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Learning to Think about Complex Environmental Systems in Environmental and Natural Resource Law and Legal Scholarship: A Twenty-Year Retrospective

LEARNING TO THINK ABOUT COMPLEX ENVIRONMENTAL SYSTEMS IN ENVIRONMENTAL AND NATURAL RESOURCE LAW AND LEGAL SCHOLARSHIP: A TWENTY-YEAR RETROSPECTIVE

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Twenty years ago, Yale law professor Donald Elliott wrote that "[e]nvironmental law is worthy of serious study not only for its own importance, but also as a case history in the use of law as an instrument of social change. Environmental law represents the state-of-the-art in using legal institutions and techniques to manage complex systems to achieve social goals."[1] His statement is important for a number of reasons, but the one I want to focus on in this essay is his acknowledgement that the environment is a complex system – an acknowledgement that has become an increasingly important part of environmental law scholarship and that desperately needs to become a more prominent part of environmental and natural resources law and policy. In particular, grappling with ecological complexity through new legal tools offers one of the best prospects for dealing with the impacts of climate change – *i.e.*, engaging in climate change adaptation – in the decades to come. Because climate change is *the* environmental and natural resources problem (not to mention social, cultural, and economic problem) of the 21st century,[2] it is well worth reviewing how scientific concepts of complexity and

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1. E. Donald Elliott, *Environmental Law at a Crossroad*, 20 N. KY. L. REV. 1, 2 (1992).

2. *See* Alexandra B. Klass, *Climate Change and the Convergence of Environmental and Energy Law*, 24 FORDHAM ENVTL. L. REV. 180, 181 (2013) (stating that the resurgence of states and private parties relying on traditional common law theories to address today's environmental challenges highlight climate change as the focal point in environmental law).

systems theory have become an active component of the environmental and natural resources law conversation in scholarship.

Scientists – particularly biologists and ecologists but also, notably, computer scientists and information systems analysts – have increasingly recognized that both natural systems and human societies are *complex systems* – that is, systems where seemingly simple entities or components self-organize into intricate and interrelated networks of functions, products, and responses.[3] Thus, "[i]n complex systems, many simple parts are irreducibly entwined, and the field of complexity is itself an entwining of many different fields."[4] Examples of complex systems include insect colonies, immune systems, brains, and economies[5] – and, many would argue, law.[6]

Complexity scientists generally distinguish *complex* systems from *complicated* systems.[7] As John Miller and Scott Page have explained:

> In a complicated world, the various elements that make up the system maintain a degree of independence from one another. Thus, removing one such element (which reduces the level of complication) does not fundamentally alter the system's behavior apart from that which directly resulted from the piece that was removed. Complexity arises when the dependencies among the elements become important. In such a system, removing one such element destroys system

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3. *See generally* MELANIE MITCHELL, COMPLEXITY: A GUIDED TOUR 4 (2009).

4. *Id.*

5. *See id.* at 4-12.

6. *See* Gregory Todd Jones, *Dynamical Jurisprudence: Law as a Complex System*, 24 GA. STATE U. L. REV. 873 (2008); *see also* J.B. Ruhl, *Law's Complexity: A Primer*, 24 GA. ST. U. L. REV. 885 (2008); Eric Kades, *The Laws of Complexity and the Complexity of Laws: The Implications of Computational Complexity Theory for the Law*, 49 RUTGERS L. REV. 403 (1997); J.B. Ruhl, *The Fitness of Law: Using Complexity Theory to Describe the Evolution of Law and Society and Its Practical Meaning for Society*, 49 VAND. L. REV. 1406 (1996); J.B. Ruhl, *Complexity Theory as a Paradigm for the Dynamical Law-and-Society System: A Wake-Up Call for Legal Reductionism and the Modern Administrative State*, 45 DUKE L.J. 849 (1996).

7. *See generally* JOHN H. MILLER & SCOTT E. PAGE, COMPLEX ADAPTIVE SYSTEMS: AN INTRODUCTION TO COMPUTATIONAL MODELS OF SOCIAL LIFE 4 (2007).

