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# How Science Has Influenced, But Should Now Determine, Environmental Policy

Jan G. Laitos

# HOW SCIENCE HAS INFLUENCED, BUT SHOULD NOW DETERMINE, ENVIRONMENTAL POLICY

JAN G. LAITOS*

This is an article about science and environmental law. More specifically, it is an article about two different versions of science, and how each has affected environmental law and the development of environmental policy. The emergence of science-driven environmental law has significantly affected how humans view and respond to the natural world that makes up the biosphere, which is the thin envelope surrounding the Earth that permits the human species to exist. This Article argues that humans, and law-makers, should embrace a different role for science. Instead of science answering "what is" questions, it should also explain the universal laws of the natural environment, so environmental laws can be consistent with those fundamental natural laws. Only then can environmental policy, and its laws, successfully ensure that the biosphere will continue to be a home for humans.

Environmental law was "invented" approximately fifty years ago.[1] In the 1960s, the United States Congress reacted to the growing awareness of human-caused threats to the natural environment by enacting the Water Quality Act of 1965,[2] and then the Natural Environmental Policy Act of 1969.[3] These statutes were just the beginning of an enormous number of environmental laws and regulations, which were put in place to address the widely held perception that human behavior has been adversely affecting the natural environment, and the health and safety of humans living in that environment.[4] Environmental policy has guided these many laws. This policy has been based on various assumptions about how the environment works and how humans behave. Science has provided law-makers with models about how the environment functions and the ways humans make choices about this environment. For much of the lifespan of environmental law, environmental policy has been aided

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* Professor of Law and John A. Carver, Jr. Chair, University of Denver Sturm College of Law.

1 Richard J. Lazarus, *The Greening of America and the Graying of United States Environmental Law*, 20 VA. ENVTL. L.J. 75, 76 (2001).

2 Water Quality Act of 1965, Pub. L. No. 89-234, 79 Stat. 903 (1965).

3 National Environmental Policy Act of 1969, Pub. L. No. 91-190, 83 Stat. 852 (1970).

4 *Id.*; Water Quality Act of 1965, Pub. L. No. 89-234, 79 Stat. 903 (1965).

by a classical version of science—*utilitarian science*.[5] That type of science became essential to the formulation of policy.[6] Science became the critical informational input for environmental decision-making.[7]

Utilitarian science is designed to help policymakers reach answers addressing "what is."[8] Those who make policy supply the "ought" answers.[9] Utilitarian science helps to supply the legal requirements of empirical proof for environmental causation.[10] In addition, environmental statutes call for policymakers to establish regulatory standards as tools for preventing pollution and human-made waste from creating environmental and human harm. Utilitarian science sets these standards. This class of science tells policymakers what is safe for human health and what is not.[11]

But classical utilitarian science has several limitations that make it an imperfect fit for environmental law and policy. It often cannot provide the definitive answers to the questions that environmental policymakers ask.[12] This failure to supply answers is due to the many uncertainties that surround environmental science.[13] Moreover, environmental conclusions based on science can easily be attacked in court, and in the political arena, for being based on flawed or inadequate data.[14] Due in part to these shortcomings in utilitarian science, commentators and scholars have increasingly suggested that environmental policymakers should instead consider using a different version of science—*explanatory science*.

Rather than only determining "what is," in order to inform policymaking, explanatory science provides unifying principles necessary to understand the underlying structure and dynamics of nature and humans.[15]

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[5] *See* Oliver Houck, *Tales from a Troubled Marriage: Science and Law in Environmental Policy*, 17 TUL. ENVTL. L.J. 163, 165 (2003).
[6] *Id.*
[7] Eric Biber, *Which Science—Whose Science—How Scientific Disciplines Can Shape Environmental Law*, 79 U. CHI. L. REV. 471, 476 (2012).
[8] *See* Houck, *supra* note 5, at 167 (discussing how scientists determined the source of pollution and then formulated steps to abate it).
[9] J.B. Ruhl, *The Battle Over Endangered Species Act Methodology*, 34 ENVTL. L. 555, 563–65 (2004).
[10] *See* Houck, *supra* note 5, at 167–69.
[11] *Id.* at 164–65.
[12] *See, e.g.*, Holly Doremus, *The Purposes, Effects, and Future of the Endangered Species Act's Best Available Science Mandate*, 34 ENVTL. L. 397, 438 (2004).
[13] Holly Doremus & A. Dan Tarlock, *Science, Judgment and Controversy in Natural Resource Regulation*, 26 PUB. LAND & RESOURCES L. REV. 1, 6 (2005).
[14] *See* Danny Hakim & Eric Lipton, *Pesticide Studies Won E.P.A.'s Trust, Until Trump's Team Scorned 'Secret Science'*, N.Y. TIMES (Aug. 24, 2018), https://www.nytimes.com/2018/08/24/business/epa-pesticides-studies-epidemiology.html [https://perma.cc/97BN-9THE].
[15] *See* Biber, *supra* note 7, at 512–13.

Utilitarian science presumes a separation between science and the value judgments inherent in environmental policy.[16] Explanatory science is more directly linked to policy; it embraces scientific "theories," such as complexity theory and systems theory,[17] as the best way to bring about successful policy reform.[18] The scientific theories that underlie explanatory science are not separated from policy; they should be integrated into policy, and influence and shape policy.[19]

This Article argues that explanatory science should do more than just "influence" environmental policy. The Article advances the proposition that, consistent with the Principle of Universality, science should *direct and determine* environmental policy. The Principle of Universality is a manifestation of explanatory science which holds that all laws of nature must work the same *everywhere*, and at *every time*.[20] The Principle states that it does not matter who conducts the experiment testing nature's laws, or where or when the test occurs; the results will be the same, regardless of whether the test involves biology, chemistry, physics, or the forces of the universe.[21] From this generally recognized, but underappreciated, principle[22] follows this realization: For environmental policy to succeed, it must conform to the demands of the Principle of Universality. And one of the demands of Universality is this: *our laws about nature should be consistent with the laws of nature*.

This Article makes the case that for environmental laws to succeed, they must reflect and conform to the universal scientific truths of nature. The mantra for policymakers is simple: successful environmental laws, as well as the policies that structure and cabin these laws, should adhere

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[16] Wendy E. Wagner, *The Science Charade in Toxic Risk Regulation*, 95 COLUM. L. REV. 1613, 1617, 1711 (1995); Biber, *supra* note 7, at 479.
[17] Andrew Macintosh & Debra Wilkinson, *Complexity Theory and the Constraints on Environmental Policymaking*, 28 J. ENVTL. L. 65, 66 (2016); Lynn M. LoPucki, *The Systems Approach to Law*, 82 CORNELL L. REV. 479, 481, 521–22 (1997).
[18] *See, e.g.*, J.B. Ruhl, *Sustainable Development: A Five-Dimensional Algorithm for Environmental Law*, 18 STAN. ENVTL. L.J. 31, 57, 63 (1999) (stating that complexity theory's optimization algorithms should be used to guide sustainable development policy); J.B. Ruhl, *Complexity Theory as a Paradigm, for the Dynamical Law-and-Society System: A Wake-Up Call for Legal Reductionism and the Modern Administrative State*, 45 DUKE L.J. 849, 852–53 (1996) [hereinafter Ruhl, *Complexity Theory*].
[19] Ruhl, *Complexity Theory*, *supra* note 18, at 852–53.
[20] NEIL DEGRASSE TYSON, ASTROPHYSICS FOR PEOPLE IN A HURRY 34–38 (2017).
[21] *Id.*; Zoran Pazameta, *The Laws of Nature: A Skeptic's Guide*, 24.5 SKEPTICAL INQUIRER (2000); Paul C.W. Davies & Sara Imari Walker, *The hidden simplicity of biology*, 79 REP. PROGRESS PHYSICS 1, 8–9 (2016).
[22] *See* DEGRASSE TYSON, *supra* note 20, at 35–36, 38.

to the fundamental laws of the natural world and our biosphere. What are these universal truths? What laws, or rules, do physical, biological, and chemical systems all follow? Scientists have begun to unravel nature's secrets, the principles which all natural phenomena obey, and which comprise nature's master plan.[23] This Article urges that our environmental policies should closely follow the basic workings that nature employs, which resonate throughout all the operating systems of the universe.[24]

Part I discusses the two roles that science has played in the development of environmental policy—as a *utilitarian* tool to provide policymakers with evidence and data, and as an *explanatory* insight into the unifying principles that describe the behavior of both nature and humans. Part II addresses how utilitarian science has played a critical role in the development of environmental law throughout the twentieth century. Its primary function has been to *inform* the decision-making of policymakers. Utilitarian science has helped to define a view of how nature works and how humans make choices. These assumptions have become embedded in most of the environmental statutes that now comprise the bulk of environmental law.

Part III chronicles how, in the twenty-first century, explanatory science has sought both to alter the relationship between science and policy and to cause us to rethink our previous assumptions about the workings of nature and the behavior of humans. Explanatory science suggests that certain scientific theories, such as complexity theory, chaos theory, and even game theory, should directly *influence* environmental policy. As a result of explanatory science, new environmental laws have been proposed that better reflect the reality of the natural environment as a nonlinear dynamical complex adaptive system. Environmental laws which embrace this reality opt for adaptive management rules and policies that protect biodiversity and ecosystem services. Similarly, explanatory science has yielded new and counter-intuitive empirical realizations about human behavior. As a result, more twenty-first century laws rely on bottom-up structures that "nudge" people to make better choices about the environment, instead of traditional top-down commands and prohibitions.

Part IV proposes a rethinking of environmental law in which science does more than inform decisions (Part II) or influence policy (Part III). Instead, science, particularly explanatory science, should directly *determine*

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[23] FRANK WILCZEK, A BEAUTIFUL QUESTION: FINDING NATURE'S DEEP DESIGN 6–11 (2015).
[24] *See, e.g.*, Steven Weinberg, *Symmetry: A "Key to Nature's Secrets,"* N.Y. REV. BOOKS (Oct. 27, 2011); CAROL BATCHELOR, OCCAM'S RAZOR: THE SIMPLEST SOLUTION IS THE BEST SOLUTION (2016).

policy. One central manifestation of explanatory science—the Principle of Universality—should be adopted by environmental policymakers so that environmental laws about nature are consistent with the laws of nature. Part IV identifies the two principal laws of nature, and offers a model of environmental policy which would conform to these universal laws. Environmental policy that satisfies the Principle of Universality stands a better chance of succeeding in establishing an environmental agenda that actually works.

## I. THE TWO ROLES OF SCIENCE IN ENVIRONMENTAL LAW

Environmental law consists of statutes, regulations from environmental agencies, executive policies, and countless court cases. This body of law seeks to address the unassailable fact of human-produced damage to the natural environment that surrounds us.[25] Because the focus of environmental law is on the physical environment, and because nature is so complex, environmental policymakers have had to rely on science. Science helps decision-makers better understand how laws can best be deployed to (1) deter the human behaviors which adversely alter the many parts of the biosphere, (2) remediate the damage that has already occurred to environmental systems, and (3) assess which laws are working and which are not.[26]

There are two versions of "science" that have assisted the development of environmental law and policy. First, *utilitarian science* is the classical science which for decades has helped decision-makers acquire data and facts about human actions that alter natural conditions and thereby pose a risk to environmental and human health.[27] Utilitarian science informs decision-making.[28] The other form of science is *explanatory science*. Explanatory science postulates various scientific theories which aid environmental decision-making by providing methodologies that explain (1) how natural systems work and (2) how legal policies can best address human-caused harm to these systems.[29] Explanatory science may either influence or explicitly direct environmental policy.[30]

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[25] Celia I. Campbell-Mohn & Frederico Cheever, *Environmental Law*, ENCYCLOPEDIA BRITANNICA (Nov. 3, 2009), https://www.britannica.com/topic/environmental-law [https://perma.cc/55R7-YJED].
[26] *See* John Holmes & Rebecca Clark, *Enhancing the Use of Science in Environmental Policy-Making and Regulation*, 11 ENVTL. SCI. & POL'Y 702, 705–06, 709 (2008).
[27] Houck, *supra* note 5, at 165.
[28] *Id.*
[29] Biber, *supra* note 7, at 512–13.
[30] *See id.* at 515.

### A. *Utilitarian Science*

Classical utilitarian science has been, and continues to be, important to environmental law as a means of making the proof between pollution and environmental-human harm. In order to establish the need for some legal remedy, or regulatory response, one needs to demonstrate that human-generated negative externalities either caused, or had the potential to cause, some kind of injury.[31] Science serves that purpose. Also, when law-makers decide to pass statutes based on environmental standards, designed to prevent harm, scientists help to set those standards.[32] Utilitarian science facilitates environmental standards that determine what is safe and what is not.[33]

A number of environmental statutes have been enacted based on determinations of "unreasonable risk" to human health in the environment.[34] Scientists have been charged with the task of deciding what substances, and what concentration of those substances, have caused a risk to human health.[35] Environmental statutes requiring cleanups of discarded or leaking hazardous wastes assume there is a point when a particular level of cleanup is adequate.[36] This question of "how clean is clean" is squarely within the purview of utilitarian science. Indeed, some environmental statutes make explicit the requirement that administrative agencies rely upon "the best available science" when making decisions.[37]

These environmental statutes presume some reliable knowledge about whether the risk of environmental harm exists and whether pollution

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[31] Mary Jane Angelo, *Harnessing the Power of Science in Environmental Law: Why We Should, Why We Don't, and How We Can*, 86 TEX. L. REV. 1527, 1529 (2008).
[32] Standard-setting environmental statutes include, among others, the Clean Air Act, 42 U.S.C. § 7401 (2012); the Clean Water Act, 33 U.S.C. § 1251 (2012); the Safe Drinking Water Act, 42 U.S.C. §§ 300f(c)–(d) (2012); the Resource Conservation and Recovery Act, 42 U.S.C. § 6901(b)(3) (2012); the Toxic Substances Control Act (TSCA), 15 U.S.C. §§ 2601(a)–(b)(1) (2012).
[33] Houck, *supra* note 5, at 165.
[34] *See, e.g.*, the Federal Insecticide, Fungicide, and Rodenticide Act, 7 U.S.C. §§ 136(x)–(bb) (2012); TSCA, 15 U.S.C. §§ 2601–2692 (1976); the Safe Drinking Water Act, 42 U.S.C. § 300f (2012).
[35] Biber, *supra* note 7, at 515.
[36] The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) is responsible for the cleanup of abandoned hazardous and toxic waste sites. 42 U.S.C. §§ 9601–9628 (2012).
[37] Marine Mammal Protection Act, 16 U.S.C. §§ 1361–1431 (2012); Endangered Species Act, 16 U.S.C. §§ 1531–1544 (2012). *See also* Holly Doremus, *The Purposes, Effects, and Future of the Endangered Species Act's Best Available Science Mandate*, 34 ENVTL. L. 397, 401–07 (2004).

will injure humans or natural systems. These laws assume that those who enforce the statutes will know what the nature of the harm is, how pervasive the harm is, and under what circumstances, or at what concentrations a pollutant harm is likely to occur to humans or the natural environment.[38] This knowledge base extends to an understanding of the technologies and processes that may be used to minimize the risk of these harms.[39] Utilitarian science provides the information to help address the effectiveness of these technologies and whether they are cost-effective.[40]

The prevailing view is that utilitarian science should determine facts, which in turn help to inform the decisions of those who set policy. But informed decision-making is quite different than establishing policy. Science can identify the kinds of risks that are present due to a toxic chemical release, but science cannot know how much risk humans should be willing to tolerate.[41] Policy makes that call. Science can reveal facts, but policy determines the value choices and preferences that ultimately find expression in environmental laws. Science may be able to predict whether a reduction in pollution will achieve a certain level of human health effects, but only policy can announce whether that outcome is optimal as a matter of politics and public perception.[42] In other words, classical science is not designed for policy-making; science, in theory, reveals what is, while policy seeks to establish what should be.[43]

This separation between utilitarian science and environmental policy has been justified because the two disciplines have different purposes and processes. Science sorts out empirical facts to posit the reality of phenomena, while environmental policy relies on this reality to achieve

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[38] Doremus, *supra* note 37, at 399–400.

