged in markets. As a result, their values must be determined indirectly by shadow pricing techniques such as hedonic pricing, travel-cost methodologies, or contingent valuation. Ecosystem services are categorized as indirect non-market uses, for while they provide clear benefits to humans they are neither directly "consumed" nor exchanged in markets. These are also classic public goods because their use cannot be exclusively controlled.

How does one measure dollar figures for indirect non-market resources—ecosystem services—which may have the greatest value of all the economic categories? A recent investment choice made by the city of New York provides one elegant example.[13] The watershed of the Catskills mountains provides New York City's primary source for drinking water. Water is purified as it percolates through the watershed's soil and vegetation. Recently, however, this water failed EPA standards for drinking water, due both to habitat degradation in the Catskills from development, and to increased sewage, pesticides, and fertilizers. New York faced two starkly different choices as to how to obtain large quantities of clean water. It could invest in physical capital, building a water purification plant with a capital cost of $4 billion plus operating expenses. Or, it could invest in natural capital at a much lower cost, restoring the integrity of the Catskills watershed through land acquisition and restoration. Choosing the latter option, last year New York floated an "environmental bond issue" to raise just over $660 million. The cost of restoring the ecosystem service of water purification provided a payback period of five to seven years as well as increased flood protection at no extra charge. The lesson: in-

12. The true value of these ecosystem goods may be less than the market price if there are substantial negative externalities or subsidies involved in its production.

13. *See* G. Chichilnisky and G. Heal, Securitizing the Biosphere (March 1997) (unpublished manuscript on file with the *Ecology Law Quarterly*).

vestments in natural capital can be more financially profitable than those in physical capital.

In many ways, the Catskills example offers an ideal measure of the worth of an ecosystem service. Replacement cost provides an effective method for valuing services because one can compare dollar investments in natural capital and physical capital to determine payback periods and overall costs. Unfortunately, ecosystem services rarely are identified so easily or valued at a local scale. Direct comparisons between manufactured services and ecosystem services break down very quickly as one moves from supplying clean water for New Yorkers to services that are not discretely purchased, such as nutrient cycling or climate regulation. Although functioning markets do not exist for these services, one could imagine calculating the value of an ecosystem service such as carbon sequestration through payments for joint implementation, for instance. Similarly, one could imagine insurance companies funding conservation of forest habitat for its flood prevention qualities. Each of these would provide a lower-bound dollar figure for services, but such market developments seem unlikely anytime soon.

Currently, there are three challenges to incorporating benefits of ecosystem services more directly into decisionmaking: identifying services on a local scale, measuring the value of these services, and projecting their future value. First, ecologists must understand the services provided by a specific ecosystem. For example, wetlands provide an important service in nutrient trapping, which retards and prevents eutrophication. The capacity to trap nutrients depends on the biophysical capacity of the site (e.g., its vegetation, benthic community, size, slope) and on the in-flow from adjacent water sources. Data on these factors can be provided in great detail. One can make empirically sound predictions that actions on a gross scale, such as clearcutting, will affect nutrient flows and services,[14] or that a loss of populations reduces ecosystem resiliency. In aggregate, such knowledge can provide policy guidance in warning against extreme actions. But in most cases, our scientific knowledge is inadequate to predict with any certainty how specific local actions affecting these factors will impact the local ecosystem services themselves.

This lack of knowledge is due both to the lack of relevant data and to the multivariate complexity of the task. Analysis of how ecosystems provide services has proceeded slowly because ecosystem level experiments are difficult, costly, and lengthy.[15] More important, research to date has focused much more on understanding ecosystem

14. *See* Harold Mooney and Paul Ehrlich, *Ecosystem Services: A Fragmentary History, in* NATURE'S SERVICES, *supra* note 2, at 16.

15. *Id.* at 15.

processes than determining ecosystem services, and how an ecosystem works is not the same as the services it provides.[16] This focus has been reinforced, and partly driven, by regulatory requirements. Federal and state wetland regulations assess the adequacy of wetland mitigation on the basis of the site's functional capacity, not on the basis of the services actually provided and their extant benefits to humans.[17] For this reason alone, publications such as *Nature's Services* are valuable: they increase awareness of the need to shift the focus of ecological research toward provision of services.