> behavior to an extent that goes well beyond what is embodied by the particular element that is removed.[8]

To dramatize the point: "A complex system dies when an element is removed, but complicated ones live on, albeit slightly compromised."[9]

What I and many other scholars have begun to argue is that environmental and natural resources law have long treated the environment – landscapes and public lands, ecosystems, watersheds – as *complicated* systems capable of being managed for individual components, when in fact they have always been complex adaptive systems.[10] Moreover, as complex adaptive systems, the subjects of environmental law (the *objects*, of course, are the human actors who affect the environment and natural resources) have frequently responded unpredictably to this often misguided approach to governance. The mismatch of legal component-based thinking and ecological complexity has perhaps become most obvious in the stock-based approach to fisheries management that has dominated in the United States under the Magnuson-Stevens Fisheries Management and Conservation Act[11] and the species-focused approach to biodiversity preservation under the Endangered Species

8. *Id.* at 9.

9. *Id.*

10. *See infra* notes 45-52 and accompanying text.

11. *See* 16 U.S.C. §§ 1801-1884 (2006). For discussions of the failures of fisheries management, *see* Eric Biber, *Which Science? Whose Science? How Scientific Disciplines Can Shape Environmental Law*, 79 U. CHI. L. REV. 471, 488-93 (2012); *see also* D. Ludwig, *Fishing Down the Food Web*, *in* PANARCHY: UNDERSTANDING TRANSFORMATIONS IN HUMAN AND NATURAL SYSTEMS 4, Box 1-1 (Lance H. Gunderson & C.S. Holling eds., 2002).

Act.[12] Climate change is simply exacerbating our awareness of the mismatch.[13]

Complex systems have several distinguishing properties. First, they exhibit complex collective behavior – that is, individual components, following readily discernible rules of behavior, act collectively in vast numbers to "give rise to the complex, hard-to-predict, and changing patterns of behavior that fascinate us."[14] This property is often referred to as the *self-organizing* nature of complex systems, and the difficult-to-predict results are deemed *emergent* behaviors or properties.[15] Explaining how this "emergent self-organized behavior comes about" is the central enterprise of complexity science.[16]

Second, complex systems exhibit signaling and information processing – that is, they "produce and use information and signals

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12. 16 U.S.C. §§ 1531-1540 (2006). For discussions of the inadequacies of species regulation, see Kalyani Robbins, *Missing the Link: The Importance of Keeping Ecosystems Intact and What the Endangered Species Act Suggests We Do About It*, 37 ENVTL. L. 573 (2007); J.B. Ruhl, *Taking Adaptive Management Seriously: A Case Study of the Endangered Species Act*, 52 U. KAN. L. REV. 1249 (2004); 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. 933, 935-36 (1997); Alyson C. Flournoy, *Coping with Complexity*, 27 LOY. L.A. L. REV. 809, 813-16 (1994).

13. Robin Kundis Craig, *"Stationarity Is Dead"—Long Live Transformation: Five Principles for Climate Change Adaptation Law*, 34 HARV. ENVTL. L. REV. 9, 10-18, 31-39 (2010).

14. MITCHELL, *supra* note 3, at 12. *See also* NEIL F. JOHNSON, TWO'S COMPANY, THREE IS COMPLEXITY 13, 15 (2007) (noting that a complex system "contains a collection of many interacting objects or 'agents,'" that it "exhibits emergent phenomena which are generally surprising, and may be extreme," and that "the emergent phenomena typically arise in the absence of any sort of 'invisible hand' or central controller.").

15. *See* MITCHELL, *supra* note 3, at 13; *see also* MILLER & PAGE, *supra* note 7, at 9 ("The behavior of many complex systems emerges from the activities of lower-level components."); JOHNSON, *supra* note 14, at 5-9 (discussing emergent behavior and giving examples from a number of areas).

16. MITCHELL, *supra* note 3, at 13. *See also* JOHNSON, *supra* note 14, at 3-4 ("Complexity Science can be seen as the *study of the phenomena which emerge from a collection of interacting objects* . . . ."), 5 ("The Holy Grail of Complexity Science is to understand, predict and control such emergent phenomena—in particular, potentially catastrophic crowd-like effects such as market crashes, traffic jams, epidemics, illnesses such as cancer, human conflicts, and environmental change.").

from both their internal and external environments."[17] As Neil Johnson has emphasized, the behavior of objects in a complex system "is affected by memory or 'feedback,'" meaning "that something from the past affects something in the present, or that something going on at one location affects what is happening at another . . . ."[18] Thus, complex systems are linked systems, both temporally and spatially. Moreover, "the nature of this feedback can change with time."[19] In other words, how components of the system respond to each other and to outside stimuli is also subject to evolution and change.