[39] *See, e.g.*, *Technology, Pollution Prevention*, POLLUTION ISSUES, http://www.pollutionissues.com/Te-Un/Technology-Pollution-Prevention.html [https://perma.cc/XQ36-HCVH] (last visited Mar. 11, 2019).

[40] Statutes requiring that agencies manage natural resources need science-based information about the status of the natural resources to be protected. *See, e.g.*, Ctr. for Biological Diversity v. Zinke, 900 F.3d 1053, 1074–75 (9th Cir. 2018) (concluding that the United States Fish and Wildlife Service (FWS) acted in an arbitrary and capricious manner by ignoring available scientific biological data showing that the Arctic grayling population was declining, contrary to the Endangered Species Act requirement that the FWS base decisions on the "best scientific . . . data available" according to 16 U.S.C. § 1533 (b)(1)(A)).

[41] Angelo, *supra* note 31, at 1528–29, 1534, 1541.

[42] Roger A. Pielke, Jr., *When Scientists Politicize Science: Making Sense of Controversy over* The Skeptical Environmentalist, 7 ENVTL. SCI. & PUB. POL'Y 405, 405–06, 415 (2004).

[43] *See* Carol M. Rose, *Environmental Law Grows Up (More or Less), and What Science Can Do to Help*, 9 LEWIS & CLARK L. REV. 273, 282–86 (2005).

larger public good.[44] Science has been characterized as being "ill-suited" for policy-making because science emphasizes understanding the workings of the physical and natural world.[45] But it is policy that then takes this knowledge and tries to fashion rules which accomplish goals benefitting humans.[46] Some commentators have proposed that science and policy be formally separated in environmental decision-making by requiring that policymakers expressly distinguish between science-derived information and facts, and policy-laden assumptions, values, and inferences.[47]

Although utilitarian science can play a useful role in the development of environmental policy, it does contain one significant limitation—there is *uncertainty* inherent in science. This uncertainty means that science often cannot provide definitive answers to the questions that environmental policymakers ask.[48] There are many reasons for this uncertainty. There may be a lack of reliable data, conflicts in how scientists interpret data, or inconsistent data.[49] Uncertainties may also occur because of the large number of complex variables that are present in environmental systems, as well as the dynamic changes that take place with those variables.[50]

This uncertainty creates frustration among policymakers, who crave certainty and fear political backlash if policy is too ambiguous.[51] Uncertainty also engenders criticism of, and skepticism about, scientific conclusions; those who disagree with what science finds may simply label it the result of "junk" or "bad" science.[52] This discounting of science can

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[44] STEVEN GOLDBERG & LAWRENCE GOSTIN, LAW AND SCIENCE 1, 3, 5 (2006).
[45] *See* J.B. Ruhl, *Reconstructing the Wall of Virtue: Maxims for the Co-Evolution of Environmental Law and Environmental Science,* 37 ENVTL. L. 1063, 1075 (2007).
[46] *Id.*; ROGER PIELKE, JR., THE HONEST BROKER: MAKING SENSE OF SCIENCE IN POLICY AND POLITICS 137 (2007).
[47] J.B. Ruhl & James Salzman, *In Defense of Regulatory Peer Review*, 84 WASH. U. L. REV. 1, 43–47 (2006).
[48] Wendy Wagner, *Commons Ignorance: The Failure of Environmental Law to Produce Needed Information on Health and the Environment*, 53 DUKE L.J. 1619, 1624 (2004).
[49] Doremus, *supra* note 37, at 438–39.
[50] Naomi Oreskes, *Evaluation (Not Validation) of Quantitative Models*, 106 ENVTL. HEALTH PERSP. 1453, 1455 (1998) (stating that the inherent uncertainty in natural systems makes it impossible to demonstrate predictive reliability of a complex natural system).
[51] Usha Varanasi, *Making Science Useful in Complex Political and Legal Arenas: A Case for Frontloading Science in Anticipation of Environmental Changes to Support Natural Resource Laws and Policies*, 3 WASH. J. ENVTL. L. & POL'Y 238, 242 (2013).
[52] Wendy Wagner, *The "Bad Science" Fiction: Reclaiming the Debate Over the Role of Science in Public Health and Environmental Regulation*, 66 LAW & CONTEMP. PROBS. 63, 68–69 (Fall 2003).

become a tool for partisan challenges to environmental agency regulations.[53] Sometimes accusations of "bad" science become so pronounced that policymakers simply reject utilitarian science altogether and declare "war on science."[54]

While utilitarian science can help inform the decisions of policymakers crafting environmental policy, it can also exacerbate existing political conflicts over environmental rules.[55] Indeed, one effective way of undermining environmental policy decisions is to allege that the supporting scientific facts are flawed or uncertain.[56] These limitations of utilitarian science have incentivized some commentators to suggest that another version of science might be better suited to achieving consensus about relevant environmental policy goals—explanatory science.[57] This science posits explanatory theories and models that can do more than just inform decisions that result in policy; explanatory science can either influence policy, or, as this Article argues, direct policy.

### *B. Explanatory Science*

Utilitarian science seeks to provide data and facts about environmental contaminants and natural organisms to assist the decision-making of those who make environmental policy.[58] Explanatory science uses various scientific "theories" to explain human and natural systems so that this understanding of reality may either influence or even direct environmental

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[53] David Adelman, *The Art of the Unsolvable: Locating the Vital Center of Science for Environmental Law and Policy*, 37 ENVTL. L. 935, 937 (2007).

[54] Juliet Eilperin, Josh Dawsey & Brady Dennis, *White House to set up panel to counter climate change consensus, officials say*, WASH. POST (Feb. 24, 2019), https://www.washingtonpost.com/national/health-science/white-house-to-select-federal-scientists-to-reassess-government-climate-findings-sources-say/2019/02/24/49cd0a84-37dd-11e9-af5b-b51b7ff322e9_story.html?noredirect=on&utm_source=reddit.com&utm_term=.18c569fcde1f [https://perma.cc/BU8L-BZGP]; Caroline Orr, *Trump's anti-science agenda exodus from the EPA*, AM. INDEP. (Sept. 11, 2018), http://www.americanindependent.com/trumps-anti-science-agenda-is-driving-a-mass-exodus-from-the-epa/ [https://perma.cc/B9WU-2ZJV]; Editorial, *The Trump Administration's War on Science*, N.Y. TIMES (Mar. 27, 2017), https://www.nytimes.com/2017/03/27/opinion/the-trump-administrations-war-on-science.html [https://perma.cc/2AUG-96BK].

[55] THOMAS O. MCGARITY & WENDY E. WAGNER, BENDING SCIENCE: HOW SPECIAL INTERESTS CORRUPT PUBLIC HEALTH RESEARCH 1 (2008); Daniel Sarewitz, *How Science Makes Environmental Controversies Worse*, 7 ENVTL. SCI. & POL'Y 385, 386 (2004).

[56] RESCUING SCIENCE FROM POLITICS: REGULATION AND THE DISTORTION OF SCIENTIFIC RESEARCH 25–26 (Wendy Wagner & Rena Steinzor eds., 2006).

[57] Biber, *supra* note 7, at 512–13.

[58] Angelo, *supra* note 31, at 1529.

policy-making.[59] Several scientific theories have been advanced to help design and implement environmental policy instruments. Complexity theory has emerged as a possible new paradigm for explaining the natural systems sought to be addressed by environmental policy.[60] Complexity theory has perhaps been most influential among environmental legal scholars wishing to advance a theory that can describe the workings of nature and affect environmental policy-making.[61] Commentators have also proposed that game theory,[62] systems theory,[63] emergy theory,[64] and even "simplicity" theory[65] be deployed as scientific explanatory methodologies to transform environmental policy-making.

Environmental law research has focused on how best to design environmental policy instruments consistent with complexity theory,[66] especially after it became apparent that natural biological and ecological systems were complex, adaptive systems.[67] Professor J. B. Ruhl has argued that the problems plaguing the environmental regulatory structure can be best addressed by assuming that the law-and-society system itself is a complex adaptive system, and complexity theory should be used to produce strategies for regulatory reform.[68] Ruhl and others justify their proposals for environmental policy reform with complexity theory's unifying principles, such as the need for environmental laws to become more adaptive and resilient in the face of perpetual environmental change.[69]

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[59] Ruhl, *Complexity Theory*, *supra* note 18, at 65.
[60] Macintosh & Wilkinson, *supra* note 17, at 65.
[61] Daniel Farber, *Probabilities Behaving Badly: Complexity Theory and Environmental Uncertainty*, 37 U.C. DAVIS L. REV. 145, 147, 156 (2003); J.B. Ruhl & Daniel Martin Katz, *Measuring, Monitoring, and Managing Legal Complexity*, 101 IOWA L. REV. 191, 206 (2015).
[62] William Dutton, *The Ecology of Games and its Enemies*, 5 COMM. THEORY 379, 379 (1995).
[63] Thomas E. Webb, *Exploring System Boundaries*, 24 L. CRITIQUE 131, 131–32, 149 (2013).
[64] Mary Jane Angelo & Mark T. Brown, *Incorporating Emergy Synthesis into Environmental Law: An Integration of Ecology, Economics, and Law*, 37 ENVTL. L. 963, 963 (2007).
[65] RICHARD A. EPSTEIN, SIMPLE RULES FOR A COMPLEX WORLD 21 (1995); Peter L. Strauss & Cass Sunstein, *The Virtues of Simplicity*, YALE L.J. FORUM (Sept. 26, 2006), https://www.yalelawjournal.org/forum/a-debate-between-peter-strauss-and-cass-sunstein [https://perma.cc/P5G5-UJW9].
[66] Macintosh & Wilkinson, *supra* note 17, at 67.
[67] *See infra* Section III.A.1.
[68] J.B. Ruhl & Harold J. Ruhl, Jr., *The Arrow of the Law in Modern Administrative States: Using Complexity Theory to Reveal the Diminishing Returns and Increasing Risks the Burgeoning of Law Poses to Society*, 30 U.C. DAVIS L. REV. 403, 407–08 (1997); J.B. Ruhl, *Thinking of Environmental Law as a Complex Adaptive System: How to Clean Up the Environment by Making a Mess of Environmental Law*, 34 HOUS. L. REV. 101, 104 (1997).
[69] ROBERT GEYER & SAMIR RIHANI, COMPLEXITY AND PUBLIC POLICY, A NEW APPROACH TO 21ST CENTURY POLITICS 5–6 (2010); Jeffrey Rudd, *J.B. Ruhl's "Law-and-Society System":*

Another form of explanatory science is game theory, which sees the design of public policy concerning the environment as a complex game.[70] There are multiple players subject to dynamic socioeconomic and institutional factors who compete, cooperate, or defect in different ways to achieve their objectives.[71] Environmental policy often establishes the rules that govern the game, as well as the norms that guide behavior and the boundaries within which the game is played.[72] Game theory can not only explain how this game is played; it can also help shape, and sometimes determine, the outcome of the game.[73]

Consider the environmental "game" popularized by Garrett Hardin and his warning about "The Tragedy of the Commons."[74] Two mountain goat herders share unregulated open-access common area where their goats can graze.[75] But if they graze too many goats there, exceeding the area's carrying capacity, the commons will collapse and the goats will starve.[76] If the two herders determine the area's carrying capacity, and both abide by an agreement to limit their goats' grazing consistent with this deal, then both are better off.[77] But if one herder secretly "defects" from the agreement, there is a possibility that one herder, or both, will be worse off.[78] The game theory question is: How to prevent defection from the agreement?[79]

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*Burying Norms and Democracy Under Complexity Theory's Foundation*, 29 WM. & MARY ENVTL. L. & POL'Y REV. 551, 552–55 (2005); J.B. Ruhl, *The Fitness of Law: Using Complexity Theory to Describe the Evolution of Law and Society and its Practical Meaning of Democracy*, 49 VAND. L. REV. 1407, 1415 (1996); J.B. Ruhl & Robert Fischman, *Adaptive Management in the Courts*, 95 MINN. L. REV. 424, 424 (2010). *See also* Donald T. Hornstein, *Complexity Theory, Adaptation, and Administrative Law*, 54 DUKE L.J. 913, 918 (2005) ("Complexity theory studies complex adaptive systems [in the environment] and asserts not only that they can reflect nonlinear properties, but that such properties can also play an essential role in the sustainability and success of some of these systems.").

[70] Dutton, *supra* note 62, at 379.

[71] Mark Lubell, *Governing Institutional Complexity: The Ecology of Game Framework*, 41 POL'Y STUD. J. 537, 538–42 (2013).

[72] *See generally Environmental Policy in the United States*, BALLOTPEDIA (2019), https://ballotpedia.org/Environmental_policy_in_the_United_States [https://perma.cc/L7QV-CU9L].

[73] *See* Lubell, *supra* note 71, at 538, 541–42; DOUGLAS G. BAIRD ET AL., GAME THEORY AND THE LAW 1, 1 (1994).

[74] Garrett Hardin, *The Tragedy of the Commons*, 162 SCI. 1243, 1244 (1968).

[75] *Id.*

[76] *Id.*

[77] *Id.* at 1247.

[78] *See id.*

[79] *See id.*

The standard policy solution is to create an administrative agency that will always detect and punish defectors, in a top-down display of an external authority vested with law-based power that imposes rules.[80] However, game theorists suggest a potentially better policy, a less costly and more efficient "bottom-up" strategy—cooperation.[81] In an otherwise non-cooperative resources game involving two or more players, such as the two goat herders, if the players *coordinate* their strategies with each other, each will receive the highest payoff.[82] This insight is known as the Nash equilibrium concept, which provides a way of predicting what will happen if several people or institutions are making decisions at the same time and the outcome for each of them depends on the others.[83] While one cannot predict the result of the choices of multiple decision-makers in isolation, one can determine the best outcome for each player if each player takes action after knowing about and taking into account the decision-making of the others.[84] This outcome can be achieved only if the players coordinate strategies and cooperate.[85] Insights from the explanatory science of game theory suggest that environmental strategies can be developed to secure the benefits of cooperation between policy-making agencies and those subject to the policies made.[86]

Explanatory science can do more than just "inform" policy decisions. Explanatory science can tell us whether an environmental law is likely to work, and whether the outcome is good as a matter of policy.[87] In Part IV, this Article will argue that explanatory science has revealed the Principle of Universality, which should direct environmental policy in the future.