As noted above, ecosystem services rarely are exchanged in functioning markets or have readily determined replacement costs. As a result, ecologists face a second challenge in deducing the monetary value of these services from non-market valuation techniques. Contingent valuation (CV), also known as willingness-to-pay, is an important valuation method in the regulations that implement the Oil Pollution Act's provisions for natural resource damages.[18] In the context of ecosystem services, CV suffers from a number of serious shortcomings. Most important, polling people's willingness to pay to preserve specific ecosystems assumes a knowledge of the services provided. Given the difficulties ecologists face in quantifying services provided by discrete ecosystems, it is specious to assume John and Mary Doe have an informed idea of ecosystem services, much less in a site-specific context. This information gap limits the application of CV to ecosystem services. Alternative shadow pricing techniques such as hedonic pricing and travel cost methods are equally inapt in valuing ecosystem services. The EPA is currently wrestling with this problem and has requested counsel from its Science Advisory Board.[19]

16. As Dr. Gretchen Daily, editor of *Nature's Services*, explains, "there is very little research specifically aimed at ecosystem services—a lot has been learned indirectly through studies with other objectives (summarized in the book), but policy could be much better honed with more research, particularly on local ecosystems and their services." E-mail from Gretchen Daily (May 12, 1997).

17. DENNIS KING, USING ECOSYSTEM ASSESSMENT METHODS IN NATURAL RESOURCE DAMAGE ASSESSMENT 14 (1997) (prepared for NOAA Damage Assessment and Restoration Program) (unpublished manuscript on file with the *Ecology Law Quarterly*). The most widely used system for wetlands assessment is the U.S. Fish and Wildlife Service's Habitat Evaluation Procedure (HEP). HEP focuses on animal populations and the wetland's suitability as species habitat as a means of assessing the ecosystem's overall fitness. This system allows for valuation, but only in terms of on-site recreation benefits. The most recent assessment method is known as the Hydrogeomorphic Assessment Method (HGM) and has a greater focus on ecosystem services, but also suffers from a weak linkage between an ecosystem's *capacity* to provide services and the *value* of those services to humans. *Id.* at 14-18.

18. *See* Final Rule, 61 Fed. Reg. 440, 470, 499 (NOAA 1996).

19. *See* Notification of Public Advisory Committee Meetings, 62 Fed. Reg. 10,853 (EPA 1997) (in response to request by EPA Deputy Administrator, the Valuation Subcommittee of the Scientific Advisory Board is holding hearings "to propose a new framework

Valuing an ecosystem service becomes even more difficult because that value is contextual. As noted above, an ecosystem's benefit to humans is not a straightforward biophysical measure, for identical ecosystems in different locations will have very different values. The value of a wetland's nutrient trapping service, for instance, depends on the location of its out-flow. Does it flow to shellfish beds (high value) or a fast-flowing ocean current (low value)? In valuing each ecosystem service, and indirectly the "cost" of its diminution, substitutes become important. Will the threatened service be replaced by other natural processes? Is it redundant or scarce? To what extent can technology overcome or mitigate these harms? If the loss of a service is important and non-linear, when will it become asymptotically more valuable approaching the point of collapse? None of these questions can be answered without intricate, localized knowledge of the ecosystem service itself.[20]

Despite these difficulties, let us assume we understand fully the ecosystem service and have determined its current value. Even then, we face a third challenge when we try to determine in dollars the *future stream* of services flowing from the current biophysical features and landscape of the ecosystem. This figure is important because the net present value of most proposed actions that will degrade an ecosystem, such as shopping mall developments, take into account future streams of income.[21] To ensure a full accounting of costs and benefits, the future "income" flow of the ecosystem service should be factored into its current value as well, since that value may change over time due to land-use patterns, weather, pollution, etc. How then does one link a site's current ecological characteristics with future ecosystem services?