Finally, complex systems "adapt – that is, change their behavior to improve their chances of survival or success – through learning or evolutionary processes."[20] As a result, complex systems – sometimes more specifically referred to as "complex adaptive systems"[21] – are dynamic systems because "they change over time in some way."[22] The dynamic capabilities of complex systems, combined with their emergent behaviors, can give these systems a certain degree of resilience, or ability to cope with changes to and around the system. Thus, "[w]hile complex systems can be fragile, they can also exhibit an unusual degree of robustness to less radical changes in their component parts."[23] Specifically, the emergence that such systems display typically "is the result of a very powerful organizing force that can overcome a variety of changes to the lower-level components."[24]

Definitions of complex systems emphasize these components. For example, Melanie Mitchell, a computer scientist and External Professor with the Santa Fe Institute, has defined complex systems to be "a system in which large networks of components with no central control and simple rules of operation give rise to complex collective

17. MITCHELL, *supra* note 3, at 13.

18. JOHNSON, *supra* note 14, at 14.

19. *Id.*

20. MITCHELL, *supra* note 3, at 13; *see also* JOHNSON, *supra* note 14, at 14 ("The objects can adapt their strategies according to their history.").

21. MITCHELL, *supra* note 3, at 13.

22. *Id.* at 15.

23. MILLER & PAGE, *supra* note 7, at 9.

24. *Id.*

behavior, sophisticated information processing, and adaptation via learning or evolution."[25]

One of the important lessons for environmental and natural resources law from complexity science is that uncertainty and unpredictability are inherent limitations on the legal system's ability to perfectly control and regulate its subjects, whether those subjects be social systems, ecological systems, or the important and dynamic intersection of the two, generally referred to as socio-ecological systems. As John Miller and Scott Page have emphasized, "At the most basic level, the field of complex systems challenges the notion that by perfectly understanding the behavior of each component part of a system we can then understand the system as a whole."[26] Or, as Neil Johnson has more colorfully summarized, complexity theory "represents a slap in the face for traditional reductionist approaches to understanding the world."[27]

This is the challenge that systems theory and complexity science pose to the future of environmental and natural resources law scholarship, even as climate change provides an ever-increasing impetus for meeting that challenge: How do we transform environmental and natural resources law into governance systems that can cope with continual change, ever-present uncertainty, and the potential for catastrophic (at least from a human perspective) threshold crossings in socio-ecological systems? Luckily, complexity scientists and others are also beginning to offer tools that might help the legal scholars meet this challenge, among them adaptive management,[28] panarchy theory,[29] and resilience theory.[30]

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25. MITCHELL, *supra* note 3, at 13.

26. MILLER & PAGE, *supra* note 7, at 3.

27. JOHNSON, *supra* note 14, at 17.

28. *See, e.g.*, John H. Davidson & Thomas Earl Geu, *The Missouri River and Adaptive Management: Protecting Ecological Function and Legal Process*, 80 NEB. L. REV. 816 (2001) (discussing adaptive management in the context of complex systems theory); *see also* Itzchak E. Kornfeld, *Adaptive Resource Management in Complex Systems*, 26 NAT. RESOURCES & ENV'T. 29 (2012); J.B. Ruhl & Robert L. Fischman, *Adaptive Management in the Courts*, 95 MINN. L. REV. 424, 438-39 (2010); Douglas E. Noll, *Searching for the Zone of Reasonableness*, 8 SAN JOAQUIN AGRIC. L. REV. 59, 70-72 (1998) (describing the use of adaptive management as an acknowledgement of the complexity of ecosystems); J.B. Ruhl, *Regulation by Adaptive Management – Is It Possible?*, 7 MINN. J.L. SCI. & TECH. 21 (2005).

