ENVIRONMENTAL POLICY IN THE ANTHROPOCENE

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INTRODUCTION

Yosemite Valley is best known for its scenic grandeur. But when Maria Lebrado returned 78 years after her Ahwahneechee tribe was driven out of the region, she was unimpressed. A guide later described Lebrado's reaction to seeing the valley for the first time since her childhood: "The wide open meadow of her day was covered with trees and shrubs. She shook her head, saying, 'Too dirty; too much bushy.'"[1]

Throughout Yosemite, the landscape today is much different than the one seen by early white visitors. "The inviting openness of the Sierra woods is one of their most distinguishing characteristics," wrote John Muir in 1894.[2] Frederick Law Olmsted's 1865 report on Yosemite described "miles of scenery" and "the most tranquil meadows," creating what he called "the greatest glory of nature."[3] Since then, 75 to 90 percent of those meadows have been lost to larger and denser forests, and many of the valley's scenic vistas have been engulfed by trees.[4] What's emerged is a new landscape that is in many ways different than the one seen by its earliest visitors.

The Yosemite scenery that early preservationists sought to protect was in fact dramatically influences by humans. "Much of the landscape in California that so impressed early writers, photographers, and landscape painters was in fact a cultural landscape, not the wilderness they imagined," writes ecologist M. Kat Anderson.[5] "While they extolled the 'natural' qualities of the California landscape, they were really

responding to its human influence." Prior to the creation of Yosemite as a park, Native Americans regularly set fire to the region to clear forests, maintain open meadows, and grow food.[6] In an important sense, the tranquil meadows seen by Muir and Olmsted were as much the product of human action as they were the glory of nature.

What is the true character of Yosemite undisturbed by human action? Is it dense forests or open meadows? We cannot readily say. In many ways the only Yosemite we've ever known is one created by the actions—or deliberate inactions—of people. An even tougher question is the policy one: If the Yosemite protected by early preservationists was the product of human influence, then to what state should it be managed today? The National Park Service has recently provided one answer: In 2011, the agency established a controversial plan to cut thousands of trees in Yosemite in an effort to restore scenic vistas that have been obscured by the encroaching forest.[7]

This example underscores a fact that is shaking the core of the environmental and conservation community: Virtually all the world's landscapes have been shaped, and are continuing to be shaped, by human action.[8] Scientists have proposed—and are considering formally adopting as Earth's new epoch—a word for this new period: the Anthropocene.[9] The notion of the Anthropocene (the "age of man") raises tough new questions for conservationists to consider. And while much of the public debate to date has focused on when the Anthropocene started, there is yet another question to confront: What does it mean for environmental policy?

In December 2015, the Property and Environment Research Center (PERC) hosted a two-day workshop to address the policy implications of the Anthropocene era. Thanks to the Searle Freedom Trust, who provided financial support for the workshop, this special volume explores many of the ideas discussed during the workshop. The chapters challenge the conventional thinking about a variety of environmental policy topics—from the role of science and the proper scale of environmental policymaking to urban land use planning and ecosystem services—and offer an ambitious vision for the future of environmental policy in the Anthropocene.

—Shawn Regan, *editor*

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ENVIRONMENTALISM WITHOUT ROMANCE

SHAWN REGAN

In 1986, James Buchanan won the Nobel Prize in economics for changing the way we think about politics. Buchanan's key insight was that economists should use the same tools and methods to analyze political behavior as they do to understand economic behavior. In other words, he viewed political actors as fundamentally the same as individuals engaging in market activity. Along with his colleague Gordon Tullock, Buchanan pioneered a new subfield of economic analysis known as public choice theory, which, in Buchanan's words, could be summed up simply in just three words: "politics without romance."[1]

Public choice theory, Buchanan argued, "models the realities rather than the romance of political institutions." Individuals are guided by the same motivations in the political process as they are in market settings, and there is no reason to think otherwise. Politicians, bureaucrats, and voters, like people engaging in everyday market exchange, are motivated more by self-interest than by the public interest.

This was a simple insight, but it had important implications for economic and political analysis. There had long been a certain degree of romance in politics, even among scholars. As late as the 1960s, most economists tended to implicitly model political actors as selfless public servants seeking to promote the public good. Politicians promoted the public interest, rather than their own interests. Bureaucrats

sought to advance their agencies' missions, not their own budgets or authority. And voters sought to improve the public good, not to extract political favors for their own personal gain. All the while, the basic rational choice model used to study individuals engaging in markets was widely accepted, but it was strangely missing from most analyses of political or regulatory action.

By the time Buchanan was awarded the Nobel Prize, this idealized view of politics, either implicit or explicit in most traditional economic models, was no longer seen as a valid approach to economic analysis. "The romance is gone," Buchanan said in 1979, "perhaps never to be regained." Today, public choice theory remains an active research program within economics, emphasizing the realities rather than the romance of politics.

Of course, politics is not the only area where we are subject to romantic tendencies. Environmental issues arguably elicit even greater romantic sentiments, particularly as they relate to views about the natural world and our place within it. Notions of a harmony with nature, Edenic visions of pristine nature, and metaphors of "Mother Nature" are prominent in modern discussions of environmental issues. Related ideas of equilibrium or the balance of nature undisturbed by humans have also dominated the science of ecology for much of its history. And many environmental policies are based on the idea of restoring ecosystems to a historic baseline or preserving a perceived balance to nature.

But the romance of environmentalism is slowly fading. Today, there is growing skepticism about these idealized undertones to environmentalism, and in turn, to environmental policy. A new generation of ecologists is challenging the idea of an inherent balance in nature based on the lack of empirical support. Moreover, scientists are concluding that human action cannot readily be separated from the natural world. Research in paleoecology and other fields is revealing that landscapes once thought to be uninfluenced by humans were in fact dramatically affected by indigenous peoples. A new generation of conservationists is rejecting the idea of pristine nature as a worthy or practical conservation goal and adopting a more nuanced vision of the environment that includes human action. Scientists have even proposed the concept of the Anthropocene—the "age of man"—as a new geologic epoch to reflect the magnitude of human influences on the natural world.[2]

These realities imply a very different lens for viewing environmental problems, one that focuses on the realities rather than the romance of the environment. Once we accept that nature is dynamic and profoundly shaped by and connected to human action, we are compelled to see environmental problems in a new light. In this view, environmental problems cannot be thought of as simply the consequence of human

violations on the balance of nature. Ecologists are rejecting the notion of a natural harmony in ecosystems. Nor can environmental problems be solved by simply separating the natural environment from human influences. The notion of the Anthropocene suggests that doing so is impractical or even impossible. Instead, in the age of the Anthropocene, environmental problems become questions of how to resolve competing human demands on an ever-changing natural world.

Most environmental issues are not resolved by science alone. Science does not tell us which ecological states are "right" or which environmental policies are best. And as we are discovering more and more, many ecological concepts are themselves normative; they offer little guidance for resolving conflicts over competing human values and preferences. Thus, most environmental problems are fundamentally questions of human values—of what landscapes we prefer, what elements of the natural world we want to preserve, and what aspects of nature we want, or do not want, around.

This essay makes the case for "environmentalism without romance." It describes why traditional environmental goals of nature in balance or nature undisturbed by human action are mistaken or unrealistic in the age of the Anthropocene. It then attempts to reorient the discussion of environmental issues as one of comparative institutional analysis.

THE BALANCE OF NATURE

The romance of nature has deep historical roots. In particular, the idea of an equilibrium or balance of nature undisturbed by human action has long permeated environmental thought. George Perkins Marsh, one of America's first environmentalists, expressed the prevailing ecological view of the 19th century: "Nature, left undisturbed, so fashions her territory as to give it almost unchanging permanence of form, outline, and proportion, except when shattered by geological convulsions."[3] Even in such rare events as geological convulsions, nature "sets herself at once to repair the superficial damage, and to restore, as nearly as practicable, the former aspect of her dominion." Any changes that do occur are so slow that for all practical purposes nature "may be regarded as constant and immutable." Were it not for man's influence, Marsh writes, nature "would have been constant in type, distribution, and proportion, and the physical geography of the earth would have remained undisturbed for indefinite periods."

The emergence of the science of ecology in the early 20th century rejected this expression of a pure, stable nature undisturbed by humans. Clearly, nature did not always remain the same. It often changed even without human influence. Beavers, for example, altered their landscapes. Temperatures fluctuated, and droughts affected

entire regions. Fires and floods at times dramatically changed the composition of species that could survive in certain areas. The vision of a completely static and balanced nature undisturbed by humans espoused by Marsh was certainly false.

In place of Marsh's vision of unchanging nature, the nascent field of ecology adopted the idea of ecological succession. Led by Danish plant geographer Eugenius Warming, scientists in the early 20th century began to consider how plant communities transitioned from one community to the next, ultimately arriving at a "climax" state. In this view, nature was not necessarily unchanging. It could be affected by drought, fires, and other natural forces, but it would progress through various stages of succession until it reached its final climax formation.[4]

Although Warming's idea of ecological succession implied at least some degree of change, it was ultimately consistent with the notion of the balance of nature. The climax equilibrium was the ultimate equilibrium, perfectly balanced and self-perpetuating unless disturbed.

As the science of ecology progressed, various ecologists expanded upon Warming's ideas of ecological succession. Most notable was Frederic Clements of the University of Nebraska, whose influence on the field of ecology in the early twentieth century is difficult to overstate. According to Oxford ecologist A.G. Tansley, Clements was "by far the greatest individual creator of the modern science of vegetation."[5] Like Warming, Clements thought that ecosystems developed through a predictable succession of stages until they reached a climax state that persists indefinitely unless disturbed. Every given climate had a climax stage or equilibrium. This process of succession could be plotted by scientists for each climatic region, and once the climax stage was attained, it would remain in balance, barring any external disturbance or major climatic shift.

The other influential facet of Clements work was his organismic view of plant formation. He considered the evolution of climax plant formations as a kind of "complex organism" of its own. This "superorganism," he wrote, was "of a higher order than an individual geranium, robin or chimpanzee."[6] To Clements, a plant community was best understood as a collective organism rather than a group of individual species. Entire communities evolved together through stages of succession into a mature adult form determined by conditions of a given climate.

The idea of Clementsian succession had a far-reaching impact on conservation and environmental values in the 20th century. The idea of an equilibrium climax forest left little room for humans other than as a disrupter of nature's final balance.[7] It implied that human action upset a predetermined balance that nature tended toward and a final state that would persist otherwise. "The notion of a superior climax state

gave a scientific validation to the conservationist's case against the machine and the farmer," writes environmental historian Donald Worster. The climax state served as "the yardstick by which man's intrusions into nature could be measured."

Clements' ideas of a climax state and "superorganisms" were quickly challenged by Henry Gleason of the University of Michigan. In 1926, Gleason argued in favor of a more individualistic view of nature.[8] Worster explains that in Gleason's view, plant formations "are mere accidental groupings, each the result of unique circumstances and too loosely related to be likened to an organized being." Each species responds individually to its environmental conditions, and the composition of species on a landscape changes continuously across time and space. Clements' characterization of plant communities as collective superorganisms was thus a useless abstraction that had little to do with the actual workings of ecosystems described in Gleason's "individualistic" conception of nature.

Despite Gleason's individualistic view, a different perspective held sway in the development of modern ecology: Eugene Odum's systems ecology. Considered a pioneer of modern ecosystem ecology, Odum used different language than Clements but "did not depart from Clements' notion that the law of organic nature was to bring order and harmony out of the chaotic materials of existence," writes Worster.[9] Succession, Odum wrote in 1969, is "an orderly process of community development that is reasonably directional and, therefore, predictable" and "culminates in a stabilized ecosystem."[10] In the 1960s and 1970s, systems ecology focused on the energy and nutrient flows through ecosystems, borrowing terms such as "producers" and "consumers" from economics to model inputs and outputs. The systems approach assumed a balancing out between various producers and consumers within ecosystems, adopting a similar equilibrium framework that was simultaneously emerging in economics. Still, Odum's science of ecology largely ignored human actions as relevant considerations other than as disrupters of nature's balance.

In the latter part of the 20th century, however, an internal critique of modern ecology began to emerge. Ecological research increasingly found that the equilibrium models theorized by early 20th-century ecologists did not adequately explain the dynamic interactions that occur within ecosystems. Over the last several decades, some ecologists began to explicitly challenge the notion of a balance of nature that underlies most traditional ecological theories. "Another generation of ecologists," Worster explains, "began to question all the older ideas, theories, and metaphors, even to assert that nature is inherently unsettled."

One question in particular was whether the outcome of ecological succession was a stable equilibrium. A study by William Drury and Ian Nisbet, published in 1973,

revived Gleason's individualistic conception of nature. The authors studied New England's temperate forests and concluded that the process of ecological succession did not lead anywhere in particular and never reached a point of equilibrium. Instead, they observed a "shifting mosaic." Increasingly, ecologists started to reject the assumptions of steady-state equilibriums and began to focus on "disturbances," both natural and man-made, as part of an ever-changing mosaic of environmental conditions.

Ecologist Daniel Botkin makes the most forceful critique of equilibrium ecology. In his influential book, *Discordant Harmonies: A New Ecology for the 21st Century*, Botkin documents how the conventional view of a balance of nature apart from human action is unsupported by evidence. He argues that "nature undisturbed is not constant in form, structure, or proportion, but changes at every scale of time and space."[11] According to Botkin, "the true idea of a harmony of nature… is by its very essence discordant, created from the simultaneous movements of many tones, the combination of many processes flowing at the same time along various scales, leading not to a simple melody but to a symphony at some times harsh and at some times pleasing."[12] This sharply contrasts the Clementsian faith in a predictable endpoint of succession, or what Botkin characterizes as the belief "that nature's melody leads to one final chord that sounds forever."[13]

Consider the wilderness of the Boundary Waters region, for example, located on the Canadian border with Minnesota. Using pollen records deposited in nearby lakes, scientists discovered that since the end of the last ice age, the forest passed from tundra, to spruce, to pine, to birch and alder, and then back to spruce and pine, changing composition every few thousand years. These changes occurred even though the area was largely spared from the impact of humans for much of that time. Likewise, the traditional logistic growth curves and predator-prey models have never been observed to fluctuate as classical equilibrium models would predict. The only instance in which such stability has been observed is in a laboratory using single-celled microbes under controlled conditions.

Botkin argues that nature undisturbed by man is not a "Kodachrome still-life," but rather "a moving picture show," continually changing "at every scale of time and space." Even in relatively wild places such as Yosemite and Yellowstone, ecosystems are constantly in flux. Tree-ring studies suggest that Yellowstone's forest ecosystem lacks a single steady state.[14] Wildlife populations, as well, have historically lacked stability.[15] Whether these dynamic forces are simply the result of ever-changing ecosystem processes or are driven primarily by human influence is often not clear. As scientists are discovering, the natural world cannot easily be separated from human action. The dynamic processes we see in nature are closely linked to ever-changing

human actions, which make up another important piece of the shifting mosaic of human-nature interactions.

THE ANTHROPOCENE

In addition to recognizing that there is no balance of nature, ecologists are increasingly learning that humans have dramatically shaped ecosystems that we once considered pristine or relatively untouched. Indeed, virtually all of the world's landscapes have been shaped in some way by human action. Recent evidence suggests that the American wilderness that Columbus, Lewis and Clark, and other early explorers witnessed had already been dramatically shaped by humans—both by native societies and, later, by the spread of European diseases.[16] In the American West, as Charles Mann explains, it is likely that "a substantial portion of the giant grassland celebrated by cowboys was established and maintained by the people who arrived there first." Ethnologist Dale Lott puts it this way: "When Lewis and Clark headed west from [St. Louis], they were exploring not a wilderness but a vast pasture managed by and for Native Americans."[17]

While there is little debate that humans exert a large influence on the environment, there is debate as to how far back the Anthropocene extends.[18] Today, some archaeologists believe that humans may be responsible for the extinction of large mammals across several continents during the late Pleistocene more than 10,000 years ago.[19] Anthropogenic forces may also have affected the global climate for thousands of years. Carbon dioxide emissions increased significantly around 8,000 years ago as humans began clearing and burning large swaths of forests for agriculture, and methane emissions increased 5,000 years ago as humans began rice farming. William Ruddiman, a paleoclimatologist from the University of Virginia, estimates that these early anthropogenic effects may have been large enough to prevent another ice age from occurring and, in effect, ensured the continued survival of humanity.[20]

Emma Marris succinctly describes the reach of human influence on ecosystems in her influential 2011 book, *Rambunctious Garden*: "Every ecosystem, from the deepest heart of the largest national park to the weeds growing behind the local big-box store, has been touched by humans."[21] Marris argues that conservationists should reject the idea of pristine wilderness and adopt a "more nuanced notion of a global, half-wild rambunctious garden, tended by us."[22] Likewise, in 2012, a group of scientists led by Peter Kareiva, chief scientist for the Nature Conservancy, criticized conservationists for viewing nature apart from people. The scientists urged conservationists to embrace "a new vision of a planet in which nature—forests, wetlands, diverse species, and other ancient ecosystems—exists amid a wide variety of modern, human landscapes."[23]

The Anthropocene idea is challenging entire sub-disciplines in ecology. In a 2012 essay, Kareiva and Michelle Marvier revisit Michael Soulé's foundational 1985 article on conservation biology.[24] Referring to the emerging Anthropocene idea, the authors claim that "we live in a world dominated by humans, and therefore, the scientific underpinnings of conservation must include a consideration of the role of humans." They challenge the very foundation of conservation biology as "concerned solely with the welfare of nonhuman nature" and instead propose a new framework of conservation science as "a discipline that requires the application of both natural and social sciences to the dynamics of coupled human-natural systems."

"In the traditional view of conservation," Kareiva and Marvier write, "people play one of two roles: The vast majority of people are a threat to biodiversity, and a relatively small number—mostly Western biologists—act as biodiversity's protectors and, one hopes, saviors." This is problematic because "conservation is fundamentally an expression of human values." People's actions and values shape and reshape the natural world. Kareiva and Marvier's conception of conservation science seeks "a more integrative approach in which the centrality of humans is recognized in the conservation agenda."

The recognition that "ecological dynamics cannot be separated from human dynamics," as Kareiva and Marvier claim, harkens back to a critique of climax communities made by British ecologist A.G. Tansley. In the 1930s, Tansley put forth the idea of an "anthropogenic" climax: "We cannot confine ourselves to the so-called 'natural' entities and ignore the processes and expressions of vegetation now so abundantly provided to us by the activities of man."[25] Today, the idea of "novel ecosystems" is gaining wider acceptance in ecology. Such ecosystems are the product of human influence. They often result in new combinations of species—both native and nonnative—that form anything but pristine, climax-stage ecosystems.

Novel ecosystems now dominate much of the world's surface, and although earlier generations of ecologists largely ignored them, they are now a focus of much research.[26] Erle Ellis, an ecologist at the University of Maryland in Baltimore, has put forth the idea of "anthromes" or "human biomes" to better understand these anthropogenic landscapes at local and global scales. In contrast to the conventional view among ecologists—a world comprised of natural biomes with occasional human disturbances—anthromes "tell a completely different story, one of 'human systems, with natural ecosystems embedded within them.'"[27]

VALUES, POLICY, AND THE ROLE OF SCIENCE

Although ecologists are discovering that the natural world is characterized by perpetual change and dramatic human influence, environmental policies remain based on assumptions of equilibrium and pristine nature. Historic baselines form the foundation for most of today's environmental statutes and regulations, which are often based on the goal of restoring the environment to an earlier set of desired conditions.[28] The Endangered Species Act, National Environmental Policy Act, and the Wilderness Act, as well as many of the statutes governing federal land management agencies such as the U.S. Forest Service, National Park Service, and Bureau of Land Management, are broadly based on the idea that an arbitrary baseline condition is the proper state to which the environment should be restored.

Equilibrium views are entrenched in the way ecologists think about environmental policy. As Daniel Botkin writes: "If you ask an ecologist if nature never changes, he will almost always say no. But if you ask that same ecologist to design a policy, it is almost always a balance of nature policy." Botkin goes on to say: "Whatever the scientist's knowledge of the dynamic, changing properties of nature, the formal representations of these remove such considerations in most cases… whether or not environmental scientists know about geological time and evolutionary biology, their policies ignore them. It is strange, ironic and contradictory."

If there is no true balance of nature to which we must restore environmental conditions, and if there is no pristine nature untouched by human action, then on what basis should we determine environmental policies? Surely there is a role for science. But to what degree can science determine which course of action is best? And what is the role of human values and preferences in charting the course? These questions are still hotly debated, but there is also a growing recognition that science alone is a lousy guide to environmental policymaking.

Even among scientists, there seems to be an increasing acknowledgment that many key ecological concepts have normative foundations. Take the notion of ecosystem health. As ecologist Robert Lackey describes, there is no universal definition of ecosystem health, yet many environmental policy issues are based on the idea of restoring or improving the health of ecosystems.[29] Ecosystem health, Lackey says, is a "value-based ecological concept" based on subjective assumptions that "masquerade as science." The assumption often embedded within the ecosystem health concept is that undisturbed ecosystems are healthiest. But as Lackey explains, this assumption is normative. Ecosystems have no preferences; people do.

For Lackey, even "naturalness" or historic baselines are value-based: "There is no scientific basis for a specific ecological state to be considered better (more healthy) and thus the benchmark." The process of setting a baseline involves making value judgments about which baseline is best. "Ecosystem health is normative because someone must decide what ecosystem condition or function is good," writes Lackey. "Ecosystems display no preferences about their states; thus benchmarks must come from the individuals doing the evaluation."

Entire ecological sub-disciplines "have strong normative and political green flavor," writes Lackey. They often "embrace normative science postulates as the core of their trade, maintaining that biological diversity is inherently good, extinction of populations and species is inherently bad, ecological complexity is inherently good, evolution is good, and biological diversity has intrinsic value." But in reality, Lackey writes, "most scientific information is of a fine scale and narrowly focused and thus only indirectly relevant to many ecological policy questions." Thus, it is political institutions that must "balance competing values and preferences, a process in which the role of scientific information is limited." On the subject of resolving conflicts over human value and preferences, "science offers no moral or ethical guidance."

What's more, some scientists are questioning whether universal ecological laws exist. In a 2004 *BioScience* article, a group of eleven ecologists noted that "there are few well-documented general ecological principles that can be applied to pressing environmental issues," urging ecologists "to reconsider some of the ways that we view our science."[30] In a recent article, Mark Sagoff questions whether there are general causal forces in ecology.[31] Examining the case of predator-prey interactions, Sagoff demonstrates how external factors vastly overwhelm internal ecosystem dynamics, making general causal forces in ecology undetectable or nonexistent, and practically useless for policymaking. And as yet another example, studies of wolf reintroduction to Yellowstone National Park are raising questions about the predictive power of ecology.[32] The anticipated effects of wolf reintroduction have not played out as expected, and some scientists are now questioning the ecological importance of top predators and the ability of conservationists to justify their protection based on science alone.

Nonetheless, even though top predators like wolves may not exert the type and magnitude of influence on ecosystems that scientists once thought—that is, they may not be the "last missing link" to restore an ecosystem into balance—most conservationists contend that their protection and restoration is worthwhile. "[E]ven if some predators do little but sit at the top of their food pyramids, creaming off a few herbivores, would we really want to live in a world without them?" asked a 2014 *Nature* editorial in

response to the new evidence of wolves' effects, or lack thereof, in Yellowstone.[33] "Answering that question really is easy." The editorial implies that even though there may not be a pure scientific rationale for restoring wolves, there are other reasons to want to keep them around—reasons that are ultimately based on human values and preferences.

CONCLUSION

Once we accept that nature is profoundly shaped by and connected to human action, we begin to consider environmental problems through a different lens. In this view, environmental problems cannot be thought of as simply the consequence of human violations of the balance of nature. Moreover, environmental problems cannot be solved by simply separating natural systems from human influence. As the notion of the Anthropocene suggests, human actions have affected virtually all of the earth's landscapes in one way or another.

Instead, environmental problems become questions of how to resolve competing human demands on an ever-changing natural world. Farmers in the American West want to use stream water for their crops, while anglers and rafters want to leave water in streams for fish habitat and recreation. Maasai herders in Africa want to use landscapes to graze cattle as they have for centuries, while environmentalists and safari guides want to use them for wildlife habitat. Thought of in this way, the central environmental policy question becomes one of comparative institutional analysis. Which institutions best allow humans to resolve their diverse and ever-changing demands on an equally dynamic environment?

Simply put, protecting the environment is not simply a matter of preventing human violations on nature's supposed balance. It involves making trade-offs, in a way that recognizes nature is as ever-changing as the demands humans place on it. How those trade-offs are made in a world of diverse and conflicting human values ought to be the central environmental question in the age of the Anthropocene.

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DESIGNING INSTITUTIONS FOR THE ANTHROPOCENE

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Writing in 1990, Daniel Botkin observed that since the beginning of the modern environmental movement in the 1960s, a core mission of environmental policymakers has been the restoration of the balance of nature. The laws and regulations intended to achieve this objective are designed to halt further human disruptions of nature or reverse the consequences of past disruptions. As Emma Marris has explained recently, this balance of nature paradigm leads virtually every scientific study of environmental change to use or assume a baseline.[1] The baseline, Marris writes, is usually assumed to be the condition of nature before being exposed to detrimental actions of Europeans or, sometimes, of any humans. For environmental scientists, the baseline serves as the "before" from which they can measure subsequent human impacts. This understanding of environmental problems easily translates into policy prescriptions for "healing a wounded or sick nature" and to ethical claims that "[w]e broke it; therefore we must fix it." Thus, says Marris, baselines "typically don't just act as a scientific *before* to compare with an *after*. They become the *good*, the goal, the one correct state."[2]

Both Botkin and Marris reject the balance of nature paradigm and its reliance on historic baselines. In their view, the natural environment is always changing, and humans have been an integral part of nature's story for millennia. Thus, there is no

balance of nature to be restored, just an unknown future. Humans may be able to influence that future, but they and all other living things must adapt to it, or perish.