The approach of Wall Street analysts to similar problems of uncertainty serves as an instructive analogy. What is the value of IBM's stock today? The price of $158 per share indicates the current earnings of the company as well as projected future revenues. This projection must account for IBM's vulnerability to competitors (some of whom do not yet exist), the diversity of its income streams, and its

for assessing the value of ecosystems to humans, including ecological services and environmentally mediated health and quality of life values").

20. *See generally,* Dennis King, *Valuing Wetlands for Watershed Planning,* Nat'l. Wetlands Newsletter, May-June 1997, at 5-10.

21. The Office of Management and Budget's traditional use of a 10% discount rate in cost-benefit analyses greatly diminishes the present value of future benefits. While beyond the scope of this essay, there are persuasive reasons to choose much lower discount rates which would, therefore, take greater account of future income streams in net present value calculations. At a minimum, the discount rate of a proposed development's future benefits should be no less than that applied to future ecosystem services. *See* MENELL AND STEWART, *supra* note 11, at 90-92.

resilience in the face of market downturns. These sophisticated earnings projections are made on the basis of information provided by a number of sources: statutorily required disclosures, a healthy secondary market in information, and companies themselves in need of market capital.

Superficially, ecosystem services share a number of similarities with IBM. An ecosystem may also be analyzed as a stream of goods (inventory) and services (equipment and infrastructure necessary to produce the goods) with independent value over time. Its vulnerability, diversity, and resiliency are strong predictors of its future performance.[22] Yet few projections of the future stream of ecosystem services can be made with the certainty of IBM stock projections. Why the difference?

Part of the difference arises from methodological difficulty. As discussed above, there is no clear method yet for valuing or measuring ecosystem services, much less future services. Differing expectations also contribute to the disparity. In the environmental context, uncertain values are often set at zero. In contrast, when assessing corporate acquisitions, financial analysts routinely provide credible values greater than zero. Uncertainty is an accepted part of the profession. Finally, the lack of information plays a role. Making accurate projections of ecosystem services (or future stock prices) requires a great deal of robust data. Yet basic research and regulatory compliance have focused far more on the biophysical capacities of ecosystems than on their services. Moreover, information on ecosystem services is expensive to collect because the benefits of ecosystem services are a public good. Since there is no financial gain from "investing" in services (unlike with IBM's stock) there is no secondary market generating relevant data.

The combination of methodological difficulty, inherent complexity, and lack of data makes placing absolute dollar figures on local ecosystem services unfeasible in many cases. At the same time, the current research and regulatory focus on ecosystems' biophysical measures is too removed from valuation of services. Is there a middle ground to inform decisionmakers? Wall Street and IBM's stock price may provide some guidance. As noted above, many of the sources on which analysts rely to value stocks are not, in fact, monetary. They are composite indicators such as market strength, consumer confi-

22. The instability of ecosystems has been the subject of a number of recent articles suggesting a need for environmental law to shift from a static to dynamic perspective. *See, e.g.*, Jonathan Wiener, *Law and the New Ecology: Evolution, Categories, and Consequences*, 22 ECOLOGY L.Q. 325 (1995); J.B. Ruhl, *Complexity Theory as a Paradigm for the Dynamical Law-and-society System: a Wake-up Call for Legal Reductionism and the Modern Administrative State*, 45 DUKE L.J. 849 (1996).

dence, and housing starts. Similarly, some of the most advanced work in wetlands valuation is now focusing on non-monetary indicators. This research area combines traditional biophysical measures (i.e., the capacity to provide ecosystem services and goods) with landscape context to determine the opportunity and impact of providing these services to people. Such indicators do not provide dollar figures for ecosystem services, but they do provide more accurate bases for assessing relative qualities of different ecosystems (which is particularly important in the context of wetlands mitigation banking and natural resource damages).[23]

III
ECOSYSTEM SERVICES AND THE LAW

In addition to its ecological and economic analyses, *Nature's Services* is fascinating because it recognizes a key role for ecosystem services in environmental law and policy. In fact, as potential symbiotic partners, both environmental law and research on ecosystem services have much to offer: together, they provide a new way to view environmental law, beyond command-and-control mandates and single-species protections.