## II. UTILITARIAN SCIENCE INFORMS DECISIONS FOR POLICYMAKERS

Classical utilitarian science helped the evolution of environmental law between 1965 and the twenty-first century by providing models

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[80] ELINOR OSTROM, GOVERNING THE COMMONS: THE EVOLUTION OF INSTITUTIONS FOR COLLECTIVE ACTION 8–10 (1990).
[81] *Id.* at 1–15, 36, 42–45.
[82] *Id.* at 15.
[83] ROBERT AXELROD, THE EVOLUTION OF COOPERATION 85, 89 (1984); Mark Schneider & Jonathan W. Leland, *Reference Dependence, Cooperation, and Coordination in Games*, 10 JUDGMENT & DECISION MAKING 123, 123 (2015).
[84] *See* Elinor Ostrom, *Polycentric Systems for Coping with Collective Action and Global Environmental Change*, 20 GLOBAL ENVTL. CHANGE 550, 551 (2010).
[85] *See* AXELROD, *supra* note 83, at 85, 89; Ostrom, *supra* note 84, at 551–52.
[86] Hornstein, *supra* note 69, at 959–60.
[87] *Id.*; RAGHURAM RAJAN, THE THIRD PILLAR: HOW MARKETS AND THE STATE LEAVE THE COMMUNITY BEHIND (2019).

explaining the behavior of both nature and humans. These science-based models have been embraced by policymakers, who created legal systems designed to protect humans from pollution and hazardous wastes and restore environmental quality. The resulting environmental laws abandoned common law solutions, adopted centralized "top-down" command and prohibition rules, and experimented with decentralized nonregulatory, market-based approaches.

### A. *The Prevailing Twentieth-Century Views of Science About Nature and Humans*

#### 1. The Nature of Nature

Throughout much of the twentieth century, the observable world, including the environmental world, was thought to be governed by deterministic rules.[88] These rules were postulated by Isaac Newton, René Descartes, Pierre-Simon Laplace, and Francis Bacon.[89] These scientists understood the world by adopting a mechanistic, "clockwork" universe view, where prediction and reliability were the norm, and deterministic laws of cause-and-effect permitted humans to understand the basic workings of nature and the environment.[90] Consistent with this view is the notion that change happens as a result of some external influence.[91] The logical outgrowth of this assumption is that change is something that humans do: humans are the best change agents.

Utilitarian science espoused a parallel view of ecosystems and other natural systems. The prevailing conception of nature through much of the twentieth century was the idea of "natural balance."[92] This model supposed that, if left alone, equilibria would exist and populations of plants, animals, and other living organisms would remain close to them.[93] Disturbances to nature were an external and undesirable phenomenon that interfered with the progress of natural communities toward a stable, predictable, balanced state.[94] Similarly, science embraced the concept of

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[88] Mark A. Stone, *Chaos, Prediction and Laplacean Determinism*, 26 AM. PHIL. Q. 123, 123 (1989).
[89] *Id.*
[90] LENNY SMITH, CHAOS: A VERY SHORT INTRODUCTION 3 (2007).
[91] *See* Stone, *supra* note 88, at 124, 126.
[92] Frederic E. Clements, *Nature and Structure of the Climax*, 24 J. ECOLOGY 252, 255–56 (1936).
[93] *Id.*
[94] *Id.*

"stationarity"—"the idea that natural systems fluctuate within an unchanging envelope of variability."[95] In other words, the thinking was that there is some kind of a mythical "natural baseline," and that the Earth system is a closely integrated, self-correcting system, where life regulates the planet's environment to keep stable.[96] Natural feedbacks and control loops stabilize conditions, eventually bringing about homeostasis.[97]

How did humans see their place in nature? First, throughout much of the nineteenth and twentieth centuries, humans saw themselves as independent and separate from their natural environmental surroundings.[98] Our "environment" was separate from, and exogenous to, humans.[99] Second, we viewed ourselves as superior to nature, because of a faith in human exceptionalism.[100] The rules governing the rest of the natural world did not apply to us, as we were an exceptional species.[101]

These science-based perceptions about nature and humans "outside" of nature affected environmental policy. On one hand, nature was seen as a resource to be used by humans to support consumptive lifestyles.[102] Natural sinks, like the atmosphere, water, and land, were a free depository of our wastes; minerals, rangeland, and forests were economic goods to be tamed, owned, and exploited as valuable commodities.[103] On the other hand, since humans were apart from nature, they saw their role as policymakers who could "protect" the environment, cure various environmental "harms," and bring damaged ecosystems back to a more normal "natural" state.[104] Humans believed they could, with their laws, manage

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[95] P.C.D. Milly et al., *Stationarity is Dead: Whither Water Management?*, 319 SCI. 573, 573 (2008).
[96] A. Dan Tarlock, *The Future of Environmental Rule of Law Litigation*, 17 PACE ENVTL. L. REV. 237, 243 (2000).
[97] JAMES LOVELOCK, GAIA: A NEW LOOK AT LIFE ON EARTH 10 (2000).
[98] *See* EMILIO F. MORAN, PEOPLE AND NATURE: AN INTRODUCTION TO HUMAN ECOLOGICAL RELATIONS 35–39 (2d ed. 2017) (describing the evolution of the study of human ecological relations).
[99] *Id.*
[100] CORMAC CULLINAN, WILD LAW: A MANIFESTO FOR EARTH JUSTICE 44–46 (2d ed. 2011); Jonathan Baert Wiener, *Beyond the Balance of Nature*, 7 DUKE ENVTL. L. & POL'Y F. 1, 3–4 (1996).
[101] CULLINAN, *supra* note 100, at 44–46, 51; Wiener, *supra* note 100, at 3–4.
[102] *See Humanity's Voracious Consumption of Natural Resources Unsustainable—UN Report,* UN NEWS (May 12, 2011), https://news.un.org/en/story/2011/05/374942 [https://perma.cc/X57P-G3XF].
[103] CULLINAN, *supra* note 100, at 31, 63, 139–41; Judith Koons, *What is Earth Jurisprudence: Key Principles to Transform Law for the Health of the Planet*, 18 PENN ST. ENVTL. L. REV. 47, 61–62 (2009).
[104] *See, e.g.*, Robinson Meyer, *How the U.S. Protects the Environment, From Nixon to Trump*,

natural resources and their surrounding environment, so as to dominate nature and control it for anthropocentric ends.[105] Our sense of superiority and exceptionalism meant that if the environment was damaged, we could reverse these human-induced changes with legal rules and restore the natural baseline. If humans threatened nature, we could enact environmental statutes to preserve and protect vulnerable places and objects.[106]

2. The Nature of Humans

Standard economic theory has for centuries relied on a model of human behavior based on rational choice theory, a theory which underscores most environmental policy. The "science" of rational choice presumes that humans act rationally when making choices, usually by balancing costs against benefits to maximize personal advantage.[107] This scientific view of human behavior is sometimes termed the *homo economicus* model, where humans base their choices on their own "utility functions."[108] *Homo economicus* ignores social (e.g., environmental) values if they do not provide individual utility.[109]

This model of human behavior presumes that natural resources and environmental goods will be managed, owned, and *used* to maximize private, self-interested utility.[110] Such resource users explicitly or implicitly weigh present values against expected future benefits while discounting future expected costs.[111] In other words, when exploiting environmental goods and natural resources, users tend to adopt a higher discount rate, which favors current use and consumption over longer-term investments and conservation.[112]

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THE ATLANTIC (Mar. 29, 2017), https://www.theatlantic.com/science/archive/2017/03/how-the-epa-and-us-environmental-law-works-a-civics-guide-pruitt-trump/521001/ [https://perma.cc/B89S-RFFA].

[105] Jedediah Purdy, *American Natures: The Shape of Conflict in Environmental Law*, 36 HARV. ENVTL. L. REV. 169, 189–97 (2012).

[106] Robin Kundis Craig, *"Stationarity is Dead"—Long Live Transformation: Five Principles for Climate Change Adaptation Law*, 34 HARV. ENVTL. L. REV. 9, 31–35 (2010).

[107] JON ELSTER, NUTS AND BOLTS FOR THE SOCIAL SCIENCES 29 (1989).

[108] GARY BECKER, THE ECONOMIC APPROACH TO HUMAN BEHAVIOR 3–6 (1976).

[109] DANIEL COHEN, HOMO ECONOMICUS: THE (LOST) PROPHET OF MODERN TIMES 12 (2014); ELSTER, *supra* note 107, at 13, 16, 29.

[110] TERRY L. ANDERSON & DONALD R. LEAL, FREE MARKET ENVIRONMENTALISM 5 (rev. ed. 1991).

[111] DANIEL H. COLE, POLLUTION AND PROPERTY: COMPARING OWNERSHIP INSTITUTIONS FOR ENVIRONMENTAL PROTECTION 89 (2002).

[112] *See id.*

A convergence of two beliefs thereby elevated resource *use* and environmental pollution over collective stewardship and protection of environmental goods and systems. First, nature was seen as a limitless array of raw commodities to be exploited and developed to benefit humans. Nature and the environment became commodified; they belonged to humans.[113]

Second, faith in economic growth meant that the natural world surrounding humans—oceans, rivers, the atmosphere, land, trees—was seen as a means of achieving human-centric ends, such as personal health, carbon-based energy use, and competitive market advantage.[114] As a result, the natural world became overused, and environmental goods (air, water, lands) became degraded and polluted.[115]

There were other negative effects of these human choices. Because resource users wished to use resources before someone else "captured" the economic potential locked in a particular natural resource, there was a race to fish, harvest, mine, graze, and appropriate before some other user did.[116] This tendency was particularly strong when there was an open access commons.[117] There was a realization that market prices did not incorporate all relevant values, such as the costs not captured in prices when there was a negative externality associated with an activity (e.g., when there was unpriced pollution or waste disposal).[118] These market failures, along with the problem of collective goods and free riders,[119] eventually helped policymakers realize that laws and legal institutions needed to be implemented. Environmental law was born.

### *B. Prevailing Legal Systems*

Before there was "environmental law," private remedies could be sought to compensate for private harms caused by environmental pollution.

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[113] JAN LAITOS & JULIANA OKULSKI, WHY ENVIRONMENTAL POLICIES FAIL 2 (2017).

[114] *See* GAR ALPEROVITZ, AMERICA BEYOND CAPITALISM: RECLAIMING OUR WEALTH, OUR LIBERTY, AND OUR DEMOCRACY 143–44 (2005).

[115] *See* ELIZABETH KOLBERT, FIELD NOTES FROM A CATASTROPHE: MAN, NATURE, AND CLIMATE CHANGE 183 (2006).

[116] *See* JAMES WILLARD HURST, LAW AND ECONOMIC GROWTH: THE LEGAL HISTORY OF THE LUMBER INDUSTRY IN WISCONSIN, 1836–1915 105, 127, 435 (1964).

[117] *See* Hardin, *supra* note 74, at 1244.

[118] Thomas Helbling, *Externalities: Prices Do Not Capture All Costs*, INT'L MONETARY FUND (Dec. 18, 2018), https://www.imf.org/external/pubs/ft/fandd/basics/external.htm [https://perma.cc/8L8X-CLE6].

[119] For a definition of this term, see Will Kenton, *Free Rider Problem*, INVESTOPEDIA (Apr. 12, 2018), https://www.investopedia.com/terms/f/free_rider_problem.asp [https://perma.cc/BJ59-LPSG].

The pollution was typically human-caused pollution of the air and water.[120] These remedies involved traditional common law causes of action, such as nuisance and trespass.[121] The common law, however, is an imperfect and costly mechanism for resolving complex environmental disputes. It is often prohibitively expensive (or impossible) to discover who, or what, is causing the problem.[122] Additionally, when it is not in the interest of a single plaintiff to bring suit, there are problems involved in arranging joint actions from parties adversely affected.[123] Finally, any permanent common law remedy risks putting out of business polluting employers and economic drivers of communities, whose continued existence is often critical to the social welfare of an impacted area.[124]

It is because common law remedies were, and are, perceived to be inefficient mechanisms for resolving environmental problems that the new field of environmental law turned to statutes and regulations.[125] These laws were designed to prevent, rather than to compensate for, the human and environmental harms caused by pollution and waste disposal.[126] Environmental policymakers sought to limit such harms by imposing centralized command, control, and prohibitory rules.[127] Utilitarian science helped to inform the decisions behind these rules.

### 1. Centralized Environmental Regulation

The modern era of environmental regulation began in the late 1960s and continued through the 1980s.[128] During this time, Congress passed environmental law statutes, based on environmental standards, which operate by seeking to prevent harm to humans and the environment.[129]

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[120] JAN G. LAITOS, A LEGAL-ECONOMIC HISTORY OF AIR POLLUTION CONTROLS 4 (1980); EARL FINBAR MURPHY, WATER PURITY: A STUDY IN LEGAL CONTROL OF NATURAL RESOURCES 6–7 (1961).

[121] Jan G. Laitos, *Legal Institutions and Pollution: Some Intersections Between Law and History*, 15 NAT. RES. J. 423, 424, 447 (1975).

[122] *Id.* at 438–39.

[123] Christopher R. Leslie, *The Significance of Silence: Collective Action Problems and Class Action Settlements*, 59 FLA. L. REV. 71, 74–75 (2007).

[124] Ronald H. Coase, *The Problem of Social Cost*, 3 J.L. & ECON. 1, 15–16 (1960).

[125] Richard A. Epstein, *From Common Law to Environmental Protection: How the Modern Environmental Movement has Lost its Way*, 23 SUP. CT. ECON. REV. 141, 143 (2015).

[126] Houck, *supra* note 5, at 164.

[127] *See id.* at 165.

[128] W. Kepner, *EPA and a Brief History of Environmental Law in the United States*, EPA (June 15, 2016), https://cfpub.epa.gov/si/si_public_record_report.cfm?Lab=NERL&dirEntryId=319430 [https://perma.cc/A49R-82PM].

[129] *See supra* notes 32, 34 and 36. *See infra* note 131.

These standards were established on the basis of utilitarian scientific analysis. For example, in the 1970 Clean Air Act, National Ambient Air Quality Standards for "criteria pollutants," like carbon monoxide and sulfur dioxide, required those standards to have "an 'adequate' margin of safety" to protect the health of even the most sensitive human populations without regard to cost.[130] That decision was "informed" by science; utilitarian science would decide what standard was safe for human health.

