RESOURCES

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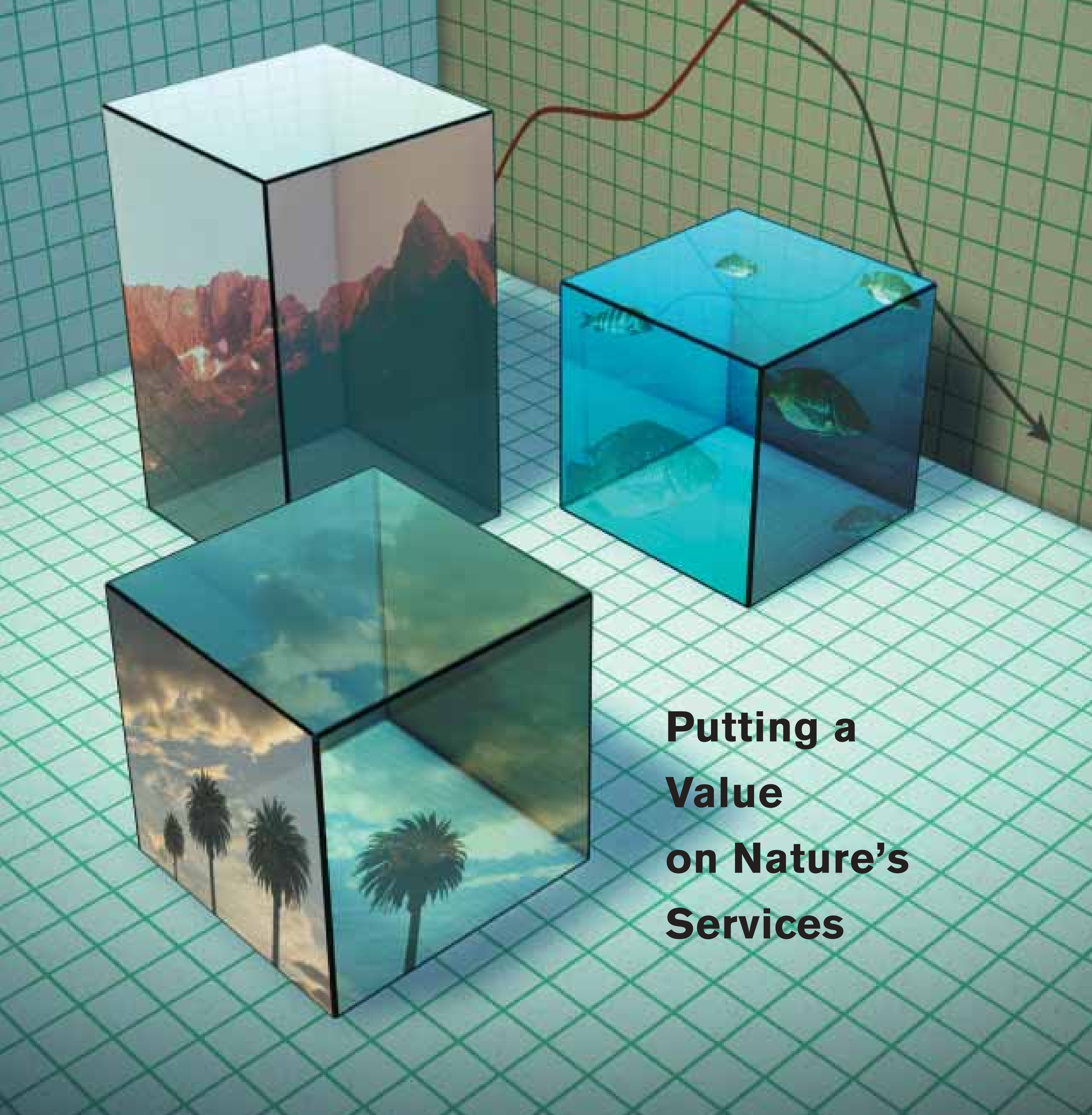

Putting a Value on Nature's Services

From the Board Chair

Lawrence H. Linden

Conserving Ecosystems Through Market Strategies

I introduce this special issue of *Resources* as someone with an intense individual interest in natural resource conservation and as chair of an institution that has long been a pioneer in devising new methods for evaluating the economics of ecosystems and informing the policy process.

As co-editors Jim Sanchirico and Juha Siikamäki discuss in their introduction, conservation in the 21st century poses new challenges to practitioners, researchers, governments, and society at large. One key challenge is how best to encourage the private sector to help curb habitat destruction by incorporating sustainable ecosystem services into everyday activities and long-term corporate strategies.

RFF is building on its strong historical base to take the lead in responding to these new challenges through its core approach—using social science methods to build a critical mass of integrated research that will lead to informed policymaking.

Looking beyond RFF and its traditional role, it is important to be realistic about the extent to which new markets might be created to deal with the social problems that inevitably are a part of ecosystem management. As a businessman, I heartily endorse efforts to harness the private sector by creating markets for ecosystem services that enlist the incredible forces of capital markets, entrepreneurship, and innovation, at least in the developed world.

Ideas for new markets are emerging that may be extremely powerful in their impact on ecosystems. The most important example by far is the market for greenhouse gas reductions and its potential application to forests. The fact that about 20 percent of atmospheric carbon dioxide results from deforestation has led to proposals that might dramatically change the economics of forest management. One proposal, from a coalition of tropical countries, calls for European nations to use credits traded in the EU Emissions Trading Scheme to pay tropical countries to reduce deforestation. According to very early projections, deforestation rates in those countries could be cut by half under this arrangement.

In my view, this could well be the biggest idea in terrestrial conservation since the development of the national park system. It faces many obstacles in navigating the elaborate national and international processes working toward an appropriate global warming treaty structure. But it shows the potentially enormous power of integrating ecosystem services into the policymaking framework.

I would like to close on a personal note. For me, the marshes, forests, riparian and coastal zones, and even the deserts constitute something very precious. Finding the best social apparatus to balance use against conservation for these natural wonders is one of the supreme challenges facing mankind today. That is why I am grateful for the opportunity to assist in RFF's efforts to get this right.

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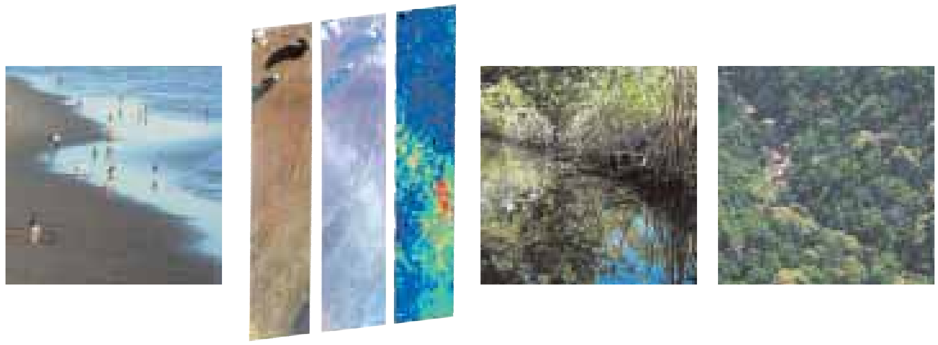

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Learn more about the feature stories in this issue at www.rff.org/natures services.

FEATURES

Special Edition: Putting a Value on Nature's Services

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RFF Senior Fellow **James W. Boyd** works in the fields of environmental regulation and environmental law and economics, in particular, the analysis of environmental institutions and policy. Specific areas of expertise include water regulation, environmental and product liability law, and incentive-based regulation.

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Alan J. Krupnick, RFF Senior Fellow, is an expert on eliciting preferences for health and environmental improvements. By creating improved methods for estimating willingness to pay for health and environmental improvements, he aims to provide credible monetary values for use by governments and other practitioners.

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RFF Senior Fellow **James N. Sanchirico** is a natural resource economist, who primarily focuses on the economic analysis of marine policies, especially the effects of individual transferable quotas and marine protected areas. His other research interests include spatial and intertemporal management of biological resources, and the interface between land use and biodiversity conservation.

After three decades on the faculty at Virginia Tech, **Leonard Shabman** joined RFF in 2002 as a resident scholar. His special interest is in expanding the contributions of economic analysis to the formation of water and related land resource policy.

RFF Fellow **Juha Siikamäki's** research focuses on valuing the environment and evaluating the benefits, costs, and cost-effectiveness of different environmental policy options. He is especially interested in understanding the preferences of consumers, households, and landowners for different policy programs.

Shalini P. Vajjhala, an RFF Fellow, studies the social impacts of large-scale physical and economic phenomena. She has worked extensively on adapting and integrating participatory mapping methods and geographic information systems (GIS) technology to engage citizen participation.

Goings On

Global Climate Policy Updates

Each issue in this space, you'll receive an update on the latest climate work from RFF. Please be sure to also visit Weathervane (www.weathervane.rff.org), our online guide to global climate policy.

RFF SCHOLARS TESTIFY BEFORE HOUSE, SENATE ON EUROPEAN EMISSIONS SYSTEM

In March, Senior Fellows Dallas Burtraw and Ray Kopp testified before congressional committees on lessons U.S. policymakers can draw from the European Union's experience with its cap-and-trade program on carbon emissions.

Kopp spoke March 26 before the Senate Committee on Energy and Natural Resources, and Burtraw testified March 29 before the House Committee on Energy and Commerce's Subcommittee on Energy and Air Quality.

One lesson that both urged U.S. policymakers to take away from the European Union's experience is the importance of permit allocation.

"Keep the allocation rules as simple and as transparent as possible," Kopp said in his remarks. "How permits are allocated can alter economic incentives leading to a variety of consequences—intended and otherwise."

"A complex allocation system can cloak unfair and dramatic transfers of wealth," Burtraw noted in his testimony, "while a transparent allocation system will build public confidence in the institution."

SIDE-BY-SIDE COMPARISON OF CLIMATE LEGISLATION

For the first time in a long while, Congress is treating climate change as a high-priority issue. Four bills setting mandatory caps on economywide greenhouse gas emissions are under active discussion in the U.S. Senate, along with narrower bills that restrict emissions from the electricity and automobile sectors.

While the bills have much in common, they vary with respect to the stringency of the caps and the chosen regulatory approaches. Differences in stringency and the regulatory approach can be expected to have significant effects on the costs of the programs and the distribution of those costs across households and businesses.

Senior Fellows Ray Kopp and Billy Pizer of RFF's Climate and Technology Policy Program have prepared a side-by-side comparative analysis of the five most recent Senate bills: Sanders-Boxer, Kerry-Snowe, Lieberman-McCain, Feinstein-Carper, and Bingaman-Specter. The table, which compares 10 attributes, including sectoral coverage, allowance allocation, and regulated entities, can be found at www.weathervane.rff.org. It is accompanied by a narrative exploring six critical questions, including "what do we know about the expected cost to reach the target?" and "do the bills limit uncertainty about costs?"

GOLDMAN SACHS CENTER FOR ENVIRONMENTAL MARKETS

Investment house Goldman Sachs's Center for Environmental Markets held its first conference, titled "The Business of Climate Change: Risks and Opportunities", on April 13. Senior Fellow Ray Kopp addressed the conference on the topic of "Greenhouse Gas Regulation in the United States: Alternative Approaches to Federal Climate Change Policy." He discussed current congressional action, lessons from the EU Emissions Trading Scheme, and the challenges and opportunities business will face in a carbon-constrained economy.

RFF President Phil Sharp participated in a closing panel of environmental leaders convened to discuss the likely path forward in the development of state and federal climate policy.

The Goldman Sachs Center for Environmental Markets was established in November 2005 to examine market-based solutions to environmental challenges. Research funded by the center will focus on finding market-based solutions to climate change, examining policy options for lawmakers, assessing market opportunities for environmental technologies, and valuing of fragile ecosystems. ■

EPA Administrator Stephen Johnson Calls for "Holistic Approach" to Environmental Challenges

Stephen L. Johnson, U.S. Environmental Protection Agency (EPA) Administrator, shared his perspective on the state of the environment at a Policy Leadership Forum at RFF in April. Johnson is the first career employee to assume the top position at EPA.

During his talk, Johnson highlighted progress the United States has made on environmental protection in recent years, remarking that "our air, our water, and our land are cleaner today than they were a generation ago." He noted, however, that there is work still to be done.