Botkin labeled his theory the "new ecology," but in fact his insight has deep roots in the work of the fourth century B.C. Greek philosopher Epicurus. In the words of author Matt Ridley, Epicurus thought "(as far as we can tell) that the physical world, the living world, human society and the morality by which we live all emerged as spontaneous phenomena, requiring no divine intervention nor a benign monarch or nanny state to explain them."[3] We only know of Epicurus from the Roman poet Titus Lucretious. His *De Rerum Natura* recounts and expands upon the Epicurean understanding of a spontaneous and constantly changing nature. Upon reading Lucretious for the first time, in his sixth decade of life, Ridley says that he was "left fuming at [his] educators" for their failure to introduce him to Epicurus. While two-plus decades hardly compare to two millennia, it says a great deal that a quarter of a century after Botkin first proposed the new ecology, policymakers seem to have paid little heed.

There can be no doubt that Epicurus and Lucretious were banished to obscurity for the same reasons Galileo was prosecuted: heresy against the teachings of the church. But apparent indifference to Botkin's new ecology probably has a more benign explanation. In *The Structure of Scientific Revolutions,*[4] Thomas Kuhn argued that scientific advances come in fits and starts. Scientists embrace a particular paradigm based on the best knowledge available. They build their own work and theories on that paradigm. When research yields conclusions that appear inconsistent with the accepted paradigm, scientists presume that the research result, not the paradigm, is in error. When such anomalies lead a single researcher to suggest that the accepted paradigm has it wrong, and to propose a new explanation that accommodates the conflicting results, there is resistance from the many scientists whose research and theories rely on the challenged paradigm

Whatever the pace of scientific revolutions, public policies inevitably trail behind. Whereas private decision makers have powerful incentives to get the facts right, policymakers are generally discouraged from adapting to new understandings of the world by those with vested interests in existing policies. As the reach of government has been extended and bureaucracies have grown, the "ship of state" becomes ever more difficult to turn. Elected officials have constituencies built upon particular understandings of how the world works and what government can do to make things better for them. A legislator's change of policy prescription founded on a new, science-based understanding is more likely to be seen as a flip-flop than as newfound wisdom. Bureaucracies face constituencies more interested in stability and the rents

derived from existing rules and regulations than in policy changes in response to new knowledge.

THE NEW ECOLOGY AND ENVIRONMENTAL POLICY

If Botkin and Marris are correct that nature is constantly changing and that humans are an integral part of nature, what are the implications for environmental policy? If they are correct the goal of restoring nature to its proper balance makes no sense. If nature is always changing, restoring it to some previous state—if that is even possible—would be contrary to nature. What has been described as the balance of nature turns out to be only the state of nature preferred by those claiming it to be in balance. But environmental policies have changed little in response to Botkin's new ecology.

In a political system where people commonly urge deference to science to resolve policy disagreements, having the science on one's side functions like a trump in a card game. Policy preferences prevail not because they better reflect the aggregated preferences of voters, but because science has declared them to be correct. Once this deference-to-science approach to resolving policy disagreements is accepted, the rationale for a particular policy preference collapses if the science behind it is proven wrong. So among the parties who support and benefit from existing policies, there is a natural reluctance to accept new scientific explanations that could support competing policy preferences.

Even if the science is correct in every instance, the case for deferring policy choices to science is unpersuasive. In any political system, policies reflect the value preferences of the officials empowered to make decisions. Science is essential to informing those policymakers of the likely consequences of the choices they make. But beyond their personal preferences, scientists have nothing useful to say about which policy alternatives are best.

Marris suggests that there is a second basis in environmental politics for claiming a trump on the policy preferences of others. If pursuit of the balance of nature, or some other more specific objective, can be said to be an ethical duty, that duty constitutes a moral high ground that demands special consideration. According to her, matters of convenience and economic cost, even if they have science on their side, pale in significance relative to moral claims. And when science and morality call for the same outcome, as environmentalists have long claimed is the case with restoring the balance of nature, there is little reason to even consider economic and social costs. Look at the ongoing debates over the appropriate policy responses to climate change. Considerations of cost in relation to expected benefits—even from those who, like

Danish economist Bjorn Lomborg, accept that climate change is happening and that human activities are a contributing cause—are generally given short shrift.[5]

Absent a baseline of nature in balance, are we left to environmental policies based on nothing more than competing preferences? In an important sense, that is what all political decisions come down to. The allocation of any scarce resource reflects the preferences of those who hold the power to decide. But how these decisions are made within the institutions we rely upon to allocate scarce resources affects many things we might care about: How well and efficiently are we utilizing the earth's resources? Are the benefits and costs being distributed fairly? Are we achieving the desired balance between liberty and community? Are nonhuman creatures being treated humanely? What are the unintended consequences of our chosen policies?

Some policy preferences relating to the allocation of scarce resources are better informed than others on matters of science. Whether science contributes what it can to informing the policy preferences of those empowered to decide depends largely upon the institutional arrangements for deciding. Decision makers, whether voters in a democratic republic or dictators in an authoritarian state, have ample incentive to understand how best to accomplish what they value. But the institutional arrangements within which they function will have a lot to do with how well they succeed.

In the context of environmental policymaking, is there a relationship between our understanding of nature and the institutional arrangements we employ? Absolutely. The balance of nature understanding encourages centralization of policymaking. If we accept that science will reveal a single correct policy goal, allowing individual states to set their own goals risks some of them getting it wrong. In deference to local autonomy and federalism, we might allow states to choose the means, as we have under some federal environmental laws, but the ends will be best established by a central authority. When there is a single correct policy goal, it would be a waste of time and an invitation to controversy and error for the 50 states to proceed separately.

But if the context for environmental policymaking across an entire continent is an evolving nature influenced by a multitude of factors, including human action, centralized institutions will struggle. Lacking a policy goal fixed by a scientific baseline, policymakers might be encouraged to look to a universal moral baseline. But opinions vary widely about what is morally right. Policymakers who justify their decisions as simply "the right thing to do" will learn quickly that people are less inclined to defer on questions of morality than on questions of science. Most people claim little expertise in science, but they usually have firm convictions about morality.

With acceptance of the human role in nature's evolution, there is no denying that human actions contribute to the problems that environmental policymakers seek

to solve. Once we accept that human actions driven by human preferences are an integral part of nature, it would be illogical to deny that human preferences are—and should be—integral to environmental policymaking. Without science or morality as trumps, policy decisions are revealed for what they are: choices among competing preferences, some well informed, others less so

What sort of institutions will best accommodate this recognition of the integral role of human preferences in both creating and solving environmental problems, while also facilitating informed choice in actions that contribute to environmental problems and to environmental policy? Absent a single correct policy objective, centralization is unlikely to be the best approach in most cases. Given shifting human preferences, a steadily changing and highly variable natural environment, and a wide array of human actions contributing to the changes and variability, decentralized institutions allow for locally appropriate and timely decisions. What we should seek are institutions that allow environmental policy to evolve along with the changing environment and in response to shifting human preferences.

SHIFTING THE DOMINANT POLICY PARADIGM

Over the past half century, as focus has shifted toward concern for human effects on the environment, there have been two dominant approaches: command and control regulation and public ownership/management. Both have tended to be highly centralized for a combination of theoretical and practical reasons. The dominant balance of nature paradigm calls for uniform national regulations designed to reestablish nature's balance by, for example, reducing pollution, restoring wildlife populations and habitat, and reclaiming degraded sites. The regulatory method of choice has been to establish mandatory targets for each regulated entity based on the perceived balance to be restored, followed by regulatory enforcement—so-called command and control regulation. At the same time, the historical circumstance of vast federal land ownership in the American West made it logical and easy to shift from centralized management for resource development to centralized management for ecological restoration. Land managers once responsible for producing timber, minerals, and forage in economically meaningful quantities gradually became responsible for the restoration of nature's balance.

In retrospect, an alternative to command and control regulation and public management that seems to have anticipated the Botkin thesis began to emerge in the 1980s. A greater reliance on private property rights, contracts, and markets, it was argued, would create ground-level incentives for the very actors being subjected to top-down, command and control regulations to instead make environmentally

sensitive decisions. Proponents of this view claimed that the advantages of such a free market environmentalist approach would be many. Even if the single objective of restoring the balance of nature made sense, it was a mistake to assume that all resources of a common type are the same across a vast continent. On-the-ground resource owners and users have local knowledge that command and control regulators and centralized public managers could never have. Unlike the bureaucrats of agencies like the Environmental Protection Agency, the Fish and Wildlife Service, the Bureau of Land Management, and the Forest Service, private resource owners can make—in fact must make, if they are to survive—timely and informed adjustments when conditions change or unexpected problems arise.

From its beginning, a routine objection to the free market environmentalist approach was that the wealthy and those interested in resource consumption rather than conservation or preservation have an advantage. But if environmental markets are truly free, and if property rights systems accommodate unconventional properties like instream flows, conservation easements, nonuse of permits to pollute the air and graze the public lands, or variably-priced temporal permits to drive on roads and bridges, preservation and conservation suffer no disadvantage. Wealth is no more a constraint on environmental markets than it is on any others.

Other contributors to this volume address how the free market environmentalist approach resonates with the Botkin and Marris explanation of ecological realities. In the remainder of this essay, I examine how legal institutions will best facilitate resource use and environmental protection in light of an evolving nature and frequently shifting human values.

SUBSIDIARITY

Europeans have looked to the principle of subsidiarity as a guide in the design of institutions governing large regions. The idea is that problems should be addressed at the most decentralized level appropriate to their solution. Why the most decentralized level? Because problems tend to be less complex on the local level, where knowledge about those problems also tends to be deeper. So when is local problem solving inappropriate? When what may appear to be a local problem has nonlocal effects or causes. Those nonlocal effects and causes can be regional, national or global, thus requiring governance at some more centralized level. Subsidiarity allows for diversity and adaptability in both policy priorities and means for achieving those priorities.

At least in theory, the American federal system is an illustration of subsidiarity. At the time of the framing of the U.S. Constitution, the United States was a loose confederation of sovereign states under the Articles of Confederation. The confederation

government had very limited powers. Most significant actions, like taxation and regulation of commerce, required unanimous approval by the states. Indeed, the Philadelphia Convention of 1787 was the culmination of a series of efforts to strengthen the central government. The resulting constitution enumerated specific powers of the federal congress, confirmed the existence of rights-based limits on those powers, and provided that "powers not delegated to the United States by the Constitution, nor prohibited by it to the States, are reserved to the States respectively, or to the people."[6]

Most commentary on American federalism focuses on the relative powers of the national and state governments. But from a subsidiarity perspective, the American federal system of government is far more complex. We can be sure that those who drafted the Constitution and the delegates in every state who voted for ratification of the Constitution presumed an ongoing and important role for local governments. Few nations have a broader array of local governments than the United States. Counties, cities, towns, school districts, zoning districts, irrigation districts, drainage districts, rural fire districts, weed control districts, and so on all perform functions of government. It is also clear from the Constitution itself that the framers recognized the legitimacy and importance of the most decentralized of decision makers—voluntary private associations and individuals. From the perspective of subsidiarity, all of these governing entities and decision makers should be viewed as parts of the whole structure of American government.

HIERARCHY AND SELF-ORGANIZATION IN NATURE

If we embrace the principle of subsidiarity, two concepts in ecology theory—hierarchy and self-organization—suggest how we might think about the allocation of authority among this wide array of decision makers. Indeed, the history of the development of human social institutions has similarities to the organic self-organization of nature's hierarchy.

In most biological sciences, as also in the law, taxonomy facilitates description and understanding of a multitude of distinct elements—organisms in the case of biology, and rules in the case of law. But taxonomy can obscure the relationships among a system's various parts. In their quest to understand and describe dependencies among organisms within a larger whole, ecologists face a daunting challenge. Ecological systems tend to be highly complex with processes that function on different timescales and across varying spatial extents. Hierarchy theory serves to isolate layers or segments of the whole for study without losing sight of the overarching objective: understanding where the isolated parts fit into the whole.

To understand the place and role of a particular organism in the larger ecological system, hierarchy theory holds that there are two necessary reasons for things being as they are. First, the underlying parts of the system must allow what observation reveals to exist—what is observed must be possible. Second, upper-level constraints must also allow what observation reveals to exist—what is observed must not be constrained by other organisms or processes. Take the lowly mouse as an illustration. Absent particular food sources, water, and temperatures within a certain range, the mouse is not possible. Thus, though it may seem otherwise, mice are not observed everywhere on earth. But the presence or prevalence of mice where they are possible is constrained by predators, disease, and even traps set by humans. This hierarchy of limits from below (possibilities) and above (constraints) helps explain the mouse and its place in a larger ecosystem.

Although we often speak of nature's design, or of the purposes of particular organisms, the existing combination of possibilities and constraints that allow the mouse to exist is not by design. It is the result of what ecologists call self-organization. According to the theory, what appears to be conscious coordination among organisms within an ecosystem is actually the result of fortuitous interactions and adaptations among individual organisms. Self-organization is a spontaneous and ongoing process triggered by random fluctuations in possibilities and constraints. The resulting organization is entirely decentralized, relatively stable and able to self-repair when disturbed. Thus, the mouse has a shot at, but is not assured, a particular role, or even a place, in any particular ecosystem at any given point in time.

HIERARCHY AND SELF-ORGANIZATION IN HUMAN INSTITUTIONS

What distinguishes humans from all other organisms in the ecosystem are the capacities to understand at least some of the interactions among organisms and to consciously regulate human and other effects on the ecosystem. This combination of human capacities can be employed through many different institutional arrangements. Individuals can and do act autonomously. Individuals of like mind also collaborate through private associations of various types. And the wide array of governments mentioned previously allow for public action in the name of everyone within a particular area, whether of like mind or not. The ecology principles of hierarchy and self-organization are instructive in applying the concept of subsidiarity to the allocation of decision-making authority among the various levels of government.

The principle of subsidiarity holds that government decisions and actions should occur at the most decentralized level where the desired results can be achieved. This

suggests that the default institution should be the private market, where individuals self-organize in pursuit of purely personal ends. Like the organisms in an ecosystem, individuals self-organize by producing and selling what their capacities, inclinations, and circumstances allow, and by acquiring from others goods and services those others are better situated to produce. Customs that develop over time to facilitate transactions and enforce promises are integral to these private markets. In Anglo-American countries, custom was gradually formalized into what came to be called the common law, administered by judges whose authority derived from the state. Only at this point could it be said that there was some element of design in the system. But even then, the rules of the common law were derived largely from custom and evolved in response to the changing demands of the private actors who looked to the law to facilitate their chosen interactions.

The common law, however, as with any other system rooted in the customs of self-organizing individuals, cannot provide solutions to all of the challenges arising from social existence. In the terms of hierarchy theory, some problems simply cannot be resolved at this most decentralized level of social action. What economists would call public goods, like defense against invading outsiders, or the construction and maintenance of highways, prove difficult to accomplish through spontaneous self-organization. Some degree of centralization is needed, but not necessarily the same degree in all cases. Defense seems best accomplished through centralized national institutions, while regional or local institutions might better provide highways and other public services. Thinking again in the terms of hierarchy theory, the optimal point on the continuum from decentralized to centralized institutions depends on the possibilities and constraints at any point in time.

Ocean Fisheries

In ecology theory, at least as it predates or rejects Botkin's recognition of the integral role of humans, possibilities and constraints are all attributed to non-human or "natural" factors. But when the concepts are applied to the design of human institutions, whether pursuant to subsidiarity or some other guiding principle, possibilities and constraints are at once both "natural" and "manmade." For example, it is often not possible for local or even national governments to manage ocean fisheries that are both widespread and transient. Governments can only manage successfully those resources over which they have jurisdiction or authority. National regulation of ocean fisheries beyond their territorial jurisdiction will be limited by those jurisdictional boundaries, while also being constrained by various international agreements preempting national choices. This combination of restraints from below and above

argues for some sort of international institution, yet the actual fishing is done by individual private entities who will be difficult to police given physical realities of the oceans. So the best solution in terms of both productivity and conservation may be one that is highly centralized in setting harvesting limits and highly localized in the creation of incentives to comply with those limits.

Land

The environmental successes and failures of resource management regimes in the United States tend to confirm the validity of the subsidiarity prescription for the most decentralized level of governance that is effective. From the very beginnings of the American nation, it was assumed that most land would be privately owned. With the significant exception of the federal public lands of the American West (considered below), this decentralized management regime has prevailed and has been highly effective from an economic perspective. Since the beginning of the modern environmental movement, however, the predominant view among environmentalists has been that private ownership of land is a contributing cause of many environmental problems. This is so, some environmentalists argue, because private owners focus on land uses with marketable values and thus ignore environmental values that generally cannot be bought and sold—they take account of the benefits to themselves but not the costs to others. The usual explanation for this perceived failing of the private property regime is market failure—some combination of transactions costs, public goods, external costs, and poorly defined property rights (really a legal system failure).

From the perspective of hierarchy theory, this absence of markets for environmental goods is the result of people presuming it impossible to establish property rights in such goods. This limits the effectiveness of markets in the allocation of scarce environmental resources. The argument concludes, therefore, that it is necessary to move to a more centralized level of governance that will be effective. Rather than accept the outcomes generated through countless property transactions presumed by market theory to optimize social benefits in relation to costs, government at some level of centralization will be called upon to assess how best to allocate environmental resources. This will be accomplished through democratic representation, a wide array of public processes, scientific and management expertise, and ultimately a political balancing of competing interests. In the case of land, a stationary resource whose use has largely local external effects, it is accepted that the relatively decentralized level of local government will often be the most effective.

Zoning by local governments is intended to protect wetlands, wildlife habitat, open space, scenic vistas, and other so-called ecosystem services, among other things.

Although some of these values either can be or already are supplied privately, an absence of markets can limit the possibilities to solve environmental problems through the decentralized institution of private property. Zoning regulations function much like nuisance law in that they limit the rights of property owners. But zoning is very different from nuisance law in that new limits can be imposed retroactively and are enforced not by private lawsuits but by government authorities. People often suggest that zoning should be implemented on a state or national level to assure that all properties are regulated and everyone shares in the expected environmental gains, but the wide variation in ecological conditions across a large area of diverse communities constrains the effectiveness of such an approach. Oregon, where a set of statewide goals and guidelines govern land use planning and regulation in every corner of the state, is illustrative. Because it is not possible for a statewide system to account for the preferences of every individual, and the state consists of a wide variety of communities with different shared values, the result has been an imposition of urban values on rural communities along with processes appropriate in some settings yet unduly burdensome in others. On the other hand, if the objective is to preserve or protect particular environmental resources without regard to the preferences of the actual humans directly affected, local governance will probably not be effective—it will often fail to embrace the objective and, in any event, lacks authority beyond its physical boundaries. In hierarchy theory terms, local governments lack the possibility of managing for broader statewide purposes.

Climate Change and Other Nuisances

Although environmentalists have generally favored centralized regimes over decentralized ones—and, therefore, have rejected the common law as an effective restraint on environmental degradation—they have recently taken an interest in the common law doctrine of nuisance, considering it an effective tool in the avoidance and remedying of environmental harms ranging from wetlands destruction to climate change. When all properties include something in the nature of an easement that protects against harm emanating from all neighboring properties, a purely private regime of land management is responsive to some environmental harms. Given that this has always been the case, what explains environmentalists' recent fascination with the common law? After all, the alleged limits (impossibilities) of common law remedies are what led earlier environmentalists to conclude that the common law is inadequate to their task.

Hierarchy theory suggests an answer. While environmentalists have scored many legislative and administrative victories over the past several decades, they have

sometimes encountered resistance. Frustrations, particularly in the context of climate change, have led some environmental advocates to explore means for circumventing these centralized law making entities. Because lawsuits have always been important to environmentalists in the enforcement of legislative and administrative standards and procedures, it is natural for them to appeal to the courts to do what the other branches of government have either failed or refused to do. Such common law claims were seldom argued previously because the kinds of rulings desired by environmentalists were not possible unless a judge was willing to make fundamental changes to existing common law doctrines. That has not changed, so to be successful, recent claims based on nuisance and the public trust doctrine require judges to make possible what has heretofore been impossible—by amending and rewriting existing law. While doing so might serve some environmental goals, it will necessarily impose significant costs on those who have relied on the constraints of existing law.

Federal Public Lands

Another example illustrates how principles of ecology theory might inform institutional choices. As mentioned above, about 50 percent of the American West is the property of the national government. This arrangement was the result of historical circumstance, but we have since made conscious choices about the retention and management of these lands. Originally, the default assumption was that the vast majority of the western public lands would be transferred to private ownership, and various laws were put in place to make that happen. Over time, retention by the government of particular parcels was thought to best serve the national interest, although there were always interests in the background who sought private advantage from public ownership. Yellowstone was thought to be a unique national treasure, while the railroads foresaw private gains from transporting tourists to protected parkland. Forest lands were reserved from private acquisition to protect water and timber resources, often over the objection of local governments who foresaw—correctly, it turns out—the loss of both economic development possibilities and tax base. More recently, Congress required the federal government to manage the public lands for multiple uses pursuant to extensive public planning, leading to the effective withdrawal of many resources from economically productive uses.

The history of federal public land policies is more the product of shifting political influence at the national level than of a reasoned approach to scarce resource allocation. To the extent that national policy aimed to exploit public lands for their timber and range resources, it made no sense to rely on federally employed foresters controlled from Washington, D.C. For some years, the futility of this approach was

acknowledged by delegating significant authority to on-the-ground forest supervisors. But even then, it would have made more sense to give private timber operators long-term leases on particular lands. Timber management is most effective when decentralized and, consequently, relieved of the limits of ignorance and conflicting objectives that inevitably come from on high. Once multiple use became national policy, something resembling zoning for different and compatible uses under local control would have made far more sense than a central mandate that all lands be managed for all purposes. To the extent timber production is a desired use of particular lands, the principle of subsidiarity holds that private ownership in some form will be most effective. To the extent preservation of a unique resource like Yellowstone is a desired use, public ownership at some level will likely be more effective. (Although aspects of national park management can be and have been more effectively performed by private entities.) As in ecosystems, the possibilities and constraints at various levels will determine success and failure.

Water

Finally, consider the example of water. Ownership of the physical resource, as with land, is not possible given the transitory nature of most water bodies. In England the institution of riparian rights emerged, likely as a result of self-organization among neighboring property owners. This riparian doctrine, under which owners of lands adjacent to a particular stream had correlative rights of use in the water, was received by the eastern states and adopted by new states heading West. But the naturally arid conditions of the American West imposed significant constraints on the effectiveness of the riparian doctrine.

As with the customs that provided the foundations of the common law, customary practices among self-organizing miners supplied the underpinning of the western appropriation doctrine. "First in time, first in right," allowed miners to dig for gold with confidence that their discoveries would be secure. The same principle allowed them to acquire a reliable supply of the water needed for mining. With the arrival of courts and the opportunity to resolve disputes in an efficient and civil manner, refinements designed to facilitate exploitation of valuable minerals and later of fertile land became part of the law. With a growing population and more water rights claimants, record keeping and permit systems were put in place in an effort to avoid conflict and inform potential users of existing rights. As water sources became more heavily exploited, concerns about future water needs and stresses on natural systems led state governments to impose conditions and limits on new permits. More recently, states have imposed restrictions on previously established rights, usually in an effort to protect fish and wildlife.

This gradual shift from a spontaneous, decentralized system of private rights acquired by putting water to use, toward a system with growing regulation of private use and the reservation of waters for public purposes, may make sense where water is scarce and growing populations have increased demand. But how do we know whether we are relying on the right water allocation institutions from an environmental, or any other, perspective? In response to increased urban demand, the requirements of the Endangered Species Act and other wildlife protection polices, and, particularly in recent years, extended drought, there has been a strong push for more centralized planning and policy directives. Indeed, contrary to the principle of subsidiarity, the default has been in the direction of greater centralization with little regard for or understanding of effectiveness. Most notably, the efficiency advantages of market allocation have been abandoned to regional and statewide planning based on expert counsel and endless public hearings. Notwithstanding that big water development projects designed and funded largely by the federal government are the source of many environmental problems (while also providing significant economic benefits), environmentalists are unified in their calls for more central planning and less deference to private rights.

While some level of centralization in water allocation is needed to achieve certain policy goals, there is little reason to think we have the institutional arrangements correct overall. The fact that the prior appropriation system was, in its beginnings, self-organized, is persuasive evidence that it served the needs of private users. At the same time, there is no doubt that public needs, particularly those of the modern environmental era, were neglected due to the constraints of the private rights system. But centralized authority has its own possibilities and constraints that will not be evaluated and understood if the default is ever more centralization.

CONCLUSION

While there are examples of what might be called self-organization in human institutions, like the custom foundations of the common law, and of the prior appropriation doctrine of western American water law, the reality is that the human capacity for choice usually leads to institutions most likely to serve the interests of those in power. Seldom are the institutions of governance chosen pursuant to abstract principles independent from the particular interests of those doing the choosing.

Although environmentalists often prefer to view their cause as the pursuit of a higher good that rises above the more mundane concerns of day-to-day life, environmental protection and preservation are really just an aspect of the larger challenge of allocating scarce resources. The fact of scarcity is what leads to concern about

polluted air, endangered species, threatened wetlands, open space, and every other resource we might value. If we understand the objective of environmental policy to be the allocation of more resources to the satisfaction of environmental values, and we accept that this objective will influence the selection of institutions for resource allocation, the new ecology provides some guidelines for getting the institutions right.

In the context of an existing system of institutional options that range from the extreme centralization of international agreements to the extreme decentralization of private property rights and markets, the principle of subsidiarity holds that we should prefer the most decentralized approach that achieves our purposes. Defaulting to the most decentralized approach that will be effective derives from the empirical reality that people closer to a problem usually have better knowledge of both the causes of the problem and the remedies likely to solve it. It's not a coincidence that decentralized approaches, beginning with private markets, also give greater regard to differing priorities and allow for experimentation in the discovery of solutions. Given that humans ultimately affect the environment at the individual level, attention to the positive and negative consequences of individual freedom of action is essential to effective environmental policies.

Self-organization as an explanation for ecological systems informs institutional design—not just as a model, but also as a recognition that, like other integral parts of the ecosystem, humans have a natural capacity for self-organization. That is what happens in markets, where the force is no less powerful than in the self-organization of less sentient participants in natural ecosystems. It is also what happens through the most disruptive obstacle to effective governance, rent seeking—a force that grows more disruptive with greater centralization. If the driving force of self-organization in an ecosystem is the self interest of the constituent organisms, is there little wonder that humans become ever more aggressive rent seekers as their opportunities for rents increase?