Similarly, environmental statutes addressing toxicity were based on determinations of "unreasonable risk" to human health in the environment.[131] Utilitarian science was used to determine what levels of a toxic substance posed a risk to human health.[132] Statutes governing cleanups of hazardous waste had to decide when the removal of the dumped waste was acceptable and adequate.[133] Again, utilitarian science informed the determination of "how clean is clean." The calibration of levels of environmental harm, as well as degrees of safety, was the job of science.

These statutes relied on centralized administrative regulatory agencies, like the federal Environmental Protection Agency, to issue either outright bans on certain substances or activities affecting environmental goods[134] or command-and-control regulations. Environmental and natural resources laws that relied on heavy-handed, top-down controls presumed that their science-based rules and standards would result in predictable outcomes.[135] Both scientists and environmental policymakers held the view that the natural superiority of humans permitted them to "manage" earth-based environmental systems.[136]

Science also affected the views of policymakers about whether anthropogenic changes to the natural world were normal and acceptable, or harmful and abnormal.[137] The prevailing scientific presumption was

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[130] Whitman v. Am. Trucking Assoc., 531 U.S. 457, 465 (2001).

[131] *See* the Federal Insecticide, Fungicide, and Rodenticide Act, 7 U.S.C. §§ 136(x)–(bb) (2012); TSCA, 15 U.S.C. §§ 2601–2692 (1976); the Safe Drinking Water Act, 42 U.S.C. § 300f (2012).

[132] Houck, *supra* note 5, at 167–68.

[133] *See* CERCLA, 42 U.S.C. §§ 9601–9628 (2012).

[134] *See, e.g.*, the ban on the pesticide DDT, or on the addition of lead in gasoline. Herbert L. Needleman, *The Removal of Lead from Gasoline: Historical and Personal Reflections*, 84 ENVTL. RESEARCH SEC. A 20, 28 (2000).

[135] C.S. Holling & G.K. Meffe, *Command and Control and the Pathology of Natural Resources Management*, 10 CONSERVATION BIOLOGY 328, 329–30 (1996).

[136] EVAN EISENBERG, THE ECOLOGY OF EDEN 286–88 (1998).

[137] PEW RESEARCH CTR., *1. Public Views on Climate Change and Climate Scientists* (Oct. 4, 2016), http://www.pewresearch.org/science/2016/10/04/public-views-on-climate-change-and-climate-scientists/ [https://perma.cc/9GZY-QFSF].

(and to a certain extent, still is) that human changes were per se harmful because humans upset the "balance of nature."[138] If anthropogenic change is degrading and unnatural, then environmental and natural resources regulation should try to reverse human-induced changes, to bring ecosystems and environmental conditions back to a more "natural" baseline.[139] The goal of environmental and natural resources regulation should thereby be preservation and restoration.[140]

2. Decentralized Environmental Legal Systems

Commentators reviewing centralized command-and-control environmental law regimes began to criticize them as being inherently inefficient, producing more social costs than benefits.[141] Instead of relying on top-down, centralized hierarchical environmental regulation, legal scholars and scientists suggested that environmental policy embrace more decentralized, flexible, and consensual legal instruments.[142] Their recommendations favored three types of decentralized, efficiency-enhancing, environmental law systems: (1) tradeable permitting and effluent taxation; (2) the creation of individual "rights" to a clean environment; and (3) enhanced use of conservation easements and land trusts.[143]

a. Transferable Pollution or Resource Rights, and Pollution Taxes

As soon as traditional command-and-control systems were in place, economists and legal commentators began to advocate for more cost-effective alternatives that relied on market dynamics.[144] Such a system could be used for air or water basins contaminated by pollution, or for open-access commons, like fisheries or rangelands.[145] A legal regime of

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[138] DANIEL B. BOTKIN, DISCORDANT HARMONIES: A NEW ECOLOGY FOR THE TWENTY-FIRST CENTURY 9, 12–13 (1990).
[139] Richard J. Hobbs & Viki A. Cramer, *Restoration Ecology: Interventionist Approaches for Restoring and Maintaining Ecosystem Function in the Face of Rapid Environmental Change*, 33 ANN. REV. ENV'T & RES. 39, 40, 50–51 (2008).
[140] Craig, *supra* note 106, at 31–35.
[141] Richard B. Stewart, *United States Environmental Regulation: A Failing Paradigm*, 15 J.L. & COM. 585, 587 (1996); T.H. Tietenberg, *Economic Instruments for Environmental Regulation*, 6 OXFORD REV. ECON. POL'Y 17, 23 (1990).
[142] Stewart, *supra* note 141, at 589–91.
[143] *Id.* at 591–93; Dinah L. Shelton, *Developing Substantive Environmental Rights*, 1 J. HUMAN RTS. & ENV'T 89, 118–20 (2010).
[144] J.H. DALES, POLLUTION, PROPERTY, AND PRICES: AN ESSAY IN POLICY-MAKING AND ECONOMICS 99 (1968).
[145] *See id.* at 88–89.

transferable pollution or resource rights would, in theory, permit the government to reduce the costs of achieving science-based pollution reduction and resource conservation goals.[146] The government sets the pollution or sustainable resource goal, and determines the amount of allowable emissions, or reduction in use of a declining resource, that science assumes will obtain the goal.[147] The government then unitizes and allocates the allowable emissions or resource rights, in the form of transferable rights, among regulated persons or firms.[148] Transferability among those regulated ensures the smallest aggregate compliance or abatement cost by creating markets that efficiently allocate the costs among those regulated.[149]

Whereas a centralized government regulator displaces the market as a resource allocation mechanism, a system of individual transferable use quotas relies on market dynamics to produce allocative efficiencies and deter resource overuse.[150] Transferable rights have been implemented or proposed for a number of unowned "commons" or "open-access" resource problems. These include pollution of the atmosphere,[151] pollution of water reservoirs,[152] exploitation of fisheries,[153] overgrazing of rangeland,[154] and overused wilderness areas.[155] With the advent of climate change, scholars again argued that tradeable permit markets may be a useful model for environmental policymakers to adopt.[156]

Effluent or pollution taxes are also, in theory, more efficient than command-and-control regulations. Some centralized government authority does not tell polluters how much pollution they may release, but only requires them to pay a tax for each unit of pollution spewed into the

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[146] *See id.* at 35.
[147] *Id.* at 100.
[148] *Id.* at 81.
[149] *Id.* at 83; COLE, *supra* note 111, at 46–47.
[150] *See* Oran R. Young, *Institutional Interplay: The Environmental Consequences of Cross-Scale Interactions*, *in* THE DRAMA OF THE COMMONS 267 (Elinor Ostrom et al. eds., 2002).
[151] Clean Air Act Amendments of 1990, 42 U.S.C. § 7651(b) (2012).
[152] Robert W. Hahn & Gordon Hester, *Marketable Permits: Lessons for Theory and Practice*, 16 ECOLOGY L. Q. 361, 391–96 (1989).
[153] Katrina Miriam Wyman, *From Fur to Fish: Reconsidering the Evolution of Private Property*, 80 N.Y.U. L. REV. 117, 164 (2005).
[154] Robert H. Nelson, *How to Reform Grazing Policy: Creating Forage Rights on Federal Rangelands*, 8 FORDHAM ENVTL. L. REV. 645, 647–48 (1997).
[155] Jan Laitos & Rachel Gamble, *The Problem with Wilderness*, 32 HARV. ENVTL. L. REV. 503, 533 (2008).
[156] THOMAS ARONSSON, KENNETH BUCKLUND, & KARL-GUSTAF LOFGREN, ENVIRONMENTAL POLICY, SUSTAINABILITY AND WELFARE: AN ECONOMIC ANALYSIS 31 (2018); MATTHIAS RUTH, ADVANCED INTRODUCTION TO ECOLOGICAL ECONOMICS 117 (2018).

environment.[157] This system permits those that pollute to individually select levels of emissions, or emission reductions, based on each polluter's differential costs of controlling the pollution.[158] The decentralized decision to pollute, or to reduce levels of pollution, is up to the polluter, not some centralized policymaker.[159] The advantages and efficiencies of a tax on emissions has made carbon-based pricing and carbon taxes a popular market-based policy instrument to address climate change challenges.[160]

b. Individual Rights to a Clean Environment

Another decentralized alternative to top-down command-and-control rules is the acknowledgment or creation of a legal "right," held by individuals, to a "clean" (and usually also a "healthy") environment. An early recognition of such a right came in the Stockholm Declaration, which emerged from a global eco-summit in 1972.[161] Since then, most United Nations member countries recognize a right "to protect and improve the environment for present and future generations."[162] In the United States, several states have added environmental bills of rights to state constitutions.[163] For these states, an often-litigated issue is whether these state constitutional provisions provide people or organizations with "liberty" or "property" interests under the Due Process Clause.[164]

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[157] COLE, *supra* note 111, at 70.
[158] Stewart, *supra* note 141, at 592.
[159] COLE, *supra* note 111, at 70.
[160] SHI-LING HSU, THE CASE FOR A CARBON TAX 5–6, 15–16 (2011); INNOVATION ADDRESSING CLIMATE CHANGE CHALLENGES: MARKET-BASED PERSPECTIVES (M. Hymel et al. eds., 2018).
[161] Lynda Collins, *The United Nations, Human Rights and the Environment*, *in* RESEARCH HANDBOOK ON HUMAN RIGHTS AND THE ENVIRONMENT 229 (Anna Grear & Louis J. Kotze eds., 2015).
[162] *Id.* David R. Boyd, *The Constitutional Right to a Healthy Environment*, 54 ENV'T: SCI. & POL'Y SUSTAINABLE DEV. 3, 4 (2012); Margherita Pieraccini, *Reflections on the Relationship Between Environmental Regulation, Human Rights and Beyond—with Heidegger*, *in* THOUGHT, LAW, RIGHTS AND ACTION IN THE AGE OF ENVIRONMENTAL CRISIS 87 (Anna Grear & Evadne Grant eds., 2015).
[163] Audrey Wall, *State Constitutions and Environmental Bills of Rights*, COUNCIL ST. GOV'TS (Sept. 1, 2015), http://knowledgecenter.csg.org/kc/content/state-constitutions-and-environmental-bills-rights [https://perma.cc/2UH9-8HB4].
[164] *Compare* Del. Riverkeeper Network v. Fed. Energy Reg. Comm'n., 895 F.3d 102, 108 (D.C. Cir. 2018) (holding that plaintiffs did not have a property or liberty interest under a Pennsylvania environmental law), *with* In re Application of Maui Elec. Co., 408 P.3d (Haw. 2017) (holding that plaintiffs did have a property interest in a clean and healthy environment).

c. Conservation Easements and Land Trusts

Another decentralized environmental protection and preservation tool relies on private owners of undeveloped land. Should those owners wish to preserve wild lands, they may convey a conservation easement—a right to prevent resource development—to a public or private land trust.[165] The owner only conveys a part of the total interest in the land—the right to develop it.[166] And when the donation is perpetual, it may qualify as a deductible gift for federal tax purposes.[167] Some scholars wish to go beyond land trusts and alter the extent of the public trust doctrine. They argue that the doctrine should be broadened to compel government, as the trustee of public environmental goods, to protect air and water for humanity—the beneficiaries of the trust.[168]

## III. EXPLANATORY SCIENCE INFLUENCES POLICY

By the twenty-first century, we began to realize that, despite decades of environmental laws and established environmental policies, humans were continuing to adversely influence Earth's environmental systems. There were three manifestations of this anthropogenic effect on the environment. First, it became largely accepted among scientists that we have entered a new, post-Holocene epoch, called the "Anthropocene."[169] This new era marks the first time in the Earth's history when changes in Earth systems, from climate change to ocean acidification to species extinction, are due to anthropogenic actions.[170] Second, scientists increasingly accepted the concept of "Planetary Boundaries" which provide a "safe operating space for humanity."[171] The consensus among scientists was that anthropogenic actions were pushing certain critical Earth systems outside of this safe place, such that human life on Earth may no

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[165] TOM DANIELS & DEBORAH BOWERS, HOLDING OUR GROUND: PROTECTING AMERICA'S FARMS AND FARMLAND 201 (1997).
[166] *Id.*
[167] *Id.*
[168] MARY CHRISTINA WOOD, NATURE'S TRUST 147 (2013).
[169] Paul J. Crutzen, *Geology of Mankind*, 415 NATURE 23, 23 (2002).
[170] Damian Carrington, *The Anthropocene epoch: scientists declare dawn of human-influenced age*, THE GUARDIAN (Aug. 29, 2016), https://www.theguardian.com/environment/2016/aug/29/declare-anthropocene-epoch-experts-urge-geological-congress-human-impact-earth [https://perma.cc/N2PV-HMVZ].
[171] Johan Rockstrom et al., *A Safe Operating Space for Humanity*, 461 NATURE 472, 472 (2009).

longer be sustainable.[172] Third, scientific researchers began to see steepening trends since the 1960s (when environmental law was "invented") toward intensified use of Earth's natural resources and higher levels of pollution.[173] They termed this alarming speeding up of anthropogenic environmental change "The Great Acceleration."[174]

These depressing realizations helped to bring about a change in our view of the role of utilitarian science. Commentators and scholars began to doubt our faith in scientifically defined environmental limits or in creative technological capacities as means to avoid negative environmental consequences of human economic growth.[175] While decisions informed by scientific evidence were, and are, thought to create better outcomes than irrational, fear-based narratives, utilitarian science alone did not seem to supply the answers sought by policymakers.[176] No amount of scientific evidence informing traditional top-down centralized rules and standards seemed to be able to solve the greatest environmental challenges of our time—global climate change, Earth system alterations, more pollution, habitat loss, and extinctions.[177]

A paradigm change emerged for science and environmental policy, first suggested by scholars and then slowly embraced by policymakers.[178] While science certainly should provide data and evidence to decisionmakers, it was thought that science should also seek to *explain* how nature really works, and how humans in fact make choices affecting their environment.[179] Moreover, we began to realize that science can offer explanatory models, or theories, which better connect environmental policies to the environmental systems subject to those policies. This other version of science, explanatory science, permits policymakers to devise environmental laws that reflect and are consistent with the reality of both nature and human behavior. And explanatory science offers theoretical models of this reality that can help shape and influence policy.

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[172] Simon L. Lewis, *We Must Set Planetary Boundaries Wisely*, 485 NATURE 417, 417 (May 2012).
[173] Will Steffen et al., *The Trajectory of the Anthropocene: The Great Acceleration*, 2 ANTHROPOCENE REV. 81, 82 (2015).
[174] *Id.*
[175] *See* Biber, *supra* note 7, at 512–13.
[176] *See id.*
[177] ERLE C. ELLIS, ANTHROPOCENE: A VERY SHORT INTRODUCTION 2–3, 29; Houck, *supra* note 5, at 171.
[178] *See* ELLIS, *supra* note 177, at 3.
[179] *Id.* at 29.