Stephen L. Johnson

"I believe America is moving into a new phase of environmental protection," he said, "evolving from pollution control to pollution prevention to sustainability."

Johnson laid out challenges facing the United States and the greater global community as they move forward. Among them, he listed ensuring a safe, clean, and sustainable water supply, greater energy security, and preserving biodiversity.

He also noted that these challenges are different from those the world faced a generation ago and likewise must be approached differently.

"Addressing the multidimensional environmental challenges of the 21st century requires a more holistic mindset, one that looks beyond today and toward achieving a truly sustainable solution for tomorrow."

The public remarks were Johnson's first since the Supreme Court ruled that EPA has the authority to regulate greenhouse gas emissions from automobiles. When asked what the response to the ruling would be, Johnson replied "We are actively reviewing the Supreme Court decision . . . and considering our options. Stay tuned." ■

"I believe America is moving into a new phase of environmental protection . . . evolving from pollution control to pollution prevention to sustainability."

The Frontiers of Environmental Economics

Extending its role as a proponent of leading-edge thinking on environmental policy, RFF, with the support of the U.S. Environmental Protection Agency's National Center for Environmental Economics, convened a conference in February to explore the frontiers of environmental economics.

The conference was structured around nine papers—on topics ranging from applying virtual experiments to policymaking to integrating economics and biology to inform fisheries management—that were selected out of more than 175 submissions. These papers advance theoretical and empirical methods in environmental and resource economics and illustrate how expanding the research frontier can inform the design and evaluation of environmental policy in the future.

Provocative presentations and intense discussion gave rise to several common themes and concerns during the two-day conference. Much of the work presented was multidisciplinary, drawing from economics as well as biology, computer science, ecology, neuroscience, physics, and psychology.

As an example, work on models of interactions between natural resources and population growth and production brought together researchers from the departments of economics and physics at Ohio State University. Presenter Elena Irwin noted that models of resource growth and use can be quite misleading for informing policy if they don't account for the feedbacks between economic and ecological components, especially as different people respond in different ways to the interactive effects of slow-changing human migration and fast-changing factors, such as pollution.

Discussant Amy Ando, University of Illinois, remarked, "Economic models simplify to clarify, but have we simplified too much? In many cases, yes."

Participants voiced concern, however, over how to communicate the results of increasingly sophisticated research. Co-organizer Alan Krupnick, RFF senior fellow, suggested that the communication of complexity to decisionmakers is another frontier. "If this work is going to go into the service of policy, it has to be presented in a way that keeps its power but is still communicable. How are we going to do that?"

"Doing math is like making salami," Simon Levin of Princeton University said in response. "It's something you don't do in public." He and Amy Ando raised up Al Gore as an example of a powerful communicator, while Glenn Harrison, University of Central Florida, pointed to the recently released *Stern Review: The Economics of Climate Change*.

Other papers addressed the implications of neuroeconomics, behavioral economics, experimental economics, and virtual reality for environmental economics. For example, work by cognitive and computer scientists and economists at University of Central Florida harnessed tools from experimental economics, virtual reality, and psychology to develop a viable tool for land-use planning and risk management, which allows decisionmakers to see the (virtual) results of their policies.

"The part of virtual reality that surprised me," said presenter Glenn Harrison, "was the 'R' part, the 'reality' part." While virtual reality often evokes images of "a gothic second world . . . a lot of the guts of VR is writing out a real, plausible model of the physics, of the biology, and of the ecology that drives the rendering," he said.

Commenting on the work, John Graham, RAND Graduate School, suggested that it could be extended beyond environmental applications, to help policymakers understand the results of complex models and inform voters about ballot propositions provided by advocates or by the government.

Douglas Bernheim, Stanford University, and Antonio Rangel, California Institute of Technology, proposed a new behavioral framework for welfare analysis to be applied when the assumptions of standard welfare economics do not hold.

"Economics assumes individuals always have well-defined preferences and make choices to maximize them, but this is a fallacy," Rangel said. Instead, a growing body of evidence shows that people's choices change in the face of shifting ancillary conditions, such as the time or order in which the decision is made. Their behavioral approach can account for these ancillary conditions, which frequently frame and influence choices, especially those affecting the environment.

While the approach departs from standard welfare economics in some ways, Rangel emphasized that it holds true to a basic principle of standard welfare economics: that of libertarianism. "Standard welfare economics as defined in neoclassical theory is about

choice . . . and it is based on a single principle, the libertarian principle: the government, when making policies or policy choices, should choose as the individual would choose for himself," he said. "All of the welfare analysis that [I've done] satisfies this principle."

But Carnegie Mellon Professor Dennis Epple warned, "If people make mistakes—which they are more prone to do in voting booths—there is little reason to think that decisionmakers are people who you want to make choices for you. Can a 'rational planner' really exist?"

RFF has published the papers as part of its Discussion Paper Series, and the video, audio, and PowerPoint presentations from the conference are available online at www.rff.org/frontiers conference. ■

Modeling Growth for the Nation's Capital: A Work in Transit

Losing only to Los Angeles and San Francisco in the dubious competition for the worst traffic in the country, the Washington, DC, metropolitan area poses an additional challenge for land use and transportation planners—multiple jurisdictions at the state, county, and federal level. Over the past few decades, the number of cars, jobs, and people has soared while long-term, strategic solutions are debated and usually litigated.

The problems encountered by DC-area planners are the same as those faced by their counterparts across the country, albeit writ large. Suburbs spawn ex-urbs that quickly overwhelm road infrastructure planned decades before. Shifting demographics, the rise or fall of the local economy, and national and worldwide economic trends introduce confounding variables that further complicate the policy process. And across the country, many governors and big city mayors are promoting once radical transportation measures like cordon pricing and high-occupancy/ toll roads as a means of combating congestion, air pollution, and climate change.

All of this makes efforts to reduce congestion all the more convoluted. Because policymakers can't run experiments in the real world by say, deciding to build a highway only to dismantle it later, they turn to the next best thing, an economic model. With a model, it is possible to examine the effects of individual policy variables one by one. More importantly, models allow us to see whether a policy of interest would be effective at what it is designed to achieve and what side effects, or unintended consequences, it is likely to produce.

Two RFF scholars, Elena Safirova and Winston Harrington, have built an integrated model of land use, strategic transport, and regional economy (LUSTRE) that can examine the long-run trade-offs of both transportation policies and land-use regulations. Because land use and transportation decisions are very much intertwined, unintended consequences are likely to be very common. For example, a cordon toll is designed to make people switch to public transit to drive less. However, in the long run a toll is also likely to encourage some residents to move to the suburbs and therefore contribute to urban sprawl.

At a recent RFF workshop, discussants talked about LUSTRE modeling results of two policies that address DC congestion problems as well as the value of models to local planners in general.

Tensions and Trade-offs

All participants agreed that models were essential in land use planning, serving as test beds for understanding how policies might play out in the real world. But any model is inevitably a simplification of reality. One simplifies because the lack of data demands it. As Michael Replogle, transportation director, Environmental Defense, noted, "The closer you are to the data, the more unhappy you are with it." Simple models are also transparent, which is especially important when used for policy analysis, said Ken Small, research professor and professor emeritus of economics, University of California–Irvine. Neither the public nor the decisionmaker is likely to trust a model that cannot be understood.

And yet, good models often need complexity as well. The real world is constantly tossing up outcomes that are unexpected and often counterintuitive, and frequently policies fail because they have unintended consequences. Because these unexpected outcomes are of special interest, models that can identify them are particularly valuable.

The problem is, how do you balance the need for transparency with the demand for complexity? And even if a model generates interesting results, how can you tell if those results are relevant to the real-world problem at hand, or are simply an artifact of the model? For modelers, balancing the tensions between simplicity and complexity and distinguishing between real and manufactured outcomes are never-ending concerns. ■

A "LUSTRE-ous" Model

LUSTRE (Land Use, Strategic Transport and Regional Economy) is an integrated and spatially disaggregated land use and transportation model that is calibrated for the Washington, DC, metropolitan area. It combines two smaller models: Regional Economy and Land Use (RELU), which represents economic and spatial behavior of consumers, firms, and developers in a metropolitan area and was developed by Alex Anas and Elena Safirova; and Strategic Transport (START), which provides details on transportation choices made by economic agents such as mode, time period, and parking. START was developed by Tony May and is now maintained by MVA Consultancy of the UK. Unlike in other land use/transportation models, the integration in LUSTRE takes place at the level of individual agents, who make tradeoffs in housing, transport, and other goods based on their idiosyncratic preferences and the unique prices they face. The model also incorporates unemployment, taxes, and alternate transportation modes.

Antibiotic Effectiveness: Managing a Common Resource

Antibiotic-resistant infections are becoming increasingly deadly. According to reports from the Centers for Disease Control and Prevention, the percentage of U.S. patients with staph infections who failed to respond to a common antibiotic, methicillin, went from 2 percent to more than 50 percent between 1974 and 2004.

The consequences are very real: when these familiar and affordable antibiotics fail, doctors must adopt more extreme measures to treat patients, from the use of much more expensive drugs to surgery. Antibiotic resistance claims more than 63,000 American lives every year, more than the U.S. death toll from traffic accidents or AIDS.

In a new report, *Extending the Cure: Policy Responses to the Growing Threat of Antibiotic Resistance*, RFF Senior Fellow Ramanan Laxminarayan and his coauthors examine the problem of antibiotic resistance from a natural resources perspective.

“Antibiotic effectiveness is a valuable shared resource, much like clean water, forests, fisheries, and oil production,” said Laxminarayan. “Success in protecting this shared resource will require incentives for all stakeholders to change their current approach to antibiotics.”

All antibiotic use, appropriate or not, “uses up” some of the effectiveness of that antibiotic, diminishing our ability to use it in the future. Hastening the spread of resistance by overuse of antibiotics, then, is like other shared resource problems, such as global warming and overfishing. The federal government has required sustainable management of resources like forests and fisheries, and more recently, genetically engineered pest-resistant crops. Similar approaches can help government craft policies for the sustainable use of antibiotics.

For many shared resources, including antibiotic effectiveness, the key to successful management is in aligning stakeholder incentives. The root causes of antibiotic resistance lie in insufficient incentives for patients, physicians, hospitals, and pharmaceutical companies to act in ways that would conserve the effectiveness of antibiotics.

Effective solutions to declining antibiotic effectiveness, the report finds, must include financial inducements, such as lower reimbursement for hospital-acquired infections, coupled with some measure of regulatory sanctions for health care providers, hospital administrators, health insurers, and drug manufacturers. The authors’ recommendations include educating patients and physicians about the risks of greater antibiotic use and using vaccinations in community settings and infection control in health care facilities to lower the burden of infections.

Even if we were to make the best use of existing drugs, resistance would arise. However, in recent decades the development of new antibiotics has not kept pace with resistance. Investment in antibiotics appears to be declining. Just as importantly, pharmaceutical companies do not have a strong incentive to care about the development of resistance to their products. Policies to encourage the timely development of new drugs would take two forms: encouraging research and development into new antibiotics, and reducing incentives for pharmaceutical manufacturers to oversell their antibiotics.