While hierarchy theory in ecology seeks to explain why things are as they are, the concepts of possibilities and constraints can be helpful to institutional design. What is impossible should not be attempted, and constraints from above—both natural and human-imposed—will limit alternatives that would otherwise be possible. It all seems rather obvious, but the tunnel vision of special interest politics too often leads to policy choices that are doomed to fail in the face of unrecognized or unacknowledged limits from below and above.

ENDNOTES

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ENVIRONMENTAL POLICY FOR THE ANTHROPOCENE:
Information, Incentives, and Effective Institutions

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In view of the uncertainty brought about by human-caused climate change, what types of institutions should we rely upon to mitigate the undesirable effects of climate change? To help answer that question, we look to the economics literature, especially work on information in markets and fiscal federalism, to see what it can tell us about the relative merits of centralized and decentralized decision-making. [1] Our main argument is that the optimal degree of centralization or decentralization will depend, in part, on (i) whether new information regarding the effects of climate change will be more easily observed at the central level or the local level and (ii) which types of institutions will be most effective in keeping the incentives of decision-makers aligned with the costs and benefits of their decisions.

Although some of the economic concepts we employ are widely recognized in the literature on climate change, others have received, in our view, far too little attention. Given the global nature of the causes and consequences of climate change, it is

Acknowledgments: For helpful comments, we thank Jonathan Adler, Terry Anderson, Lynne Kiesling, and participants at PERC's Workshop on Environmental Policy for the Anthropocene. Special thanks to Shawn Regan for many helpful conversations and for pointing out to us the nascent literature on the policy implications of the Anthropocene.

unsurprising that so much attention has been focused on efforts to reduce greenhouse gas emissions through international treaties. This makes sense because, in essence, the textbook solution to a problem of this type would be to negotiate a global level of emissions (ideally weighing all the costs and benefits), and then employ a system to achieve the desired level of global emissions in a relatively low-cost way, such as through carbon taxes and other price mechanisms. Of course, whether we will see anything even remotely resembling an enforceable agreement in the real world, let alone an agreement yielding a close-to-optimal level of emissions, remains to be seen.

Regardless of the degree to which negotiations, other policies, or individual actions succeed in reducing greenhouse gas emissions, the question of how to reduce the costs of climate change remains. And it is on this aspect of policy for the Anthropocene that we argue key ideas from public economics have received too little attention. In particular, as Mother Nature reveals more information about the effects of human activity on the climate, the question of how and when that information becomes known will influence the success or failure of different policy approaches. If new information is acquired in a dispersed manner, such as by individual landowners observing changes on their own land, a centralized decision-making system will tend to perform poorly relative to a system that allows the localized information to guide decisions. By contrast, if the new information were easily observed by experts, such as scientists, and individual landowners lacked incentives to use that information in a manner that yields good outcomes, then a more centralized system of decision-making could be preferable.[2]

To understand our argument, it is essential for the reader to recognize our starting point. Although the political rhetoric surrounding climate change has often revolved around accusations of climate change "denial" and counter-accusations of politically driven scientific reports, those issues are red herrings with respect to the concerns in our paper. If everyone came to view climate change as a serious problem, that might move us a step closer to an effective policy response, but it is far from clear that merely recognizing a serious global problem will lead to a good solution. Indeed, even when large numbers of people face imminent threats of death (in wars, for example), collective responses may fail to avoid disastrous outcomes. Thus, for any serious effort to guide policy responses to climate change, the question of what types of policies will actually work must be treated as a topic of first-order importance. And it is with this "what actually works" focus in mind that we examine the policy implications of the Anthropocene. By taking this approach, we hope that our analysis will be valuable to readers with a range of perspectives—whether optimistic or pessimistic about climate change and the role of government in society.

As a starting point for our analysis, we outline (in Section II) the standard economic explanation of why well-functioning markets are so valuable. In essence, when markets function well, market prices serve two critical roles: They provide incentives to engage in mutually beneficial exchange, and they convey otherwise unobservable knowledge about costs and benefits of activities. Closely related to that point is the standard approach to the question of which levels of government—centralized or local—will tend to deliver better public policy when markets, if left alone, fail to account for important costs and benefits.

By applying these ideas to environmental problems, we are following a path similar to those taken by many previous scholars, particularly those affiliated with PERC.[3] Most directly, we build on the nascent literature that uses lessons from law and economics to assess what types of institutions will work for the Anthropocene. Regan emphasizes the value of adaptability in the face of an ever-changing world.[4] In particular, he relates ideas from Austrian economics to ones from ecology, pointing out the importance of approaching environmental policy decisions in light of evolving economic and environmental conditions. On a similar theme, Adler calls for "adaptive management" in environmental law and policy, emphasizing the value of adaptability in response to environmental changes.[5] In earlier papers, Adler focuses on water policy, explaining the roles for property rights and markets in successful responses to climate change.[6] Huffman explains the advantages of relying on legal rules that have evolved over time, particularly those rules that define and allow the enforcement of property rights.[7] He emphasizes, as we do, the importance of Friedrich Hayek's work suggesting that a good legal system must make use of diffuse private knowledge.

CORE ECONOMIC CONCEPTS: MARKET PRICES, INCENTIVES, AND INFORMATION

Underlying the critical incentive and informational roles of market prices is the fact that prices indicate how much of one good can be voluntarily exchanged for other goods. The field of economics has, at its core, a rigorous exposition of that point.[8] For our purposes here, we will present a simple thought experiment to convey the intuition underlying the way economists view markets and prices. This will set the stage for our discussion of environmental policy for the Anthropocene.

Voluntary Exchange and Information: A Very Simple Example

Consider a teenager who works as a gardener for neighbors at a wage of $10 per hour. She has the option of forgoing leisure hours in exchange for pay, which can in turn be exchanged for other goods. To purchase a $1,200 mountain bike, the teenager

would need to forgo 120 hours of leisure. Thus, the opportunity cost of the mountain bike is 120 hours of leisure, and, symmetrically, the opportunity cost of the leisure is the mountain bike. Similarly, by purchasing an hour of the teenager's gardening services for $10, the neighbors are forgoing some other good, perhaps trading away 15 minutes of leisure if they earn $40 per hour, or perhaps forgoing a restaurant meal that would cost $10 more than eating at home.

The incentive role here is quite obvious: The ability to trade goods and labor at market prices provides incentives to engage voluntarily in mutually beneficial exchange. The most famous comment on this point is from Adam Smith's *Wealth of Nations:* "It is not from the benevolence of the butcher, the brewer, or the baker, that we expect our dinner, but from their regard to their own interest."[9]

Less obvious is the essential informational role of market prices.[10] The fundamental problem with most non-market systems of allocation is that they provide, at best, little information about the opportunity costs of goods and the value of goods to consumers. Quite simply, there is no reliable way to estimate how much people value some good—such as a mountain bike, leisure, or gardening services—unless we observe how much they are willing to give up in order to have it. Moreover, if we see voluntary trades, it is usually reasonable to infer that we are observing mutual gains from exchange. People make mistakes, of course, but if we see a teenager provide 120 hours of gardening labor in exchange for money to buy a mountain bike, it is likely that the teenager preferred the mountain bike to the forgone leisure, that the buyer of the gardening labor preferred the improved garden to other forgone goods, and that the seller of the mountain bike expects that $1,200 can buy something he or she values more than the mountain bike.

The key point, of course, is not that markets work perfectly, but that in most cases knowledge problems render the alternatives worse. For example, if instead of allowing voluntary exchanges of labor and mountain bikes, we empowered a city official to conscript teenage gardeners and to allocate mountain bikes and other goods, even a well-meaning official would be destined to make mistakes. There would be no reliable way to find out who valued a bike (or $1,200 of other goods) more than 120 hours of leisure, who valued gardening services more than $1,200, and so forth. Inevitably, centrally planned allocations enforce what are, in effect, mutually undesirable exchanges and prevent desirable exchanges. And if a non-market system allocated gardening services and bikes to the politically well-connected—doing so by taking leisure and bikes from the less well-connected—that would be even worse. The principal point regarding knowledge, however, is that even a well-meaning government official would be unable to allocate goods in a sensible manner.

The real world is, of course, far more complex than our story about gardening and mountain bikes. Each of us regularly chooses among a huge number of goods and ways to spend our time. Note that even a decision to buy a mountain bike involves not just whether to buy one, but making a selection among many quality levels and styles. In this light, the knowledge problems faced by a central planner trying to allocate goods and services are insurmountable—far more so than in our simple story.

An Example of a Missing Market

As a practical matter, the success of markets in weighing costs and benefits—when they do indeed succeed—comes from getting the incentives right and making use of the price system as a mechanism to aggregate and employ otherwise dispersed private knowledge. A critical concern, then, is whether prices will, in fact, reflect opportunity costs in a sufficiently accurate manner. In this light, if we see an environmental problem in the sense that some type of activity is generating costs greater than the benefits, we can ask whether a price system might resolve the problem.

A classic example is that of a common pool resource with unrestricted access. To illustrate the problem, consider a lake surrounded by residents who use the lake for fishing. If each individual chooses how much to fish by weighing only his or her costs (e.g., time) and benefits (fish caught), the stock of fish may be rapidly depleted, leaving all the residents worse off than if they agreed to reduce their catch. The fundamental problem can be viewed as a "missing market" in the sense that taking a fish out of the lake has an opportunity cost: Neither the fish nor its potential offspring can be caught in the future. This opportunity cost is incorporated only incompletely (or not at all) into individuals' fishing decisions. Thus, in the absence of some kind of agreement or restriction on fishing, individuals decide to fish "too much" relative to what they would do if they reached a mutually beneficial agreement.[11] Note that one potential solution would be to collect a fee for every fish caught: With an appropriately set fee, the problem of a missing market, and hence the problem of overfishing, would be eliminated.

Once again, consider the central factor in our discussion: the role of information. An extreme case would be a perfectly informed benevolent official. With perfect information about every individual's benefits and costs, the official could simply assign fishing quotas (as individual-specific allotments) so that each resident would catch fish until the point where the next fish caught would be worth more in the lake than if caught. With more than a trivial number of resident-fishers involved, the task of obtaining such information, other than through a market, would be prohibitively

difficult. Yet a more market-oriented solution can be implemented with much less information. Even if no single individual knows much about any other individual's costs or benefits, setting a total number of fish caught, (known as a "total allowable catch," and allocating tradable rights to catch those fish may generate something close to what a perfectly functioning market would yield.[12]

The key point is that the market price of the tradable right to catch a fish implies that each individual catching a fish incurs an opportunity cost—either buying the right to catch the fish or forgoing the opportunity to sell the right to someone else. If the total allowable catch is set appropriately, with the price of fishing rights set by supply and demand, the outcome will match the ideal market case because the otherwise missing market is no longer missing. Crucially, there is no need for any official to ascertain the benefits and costs to each individual, because each individual will buy or sell the fishing rights according to his or her own benefits and costs. Of course, the question of how to set the total allowable catch remains, but one reason for optimism relative to a top-down, command-and-control approach is that all holders of tradable rights have an incentive to oppose setting an excessively large catch (because the value of future fishing rights will fall as the stock of fish is depleted) or an excessively small catch (because the value of catching a few fish will be small). In sum, when knowledge is dispersed, market mechanisms—even if they rely on centrally created rights—have more plausibly satisfied information requirements than do command-and-control mechanisms.

INFORMATION AND THE ANTHROPOCENE

Using the ideas we set out in Section II, we will now turn to our paper's central question: As Mother Nature reveals the effects of human-caused climate change, what types of institutions will be most effective in making use of that information? A useful way to address this is to identify two types of mismatches between institutions and the nature of information, then examine the inevitable tradeoffs involved when choosing whether to make decisions in more versus less centralized ways. We will illustrate this by discussing three topics: greenhouse gas emissions, water use, and the protection of wildlife habitat.

Greenhouse Gas Emissions

Greenhouse gas emissions provide a textbook-style illustration of a case in which decentralized decision-making will fail to weigh important costs and benefits. The fundamental concern is that even if individuals could know the consequences of their actions (e.g., how driving more miles on a road trip will, at the margin, influence

environmental outcomes on barely-above-sea-level islands), it would be impossible for decentralized contracts among the affected parties (e.g., drivers in Montana, residents of islands) to contract with each other in an effective manner. Moreover, because individuals bear such a small fraction of the consequences of their own greenhouse gas emissions, there is no reason to expect that relying on individuals to weigh their own costs and benefits will suffice to approximate weighing the costs and benefits to all individuals. In this light, some central coordination can be valuable, making international agreements an obvious consideration.[13] That said, a centralized effort to determine who should reduce emissions by how much would be, at best, inefficient because information about the costs of reducing emissions is dispersed and, indeed, individual-specific. Put another way, in the absence of information obtainable only through market prices or some other type of voluntary exchange, mandated emissions reductions will in some places impose large costs for relatively small environmental gains, while in other places miss opportunities for large environmental gains at relatively low cost.

Note that regulations targeting specific aspects of goods—such as fuel economy standards for automobiles—are commonly used and can be imposed without using a market mechanism to address the problem of dispersed knowledge. Policies of this type may be effective in reducing greenhouse gas emissions. Crucially, however, such policies address the missing-market problem in, at best, an indirect manner. In the case of fuel economy standards, for example, an increase in miles per gallon must come at some cost, such as engineering costs, construction costs, safety, performance, or discomfort. Imposing these costs does not solve the fundamental problem of missing markets. Note that in the case of an individual who drives very few miles, the additional cost of a mandated "green" car will yield little reduction in emissions. Moreover, the incentives created by such policies need not align individuals' incentives with the policies' objectives. For example, increased fuel economy will, all else equal, reduce the cost per mile driven and may therefore increase miles driven and weaken incentives to carpool.[14]

In sum, the effectiveness of efforts to reduce greenhouse gas emissions will depend on two fundamental lessons from public economics. First, negotiations will likely need to be conducted at a relatively centralized level in order to "get the incentives right" in the sense of having a sufficient portion of the global costs and benefits accruing to the constituents represented by the negotiators. Second, for whatever emissions objectives are set, reaching those objectives in a sensible manner will require the use of dispersed knowledge. Therefore, we expect that price mechanisms, such as emissions taxes or tradable rights, will be necessary for

reaching any meaningful emissions objectives—otherwise, excessive costs will derail public support.

Water Use

The effects of climate change on the allocation of water can be viewed in a similar manner. For the purpose of discussion, let us assume that climate change will bring about undesirable shifts in patterns of precipitation, such as prolonged droughts. This would provide further reason to seek international agreements that reduce greenhouse gas emissions—even more so if prolonged droughts would present a national security threat.[15] Yet once the snow and rain have fallen wherever they fall, decentralized decisions are essential for reducing the harm done by droughts.[16]

Again, the potentially useful role of centralized decisions, along with the information problems created by centralized decision-making, are clear. Allocating water for environmental uses—such as leaving water in streams, lakes, and wetlands—may have such broadly distributed benefits that decentralized individual actions lead to undesirable outcomes. Put another way, the overconsumption of water by individual users may be exactly analogous to the overfishing problem discussed in Section II. Yet without a price mechanism based on voluntary exchange, the value of water for agricultural, residential, and commercial uses cannot be reliably identified: A farmer facing market prices for his or her crops generally will be able to assess how much an additional acre foot of water is worth on his or her farm, whereas bureaucrats will not. Similarly, bureaucrats who impose per-household limits on water consumption will do so without knowing which households would benefit a lot or a little from additional water.

Thus, when choosing between more versus less centralized decision-making mechanisms, the key practical question is not what would be ideal, but what is most effective. In circumstances where government officials can and will assess environmental benefits relatively well—such as knowing how much water left in a river will preserve highly valued wetlands downstream—a centralized decision regarding the quantity left in the river, combined with tradable water rights and price mechanisms, may work well. And, if climate change brings about major shifts in precipitation patterns, such as severe droughts combined with intensified El Niño effects, there will be more at stake in the quality of centralized decisions (for which scientific expertise is essential) and from allowing market mechanisms that make use of dispersed knowledge. Put another way, the potential harm from allowing unrestricted water use will likely become greater as a result of climate change, and so will the potential harm from restricting market-based trade in water.

Wildlife Habitat

As a starting point, consider the following scenario, which we intend to be a useful abstraction rather than a description of the real world. Suppose that the current habitat of some type of charismatic megafauna (e.g., sea lion, whale, lion, elephant, bear) will become too warm or otherwise unsuitable for that species. Also suppose that having the species in the wild provides great value to humans, so that the relevant policy question is not whether to allow the species to relocate, but rather how to set policy that allows the species to make a successful move. Once again, the degree to which we should expect centralized or decentralized decision-making to prove effective will depend on how Mother Nature reveals information—and on the extent to which making good use of that information depends on inherently private knowledge.

For the case of, say, protecting easily tracked, endangered marine mammals that migrate long distances, relying on "command-and-control" style policies could be effective. The better the ability of experts to observe the animals' locations and health status, and the less informed the general public, the more potential benefits there would be from issuing regulations centrally—perhaps along the lines of a national agency issuing orders to restrict fishing or boating in specific locations as the endangered mammals migrate. Moreover, if a changing climate reduces the degree to which past migration paths and timing can predict future paths and timing, that would imply more reason to rely on centrally observed scientific information, and less on local knowledge. Similarly, the more easily the government can enforce restrictions on the types of boats and fishing practices that might harm the migrating mammals, the more effective will be those restrictions.

Yet the example just described may be far from the norm, because much of the information about wildlife habitat, and about the opportunity cost of keeping habitat suitable for wildlife, will be dispersed. One reason is that local landowners are typically the best positioned to observe their land. Serious problems arise for centralized "command and control" approaches to wildlife protection when (i) local landowners know much more about local conditions than do those setting or enforcing the policies and (ii) the existence of protected species on private land (when known to authorities) may activate legal restrictions on land use. This can lead to clandestine killing of legally protected wildlife, and it encourages landowners to engage in preemptive destruction of habitat before protected species arrive.[17] As climate change brings about shifts in where specific flora and fauna will thrive, the scope for preemptive habitat destruction will increase.[18]

Given the importance of dispersed information about wildlife and its habitat, any serious response to climate change will need to include policies that make use of that information. To see how this may work, consider the case of wildlife—such as elephants, lions, and leopards—that can be dangerous or destructive.[19] People who suffer the risk (e.g., damage to crops, lost livestock, physical harm) of living in proximity to these animals may, for good reason, see the animals as undesirable. This presents a problem for command-and-control policies, such as simple prohibitions on hunting. One reason why poachers so often succeed is that the local population has little reason to report poachers, much less keep a watchful eye on the wildlife. Yet if property rights and contracts can be established in a manner so that the costs to local residents are more than offset by the gains, such as income from tourism and hunting licenses, the locally observed information (e.g., activities of poachers) will more likely be used in a manner that protects the wildlife. In short, in recognition of the Anthropocene, policymakers seeking to protect wildlife, especially wildlife displaced from their historical habitat, should look for decentralized market solutions to habitat protection problems.[20]

Choices Within a Federal System

Before concluding, we discuss briefly how our main point relates to a federal system of government. One of the fundamental strengths of a federal system is flexibility with respect to the level of decision-making. Perhaps most obviously, by providing public goods through the federal branch, notably national defense, the scope for free-rider problems, which can lead to the under-provision of public goods, will be minimized. Of course, even in the case of national defense, there are still incentive and information problems.[21] Nevertheless, the broader the sharing of the benefits, all else equal, the more reason to make decisions at the federal level. And when dispersed information renders centralized decisions highly problematic, a federal system allows state and local decision-making. In short, the level of government that will perform best on a given policy depends on (i) the level at which decisions best weigh costs and benefits , and (ii) the extent to which decentralized decisions make better use of dispersed information.[22]

The performance of state versus federal management of forests provides a useful example. The evidence shows that state forests perform better on many dimensions.[23] It could be that state-level management ignores some benefits, because forests in one state, say, Montana, provide benefits to those who reside outside the state. But the consequences of that are likely minor—it is unclear why non-Montanans would want Montana forests to be managed in a far different manner than Montanans would.

By contrast, the problems with federal management will likely be large, because the "owners" (i.e., all Americans) will have little information or incentive to obtain information about what is happening on federal forests in Montana. Thus, it is unsurprising that, in practice, state-level management yields more benefits.

What might the Anthropocene imply for decisions within a federal system? At this point, we can only speculate, but it seems plausible that rearrangements both toward and away from centralization might be beneficial. On the one hand, an obvious point is that greenhouse gases have a much broader geographical effect than do the types of pollution that have had historical importance. Thus, local decisions—such as those using common law to adjudicate disputes between neighbors—will be ineffective for the control of such emissions. This increases the scope for useful federal decision-making. On the other hand, federal policies regarding land use and habitat may become ineffective or even counterproductive. For example, if climate change drives wildlife off a historical range on federal land or has a similar effect on vegetation, policies that rely on local knowledge will probably be essential for successful management. And this provides a reason to rely more on state and local governments—and on contracts between private parties.

CONCLUSION

Although no one knows precisely what the effects of human-caused climate change will be, we can nevertheless look to public economics for guidance. An obvious point is that the effectiveness of environmental policy in the Anthropocene will depend on how well institutions set policies that account for costs and benefits that accrue on a global scale, and this leads naturally to a focus on international agreements. Yet as Mother Nature reveals more information about the effects of human activity on the environment, much of that information will be revealed in a dispersed manner. And this calls for policies and institutions—notably those that support voluntary exchange and rely on market prices—that utilize dispersed new information and private knowledge.

ENDNOTES

1 See, e.g., Hayek, Friedrich A. 1945. "The Use of Knowledge in Society." *American Economic Review* 35:519-530; Oates, Wallace E. 1999. "An Essay on Fiscal Federalism." *Journal of Economic Literature.* 37:1120-49.

2 We focus our discussion on new information because so much remains unknown about the effects of human activity on the future environment. Note, however, that the issue of dispersed information being difficult or impossible to observe is not limited to new information. Indeed, much of what individuals (e.g., landowners) already know, and will eventually know, about the value of resources (e.g., alternative uses of their land and labor) will be diffuse private knowledge that cannot be unobserved centrally—price systems will, at best, serve as surrogates for that knowledge. On the "knowledge problem" and, in particular, the value of distinguishing between information and various types of knowledge, see Kiesling, Lynne. 2015. "Knowledge Problem." In Peter Boettke and Christopher Coyne, eds., *Oxford Handbook on Austrian Economics.* Oxford: Oxford University Press.

3 See, e.g., Anderson, Terry L. and Gary D. Libecap. 2014. *Environmental Markets: A Property Rights Approach.* Cambridge University Press.

4 Regan, Shawn E. 2015. "Austrian Ecology: Reconciling Dynamic Economics and Ecology." *Journal of Law, Economics, & Policy* 11:203-228; see also Regan, Shawn. 2016, this volume.

5 Adler, Jonathan H. 2016, this volume.

6 Adler, Jonathan H. 2008. "Water Marketing as an Adaptive Response to the Threat of Climate Change." *Hamline Law Review* 31:730; Adler, Jonathan H. 2012. "Water Rights, Markets, and Changing Ecological Conditions." *Environmental Law.* 42.

7 Huffman, James L. 2015. "People Made Law: Spontaneous Order, Change and the Common Law." *Journal of Law, Economics & Policy.* 11(2):179-202.

8 See, e.g., Debreu, Gérard. 1959. *Theory of Value: An Axiomatic Analysis of Economic Equilibrium.* New Haven: Yale University Press.

9 Adam Smith. 1776. *An Inquiry into the Nature and Causes of the Wealth of Nations.*

10 Hayek, Friedrich A. 1945. "The Use of Knowledge in Society." *American Economic Review*. 35:519-530.

11 The economic analysis here is related to the "tragedy of the commons" idea popularized by Garrett Hardin (Hardin, Garrett. 1968. "The Tragedy of the Commons." *Science.* 162:1243-1248), though Hardin's analysis strays from economic logic in critical ways. For good textbook discussions of efficient markets, market failures, and the classic work of Coase (Coase, Ronald H. 1960. "The Problem of Social Cost." *Journal of Law and Economics* 3:1-44), see, e.g., Landsburg, Steven E. 2005. *Price Theory & Applications,* 6e. Mason, OH: Thomson; or Rosen, Harvey S. 2005. *Public Finance,* 7th edition. Boston: McGraw-Hill. .

12 On the economics of establishing catch limits and creating property rights to marine assets, see, e.g., Costello, Christopher, Steven D. Gaines, and John Lynham. 2008. "Can Catch Shares Prevent Fisheries Collapse? *Science.* 321:1678-1681; and Deacon, Robert T. 2009. "Creating Marine Assets: Property Rights in Ocean Fisheries." *PERC Policy Series* PS-43.

13 This is not to say that international agreements will lead to good outcomes. Several factors suggest they will not, including information problems. First, no one knows the precise relationship between greenhouse gas emissions and climate change. Second, negotiators will not know the costs of reducing emissions—because those costs depend on dispersed information regarding individual-specific costs of what will be forgone in order to reduce emissions—say, by driving fewer miles in less comfortable (and/or more expensive) cars, living in smaller (and/or more expensively insulated) houses at less comfortable temperatures, etc. Third, historical experience shows that, even when the stakes are huge (as when negotiating to avoid or end warfare), efforts to negotiate may fail to avoid disasters. Thus, it is far from clear that international agreements will yield good outcomes.

14 On the economics of fuel economy mandates, see, e.g., Crandall, Robert W., and John D. Graham. 1989. "The Effect of Fuel Economy Standards on Automobile Safety." *Journal of Law and Economics.* 32:97-118; Austin, David, and Terry Dinan. 2005. "Clearing the Air: The Costs and Consequences of Higher CAFE Standards and Increased Gasoline Taxes." *Journal of Environmental Economics and Management.* 50:562-582.