## A. *Environmental Policies That Conform to Nature's Reality*

### 1. A More Realistic View of Nature

Throughout much of the twentieth century, the end goal of environmental policies was grounded in the twin objects of "stationarity" and "separateness." The concept of *stationarity* reflected the prevailing idea "that natural systems [usually] fluctuate within an unchanging envelope of variability."[180] Environmental laws sought either to preserve ecosystems or to restore environmental resources back to some "natural baseline."[181] Similarly, scientists thought that all of Earth's living organisms worked to achieve a state of *equilibrium*, ensuring that "Gaia's living system" would always self-regulate to re-optimize variables for life to persist.[182] For environmental policymakers, this view, along with the concept of separation between humans and their environment, meant that environmental laws should minimize or eliminate the destructive impact of human actions on Earth systems, and that our laws should bring us back to a more natural and less anthropomorphic state.[183]

However, in the twenty-first century, explanatory science offered two theories—chaos theory and complexity theory—which challenged these beliefs about the nature of nature. *Chaos* theory is the study of deterministic natural systems that are non-linear.[184] In such a system, small changes might produce a large change (resulting in a tipping point) at certain times.[185] *Complexity* theory studies complex systems that are a special type of chaotic system.[186] They are not deterministic, and display the concepts of emergence and adaptability.[187] Emergence is the appearance of patterns arising from the interactions of a system's components.[188] This development of patterns is bottom-up, which means the outcome of

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[180] Milly et al., *supra* note 95, at 573.
[181] Tarlock, *supra* note 96, at 243.
[182] J.E. LOVELOCK, GAIA: A NEW LOOK AT LIFE ON EARTH 131; ROBERT MACARTHUR & E.O. WILSON, THE THEORY OF ISLAND BIOGEOGRAPHY 65.
[183] Simon Levin et al., *Social-Ecological Systems as Complex Adaptive Systems: Modeling and Policy Implications*, 18 ENVTL. & DEV. ECON. 111, 114 (2013).
[184] JAMES GLEICK, CHAOS: THE MAKING OF A NEW SCIENCE 62–64 (1987) (describing the relationship between non-linearity and ecology).
[185] *Id.*
[186] *See Definition of Complexity Theory*, COLLINS DICTIONARY (2019), https://www.collinsdictionary.com/dictionary/english/complexity-theory [https://perma.cc/4VUV-H2UZ].
[187] DAVID BYRNE, COMPLEXITY THEORY AND THE SOCIAL SCIENCES: AN INTRODUCTION 16–17 (1998).
[188] *Id.* at 47–49.

the interaction of a system's components is inherently unpredictable. Adaptation is a transformative modification of the initial system. Complex systems display a distinctive type of emergent behavior called "complex adaptive behavior"—many agents forming, dissolving, reforming, again and again.[189] It is a form of non-linear self-organization that brings about a higher level of operational complexity, and a change from the starting point which is not just different in degree, but also different in kind.[190]

The study of non-linear adaptive and dynamical systems through the development of chaos and complexity theory helped to break the Newtonian paradigm of a clockwork universe promising prediction and reliability.[191] Complexity theory has profound implications for traditional linear understandings of cause-and-effect. A complex system, like an ecosystem, does not conform to a Newtonian world, but rather a world more aligned with quantum physics.[192] Such a quantum world deals with probabilities, not certainties.[193] It is a world of potentialities and possibilities, which rejects causality, and measures Earth's systems as being in an ever-changing indeterminate state.[194]

Coincident with the rise of complexity theory and its embrace of quantum physics theory has been the emergence of a new standard model for nature and the environment. The previous model, outlined in Part II, saw the natural environment as a system that was linear, predictable, and seeking homeostasis and equilibrium. It also assumed that humans were separate from, and outside of, their physical environment, which permitted policymakers to "manage" that environment. Explanatory science rejected this standard model as not realistic for two reasons.

First, nature's systems are non-linear, unpredictable, and exceedingly difficult to manage by top-down regulations. Nature is characterized by complex behaviors and physical interactions that emerge as a result of non-linear spatiotemporal exchanges among component systems and subsystems that adapt to constant changes in the environment.[195] Consistent with complexity theory, the "environment" is best understood as

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[189] Mustafa Canan & Andres Sousa-Poza, *Complex Adaptive Behavior: Pragmatic Idealism* 95 PROCEDIA COMPUTER SCIENCE 73–74 (2016).
[190] ROGER LEWIN, COMPLEXITY: LIFE AT THE EDGE OF CHAOS 51–53 (Macmillan Publ. Co. 1993).
[191] *Id.* at 11.
[192] *Id.*
[193] *See id.*
[194] *See* ADAM BECKER, WHAT IS REAL? THE UNFINISHED QUEST FOR THE MEANING OF QUANTUM PHYSICS 14.
[195] LEWIN, *supra* note 190, at 11.

a "complex adaptive system."[196] If the natural environment acts as a complex adaptive system ("CAS") in accordance with the rules of complexity theory,[197] then the lesson for environmental policymakers is obvious. Environmental law needs to be revised to reflect that the ecological and environmental reality is one of complex, unstable, non-linear, and unpredictable change, where environmental systems are not seeking equilibrium or stationarity, but adaptive resilience.[198]

Second, explanatory science did more than simply explain how the environment works like a CAS; it also provided a more realistic model of the relationship between humans and their environmental surroundings. Humans are not separate and apart from the physical environment. Rather, humans are an integral part of that environment. Humans, along with the Earth, natural systems, the biosphere, and environmental goods, are all part of a unified system, a "social-ecological" system (the "SES").[199]

The premise behind the idea of the SES is that there are no natural systems without people, nor are their anthropocentric social systems without natural systems.[200] The SES is interdependent, constantly evolving like a CAS, and conforming to the key tenets of complexity theory.[201] Environmental policymakers cannot ignore the implications of the idea of the SES. Failure will be the fate of environmental policies grounded in the belief that humans are in effect puppeteers, able to master and manipulate natural resources and environmental systems to anthropocentric ends. There is no separate human "us" in the SES; humans and their planet's biosphere are evolving together.[202] Environmental policies

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[196] C. Folke et al., *Resilience Thinking: Integrating Resilience, Adaptability and Transformability*, 15 ECOLOGY & SOCIETY 20 (2010); S.A. Levin, *Ecosystems and the Biosphere as Complex Adaptive Systems*, 1 ECOSYSTEMS 431 (1998); Wendell Jones, *Complex Adaptive Systems*, BEYOND INTRACTABILITY (Oct. 2003), https://www.beyondintractability.org/essay/complex_adaptive_systems [https://perma.cc/RB7M-PNA7].

[197] Aaron Pycroft, *Complexity Theory: An Overview*, *in* APPLYING COMPLEXITY THEORY 25 (A. Pycroft & Clemens Bartollas eds. 2014).

[198] J.B. Ruhl, *Thinking of Environmental Law as a Complex Adaptive System: How to Clean Up the Environment Without Making a Mess of Environmental Law*, 34 HOUS. L. REV. 933, 940–41 (1997).

[199] Brian H. Walker et al., *Exploring Resilience in Social-Ecological Systems Through Studies and Theory Development*, 11 ECOLOGY & SOC'Y 1, 1 (2006).

[200] George S. Sessions, *Anthropocentrism and the Environmental Crisis*, 2 HUMBOLDT J. SOC. REL. 71, 71 (Fall/Winter 1974).

[201] BYRNE, *supra* note 187, at 93–94. Levin et al., *supra* note 183.

[202] *See* Jason Bittel, *4 Clever (and Kind of Sad) Ways Animals Adapt to Humans*, NAT'L GEOGRAPHIC (Feb. 11, 2015), https://news.nationalgeographic.com/news/2015/02/150211-climate-change-science-animals-adaptation-orangutans-manatees/ [https://perma.cc/DY6J-DPXL].

are best directed toward the holistic SES, not just the SES's "social" or "ecological" components.[203]

2. Legal Systems That Reflect the Reality of Nature

After explanatory science began to describe natural and social systems in light of CAS and SES theories, legal scholars and commentators began to urge that environmental policy mirror this new scientific "reality." Some of these suggestions were adopted as environmental policy, and some became a part of twenty-first century environmental law.[204] For example, there has been a trend towards more flexible and consensual styles of governance, instead of top-down, hierarchical command-and-control regulation and prohibition.[205] Resource managers realized that such centralized, authoritative rules, with an attendant belief in predictable outcomes, worked counter to the characteristics of complex adaptive systems.[206] A CAS, like a forest, relies on non-linear bottom-up dynamics; managers of forests, rangelands, and ecosystems relied on complexity theory to enhance the resilience and adaptability of biological systems.[207] Even the Paris Agreement of 2015 shifted from a top-down approach for national governments in addressing global climate change to a more manageable bottom-up implementation strategy.[208]

Commentators have also urged that, in an era where complexity theory and SES theory have been generally accepted, environmental and natural resources laws should adjust to a different view of the natural world.[209] Rather than assume "nature" is exogenous to humans, environmental policymakers need to direct their laws to socioecological systems,

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[203] L. Lebel et al., *Governance and the Capacity to Manage Resilience in Regional Social-Ecological Systems*, 11 ECOLOGY & SOC'Y 4–5 (2006).
[204] *See* RISK, RESILIENCE, INEQUALITY AND ENVIRONMENTAL LAW 129–32 (B. Hutter ed. 2017); DECISION MAKING IN ENVIRONMENTAL LAW 63–67 (L. Paddock, R. Glicksman & N. Bryner eds. 2016).
[205] Arthur P.J. Mol, *Social Theories of Environmental Reform: Towards a Third Generation*, *in* ENVIRONMENTAL SOCIOLOGY: EUROPEAN PERSPECTIVES AND INTERDISCIPLINARY CHALLENGES 25 (M. Gross & H. Heinrichs eds. 2010).
[206] *See id.* at 25–26, 31.
[207] *See* C.R. Drever et al., *Can Forest Management Based on Natural Disturbances Maintain Ecological Resilience?*, 36 CANADIAN J. FOREST RES. 2285, 2287, 2291 (2006); C.S. Folke et al., *Regime Shifts, Resilience, and Biodiversity in Ecosystem Management*, 35 ANN. REV. ECOLOGY & EVOLUTION 557, 559 (2004).
[208] Daniel Esty, *Is There Reason for Optimism on Climate Change?*, YALE INSIGHTS (Sept. 6, 2018), https://insights.som.yale.edu/insights/is-there-reason-for-optimism-on-climate-change [https://perma.cc/7QKP-E4LX].
[209] Craig, *supra* note 106, at 36–37; Cormac Cullinan, *Do Humans Have Standing to Deny Trees Rights?*, 11 BARRY L. REV. 11, 19–20 (2008).

which include human societies.[210] Indeed, explanatory science describes the SES in terms of complexity theory, requiring reform of the prevailing regulatory state.[211]

These different, but more realistic, perspectives of nature have influenced policy in three specific ways. First, adoption of complexity theory has helped to justify and implement "adoptive management" and "ecosystem management" as decision-making methodologies. Second, "emergy theory" provides a method to more accurately value natural resources and ecosystem services in a way that captures their inherent value. Third, in a departure from affording only humans with environmental rights, the notion of "nature's rights" has become an alternative bottom-up policy.

a. Adaptive and Ecosystem Management

If the natural environment is centered on the concept of complex *change* and subsequent ecological *adaptation* to change, then environmental laws need to be flexible, requiring an adaptive, iterative management decision-making methodology.[212] This methodology may be termed "adaptive management," which has been described as a policy "that recognizes uncertainty in its consequences, and seeks to improve understanding . . . by learning about management outcomes and incorporating what is learned into ongoing management."[213] Adaptive management may be perceived as pragmatic management, in which there is never a fixed decision by policymakers.[214]

Adaptive management has been used as a resource management tool for fisheries and public lands.[215] A realization that forests are complex adaptive systems helped cause silviculturists to shift from managing forests to be homogenized to maintaining timber heterogeneity and diversity

[210] Craig, *supra* note 106, at 37.
[211] J.B. Ruhl, *Complexity Theory as a Paradigm for the Dynamical Law-and-Society System: A Wake-Up Call for Legal Reductionism and the Modern Administrative State*, 45 DUKE L.J. 849, 917 (1996).
[212] J.B. Ruhl, *Regulation by Adaptive Management—Is It Possible?*, 7 MINN. J.L. SCI. & TECH. 21, 28 (2005).
[213] LAITOS & OKULSKI, *supra* note 113, at 115.
[214] Bradley C. Karkkainen, *Adaptive Ecosystem Management and Regulatory Penalty Defaults: Toward a Bounded Pragmatism*, 87 MINN. L. REV. 943, 960 (2003).
[215] Robert L. Glicksman, *Ecosystem Resilience to Disruptions Linked to Global Climate Change: An Adaptive Approach to Federal Land Management*, 87 NEB. L. REV. 833, 838 (2009); Samuel P. Hays, *The Future of Environmental Regulation*, 15 J.L. & COM. 549, 579 (1996); John M. Volkman & Willis E. McConnaha, *Through a Glass Darkly: Columbia River Salmon, The Endangered Species Act, and Adaptive Management*, 23 ENVTL. L. 1249, 1251, 1255 (1993).

through adaptive management.[216] When silviculturists manage forests as complex adaptive systems, the forests are better able to respond to a variety of changes, are more resilient, and become more productive.[217] Adaptive management can also benefit forests by applying complexity theory to the harvesting of deer in forests in order to blunt the adverse effects of large deer numbers that voraciously eat all new regenerative growth.[218]

As explanatory science better understood natural systems to be CASs, so too did environmental policymakers realize that the dynamic complexity of these systems meant that environmental strategies needed to conform to the science of "ecology." When nature is viewed through the lens of ecology, living organisms are not considered stable communities that seek equilibrium and stationarity; rather, they are "ecosystems" that are dynamic, adaptive, and stochastic.[219] Ecosystems are best addressed within an "ecosystem management" framework, which calls for creative and adaptive use of policy instruments that reflect complexity theory.[220] Ecosystem management acknowledges that virtually all Earth-based environmental systems are strengthened by biodiversity, which brings about system sustainability.[221]

b. Emergy Theory

In addition to complexity theory, explanatory science offered a new model for valuing natural resources and ecosystems. This methodology is known as the "emergy" theory of valuation synthesis. Instead of valuing the worth of environmental goods based on anthropomorphic consumer preferences, emergy theory argues that the worth of the natural environment

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[216] M.L. HUNTER, MAINTAINING BIODIVERSITY IN FOREST ECOSYSTEMS 26–27 (1999); M. LOREAU ET AL., BIODIVERSITY AND ECOSYSTEM FUNCTIONING: SYNTHESIS AND PERSPECTIVES 240–41 (2002).
[217] KLAUS J. PUETTMANN, K. DAVID COATS & CHRISTIAN MESSIER, CRITIQUE OF SILVICULTURE: MANAGING FOR COMPLEXITY 112, 117, 119 (2009).
[218] Jason Stein, *The Hunt for Answers: Are There Too Many Deer? A U.W. Scientist Says Reducing the Herd Will Help Our Forests*, ON WISCONSIN (Winter 2018), https://onwisconsin.uwalumni.com/features/the-hunt-for-answers/ [https://perma.cc/7VYD-7LQQ].
[219] S.A. Levin, *Ecosystems and the Biosphere as Complex Adaptive Systems*, 1 ECOSYSTEMS 431, 432 (1998).
[220] ALANNA CORTNER & MARGARET MOOTE, THE POLITICS OF ECOSYSTEM MANAGEMENT 1 (1999); S.A. Levin, *Self-organization and the Emergence of Complexity in Ecological Systems*, 55 BIOSCIENCE 1075, 1075–76 (2005).
[221] S.A. Levin, *Multiple Scales and the Maintenance of Biodiversity*, 3 ECOSYSTEMS 498, 504 (2000); S.A. Levin, *Science and Sustainability*, 3 ECOLOGICAL APPLICATIONS 545, 545 (1993).