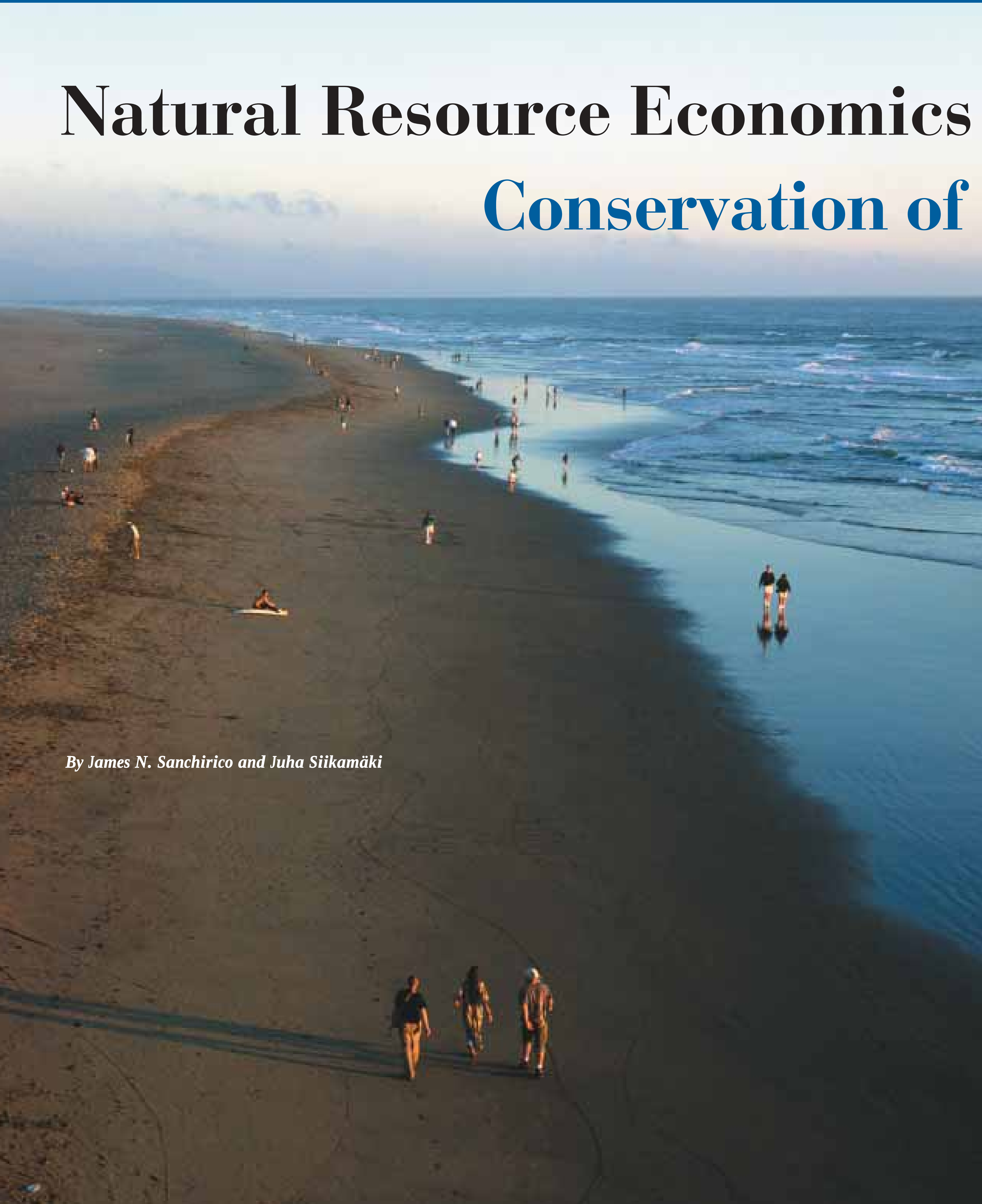
“Practical economic incentives are a time-tested and powerful way to change behaviors,” said Laxminarayan. “Without providing positive rewards for those who use and produce antibiotics to change their practices, we will continue to see our arsenal of disease-fighting drugs shrink.”

Extending the Cure was developed by a team of researchers from RFF, the University of Chicago, the National Institutes of Health, and Emory University. The researchers were advised by a distinguished panel of academics, including Nobel Prize-winning economist Kenneth Arrow, and Donald Kennedy, former U.S. Food and Drug Administration Commissioner and current editor-in-chief of *Science*. The report is available at www.extendingthecure.org. ■

Natural Resource Economics

Conservation of

By James N. Sanchirico and Juha Siikamäki



and Policy in the 21st Century

Ecosystem Services

As *Resources* readers are aware, the marketplace is the core of our economy, the means by which goods and services move back and forth. Many environmental goods and services are left out of the marketplace, however, not because of any conscious effort but rather because they are not easily traded and priced. For example, landowners face little difficulty in selling crops or timber but are less able to market the environmental services of their property, such as providing wildlife habitat or protecting rare species. And without economic rewards, landowners have little incentive to engage in such activities.

If the 20th century witnessed the birth of the environmental movement that raised concerns about how the marketplace inadequately conserves natural resources, early predictions for this century see the expanding recognition of the need to bring environmental and natural resource services—ecosystem services, in short—into the marketplace. These services denote the full range of benefits that people obtain from different ecosystems, including, for example, provision of food, water, timber, and fiber; regulation of climate, floods, and water quality, and provision of recreational and aesthetic benefits.

For evidence of this trend, you don't need to look very long or hard. The Millennium Assessment by the United Nations, federal agencies such as the U. S. Forest Service, and more than a few nongovernmental environmental organizations are all focusing their efforts on devising strategies for sustaining the provision of ecosystem services. In this issue, an essay by Allen Blackman, Francisco Alpízar and Alexander Pfaff focuses on cases in Costa Rica and Honduras, and another by Len Shabman and Sarah Lynch discuss efforts in the Florida Everglades, north of Lake Okeechobee.

A Sea Change

So what is bringing about this marked shift in perspective? One major reason is the view that the traditional (20th century) approach of creating protected areas to preserve and sustain services combined with the limited worldwide budget for conservation can only get you so far. Full protection of habitats and species by way of excluding all activities is extremely costly and socially disruptive. Shifting attention to conservation of ecosystem services on non-fully protected lands (or working landscapes) requires merging environmental protection with economic activities. As James Boyd mentions in his "call-to-arms" essay, this has created a greater need for natural resource economists and conservation biologists and ecologists to work together.

What does creating economic incentives for managing and sustaining ecosystem services entail? This exercise includes selecting the ecosystem services to consider; measuring the provision of the services and their value; creating markets or other economic incentive schemes, such as payments for ecosystem services programs; and designing monitoring systems to ensure the delivery of the services. How to approach these tasks depends in part on perspective and context; for example, in the Lake Okeechobee case, all of the parties are actively involved in the choice of these components. In Honduras and Costa Rica, the choices involve balancing improved refinements in the proxies used for measuring the provision of ecosystem services to ensure getting the greatest return from the payment-for-ecosystem-service program against the costs of doing so. In both cases, government payments provide landowners with the incentives to protect and to provide ecosystem services.

Many times, values related to ecosystems are related to their intrinsic worth, such as protection of biodiversity or rare species. Such non-use values are challenging to measure because they are captured neither in market data nor by other behaviors that are commonly applied for measuring use values. This problem has given rise to the development of nonmarket valuation methods, specifically surveys in which citizens are asked to state their preferences and willingness to pay to support the provision of ecosystem services. Alan Krupnick and Juha Siikamäki describe the principles and challenges of these methods. With an example from New York's Adirondacks, they highlight practical issues, such as how to best identify and describe the services that are not related to the direct use of the ecosystem.

James Sanchirico and Peter Mumby on the other hand, utilize a framework that combines population biology, ecology, and economics to measure and value the provision of services from habitats. This time, the analysis is for coastal mangroves and their importance in the abundance and diversity of fish on coral reefs. Using methods that are similar to valuing inputs to the production of "run-of-the-mill" economic goods and services, Sanchirico and Mumby impute one aspect of the value of coastal mangroves by measuring the changes to the value of the associated coral reef fishery.

An important feature of sustaining and conserving ecosystem services is determining how the different components of an ecosystem—such as forest parcels, hectares of mangroves, or coral reefs—relate to its overall functioning. As Molly Macauley, Shalini Vajjhala, and William B. Gail discuss, our ability to see how components fit into systems has evolved from static paper maps and charts to dynamic 3-D fly-bys on personal computers. This revolution not only provides exciting environmental information on spatial environmental relationships but is also leading to new social science research questions on how people perceive their connectedness to the environment at various spatial scales. Some of these tools are already being deployed in the Costa Rica and Honduras programs but the full potential of blending visualization technology and ecosystem valuation has yet to be realized.

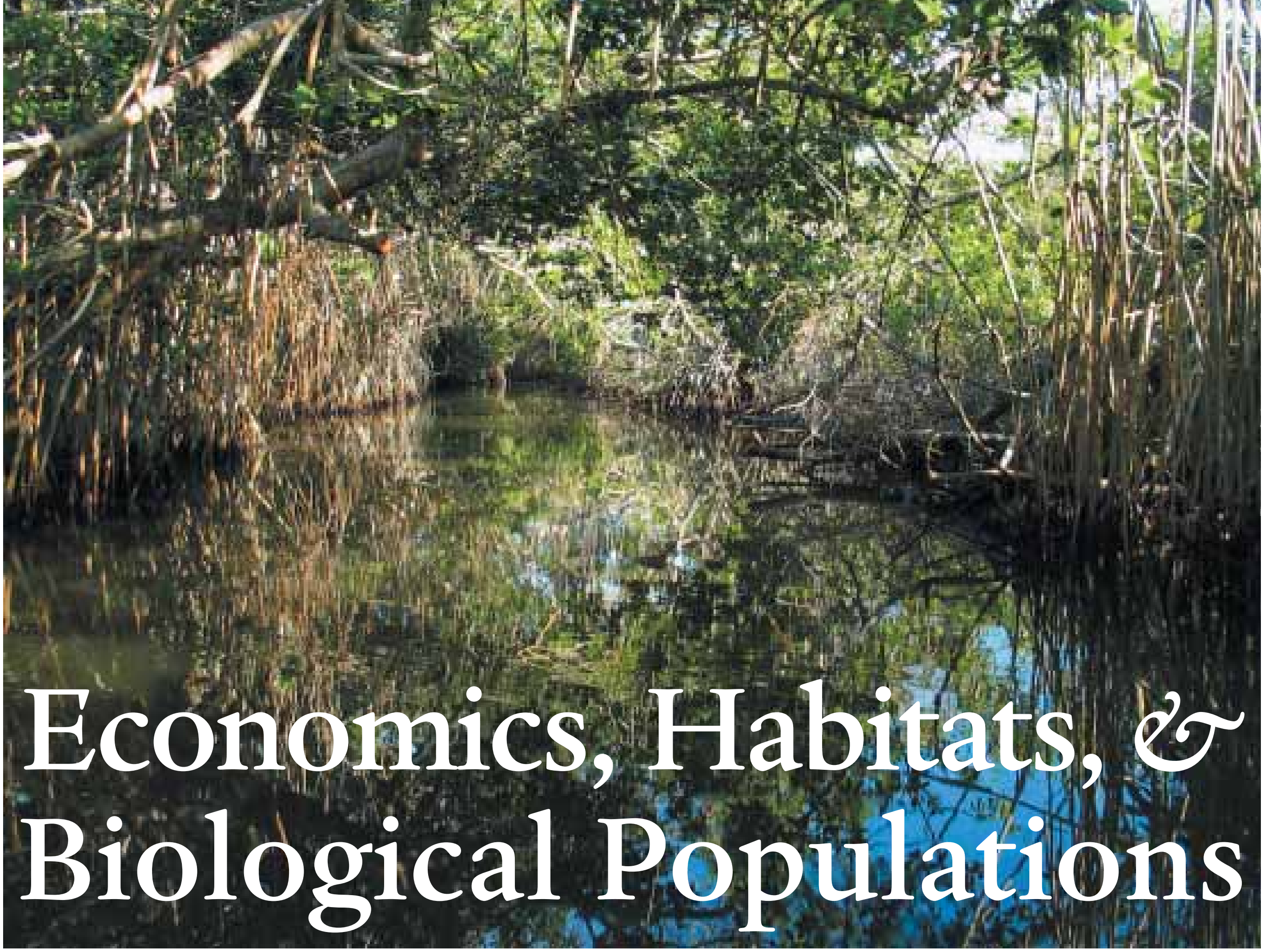
What Questions to Ask Next

After all this effort and research, a natural question to ask is whether the health of our ecosystems is improving. To find answers, we need to find ways to track the benefits from nature over time. But exactly what endpoints should we focus on? Boyd discusses defining and illustrating measurable, countable endpoints that can act as consistent "points of contact" between ecological and social science. The need for well-defined units and values for nature's services emerges from both macro- and micro-level perspectives, such as generating economywide environmental statistics and payment programs for providing specific ecosystem services.

But many important questions remain. For example, our case studies are examples of governments providing payments for the services. In some cases, such as carbon sequestration, these payments might stem from private individuals, NGOs, or corporations participating in markets. How can we design such markets to ensure continued support and achievement of the ecosystem goals? Also, how do we reconcile the necessary context-specific definition of services and their provision with the need for consistent definitions and measurement so that we can track performance in national accounts?

Interdisciplinary research on ecosystem services is evolving on two fronts: theoretical, with the development of new concepts and techniques; and practical, with lessons to be learned from projects in the field. The tensions between these fronts and ongoing efforts on both to evaluate and account for the tradeoffs between different benefits from nature will surely lead to advances in our understanding. The next 10 years will also likely see important *ex post* evaluations of the payment for ecosystem service programs now under way.