15 Note that the idea of climate change, and in particular its effects on drought, creating a national security threat has received serious attention in the political arena. See, for example, CBS News. 2015. "Democratic debate transcript: Clinton, Sanders, O'Malley in Iowa." Available at http://www.cbsnews.com/news/democratic-debate-transcript-clinton-sanders-omalley-in-iowa/. Of course, such a view, if justified, indicates the absence of well-functioning markets: With secure property rights and good market mechanisms in place, droughts would lead to trade (thus reducing the harm done by the drought) rather than to warfare. This is not to suggest that setting up well-functioning markets in war zones or in otherwise failed states is feasible; indeed, our own research provides reason for pessimism. See, e.g., Fleck, Robert K., and F. Andrew Hanssen. 2013. "How Tyranny Paved the Way to Democracy: The Democratic Transition in Ancient Greece." *Journal of Law and Economics.* 56:389-416; Fleck, Robert K., and F. Andrew Hanssen. 2015. "The Foundations of Wealth-Enhancing Democracy: Aristotle, Lindahl, and Institutional Design in Ancient Greece." Working Paper, Clemson University. It is nevertheless worth remembering that whether or not scarcity leads to conflict is a function of institutions.

16 The potential gains from water markets are widely discussed in the economics literature, as is the environmental harm done by removing too much water from rivers, lakes, and groundwater sources; see, e.g., Glennon, Robert Jerome. 2002. *Water Follies: Groundwater Pumping and the Fate of America's Fresh Waters.* Washington, DC: Island Press; Scarborough, Brandon. 2010. "Environmental Water Markets: Restoring Streams Through Trade." *PERC Policy Series.* PS-46; and Libecap, Gary D. 2005. "Rescuing Water Markets: Lessons from Owens Valley." *PERC Policy Series.* PS-33. As we mentioned earlier, Adler examines the role for water markets in adaptive responses to climate change. Adler, Jonathan H. 2008. "Water Marketing as an Adaptive Response to the Threat of Climate Change." *Hamline Law Review.* 31:730; Adler, Jonathan H. 2012. "Water Rights, Markets, and Changing Ecological Conditions." *Environmental Law.* 42. Although a greater reliance on water markets has long had substantial support among economists, policymakers have often shown resistance to markets and, more generally, to price-based allocation systems. Nevertheless, the potential for using markets to mitigate the harm from climate change has been recognized by international organizations, including the United Nation's Intergovernmental Panel on Climate Change.

17 Lueck, Dean, and Jeffrey A. Michael. 2003. "Preemptive Habitat Destruction under the Endangered Species Act." *Journal of Law & Economics.* 46:27-60.

18 To understand why we expect this to be a major concern, it is important to recognize that the obstacles to monitoring from a distance what happens on land are severe. Indeed, one of the quintessential examples (perhaps the quintessential example) of private enterprise outperforming state-owned firms is the dominance of private farms, particularly family farms, over collective farms (e.g., Allen, Douglas W., and Dean Lueck. 2003. *The Nature of the Farm: Contracts, Risk and Organization in Agriculture.* Cambridge: MIT Press). The reason is that families working their own farms are, as a general rule, the best informed regarding their efforts and the output generated by their efforts. Setting up collective farms, and in doing so failing to recognize the importance of Hayek's critique, was sometimes catastrophic (e.g., Li, Wei, and Dennis Tao Yang. 2005. "The Great Leap Forward: Anatomy of a Central Planning Disaster." *Journal of Political Economy.* 113:840-877).

19 We are drawing on a substantial literature here. For a recent discussion, see, e.g., 't Sas-Rolfes, Michael, and Timothy Fitzgerald. 2013. "Can a Legal Horn Trade Save Rhinos?" PERC Working Paper.

20 Much of our focus in this paper is on the scope for useful government policy. We chose this focus because international agreements and nationwide policies tend to be the starting points for discussions of climate change. In practice, many potential environmental problems have been addressed successfully using informal agreements and private contracts. See, e.g., Anderson, Terry L. 1995. *Sovereign Nations or Reservations? An Economic History of American Indians.* San Francisco: Pacific Research Institute; Ostrom, Elinor. 2010. "Beyond Markets and States: Polycentric Governance of Complex Economic Systems." *American Economic Review.* 100:1–33.

21 An example is politicians opposed to closing home-district military bases with minimal value for national security; see, e.g., Defense Base Closure and Realignment Commission. 2005. "Report."

22 For a relevant review of the literature on fiscal federalism, see Oates, Wallace E. 1999. "An Essay on Fiscal Federalism." *Journal of Economic Literature.* 37:1120-49. For a review of the empirical literature on environmental federalism, see Millimet, Daniel L. 2014. "Environmental Federalism: A Survey of the Empirical Literature." *Case Western Reserve Law Review.* 64:1669-1757. To the extent that different jurisdictions learn from each other and/or compete with each other on the basis of public policy, there may be additional benefits from decentralization (e.g., Tiebout, Charles. 1956. "A Pure Theory of Local Expenditures." *Journal of Political Economy.* 64:416–24; Oates, Wallace E., and Robert M. Schwab. 1988. "Economic Competition Among Jurisdictions: Efficiency Enhancing or Distortion Inducing?" *Journal of Public Economics.* 35:333-54; Fleck, Robert K., and F. Andrew Hanssen. 2007. "Do Profits Promote Pollution? The Myth of the Environmental Race to the Bottom." *PERC Policy Series.* PS-41; Fleck, Robert K., and F. Andrew Hanssen. 2013. "When Voice Fails: Potential Exit as a Constraint on Government Quality." *International Review of Law and Economics.* 35:26-41).

23 Leal, Donald R. 1995. "Turning a Profit on Public Forests." *PERC Policy Series,* PS-4; Fretwell, Holly, and Shawn Regan. 2015. "Divided Lands: State vs. Federal Management in the West." *PERC Public Lands Report.*

ECOLOGICAL DYNAMISM, ECONOMIC DYNAMISM, AND CO-EVOLUTION:
Implications for Urban Land Use Planning

MARK PENNINGTON

Recent developments in ecological science have emphasized the dynamic character of ecological systems, focusing on the role of disequilibrium responses to both endogenous and exogenous change. This understanding of ecosystems mirrors approaches within economic theory that emphasize the role of competition not as a "stationary state" but as the driving force of adaptive socio-economic change. Combining these insights suggests that the relationships between human action and the natural world should be seen as a co-evolutionary process rather than one of separate development. Unfortunately, much public regulation continues to be dominated both by a static equilibrium perspective and by one that sees human action as a disruptive intervention in the natural world. Nowhere is this approach more evident than in the realm of urban land use planning, where cities are often represented as an external threat to the natural order.

This short chapter sketches the implications of a dynamic, co-evolutionary perspective for the institutional management of the relationship between cities and ecology. It begins by outlining the core concepts of disequilibrium and dynamic adaptation in both ecological and economic theory. It proceeds to highlight the deficiencies of current urban land use policies when seen from a co-evolutionary standpoint. It concludes by outlining some institutional implications for land use and urban policy that is appropriately informed by co-evolutionary principles.

DYNAMISM IN ECOLOGICAL AND ECONOMIC THEORY: TOWARD A CO-EVOLUTIONARY VIEW

Ecological Theory: From Equilibrium to Dynamism

Until relatively recently, the science of ecology was understood in terms of the equilibrium or steady-state properties of environmental systems. The natural balance of ecological processes was taken as a given, and the primary threat to the natural order was thought to arise from the exogenous intervention of human agents. Though these models recognized some role for change within nature itself, such changes were conceived as temporary shocks or destabilizers that would be corrected by equilibrating forces. Concepts such as "climax communities," for example, recognized that climatic changes or events including fire or volcanic eruptions could disrupt the natural order. But the assumption was that the process of ecological succession would over time return toward a natural equilibrium point. In this view, insofar as ecological systems failed to return to their natural state, it was primarily owing to human action *disrupting* the path to a natural balance.

Though these notions of steady state ecology and the balance of nature still hold considerable sway in the popular imagination, contemporary ecological science has now largely abandoned the equilibrium perspective. In place of this view is one that emphasizes a complex process of dynamic, evolutionary adaptation in response to both endogenous and exogenous changes. Some are beneficial to elements of the system, and others are harmful.[1] While this new understanding has the potential to harm some species and habitats, change is also what creates opportunities for new and better-adapted forms to evolve and grow. From the perspective of disequilibrium or dynamic ecological science, there is no baseline or natural state against which the condition of ecological systems can be judged. Neither is there any particular direction or "end point" toward which these systems are or should be headed. In essence, ecological systems are open-ended processes with no fixed start or ending point toward which they can be managed or directed.

Economic Theory: From Equilibrium to Dynamism

The shift toward recognition of disequilibrium and adaptation in ecological science has a parallel in economic theory. For much of the post-war period and still to some extent today, theorists in the neo-classical tradition have been concerned with defining the conditions where the forces of supply and demand can be perfectly equilibrated. Equilibrium models that posit the existence of perfectly informed agents operating in an institutional setting of zero transactions costs depict a world

of full efficiency where all possible gains from trade are exhausted. Models of this kind are often viewed as a rough description of economic reality, but full information equilibrium is also seen as a normative benchmark against which to *indict reality* and call for appropriate corrective measures. Thus, if market participants are thought to have less than perfect information (or a proxy for such information); if competition is "imperfect," with some agents exercising a greater influence on prices than others; and if transactions costs are positive; these are taken to be instances of "market failure" in need of corrective government interventions.

Though equilibrium theories continue to be influential in policy circles, critics such as Friedrich Hayek and, more recently, Vernon Smith have pointed out that these models ignore the dynamic processes through which knowledge of resource scarcities is acquired and communicated.[2] In this view, the relative strength of market-based systems compared to central planning and control is their greater capacity to generate dynamic adaptation in response to exogenous and endogenous change. Entrepreneurial action in markets is often of the "price-making" variety, where firms duel with one another, launch price-cutting campaigns, and fashion new products and forms of business organization. In conditions of uncertainty and highly imperfect knowledge, it is precisely the inequalities in bargaining power arising from entrepreneurial competition that help to spread dispersed knowledge about which business models to copy and which to avoid. As knowledge spreads throughout the market via price signals, the plans of producers and consumers are gradually adapted to each other. But the resultant "order" has no tendency towards a fixed equilibrium point, because there will be a constant stream of perturbations generated by new innovations and entrepreneurial discoveries that demand further adjustments. Neither can the results of this process be judged against an overall "social standard" of efficiency. A market economy does not maximize any one set of values. It is a process of exchange where the often-conflicting plans of agents with diverse standards are subject to mutual adjustment through the push and pull of contractual bargaining.

The Dynamics of Social Ecology

Both ecological and socio-economic processes can best be understood as examples of complex, adaptive systems that adjust dynamically to exogenous and endogenous changes. Exogenous changes in weather patterns may, for example, create opportunities for some species to thrive, where those less well adapted to the new circumstances may migrate or see a decline in their population. In markets, meanwhile, exogenous shocks such as meteorological events prompt adjustments through shifts in the relative prices of different goods. Endogenous changes within ecosystems may occur by way

of genetic mutations that result in some species becoming more or less adapted to their environment and hence creating opportunities and constraints for competitors. The equivalents of these genetic mutations in markets are entrepreneurial innovations in consumption, production, and organizational ideas, the least successful of which are weeded out though competition and profit-and-loss accounting.

The processes of evolution in the natural and human worlds do not occur separately but should be conceived as a process of *co-evolution.* Changes in ecological conditions affect resource scarcity in the human world, and human action can change environmental conditions, creating ecological niches and constraints for different species and habitats. Within this context, ecological theorists have increasingly questioned the wisdom of seeing human agency as separate from, or an "intervention" in, an otherwise "natural" order. There is no baseline equilibrium state against which to judge the effects of human activity. Even some of the oldest "natural" habitats and environments bear the imprint of human action in some form or another. It follows from a co-evolutionary standpoint that no one set of socio-ecological conditions can be considered more or less "natural" than another.[3] This is not to imply that no state of the world, whether in terms of aesthetic appeal or contribution to health and well-being, can be considered better, but that whatever criteria of "better" we use will not relate to how "natural" that state happens to be. Trade-offs between potentially conflicting values will always arise, but these cannot be judged in terms of their compatibility or incompatibility with an underlying "natural order."

A disequilibrium or dynamic perspective recognizes that adaptability and change are critical to the robustness of co-evolving socio-ecological systems. Change and variation, both natural and human-induced, create the space within which new and potentially better adapted forms of life emerge and grow. A system that does not generate variety will be prone to evolutionary "dead ends." Thus, protecting ecosystems from change by trying to zone them off from other natural or human influences is unlikely to improve the robustness of such systems any more than protectionism in markets helps the robustness of firms. A framework allowing for competing responses to ecological and human-induced change cannot guarantee beneficial outcomes, but it may increase the possibility for people to learn about the trade-offs associated with different socio-ecological inter-actions and to adapt to the new possibilities that arise as people make these very trade-offs. It is important, therefore, to avoid the creation of one-size-fits-all regimes that thwart competition and experimentation. The institutional environment should allow a variety of solutions rather than impose a single conception of "what is right for nature" or what the "right trade-offs" are for humans to make.

Though direct planning at the *micro-scale* has an important role to play, such planning at the macro-scale is to be avoided because planners have no way of knowing in what direction to move the system as a whole. Priority should be given to indirect forms of coordination that communicate information from the many dispersed nodes that constitute the socio-ecological order. Signaling mechanisms, such as prices that communicate shifting trade-offs via movements in supply and demand conditions, or changes in tax revenues that communicate movements of people and resources across jurisdictions, may enable people to adapt to both the intended and unintended opportunities and constraints emergent from the decisions of countless agents.

LAND USE AND URBAN POLICY IN CO-EVOLUTIONARY PERSPECTIVE

Seen from the standpoint sketched above, far too much environmental policy fails to take into account the dynamic nature of human-ecological relations and the conflicting trade-offs generated by these interactions. One area where this tendency is especially pronounced is urban land use planning. Many land use policies have been predicated on the notion that nature is fundamentally separate from the city—with cities seen as threats or intrusions into an otherwise settled equilibrium state. Consider in this context the "urban containment" policies that have been pursued in many nations. In the United Kingdom, for example, throughout the entire post-war period land use policy has been dedicated to limiting urban expansion with the intention of keeping tight boundaries between urban areas and the surrounding countryside. In the recent past, these policies have received support from a "deep green" standpoint that views urban development as a threat to the stock of critical "natural capital." According to this view, transfers of land into residential and other urban uses represent a net loss of irreplaceable natural assets that should be avoided at all costs.

From a co-evolutionary standpoint, cities should not necessarily be seen as "bad" for "the environment." Human beings and their activities have always been bound up with ecological systems irrespective of whether these activities have been rural or urban. What is clear, however, is that the productivity gains and technological developments that arise when large numbers of people are clustered in cities—while they may have some negative consequences—can help reduce the impact of human activity outside of urban areas. Improvements in agricultural machinery, for example, have been stimulated by the size of urban markets and facilitated by technological expertise that congregates in cities. These improvements have enabled much higher levels of food production from a smaller amount of land. Were it not for the policies of agricultural subsidization that often lock land into farming, these improvements

might enable a significant amount of "rural" land to be withdrawn from production altogether, creating space for alternative land uses. Policies that block the development of cities on the grounds that they are in some sense "less natural" or "bad" for the environment therefore should be questioned.

In the British case, for example, the countryside that is "protected" from urban development is not remotely a "natural" phenomenon, and its qualities vary enormously. On the one hand, some of the most prized rural landscapes in the designated national parks are in fact farmed landscapes where practices such as sheep farming and grouse hunting have created a more diverse set of habitats than might have prevailed had they been devoid of human interference. On the other hand, a large proportion of the land that is directly protected from urban development is devoted to highly subsidized farming practices that have created agricultural monocultures far less supportive of bio-diversity than the suburban residential gardens that might replace them if a less hostile attitude to new urban development were to emerge. Indeed, one of the unintended consequences of urban containment policies in the United Kingdom has been an increasing loss of gardens and wooded areas within urban areas as developers scramble to build on the few plots of land that have been deemed by planners to be of lesser ecological significance.[4]

None of the above implies that urban growth can be considered objectively good from an environmental point of view either. Many people may consider a rural form of living superior from an aesthetic standpoint and would willingly accept lower material living standards as a price worth paying to avoid the costs of urbanization. There is a strong case for any balanced land use policy to ensure that open spaces and scenic vistas should be maintained because of their contribution to quality of life—though it must be recognized that such landscapes are not the result of "pristine" natural processes. What matters in this context is that *neither* a rural nor an urban pattern of human settlement has any claim to be one that is more in tune with nature. Deciding in favor of more or less urbanization should be recognized as a conflict between various human values. The realization of that fact will create a different set of opportunities and constraints, both for human beings and for elements of the environmental systems with which they interact—but none of these has any unique claim to ecological virtue. These conflicts point toward a case for allowing the trade-offs and value-judgments at their heart to be made in different ways by different people. Increasing the variety of decisions rather than ruling in favor of any one trade-off will increase the scope for learning. It will also facilitate more rapid adaptation to the unintended or unexpected benefits and costs that follow from the decisions people take, and it will reduce the probability of becoming locked in to any single path.

A similar set of issues arises in debates over the question of what has come to be known as "sustainable urban form." Even among those who recognize that cities are not necessarily "bad" for the environment, urban land use policy has nonetheless been formulated on the assumption that *particular* settlement patterns should be promoted because they have a less pronounced "ecological footprint" than others. In discussions over climate change, for example, it has been suggested that land use planning policies should promote higher-density urban settlements because they reduce energy use, commuting lengths, and the need for car-based travel, relative to the low-density style "sprawl" that is typical of many American cities. According to this perspective, higher-density cities can contribute to a reduction in CO_2 emissions by reducing the need for automobile use as people can access a wider range of services within a smaller surface area. Others claim a whole host of additional benefits from higher density living, such as higher energy efficiency and lower heating bills.

From a co-evolutionary standpoint, the problems with the above line of thinking are two-fold. First, there is the assumption that there is a natural climatic state that would prevail absent human intervention, when in fact climate is subject to considerable natural variation. This is not to deny that anthropogenic impacts associated with the emission of CO_2 and other greenhouse gases may contribute to, or exacerbate these changes. What it does suggest, however, is that it is pointless to speak of a natural climatic state as if this is somehow "optimal" from an ecological standpoint. Different climatic conditions create different sets of opportunities and constraints for both humans and non-humans, none of which should necessarily be considered "optimal" from some global point of view. Of course, different parts of the world may be affected for better or worse by climate changes, and this possibility creates conflicts between people which are a legitimate cause for concern, both in terms of their economic dimension and with regard to distributive fairness. Ultimately, however, any resolution of these conflicts cannot be judged against an assumption that absent human intervention climate would not be changing and that such natural changes *would not cause a different set of conflicts.*

Second, recognizing that CO_2 emissions are a legitimate policy concern, it does not follow that any one form of urban settlement should be targeted as a way of reducing emissions. Urban areas are themselves examples of dynamic, evolving systems where the range of inter-connected variables that reflect the shifting choices of residents and businesses in response to changing socio-economic conditions may be far too complex for policy-makers and planners to comprehend. Within this context, it is not at all obvious that higher densities, whether now or in the future, would help to lower emissions. While lower densities may contribute to increased travel to work

distances, in other circumstances there is evidence that the growing decentralization of employment centers toward suburban areas may actually lower journey times and emissions.[5] Moreover, even if it is the case that with *current* technology higher density development produces fewer emissions, this may cease to be so in the wake of future technological evolution. Widespread adoption of the electric car and new forms of employment relationship arising from the further growth of online technologies may, for example, make a much less emissions-intensive form of suburbanization feasible. Yet the opportunities that this might afford will be foreclosed by policy measures that deliberately seek to favor higher densities. There may, of course, be aesthetic reasons why people prefer higher- to lower-density living, and vice versa, but the trade-offs people make in this regard should not be judged from a static perspective that views one form of development as *inherently* unfavorable from an emissions-related standpoint.

POLICY IMPLICATIONS FOR URBAN LAND USE PLANNING

In view of the preceding remarks, adopting a co-evolutionary perspective implies the need for an open-ended and experimental approach to urban land use planning of a sort that is hard to find in a context where one-size fits all thinking tends to dominate.

The first principle of a land use policy informed by co-evolutionary thinking should be to strive for *neutrality* between different land use patterns. If no particular configuration of land uses, whether rural or urban, has any unique claim to be more or less natural or "good" for the environment, and if variation and competition are important in promoting adaptation to shifting conditions, then land use policies should not seek to promote any particular path. In the British context, for example, this would imply abandoning the commitment to urban containment and "green belts" in favor of a framework that is neither hostile to urban growth *per se* nor favors a high-density form of growth. Opportunities that might arise for low-density development that combine residences with woodland and open space have been largely shut down by a regime that aims for a rigid separation between town and country and that shoehorns new buildings into smaller and smaller plots. Within this context, the "green belts" enforced around many of the major cities may actually have contributed to increases in travel-to-work times, congestion, and subsequent pollution as development that might have occurred on the urban fringe has been pushed outward, miles beyond the green belts over which people must then commute.[6] It is ironic that a country where one of the founders of the town planning movement, Ebenezer Howard, argued for a form of development that brought the "town into the country" and "the country into the town" should have institutionalized a framework that has made experiments with such ideas next to impossible.

In the U.S. context, by contrast, a more neutral land use policy would imply moving away from a regime that has historically promoted low-density sprawl. The combination of large lot zoning ordinances and federal subsidies to road construction such as the interstate highway system has promoted a highly dispersed and energy-intensive form of growth, which has had many negative environmental consequences. Recognizing the existence of such negative consequences, however, does not imply that policy should seek to deliberately favor high-density settlements instead. As noted earlier, that a particular pattern of development may have been associated with negative external effects in the past does not imply that this will be the case in the future given ongoing shifts in technology, employment, and lifestyle patterns.

A second implication arising from the co-evolutionary perspective is to recognize that trade-offs and value conflicts are inevitable to land use planning decisions and that these conflicts cannot be decided by an appeal to what is "better for nature." The notion that there is "one best way" allows policymakers, regulators, and activists to depict some land use patterns as inherently damaging when it would be more appropriate to recognize that where there are conflicting value judgments, the issue is really one of "who is allowed to damage whom."[7] It is not necessarily the case that those proposing new residential or commercial development are imposing costs on those wanting to preserve nature, any more than those who wish to preserve nature are imposing costs on those who wish to see urban development. Who is deemed to be imposing costs is really a question of who has the right not to be damaged and whether they wish to cede such a right in exchange for compensation. The key, therefore, is not to look for a framework that decides what the best decision is, but to specify who has the right to take the relevant decision within a particular domain and to whom any compensation is owed. If rights are specified in this way then the parties concerned will have incentive to take into account the values that other agents place on the rights at issue.

Seen in this light, there is a strong case in favor of property rights and contractual approaches to land use planning issues rather than reliance on direct government regulation to allow the holders of different values the greatest scope to bargain toward their own solutions and communicate opportunities for gains from trade. Where possible, such property rights should reside with individuals and voluntary associations. Attempts to impose regulatory solutions from the center are unlikely to match the dispersed knowledge of the trade-offs associated with particular land uses accessible to those closest to them. In addition, a process that allows different property owners to arrive at different decisions may generate more knowledge about the potential costs and benefits associated with alternative models of land use "regulation." Many environmental goods are not completely indivisible, and their supply can vary across

different territorial zones, thus enabling them to be packaged as "club goods" by proprietary residential communities. Competition between different packages of land use controls would facilitate a process of adaptive learning. Competitive decentralization is appropriate not only because it offers more scope for people with varying aesthetic tastes to realize their values but also because it allows for greater responsiveness to change as the effects of past decisions emerge. Though these benefits can be generated to some extent by more localized forms of government regulation, such as those found in federal political systems like the United States, in many cases even local government regulation works to stifle decision-making by potentially smaller geographical units.

Finally, insofar as decentralized contractual approaches to environmental conflicts are impractical, it is better to encourage behavioral changes via signaling mechanisms such as pollution taxes or congestion charging schemes, rather than attempt to directly control land use patterns. From an informational viewpoint, decentralized signaling generated through a bottom-up process of bargaining in markets is preferable. But where this cannot be organized, centrally imposed signals may be required as a second-best option. One of the advantages of pollution taxes is that they provide signals to individuals and organizations that they should change their behavior in response to environmental costs and provide a financial incentive for them to do so. They do not, however, attempt to specify the nature of the changes concerned, leaving ample room for actors to experiment with different ways of reducing costs or finding substitutes. In a land use context, this is crucial because the discovery procedure that might arise from allowing different groupings of people, whether property owners or municipalities, to experiment with alternative packages would be squashed by any attempt to achieve reductions in pollution or other environmental costs by forcing people into a single pattern of living.

CONCLUSION

I have sought in this paper to outline an approach to the regulation of urban land use that is informed by co-evolutionary principles. With its focus on dynamic processes and the complex interaction between humanity and the natural world, this perspective is unlikely to inspire those who believe they can identify which particular land use decisions are "good" both from a human and from an ecological standpoint. For those who appreciate that we do not know how best to mix humanity and nature, however, it may be inspiring to embrace change in the recognition that learning and adaptation in the face of uncertainty are the keys to survival.

ENDNOTES

1 Botkin, Daniel B. 2012. *The Moon in the Nautilus Shell: Discordant Harmonies Reconsidered*, New York: Oxford University Press.
2 Smith, Vernon. 2009. *Rationality and Economics*, Cambridge: Cambridge University Press; Hayek, F.A. 1978. Competition as a Discovery Procedure, in Hayek, F.A. (1978) *New Studies in Politics, Economics and the History of Ideas*, London: Routledge.
3 Botkin, Daniel B. 2012. *The Moon in the Nautilus Shell: Discordant Harmonies Reconsidered*, New York: Oxford University Press.
4 See, e.g., Evans, A., and O. Hartwich. 2006. *Better Homes, Greener Cities*, London: Policy Exchange.
5 See, e.g., Gordon, P., and H.W. Richardson. 1997. Are Compact Cities a Desirable Planning Goal? *Journal of the American Planning Association*. 63 (1): 95-107; Bogart, W. 2006. *Don't Call it Sprawl*, Cambridge: Cambridge University Press.
6 Pennington, Mark. 2002. *Liberating the Land*. London: Institute of Economic Affairs.
7 See Coase, Ronald H. 1960. The Problem of Social Cost. *Journal of Law & Economics*. 3: 1-44.