should be measured on its ecocentric *intrinsic* value.[222] Emergy theory is useful to environmental policy for two reasons. First, such policy should facilitate the delivery of certain service functions provided by humans' environmental surroundings, such as "natural capital" and "ecosystem services."[223] Second, instead of relying on neoclassical economics to value ecological resources and services as part of a traditional human-based cost-benefit analysis, emergy theory points out that the real worth of nature does not stem only from its utilization by humans.[224] The importance, or "benefit" in a cost-benefit calculation, of ecosystem services and natural capital is tied to the concepts' role in permitting and sustaining life on this planet.[225]

c. Rights of Nature

The twenty-first century witnessed a growing skepticism about the ability of traditional environmental laws to deter or reduce anthropomorphic actions adversely affecting the SES. Such laws tend to regard nature as separate from humans, where natural resources and environmental systems are viewed as property, primarily useful as a means to benefit one species: humans.[226] Commentators, and some countries, advanced the idea that nature, the environment, or natural resources are in reality a partner with which humanity coevolved in the SES.[227] As such, nature and the natural environment should be acknowledged to have, or should be given, legal rights.[228] Provisions in the positive law of countries recognizing the rights of nature, sometimes referred to as Earth Jurisprudence, point toward environmental policy that permits persons and

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[222] MARK SAGOFF, PRICE, PRINCIPLE, AND THE ENVIRONMENT 5 (2004); Mark T. Brown & Sergio Ulgiati, *Emergy Evaluation of the Biosphere and Natural Capital*, 28 AMBIO 486, 491–92 (1999).
[223] GRETCHEN DALY, NATURE'S SERVICES: SOCIETAL DEPENDENCE ON NATURAL ECOSYSTEMS 3, 13 (1997); DIETER HELM, NATURAL CAPITAL: VALUING THE PLANET 2, 63 (2015).
[224] Mary Jane Angelo & Mark T. Brown, *Incorporating Emergy Synthesis into Environmental Law: An Integration of Ecology, Economics, and Law*, 37 ENVTL. L. 963, 986 (2007).
[225] *Id.*
[226] *See* UN NEWS, *supra* note 102.
[227] Michael Schoon & Sander van der Leeuw, *The Shift Toward Social-Ecological System Perspectives: Insights Into the Human-Nature Relationship*, NATURES SCIENCES SOCIÉTÉS, 23, 167 (2015).
[228] JAN LAITOS, THE RIGHT OF NONUSE 122–24 (2012). *See* Constitución Política de la República del Ecuador [Ecuador], 20 October 2008, Art. 71 (recognizing the inalienable rights of nature).

organizations to represent and assert the legal interests of ecosystems and environmental goods.[229]

### *B. Environmental Policies That Conform to Human Reality*

#### 1. A More Realistic View of Human Behavior

Standard neoclassical economic theory for centuries relied on a model of human behavior based on the *homo economicus* assumption.[230] This assumption underscores most environmental policy.[231] It presumes that individuals act rationally when making choices.[232] This "rational choice" view of human behavior assumes that we act by balancing costs and benefits to arrive at decisional action that optimizes or maximizes personal advantage.[233] In other words, humans ignore most social values while they base their choices on their selfish "utility functions."[234] Many environmental laws, such as fines, penalties, and prohibitions, along with market-based instruments like taxes and cap-and-trade systems, are all based on this traditional rational choice model.[235]

By the latter part of the twentieth century, explanatory science began to cast doubt about these standard reasons for human behavior.[236] Observed behaviors seemed inconsistent with the orthodoxy of *homo economicus*.[237] A new theory arose that seems equally able to explain human choices about our environmental surroundings: *behavioral economics*.[238] This new explanatory theory of human behavior presumes that

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[229] Judith Koons, *What is Earth Jurisprudence?: Key Principles to Transform Law for the Health of the Planet*, 18 PENN ST. ENVTL. L. REV. 47, 47 (2009); *Rights of Nature Law, Policy and Education*, HARMONY WITH NATURE, http://www.harmonywithnatureun.org/rightsOfNature/ [https://perma.cc/5HP2-7WHC] (last visited Mar. 11, 2019).
[230] DANIEL COHEN, HOMO ECONOMICUS: THE PROPHET OF MODERN TIMES 15–17 (2014).
[231] *See generally* Elizabth Gsottbaner, *Environmental Policy Theory Given Bounded Rationality and Other-Regarding Preferences*, 49 ENVTL. & RESOURCES ECON. 263 (June 2011) (describing the assumption of *homo economicus* in relation to environmental policy and behavioral economics).
[232] *Id.*
[233] LAITOS & OKULSKI, *supra* note 113, at 32.
[234] WILLIAM NORDHAUS, THE CLIMATE CASINO: RISK, UNCERTAINTY, AND ECONOMICS FOR A CHANGING WORLD 19–23 (2014).
[235] *Id.* at 239–43.
[236] LAITOS & OKULSKI, *supra* note 113, at 126.
[237] *Id.* at 207.
[238] YANNIS PAPADOGIANNIS, THE RISE AND FALL OF HOMO ECONOMICUS: THE MYTH OF THE RATIONAL HUMAN AND THE CHAOTIC REALTY 239 (2014).

individuals are equally susceptible to a selfless desire to enhance collective welfare.[239] According to this theory, humans often display a willingness, known as "green behavior," to incur certain costs because of the psychic gain experienced knowing that the natural environmental thereby benefits.[240]

Behavioral economics has slowly become an accepted explanatory science, which suggests we need to rethink environmental policy.[241] This brand of economic "science" holds that people are more responsive to desired, rather than undesired information.[242] If so, environmental laws should do more than impose a flat mandate, or prohibit certain behaviors, or issue a command-and-control rule.[243] Environmental laws should disclose to the public how well a person is doing in terms of environmental conscientiousness—for example, how energy-efficient they are compared to their neighbors.[244] Indeed, behavioral economics urges environmental policymakers not to *compel* environmentally friendly behaviors, but to *persuade* people while preserving their freedom of choice.[245]

2. Legal Systems That More Realistically Reflect Human Behavior

There have been a number of twenty-first century environmental policies, either proposed or adopted, that reflect this more enlightened, and empirically derived, modern view of human behavior.

a. Impose Positive Duties

Much of traditional environmental law entails "negative laws."[246] These are laws that in different ways repeat the notion that humans are

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[239] PETER SINGER, THE MOST GOOD YOU CAN DO: HOW EFFECTIVE ALTRUISM IS CHANGING IDEAS ABOUT LIVING ETHICALLY 4–5, 7 (2015).
[240] *See* EUROPEAN COMM'N, *Future Brief: Green Behavior*, 4 SCIENCE FOR ENVIRONMENTAL POLICY 2–3, 8 (Oct. 2012).
[241] Tansif ur Rehman, *Historical context of behavioral economics*, 10 INTELLECTUAL ECON. 128, 131 (2016).
[242] LAITOS & OKULSKI, *supra* note 113, at 28.
[243] *Id.*
[244] *See, e.g.*, Jim Tankersley, *Can We Nudge People into Conserving Energy?*, WASH. POST (Oct. 27, 2014), https://www.washingtonpost.com/news/storyline/wp/2014/10/24/can-we-shame-people-into-conserving-energy/?utm_term=.07cda0ad0b6a [https://perma.cc/87ZF-HAV8].
[245] CASS R. SUNSTEIN, WHY NUDGE? THE POLITICS OF LIBERTARIAN PATERNALISM 57–58 (2014).
[246] LAITOS & OKULSKI, *supra* note 113, at 38.

"harming" the natural environment.[247] This perspective usually results in laws ordering humans to *not* take actions that perpetuate the harm.[248] Modern behavioral economics reveal that humans prefer to be told what *to do*, instead of being ordered *not to do* certain acts.[249] Several states and cities have recognized this truth about humans.[250] California will require solar panels on new homes starting in 2020, and Denver, Colorado mandates rooftop living green coverings for all new buildings larger than 25,000 square feet.[251]

b. Towards "Soft" Government Paternalism

Environmental policy influenced by behavioral economics uses the mildest and most choice-preserving forms of government intervention.[252] Scholars call these policy instruments "nudges."[253] The central idea behind nudges as a policy choice is social science research suggesting that soft government paternalism (policies that persuade) are more effective than "hard" government paternalism (policies that compel).[254] Behavioral economists have found that soft paternalism is more libertarian in that it tends to preserve freedom of choice; people exercising that choice are promoting their own ends as they understand them.[255] Environmental nudges include disclosure of information (e.g., mileage-per-gallon estimates for new cars), warnings (e.g., comparing a consumer's energy use on their utility bill with other neighbors), and promoting behavior that signals a

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[247] *Id.*
[248] *Id.*
[249] *Id.* at 16–40.
[250] Jon Murray, *As nation's strictest green roof law takes effect in Denver, plenty of uncertainty swirls around voter-passed requirements*, DENVER POST (Jan. 17, 2018), https://www.denverpost.com/2017/12/31/denver-green-roof-law/ [https://perma.cc/BEJ7-WGNR]; Kathleen Ronaye, *California moves to require solar panels on all new homes*, ASSOC. PRESS (May 9, 2018), https://www.apnews.com/afa0978eff8443af9e5d7c77a3c285bf [https://perma.cc/L7U5-MBM3].
[251] *Id.*
[252] LAITOS & OKULSKI, *supra* note 113, at 128.
[253] RICHARD THALER & CASS SUNSTEIN, NUDGE: IMPROVING DECISIONS ABOUT HEALTH, WEALTH, AND HAPPINESS 6 (2009).
[254] LAITOS & OKULSKI, *supra* note 113, at 128–29.
[255] RICCARDO REBONATO, TAKING LIBERTIES: A CRITICAL EXAMINATION OF LIBERTARIAN PATERNALISM 95–96 (2012); William Wan, *People can't be educated into vaccinations but behavioral nudges help, study finds*, WASH. POST (Apr. 4, 2018), https://www.washington post.com/news/to-your-health/wp/2018/04/04/people-cant-be-educated-into-vaccinations-but-behavioral-nudges-help-study-finds/?utm_term=.afce17ec13f3 [https://perma.cc/C9YM-CVZG].

belief in the value of the behavior (e.g., residents installing solar panels on their home, influencing similar behavior by their neighbors).[256]

c. The Utility of Cooperation and Common Property

Standard neoclassical economics assumes that whenever there is an open-access "commons," like a fishery, grazing lands, or common-field agriculture, individual resource users will seek to exploit the resource before other users do the same.[257] The result is a "tragedy" of the open-access resource, requiring the imposition of property rights or government regulation.[258] However, scholars who have empirically studied such commons have realized that another driver will sometimes override this race to use the common resource—the human desire to *cooperate* with otherwise competing individuals to foster larger community ends.[259]

Explanatory science has been able to shed light on what leads (or fails to lead) resource users to cooperate in order to improve a common property regime that averts resource overuse.[260] It appears that individuals will work together voluntarily if other similarly situated individuals do likewise and if the long-term benefits of cooperation exceed the long-term benefits of an individualistic strategy.[261]

d. Game Theory

Explanatory science offered another model to policymakers wishing to bring about cooperation between resource users: game theory.[262] Game theory shares with complexity theory the idea that natural equilibria are possible if the multiple players in the resources game adopt informed

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[256] SUNSTEIN, *supra* note 245, at 17; Gordon T. Kraft-Todd et al., *Credibility-Enhancing Displays Promote the Provision of Non-Normative Public Goods*, 563 NATURE 245, 245–46 (Oct. 24, 2018).
[257] Hardin, *supra* note 74.
[258] *Id.* at 1245; S.V. Ciriacy-Wantrup & Richard Bishop, *"Common Property" as a Concept of Natural Resources Policy*, 15 NAT. RESOURCES J. 713, 714 (1975).
[259] ROGER SCRUTON, CONSERVATISM: AN INVITATION TO THE GREAT TRADITION 10 (2018) (stating that human beings live naturally together in communities); D. ZOHRA & I. MARSHALL, THE QUANTUM SOCIETY: MIND, PHYSICS, AND A NEW SOCIAL VISION 37–38 (1994).
[260] ELINOR OSTROM, GOVERNING THE COMMONS: THE EVOLUTION OF INSTITUTIONS FOR COLLECTIVE ACTION 186 (1990).
[261] *Id.*
[262] *See* Shi-Ling Hsu, *A Game Theoretic Approach to Regulatory Negotiation and a Framework for Empirical Analysis*, 24 HARV. ENVTL. L. REV. 33, 63–65 (2002); Lubell, *supra* note 71, at 538.

norms for decision-making.[263] Environmental policy can encourage negotiation among stakeholders that can result in adaptive collaboration.[264] Use of game theory can be a regulatory strategy to bring about the benefits of cooperation between agencies and resource users.

e. Alternative Policy Goals

Traditional environmental policy is often built upon the belief that environmental laws exist to "clean up" the environment, or to make environmental goods and resources "safe" for humans.[265] Utilitarian science would supply the data to policymakers to ensure the end goals of an environment that was clean and safe.[266] Explanatory science has offered a different end game for environmental laws. A growing body of research is revealing that what humans really want is to feel good—they desire human happiness and well-being.[267] Those who set environmental policy might tap into this science-based approach to improving individual and social levels of well-being. What humans desire is more complicated and nuanced than simply reducing pollution levels and preserving more endangered wildlife.[268]

## IV. SCIENCE DETERMINES POLICY CONSISTENT WITH NATURE'S LAWS

Humans initially tended to view nature as a mortal enemy. The natural world threatened us, and often stood in the way of our survival. As humans became more technologically sophisticated, beginning in the seventeenth century, we embraced the anthropocentric belief that nature and its natural resources were meant for productive human *use*.[269] For the next three centuries, humans exploited nature by utilizing its seemingly limitless raw materials and pollution sinks.[270] Humans perceived

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[263] *See generally* SHAUN HARGREAVES HEAP & YANIS NAROUFAKIS, GAME THEORY 41–79 (1995) (explaining the elements and concepts of game theory).
[264] AXELROD, *supra* note 83, at 19–20; Hornstein, *supra* note 69, at 949–50.
[265] *See generally Main U.S. Environmental Laws*, CARNEGIE MELLON UNIVERSITY (2003), http://environ.andrew.cmu.edu/m3/s7/us_laws.shtml [https://perma.cc/D7QC-7BBR] (describing American laws designed to promote safety and cleanliness).
[266] Houck, *supra* note 5, at 165, 169.
[267] *See generally* C. ROBERT CLONINGER, FEELING GOOD: THE SCIENCE OF WELL-BEING (2004); THE SCIENCE OF WELL-BEING (F. Huppert, N. Baylis & B. Keverne eds., 2005).
[268] *Id.*
[269] Jan Laitos & Lauren Wolorgevicz, *Why Environmental Laws Fail*, 39 WM. & MARY ENVTL. L. & POL'Y REV. 1, 24–28 (2014).
[270] *Id.*

that they were separate from nature, which meant that environmental goods were for our benefit—to extract, consume, or receive our wastes.[271]

By the twentieth century, it was no longer possible to take seriously the premise that nature was a threat to humans; it became obvious that humans, and human exploitation of the environment, were a threat to the workings of nature.[272] This observation, along with warnings by commentators about the loss of wilderness and contamination of land, air, and waste,[273] led to the invention of "environmental law." The catalyst for environmental protection laws can still be characterized as anthropocentric and based on assumptions about the inherent separateness between humans and nature. Utilitarian science informed environmental policy.[274]

By the twenty-first century, explanatory science influences more environmental policy. Explanatory science demonstrates that nature has no "natural baselines" for policy to restore and preserve.[275] Rather, the ecological reality is one of non-linear, constant complex change, where adaptive dynamism is the rule; humans and their environmental surroundings are best seen as a holistic CAS.[276] Moreover, explanatory science shows that there is no separation between nature and humans; nature adapts to humans, and as humans interact with their environment, they too adapt.[277] The combined, integrated combination of human-natural systems is an SES.[278] Explanatory science has offered theories, such as complexity theory, for policymakers to consider as tools to adopt when addressing human-generated threats to the CAS or SES.[279]

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[271] *Id.* at 25.