And you can't forget the 800-pound gorilla now peeking out of the closet: How will climate change affect everything? ■



COURTESY GEOFF SHESTER

Economics, Habitats, & Biological Populations

FINDING THE RIGHT VALUE

By James N. Sanchirico and Peter Mumby

Imagine a coastal planner confronted with the following decision: whether to allow a tourism development project to go forward and, if so, where and how large an area of the coastal environment to convert? According to Economics 101, the planner would set out to determine the benefits to the local economy from the tourism development and the costs of converting the open space on the coast, where the benefits and costs would depend on the location and scale of the development project. If the total benefits were greater than the total costs, the decision would be to move ahead with the project.

While not necessarily straightforward, the benefits from the tourism project, such as new jobs and increased tax revenue, are easier to quantify and more defensible than the costs of converting the natural environment, which would entail the lost ecosystem functions and services and non-use values. So what should the planner do? Everyone would agree that placing a value of zero on the coastal environment would not be a satisfactory approach. But what is the appropriate value of a beach, forest, coral reef, sea grass bed, or wetland? And what tools can the planner use to determine the value of the habitat? One method is bioeconomic analysis, which traditionally combined population biology and economic modeling but more recently also includes geophysical processes and ecological functions.

Bioeconomic analysis is an appropriate tool in environmental and resource economics for a couple of reasons. First, it requires one to specify how a fish, bird, or animal population changes over time by incorporating the life-cycle characteristics—such as the speed at which a population grows—

of the species under consideration. Second, the costs and benefits either from harvesting the species or from nonconsumptive uses or both can be explicitly accounted for. Putting these parts together in one framework permits an analyst to understand the full economic and ecological trade-offs involved in managing animal populations. For example, sustaining larger populations comes at the cost of lower levels of extraction; bioeconomic analysis can help shed light on what the benefits and costs are for different population sizes, given the goals of the resource manager and society more generally.

Coastal mangroves above water.

Valuing Mangrove Habitat

To set the coastal planner's problems in a more specific context, we can use the example of coastal mangroves to show what bioeconomic analysis can contribute. Coastal mangroves are intertidal forests located throughout tropical regions around the world (see photographs). Current estimates are that between 35 and 50 percent of mangroves worldwide have already been lost, with current deforestation rates greater than those of tropical rainforests. The primary threats to these systems are coastal development and conversion to shrimp aquaculture. One reason why mangroves are threatened is that the economic value of the harvestable products, like wood, and the "services" they provide, including hurricane and tsunami protection, have not been properly determined and considered in the clearing decision.

Here, we will focus on just one function, the role of mangroves in the "production" of coral reef fish species. Some exciting new scientific studies have shown that coral reefs in close proximity to mangrove habitats exhibit larger abundances of some species and greater biodiversity. Species that show this benefit, such as snapper and parrotfish, apparently hide in the root structure of the mangroves during their juvenile stage to avoid predators. This refuge allows them to grow to a size such that when they migrate to the coral reef in their adult stage they can escape predators on the reefs.

How can we capture the production value of the mangrove habitat to help inform the coastal planner of what the costs of conversion are? From an economist's perspective, the mangroves are similar to the machines and other inputs that produce economic outputs (here the coral reef fish). Unlike labor, where there is a market to determine the going wage rate, no market exists for this ecosystem function. We can, however, calculate the value of the mangroves by incorporating their role in species population dynamics. That is, we can use bioeconomic analysis to investigate the difference in the value of a fishery with and without the mangroves present.

Our findings show that for any number of fishing boats and fishermen, the profits from fishing are greater with the mangroves present than without them. This benefit results from the greater abundance of fish that are protected from predators by the refuge in nearby mangroves. Another interesting implication of having coastal mangroves in the vicinity of the coral reefs is that the fishery can support greater levels of fishing effort than without the mangroves. We can measure the value of the mangrove or "mangrove effect" by simply calculating the difference between fishing profits with and without mangroves present.

The size of the mangrove effect depends in some complicated ways on ecology, economics, and governance—how the fishery is managed. On the ecological side, what matters is how the species utilize different habitats in their life cycle and where the fish are subject to the greatest levels of predation. On the economic side, the size of the mangrove effect depends on the price of the fish and the costs of fishing. For example, the higher the price or lower the fishing costs, the greater the value, holding all else the same. In terms of governance, the potential value depends on how many fishing vessels are permitted to fish and the nature of their rights to the total catch. If local fishery managers do not implement rights-based tools, such as a harvesting cooperative or individual fishing quota system, then there might not be any value to the fishery from the mangroves. The important role of governance and institutions in determining the value of ecosystem services is a point often lost in discussions on the provision of these services.

Coastal mangroves below water.

Balancing Costs and Benefits

Let's return to our coastal planner. How might he or she use this information? In addition to the costs of converting the mangroves in terms of lost storm protection, lost non-use values, etc., we can add in the costs resulting from the reduced profits from fishing the species that depend on them. In other words, the larger the development project (in terms of the number of hectares of mangroves converted), the greater the opportunity costs of converting the mangroves. Together these are the economic costs of the development project.

On the other hand, there are benefits to the development project. Balancing the costs and benefits, we can determine the efficient size and location of the project. We find that when the coastal planner ignores the value of the mangroves to the fishery, the size of the development project is larger and possibly in the wrong location. It could also be the case that the opportunity cost of clearing the first hectare of the mangrove is so high in this particular location that no development project of any size is initiated.

Again, the size of the project that just balances the benefits and costs with and without considering the mangroves will depend, in part, on the same factors that lead to greater fishing profits. That is, it depends in non-trivial ways on the economics, ecology, and governance.

As a tool for helping policymakers and regulators understand the value of ecological functions and the value of the services provided by habitats, such as wetlands, forests, coral reefs, mangroves, and by biological populations, bioeconomic analysis is well developed and perfectly suited for such demands. Modeling tools by their very nature, however, are part science and part art. Therefore, we recommend using such analysis as a means to inform the policy process, not as a blunt metric yielding a "yes or no" answer.

Currently, academia, government, and NGO communities are discussing the need for interdisciplinary approaches to help address some of the more difficult conservation decisions we are facing in the 21st century, including valuing ecosystem functions and services and setting up private and public payment systems for these services. Since its origins in the late 19th century and its blossoming in the middle of the 20th century, bioeconomic analysis has been and will continue to be an important tool for determining the value to society of biological populations and habitats—and one that is interdisciplinary at its core. ■

How People Value What Nature Provides

Alan J. Krupnick and Juha Siikamäki

Economists use people's actions and choices to value their preferences for experiencing nature through activities like hiking, camping, fishing, hunting, or viewing wildlife. This information helps set priorities for managing and protecting nature and also allows people to determine losses to valuable environmental resources when they are somehow damaged, for example, by the loss of habitat or major chemical spills. Personal preferences for nature in some settings, however, are based on more than their worth in use. For example, though few people have seen bald eagles or manatees up close, many want to make sure that their habitats are preserved.

Such non-use values are challenging to measure because they are not captured in market transactions or other observable choices. One way to reveal these values is to examine people's decisions to join or financially support environmental organizations. Unfortunately, these observations do not fully reflect values for public goods—benefits that are available for everyone's enjoyment once somehow provided—because, for one thing, they are based on the opinions of a small subset of the population.

Ways to Value Nonmarket Goods

This problem has given rise to the development of a variety of nonmarket valuation methods that use surveys to elicit preferences for public goods. Because these methods are generally based on eliciting "stated" rather than "revealed" preferences, they are broadly categorized as stated preference methods. The contingent valuation method is perhaps the most common one. Contingent valuation involves developing and administering surveys, in which respondents are presented with a scenario or a program with specified environmental outcomes and cost to the respondent. Each respondent is asked to indicate approval or disapproval of the proposed environmental scenario and its monetary cost. Researchers vary the proposed costs across different survey respondents and use their choices to estimate how much people on average are willing to pay for different scenarios to improve the environment. Because some of the respondents may use a public good also for direct enjoyment, say viewing an endangered bird, the surveys capture total value for the improvements, rather than just their non-use value.

Another leading stated preference method is the choice experiment, also known as conjoint analysis, a term borrowed from marketing research. Here, survey respondents identify their preferences among one or more programs or alternative management strategies specifically altering different attributes of the program, such as the different environmental outcomes and monetary cost. By varying the levels of these attributes (including cost) across different scenarios and examining respondents' choices, it is possible to estimate how much people are willing to pay for the different attributes of the program, as well as the entire program.

Valuing the Ecological Effects of Acidification in the Adirondacks: A Case Study in Contingent Valuation

RFF scholars recently carried out a contingent valuation survey to estimate New York State residents' willingness to pay (WTP) for improving the Adirondacks aquatic ecosystem, which has been compromised by acid rain. For 20 years, a central issue in the debate about clean air regulation has been acid rain, and one focus of that issue has been Adirondack Park. During most of this debate, monetary value estimates, which our research now provides, have been unavailable for assessing the ecological changes likely to occur as a result of reduced air pollution.

The survey was administered by mail and web to a random sample of individuals in New York State. Based on extensive focus group testing, the survey first describes the area through a series of maps and text, then explains the problem as 1,500 "lakes of concern" out of 3,000 lakes in total that have compromised aquatic life caused by acid deposition. Next, using graphics and text, the survey introduces a prospective program to reduce the effects from acidification in the Adirondacks. Figures below illustrate how we graphically described this program to respondents. Figure 1 specifies that the program would improve the quality of 20 percent of the lakes of concern. Figure 2 demonstrates a hypothetical liming program to mitigate the effects of acidification. The question used to elicit WTP in the survey is posed on a screen shown in Figure 3. Then a series of debriefing questions is posed to test whether individuals understand and believe the information in the survey. Finally, the survey explains that the program considered is a hypothetical one and was constructed for the purposes of eliciting New Yorkers' preferences for reducing ecological effects from acidification in Adirondacks.

Figures in the survey embody numerous choices by the researchers. Figure 1 covers current and future baseline conditions (where the future baseline is unchanged), as well as future conditions under the improvement scenario. We needed to be explicit about the future conditions without the scenario; in the absence of our description, individuals would have substituted a worsening situation that is inconsistent with the science. These pie charts were the most successful way we found to communicate these changes.

Figure 2 also resulted from much iteration. In reality, the program depicted may not be the most practical one. But we succeeded in making this program appear believable and realistic and, by using airplanes, very costly without raising suspicions. (Using a wide range of cost estimates across different respondents is needed to properly estimate WTP.) A curious finding was that the lime pellets being dropped from the plane had to be of a small size; otherwise some respondents became concerned they would damage wildlife from their impact!

Finally, Figure 3 shows a number of key elements of the voting question. First, it evokes a budget constraint to be consistent with how individuals would make costly decisions in the field. Second, it contains a "cheap talk" script alerting people that in surveys, people may not vote as they really would and urging them to take this task seriously. Third, the voting format presented is consistent with referenda New Yorkers have faced in the past.

Overall, we found that New Yorkers—users and non-users alike—place significant value on rectifying damages from acid rain in the park. Depending on the improvement scenario in our survey, they would be willing to pay from \$48 to \$159 per household each year. With 7 million households in the state, this amounts to benefits of \$336 million to \$1.1 billion annually. The values of non-users are a large percentage of these totals.

These estimates have already made it into the policy process: they were included in a case study of the value of ecosystem improvements in U.S. Environmental Protection Agency's current efforts to estimate the costs and benefits of various initiatives to improve air quality. In addition, they are relevant to considering proposals to further reduce acid deposition and to estimate the ancillary benefits of reducing greenhouse gas emissions, because the pollutants that cause acid deposition—sulfur dioxide and nitrogen oxides—are likely to be affected by such efforts. Building on this earlier work, we are currently designing other related valuation surveys for the Adirondacks and Southern Appalachian Mountain Region.