Nevertheless, the incorporation of complexity theory into environmental and natural resources law scholarship remains nascent, albeit growing, especially from the perspective of finding an adequate governance system for climate change adaptation. Prior to 1992, legal scholarship did occasionally acknowledge that "the environment," however defined, was a complex system, but such acknowledgements were rare and undeveloped. For example, in a 1980 *Texas Law Review* Note, Howard Marek quoted the congressional testimony of David M. Gates, Director of the Missouri Botanical Gardens, during the enactment of the National Environmental Policy Act ("NEPA"), for the proposition that "[t]oday we are manipulating an extremely complex system: The ecosystems of the earth, the units of the landscape, and we do not know the consequences of our actions until it is too late. We need to study ecosystems in advance and work out the strategies of living with the landscape."[31] To a more legal effect, in 1983 Terrence

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29. *See, e.g.*, Ahjond S. Garmestani, Craig R. Allen & Heriberto Cabezas, *Panarchy, Adaptive Management and Governance: Policy Options for Building Resilience*, 87 NEB. L. REV. 1036 (2009); C.S. Holling et al., *Sustainability and Panarchies*, *in* PANARCHY: UNDERSTANDING TRANSFORMATIONS IN HUMAN AND NATURAL SYSTEMS 63-102 (Lance H. Gunderson & C.S. Holling eds., 2002) (describing the importance of panarchy theory's nested hierarchies of resilience loops).

30. *See, e.g.*, C.S. Holling & Lance H. Gunderson, *Resilience and Adaptive Cycles*, *in* PANARCHY: UNDERSTANDING TRANSFORMATIONS IN HUMAN AND NATURAL SYSTEMS 25-62 (Lance H. Gunderson & C.S. Holling eds., 2002) (describing the four-stage looped model of resilience); BRIAN WALKER & DAVID SALT, RESILIENCE THINKING: SUSTAINING ECOSYSTEMS AND PEOPLE IN A CHANGING WORLD (2006); *see also* Robin Kundis Craig, *Legal Remedies for Deep Marine Oil Spills and Long-Term Ecological Resilience: A Match Made in Hell*, 2011 BYU L. REV. 1863, 1886-96; BRIAN WALKER & DAVID SALT, RESILIENCE PRACTICE: BUILDING CAPACITY TO ABSORB DISTURBANCE AND MAINTAIN FUNCTION (2012); Barbara Cosens, *Transboundary River Governance in the Face of Uncertainty: Resilience Theory and the Columbia River Treaty*, 30 J. LAND RES. & ENVTL. L. 229, 231-42 (2010); *see* Craig, *supra* note 13, at 39-40; FOUNDATIONS OF ECOLOGICAL RESILIENCE (Lance H. Gunderson et al. eds., 2010); Barbara Cosens, *Resolving Conflict in Non-Ideal, Complex Systems: Solutions for the Law-Science Breakdown in Environmental and Natural Resource Law*, 48 NAT. RESOURCES J. 257 (2008).

31. Howard R. Marek, Note, *Inaction as Action Under Section 102(2)(C) of the National Environmental Policy Act of 1969*, 58 TEX. L. REV. 393, 413 & n.115 (1980).

Thatcher argued, in the context of a discussion about the Columbia River hydroelectric dams and their effects on fish and wildlife, that:

> [E]ven physically small hydro projects can have significant, perhaps devastating, impacts. A river is a complex system. What appear to be unimportant, perhaps even intermittent, streams may be crucial to fish and wildlife. In one basin in the Sierra Nevadas, biologists discovered that forty percent of the system's cutthroat trout were produced from one small intermittent stream, an unlikely location that, without careful study, could have been written off as irrelevant to the basin's fishery.[32]

In other words, Thatcher pointed out, because rivers are complex systems, we should not assume that we know what's important and what's not for purposes of environmental and natural resources management.

These early pioneers were trying to provide snapshot insights into a concept with which neither environmental law nor its scholars were yet prepared to grapple fully: the ecological concept of complexity, as viewed through the lens of systems theory, more recently "popularized" (at least academically) in the theory of panarchy and the paradigm of resilience thinking. Instead, twenty years ago, when environmental legal scholars looked for complex systems, they were much more likely to find them in environmental law itself than in the subjects of that law.[33] Notably, moreover, many of these scholarly

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32. Terence L. Thatcher, *The Pacific Northwest Electric Power Planning and Conservation Act: Fish and Wildlife Protection Outside the Columbia River Basin*, 13 ENVTL. L. 517, 520 (1983).