[272] *See, e.g.*, Dino Grandoni, *Drilling on federal lands increasing climate change, Trump administration report says*, DENVER POST (Nov. 27, 2018), https://www.denverpost.com/2018/11/27/drilling-federal-lands-climate-change/ [https://perma.cc/J7DF-VJC4] (extracting and burning of fossil fuels from federal lands made up a quarter of all carbon dioxide emissions in the United States).

[273] For examples of these warnings and observations, see generally GEORGE PERKINS MARSH, *Man and Nature* (1864), *in* THE ENVIRONMENTAL DEBATE: A DOCUMENTARY HISTORY (Peninah Neimark & Peter Rhoades Mott eds., 2017); JOHN MUIR, THE YOSEMITE (1912); RODERICK NASH, WILDERNESS AND THE AMERICAN MIND (1967); *supra* Part II.

[274] *Environmental Ethics*, STANFORD ENCYCLOPEDIA OF PHILOSOPHY 12 (July 21, 2015), https://plato.stanford.edu/entries/ethics-environmental/ [https://perma.cc/YT8P-LC7A].

[275] Craig, *supra* note 106, at 31–35.

[276] S.A. Levin, *Ecosystems and the Biosphere as Complex Adaptive Systems*, 1 ECOSYSTEMS 431, 431–32 (1998).

[277] *See* Bittel, *supra* note 202.

[278] Elinor Ostrom et al., *Going Beyond Panaceas*, 104 PROC. NAT'L ACAD. SCI. 15,176, 15,176 (2007).

[279] INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, *Global Warming of 1.5°C, Summary*

A central thesis of this Article is that explanatory science should do more than simply "influence" environmental policy; it should *determine* and *establish* environmental policy. This far more dominant role of science is warranted because of a central principle: to be effective, our environmental laws must be consistent with nature's laws.[280] Explanatory science can both justify the truth of this prime directive, as well as identify the principal laws of nature, to which environmental laws should conform.

The notion that science should be more prominent for environmental policy seems particularly timely when there is such a disconnect in the United States between science and environmental policy. For example, in late 2018, the federal government issued its National Climate Assessment report, a 1700-page study produced by scientists for various federal agencies.[281] It traced the negative, costly effects of climate change upon every region and sector in the United States, and warned of the environmental devastation yet to come.[282] The report contradicts every position taken on the issue by President Trump.[283] Although the report acknowledges the anthropogenic causes of climate change, the Trump administration denies there is climate change, and argues that global temperature changes are natural.[284] Worse, the Trump administration's environmental policy is to direct federal agencies to weaken rules for curbing planet-warming pollutants. The White House has ordered a repeal or loosening of laws that would restrict greenhouse gases from vehicle tailpipes.[285] It has also issued orders preventing air pollution laws from applying to power plant smokestacks.[286] In 2017, President Trump announced that, due to

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*for Policymakers* B.6.1–B.6.3 (Oct. 2018); *see generally* Ruhl & Katz, *supra* note 61 (discussing the implications of legal complexity for complex adaptive systems).

[280] *See supra* notes 20–21 and accompanying text.

[281] U.S. GLOBAL CHANGE RESEARCH PROGRAM, FOURTH NATIONAL CLIMATE ASSESSMENT 10–11 (Nov. 2018), https://nca2018.globalchange.gov/downloads/NCA4_2018_FullReport.pdf [https://perma.cc/KJY5-26BN].

[282] Rachel Gutman, *The Three Most Chilling Conclusions from the Climate Report*, THE ATLANTIC (Nov. 26, 2018), https://www.theatlantic.com/science/archive/2018/11/most-chilling-parts-2018-climate-assessment/576598/ [https://perma.cc/S36U-V9YV].

[283] *Compare* U.S. GLOBAL CHANGE RESEARCH PROGRAM, *supra* note 281, at 25–32 *with* notes 284–87, *infra*.

[284] Igor Bobic, *GOP Shrugs Off Bombshell Climate Report*, HUFFPOST (Nov. 25, 2018), https://www.huffingtonpost.com/entry/climate-change-report-gop_us_5bfab61de4b0771fb6b9bf48 [https://perma.cc/JG65-S2QD].

[285] Coral Davenport, *Trump Administration Unveils Its Plan to Relax Car Pollution Rules*, N.Y. TIMES (Aug. 2, 2018), https://www.nytimes.com/2018/08/02/climate/trump-auto-emissions-california.html [https://perma.cc/GMX4-NH59].

[286] Coral Davenport, *Trump Administration's Strategy on Climate: Try to Bury Its Own*

a lack of scientific proof, he would withdraw the United States from the 2015 landmark Paris Climate Accord.[287] At a time when United States' environmental policy is undergoing what has been called "a new frontier of disavowance of science,"[288] it seems appropriate to make the case that science should not be ignored, but instead should set policy.

### *A. The Principle of Universality: Why Environmental Laws Should Be Consistent with Nature's Laws*

There are two general categories of "laws." One kind of law is a system of rules which a country or community recognizes as regulating the actions of its members, who are usually humans or human-created institutions.[289] The other kind of law is "a statement of fact, deduced from observation, to the effect that a particular natural or scientific phenomenon *always occurs* if certain conditions are present."[290] The latter type of law describes the physical laws that govern how things in our environment work, how natural systems function, and how the universe operates.[291] To qualify as a "law" under this second meaning, the law must be derived from scientific observations, experimental testing, and mathematical formulas.[292] Such physical laws constitute the best explanation of the natural world; they also enable us to make reliable predictions about the workings of the Earth's environment.

An "environmental law" is a law that regulates, and often tries to mitigate, the impact of human activities on nature and the physical environment in order to achieve a "healthy environment" and "protect natural systems."[293] As such, environmental laws involve both the first type of law—those laws that regulate human behavior—as well as the second type of law—those laws that reveal truths about the dynamics of nature. To be

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*Scientific Report*, N.Y. TIMES (Nov. 26, 2018), https://www.nytimes.com/2018/11/25/climate/trump-climate-report.html [https://perma.cc/RMY6-U56R].

[287] Robinson Meyer, *A Grave Climate Warning, Buried on Black Friday*, THE ATLANTIC (Nov. 23, 2018), https://www.theatlantic.com/science/archive/2018/11/national-climate-assessment-black-friday/576589/ [https://perma.cc/5JXK-JYBC].

[288] Davenport, *supra* note 286 (quoting William K. Reilly, head of the EPA under President George H.W. Bush).

[289] *Law—Definition of Law in English*, OXFORD DICTIONARIES (2019), https://en.oxforddictionaries.com/definition/law [https://perma.cc/3K5G-S6J2].

[290] *Id.* (emphasis added).

[291] *Id.*

[292] John T. Roberts, *Measurability and Physical Laws*, 144 SYNTHESE 433, 434 (2005).

[293] ROBERT V. PERCIVAL ET AL., ENVIRONMENTAL REGULATION 1, 66 (8th ed. 2018).

effective, it would follow that environmental laws should be concerned not only with human acts that affect the environment, but also with the universal "laws" that govern that natural environment. Explanatory science has revealed that nature usually acts as a CAS, and that the humans-and-nature pairing is a non-divisible, integrated holistic SES.[294] Explanatory science has also revealed that the natural environment seems to operate according to fixed, definite rules.[295] This realization is known as the Principle of Universality.[296]

The Principle of Universality is a "law" that governs nature. It holds that for the natural forces and relationships that scientists observe in the natural world, all apply universally, regardless of location or time.[297] In other words, there are predictable rules by which nature always operates,[298] ranging from gravity to chemical reactivity to photosynthesis to the homologous macromolecules (DNA, RNA) that derive from a common ancestor. These laws determine how things work everywhere in the universe, no matter when or by whom the experiment is carried out, and irrespective of scale.[299] The universal laws of nature encompass physics, chemistry, and biology.[300]

Since environmental law imposes rules on humans to regulate their anthropogenic impact on nature,[301] and since nature itself (including the Earth's environment) behaves in accordance with general, universal rules,[302] it would seem that there should be a linkage between our environmental laws and nature's laws. The Principle of Universality suggests this result. So too does common logic: "[I]f laws are to be effective

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[294] *See supra* notes 276–79.
[295] *See* PEDRO FERREIRA, THE PERFECT THEORY 4–5 (2014).
[296] *See* Pazameta, *supra* note 21, at 1.
[297] *See* FERREIRA, *supra* note 295, at 4–5. It was Albert Einstein who concluded that the laws of physics and nature must look the same in any "inertial frame," which means that the laws of nature should be the same at all locations and times. *Id.*
[298] *See* Pazameta, *supra* note 21, at 1.
[299] *Id.*
[300] *Id.*; *Laws of Biology and True Universality*, BIOPOLYVERSE (Sept. 8, 2013), https://biopolyverse.com/2013/09/08/laws-of-biology-and-true-universality/ [https://perma.cc/S5FH-V7VJ]; *How the Universe Works—Scientists Baffled by Laws of Nature*, EVERYSTUDENT.COM, http://www.everystudent.com/wires/organized [https://perma.cc/3NZZ-AM65] (last visited Mar. 11, 2019). *See* Paul C.W. Davies & Sara I. Walker, *The hidden simplicity of biology*, 2016 REP. PROG. PHYS. 79 102,601, 102,601.
[301] A. Dan Tarlock, *Is There a There There in Environmental Law?*, J. LAND USE & ENVTL. L. 213, 235 (2004).
[302] NEIL DEGRASSE TYSON & DONALD GOLDSMITH, ORIGINS: FOURTEEN BILLION YEARS OF COSMIC EVOLUTION 16 (2004).

they need to recognize the inherent subject matter with which they are concerned. This means that a governance system must to some extent reflect, or at least correspond with, the qualities of that which it is seeking to regulate."[303]

Anthropogenic environmental law systems should reflect the central attributes of the natural systems in which they are embedded. These systems can be discovered because they all follow a code of nature.[304] What, then, are the central attributes, or "laws," of nature?

### B. *The Two Central Laws of Nature*

The object of environmental law is to alter the actions of humans toward their environmental surroundings. Traditional environmental laws have been fashioned to satisfy anthropocentric needs, and anthropomorphic assumptions about how nature and the environment work.[305] To succeed and be effective, environmental policy should not simply appease human needs regarding the human environment; environmental policy must obey the laws of the natural environment. For knowledge of the physical environment surrounding humans, and the universal laws governing this environment, we should turn to science. And when we do, science reveals that the two central hallmarks of nature are *symmetry* and *economy*.[306] The laws of symmetry and economy guide and explain the workings of the natural environment.[307]

#### 1. Symmetry

Over the course of the twentieth century and continuing through the present, scientists have increasingly agreed that the idea of symmetry dominates our understanding of the fundamental laws of the natural environment.[308] What scientists, mathematicians, physicists, and biologists have come to realize is that if one wishes to learn the immutable laws of the environment, one needs to *start with symmetry*. The requirements of

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[303] CULLINAN, *supra* note 100, at 26.
[304] DEGRASSE TYSON & GOLDSMITH, *supra* note 302, at 16.
[305] JAN G. LAITOS, THE RIGHT OF NONUSE 55, 169 (2012); Laitos & Wolorgevicz, *supra* note 269, at 1, 25.
[306] *See infra* notes 309–16.
[307] WILCZEK, *supra* note 23, at 11, 49; Steven Weinberg, *Symmetry: A "Key to Nature's Secrets,"* N.Y. REV. OF BOOKS (Oct. 27, 2011) at 1, 2.
[308] *See infra* notes 309–16.

symmetry come first, and typically dictate the laws that nature then must obey; nature's laws may be deduced from the requirement of symmetry.[309]

Nobel Laureate Frank Wilczek defines symmetry as "change without change."[310] In a mathematical sense, the equation A=B is symmetrical. If one reverses the equation so that B=A, there has been a change in form, but not content. Transforming A=B to B=A is a change without change; the equation is symmetrical.

Similarly, a symmetry of some biological structure, some environmental good, or of some force observed in the universe is a transformation of that structure, good, or force that leaves properties of the structure unchanged.[311] This view of nature predicts how biological organisms will evolve. Bilateral symmetry is so prevalent in animals on Earth that one may presume that natural selection prefers living organisms that exhibit this kind of symmetry.[312] Indeed, bilateral symmetry helped James Watson and Frances Crick deduce that the DNA molecule consists of two symmetrical strands of a double helix.[313] Symmetry is equally integral to the way the forces of the universe work; Albert Einstein used symmetry as a guiding principle when he devised his General Theory of Relativity.[314] Under the symmetry in the universe called general covariance, physical laws act the same whether an object is accelerating or at rest: the force of gravity and the force resulting from acceleration are symmetrical facets of the same force.[315]

Symmetry is fundamental to the core theories of physics, relativity, and even quantum theory, and is also relevant to patterns observed in the natural world, including living organisms in the biosphere.[316] Why, then, is symmetry such a driving force in nature? Science suggests that symmetry is prevalent because it *simplifies* things. Symmetry permits living biological

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309 MARCO LIVIO, THE EQUATION THAT COULDN'T BE SOLVED: HOW MATHEMATICAL GENIUS DISCOVERED THE LANGUAGE OF SYMMETRY 43, 205, 231 (2005).

310 WILCZEK, *supra* note 23, at 137, 238. *See also* HERMANN WEYL, SYMMETRY 3 (1983) ("A thing is symmetrical if there is something you can do to it so that after you have finished doing it, it looks the same as before.").