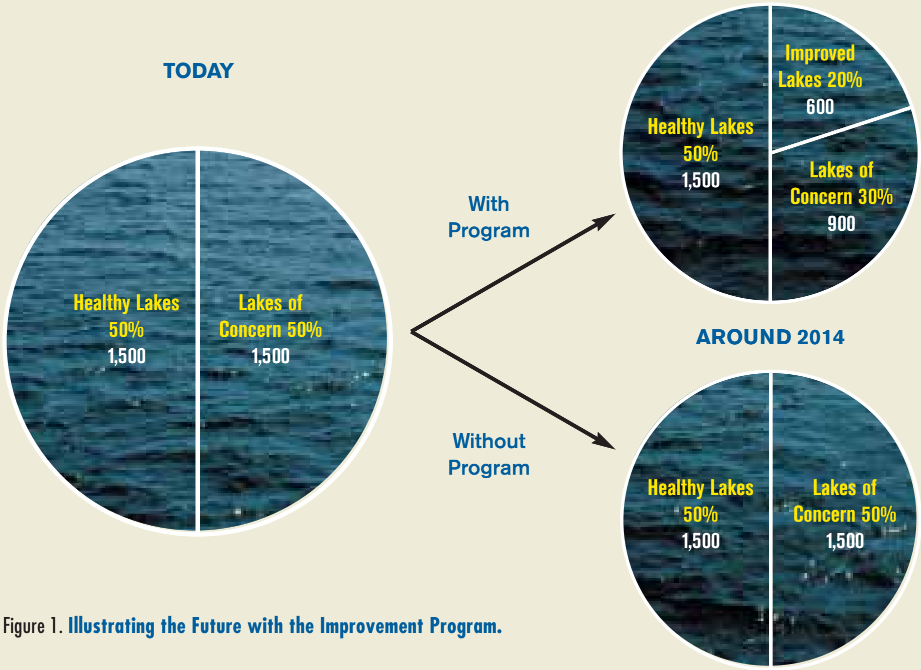


Figure 1. **Illustrating the Future with the Improvement Program.**

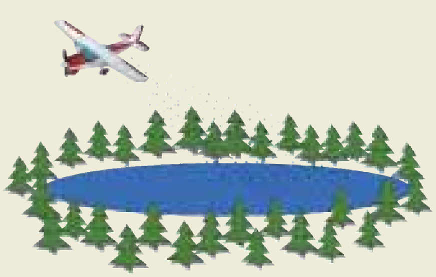


Figure 2. **Demonstrating the Use of Aircraft for the Hypothetical Liming Program to Reduce Acidification**

Different valuation problems call for different valuation methods. Contingent valuation is particularly well suited for estimating survey respondents' willingness to pay (WTP) for specified policy programs to improve ecosystem services, such as predetermined regulations to improve water or air quality in a certain area. Choice experiments focus on examining preference trade-offs and substitution patterns between different attributes of proposed programs rather than predicting WTP for a specific program. They are especially useful for helping design programs to best meet the public's preferences. Also, values for ecosystem services at a new location are sometimes predicted using valuation results from another area. Results from choice experiments are especially useful for such predictions.

Because stated preference methods are based on what people say and not on what they do, there is a tendency to discount the credibility of these results. To address this flaw, the NOAA Expert Panel that reviewed the highly publicized studies valuing damages from the Exxon *Valdez* oil spill recommended that a series of validity tests be built into stated preference surveys. The hardest to pass is the external scope test, which involves showing that the WTP measure from one sample for a program (or change in attribute) is statistically greater than the WTP from another sample for a program with smaller improvements. These tests are now considered important quality criteria for stated preference studies.

Another challenge is in communicating the key information needed to make a decision. In real life, as captured by revealed preference approaches, individuals collect the amount and type of information they feel they need to make a decision, so the analyst doesn't need to be involved. This challenge to survey design is also an advantage, as information in the real world is messy and often incomplete or even erroneous. With stated preference methods, it is possible to ensure that the results are clearly presented and consistent with the underlying science.

Defining "Values"

Economic values should not be confused with the ethical values commonly referred to as "values" in everyday parlance and other disciplines, such as philosophy or psychology. Economic valuation deals with the relative usefulness of goods and services, which is commonly expressed in dollar terms. Economic values are not rigid; rather, they are conditional on the availability of other goods and services.

Although the concept of economic value is different from ethical value, the two are not necessarily unrelated. For example, we may be able to predict WTP for different ethically important aspects of the environment—for example, the protection of biodiversity by preventing imperiled species from going extinct. The objective of such an exercise is not to equate dollar and ethical values but to provide commensurate reference points for highlighting different trade-offs involved. While this practice can be controversial, especially when dealing with emotionally powerful issues, many important as well as everyday policy issues center on more practical considerations, such as how to manage publicly owned ecosystems so that they provide their owners (the public) with the most value. Despite all its challenges, the ability to place an economic value on ecosystem services is central to formulating sound environmental policy. ■

Figure 3. **Describing the Vote:** The New York government is interested in your views about its spending priorities for a number of programs, including those mentioned at the beginning of this survey. We specifically want to know if you would vote for or against the Adirondacks improvement program, knowing that it would be adopted if a majority of voters support it. How people vote in surveys is often not a reliable indication of how people will actually vote. In a survey some people ignore the sacrifices they would need to make if their vote actually meant they would have less money to spend. We need to know if you think the Adirondacks improvement program is worth spending your household's money on. Your answer will have the effect of a vote on this proposal.

PLEASE VOTE

The government is considering a program to improve lakes in the Adirondacks. This program will increase the populations of fish and improve the ecosystem of 600 lakes of concern in the Park. Without this program, the number of lakes of concern will remain the same; and their quality will not improve or worsen. If the majority of voters support this program your household's share of its cost would be $500 **in total**, or $50 **per year**, paid as an additional tax over the next **ten years**.

If a vote were held today, would you vote FOR the program or AGAINST it?

VOTE FOR IT ☐ VOTE AGAINST IT ☐

The Florida Ranchlands Environmental Services Project: Field Testing a Pay-for-Environmental-Services Program

Sarah Lynch and Leonard Shabman

THE EVERGLADES—today about half its original size—once stretched south from what is now Orlando, Florida, toward Lake Okeechobee, and then on to Florida Bay. Rain fell on the wetland and water flowed slowly south, passing through the lake as a wide and shallow "river of grass," a term often used to describe the Everglades. But beginning more than 100 years ago, public agencies and private landowners began to transform the land, building a vast ditch network. After two early 20th century hurricanes killed thousands, a dike was built around Lake Okeechobee that kept hurricane-driven lake water from inundating nearby towns but also interrupted the historic patterns of water flow.

The system of drainage and storm protection works has become the foundation of Florida's economy. The dried-out land first supported agricultural production and more recently has accommodated a dramatic increase in human settlement: 400 people per day now move to Florida. But there have been unanticipated and undesired environmental consequences.

While it is still the "liquid heart" of the Everglades, Lake Okeechobee now receives a rush of water from drainage canals, drowning near-shore fish and bird-nesting and nursery areas and threatening the dike. Agriculture, particularly cow-calf operations, remains the dominant land use in the heavily drained 3.5 million acre watershed north of the lake. The decades of agricultural land use, as well as current agricultural practices and new urban development, mean the water coming to the lake carries an unnatural load of phosphorus and other nutrients. When lake levels get too high and threaten the lake's ability to hold storm water, nutrient-laden freshwater is pumped through canals to the estuaries—the St. Lucie and Caloosahatchee—on Florida's eastern and western coasts. The combination of excess fresh water and high nutrient concentration has brought rapid and dramatic changes in the environmental condition of the estuaries.

Over the past several decades, multibillion dollar state and federal initiatives—such as the Lake Okeechobee Protection Plan (LOPP) and the Comprehensive Everglades Restoration Plan—have been launched to restore the watershed. These programs use public funds to buy land to build large treatment wetlands that remove phosphorus from drained water, construct large reservoirs to capture rainwater north of the lake and delay its arrival, and drill aquifer storage and recovery wells that store excess water underground. The LOPP also includes regulations that, when combined with U.S. Department of Agriculture (USDA) expenditures and state funds, will change agricultural and urban land-use practices to reduce phosphorus runoff. More recently, the Florida Ranchlands Environmental Services Project (FRESP) was launched, which will field test a program to complement the existing restoration programs by paying cattle ranchers to provide environmental services that will benefit the lake.

The program came about after a 2004 study conducted by World Wildlife Fund (WWF) with several cattle ranchers concluded that a program to promote changes in water management practices on 850,000 acres of improved and unimproved pasture could moderate water flows to the lake, reduce phosphorus loads beyond what is required by LOPP, and add to wetlands habitat. The study concluded that the agencies could buy these environmental services from cattle ranchers at a lower cost than producing the services by building new public works projects. The same study identified barriers to be overcome if a pay-for-services concept was to become a reality. For this reason, a pilot program was envisioned as an essential step toward implementation.

FRESP was launched in 2005 to design such a program and conduct the pilot work. It is a collaboration of ranchers, WWF, agencies of the state (Florida Department of Agriculture and Consumer Services, South Florida Water Management District, and Florida Department of Environmental Protection), USDA's Natural Resources Conservation Service, and scientists from the McArthur Agro-Ecology Research Center (Patrick Bohlen) and the University of Florida (Mark Clark and Sanjay Shukla). FRESP secured more than $4 million to conduct a five-year pilot project to identify and field test critical elements of a program.

ANSWERING DESIGN QUESTIONS

Under the program, ranchers will sell environmental services to agencies of the state and other willing buyers. The public will benefit when services are provided at a lower cost than can be secured from public investment in regional water storage and water treatment facilities. And ranchers, who face low profit margins and fluctuations in the price of beef, will be provided with another source of income, creating a financial incentive for land to remain in ranching rather than be converted to more intensive agriculture and urban development—land uses that will further aggravate water flow, pollution, and habitat problems.

FRESP has made significant progress. Essential program design questions—such as how to establish a dedicated, multiyear funding source to pay for services; how to establish what prices will be paid for services; and how to integrate a new pay-for-services program with other state and federal programs—have been identified and are being discussed among the members of the collaboration team, with multiple stakeholders, and with state agency officials.

The public will benefit when services are provided at a lower cost than can be secured from public investment in regional water storage and water treatment facilities.

Answering these questions is an essential task for a coherent program design to emerge. Some of the answers will be informed by the actual construction and operation of water management projects by a group of volunteer ranchers. The water management projects include rehydrating drained wetlands, raising the height of the water table in the ranch soil profile and drainage network, and pumping water from a nearby canal through existing ranch wetlands and flowing back into the canal.

At these same sites the collaboration partners are field testing different methods of measuring the environmental services that are being provided by the projects. During the pilot, different documentation methods will be compared. The trade-off between the cost of documentation and the accuracy of measurements that is acceptable to buyers and sellers will be the basis for selecting a documentation approach.

The focus on project implementation and documentation methods recognizes that the first step in the design of a pay-for-services program is assuring that buyers (state agencies and others) and sellers (ranchers) agree on the definition of services ("commodities") that are going to be sold and how the provision of the services will be documented.

Documentation is needed for accountability. Buyers who will be spending public funds must know they are getting the service they are paying for—at any place or time. And they must know that if they make a payment, service will increase compared with what the service level would have been if no payment had been made.

Documentation benefits the ranchers. Ranchers will produce their own chosen amount of the service in whatever ways they choose, consistent with their own ranch operations and alternative ranch income opportunities. A rancher's choice of what and how much of a service to produce is facilitated when the commodity can be readily measured with a metric that is related to alternative ranch investment and operation decisions.

Documentation guides price discovery. Clearly defining the services and how they will be measured facilitates the negotiation of a price acceptable to buyers and sellers. Because the services demanded are site specific, definition and documentation methods need to reflect local environmental problems.

Any definition of "environmental services" must reflect the problems faced in a specific community. Such definition is the first step in to establishing documentation procedures that are acceptable to buyers and sellers and, to the extent that public funds are involved, the taxpayer. With these principles in mind, The Florida Ranchlands Environmental Services Project is currently working to define three services and establish acceptable documentation methods.

The **Water Retention** service is the potential to retain water in ranch soils, low-lying areas, and ditches during high rainfall years. The volume of water lost to evaporation does not reach the lake, and the retained water that does arrives slowly during the year. This service has value because it changes the volume, pattern, and timing of flows to Lake Okeechobee to better mimic the historic flow patterns, enhancing near-shore habitat for commercial and recreational fisheries and reducing peak discharges to the coastal estuaries protecting habitat in those areas. Remote instruments will transmit data on rainfall, water stages in retention facilities, and flow to a central location. A calculation comparing the flows in drainage ditches after the payment program will be compared to estimated flow before the program, to assure that water is being retained.