How can environmental law promote our understanding of ecosystem services? It can do so through the creation of information markets that drive scientific research. Our understanding of groundwater chemistry and hydrology has increased tremendously in recent years, due primarily to markets created for this information as a result of CERCLA actions. Potentially responsible parties require a sophisticated understanding of local groundwater conditions to design the most efficient remediation strategies, and now-wealthy consulting businesses have arisen to meet these needs. Indeed, the role of regulation in creating secondary information markets is an important pillar of economics of information theory.[24]

Ecosystem services have real value, yet they are not understood well enough to be valued monetarily. Could current regulations spur the creation of secondary information markets without the liability hammer of CERCLA? To a large extent, current wetlands regulations have already created information markets for wetlands vegetation and hydrology data. A great deal more is known today than just ten years ago, largely because the assessment models used to comply with wetlands regulations have focused on biophysical characteristics. But

23. *See* King, *supra* note 17, at 13-16.

24. *See, e.g.*, Howard Latin, *Environmental Regulation and Consumer Decisionmaking Under Uncertainty*, 6 HARV. ENVTL. L. REV. 187 (1982); Mary L. Lyndon, *Information Economics and Chemical Toxicity: Designing Laws to Produce and Use Data*, 87 MICH. L. REV. 1795 (1989).

such emphasis is misplaced if ecosystem services are as valuable as current research indicates.[25]

If government officials explicitly required significant data on ecosystem services for natural resource damage assessments and environmental impact statements, then a secondary information market likely would develop. Some regulations have begun to make these demands in the areas of groundwater hydrology and wetlands vegetation. Current regulations implementing the Oil Pollution Act,[26] CERCLA,[27] the Clean Water Act,[28] and NEPA[29] already provide sufficient authority to spur just such a secondary information market. If ecosystem services are significantly undervalued, and such undervaluation therefore leads to misallocation of resources, then the use of regulations to create a profitable secondary market in ecosystem service data and indicators could prove an efficient intervention for improved management of resources.

What does ecosystem service research offer in return to environmental law? There are three intriguing possibilities. The first is specificity of indicators. For some services, benefits are too diffuse and monetary valuation is no more than a guess. Here, the law can use indicators of ecosystem services as a surrogate for economic value.

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25. Reliance on biophysical indicators such as vegetation type rather than service indicators has also proven inadequate in ensuring that mitigation projects result in real restoration. As Professor Flournoy has observed in regard to the use of indicators in mitigation projects, "Whether on- or off-site, mitigation requirements may only require the developer to undertake certain excavation work and assure a certain percentage cover of designated species of vegetation over a five-year period. This focus on endpoints rather than processes may not produce functioning wetlands." Alyson Flournoy, *Preserving Dynamic Systems: Wetlands, Ecology and Law*, 7 DUKE ENV. L. & POL'Y 105, 127 (1996).

26. The 1996 implementing regulations of the Oil Pollution Act specifically address damage to "natural resources *and natural resource services*" to be considered in determining lost value. Final Rule of Natural Resource Damage Assessments, 61 Fed. Reg. 440 (NOAA 1996) (italics added).

27. CERCLA provides for assessment of damages to natural resources resulting from the release of a hazardous substance. 43 C.F.R. § 11.10 (1997). The implementing regulations treat loss of "services" as a natural resource damage. Services are defined as "the physical and biological functions performed by the resource including the human uses of those functions." 43 C.F.R. § 11.14(nn) (1997). The damages cover, in part, the costs to replace and restore the injured natural service so that it "provides the same or substantially similar services" as before. 43 C.F.R. § 11.14(ii) (1997). This cost can only be determined from an assessment of the baseline services provided.