311 IAN STEWART, SYMMETRY: A VERY SHORT INTRODUCTION 19 (2013).

312 Mario Livio, *Why Are We Symmetrical?*, HUFFPOST (Dec. 6, 2017), https://www.huffingtonpost.com/mario-livio/why-are-we-symmetrical_b_1836534.html [https://perma.cc/VH46-L7FR].

313 J.D. Watson & F.H. Crick, *Molecular Structure of Nucleic Acids*, 171 NATURE 737, 737 (Apr. 25, 1953).

314 *Special Relativity as a Symmetry of Nature*, UNIV. BRITISH COLUMBIA (2019), https://www.phas.ubc.ca/~mav/p526/read5.pdf [https://perma.cc/B62L-58LV].

315 FERREIRA, *supra* note 295, at 13.

316 IAN STEWART, WHY BEAUTY IS TRUTH: A HISTORY OF SYMMETRY vii–viii (2007).

organisms to economize how they function;[317] symmetry ensures that larger objects in the universe, like stars and planets, eventually achieve a natural minimum-energy configuration.[318] Wherever one finds symmetry in nature, what will also be found is a corresponding conservation of momentum or energy.[319] Symmetry is thereby linked to the other central law governing the natural environment: the economy of means.

2. Economy

The concept of "economy" has been defined as "producing an abundance of effects from very limited means."[320] In other words, when nature is faced with a question—what should be the shape of a snowflake, the structure of the DNA molecule, or the organization of a bee's honeycomb?—nature will inevitably opt for the simplest, most efficient, most economical solution. Consistent with the first central principle underlying nature's laws,[321] that solution will employ symmetry.

A snowflake is most stable when its shape is symmetrically six-sided.[322] The sturdy, billions of years old DNA molecule, is a symmetrical double helix.[323] The cells of a bee's honeycomb are always a hexagon.[324] Why a hexagon? Much effort is required for bees to make honeycombs; many individual cells must be made in order to have sufficient comb for storing honey, the bees' natural food source.[325] But why should these cells be hexagonal, instead of round, triangular, or square? The bees need to find a shape where gaps are minimized, no space is wasted, where each individual cell shares its walls with its neighbor, so that the bees can produce the maximum number of cells with the amount of wax used.[326] The bees construct hexagons because that shape, *more so than any other*

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[317] STEWART, *supra* note 311, at 90–91; WILCZEK, *supra* note 23, at 49.
[318] STEWART, *supra* note 311, at 107.
[319] LIVIO, *supra* note 309, at 217 (this principle is known as Noether's Theorem).
[320] WILCZEK, *supra* note 23, at 11, 15.
[321] *See supra* notes 20–21 and accompanying text.
[322] *See* Ian Stewart, *Symmetry of Snowflakes*, WARWICK KNOWLEDGE CENTRE ARCHIVE (Jan. 3, 2016), https://warwick.ac.uk/newsandevents/knowledge-archive/science/snowflakes/ [https://perma.cc/HM5Q-ELZL].
[323] *See generally* Watson & Crick, *supra* note 313 (describing the double helix).
[324] Robert Krulwich, *What Is It About Bees and Honeycombs?*, NPR (May 14, 2013), https://www.npr.org/sections/krulwich/2013/05/13/183704091/what-is-it-about-bees-and-hexagons [https://perma.cc/3PWE-H9A5].
[325] *Id.*
[326] *Id.*

*shape in nature*, holds the most honey.[327] Hexagons break up flat space into little units more economically, using less wax in doing so.[328] Consistent with nature's law of "economy of means," hexagonal honeycombs hold the most amount of honey while using the least amount of wax.[329] And hexagons are, of course, symmetrical.[330]

A "law" holding that nature will favor the simplest, most economical approach, or an approach producing "an abundance of effects from very limited means," is consistent with Occam's Razor, or the principle of parsimony.[331] Occam's Razor advises that when one has to choose from a set of possible explanations for a given phenomenon, the "simplest" explanation is usually the correct one.[332] The Occam's Razor principle underlies all scientific modeling of the natural environment, and is consistent with how nature usually prefers the simplest solution: "[a]lthough the symmetries may be hidden from us, we can sense that they are latent in nature, governing everything about us . . . . Nature is much simpler than it looks."[333]

That nature favors economy, efficiency, and simplicity[334] is consistent with what explanatory science has discovered about complex environmental systems. An unpredictable, non-linear, multidimensional system, like the Earth's climate, is known as a system in *chaos*.[335] However, chaos science has shown that one can, paradoxically, find order, patterns, and even simplicity within such systems. A system in chaos ultimately has a shape and boundary it will not violate, and it produces symmetrical patterns.[336] Nature's law of economy and simplicity disaggregates complexity.

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[327] *Id.*
[328] *Id.*
[329] *Id.*
[330] In 1999, a scientist at the University of Michigan named Thomas Hales produced a mathematical proof demonstrating that "a regular hexagonal grid is the best and most economical way to divide a surface into regions of equal area with the least total perimeter." Frank Morgan, *Hales Proves Hexagonal Honeycomb Conjecture*, MATHEMATICAL ASS'N OF AMERICA (June 17, 1999), https://www.maa.org/frank-morgans-math-chat-hales-proves-hexagonal-honeycomb-conjecture [https://perma.cc/RTH2-75ZP].
[331] WILCZEK, *supra* note 23, at 11; *see* E.C. Banks, *The Philosophical Roots of Ernst Mach's Economy of Thought*, 139 SYNTHESE 23, 23–25 (2004).
[332] *See* Banks, *supra* note 331, at 23–25.
[333] WILCZEK, *supra* note 23, at 165 (quoting physicist Steven Weinberg). A preference for economical, more simple explanations is consistent with Bayesian statistics, which presume that the more economical of two explanations is more likely to be the correct one.
[334] *Id.* at 11.
[335] GLEICK, *supra* note 184, at 6–7.
[336] *See generally* ROBERT GILMORE & CHRISTOPHE LELELLIER, THE SYMMETRY OF CHAOS (2007) (analyzing these patterns and boundaries).

### C. *Towards an Environmental Law Paradigm That Aligns with Nature's Laws*

There are three important takeaway lessons from the past fifty years of environmental policy. First, environmental laws should not be premised on a belief in human superiority or separation from our environmental surroundings. Rather, such laws should reflect the scientific fact that humans and the natural environment are integrated, and have evolved together, as the SES.[337] Second, environmental laws should be consistent with a realistic model for how humans make decisions. Modern behavioral economics has caused us to rethink standard neoclassical economic orthodoxy holding that humans optimize and maximize individual welfare.[338] Instead, human behavior appears more nuanced, and more effectively influenced by policy urging us to *do* something, rather than rules ordering us to *not* do something.[339] Third, to be effective, environmental policy should follow the Principle of Universality, which posits that environmental laws should parallel nature's fundamental laws.[340] It seems that the twin truths governing nature are symmetry and economy.[341]

Environmental policy which obeys symmetry and economy and which is sensitive to these three lessons could take various forms. What is proposed here is a simple and symmetrical *right-duty* dichotomy. The legal right would be granted not just to humans, and not only to nature, but to the SES. The duty would be imposed only on humans, as it is just our species—*homo sapiens*—that is affecting Earth's natural systems and the biosphere.

#### 1. A New Legal Right to a "Safe Operating Space"

The proposed right granted to the SES would be a "positive" right, in that it would provide something to the right-holder.[342] It is a claim on legal grounds to obtain something.[343] This SES right would be to obtain

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[337] *See* LAITOS & OKULSKI, *supra* note 113, at 107. *See generally* Levin et al., *supra* note 183; ELLIS, *supra* note 177.
[338] *See supra* notes 238–45, 253, and accompanying text.
[339] *Id.*
[340] *See supra* notes 20–22 and accompanying text.
[341] WILCZEK, *supra* note 23, at 11, 49.
[342] *See* Leif Wenar, *Rights*, STANFORD ENCYCLOPEDIA OF PHILOSOPHY (Sept. 9, 2015), https://plato.stanford.edu/archives/fall2015/entries/rights/ [https://perma.cc/5ZLN-GKLX].
[343] R.M. HARE, THE LANGUAGE OF MORALS 44 (1952).

what science is calling a "safe operating space."[344] The idea of a safe operating space is premised on a science-based model of environmental conditions that permit Earth's natural systems to operate so that the SES may exist.[345] These systems, and the resulting safe operating space, require that so-called "planetary boundaries" are not breached.[346] Science defines planetary boundaries as environmental limits within which the SES can safely operate.[347] Anthropocentric actions have already compromised four such boundaries—climate change, biosphere integrity, biochemical flows, and land system changes.[348] The proposed legal "right" held by the SES would be to the protection of Earth systems so as to create a global safe operating space[349] and the restoration of planetary boundaries.[350]

Since the right is held by the SES, it may be raised by either of the two components that make up the SES: humans, or ecological systems and organisms.[351] Although the nonhuman components of the SES will not be able to assert this right on their own, humans can raise the rights of ecological/biological interests on behalf of the SES through the doctrine of *just tertii*.[352] The right should be asserted to promote the resilience and sustainability of Earth's SES.[353] It should be raised whenever there are anthropogenic actions that threaten to either disconnect human actions from the functioning of Earth's ecological systems or prevent a safe operating space for the SES.[354]

The proposed right conforms to the two central tenets of nature's laws: symmetry and economy. It is accompanied by a reciprocal, and

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344 Johan Rockström et al., *Planetary Boundaries: Exploring the Safe Operating Space for Humanity*, 461 NATURE 472, 472 (2009).
345 *See generally* Will Steffen et al., *Planetary Boundaries: Guiding Human Development on a Changing Planet*, 347 SCI. 6223 (Feb. 15, 2015) (describing this science-based model).
346 *Id.* at 736–38.
347 *Id.*
348 *Id.*
349 T. Hayha et al., *Operationalizing the Concept of a Safe Operating Space at the EU Level—First Steps and Explorations*, STOCKHOLM RESILIENCE CENTER 4 (2018); John McLaughlin, *Safe Operating Space for Humanity at a Regional Scale*, 23 ECOLOGY & SCI. (2018), at 1–2.
350 Katherine Richardson et al., *Planetary Boundaries: Exploring the Safe Operating Space for Humanity*, 14 ECOLOGY & SOC'Y (2009), at 1–2, 4, 19–21.
351 LAITOS & OKULSKI, *supra* note 113, at 21, 39.
352 Powers v. Ohio, 499 U.S. 400, 410–11 (1999); CULLINAN, *supra* note 100, at 108.
353 Carl Folke et al., *Adaptive Governance of Social-Ecological Systems*, 30 ANN. REV. ENVTL. RESOURCES 441, 443–44 (2005).
354 *See, e.g.*, NAVIGATING SOCIAL-ECOLOGICAL SYSTEMS 1–2 (F. Berkes, J. Colding & C. Folke, eds.) (2003) (describing human domination of Earth and the challenges this poses for complex systems).

symmetrical, legal *duty*, and it has economy; it is *simple* to understand and implement. Consistent with symmetry, the positive right has a corollary to this right, a corresponding affirmative duty. As noted below, the right to a safe operating space requires a duty to support natural systems, biological organisms, and environmental goods so that humans as a species will be able to survive.[355] A right-duty dichotomy satisfies symmetry, while the right held by the SES ensures economy. It does not require a vast administrative superstructure with myriad top-down regulations. A rights system conserves legal resources. The right is held by the twin components of the SES. It is bottom-up, triggered only when one of the parts of the SES asserts the right to ensure a safe operating space.

2. A Human Duty to the Environment

If a positive right is held by the Earth-based SES, then symmetry predicts that an affirmative duty should be also created. The existence of a positive right to a safe operating space suggests there must be, or should be, a symmetrical affirmative duty to provide that safe space. While the right is held by the SES, the duty is imposed on the "social" component of the SES right-holder: humans. *Homo sapiens* has a duty to the SES to maintain planetary boundaries and natural systems so that human life is sustained. Humans alone bear the burden of the affirmative obligation because, in the Anthropocene Era, only one species is so affecting the natural environment that human long-term viability cannot be assumed.[356]

Since the right to a safe operating space held by the SES is positive, so too is the correlative duty held by humans. A positive duty is more than a duty to not act; it is an affirmative obligation to actively provide something[357] to the right-holder: the SES. In short, humans should have a duty to provide the SES with a safe operating space. The important role of affirmative duties in environmental policy has been succinctly summarized by a leading American environmental law scholar, Professor A. Dan Tarlock: "[i]f environmental protection is to succeed as a legitimate, permanent policy, it must evolve from a *negative* strategy of simply trying to stop an action that disturbs a mythical natural baseline, to a pervasive *affirmative* one which provides incentives for creative . . . protection solutions."[358]

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[355] *See infra* Section IV.C.2.
[356] Will Steffen et al., *The Anthropocene: From Global Change to Planetary Stewardship*, 40 AMBIO 739, 740 (2011).
[357] *See* Marcus G. Singer, *Negative and Positive Duties*, 15 PHIL. Q. 97, 98–99 (Apr. 1965).
[358] Tarlock, *supra* note 96, at 243 (emphasis added).

A duty to provide something, instead of an obligation to halt or prevent something, is consistent with what behavioral economics tells us about human decision-making. Scientific research has revealed what motivates people to change. Humans are motivated not when they are threatened, but when their affirmative actions have power, when they can do something.[359] As noted previously in this Article, an environmental law is efficient, and more likely to succeed, when it tells humans *what to do* instead of ordering them *what not to do*.[360] Moreover, an affirmative duty to provide for the right-holder is simpler than a negative duty to avoid harming the right-holder.[361] A simpler duty conforms to nature's preference for "economy."

## CONCLUSION

While science, especially utilitarian science, has always played a prominent role in the development of environmental policy, it should now assume a different role. Instead of informing policy, it should direct policy. The science that performs this task should not be utilitarian science, but explanatory science. Environmental policymakers who turn to explanatory science will discover that the Principle of Universality can guide the formulation of environmental laws that actually bring about efficient change to natural environmental systems. This science-based Principle, which underscores physics, chemistry, and biology, suggests that our environmental laws should be consistent with nature's laws. The two central truths of the universe, and Earth's environment, are symmetry and economy. To succeed, our environmental laws should similarly feature a symmetrical structure, such as a right-duty dichotomy. This dichotomy is not to be implemented by a huge government bureaucracy, but by the holders of the right and duty. This bottom-up system is simple and reflects economy.

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[359] John Brandon, *Is Your Culture One of Encouragement or Blame?*, CHI. TRIB. (Nov. 20, 2016), https://www.chicagotribune.com/business/success/inc/tca-is-your-culture-one-of-encouragement-or-blame-20161109-story.html [https://perma.cc/7FXX-D3EV].

[360] *See supra* notes 240–44 and accompanying text.

[361] T. Irwin, *Pufendorf*, *in* THE DEVELOPMENT OF ETHICS: HISTORICAL AND CRITICAL STUDY 351–52 (2011).