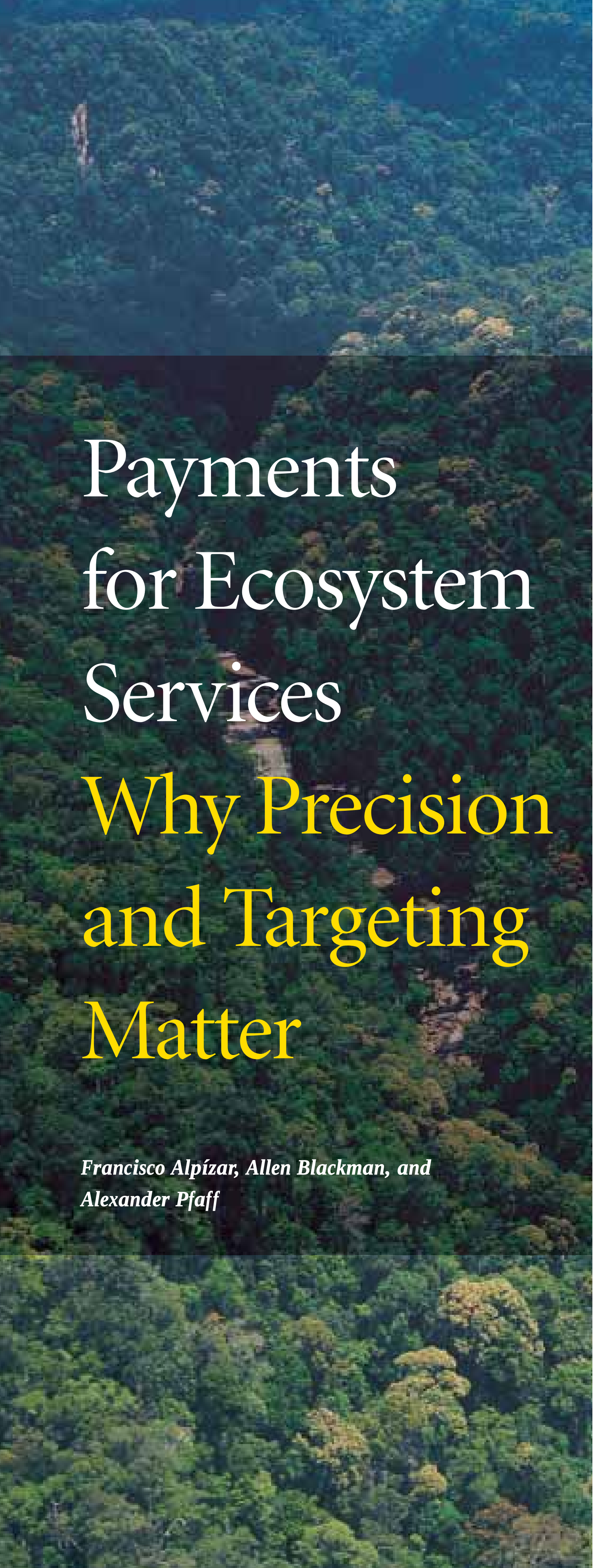
The **Phosphorus Load Reduction** service is provided when a ranch sequesters phosphorous applied in past years in the ranch's wetland and upland soil. It has value because it will increase dissolved oxygen in Lake Okeechobee and limit algal blooms. Remote instruments will send rainfall, measured flow data, and concentration data to a central location, where the amount of phosphorus leaving the site will be calculated. Explorations are under way during the pilot to establish the prepayment-program phosphorus load to allow for estimates of the load reduction before and after the program is initiated.

The **Wetlands Habitat Expansion** service is provided as the number of acres with a water fluctuation regime typical of historic wetlands north of the lake increases. The service's value comes from reversing the loss of wetlands to drainage, enriching the wetlands/uplands landscape mosaic on cattle ranches, and thus improving habitat for multiple species. Measurements made each year at sample locations will indicate the changes from upland to wetlands vegetation. They will be used to compute the change in wetlands area before and after the payment program.

Environmental Services from Florida Ranchlands

LOOKING AHEAD

Among the many program design topics that will be addressed during the five-year pilot, FRESP first has emphasized the need to define the environmental services and then produce credible, transparent, and low-cost means to document that the services are being provided. At the end of the pilot, Florida agencies will have an additional option for achieving Lake Okeechobee restoration goals. The pay-for-environmental-services program will contribute directly to lake restoration and become a profit opportunity for working ranches, helping to forestall conversion of ranchlands to more intensive and environmentally adverse land uses. ■



Payments for Ecosystem Services

Why Precision and Targeting Matter

Francisco Alpízar, Allen Blackman, and Alexander Pfaff

Forests and farms supply a wide array of valuable ecosystem services including sequestering carbon, harboring biodiversity, and preventing soil erosion. Yet forest and farm managers rarely, if ever, receive a financial reward for these services. As a result, from society's perspective, they may be too quick to clear trees and engage in other activities that disrupt ecosystem benefits. An increasingly popular approach to this problem is to pay land managers for the ecosystem services their parcels provide.

Payment-for-ecosystem-services (PES) programs have been established in a number of places around the globe, and they function at a variety of geographic scale: emerging markets for carbon sequestration credits constitute an international program; national forest conservation programs are operating in Australia, Costa Rica, and Mexico; and the World Bank, among others, has piloted watershed-level initiatives in several countries.

Why Precise Measuring Matters

Because payments are based on the quantity of services supplied, PES programs must measure the ecosystem services, a difficult task. Measurements depend on complicated ecological relationships that are often poorly understood. For example, the contribution of a hectare of forest to aquifer recharge depends on the flora, soil, hydrology, and weather in the forest. Given the challenges involved in measuring ecosystem services, most PES programs use relatively coarse estimates, or "proxies."

For example, the Costa Rican national initiative—probably the world's best-known PES program—uses a simple proxy: whether a parcel is forested or not. The proxy does not take into account variation in the levels of ecosystem services that forested plots provide due to the number and type of trees present, proximity to surface and to ground water, or slope.

Such blunt proxies can be inefficient. Land managers in Costa Rica receive the same payments for a hectare planted with commercial teak as for one planted with native species. However, by definition, a teak plantation harbors less biodiversity. In addition, it can actually contribute to soil erosion rather than preventing it because teak's large leaves tend to concentrate rain droplets into more disruptive streams. The Costa Rican program would get more "bang for the buck" if it used a proxy that distinguished between types of forests.

More precise proxies help when PES programs aim to preserve the supply of more than one ecosystem service. An example is a program that seeks to conserve both wildlife habitat and aquifer recharge. Unless hectares that provide relatively high levels of wildlife habitat also always provide relatively high levels of aquifer recharge, PES administrators can enhance program efficiency by identifying hectares that do both well and targeting them for payments.

As awareness of these issues grows in Costa Rica and elsewhere, program administrators are increasingly using more precise proxies, such as the number of trees per hectare.

Why Targeting Matters

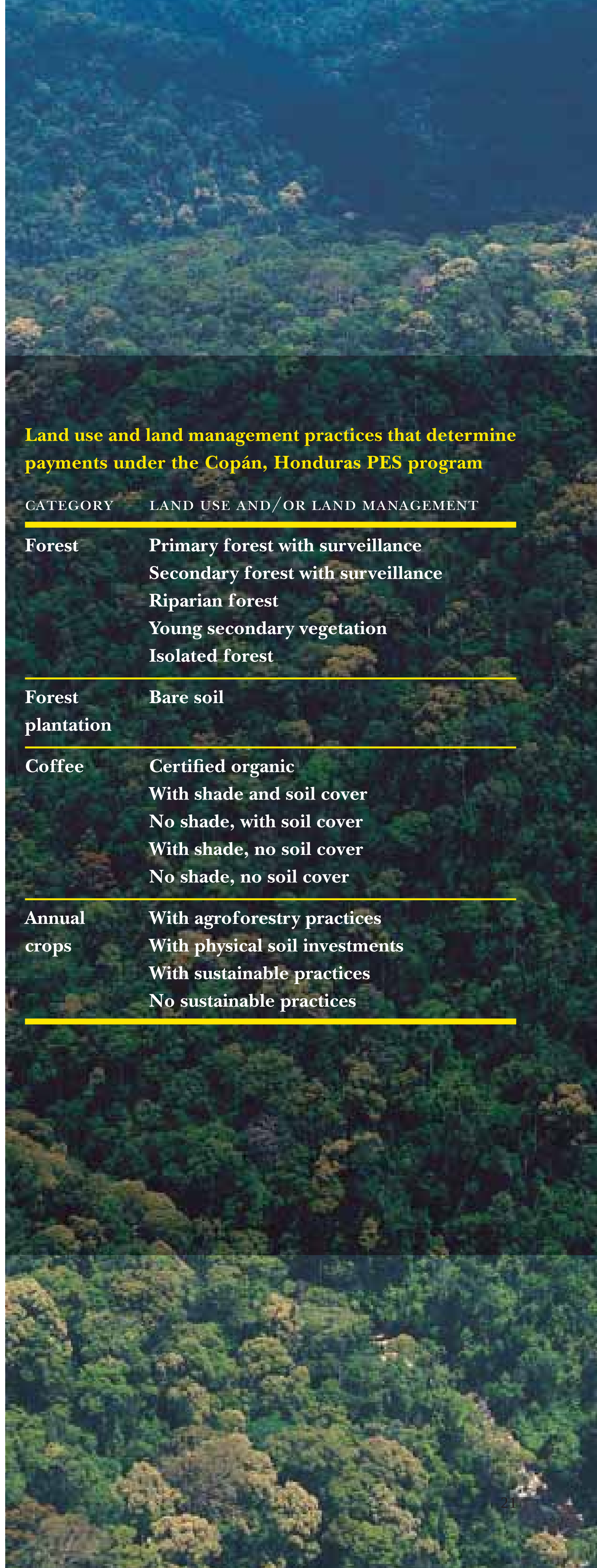
Even a perfect measure of the ecosystem services provided by each parcel enrolled in a PES program would be insufficient to measure the overall effectiveness of the program. The simple reason is that if a PES program does not lead to an *increase* in the provision of ecosystem services compared to what would have happened in the absence of the program—that is, the baseline or "counterfactual"—then it has not accomplished anything.

Imagine a PES program focused on forest conservation that makes payments to managers of ecologically rich forest land, who have no incentive to clear the land because it is ill-suited for logging, agriculture, or urbanization. Payments to these managers would have little impact on deforestation because the risk of clearing was minimal to begin with. In contrast, payments to managers who have incentives to clear their land would be much more likely to have an impact.

For PES programs to be effective and efficient, focusing on parcels with a higher likelihood of being cleared makes all the difference. The Costa Rican program again provides a useful example. The program is voluntary, that is, land managers must opt in. But many of the participants to date have been managers who stand to gain little by clearing the tree cover. In other words, the program is sometimes focusing on the "wrong" land.

Targeting and Precision in Copán, Honduras

A Honduran pilot project illustrates how targeting and the use of more precise proxies can be used to enhance effectiveness and efficiency of a PES system. Approximately 1,000 families in two watersheds in the municipality of Copán Ruinas, Honduras (or Copán), get their drinking water from three local rivers: El Malcote, El Escondido, and Don Cristóbal. The quality and quantity of this drinking water is lessened by human activities like illegal logging, fires, the application of agrochemicals, and unsustainable agricultural land uses more generally. A PES program is being developed to mitigate these impacts.