28. The Clean Water Act provides for assessment of damages to natural resources resulting from the discharge of oil, and the C.F.R. sections cited in the preceding note apply also to Clean Water Act natural resource damage actions. 43 C.F.R. § 11.10 (1997).

29. NEPA's implementing regulations require the scientific basis for comparison of alternatives to include "the relationship between short-term uses of man's environment and the maintenance and enhancement of long-term productivity. . . ." 40 C.F.R. § 1502.16 (1997). Also, where information is "essential to a reasoned choice among alternatives and the overall costs of obtaining it are not exorbitant," the regulations require that such information be included in the statement. This provision could serve as a basis for considering ecosystem services as valuation methodologies improve. 40 C.F.R. § 1502.22(a) (1997).

While ecosystem management has become a catchword in government, a recent study by Professor Oliver Houck indicates serious shortcomings. He makes a strong case that, despite the trumpeting of an ecosystem approach to conservation, "[e]cosystem management, as currently promoted, is politics with a strong flavor of law-avoidance."[30] He argues that the only effective *legal* standards to ensure protection of an ecosystem rely on assessments of keystone or indicator species:

> Why is it that indicator species work? Granted, they are by no means perfect surrogates for ecosystems and, granted again, the proof of their requirements can be complex and demanding for scientists operating at the far edge of data and predictability and trained to conclude nothing until all possible alternative hypotheses, however remote, have been disproved. Nonetheless, indicators work because, in the end, they produce specifics.[31]

Robust, quantified indicators of ecosystem services could serve a similar role, providing an additional legal standard on which to base ecosystem management strategies. Much as the NFMA currently requires conservation of indicator species as a surrogate measure for ecosystem health, one could imagine a legal standard requiring maintenance of a specified, measurable level of local ecosystem services. Thus indicators assessing water flow into and out of a wetland might, for example, include dynamic measures of water retention, nutrient trapping, or water quality. These indicators, at least on the local level, could mandate management of ecosystems based on functional standards, i.e., maintaining the provision of baseline levels of services. Moreover, the direct benefit to humans of such conservation actions would be more obvious than the current focus on indicator species.

The second possible influence of ecosystem service research on environmental law is through specificity of causation. Defenders of Wildlife, in its Supreme Court brief in *Lujan v. Defenders of Wildlife*, proposed a theory of standing known as the "ecosystem nexus." Under this theory, Defenders claimed that its members were injured by a federal agency action located some distance away but within the same ecosystem as the members' activities. Specifically, Defenders contended that the challenged action would reduce the species population of a contiguous rain forest, in turn reducing the size of the gene pool and making it more vulnerable to catastrophic events. This harmed the work of a Defenders of Wildlife member studying rare

30. Oliver Houck, *On the Law of Biodiversity and Ecosystem Management*, 81 MINN. L. REV. 869, 975 (1997).

31. *Id.* at 976-977.

marmosets and jaguars in an area of the rainforest several hundred miles from the project.[32]

Justice Scalia, writing for the majority, criticized the term "ecosystem nexus" as being "inelegantly styled" and rejected the theory. Scalia's opinion stated that to establish standing parties must:

> [U]se the area affected by the challenged activity and not an area roughly "in the vicinity of it" . . . . To say that the Act protects ecosystems is not to say that the Act creates (if it were possible) rights of action in persons who have not been injured in fact, that is, persons who use portions of an ecosystem *not perceptibly affected* by the unlawful action in question.[33]

The dissent, however, argued that geographic proximity to the harm was not necessary for certain types of environmental actions (e.g., whale watching cruises affected by Japanese whaling activities thousands of miles away). As Justice Blackmun stated,

> As I understand it, environmental plaintiffs are under no special constitutional standing disabilities. Like other plaintiffs, they need show only that the action they challenge has injured them, without necessarily showing they happened to be physically near the location of the alleged wrong.[34]

The geographic requirement does seem inapt for certain types of harm, leaving Scalia's requirement of a perceptible injury the primary hurdle to establish standing. As our understanding of ecological services develops, however, it well may be possible with a degree of certainty to establish connections between identifiable injuries and specific harms to services such as pollination or water retention. Indeed, such scientific understanding seems a likely outcome if increased research driven by secondary markets focuses on the production and delivery of ecosystem services.[35]

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32. Brief for the Respondents, Lujan v. Defenders of Wildlife, 504 U.S. 555 (1992) (No. 90-1424).