DYNAMIC ENVIRONMENTALISM AND ADAPTIVE MANAGEMENT:
Legal Obstacles and Opportunities

JONATHAN H. ADLER

"Stationarity is dead." So declared the authors of a widely cited *Science* article on water management.[1] In the 21st Century, resource managers can no longer operate under the assumption that "natural systems fluctuate within an unchanging envelope of variability."[2] Long-standing assumptions about the operation of natural systems would have to be revised due to climate change and other anthropogenic influences on environmental systems. Resource decisions could no longer be guided by models that rely upon the past to predict the future. The inevitable and-yet-uncertain ecological changes wrought by climate change would demand the development of more adaptive and resilient approaches to environmental management.

Climate change brought the need for more adaptive approaches to environmental management to the forefront of environmental policy discussions. Yet the emerging reality of climate change is not the only reason more dynamic and resilient approaches to environmental protection are necessary. Stationarity was never a sound premise for ecological management. Ecologists have long recognized the dynamic nature of environmental systems, but their counsel had not been heeded. If the need for more adaptive and resilient approaches to environmental management has become urgent, it is perhaps because the need was ignored for so long. If stationarity is dead, perhaps it never existed.

Most of today's environmental laws and programs are based upon outmoded assumptions about the relative stability of natural systems when free of human interference. Scientists have understood for decades that ecosystems are anything but stable. To the contrary, ecosystems are incredibly dynamic and change over time due to both internal and external forces. An ecosystem is the "paradigmatic complex system," exhibiting dynamic and discontinuous behavior.[3] To be effective, therefore, environmental management systems must themselves be sufficiently adaptive.

Noted ecologist Daniel Botkin argues that "solving our environmental problems requires a new perspective" of environmental concerns that incorporates contemporary scientific understandings and embraces humanity's role in environmental management.[4] Recognizing a new perspective is but the first step, however. There is also a need to identify how this perspective can inform environmental policy, not just on the ground but in the very institutional architecture of environmental law and management. Then comes the really hard part, for even if it is possible to conceive of how environmental management should proceed, it may be devilishly difficult to put such ideas into practice. Old habits die hard. Legal and institutional norms die even harder.

Accounting for dynamic nature may require revisiting conventional notions of environmental protection and the underpinnings of environmental law and management. This presents an enormous challenge. Conventional approaches to environmental management may be unable to heed dynamic environmentalism's call so long as they are confined by contemporary notions of fair administrative process, whether such constraints are the product of norms, statutes or even the Constitution. The challenge of recognizing dynamic nature as such implicates the very foundations of contemporary environmental law and policy.

Part I of this chapter provides a brief overview of how contemporary ecological science has upset traditional notions of ecology, emphasizing the dynamic nature of natural systems. Part II explains how the dominant approach to environmental protection, as constrained as it is to begin with, is a particularly poor fit for the management and protection of dynamic ecological systems. Part III provides a brief overview of "adaptive management," the dominant management approach suggested to accommodate the dynamic nature of natural systems. Part IV then identifies some of the obstacles to (and opportunities for) adaptive management in environmental law. The aim here is to identify potential avenues for further study and analysis more than to define or delimit the prospects for adaptive management in environmental law.

DYNAMIC ENVIRONMENTALISM

Contemporary environmental law embodies archaic assumptions about the natural world. Through the middle of the 20th century, "the predominant theories in ecology either presumed or had as a necessary consequence a very strict concept of a highly structured, ordered, and regulated, steady-state ecosystem."[5] Under this view, nature naturally tended toward an equilibrium state—a "balance"—absent human interference.[6] Maintaining and protecting this balance was, in this view, ecologically superior and ultimately better for humanity as well.

Contemporary ecological science has "dismissed" these theories and the accompanying notion of a "balance of nature."[7] Notions such as Aldo Leopold's famous "land ethic" are based upon an "equilibrium paradigm" that has unraveled under examination.[8] In Wallace Kaufman's eloquent formulation, the equilibrium paradigm of ecology made for "good poetry but bad science."[9] Leopold's land ethic provided the foundation for an environmental philosophy that ultimately had little to do with ecology. However normatively or aesthetically attractive such conceptions of nature may be, and however much such conceptions facilitate the development of legal rules governing human interactions with nature, they lack a meaningful grounding in contemporary ecological science.

The architecture of contemporary environmental law was erected when the equilibrium paradigm still held sway. As a consequence, the edifice of environmental law sits on an unstable foundation. The equilibrium paradigm justified "a wide range of prohibitions on human activities that alter 'natural' land and water systems" and other environmental restrictions on productive activity.[10] Yet this paradigm has not "been rejected in ecology and replaced with a complex, stochastic nonequilibrium one."[11] As Botkin explains,

> we had approached environmental problems from the wrong set of assumptions, assumptions deeply rooted in our civilization and culture. These assumptions, considered at the time to be scientific, were in fact heavily based on ancient, pre-scientific myths about nature.[12]

Myth or not, these conceptions heavily influenced the contours of environmental law and regulation.

Contemporary ecological science embraces a more dynamic understanding of the natural world and rejects the idea of a "balance of nature" that would exist but for human interference. Two insights about natural systems are essential to the

contemporary view. First is the recognition that ecological systems are always in flux. There is no true "natural" state for ecosystems.[13] No "climax" or endpoint toward which ecosystems move or evolve if left undisturbed. Second, in this day and age, there is no part of the globe in which ecosystems exist wholly apart from human influence. As noted environmental historian William Cronon observed, "the natural world is far more dynamic, far more changeable, and far more entangled with human history than popular beliefs about 'the balance of nature' have typically acknowledged."[14]

The idea of a balance of nature still infects much environmental discourse, and remains embedded into much environmental law and policy, but scientists recognize that ecosystems are not static systems and do not trend toward equilibria. They are complex, dynamic systems that are always changing and evolving and that even exhibit a degree of chaotic flux; "ecosystems fluctuate without equilibrium and beyond the capabilities of humans to assess and control them without error."[15] Like social and market-based economic systems, ecological systems are "complex, dynamic, and subject to abrupt and unpredictable change."[16]

Even those who once embraced the static view of ecosystems now recognize that "an ecosystem is a thermodynamically open, far from equilibrium system."[17] Botkin states it well: "Nature changes over essentially all time scales, and in at least some cases these changes are necessary for the persistence of life, because life is adapted to them and depends on them."[18] Further, "nature is not a constant, it is not like a single tone held indefinitely, but is composed of patterns that themselves change, like a melody played against random background noises."[19]

Equally important to the idea that ecosystems are inherently dynamic, complex, and adaptive systems is the recognition that nature does not exist apart from humanity, and humanity inevitably influences the course and operation of natural systems. Human beings have been altering the landscape and altering the operation of ecosystems for centuries. Whether such a degree of influence is desirable, it is unavoidable, for "there is no longer any part of the Earth that is untouched by our actions in some way."[20] "Nature," as an ideal, is over.

Consider the concept of wilderness. The federal Wilderness Act "recognize[s]" wilderness as "an area where the earth and its community of life are untrammeled by man, where man himself is a visitor who does not remain."[21] It further defines wilderness as, *inter alia*,

> an area of undeveloped Federal land retaining its primeval character and influence, without permanent improvements or human habitation, which is protected and managed so as to preserve its natural conditions and which

> generally appears to have been affected primarily by the forces of nature, with the imprint of man's work substantially unnoticeable.

Yet whether the "imprint" of human activity is "noticeable," it is there. However wild and untouched by human hands a given landscape may appear, it is not truly primeval or "natural." The idea of a wilderness as a natural area completely free from human influence is as fantastical as a unicorn.

The idea of wilderness is really something in our minds, not something that exists out in nature. Wilderness, writes Cronon, "is not quite what it seems. Far from being the one place on earth that stands apart from humanity, it is quite profoundly a human creation."[22] The idea of "wilderness" as it has manifested itself in the United States in particular, has been quite unnatural, and has denied the very humanity of this continent's first human inhabitants. That is, the "natural" state of many ecosystems is one that was heavily influenced by Native Americans. Yet "wilderness serves as the unexamined foundation on which many of the quasi-religious values of modern environmentalism rest."[23] It is an idea that, left unexamined, "poses a serious threat" to responsible environmental management.

In practice, wilderness today consists of those areas that people have decided to cordon off, separate from the rest of nature, and "protect" from additional human intrusion. Yet the very act of defining and demarcating such lands, and treating them differently from other lands nearby, alters them. True "wilderness", in the sense of places free from human influence of any kind, does not exist.[24] "Wilderness is managed land, protected by three-hundred page manuals specifying what can and cannot be done on it."[25] If natural parks and designated wilderness areas represent what is natural, "then nature is synonymous with human intervention," for it is only human intervention that keeps such places as they are.[26] Designated wilderness areas are, in this respect, merely the most conspicuous example of a wider phenomenon.

Contemporary ecology has embraced the dynamic view of nature and recognizes the pervasiveness of human influence on natural systems. Even steadfast proponents of the equilibrium model have recanted.[27] Yet there is relatively little evidence of contemporary understanding in contemporary environmental policy. The environmental laws and regulations on the books are "out of date."[28] As Botkin observes, "whether or not environmental scientists know about geological time and evolutionary biology, their policies ignore them."[29] Too often environmental policy and protection measures are based upon "nonrational, ideological beliefs instead of rationally derived facts in harmony with modern understanding of the environment."[30] Yet, many of the most pressing environmental problems today "exhibit the hallmark characteristics of

complex adaptive systems."[31] As Professor Ruhl explains, "[t]heir behavior emanates from a multitude of diverse, dispersed sources responding to coevolving interactions, feedback loops, and nonlinear cause and effect properties."[32]

The dynamic nature of natural systems is no longer disputed, but it is not embodied in contemporary environmental laws. Federal environmental law, in particular, incorporates and relies upon outdated conceptions of nature and environmental problems, often at the expense of more effective environmental protection. As Botkin counsels,"[t]he idea that change is natural and the failure to accept it have created problems in natural resource management and have led to destructive, undesirable results."[33] Existing environmental management efforts are hampered by their lack of fit with the nature of the environment they seek to manage.

STATIC REGULATION

The dominant approach to environmental protection in the United States has been a top-down, administrative regulatory model.[34] Though often adorned with symbolic flexibility or market-oriented ornamentation, the system retains a relatively rigid and centralized structure at its core. Flexibility is rarely more than interstitial or on the margin. Existing environmental laws also implicitly, and at times explicitly, presume an antiquated, static equilibrium model of natural systems. This is particularly true of those statutes which seek to conserve species or otherwise manage living natural resources.[35] Yet for all of its faults, the conventional administrative regulatory model seems entrenched. Writes Botkin:

> If you ask ecologists whether nature is always constant, they will always say "No, of course not." But if you ask them to write down a policy for biological conservation or any kind of environmental management, they will almost always write down a steady-state solution.[36]

The conventional administrative regulatory model of environmental protection is capable of achieving some environmental gains, and it has.[37] Yet this approach experiences severely diminishing marginal returns once the "low-hanging fruit" are picked.[38] It is relatively rigid and mal-adaptive, and is increasingly unable to generate environmental gains at an acceptable cost. As Richard Stewart observes, centralized environmental regulation is inherently limited by "the inability of central planners to gather and process the information needed to write directives appropriately responsive to the diverse and changing conditions of different economic actors, and the failure of central planning commands to provide the necessary incentives and flexibility

for environmentally and economically beneficial innovation."[39] Adopting market-based reforms helps on the margin, but only on the margin so long as environmental protection is dominated and constrained by a top-down administrative regulatory model.[40]

The dynamic, complex environmental problems that remain are particularly difficult to address through traditional regulatory approaches because "there are no readily available targets for the prescriptions and, even worse, we have no idea what response the system would exhibit to any particular command."[41] Many existing environmental laws impose binary decisions on agencies—either a species is endangered or it is not, a level of pollution may be anticipated to endanger health or it is not, etc. Once such determinations are made, specific regulatory consequences follow automatically. If a species is endangered, it triggers the regulatory requirements of the Endangered Species Act (ESA).[42] If a pollutant may be reasonably anticipated to threaten health and welfare, certain types of emission controls must be imposed.[43] And so on. Meaningful agency discretion only comes after the initial determination is made.

This regulatory approach was adopted, in part, because Congress was wary of leaving agencies more discretion about how to handle certain types of environmental problems for fear that agencies would shirk their duties or devote resources elsewhere. Yet a consequence of this approach is that agencies do not have as much flexibility or discretion as might be desirable to match specific policy measures with specific problems, and abandon the largely "one-size-fits-all" approach embodied in much federal environmental law. Many environmental laws leave little room for marginal analysis or comparative assessment of alternative policy measures.

Markets are also complex, adaptive, and dynamic systems. Just as it is not always possible to predict the ecological consequences of specific environmental management measures, it is often not possible to predict the market effects of such measures, or—perhaps more importantly—how such interventions will affect the interplay of economic decisions and environmental outcomes. Market actors will often respond to regulatory constraints in unanticipated ways, with unforeseen (and perhaps undesirable) effects.

Examples of unintended, and often unanticipated, effects from environmental regulatory interventions are legion.[44]

- Restricting a private landowner's ability to cut pine trees on his land today may preserve those trees as habitat for red-cockaded woodpeckers today, but it may also discourage other landowners from allowing their trees to grow long enough to become woodpecker habitat in the future.[45]

- Banning the use of ethylene dibromide (EDB), a pesticide, due to concerns about its carcinogenicity reduces human exposure to one potential health threat, but may result in the increased production of natural compounds, such as aflatoxin, that pose an equal, if not greater, threat to human health.[46]
- Mandating emission reductions of all ozone precursors seems like an effective means of reducing tropospheric ozone pollution (smog) until one learns that ozone formation is a function of the ratio of such pollutants in the atmosphere, and not merely their absolute level, such that emission reductions can, in some instances, increase ambient ozone levels.[47]
- Requiring oil companies to increase oxygen levels in gasoline may reduce carbon monoxide emissions—at least until automakers are required to install emission-control systems that provide the same benefit—but it may also encourage the use of a fuel additive (methyl tertiary butyl ether, aka MTBE) that causes substantial groundwater pollution throughout the United States.[4]
- Requiring the use of ethanol in gasoline may, by some account, reduce the life-cycle carbon intensity of transportation fuels, but may also increase pressures on fresh water supplies, encourage the displacement of waterfowl habitat, and increase food prices.[49]

If it were not difficult enough to anticipate the ecological effects of human activities, including environmental measures, it is also necessary to anticipate how such measures will influence human activity, and how such activity feeds back into the system and generates additional environmental effects. Fully accounting for all this information so as to predict the likely consequences of regulatory interventions is tremendously difficult.

Environmental policy also often proceeds as if the answers to many questions are purely scientific. Yet the lack of a true environmental nature—of a natural state of the environment that would exist through time were it not for human interference—means that environmental management necessarily involves making choices about what sort of environmental resources and amenities should be protected, preserved, enhanced, or conserved. Further, as Botkin notes, "choosing what to do is not a search for the single 'true' condition of nature. Rather it is a design problem."[50] Environmental management decisions necessarily involve trade-offs, and often these trade-offs are between incommensurable things. Should there be more wolves in Yellowstone National Park, or more elk? More elk or more Aspen trees? As Cronon notes, "we face the dilemma of deciding whether to clean up waste dumps even if doing so might endanger the creatures that now make their homes there."[51]

The existence of such trade-offs does not mean that there are no "right" answers. Normative disagreement remains possible. The implication is only that we cannot resolve such debates by resorting to what is "natural" or dictated by science.[52] While scientific and technical expertise may—indeed, must—inform environmental decision-making, it cannot tell us what to do. Ecological research may help us identify the likely consequences of one course of action or another, and help to document the effects of such decisions after they have been made, but it cannot substitute for the inherently value-based decisions that must be made about how environmental policy should proceed. And if such decisions are to be made through a relatively centralized administrative apparatus—as most environmental policy decisions are made today—then environmental management will be political management.

ADAPTIVE MANAGEMENT

One response to the contemporary ecological understanding is the adoption of "adaptive management." Though much discussed, it is still relatively underutilized in environmental management.[53] Although some federal agencies have sought to implement some forms of adaptive management—or what some might call "adaptive management-lite"[54]—there is not much to show for it; "its implementation has failed more often than not."[55] As Professors Craig and Ruhl report, "Putting adaptive management into practice has proven far more difficult than its early theorists expected."[56]

Different commentators have put forward slightly different formulations of what adaptive management requires, but there are some common threads. According to Professor Ruhl, "The 'essence' of adaptive management [theory is] an iterative, incremental, decision-making process build around a continuous process of monitoring the effects of decisions and adjusting decisions accordingly."[57] The National Research Council fleshed out what adaptive management requires:

> The concept of adaptive management promotes the notion that management policies should be flexible and should incorporate new information as it becomes available. New management actions should build upon the results of previous experiments in an iterative process. It stresses the continuous use of scientific information and monitoring to help organizations and policies change appropriately to achieve specific environmental and social objectives.[58]

Adaptive management requires agencies to emphasize the discovery and acquisition of information through ongoing monitoring and evaluation of existing management decisions against a reliable metric that can be fed back through the

policy-making and management process so that mid-course corrections can be made, and then made again as information and circumstances require. In this sense, adaptive management also favors ongoing environmental assessments over *ex ante*, predictive examinations of expected environmental impacts, such as those required under NEPA.[59] Whereas the NEPA process operates under the tacit assumption that an agency can with enough effort, identify all relevant information about the environmental consequences of a potential course of action *before* that action is undertaken, adaptive management recognizes that much relevant information will not be known until after management decisions have been made and things are underway. Thus adaptive management calls for regular reevaluation and adjustment to account for what has been learned.[60]

Adaptive management approaches cannot be static. Rather, they must evolve in response to new information and experience. As Professor Tarlock notes, "Adaptive management . . . is premised on the assumption that management strategies should change in response to new scientific information. All resource management is an ongoing experiment."[61] Yet adaptive management is more than simple trial and error or contingency planning. It requires a meaningfully structured process than ensures iterative consideration of the problem to be solved, measurements of success at solving the problem, evaluation of existing measures, and modification of ongoing measures in response to new information and discovery.[62]

Although adaptive management seems quite alien to how most government agencies operate most of the time, it is not all that new. As Professor Ruhl comments, "nothing about this is startlingly new or unusual as a general means of decision-making—business implement adaptive management all the time, or they perish."[63] Successful firms in competitive industries routinely adapt to changing market conditions and new information, lest they fall behind their competition. What is new is expecting administrative agencies to behave in this fashion, at least in those contexts in which adaptive management is possible and desirable. Applied in this context, it is somewhat revolutionary, but it is also necessary. As Professors Craig and Ruhl advise:

> adaptive management is not a panacea for the administrative state, yet it is difficult to conceive how regulation can function effectively in the future without making true adaptive management available to agencies in contexts where it is likely to be useful.[64]

Unlike private firms that may adopt adaptive management techniques in order to maintain or enhance their position in a competitive marketplace, government

agencies have little incentive to innovate or adapt in response to a changing environment, as their survival does not depend upon it.

CONSTRAINTS AND OPPORTUNITIES

There are opportunities to improve the adaptive and responsive nature of environmental protection efforts in the United States, but such opportunities are inherently limited so long as environmental protection is dominated by a relatively centralized, top-down administrative structure. Conventional regulatory and administrative systems are not particularly adaptive or responsive to changing environmental conditions, or even to changed understanding of environmental needs. Bureaucratic systems change slowly and are rarely forward looking. This is due, in part, to legal constraints, but also due to the nature of monopolistic bureaucratic systems, and the inherent information limitations that hamper the ability of such systems to acquire and account for relevant information—let alone to encourage the discovery of such information in the first place. Bureaucratic structures are resistant to change, and this is particularly true where such resistance poses few risks. Regulatory agencies do not go out of business when they fail to adapt. To the contrary, a failing agency is more likely to see a budget increase than it is to close its doors. The feedback mechanisms that force private firms to be adaptive and responsive to changing market conditions are largely absent from the administrative state.

If adaptive management is to be successful, there must be careful consideration of how to integrate it into the modern administrative state. While many have advocated greater reliance upon adaptive management, "very few commentators from science or law are asking whether it can succeed in the conventional administrative law system."[65] Those that have considered such questions are often quite skeptical that adaptive management can be grafted onto existing agency processes to any meaningful degree. The obstacles are both practical and political. "Institutional structures and arrangements, in particular, have repeatedly been fingered as key impediments to realizing the promise of adaptive management," observes Professor Doremus.[66] Yet so are the practical political realities that substantial change in agency operations will threaten the balance of interest group power and potentially deprive some groups of their ability to influence environmental policy decisions. In some manifestations, efforts to adopt adaptive management could even chafe against constitutional constraints.

What follows is a partial list and exploration of some of the obstacles to the adoption of adaptive management in federal environmental policy and potential reform opportunities worthy of further exploration.

Resource Constraints

Environmental agencies face substantial resource constraints. Existing environmental laws impose more obligations on environmental agencies than Congress appropriates the funds to carry out. Neither the money nor person-hours exist to do what Congress has called upon these agencies to do.

Adaptive management, with its requirement of iterative evaluation and course correction, is far more resource intensive than conventional, top down regulatory strategies. Where agencies have sought to adopt adaptive management, even what some would consider "adaptive management lite," they have chafed against the additional demands this approach places upon agency resources, in particular the "additional burdens of monitoring and evaluation."[67] Unless the legislative authorization of adaptive management is accompanied by an increase in resources, it is unlikely that many agencies will rush to implement such approaches, at least not in any meaningful respect. Agencies may well use the mantra of adaptive management to justify a greater degree of discretion where desired, but it takes far more than the embrace of agency discretion to make adaptive management work.

Adaptive management not only places greater demands on financial and personnel resources, it also demands more information. The knowledge problem has always constrained environmental regulation.[68] Existing environmental laws do a poor job of encouraging the development and discovery of the environmental information, and knowledge upon which successful environmental management depends.[69] Once one acknowledges the dynamic nature of natural systems, this problem is multiplied many times over. If nature cannot be relied upon to guide itself to some ideal, natural state, environmental managers must know even more about the systems they seek to conserve and protect. And yet, "in most areas, we lack even the most basic information on the condition of nature."[70] Implementing adaptive management, if it is to be effective, will also require an increase in resources devoted to research and information gathering, above and beyond that which is required for the management process itself.

Centralization

A common critique of federal environmental law is that it is unduly centralized, and places too much control in Washington, D.C. While some environmental problems are global in scope, most environmental problems manifest themselves at the local or regional level. Few are "national," and yet most environmental policy-making occurs at the national level.[71] Federal statutes impose uniform environmental priorities and standards without much regard for regional variation in ecological conditions or local priorities.[72] This mismatch hampers effective environmental protection.[73]

Existing environmental statutes provide relatively little meaningful opportunity for state level innovation. While most pollution control statutes speak of cooperative federalism and reaffirm the need to respect state-level policymakers, most priority-setting occurs at the federal level. In practice, state level policymakers have relatively little flexibility in identifying and selecting environmental policy goals and implementing regulations offer states relatively little leeway to experiment. Statutes such as the Clean Air Act and their implementing regulations constraint the ability of states to adopt new approaches, even as they pay lip service to flexibility. State implementation plans, for instance, are evaluated based upon how they fare under the Environmental Protection Agency's (EPA) modeling, not based upon the extent to which they produce results or satisfy the needs and demands of local citizens.[74]

Federal agencies are also not particularly supportive of state or local efforts to innovate, particularly if such innovation involves taking a different approach than that preferred in Washington, D.C. As a 2002 Government Accountability Office report found, states faced substantial "cultural resistance" from EPA officials, largely in the form of time- and resource-consuming reviews when they sought to innovate.[75] Although the Clinton Administration made some efforts to facilitate state level experimentation, these initiatives were never legislatively authorized and were short-lived.[76] The Bush Administration showed even less interest in facilitating state-level experimentation.[77]

Fostering greater regional or local experimentation with environmental management is one way to encourage adaptive management, while also responding to the ecological variation found throughout the nation. A more decentralized and "polycentric" approach to many environmental problems may help facilitate more adaptive approaches to environmental management.[78] True adaptive management, particularly if it is to lead to the discovery of additional information about natural systems and how they respond to different types of interventions and conservation measures, must be decentralized and, to some degree competitive.

The competitive regulatory dynamic embodied in the federalist system can facilitate the sort of learning by doing that is so often absent from centralized regulatory agencies. Among other things, such approaches allow for more experimentation and innovation, greater risk diversification, and facilitate active learning from the implementation of differing management approaches. Providing states with a formal mechanism through which they could opt out of existing federal environmental requirements could provide the opportunity for experimentation with different approaches to environmental management, including forms of adaptive management.[79] A mechanism could even be a form of adaptive management insofar as it encouraged

regular evaluation of the successes and failures of competing management approaches and facilitated iterative learning about how to make environmental measures more successful among competing jurisdictions.