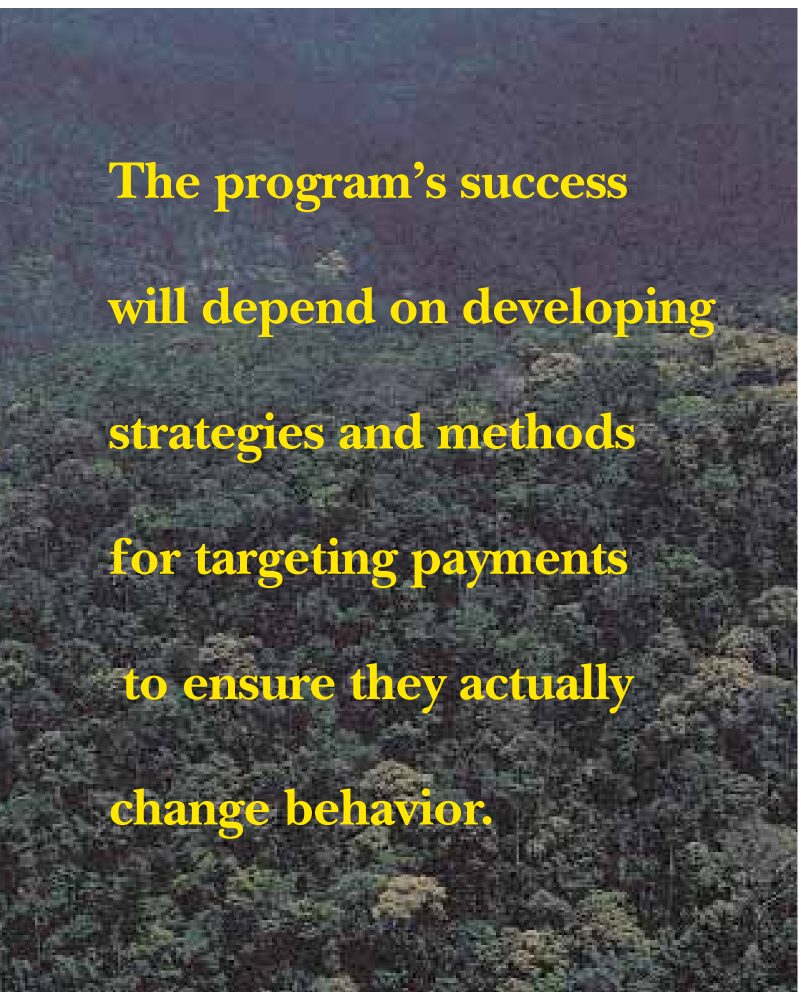


Land use and land management practices that determine payments under the Copán, Honduras PES program

CATEGORY	LAND USE AND/OR LAND MANAGEMENT
Forest	Primary forest with surveillance Secondary forest with surveillance Riparian forest Young secondary vegetation Isolated forest
Forest plantation	Bare soil
Coffee	Certified organic With shade and soil cover No shade, with soil cover With shade, no soil cover No shade, no soil cover
Annual crops	With agroforestry practices With physical soil investments With sustainable practices No sustainable practices

To ensure that the PES program would have a significant impact, program administrators used a two-step approach to target sites where the provision of ecosystem services is both high and under threat. First, they ranked water sources based on the number of households they service, current levels of water extraction, and the number of potential future households using the sources. Second, they ranked sites in the drainage areas of these water sources based on their potential for providing watershed services and their vulnerability to reductions of these services. In doing this, they took into account rock type, presence of soil failures or fractures, soil texture, slope, land use, organic cover, and pollution sources.

After targeting the program to high-benefit, high-risk sites, the next step was to precisely measure the hydrological services these sites provide. To this end, program administrators developed an index of 15 combinations of land uses and land management practices commonly observed in Copán (see the table on page 21). Primary forest with surveillance (that is, monitoring) received the highest ordinal "services rank" while annual crops with no sustainable practices received the lowest. The index was constructed by 30 international experts in the field during a two-day workshop organized for this purpose alone.



Finally, program administrators developed a method for basing payments on the level of ecosystem services provided by each site, which provides land managers with incentives to move from lower-ranked to more highly-ranked land uses and management techniques. For a land-use change such as from coffee to forest, payments are based upon the estimated opportunity cost (for example, forgone profit from coffee). For a shift among management practices within a land-use category, for example from shade coffee to organic coffee, payments cover the cost of obtaining an organic certification.

Scaling Up Targeting and Precision: The Issue of Cost

The Copán program nicely illustrates not only the potential gains from targeting and precision in measuring ecosystem services, but also the transaction costs of realizing those gains. Identifying priority parcels and the measuring services provided by these parcels took real effort, and generated real costs.

The Copán approach may work well for a single watershed. At larger scales, such as a country or the entire world, it may not be practical, however. For example, it is feasible to estimate carbon density in a forest parcel with a thorough local sample (although cost rises with accuracy even at that scale) but the cost of such an approach applied to large numbers of parcels may outweigh gains from precision.

Hence, policymakers face a trade-off. To achieve large-scale benefits, they should apply PES programs at large scales. Yet at such scales, the cost of targeting and precise proxies for ecosystem services provision becomes prohibitive.

As is so often the case, many hope that technological innovation can step into the breach. Of particular relevance for the forest-carbon case, remote-sensing technologies have steadily improved over the past several decades. Scientists hope to soon be able to accurately estimate forest carbon density relying solely on the information available from satellite images with rapid global coverage. However, reality is likely to intervene in the form of declining public investment in satellite measurements of the Earth.

A promising concept that has received considerable attention, PES has the potential to become a conventional environmental management tool. Whether it lives up to its early billing, however, will depend on the ability of its proponents to develop strategies and methods for targeting payments to ensure they actually change behavior, and for more precisely measuring ecosystem services to ensure that payments are as cost-effective as possible. ■

New Opportunities to "See" Our Environmental Relationships

William B. Gail, Molly Macauley, and Shalini P. Vajjhala

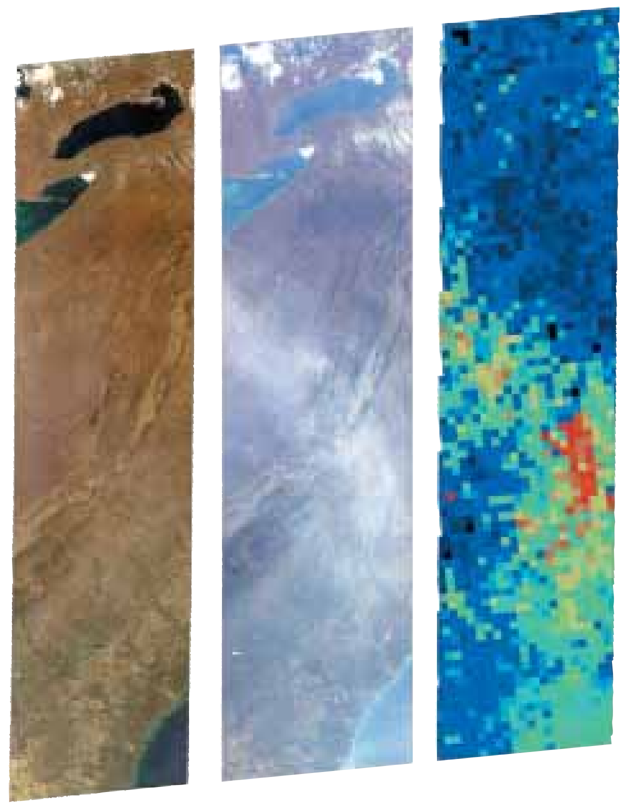


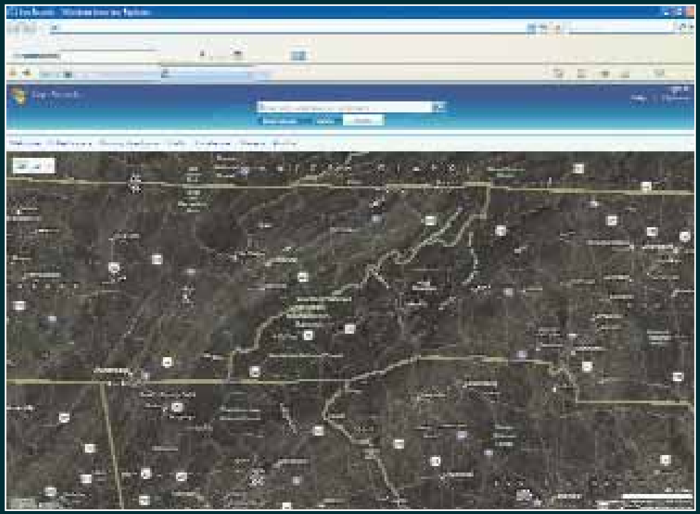
Figure 1. The Appalachian mountains and air pollution.

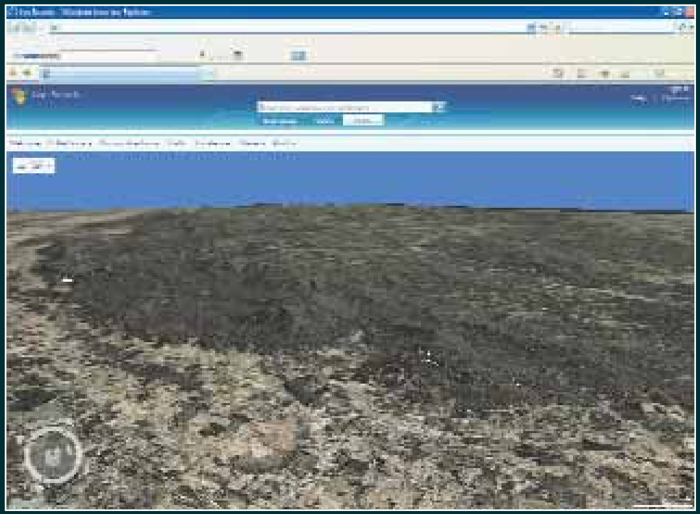
Understanding our relationship to our environment and natural resources markedly influences how—and how much—we value them. The tools and methods vary in a number of ways, but they all rely on how we "see" this relationship. In the case of places we'll never visit, our imagination may be informed by pictures, maps, and other visual information. How we envision and understand physical spatial relationships also can inform our views on natural resources affected by human activity taking place hundreds of miles away, as well as the future effects of resource use on the environment.

For thousands of years, maps and the sense of distance they connote have contributed a spatial dimension to places unknown. But today's technology enables us to "virtually" be anywhere, under nearly any condition or scenario. Tools such as Virtual Earth, Google Maps, and Geographic Information Systems (GIS) software have moved map making from the province of cartographers to anyone with access to a laptop or cell phone. These and other tools allow Earth science data (topography, geology, the atmosphere, and the hydrologic cycle) and social science information (population, income, and land-use data) to be combined with traditional maps. And merged with photos and three-dimensional, often near-time dynamic renderings, these maps allow us to virtually be in places we may never visit. We can walk around and explore or see the effects of proposed activities—say, pesticide applications that affect runoff transported to a watershed hundreds of miles away. And the visualization is informed, not hypothesized, because Earth and social science data are included in the representation.

The images in this article illustrate how visualization has evolved in recent years from simple maps and esoteric "remote-sensing data" to help us view, understand, and manage our environment.

Figure 1 is a set of images of the eastern United States during March 2000 taken by a satellite-borne instrument that, as its name(the Multiangle Imaging Spetroradiometer) suggests, uses different angles to observe features of Earth. The left panel shows the region from





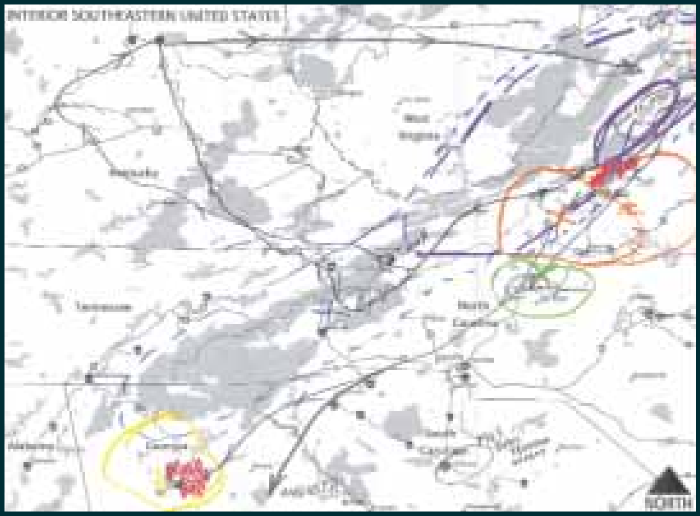


Figure 2. (left, top): An overlay of vector data on an image of the Appalachians from the Landsat satellite at a spatial resolution of 15 meters.

Figure 3. (left, center): GIS map of the region showing land uses and jurisdictional boundaries.

Figure 4. (left): A map showing how one resident defines key natural areas that he values in the region, indicated by the different colors.

Figure 5. (above, top) The Landsat imagery from Figure 2 layered on a 3D topographic model.

Figure 6. (above) An aerial photograph of the region.

Lake Ontario to northern Georgia, spanning the Appalachian mountains. The middle panel is an image taken at a slight angle to show the thin haze over the mountains and measure particulate pollution. The right panel shows, in gradations from blue to red, increasing amounts of airborne particles (aerosols). By showing how these particles interact with sunlight, the images enable better understanding of Earth's climate.