33. Lujan v. Defenders of Wildlife, 504 U.S. 555, 565 (1992) (emphasis added).

34. 504 U.S. at 594. Justices Kennedy and Souter, in a concurring opinion, were "not willing to foreclose the possibility, however, that in different circumstances a nexus theory similar to those proffered here might support a claim to standing." *Id.* at 579. Thus four justices challenged Scalia's outright rejection of an ecosystem nexus basis for standing.

35. If the law adopts a stronger ecosystem services perspective, the public trust doctrine could also be influenced. Traditionally, the trust resources managed by government on behalf of the public have been tidelands and lake shores in the context of fisheries, commerce, and navigation. *See, e.g.,* Illinois Central Railroad v. Illinois, 146 U.S. 387 (1892); Phillips Petroleum Co. v. Mississippi, 484 U.S. 469 (1988). An argument could be made that the public trust doctrine should expanded to explicitly include ecosystem services, in order to accommodate changing public needs and sensibilities. *See, e.g.,* Marks v. Whitney, 6 Cal. 3d 251, 259-60 (1971) (holding that in administering the trust, the state is not limited to traditional land uses but may address changing public needs and preserve the lands in their natural state as "ecological units"); National Audubon Society v. Superior Ct. of Alpine Co., 33 Cal. 3d 419, 425-25 (1983) (reaffirming the *Marks* holding and expanding the public trust protection to flowing waters to protect Mono Lake).

Increased understanding of ecosystem services would not only justify an ecosystem nexus theory of standing, but it could also support a defense of federal environmental laws against Commerce Clause challenges based on the "substantial connection" requirements recently articulated by the Supreme Court in *United States v. Lopez*.[36] Even more importantly, it could provide the proximate causation link currently lacking in tort. Indeed the recent history of toxic tort litigation, recounted well in the bestseller *A Civil Action*,[37] serves as an important reminder that increased scientific understanding of hydrology and toxicology has permitted legal actions that would have had little or no chance of success just twenty years ago. It is too early to assess whether ecosystem services research will follow the same path, opening the door to legal challenges against environmentally harmful actions now immune through lack of proximate causation. The similarities seem striking.

Perhaps the greatest value that increased understanding of ecosystem services offers to environmental policy, however, is its persuasive argument that biodiversity and habitat protection provide important benefits in ways not normally considered. Wheeling out the rosy periwinkle and charismatic megafauna every time the Endangered Species Act or wetlands protections come under threat goes only so far. *Nature's Services* takes a different, potentially more effective tack, calling for explicit recognition of ecosystem services because of the direct, tangible benefits they provide. Such recognition could provide a more integrated and compelling basis for action than those suggested by a focus on single-species or biodiversity protection for the simple reason that the impacts of these services on humans are more immediate and undeniably important. Indeed, a focus on ecosystem services has the potential to unify disparate parts of environmental law, linking the conservation goals in laws such as the Endangered Species Act and National Forest Management Act more closely with the human health goals in seemingly unconnected laws such as the Clean Air Act and Safe Drinking Water Act.

These developments in environmental law are at once speculative and foreseeable consequences of future research on the production and delivery of ecosystem services. The study of ecosystem services is a new and very promising area of interdisciplinary research with the potential to create a significant shift in how we address environmental protection. Just as *Nature's Services* provides a valuable bridge linking ecologists and economists to policymakers, so, too, is it important for environmental lawyers to engage themselves in this research effort,

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36. 514 U.S. 549 (1995).
37. Jonathan Harr, A Civil Action (1995).

both to explore the role ecosystem services should play in the law's development and to influence the direction of research so that the services provided by nature may be accorded their proper value.

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