Decentralization to encourage adaptive management could also take the form of decentralizing the management of the federal estate. One possibility, that has been tried to a modest degree, would be to provide greater autonomy for individual parks, refuges, or forest units within the federal system so that those managers with the greatest knowledge and experience with the resources in question could experiment with different conservation measures.[80] The National Park Service's fee demonstration project, while not without controversy, could serve as the basis for this sort of decentralized experimentation with park management.[81] If properly structured, it would help reveal substantial information about how such lands can be managed in economically sound and ecologically desirable ways. There is also reason to suspect that decentralizing land management by placing greater responsibility in the hands of state governments would improve the effectiveness and responsiveness of land managers.[82]

Statutory Requirements

Adaptive management, as such, is rarely authorized by statute.[83] As a consequence, adaptive management "has not been seriously incorporated into environmental regulation."[84] This is a meaningful obstacle to more widespread adoption of adaptive management by environmental agencies. In simple terms, "in order for adaptive management to flourish in administrative agencies, legislatures must empower them to do it."[85]

Where agencies have sought to adopt adaptive management, they have generally endeavored to do so by exploiting ambiguities in their statutory delegations of authority. Although some agencies may have genuinely tried to implement true adaptive management strategies, they generally lack statutory authority for such reforms. So even if agency heads are willing to make the effort, they face a daunting gauntlet of interest group opposition and judicial scrutiny. According to Professor Ruhl, when the Fish and Wildlife Service (FWS) sought to integrate adaptive management into the habitat conservation plan (HCP) permitting process, interest group litigants and courts were quick to challenge the agency's authority to incorporate greater flexibility into the program.[86]

The FWS's desired reforms may have prompted litigation and stoked controversy, but they were hardly an example of aggressive adaptive management. To some, what the FWS considers to be "adaptive management" is little more than "a series of pre-specified contingency measures that will be adopted at pre-specified triggering

thresholds if the initial effort fails to produce the expected results."[87] In other words, it is little more than "contingency planning."[88] While it is no doubt preferable to engage in some degree of contingency planning than to blithely assume the accuracy of every predictive assumption upon which a regulatory or other conservation decision was made, this is a far cry from true adaptive management.[89] Thus, Professor Karkkainen concludes, despite lots of statements to the contrary, "FWS may never have really tried to incorporate genuine adaptive management (as the rest of us know it) into the HCP process."[90]

Legislative grants of authority to implement adaptive management schemes are necessary for more federal agencies to begin utilizing such approaches, but they are not sufficient. For agencies to have a meaningful opportunity to adopt adaptive management approaches, Congress must also scale back some of the legislatively created mechanisms that interest groups use to frustrate agency initiatives and pursue agency capture. The combination of expensive procedural requirements, such as those mandated by the Administrative Procedure Act (APA) or specific authorizing statutes, and substantive statutory constraints create a barrier that is hard for all but the most committed agencies to scale.

It is particularly difficult for agencies to promulgate meaningful reforms when any innovative initiative exposes the agency to litigation. Broad citizen-suit standing makes it possible for a wide range of interests to hold up agencies that seek to shift their management approaches. Under cross-cutting statutes, such as the National Environmental Protection Act (NEPA), agencies are required to conduct extensive *ex ante* studies of the likely effects of proposed reforms. Because meaningful predictions are, in a real sense, incompatible with true adaptive management, it will be difficult for many agencies to move forward in this regard while complying with NEPA's requirements. Indeed, interest groups unhappy with the potential results of adaptive management have made such claims in court.[91] While it would be a mistake to reduce agency obligations to consider the environmental effects of their actions, the existing NEPA process will make it particularly difficult for agencies to adopt adaptive management across many environmental programs.

Administrative Law Norms

Above and beyond the specific constraints imposed by existing environmental statutes and the APA, dominant norms of administrative law may provide further obstacles to the widespread adoption of adaptive management.[92] Rule of law concerns may be in tension with the demands of adaptive management.[93] Some might even suggest that they are "incompatible."[94] The requirements for extensive *ex ante* assessment of options

and consequences, meaningful public participation, and subsequent judicial review of agency decision-making may make it difficult to adopt true adaptive management approaches to environmental management even if statutorily authorized.

Administrative law generally requires agencies to invest substantial time and effort up front to analyze potential courses of conduct and solicit public participation. Agencies are expected to explain the bases for the decisions they make and the likely expected consequences, and courts stand ready to review the explanations agencies give to ensure that the agencies have complied with their statutory mandates and engaged in "reasoned decisionmaking." This general approach leaves little room for "learning by doing" or meaningful experimentation.[95]

Whereas adaptive management requires an ongoing iterative process in which managers are evaluating newly revealed information about the consequences of existing measures and adjusting management policies accordingly, administrative law places a premium on finality.[96] This creates a stark conflict. As Professor Tarlock comments, "The idea that all management is an ongoing experiment poses a profound challenge to our legal system because it undermines a core principle of procedural and substantive fairness: finality."[97] Adaptive management's emphasis on "feedback loops to update regulatory efforts as information increases"—to adjust the dial in an ongoing basis—"is counterintuitive for the American legal system, which puts a premium on firm rules of law."[98]

Finality serves several purposes in administrative law. For one, it helps to provide a degree of certainty to regulated parties and those who depend upon administrative agencies. The regulatory process has a definitive endpoint, after which all affected may rely upon a duly promulgated rule as binding and secure. This generates a degree of legal certainty. Yet if the administrative law process desires certainty, adaptive management avoids it:

> Legal certainty does not mesh well with environmental unpredictability. One of the most significant barriers for managing linked social-ecological systems is that often the aspects of a society that make it free (e.g. certainty of law) are not in concert with ecological realities (e.g. multiple regimes and non-linear systems and responses. The certainty of law and institutional rigidity often limit the experimentation that is necessary for adaptive management."[99]

A system in which agencies were free to recalibrate regulatory obligations would provide little certainty for regulated entities. As Professor Tarlock notes, "the application of adaptive management supported by non-equilibrium ecology undermines

settled expectations and increases the risk to those who undertake activities in areas targeted" for ecological protection.[100] Insofar as agencies maintain discretion to alter their decisions, they risk upsetting the expectations of those that have relied upon the agency's decision. And yet, "continuing discretion to alter a decision is *the essence* of adaptive management."[101] This tension, between providing regulated entities with certainty and the need under adaptive management to revisit decisions and make dial adjustments as necessary can be seen in ESA implementation, where the FWS claimed to be working toward an adaptive management approach while simultaneously trying to promise landowners that there would be "no surprises" and that HCP requirements would not change over time.[102]

Insofar as adaptive management relies upon nimble administrative agencies that are able to respond quickly to new information as it emerges, the existing administrative structure is a poor fit. It takes a substantial amount of time for agencies to develop policies to implement statutes, issue regulations, or develop management plans subject to NEPA or other review requirements.[103] Public participation mandates further increase the time and other resources agencies must devote to substantial initiatives, particularly if agencies are responsive to public comments and make any meaningful effort to adjust their proposal in response to the information and opinions submitted to the agency. The current rulemaking process can be cumbersome and does require a substantial investment of agency time and resources. Agencies that are not careful to ground their policy decisions in the relevant grant of statutory authority and properly respond to adverse public comments can find themselves sent back to square one by reviewing courts.

Yet one should not overstate the extent to which existing procedural requirements prevent agencies from adapting to new information and updating outdated policies. The extent to which administrative law entrenches agency decisions and prevents them from revisiting prior policy decisions in light of new scientific or other evidence is likely overstated.[104] The evidence for regulatory "ossification" is mixed.[105] Agencies may be slow to revise or reconsider prior decisions, but this is not because administrative law prevents them from doing so. The Supreme Court has made clear that insofar as agencies are exercising delegated regulatory authority, they are free to reverse course and adopt new policy agendas, provided they remain within the scope of their delegation.[106]

Professors Craig and Ruhl argue that for adaptive management to be truly successful, and advance beyond the watered-down "adaptive management lite" utilized by some federal agencies, there must be an "alternative administrative procedure model that enables agencies to practice adaptive management in its purer form."[107] They

recognize that this requires a model that departs substantially from the dominant administrative law norms. Among other things, such an administrative procedure model may not provide as much room for public participation, at least not in the form utilized now.[108] In addition, agencies will need to forego some degree of ex ante examination and predictive assessment in return for greater responsibility to evaluate programs on an ongoing basis, while being committed to engaging in course adjustments as the consequences of various management approaches reveal themselves.

Professors Craig and Ruhl also suggest that adaptive management requires the scaling back of judicial review of agency actions. In their view, judicial review as currently constituted is too "intrusive" on agency decision-making[109] and does not focus on the right criteria, at least as far as adaptive management is concerned. Such an alternative administrative procedure framework may have some promise, although it would likely be quite controversial. Interest groups—environmentalists and industry-based groups alike—will be wary of any reforms that limit their ability to second-guess potentially unfavorable agency decisions.[110] It could also bump up against some serious constitutional constraints on the ways that agencies exercise their delegated authority. To many, judicial review is an essential element of due process within the administrative state.

Constitutional Concerns

To some degree, trying to make the existing administrative regulatory structure flexible and adaptive is like teaching a shark to fly, insofar as it ignores the fundamental nature of the beast. But even if one is more optimistic about the ability, and desirability, of altering such norms and legal requirements, some obstacles remain. This is not merely a question of what we have allowed and come to expect in administrative law. The requirements outlined in the APA were created by Congress, but we should not be so quick to assume that all such requirements, such as for notice and an opportunity to be heard, are merely a function of statute. There are constitutional law norms underlying the basic protections and procedures of the APA. It may well be that "[o]ur conception of responsible rulemaking was developed with an image of static ecosystems,"[111] but some of the norms of administrative law are also the result of underlying constitutional guarantees.

No matter how desirable adaptive management may be, it cannot operate in a vacuum. As Professor Tarlock cautions, insofar as adaptive management is adopted by regulatory agencies, "it is public regulation that must satisfy constitutional requirements of substantive and procedural due process."[112] Granting agencies the authority to engage in true adaptive management "raises the specter of an unchecked branch of government with the power to alter laws anytime it desires."[113] And this raises due

process concerns. Demands for fair notice and a meaningful opportunity to be heard constrain the extent to which agencies may engage in the constant modification and dial tuning that adaptive management may envision.

Apart from the procedural guarantees provided in the APA, the Fifth Amendment to the Constitution provides that life, liberty and property may not be taken without due process of law. At the time the Fifth Amendment was adopted it was well established that, among other things, due process meant that "the executive could not deprive anyone of a right except as authorized by law, and that to be legitimate, a deprivation of rights had to be preceded by certain procedural protections, characteristic of judicial process."[114]

Although subjecting private land-use to legislatively authorized permitting requirements is not, in itself, a due process violation or a taking, private landowners are constitutionally entitled to due process in the administration of such a system.[115] Among other things, this means that landowners are entitled to notice of what the system requires and "the opportunity to be heard at a meaningful time and in a meaningful manner" before the government infringes upon a constitutionally protected interest.[116] This further means that if an agency denies a landowner the ability to make productive use of her land, such as by imposing a land-use restriction or denying a permit, the landowner must have some opportunity to make her case. In the context of permitting, this entitles the landowner to some degree of administrative, if not judicial, review at a time that is sufficient to safeguard the landowner's interests.

In *Sackett v. Environmental Protection Agency*, the EPA had claimed that it could issue a compliance order mandating that landowners restore land they had begun to develop without a Clean Water Act permit.[117] Under the EPA's interpretation, the landowners could not obtain pre-enforcement review of the EPA's action. The Court unanimously disagreed. Had the Court accepted the EPA's interpretation of the Act, however, the Sacketts would have had a colorable Due Process claim against the federal government.[118] A system of land-use regulation need not deprive a landowner of all productive use in order for it to constitute a deprivation of property for due process purposes. In *Connecticut v. Doehr*, for example, the Supreme Court explained that "even the temporary or partial impairments to property rights that attachments, liens, and similar encumbrances entail are sufficient to merit due process protection."[119] Thus agency decisions that substantially encumber private lands may implicate the Due Process Clause.

Notice is an essential element of due process. Legal obligations and prohibitions must be sufficiently intelligible and clear so that a diligent landowner could be aware of the legal rules to which she is bound. A statute—or regulation for that matter—

that defines obligations or prohibitions "in terms so vague that men of common intelligence must necessarily guess at its meaning and differ as to its application, violates the first essential of due process of law."[120] As the Supreme Court explained as recently in 2012, it is a "fundamental principle" that "laws which regulate persons or entities must give fair notice of conduct that is forbidden or required."[121] Further, "clarity in regulation is essential to the protections provided by the Due Process Clause of the Fifth Amendment."[122] Although due process challenges to federal regulation are relatively rare, lower courts have reaffirmed the importance of notice in this context. The U.S. Court of Appeals for the D.C. Circuit, for example, concluded that the principles of due process also cautions against "validating the application of a regulation that fails to give fair warning of the conduct it prohibits or requires."[123]

Statutory reforms that authorize agencies to sidestep the APA's procedural requirements would not necessarily insulate agency actions from constitutional challenges. Insofar as agencies are authorized to alter regulatory burdens placed upon private lands or otherwise change regulatory requirements in response to emerging information, they may be required to provide some amount of process to regulated parties.

Due process concerns about adaptive management are greatest where federal agencies are engaged in the regulation of private land or the imposition of restrictions that directly affect private rights, including some rights on federal lands. Adopting adaptive management polices and techniques is far less problematic in the context of managing government lands than where environmental management decisions encroach upon private interests or risk infringing upon private property rights. While there may be political obstacles, including interest group resistance, to reducing the procedural obligations of agencies engaged in resource management decisions, there are less likely to be judicially cognizable property interests of the sort that could implicate due process concerns.[124]

Constitutional constraints on the adoption of adaptive management where the regulation of private land-use or disposition of private resources are concerned are largely, if not wholly, absent in the context of federally owned resources.[125] Under current law, statutes like NEPA grant outside groups extensive opportunities to influence and object to resource management decisions. Such procedural rights are purely a creation of statute, and could be legislatively revised or even repealed. So long as federally owned and managed resources are at issue, whether or not to facilitate this degree of public participation and judicial review of agency decisions is a matter of policy to be determined by the legislature. There is no constitutional requirement that citizen groups have more input to such resource management decisions than is provided for within the political process. As a consequence, it would be easier to

implement a dynamic and adaptive approach to the management of federal lands and federally owned resources than it would be to integrate adaptive management into the regulation of private land use under existing environmental laws.

Market Participation

It is a mistake to think that the emergence of a dynamic view of natural systems is the first time the administrative state has had to confront complexity. Markets, and the private ordering that spontaneously emerges where property rights are defined and voluntary exchange is possible, exhibit all the features of complex, dynamic adaptive systems. Government agencies may have more success at implementing adaptive management strategies, and avoiding some of the aforementioned constraints, insofar as they seek to advance environmental goals as market participants, and through the adoption of collaborative, contractual, or voluntary initiatives.

As commentators regularly note, many private entities adopt adaptive management techniques of one sort or another. More broadly, the private marketplace acts as a form of adaptive management as different firms try to innovate and meet market demands in different ways, learning from the successes and failures of other. There is no reason, in principle, why a government owned entity cannot operate in a like fashion, trying new management approaches, learning from its own mistakes, and replicating the successful innovations of others. The question is whether the relevant administrative rules and laws will allow such flexibility and the necessary freedom from political and judicial oversight than can hamstring such efforts.

One possible response to the belated recognition that natural systems are dynamic, complex, adaptive systems would be to rethink the dominant reliance upon regulation as the means for safeguarding environmental values. Where government acts not as a regulator but as a participant in a complex, dynamic and adaptive system—the marketplace—it is both more nimble and less hemmed in by constitutional constraints.

The federal government has substantial ability to intervene directly in markets through the purchase of resources and contracting with private owners and indirectly by providing incentives for market actors to give greater consideration of particular concerns. Such non-regulatory strategies may not suffer from some of the same legal constraints as regulatory strategies. Much as the management of federally-owned resources does not implicate constitutional concerns to the same extent as the management or regulation of resources continued or dependent upon private land, non-regulatory measures may be more amenable to adaptive management strategies.

Some federal agencies already operate programs that could readily become more adaptive in their operation.[126] The Department of Agriculture, for instance, acquires

temporary easements for the purpose of protecting waterfowl and their habitat. Purchasing such easements through voluntary transactions raises no due process concerns. Even forced sales, through eminent domain, raise fewer due process concerns than regulatory impositions on private lands. The temporary, yet renewable, nature of the easements acquired under some programs also facilitates regular reevaluation and necessary course corrections in response to changing conditions and new information. The use of these sorts of contractual measures to address environmental concerns holds substantial promise and has been under-explored to date, particularly insofar as it could contribute to or facilitate adaptive management of environmental resources.

CONCLUSION

The demand for complex, adaptive approaches to environmental protection was generated by a revolution in our understanding of the natural world, and environmental systems in particular. Perhaps notions of environmental management and, in particular, the role of government in advancing environmental values needs to undergo a revolution as well. Particularly insofar as one concludes that the conventional administrative, regulatory model of environmental protection is incompatible with the demands of dynamic environmentalism, it may be worth reconsidering whether such a model continues to be the best way forward for environmental protection. Whether it was ever the best model to adopt, it may have outlived its usefulness. "Only political will and our basic perspective prevent us from moving constructively" toward sounder environmental policy, commented Botkin in 1990.[127] This remains true today.

ENDNOTES

This article was originally published in the *Journal of Law, Economics & Policy*, Summer 2015, 11(2): 133-161. Reprinted with permission.

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108 Craig and Ruhl, "Designing Admin. Law," p. 30.
109 Craig and Ruhl, "Designing Admin. Law," p. 33.
110 See Freeman and Farber, "Modular Environmental Regulation," pp. 893-94.
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116 Mathews v. Eldridge, 424 U.S. 319 U.S. 333 (1976).
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120 Connally v. Gen. Contr. Co. 269 U.S. 385, 391 (1926).
121 FCC v. Fox TV Stations, Inc., 132 S.Ct. 2307, 2317 (2012).
122 FCC v. Fox TV Stations, Inc., 132 S.Ct. 2307, 2317 (2012).
123 Gen. Elec. Co. v. EPA, 53 F.3d 1324, 1328 (D.C. Cir. 1995).
124 Whether private interests in public lands or government-managed resources are entitled to Due Process protections under the Fifth or Fourteenth Amendment would be a context-specific inquiry. In some cases, courts have recognized that permits or other private interests in federally managed resources are property interests for Constitutional purposes. See, e.g., Foss v. Nat'l Marine Fisheries Serv., 161 F.3d 584 (9th Cir. 1998).
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SAILING THE SAGEBRUSH SEA

GREGG SIMONDS

A cattle rancher surveys his land, gazing across a vast expanse of the western range. The land surges and rolls, lifting sharply in waves of stone, and receding softly onto the open plains. Before him is a living sea—a Sagebrush Sea, as vast and as variable as any ocean.

Each year, ranchers set sail on the Sagebrush Sea, and by grazing livestock, they convert relatively low-valued plants into higher-quality protein. Like sea captains, ranchers must deliver their cargo in good shape while maintaining their capacity to make the next voyage, navigating the ever-changing conditions of the high seas. These wildly variable conditions—wind and currents on the ocean, rainfall and temperature on the land—are both influential and unpredictable. A salty sailor is one who learns how to respond to these changes and navigate conditions that would sink a less canny sailor's ship.

On the Sagebrush Sea, success depends on the flexibility the rancher is afforded to adapt his management to changing environmental conditions. Regulations that restrict a rancher's ability to maneuver his ship in response to these changes can threaten the voyage. For instance, policies that restrict the duration or season of grazing—known as "time" and "timing"—can undermine the very management practices that are needed most. Strict limits on the frequency or intensity of grazing can also

hinder what we now understand to be proper rangeland management.

Today, federal grazing policies assume we can navigate the Sagebrush Sea with a static view of the natural world. In effect, we are locking the captain's sail-set and tiller position based on the average wind speed and direction of the South Pacific. But averages are useless on the Sagebrush Sea, just as they are on the open seas, and every voyage is doomed without the capability to constantly adjust to the vagaries of nature.

Moreover, the terms and conditions of federal grazing permits are based on rangeland assessments made infrequently on small plots that are then extrapolated across vast regions. It would be like peering over the gunnels to observe the waves at a single moment and assuming this observation will predict sea conditions over the next year, or even the next decade.

Making matters worse, many ranchers lack the basic instruments of navigation—the feedback mechanisms necessary to understand and adapt to changes on the landscape. They lack the equivalent of a compass to tell them which direction their enterprise is heading. They lack a sextant to inform them of their position and to assess just how far they have deviated off course.

The reality is that we are blindly sailing the Sagebrush Sea, with rudder and sails in a locked position—and we have little or no way to understand which direction we're heading. Until now.

THE BACKGROUND

"There is perhaps no darker chapter nor greater tragedy in the history of land occupancy and use in the United States than the story of the western range," claimed a 1936 report by the Interior Department.[1] Since much of the Sagebrush Sea was never homesteaded, the land remained largely under public ownership. As a result, a textbook example of the "tragedy of the commons" unfolded, as destructive grazing practices gradually eroded public rangelands.

In response, the federal government created new standards designed to prevent overuse of the western range. The federal rangeland was partitioned into public grazing allotments administered by the Bureau of Land Management or U.S. Forest Service. Ranchers lease the allotments and graze livestock based on ten-year permits with fixed terms and conditions that dictate the time, timing, and number of livestock that can be grazed on each allotment. Every five to ten years, rangeland assessments are made to re-set stocking rates for each allotment.

In the 1970s, a broader vision of rangeland health began to emerge—one that included recreation, watershed health, species protection, and other environmental values. New groups were afforded a seat at the rangeland planning table through

policies such as the National Environmental Policy Act, which requires environmental assessments and public input for management actions on federal lands.

These new definitions of rangeland health, however, did not include the development of new tools that could adequately measure them. As a result, ranchers today face a growing set of management demands but are left adrift without the basic instruments to chart a course for long-term land stewardship.

And there's yet another problem: The fixed terms and conditions of federal grazing permits often do not provide ranchers the flexibility needed to adapt to the unpredictability of the Sagebrush Sea. Even a low level of rangeland use does not necessarily stop overgrazing. A good manager must continually adjust the number of livestock, the amount of time livestock are allowed to graze, and the location and season that grazing occurs. Understanding the relationship between these management tenets and their effects on the land requires practice—as well as a feedback system that provides the information necessary to constantly adjust our sails.

NEW DIRECTIONS

I have sailed the Sagebrush Sea many times. For more than 40 years, I worked as a ranch manager and consultant for many of the largest ranch enterprises in the United States. For the last 18 years, I have worked to develop rangeland assessment technologies that provide better measurement tools to help other sagebrush captains navigate the dynamic conditions of the Sagebrush Sea.

What I have discovered over my career is this: Although the sagebrush ecosystem is extremely dynamic, sagebrush captains can adjust their sails and rudder to the waves of change that surround them. With the right tools and the freedom to use them, they can harness these natural forces to promote the long-term health of the land. This is what is known as results-based, adaptive management.

Due to the history of the western rangeland, overgrazing has unfortunately been oversimplified to mean "too many cows." This view has led to policies and conventions that fixate on reducing livestock grazing, and thus restrict ranchers' abilities to implement adaptive grazing management. We now know, however, that this simplistic view is wrong.

In reality, grazing is simply the removal of tissue from a living plant. As long as a plant is free to regrow what has been removed, the type or number of organisms removing that tissue is of little consequence to the plant during the growing season. The situation only becomes "overgrazing" when the plant is not able to replace the lost tissue during the growing season because of repeated grazing before full recovery. But this has nothing to do with the number of grazing entities. One goat,

one grasshopper, one lawn mower, one wild mustang, one cow, or one elk chewing a blade of grass can all have the same effect on a plant. The proper management approach is the same: Leave the plant alone until it regrows all of the removed tissue, however long that takes. In some places, this can take more than a year.

All rangeland plants evolved with defoliation, even severe defoliation under insect swarms, hail storms, and wildfires. Over the ages and around the world, grazing is the primary form of defoliation on rangelands. Grazing is integral to plant health but must be balanced with adequate rest periods. Plants respond to grazing by producing new growth, beginning a cycle that converts sunlight into biomass. But the process of generating new growth is taxing. If animals are not moved onto new pastures at the appropriate time, they will continue to eat their preferred plants as they produce new growth. This can prevent plants from recovering and eventually kill them.

These basic facts are why the timing of grazing is so important—to ensure that plants, once eaten or trampled, have time to recover. When done at the right times, grazing can strengthen and stimulate plants to produce even more tissue. If plants are allowed time to recover, then the initial damage of grazing has much the same strengthening effect as muscles torn down through exercise and then allowed to rest. Over time, the cycle between use and rest increases the ecosystem's productive capacity.

The basic task of the rangeland manager, therefore, is to achieve a proper balance between grazing and recovery. And, like sailing, it is simple in the abstract but frustratingly complex in practice. Among the most important parameters an experienced manager must account for are season of use (timing), length of use (time), and intensity of use (stocking rate). These factors help the rancher determine the duration of the rest plants need to recover.

Along with this comes the recognition that grazing during the growing seasons of plants has the most severe effect and most influences the need for recovery. When plants are actively growing, it is the growing points that are most likely to be grazed, which can have dramatic implications on a landscape. The active growing season is the only time that plants can make new leaves and recover from the demands of maintaining themselves through the dormant seasons, when the lack of water and temperatures don't allow them to use sunshine for photosynthesis. This active growing season is short, usually only May and June, and it is the only season of the year in which plants can store up nutrients to be used to maintain themselves during dormancy. Pastures that have been used during the active growing season have to be rested over this same period in subsequent years to ensure that they recover. The use or rest of a pasture during any other season of the year besides the active growing season is of little importance to long-term plant heath.

The most critical insight from this basic understanding is that the timing of grazing is more important than the intensity or amount of use. This insight, however, runs counter to most federal grazing policies, which overemphasize stocking rates. As a result, the proposed solution to rangeland degradation is almost always to "de-stock." While this might be necessary at certain times and places, it is equally likely to be detrimental to rangeland health. Too much rest can be damaging to plant health. Old plant growth can begin to shade out young shoots, and plants begin to die from a shortage of sunlight. Strange as it may seem, intensive, short-term grazing might be exactly what's needed to rejuvenate plant health in some cases.

Today, federal rangelands are often considered to be in poor condition. But this is not because there are too many cows. In fact, the amount of livestock grazing on federal lands declined by more than half since the 1950s. Instead, a lack of understanding of the interactions between time, timing, and stocking rates is the primary reason federal rangelands generally remain in bad shape.

THE SEXTANT AND THE COMPASS

And here lies the crux of the great debate over the western range: We lack the tools necessary to measure our position on the Sagebrush Sea and to objectively assess the effects of our management practices. In essence, we lack a sextant and a compass that can accurately gauge the swells and tides of an ever-changing ocean. Such tools would assure a flow of information that would allow sailors of the Sagebrush Sea to adapt and improve in the face of new conditions and new demands upon the land.

Until recently, our ability to measure and monitor changes on rangelands have been limited in time and space. Traditional field-based monitoring is not done frequently enough or on a large enough scale to account for the tremendous variations on this ever-changing sea. As a result, our policies are focused on inputs rather than outcomes—the number of livestock grazing rather than measurements of vegetation, water quality, and other public benefits provided by western rangelands.