Figure 2 is an image of the Appalachians from the Landsat satellite at a spatial resolution of 15 meters, with vector data—lines and polygons—noting political boundaries, roads, and other features. The sources of vector data can be quite diverse: government records of property boundaries, companies with vehicles equipped with global-positioning technology to trace roads, corporate databases of store locations, and more.

Figure 3 is a GIS map of the region showing land uses and jurisdictional boundaries, including lands of the National Park Service and the U.S. Forest Service, as well as rivers and streams.

Figure 4 illustrates how one resident in this region perceive environmental degradation associated with acidification in the mountains. Using a process of cognitive or mental mapping, residents were asked to add information to a basic map. The figure shows map additions made by a study participant when asked first to identify places that she visited regularly while living in the region, then to add the center points and boundaries of five natural areas in the region that she thought were most important, and finally, to mark the locations and causes of improvement and deterioration in the region. Maps such as these provide a reference point for understanding how people define the areas they value, including the Great Smoky Mountain National Park and Shenandoah National Park (which, interestingly, nearly all respondents marked as larger than the National Park Service boundaries). Their perceptions were an integral part of an ongoing study of differences among residents of the extent of concerns about degraded resources in the states where they live, in neighboring states, on public lands, and more broadly across the region.

Looking toward the future, the transition from information to visualization leads naturally to new frameworks for communication. This future requires newly developing functionality of the web itself, particularly the ability for one website to query another and return not only data but software "snippets" that perform analytic functions. For example, a website with maps and other information about the Appalachians can allow us to query the status of a stream. That website will go to other websites to find imagery, news releases, even data on water quality and stream depth, and present them all in a single package—not just as a set of links to follow. Many people can now use the web as a collaboration platform, working together (often in different places and at different times) to produce a single result. To this end, we might consider the first phase of the Internet to be individual publication, the second to be community publication, and the third to be community collaboration. The proliferation of "mashups" (the layering of highly individualized information, such as "my favorite hiking trails," on basic maps or imagery) and the ease with which people everywhere access and update their contribution, is an example of this third phase—a phase that, as we look to the very near future, will provide further potential for the use of Earth science, visualization, and resource valuation.

Ultimately, we lead our lives in a three-dimensional world. Our ability to understand and visualize the world is best achieved with 3D rather than 2D representations. Figure 5 shows the Landsat imagery from Figure 2 layered on a 3D topographic model. The 3D perspective—readily available on the Internet—provides a much more intuitive sense of the role of topography in, say, the transition of land use from urban to rural to forests. As the fidelity of 3D Internet worlds approaches that of Figure 6, our ability to connect this information with our everyday understanding of the world will grow. For basic imagery this may seem trivial. But imagine being able to easily look at the higher level derivatives of basic imagery in this way—3D renderings of flood plains, temperature statistics, or wildlife habitats. And imagine the even greater power of viewing the world in "what if" scenarios—the same Smoky Mountains imagery modified as if the forests are replaced by a transportation corridor or altered by climate change. This ability to communicate remotely sensed information about the ecosystem, both in 2D form and in the "I am there" feeling of 3D, will enable us to both measure and understand ecosystem services much more effectively. ■

Ultimately, we lead our lives in a three-dimensional world. Our ability to understand and visualize the world is best achieved with 3D rather than 2D representations.

The Endpoint Problem

James W. Boyd

Environmental scientists, economists, and managers need to focus. As a broad generalization, environmental professionals—conservationists, biologists, managers, ecologists, and environmental economists—are drawn to nature's complexity and interconnectedness, its sheer comprehensiveness. A butterfly flaps its wings in South America, and a storm forms in the North Atlantic.

Unfortunately, nature's complexity creates a barrier to cooperation, collaboration, and communication. The scientific community's descriptions of nature suggest the parable of the elephant and the five blind men: none can agree on what they have found—a tusk, a trunk, a tail—and argument ensues. In environmental science, each sub-discipline touches a different part of the elephant.

The Public Policy Issue

Why is the lack of coordination a social problem? If what we care about in public policy is the relationship of nature to human well-being—and that is what we should care about—biophysical scientists and social scientists must work, produce results, and communicate in concert. Forty years into the environmental movement, concerted action between ecology and economics is still the exception, rather than the rule. Unlinked descriptions and the perception of conflict they produce confuse the public and our decisionmakers. The cost of confusion is that environmental science still lacks the ability to comprehensively benchmark and communicate the state of nature.

Government has proven to be an ineffective agent when it comes to measuring its own environmental performance. The private sector has no particular reason to take on the role of environmental watchdog and truth teller either. And the challenge is too big for any single environmental group or think tank. So who should society look to if it wants to know what is actually happening to the environment? When it comes to nature, society depends on scientists to "mind the store." That may not be the job we all signed up for, but it is a particularly worthy mission.

While not a panacea, the scientific community is our best hope. But what about the blind men and the elephant?

The Challenge

Consider the following practical, common issue in public policy: should we preserve a piece of land in its natural state? The piece of land could be the Arctic National Wildlife Refuge, a wetland on the side of a highway, or a part of the Everglades. What are the benefits of preservation? Even the simplest analysis of the question requires conservation science. Conservation science tells us *what* will be preserved and *where*. How will the preservation affect habitats, species populations, water and air quality, land cover, water availability, and other biophysical outcomes now and in the future?

Note that conservation science itself is not one discipline, but many. Ecology, biology, hydrology, and atmospheric science are all part of conservation science. Achieving coordination in this realm alone will be a significant challenge.

But the policy problem requires social science as well. Social science really matters in two areas. First, social factors interact with preservation and affect biophysical outcomes. Demography is an obvious consideration. Are communities encroaching on the preservation in a way that has implications for biophysical outcomes? Is the landscape actively managed? If so, what are the results of that management? What if a commercial fishery is harvesting fish at the same time we are protecting fish habitat? The social and economic sides of this—the commercial harvests—are as important to predictions of fish population as the purely biophysical analysis of conservation is.

Note the various disciplines that must be involved: not only conservation science, but conservation management and the field of bioeconomics, which describes linked biophysical and social systems. And we still haven't fully described the public policy solution.

The second significant role for social science is to take the biophysical outcomes of preservation (the species, land cover, air quality, and water availability) and ask: how important are these factors to society? Most environmental economists focus on this issue. Whenever you hear terms like nonmarket valuation, contingent valuation, revealed preference, hedonic pricing, or travel cost studies you are hearing economists talking about the ways in which they propose to weight outcomes in nature.

Natural science cut off from social science cannot effectively influence public policy because it cannot make the direct connection to human well-being. Social science cut off from natural science cannot describe outcomes in nature, so it can't influence public policy either. Together we stand; divided we fail.

Need for a Common Language

When natural and social scientists are not coordinated, the situation manifests itself in something we can call the "endpoint problem." If linked social and natural science is a relay race, endpoints are the baton. The problem is that the baton never gets handed off smoothly.

Economists are often content to apply their methods to simplistic caricatures of nature. An example is the way in which economic "dollar valuations" of environmental goods focus on what can be easily measured, rather than on what may be most important to society. Or the way economic studies typically ignore the natural and social landscape when they estimate benefits. Look at an average refereed economic valuation of something in nature and what you'll see is a very narrow view of nature.

If linked social and natural science is a relay race, endpoints are the baton. The problem is that the baton never gets handed off smoothly.

Conservation science hasn't done much better. A historic rejection of the relevance of choices, trade-offs, and human-centered measures of success has led the discipline to focus on biophysical outcomes that are themselves narrow and unfortunately disconnected from the cares of nonscientists. For example, the obsession with biodiversity as the sine qua non of scientific conservation studies has led to measures of success and failure that often do not resonate with nonscientists.

Ecological endpoints are concrete statements, intuitively expressed and commonly understood, about what matters in nature.

Technical expressions or descriptions meaningful only to experts are not ecological endpoints.

The relative success of EPA efforts to translate air quality problems into human health-related social effects is due in large part to the presence of *health endpoints*. These endpoints, while still debated, are a lingua franca understood by disciplines as different as pulmonary medicine and urban economics. This common language had to be developed—and is still being developed. In the old days, health impacts were described in highly technical, medical terms, such as oxygen transfer rates in the lung. Today, epidemiologists count things like asthma attacks, reduced activity days, and reductions in life expectancy. Tell the public about oxygen transfer in the lung, and they won't know what you're talking about. Tell them about asthma attacks, and they will know exactly what you are talking about.

"Common man" descriptions of outcomes are usually a prerequisite to social science. The social sciences tend to rely on the assumption that people are reasonably well informed when they make choices. How can people be well informed if outcomes aren't described in terms that are meaningful to average people?

It is important to emphasize that economists aren't authorized to define endpoints and then turn around and demand that natural science cough up the answers. Rather, the natural and social sciences—with the imprimatur of both science and government—should collectively debate and define these endpoints.

Consistent Points of Contact

So how do we solve the endpoint problem? This is a central subject of current RFF research. In a set of linked research projects, we have been defining and illustrating measurable, countable endpoints that can act as consistent "points of contact" between ecological and social science.

Ecological endpoints have several broad characteristics.

- They are purely biophysical.
- They are concrete, tangible, and measurable.
- They are directly connected to human well-being.

While these features sound simple, their application is less so.

For example, what is meant by "purely biophysical?" If you catch a fish, isn't the fish purely biophysical? No, a fish in the hand is different from a fish in the lake. A fish in the hand is the result of several things, not all of them biophysical: in particular, the rod and reel, the skill, and the time provided by the angler. A fish in the hand is a combination of biophysical and social factors. The ecological endpoint—the thing that is purely biophysical here—is the fish population in the particular lake.

Another important clarification is that "purely biophysical" does not mean "untouched by human hands." Most things in nature are touched in some way by human action. In this case, the fish population may be reduced by harvests or improved by stocking. Human influence does not rule something out as an ecological endpoint.

Other possible sources of confusion are associated with the second characteristic: endpoints' concreteness. Economists split environmental benefits into two broad classes: direct and indirect. Indirect benefits are things like the value of species' existence. I may never come within a thousand miles of a wildebeest, but I still care that it exists. If I'll never see a wildebeest, how is that concrete? Here, the benefit is intangible, but the physical requirement necessary for the benefit is absolutely tangible: it's the existence of wildebeests as a species. That is concrete and can be counted.

Ecology often depicts nature as a collection of interrelated processes and functions; examples include sequestration, predation, and nutrient cycling. Processes and functions are not endpoints. However, understanding ecology as process and function is what allows us to test and depict causality in nature. If a butterfly flaps its wings, what *does* happen, exactly? Ecological process and function are necessary if we are ever to predict changes in nature, particularly changes in endpoints. Endpoints are just that: the tangible, concrete, end results of processes and functions.

Finally, consider the qualification that endpoints must have direct relevance to human well-being. This raises some sticky issues. If human life itself depends on nature and if nature is an integrated whole, aren't all things in nature directly relevant to our welfare? From a philosophical and ethical perspective, the answer is yes. From a measurement perspective, however, the answer is no. Consider all the things we can count in nature: the number of things and qualities is almost infinite. Focusing on those that are directly relevant to human well-being is, first, a way to make the problem manageable. Second, direct features can be thought of as nature's end products. Their value will embody all of the indirect products necessary to them.

A set of RFF research papers, listed at www.rff.org/endpointproblem, develops these ideas in much greater detail.

Endpoints are a lingua franca understood by disciplines as different as pulmonary medicine and urban economics.

Reasons for Optimism

Among practitioners of environmental assessment, recognition that we have an endpoint problem is growing. This is due partly to the decades-long failure to integrate ecology and economics in a way that effectively contributes to solving the broad public policy problems facing us.

Ecology and economics are growing toward each other. Ecologists increasingly see nature's broad contributions to economic well-being as a subject for ecological study. Conservationists, too, increasingly see economic arguments as useful to their mission. Likewise, economists have become much more sensitive to and skilled at the analysis of nature's goods and services, including those that resist traditional economic analysis.

The pursuit of common ecological endpoints will further foster this integration of approaches. In fact, common endpoints are the only way to debate and convey a shared mindset. They will lead to coordination, scientific advance, greater legitimacy in the halls of public debate, and clearer public communication about what in nature is being gained and lost. ■

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