33. *See, e.g.*, Ronald Edward Kilroy, *Making an Oily Mess Less Messy: Use of Rule F Concursus to Reduce Oil Spill Litigation Complexity*, 2 ENVTL. LAW. 665 (1996); William H. Rodgers, Jr., *Environmental Law Trivia Test No. 2*, 22 B.C. ENVTL. AFF. L. REV. 807 (1995) (referring to the "theme of complexity" in environmental law); Kurt C. Hofgard, *Is This Land Really Our Land? Impacts of Free Trade Agreements on U.S. Environmental Protection*, 23 ENVTL. L. 635, 670 (1993) (referring to the United States's "complex systems of environmental regulations"); William H. Rodgers, Jr., *A Superfund Trivia Test: A Comment on the Complexity of the Environmental Laws*, 22 ENVTL. L. 417 (1992); R. Christopher Locke, *Environmental Crimes: The Absence of "Intent" and the Complexity of Compliance*, 16 COLUM. J. ENVTL. L. 311 (1991); Michael C. Blumm & D. Bernard Zaleha, *Federal Wetlands Protection Under the Clean Water Act: Regulatory*

identifications of "complexity" are more accurately described as identifications of *complicated* issues and structures in environmental and natural resources law. Importantly, however, as complexity theory has been increasingly absorbed into environmental and natural resources legal scholarship, the theoretical construction of that body of law as its own complex system has also become correspondingly richer.[34]

With respect to ecosystems and the societies that depend upon them, beginning in about 1992, references to the subjects of environmental and natural resources law as complex systems began to become more common. Thus, for example, scientist Nathan Buras closed a legal conference at the University of Arizona by emphasizing that both the environment and energy are "dynamic and extremely complex systems."[35] Michael Donnellan defined "ecosystems" as "complex systems where interdependent species of plants and animals live together."[36] Similarly, Michael McGinnis emphasized that "[e]cosystems are open, changing, and complex

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Ambivalence, Intergovernmental Tension, and a Call for Reform, 60 U. COLO. L. REV. 695, 699 (1989) ("Congress has been unwilling to assign the Corps plenary authority over wetlands regulation. Instead, it has ratified a complex system of interagency coordination and checks . . . ."); Robert F. Blomquist, *The Beauty of Complexity*, 39 HASTINGS L. J. 555 (1988) (reviewing William H. Rodgers, Jr., ENVIRONMENTAL LAW: AIR AND WATER (1986)); Barry Boyer & Errol Meidinger, *Privatizing Regulatory Enforcement: A Preliminary Assessment of Citizen Suits Under Federal Environmental Laws*, 34 BUFF. L. REV. 833, 916 (1985) ("According to some of the EPA's internal evaluations, codification seems to make a complex system of shared enforcement responsibility function more smoothly."); Cynthia E. Carlson, *Ten Years After Stockholm—International Environmental Law*, 77 AM. SOC'Y INT'L. L. PROC. 411, 412 (1983) (noting that "much institutional progress has occurred in the field of international environmental law as a result of the current complex system of organizations."); Ernest L. Edwards et al., *Constitutional and Policy Implications of Louisiana's Proposed Environmental Energy Tax: Political Expediency or Effective Regulation?*, 58 TUL. L. REV. 215, 220 (1983) (describing "the complex system of exemptions and credits designed to immunize in-state concerns from the effects of the First Use Tax.").

34. *See e.g.*, 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. 933 (1997).

35. Nathan Buras, *Closing Reflections*, 9 ARIZ. J. INTL. & COMP. L. 273 (1992).

36. Michael T. Donnellan, Note, *Transportation Control Plans under the 1990 Clean Air Act as a Means for Reducing Carbon Dioxide Emissions*, 16 VT. L. REV. 711, 717 n.48 (1992).

systems," simultaneously reaching a legal consequence, that "an ecosystem approach requires an institution that crosses political and ownership boundaries."[37] However, most if not all of these references were little more than hand-waving statements, rather than mature theories of how to incorporate complexity science into environmental and natural resources law. More productive for future engagement with true complexity theory were the pioneer legal scholars who began to grapple with scientific revelations that ecosystems were not steady-state systems that tended toward equilibrium but rather continually dynamic systems that could be thrown into new states of being.[38]