I have spent the last 18 years developing a monitoring assessment technology that uses high-resolution photography and remotely sensed imagery to evaluate rangelands and their responses to specific management practices. The assessment protocol, recently published in the journal *Ecological Indicators*, models the percent of bare ground, shrub, and other vegetation cover across sagebrush landscapes in the West.[2] It provides accurate information on rangeland conditions at scales ranging from millimeters to kilometers across multiple decades, costs one-tenth the amount of traditional methods, and can be readily assessed by computer or smartphone.

This technique has great potential to help us understand land cover change and rangeland health in a way that had not been available before. Ranchers can use this method to evaluate past management practices based on their effectiveness in altering basic cover components of rangelands. They can also develop improved management strategies, providing a valuable tool to assess public grazing allotments for land health, or even to gauge habitat quality for threatened species like the greater sage grouse.

This protocol vastly improves upon our current field-based monitoring techniques, which are used to measure individual plant species on a small plot and extrapolate the findings over enormous landscapes. Assessing rangeland conditions at a landscape level consistently is the only legitimate way to understand the effects of land management decisions. This feedback system, combined with a manager's experiential knowledge of the landscape, allows managers to regularly assess conditions and chart a proper course on the Sagebrush Sea.

FUTURE VOYAGES

Today's rangeland assessment methods are flawed because they fail to recognize that nature is dynamic and, at times, reliant upon disturbances to promote health. Furthermore, many assessments of rangeland health are based on the outdated assumption that there is a "natural" plant community for each soil type. By knowing the correct endpoint, the theory goes, rangeland health can be assessed relative to its proper plant community. But these static endpoints are an illusion, and they have long been disputed in ecological science.

Flexible, results-based grazing policies are the only way to allow sagebrush captains sufficient latitude to navigate an unpredictable and variable environment and also achieve the results that the public cares about. We don't need to dictate how our rangelands are improved. We just need to determine the desired results, establish the proper incentives, and step back to give rangeland managers the flexibility to achieve those results on their own.

We now have the tools to measure important land health characteristics in great detail across time and space. We can formulate precise and measurable goals for our rangeland ecosystems—whether it's more riparian area, fewer wildfires, or more sage grouse. Ranchers can then figure out how to best achieve these goals. The simplest incentive is to allow ranchers to implement the practices best suited for the dynamic landscapes they inhabit, while holding them to objective, measureable outputs that ensure the rangeland conditions we care about are provided and protected.

This is possible today. But there needs to be regulatory flexibility to achieve these goals, given the tremendous unpredictability and dynamics of the Sagebrush Sea.

It is time for a serious examination of the state of modern rangeland management on the Sagebrush Sea. New technologies to provide adequate feedback and flexible administration, coupled with the long-term view of the ranchers who live and work there, could offer the public the kind of management required to manage this vast resource. Ahead, full sail.

ENDNOTES

1 U.S. Department of Agriculture. 1936. *The Western Range.* 74th Cong., 2d sess, *Senate Document* No. 199.

2 Sant, Eric D., Gregg E. Simonds, R. Douglas Ramsey, and Randy T. Larsen. "Assessment of Sagebrush Cover Using Remote Sensing at Multiple Spatial and Temporal Scales" 2014. *Ecological Indicators.* 43:297-305.

ECOSYSTEM SERVICES:
What are the Public Policy Implications?

R. DAVID SIMPSON

For the last few decades, ecosystem services have been a popular theme in conservation policy. By preserving or restoring areas of natural habitat, the argument goes, important goods and services such as clean air and water, flood control, and crop pollination will be provided to society. Those goods and services, if properly accounted for, may even be worth enough to justify the protection of the forests, grasslands, wetlands, and other ecosystems that provide them.

It is not surprising that the logic of ecosystem services has struck a chord. To some, the appeal of ecosystem services is that all the environmental benefits that "the market" has purportedly failed to account for might now be factored into public and private decision-making. To others, the possibility of structuring payments for ecosystem services that assign and respect property rights, and bringing the power of that same "market" to bear, may seem equally appealing.

But the situation is not as simple as these caricatures might suggest. If it is just a matter of structuring payments for the delivery of services of known and agreed value, it is difficult to explain why so much public-sector effort is being put into studying ecosystem services and enhancing their provision.

The views expressed here are the author's own and do not necessarily reflect those of the U.S. Environmental Protection Agency.

Public sector entities are, however, deeply involved in such efforts. An alphabet soup of multinational organizations is engaged, including TEEB (the Economics of Ecosystems and Biodiversity, funded by the European Commission, United Nations, and others), WAVES (Wealth Accounting for the Value of Ecosystem Services, a World Bank program), and IGPBES (Intergovernmental Platform on Biodiversity and Ecosystem Services, funded by several United Nations programs). National governments are also becoming more involved in ecosystem service valuation. The United Kingdom is undertaking a National Ecosystem Assessment that includes, among other aspects, the valuation of several ecosystem services. In the United States, all executive branch departments and agencies are now directed to "develop and institutionalize policies to promote consideration of ecosystem services… and, where appropriate, monetary or nonmonetary values for those services."[1] Even before this directive was issued, the Environmental Protection Agency, Department of Agriculture, U.S. Geological Survey, and the National Oceanic and Atmospheric Administration had each initiated programs on ecosystem services.

What motivates public policy toward ecosystem services? One common answer is that the services afforded by natural ecosystems are, by and large, public goods.[2] Since public goods will not be efficiently allocated by private actors, public policy is required. But some commonly cited ecosystem services are not necessarily public goods. And even if some ecosystem services are public goods, it is not always clear that they serve large enough populations to justify using national governments, let alone international organizations, to allocate them efficiently.

Information is a public good. So perhaps a better argument for large-scale public involvement in ecosystem service policy is that government provision of research will be required to determine the proper values of ecosystem services. But this raises the question: What is such research likely to find? Are ecosystem services really so valuable that an appreciation for them would motivate us to forgo alternative uses of the areas that provide them?

Despite the accumulation of writing on the topic, there continues to be a surprising dearth of reliable evidence on the value of ecosystem services. If compelling cases have not yet been made for their values, one might reasonably ask whether there ever will be. Many approaches to the valuation of ecosystem services remain controversial and are unlikely to ever be wholly convincing. At the same time, as this essay will discuss, simple arguments suggest that the value of many ecosystem services may be relatively modest in most times and places. Moreover, the exceptions may prove the rule: While it may seem paradoxical, the value of ecosystem services might be highest when the incentives they provide for conservation are modest.

If after years of effort and thousands of articles, we have so little compelling evidence concerning the value of ecosystem services, why has interest remained so high? Some historical context is useful in answering this question. The current enthusiasm for ecosystem services is best understood as an episode in a century-long debate between what we might call "nature-for-nature's-sake" conservationists and those who seek to motivate conservation by appealing to instrumental arguments. The new twist in the ecosystem services literature is that some who sympathize with the "nature-for-nature's-sake" argument seem to have adopted the instrumental approach as a sort of reluctant expedient. Having conceded that they will not succeed by appealing to the intrinsic merits of conservation, this new group hopes to salvage a partial victory by making more pragmatic arguments for conservation based on ecosystem services.

This perspective raises important questions, and I will conclude this essay by posing if not resolving them. First, do conservation advocates who champion an ecosystem-services approach intend for their arguments to be taken literally? Second, if advocates propose ecosystem service-based arguments in pursuit of ulterior motives, can policymakers be assured that conservation is conducive to community development and well-being? Third, does the ecosystem-services approach to conservation envision a world of human communities that is so closely integrated with ecosystem processes that ecosystems themselves are necessarily diminished as a result? In other words, does the ecosystem services paradigm mistakenly presume that the best way to conserve nature is to use it for its goods and services?

All in all, the value of ecosystem services has not been sufficiently demonstrated. Furthermore, a compelling case has yet to be made that public intervention is required to assure adequate areas are set aside to provide ecosystem services. Will more research resolve the issue? I am not optimistic. Perhaps the most important policy question to ask is the most fundamental: What is it that we as a society wish to save of nature? If we can agree to an answer to that question—admittedly a big "if"—we can better determine what policies will most effectively take us toward the goal.

HOW "PUBLIC" ARE ECOSYSTEM SERVICES?

The claim that ecosystem services are public goods is ubiquitous. Economics textbooks define public goods as non-rival (meaning that my consumption of the good does not reduce your ability to enjoy the same good) and non-exclusive (once the good is provided, I cannot prevent you from enjoying it). Many authors assert that public action is required to ensure that public goods such as ecosystem services are adequately provided, as if it were a self-evident truth. Robin Naidoo and Taylor

Ricketts, for example, write that "Ecosystem services often hold significant economic value, but they remain undervalued within policy decisions because they are poorly understood and typically external to markets."[3] A TEEB report on valuing ecosystem services states that "since most ecosystem services and biodiversity are public goods, they tend to be overconsumed by society."[4] And a recent survey asserts that "Fundamental asymmetries in economic systems leading to undervaluing stewardship of natural capital remain largely unchanged."[5]

These claims raise the question: What should be the appropriate public policy to address ecosystem services? We might begin by appreciating the fact that a good has some "public" aspects is not a sufficient argument for turning to the public sector to provide it. Just because an ecosystem generates *some* public benefits does not assure that those benefits offset the opportunity costs of maintaining the ecosystem. The choice to intervene should also be tempered by the concerns that accompany any public intervention, such as the marginal excess burden of taxation,[6] infringements of individual liberties, and the potential for corruption.

Moreover, public goods may be classified by where they lie along a spectrum of "publicness." There are local, regional, and global public goods. When benefits are local, simple measures may effectively render public goods as private. Some ecosystem services might be non-rival and non-exclusive if small areas of natural habitat are sufficient to provide them. If it is in fact worth the opportunity cost of land use to provide the public good, we would expect one landowner to acquire the necessary holdings and appropriate the benefits of the ecosystem service for herself.

Several ecosystem services fit this scenario. Consider pollination, which is often cited as a classic example of an ecosystem service.[7] If someone maintains an area of natural habitat on her land, bees and other pollinators may be healthier and more abundant. But insects are, of course, mobile. They might fly off and benefit others as well. In this case, farmers might simply purchase enough farmland to appropriate a greater share of the benefits the bees create. Or alternatively, they might reach an agreement with neighboring landowners to set aside enough pollinator habitat.[8]

Similar questions might be asked of a number of other ecosystem services. Trees and natural vegetation may provide barriers against wind and flood, but if they are cost-effective in this role, what prevents landowners or communities from providing themselves with this protection? Commercial or residential land developers often have the choice of how much and where to retain or recreate forests, wetlands, and other areas that would shade buildings, and protect them from winds and floods. If relatively small areas are needed to provide such services, why would a profit-maximizing developer not set them aside? Of course, municipal and local governments *do*

regularly set aside some lands for less-intensive use in parks and other public lands, so it is not clear that higher levels of government need to be involved in the allocation of land for the provision of many ecosystem services.

INFORMATION ON THE VALUE OF ECOSYSTEM SERVICES

Even if private actors or local governments can effectively allocate some ecosystem services, there might be a second public-goods argument for government involvement at national or international scales. It may be that the role for public policy is to provide information on the value of ecosystem services, which can then be used by the public to better determine what is in their individual or collective interest. So let us examine what efforts to provide such information have revealed so far, and what they might be expected to show in the future.

What does the research tell us about the value of ecosystem services? The answer remains "surprisingly little." Although there are now thousands of published articles on the topic, several survey papers remark on how little has been settled. Kate Brauman finds that a majority of 381 peer-reviewed studies relating water to ecosystem services "failed to adequately link changes in environmental conditions to human well-being, instead stopping at the point of suggesting that one was connected to the other."[9] Concluding their review of ecosystem service studies, Ralf Seppelt et al. state that "less than one-third of all studies provided a sound basis for their conclusions."[10] Ricketts et al. (2004) perhaps inadvertently underscored an irony that persists.[11] "Although the societal benefits of native ecosystems are *clearly immense*, they remain *largely unquantified*," they wrote (emphases added), without explaining how we can be so sure that the benefits are "clearly immense" if they remain "largely unquantified."

Given the lack of robust work on ecosystem service valuation, it is not surprising that, as Laurans et al. report, the literature "rarely reports cases where ESV [Ecosystem Service Valuation] has been put to actual use, even though such use is frequently referred to as founding the goal and justification of ESV."[12] Another survey finds that "In many cases, interest from decision-makers has created demand for information that has outstripped the supply from science."[13]

Since the information that is available now is limited, it may be instructive to consider what basic economic principles imply concerning the value of ecosystem services. The single most important thing to remember when thinking about economic value is that value is determined on the margin. The economic value of a hectare of forest, as one example of native habitat, is determined by the *increase* in services that an additional hectare affords over and above all other hectares of forest—not by the total value of the forest, nor by the average value of a hectare of forest. This principle

is fundamental, but it is often not appreciated by non-economists who have been engaged in much of the research on ecosystem services.

A clearer focus on the basic economics of ecosystem services can help clarify their values and help us understand how to devise defensible estimates of those values. Many ecosystem services are comprised of some natural asset—the ecosystem, or some of its components—that contributes to the production of something. We can then derive the value of the asset providing the service by multiplying the value of the thing being produced by the additional amount of the ecological asset. Moreover, for many types of ecosystem services, the more of the service the ecosystem supplies, the less of the service remains to be performed.

Table 1 gives several examples of this paradigm. For example, think of wild bees as ecological assets. A bee's economic value is determined by multiplying the price at which the fruit that may form from the flowers it pollinates can sell (net of the costs of raising and harvesting it), multiplied by the number of additional fruits expected to result from the bee's presence. Once an egg has been fertilized, the arrival of additional bees makes no difference to its development. The more bees there are, the less likely it is that a flower has not yet been pollinated. So, when there are large numbers of bees, the value of the marginal bee for pollination services is negligible.

Similar considerations determine the value of other ecological assets and demonstrate why those values decline as the assets become more abundant. Forests or grasslands retained in a riparian buffer may remove some of the pollution that would otherwise enter streams and cause environmental damage.[14] But the wider the buffer, the less pollution remains for the marginal meter of buffer to remove. In the case of flood and storm protection, the "production" of protective services might be modeled as the capability to withstand larger and stronger influxes of precipitation. The greater the area set aside to retain rain and snow, however, the lower the probability of a storm large enough to exceed its retention capacity.[15]

Several interesting implications are illustrated in Table 1.

- In some cases, ecosystem services may be of considerable value. This would be the case if the "value of the product" is high, the "capacity" of the marginal unit to provide that product is high, and, crucially, if the ecological assets providing the service are scarce. If there are few ecological assets providing a service, then great potential to provide that ecosystem service remains. For example, if there is little or no riparian buffer to filter pollutants from a stream, then the marginal value of an additional meter of riparian buffer may be quite high.

Table 1: Examples of ecosystem services and sources of diminishing returns

Example	Ecological asset providing the ecosystem service	Value of product	Capacity to produce ecosystem service	Amount of service still lacking
Pollination	Pollinating insects	Price of fruit	Number of flowers the "marginal pollinator" is capable of visiting	Likelihood that the flowers the marginal pollinator visits would not be fertilized by any other pollinator
Pollution treatment	Meters of riparian buffer	Marginal damage from pollution	Fraction of pollution removed in the "marginal meter"	Amount of pollution that remains to be removed when a contaminated flow reaches the marginal meter
Flood protection	Hectares of wetlands	Losses in the event of a flood	Water storage capacity of the "marginal hectare"	Probability that the volume of precipitation that must be stored to prevent flooding exceeds the storage capacity of all hectares of land available for flood control

- By the same token, ecosystem services must not be of much value if the assets already providing them are abundant. And if the "capacity" of each unit to provide services is high, there may be little left for the marginal unit to do. For example, if pollinators are abundant, and each individual pollinator visits thousands of flowers, then the marginal value of additional pollination services may be low.
- The above considerations give rise to a basic principle: "If a little goes a long way, you don't need a lot." Ecosystem services might be very valuable if provided in

small quantities, but the same "capacity" that makes a little bit valuable necessarily means that marginal values will be negligible when assets are abundant.

- But what if a little does not go a long way? What if the marginal value of an additional meter of riparian buffer does not yield additional benefits for pollution reduction? This would lead to a catch-22 effect. Ecosystem services and manufactured systems are often substitutes. If ecosystems do not perform effectively, it could be more cost-effective to rely on artificial substitutes, such as water-treatment facilities.

It is worth underscoring that these considerations do not mean that ecosystem services are not valuable. To the contrary, they could be very valuable; however, they would only be valuable when they are relatively scarce. Basic economic principles suggest that ecosystem service values might be limited in many cases, and that it is unlikely that an appeal to ecosystem services would motivate large-scale conservation when opportunity costs are significant.

What does this mean for the question of whether public funds should be allocated to estimating the value of ecosystem services? At the very least, it suggests that we should not expect that we are setting aside far too little land for the provision of ecosystem services. But if this is the case, then why is it that the ecosystem services framework is often used to suggest that society is conserving too few native habitats?

ORIGINS AND OBJECTIVES

Ecosystem services may seem to be a modern development in conservation policy, but current debates retrace a century-old conflict over the value of nature. In the early 20th century, John Muir, the founder of the Sierra Club, championed a vision of preserving nature for its own sake. Muir clashed with Gifford Pinchot, who would become the first Chief of the U.S. Forest Service. Pinchot promoted conservation as a means of enhancing the flow of nature's more tangible benefits to society, and, in some instances, advocated more intensive uses of public lands.[16] For most of the last four decades, the latter vision has been ascendant, although the reasons for its rise are complicated. In the case of ecosystem services, some latter-day Muirists seem to have turned defeatist, resigning themselves to Pinchot's utilitarian vision as a less-dreadful outcome than simply throwing in the towel.[17]

The ecosystem services approach might be traced to several earlier writings such as Westman (1977) and Ehrlich and Ehrlich (1981).[18] Another that may have been particularly important, however, was the 1980 publication of *World Conservation Strategy: Living Resource Conservation for Sustainable Development,* by the International Union for the Conservation of Nature.[19] The document signaled a change in course,

away from a vision in which protected areas were to be guarded for their intrinsic merits, and toward one in which such areas would be conserved to promote the sustainable development of the communities in which they are located. The 1990s saw the growth of numerous "integrated conservation and development projects" (ICDPs). The rationale for these ICDPs was similar to that of ecosystem services today. Nature could, ICDP advocates claimed, essentially pay for itself, if only we recognized its value. Natural areas might support sustainably harvested products, provide genetic models for new pharmaceutical compounds, offer recreational destinations for international "eco-tourists," and a host of other valuable goods and services.

Nature, however, didn't necessarily cooperate. In fact, in many instances it turned out to be "worth more dead than alive," as John Terborgh put it.[20] A number of reports documented problems with the sustainable-use approach of ICDPs.[21] Hopes for some natural products were dashed when the markets for them turned out to be smaller than advocates anticipated. In other situations, the ICDPs may have backfired; some destinations were "loved to death" by excessive flows of tourists.[22] Projects intended to promote the sustainable harvest of natural products may have resulted in disturbances to the ecosystems the projects were intended to protect.[23]

At the most basic level, the economics of ICDPs rarely made sense. In some respects, nature is too generous. Some of the goods and services ICDPs were supposed to provide are so abundant that people are willing to pay very little for them. This appears to be the case with "bioprospecting," the search among naturally occurring organisms for chemical compounds that might be valuable in industrial, agricultural, or pharmaceutical applications. In the early 1990s, an agreement between Merck Pharmaceuticals and Costa Rica's National Biodiversity Institute (known by its Spanish acronym as *INBio*) was hailed as a major development in conservation policy.[24] *INBio* would provide Merck with samples of indigenous plant and animal species for research, and Merck would compensate *INBio* for the samples. The compensation offered was relatively modest, however, and some conservation and development advocates railed at the alleged "biopiracy."[25] Yet such modest compensation is exactly what one would expect in a world in which species that have not yet been tested for their pharmaceutical potential still number in the hundreds of thousands.[26] In the years since the Merck-*INBio* deal was announced, enthusiasm for bioprospecting has generally faded.[27]

Other ICDPs foundered because ancillary infrastructure was lacking—the world may be filled with natural wonders, but many are located in places that are too inaccessible and dangerous to attract many tourists.28 Moreover, low-intensity use of natural systems can only exist as long as the products or services being provided

are of relatively little value. At higher prices, more intensive exploitation displaces sustainable use of diverse systems.[29]

The experience with ICDPs poses uncomfortable questions for ecosystem services: If nature-based ventures would be profitable, why would the public sector have to subsidize them?[30] There does not seem to be a compelling answer. So why is there renewed enthusiasm among ecosystem service advocates for the idea that nature can be made to pay for itself?

The likely answer is that conservationists still perceive a mismatch between their goals and the means to achieve them. Some authors have used the image of a "silver bullet" in describing ecosystem service-related approaches to conservation.[31] Conservation can be an expensive proposition. Preserving the natural areas that shelter biodiversity requires amassing sufficient funds to compensate their owners for the opportunity costs of not converting forests, wetlands, and other areas to alternative uses. It may also require ongoing expenses to monitor natural areas and assure that they are kept intact. Conservation advocates and their funders seek ways to motivate more habitat conservation without bearing the full cost.

This hope of getting a lot for a little has animated several advocates. Gretchen Daily and Pamela Matson write of "a growing feeling of Renaissance in the conservation community" arising from working with "a much more diverse and powerful set of leaders… for new approaches that align economic forces with conservation."[32] Heather Tallis and Peter Kareiva give a sense of what the conservation community hopes to gain from an appreciation of ecosystem services: "…realization of the market worth of ecosystem services has the potential to increase conservation funding by orders of magnitude. Ecosystem services also have the possibility of aligning conservation value and poverty alleviation."[33]

Tallis and Kareiva's emphasis on aligning conservation and development interests underscores certain challenges that arise in international conservation policy. The concept of ecosystem services came to prominence at roughly the same time as did concerns over preserving global biodiversity. Appeals to ecosystem services are often made as part of a strategy for conserving biodiversity.[34] Biodiversity, as measured by numbers of species, tends to be concentrated in the countries of the less-developed global South.[35] To many ecosystem service advocates, then, the conservation challenge was to find a way to motivate these generally poorer nations to see biodiversity conservation as in their own best interests. As Armsworth et al., put it, "In the face of a sea of poverty, demonstrating the ignored links between nature and elements of well-being—safe drinking water, food, fuel, flood control, and aesthetic and cultural benefits that contribute to dignity and satisfaction—is the key to making conservation relevant."[36]

The claim that preserving nature—and with it, the ecosystem services it provides—will help the world's poor is problematic on a number of levels. Tallis and Kareiva note that "Functioning ecosystems provide clean, disease-free water, fertile soil and numerous other basic human needs."[37] Perhaps they do. As Hobbes famously noted, however, life in the midst of ecosystems that function as nature may have intended also tends to be "solitary, poor, nasty, brutish, and short." Why would the poor be better served by continued immersion in the "nature" from which wealthier people have largely distanced themselves?

To an economist, the objective of "aligning" conservation and poverty alleviation is suspect. "Economic forces" are what they are: People have preferences over what they wish to consume and enjoy, and biology and technology impose constraints on the degree to which those preferences can be satisfied. It seems that at least part of the intent of ecosystem services advocates is to change the preferences people have between nature and the things that imperil it.

There may, however, be a fine line between changing preferences and providing better information. Do arguments for reliance on ecosystem services convey new information to people who might benefit from them? I have argued above that they may not provide much information. But it may also be prudent to consider the interests of the sources purveying the claims. Armsworth et al. write that "Nature for nature's sake resonates only with the already converted."[38] The religious imagery of "the converted" suggests that the real goal is to motivate those who failed to receive the conservationists' revelation. If the masses are too venal to have appreciated appeals to "nature for nature's sake," why are they not venal enough to appreciate what is in their own best interest? Moreover, it is troubling to read an exhortation by ecosystem service researchers "to plan our research programs from the desired endpoint and work backwards from there."[39] One would hope that research, and particularly publicly funded research, is not intended to support the predetermined conclusions of advocates.

Some authors suggest that the conservationists' claims concerning ecosystem services were not intended to be taken literally. Gómez-Baggethun et al. refer to ecosystem services "as a pedagogical concept designed to raise public interest for biodiversity conservation."[40] Norgaard describes them as "an eye-opening metaphor intended to awaken society to think more deeply about the importance of nature," and Janet Fisher and Katrina Brown ask if they are "just a rhetorical tool."[41]

Fisher and Brown conclude that, regardless of how they were originally intended, ecosystem services are not just a rhetorical tool now. This raises further questions. Would some conservation advocates be happier if ecosystem services were regarded as

simply a rhetorical flourish, or had never been proposed at all? Some would. Douglas McCauley alleges that the approach of setting values on ecosystem services is "selling out on nature."[42] Richard Norgaard claims that an emphasis on ecosystem services diverts attention from more fundamental environmental concerns.[43] And Michael Soulé writes that an ecosystem services paradigm in which human and natural systems are more closely integrated "would hasten ecological collapse globally, eradicating thousands of kinds of plants and animals and causing inestimable harm to humankind in the long run."[44]

Why might some conservationists oppose emphasizing ecosystem services as a tool for conservation? An answer might be found in a current controversy over the future of conservation.

In recent work, Peter Kareiva, Robert Lalasz, and Michelle Marvier advanced a vision in which "conservation will measure its achievement in large part by its relevance to people, including city dwellers. Nature could be a garden—not a carefully manicured and rigid one, but a tangle of species and wildness amidst lands used for food production, mineral extraction, and urban life."[45] Other conservation advocates—or rather, advocates for different interpretations of conservation—reacted angrily.[46] The acrimony of the resulting debate sparked appeals by the scientific community for conservationists to reconcile their differences.[47] Yet the need for such appeals reveals fundamental differences in the objectives of conservation scientists.

Importantly, not everyone's vision of conservation is, as Kareiva, Lalasz, and Marvier write, "wildness amidst lands used for food production, mineral extraction, and urban life." To others, a crucial objective of conservation is the preservation of large enough areas of relatively wild habitat to assure the survival of large carnivores *in situ*.[48] Yet much of the ecosystem services literature implies that we should value—and presumably, retain—ecosystems that provide services in the midst of otherwise human-dominated landscapes. Flood protection services are most valuable when they adjoin expensive, densely inhabited areas that need to be protected against floods. Pollution treatment services are most valuable when the natural wetlands and vegetation that provide them are located between decidedly unnatural sources of pollution and large concentrations of people. Native pollinators are most valuable when there is a large expanse of cropland nearby for them to pollinate.

Ecosystem-service-based arguments, if taken literally, are not arguments for conservation in some generic and universal sense so much as for the conservation of *particular types* of areas. Many of the arguments for ecosystem services are, implicitly, exhortations to create checkerboard landscapes consisting of numerous small pockets of "natural" habitats situated within areas devoted to less-intensive cultivation,

production, or settlement. If land is used less intensively in production, however, it means either less will be produced or more land must be used to maintain the level of production, and human activities would expand further into the remaining "wild" areas of the planet.[49]

CONCLUSION

Do we as a society want a world with many small areas devoted to conserving a limited suite of native species, or one in which production and human habitation are more intensive in some areas while more of the landscape is left relatively untrammeled? I don't propose to answer this question; what society wants should be worked out through society's institutions. This, however, is why the current interest in ecosystem services, particularly among national and international policymakers, is problematic. Many advocates speak and write as if it were an established fact that ecosystem services are undervalued and that public policies should be enacted to assure that the ecosystems providing them are sufficiently protected. I have argued that these propositions are not, in fact, well established on a broad basis.

That is not to say that there are not important reasons to be concerned with the decline of natural ecosystems. There may well be, as some have suggested, systemic risks inherent in degrading systems whose workings we do not fully understand and whose failure might not be preceded by actionable warnings.[50] Moreover, many of us feel ethical or even spiritual obligations to be good stewards of the natural world. Current research on ecosystem services, however, has little to say about these questions. Instead, it seems intended to create the impression that technical calculations can inform conservation choices. Such a view would fit neatly into a paradigm in which regulators determine the externalities inherent in land-use choices and restrict property rights accordingly. In our society, however, we rightly set a high bar to such "takings." At present, there is not enough reliable information about the value of ecosystem services to justify a regulatory approach, and there is no indication that science will progress quickly enough to change this state of affairs any time soon.

ENDNOTES

1 Executive Office of the President of the United States. Memorandum for Executive Departments and Agencies. "Incorporating Ecosystem Services into Federal Decision Making." October 7, 2015.

2 In this essay, I will only address whether *setting aside land* for the provision of ecosystem services should be regarded as a public good and/or the focus of public policy. I will not consider the *effects* of other factors on lands that provide ecosystem services, for example, how acid precipitation affects the health of forests.

3 Naidoo, R. and T.H. Ricketts. 2006. "Mapping the Economic Costs and Benefits of Conservation." *PLOS Biology.* 4(11).

4 TEEB. 2010. *The Economics of Ecosystems and Biodiversity: Ecological and Economic Foundations.* Edited by Pushpam Kumar. London and Washington: Earthscan.

5 Guerry, A., et al. 2015. "Natural Capital and Ecosystem Services Informing Decisions: From Promise to Practice." *Proceedings of the National Academy of Sciences.* 112(24): 7348–7355.

6 Because tax collection imposes a deadweight loss, the social cost of a dollar of tax revenue typically exceeds a dollar because economic behavior is distorted by the tax.

7 See, e.g., Ricketts, T. H., et al. 2004. "Economic Value of Tropical Forest to Coffee Production." *Proceedings of the National Academy of Sciences.* 101(34): 12579–12582; or Armsworth, P.R., et al. 2007. "Ecosystem Service Science and the Way Forward for Conservation." *Conservation Biology.* 21(6): 1383–1384.

8 The usual argument suggested against such arrangements is that the larger the area that must be acquired in order to appropriate the benefits of conserving some habitat, the more difficult they become to institute and monitor. Would this make sense in the context of pollinators, however? If agreements must cover large areas, it would be because pollinators have very wide ranges. If native pollinators can easily cover wide ranges, however, why are those that remain abundant in areas farther from existing farms not sufficient to serve the farms?

9 Brauman, K.A. 2015. "Hydrologic Ecosystem Services: Linking Ecohydrologic Processes to Human Well-Being in Water Research and Watershed Management." *WIREs Water.* 2(4): 345–358.

10 Seppelt, R., et al. 2011. "A Quantitative Review of Ecosystem Services Studies: Approaches, Shortcomings, and the Road Ahead." *Journal of Applied Ecology.* 48(3): 640–646. Their criterion for a "sound basis" was that one could draw a clear path between the premises and conclusions of a study, not whether the inferences made along such a path were logically sound. The fraction might be lower yet if one also applied a filter for conformance with received principles of economic valuation.

11 Ricketts, T.H., et al. 2004. "Economic Value of Tropical Forest to Coffee Production." *Proceedings of the National Academy of Sciences.* 101(34): 12579–12582.

12 Laurans, Y.A., et al. 2013. "Use of Ecosystem Services Economic Valuation for Decision Making: Questioning a Literature Blindspot." *Journal of Environmental Management.* 119: 208–219.

13 Guerry, A., et al. 2015. "Natural Capital and Ecosystem Services Informing Decisions: From Promise to Practice." *Proceedings of the National Academy of Sciences.* 112(24): 7348–7355

14 See, e.g., Mander, Ü. 2008. "Riparian Zone Management and Restoration." *Encyclopedia of Ecology.* Edited by S.E. Jørgensen and B. Fath. Amsterdam: Elsevier. 3044–3061.

15 Simpson, R. D. 2015. "Developing 'Reality Checks' on Ecosystem Service Values: Characterization and Bounding Results for a Broad Class of Models." Paper presented to the 17th annual meeting of the BioEcon Network, Cambridge, United Kingdom.

16 Another fascinating instance of history repeating itself may be found in the rise and fall of "economic ornithology" in the early 20th century. (See Kronenberg, J. 2015. "Betting Against Human Ingenuity: The Perils of the Economic Valuation of Nature's Services." *BioScience.* 65(11): 1096–1099; I am grateful to Mark Sagoff for bringing this example to my attention). If one did not notice the dates in the text, attempts conservation advocates made at the time to assign a value to the pest control services provided by native bird populations might be mistaken for a current submission to a journal such as *Ecological Economics.*

17 Armsworth, P.R., et al. 2007. "Ecosystem Service Science and the Way Forward for Conservation." *Conservation Biology.* 21(6): 1383–1384.
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19 International Union for the Conservation of Nature, United Nations Environment Program and World Wildlife Fund. 1980. *World Conservation Strategy: Living Resource Conservation for Sustainable Development.* Switzerland: Gland.
20 Terborgh, J. 1999. *Requiem for Nature.* Washington, D.C.: Island Press.
21 See, e.g., Wells, M. and K. Brandon. 1991. *People and Parks: Linking Protected Areas with Local Communities.* Washington, D.C.: World Bank; or Terborgh, J. and C. van Schaik. 2002. "Why the World Needs Parks." In *Making Parks Work: Strategies for Preserving Tropical Nature.* Edited by J. Terborgh, C. van Schaik, L. Davenport, and M. Rao. Washington, D.C.: Island Press. 3–14.
22 Honey, M. 2008. *Ecotourism and Sustainable Development: Who Owns Paradise?* 2nd edition. Washington, D.C.: Island Press.
23 Chomitz, K. and K. Kumari. 1998. "The Domestic Benefits of Tropical Forests: A Critical Review." *World Bank Research Observer.* 13: 13–35; Terborgh, J. 1999. *Requiem for Nature.* Washington, D.C.: Island Press.
24 See, e.g., Blum, E. 1993. "Making Biodiversity Conservation Profitable: A Case Study of the Merck/INBio Agreement." *Environment.* 35(4): 17–20, 38–45.
25 See, e.g., Shiva, V. 1997. *Biopiracy: The Plunder of Nature and Knowledge.* Cambridge, MA: South End.
26 Simpson, R.D., et al. 1996. "Valuing Biodiversity for Use in Pharmaceutical Research." *Journal of Political Economy* 104: 163–85.
27 See, e.g., Firn, R.D. 2003. "Bioprospecting: Why is It So Unrewarding?" *Biodiversity and Conservation.* 12(2): 207–216; Coniff, R. "A Bitter Pill." *Conservation.* March 9, 2012.
28 Terborgh, J. 1999. *Requiem for Nature.* Washington, D.C.: Island Press.
29 *Ibid.*
30 For a more formal approach to this question, see Ferraro, P. J. and R.D. Simpson. 2002. "The Cost-Effectiveness of Conservation Payments." *Land Economics* 78: 339–53.
31 See, e.g., Landell-Mills, N. and I.T. Porras. 2002. *Silver Bullet or Fools' Gold? A Global Review of Markets for Forest Environmental Services and Their Impact on the Poor.* London: International Institute for Environment and Development; or Vira, B. and W. Adams. 2009. "Ecosystem Services and Conservation Strategy: Beware the Silver Bullet." *Conservation Letters.* 2(4): 158–162.
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34 Gómez-Baggethun, et al. 2010. "The History of Ecosystem Services in Economic Theory and Practice: From Early Notions to Markets and Payment Schemes." *Ecological Economics.* 69(6): 1209–1218.; Norgaard, R. 2010. "Ecosystem Services: From Eye-Opening Metaphor to Complexity Blinder." *Ecological Economics.* 69: 1219–1227.
35 See, e.g., Hillebrand, H. 2004. "On the Generality of the Latitudinal Diversity Gradient." *American Naturalist.* 163(2): 192–211.
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37 Tallis, H. and P. Kareiva. 2005. "Ecosystem Services." *Current Biology.* 15, 18.
38 Armsworth, P.R., et al. 2007. "Ecosystem Service Science and the Way Forward for Conservation." *Conservation Biology.* 21(6): 1383–1384.
39 *Ibid.* Short quotations may be taken out of context. I don't believe this one is. The entire article from which it is taken is short, and the reader may draw her own conclusion.
40 Gómez-Baggethun, et al. 2010. "The History of Ecosystem Services in Economic Theory and Practice: From Early Notions to Markets and Payment Schemes." *Ecological Economics.* 69(6): 1209–1218.

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45 Kareiva, P., et al. 2012. "Conservation in the Anthropocene: Beyond Solitude and Fragility." *Breakthrough Journal;* see also Kareiva, P. and M. Marvier. 2012. "What is Conservation Science?" *BioScience.* 62(11): 962–969.

46 See, e.g., Soulé, M. 2013. "The New Conservation." *Conservation Biology.* 27(5): 895–897; Kloor, K. 2015. "The Battle for the Soul of Conservation Science." *Issues in Science and Technology.* 31(2); and Pimm, S. 2014. "Review of *Keeping the Wild: Against the Domestication of Earth.*" *Biological Conservation.* 18: 151–152.

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49 For formal arguments for this proposition, see Simpson, R.D. 2014. "Ecosystem Services as Substitute Inputs: Basic Results and Important Implications for Conservation Policy." *Ecological Economics.* 98(C): 102–108.

50 One may say what one likes about the Ehrlichs' "rivets" analogy (see Ehrlich, P. and A. Ehrlich. 1981. *Extinction: The Causes and Consequences of the Disappearance of Species.* New York: Random House; losing species, the authors say, is like removing the rivets from an airplane; some may be inessential, while the loss of others might cause a catastrophe), but it is difficult to say definitively at what point—if any—planetary stresses could become existential threats.

HOW HUMANS SPARE NATURE

LINUS BLOMQVIST

Humanity has, by most measures, done extraordinarily well over the past century.[1] People on average live longer and eat better. The share of the global population living in poverty is lower than ever before. But supplying food, energy, materials, and water to a growing and increasingly wealthy population has come at a steep cost for the natural world. Humans today use at least half of all ice-free land, mostly for farming and forestry. Habitat loss, overexploitation, pollution, and other environmental impacts have on average reduced wildlife populations by more than half since 1970. Hundreds of species of birds and mammals have gone extinct over the past few centuries, and many more are threatened today.

But there are glimmers of hope. Even as biodiversity continues to be lost, there are signs that economic growth and human welfare are becoming increasingly decoupled from environmental impacts. While many of humankind's environmental impacts have grown in absolute terms, several have started to flatten out or even decline. Per-capita impacts have in many cases gone down, in large part because the technologies used to produce goods have become less environmentally harmful. If these decoupling trends continue, it is possible that human impacts on the environment will peak and decline this century, even as the global population approaches 10 billion and people around the world become more materially rich and secure.

"Peak impact" offers an inspiring vision for global conservation. It can be achieved by accelerating beneficial economic and technological processes while continuing to use protected areas, payments for ecosystem services, and other conventional conservation tools at a landscape levels. Here is how it works.

TAKING A BURDEN OFF NATURE

While population and per-capita consumption have added to humanity's overall burden on the environment, technological shifts have for the most part reduced it. These shifts can be reduced to two mechanisms: substitution and intensification.

The substitution of tractors for horses eliminated the need to dedicate about one-quarter of all U.S. farmland to feed draft animals. The introduction of synthetic nitrogen meant farmers no longer needed to keep as much as half of their cropland in fallow to replenish soil nutrients. Together with agricultural intensification in the forms of rising crop yields and greater efficiencies in meat production, these technological advances have allowed the area of farmland per capita to fall by half over the last half century, even as diets have gotten richer. While global farmland area has increased by about 10 percent since 1960—causing widespread habitat loss—it has barely grown since the early 1990s. During that period, global population rose by more than 20 percent and GDP per capita nearly doubled.

The transition from fuelwood to fossil fuels, nuclear power, and hydro as sources of energy has also contributed to flattening global demand for wood. In fact, per-capita wood consumption has declined so much as to offset the concurrent increase in food consumption, such that the total per-capita demand for biomass has stayed constant for more than a century. Today, it takes on average less than one hectare to provide food, energy, and living space per person, compared to an estimated four hectares per person among early agriculturalists some 7,000 years ago.

Through similar mechanisms, farmed meat and fish have taken pressure off wild populations. Petroleum- and plant-based substitutes for whale oil spared global whale populations—not just in the 19th century when kerosene replaced whale oil in lighting, but also in the 20th century when innovations made whale products unneeded for lubricants, soap, and margarine. Shifting from coal to natural gas to nuclear and hydro—and wind and solar power more recently—has gradually reduced the amount of carbon emissions per unit of energy, even as total global carbon emissions have continued to rise. As humans shift from harvesting goods in the wild—such as bushmeat hunting or whaling—to farming them, or to producing goods in factories, the amount of environmental harm per unit produced tends to fall.

In other words, in most cases, the more synthetic our consumption, the less nature we destroy. We spare nature by using less of it.

So far, in most cases, technological improvements have not fully offset the increasing pressure from a growing population and higher consumption, so most environmental impacts have grown in absolute terms. Indeed, increasing efficiency has often enabled greater consumption. But as population growth slows and demand for material goods saturates at high levels of income, the peak and subsequent decline of human impacts on the environment is a distinct possibility this century.

THE DEFINING CHALLENGE FOR CONSERVATION

To understand what decoupling means for conservation, we need to focus on the micro level. Here, the fate of conservation boils down to an evolving race between consumptive uses of the environment, such as conversion of forests to farmland, and non-consumptive uses, such as the preservation of land or wildlife for aesthetic or recreational purposes. Put differently, the conservation of natural habitats and wildlife is ultimately a question of opportunity costs. In the words of ecologist John Terborgh, as long as a forest is "worth more dead than alive," conservation is an uphill battle.

Conservationists have devised several strategies to deal with opportunity costs. Protected areas—one of the cornerstones of global conservation—exclude some or all ecologically harmful activities by legal means. They allow constituencies to identify and protect the most unique and highly prized places for their biodiversity, scenery, or other values. When adequate resources are available, such legal designations can be backed up by interventions to save threatened species or landscapes. Yet protected areas face a number of limitations.

Societies and communities are often not willing to make big economic sacrifices for the intrinsic or aesthetic value of biodiversity or landscapes, especially—and understandably—in poorer countries. The vast majority of protected areas are located in places where there are no competing land uses, either because the land is too infertile, rugged, or remote. Where farming, logging, or mining is viable, and where population densities are higher, protected areas are much less common, or they are poorly enforced or dismantled altogether when pressures become too high. Where protected areas make a difference, they tend to displace the harmful activities to other places, rather than eliminating them altogether. When logging or farming is banned from an area, the wood and food will still be produced somewhere—either close by or in a different region. For this reason, local successes do not necessarily add up to less habitat loss globally, even though they have helped many individual species and populations to survive.

Another way to win the race between consumptive and non-consumptive uses is to identify and capture value from conserved land or wildlife. Ecotourism, as well as ecosystem services like purification of water and air by plants, flood control by wetlands, and crop pollination by wild insects, are examples of how benefits might match or exceed the value of developing land for farming or housing. Several of these have proven effective conservation tools at local levels. Buffer strips, which capture pollutants from agricultural runoff, have helped restore riparian ecosystems across many parts of the United States and Europe. Ecotourism tips the balance in favor of conservation in some scenic or biodiverse parts of the world, notably the tropical forests of Costa Rica and many wildlife reserves in Africa.

Yet these tools, too, face certain limitations in achieving conservation at larger scales. Ecotourism can bring large incomes in accessible places with unique qualities, but is often not feasible in areas lacking these features or at wide geographical scales.

As for ecosystem services, many of the most biologically rich ecosystems are so far from cities, farming, and other human activities that their services do not really have economic value. For instance, riparian vegetation only serves humans if there is a nearby source of pollution, like farming, and a downstream population to benefit from cleaner water. Trees only provide an air quality service when there are humans nearby to benefit from cleaner air.

In other cases, it can be more profitable to develop land for farming at the expense of natural habitats and their ecosystem services, and instead rely on substitutes. Rather than use large amounts of cropland for legumes to supply nitrogen to the soil, for instance, farmers could use the land to grow other crops and apply synthetic fertilizer.

In places where farming or housing is not profitable, the opportunity cost of setting aside land is often much lower. But if the land was not under threat of conversion anyway, relying on the ecosystem services does not result in more land for nature. This presents a paradox: We might benefit from ecosystem services the most in the areas where they make the least difference to conservation outcomes.

Finally, if ecotourism, ecosystem services, or other economic benefits of conservation really do alter the use of land and other resources, these activities tend to be displaced elsewhere rather than eliminated.

By no means does this imply that we should abandon protected areas or ecosystem services. Nor does it mean that paying people to protect their land or provide ecosystem services is not beneficial. But the effects on land use and conservation may not be able to stem the global tide of habitat and species loss, as long as demand for land and material goods keeps increasing. Conventional conservation tools are necessary, but not sufficient, for global conservation to succeed.

TOWARDS PEAK IMPACT

Decoupling through intensification and substitution can pick up where conventional conservation leaves off. Decoupling can reduce the consumptive value of land and wildlife, so that their exploitation becomes less profitable—in other words, so that the opportunity cost of conservation falls.

For example, once kerosene was widely adopted, there was little reason to continue whaling, since no one would buy the more expensive whale oil. As intensive farming in the American Midwest combined with better transportation networks to lower food prices across the country, marginal farming operations in places like New England became a losing proposition, and much of the farmland was left to resurgent forests. This process was reinforced by the fact that a growing manufacturing sector offered better uses for people's time and capital. A similar phenomenon is now playing out across other regions, including Latin America.

Substitution and intensification generally follow economic growth and modernization, but they are not entirely spontaneous or natural processes. They can be accelerated through targeted policies, investments, and institutional reforms by governments, civil society, and entrepreneurs. Four priorities stand out.

The first is to spread existing technologies to spur substitution and intensification in more places. Perhaps the most important part of this is to enable farmers, especially in poor countries, to adopt modern agricultural technologies. This is an urgent priority that can halt the expansion of farmland as food demand continues to grow globally. And we know that it is possible: If agricultural yields across the world come closer to their potential, crop production on existing farmland could more than double.

Along with agricultural modernization, moving up the energy ladder can make a big difference for conservation. Modern energy, mostly fossil fuels, has substituted for fuelwood, organic fertilizers, and horses, resulting in "land sparing." But decoupling is not just about changing the source of energy; it's also about using larger amounts of energy in order to reduce impacts on wildlife and habitats. So the second big factor in decoupling is energy—lots of it. Aquaculture takes more energy than capture fisheries, and feedlot systems use more energy than bushmeat hunting. The impressive yield improvements we have seen in agriculture would be impossible without huge energy inputs in the form of fertilizers, pesticides, machinery, and irrigation. Abundant modern energy is also needed to power the industries and cities that allow decoupling to happen.

So we save nature with energy, but since our energy has so far mostly come from fossil fuels, sparing land and wildlife also releases large amounts of carbon dioxide

into the atmosphere. This presents a huge trade-off. The only way to reduce our impacts on land and wildlife while also avoiding the worst impacts of climate change is to decarbonize our energy supply. Renewables like solar and wind will play a part in this, but they are far from sufficient. We need energy sources, such as nuclear power, that work when the sun is not shining or the wind is not blowing, and that can provide baseload power for cities and industries.

Neither agricultural modernization nor energy transitions, however, are purely about technology. Both are fundamentally underpinned by broader social and economic shifts, including urbanization, income and consumption growth, and a shift from subsistence farming to manufacturing and services. These shifts not only lift people out of poverty and increase their choices and freedoms, but they are also associated with lower population growth, which can reduce pressure on the natural environment. Therefore, accelerating these processes in a just way is our third priority.

The fourth and final priority for decoupling is innovation, which creates more opportunities for substitution and intensification. For example, the improved seeds that were part of the Green Revolution are estimated to have saved an area half the size of France from conversion to farmland. Looking forward, if clean energy sources like nuclear power are to diffuse more rapidly, we will need innovations that lower their costs.

NECESSARY BUT NOT SUFFICIENT

Even as decoupling takes pressure off forests and wildlife, it does not solve every conservation problem. It does not guarantee that the landscapes conservationists care about most, such as old-growth forests, will be preserved, or that land that remains in production will be concentrated in areas where ecological impacts are least significant.

There are places where consumptive values are virtually non-existent and conservation is the highest use by default. This is referred to as passive protection, and it includes parts of the Amazon basin and the Siberian Taiga. But in many places, consumptive values will remain significant, making passive protection insufficient. As a result, conventional conservation measures like protected areas or direct payments remain essential. Decoupling is a complement, not an alternative, to these strategies—it is a means of making them more feasible. Only when the two are combined, especially at a landscape level, can the scales be tipped in favor of conservation.

The role of conventional conservation approaches in the context of decoupling is highly contextual. In many temperate regions, and on marginal lands in the tropics, pressures are easing and land prices are falling as a result of decoupling. In these cases, governments and conservation organizations can step in to make the most of these opportunities.

For example, competition from agriculture in more productive regions led to the abandonment of marginal farming operations in parts of the Mississippi basin. But it took a concerted effort by governments and conservation groups to restore floodplains such as the Oachita River. Likewise, greater efficiencies in cattle production have made ranching less profitable in some regions, but it still requires the work of conservation organizations to purchase marginal ranchland, tear down fences, reintroduce wildlife, and create nature reserves—as the American Prairie Reserve has done in Montana, for instance. In some cases, such as in Mexico, payments for ecosystem services have accelerated the abandonment of marginal agricultural land.

In fertile lowlands in the tropics, agricultural intensification can be a double-edged sword. Higher yields in these regions are essential for the global land footprint of agriculture to peak and decline. However, higher productivity in these lowlands makes farming more competitive and can bring even more pressure to expand agriculture locally. In this situation, protected areas and strategic, landscape-level strategies can help concentrate production on lands that are already cleared, while ensuring protection for the most biologically rich areas.

A MORE ECOLOGICALLY VIBRANT FUTURE

Decoupling through intensification and substitution, modernization, and innovation can combine with conventional conservation approaches to offer a practical strategy to achieve peak impact and leave more room for nature. But decoupling also presents tough choices and trade-offs. Further intensification of farming, including the use of biotechnology, will be needed to shrink humanity's footprint. Dense and abundant (but sometimes unpopular) energy sources like nuclear power must be a part of our energy future to spare land and decarbonize our economies. Large amounts of meat and fish will have to be farmed instead of harvested in the wild.

Yet these technologies can also enable us to find greater spiritual and aesthetic connections to nature. If food and energy production take up less land, there will be more space for nature, both near and far from cities. Less demand for wild meat might bring wildlife back in many regions. Substitutes have helped bring the whales back, giving people a better chance of seeing these spectacular creatures in the wild. To put it differently, decoupling from nature in material terms might give us more of the beauty, diversity, and other immaterial benefits that nature has to offer.

ENDNOTES

1 This essay is based on "Nature Unbound: Decoupling for Conservation" by Linus Blomqvist, Ted Nordhaus, and Michael Shellenberger, published by the Breakthrough Institute (2015). For complete references and more information, see the full report available at thebreakthrough.org.

"With the advent of a new epoch—the Anthropocene, where humans dramatically shape the functioning of ecosystems—a new approach to environmental policy is required. Gone are many of the standard constructs of the proceeding era, such as 'balance of nature' and 'equilibrium ecology.' The chapters in this volume begin an examination of what types of constructs may be appropriate for this new era, and what associated policies might follow."

—Roger A. Sedjo
Senior Fellow, Resources for the Future

Environmentalists are increasingly confronted with two emerging ideas about the natural world: that there is no balance of nature, and that nature cannot be easily separated, if at all, from human action. Many are now embracing a new reality—known as the "Anthropocene"—reflecting the magnitude of human influences over the planet.

The Anthropocene implies a new way of thinking about environmental problems. No longer can environmental problems be thought of as simply the consequence of human violations on nature's balance, nor can they be solved by simply separating the natural world from humans. Instead, environmental problems become questions of how to resolve competing human demands over an ever-changing natural world.

What institutions best allow us to resolve those competing human demands over a dynamic natural world? What policies will allow us to account for dynamic nature and dynamic human action in this human-dominated era? By bringing together scholars and practitioners from a variety of disciplines, this volume aims to foster an engaging discussion of environmental policy in the Anthropocene—as well as the future of environmentalism.

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PERC—the Property and Environment Research Center—is a nonprofit research institute dedicated to improving environmental quality through markets and property rights. Located in Bozeman, Montana, PERC pioneered the approach known as free market environmentalism. PERC's staff and associated scholars conduct original research that applies market principles to resolving environmental problems.

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