In 1994, Alyson Flournoy, in an essay much like this one, offered one of the first realizations in environmental and natural resources scholarship that the enterprise to which we all are committed might be a different and more complex one than was envisioned in the 1970s, when Congress enacted most of the environmental statutes. In "Coping with Complexity"[39] she emphasized:

> [T]he ever-increasing complexity that characterizes our relationship to the environment. Closely linked with this theme is our limited knowledge in this area as we try to understand and respond to the complex reality of environmental degradation. How well we cope with this complexity and uncertainty will be an important

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37. Michael V. McGinnis, *On the Verge of Collapse: The Columbia River System, Wild Salmon, and the Northwest Power Planning Council*, 35 NAT. RESOURCES J. 63, 66 n.13 (1995).

38. *See* Fred Bosselman & A. Dan Tarlock, *The Influence of Ecological Science on American Law: An Introduction*, 69 CHI.-KENT L. REV. 847, 869-73 (1994); E. Donald Elliott, *Law and Biology: The New Synthesis?*, 41 ST. LOUIS U. L. J. 595, 606 n.58 (1997) (describing the new science of complex adaptive systems); William H. Rodgers, Jr., *Adaptation of Environmental Law to the Ecologists' Discovery of Disequilibria*, 69 CHI.-KENT L. REV. 887, 891 (1994); A. Dan Tarlock, *The Nonequilibrium Paradigm in Ecology and the Partial Unraveling of Environmental Law*, 27 LOY. L.A. L. REV. 1121, 1128-44 (1994); *see also* Jonathan B. Wiener, *Law and the New Ecology: Evolution, Categories, and Consequences*, 22 ECOLOGY L.Q. 325, 355-56 (1995).

39. Alyson C. Flournoy, *Coping with Complexity*, 27 LOY. L.A. L. REV. 809 (1994).

> determinant of the success of our regulatory enterprise in the coming years.[40]

Thus, Flournoy recognized, after 25 years of experience with environmental and natural resources law (dated to the enactment of the National Environmental Policy Act of 1969[41]), complexity and uncertainty were the new challenges—a recognition in the larger scholarly community that helped to pave the way for the importation of complexity science. Thus, in species regulation, for example, Flournoy noted that "[o]ne need not look beyond the well-known controversy over protection of the northern spotted owl and old-growth forests in the Pacific Northwest for an example of how the complexity of environmental problems and the limits of our understanding are inadequately accounted for under existing law."[42] Traditional wetlands regulation also fell short:

> Traditional cost-benefit analysis may permit us to account for the value of an identified wetland parcel in isolation from the ecosystem. Yet this approach excludes values we know to be associated with the wetland in its larger environmental context. We are still far from being able to quantify all the values that may be affected by wetlands alteration. In the face of this uncertainty and complexity, we can fall into the trap of reductionism, quantifying some values and ignoring those we cannot fully understand or quantify.[43]

Section 404 of the Clean Water Act,[44] in other words, tends to approach wetlands as though they are part of, at best, *complicated systems*, ignoring the ecological complexities that wetlands truly represent. Finally, Flournoy noted "the complexity and uncertainty that limit our understanding of toxic substances," praising new approaches to coping with uncertainty such as expedited risk

40. *Id.*
41. 42 U.S.C. §§ 4321-4370h (2006).
42. Flournoy, *supra* note 39, at 813.
43. *Id.* at 816-17.
44. 33 U.S.C. § 1344 (2006).

assessment.[45] Flournoy's proposed improvements to environmental and natural resources law, however, focused on the communication of these uncertainties and complexities to the regulated public, not on fundamentally changing our perception of the subjects of that law:

> Regulatory decisions that oversimplify the choices involved, disguise relevant policy choices as science, or favor the status quo automatically when faced with a certain level of complexity or doubt encourage public hostility. Greater public understanding of the factual and normative conflicts embedded in regulatory policy will not overcome the human tendency to blame others for intractable problems and difficult choices, but it may facilitate public acceptance of responsibility for the tradeoffs that our regulatory policies demand.[46]

While Flournoy and others recognized the problems, however, J.B. Ruhl is probably the environmental and natural resources law scholar most prominently associated with the active importation of complexity science and systems theory into law. In 1996, for example, in "Complexity Theory as a Paradigm for the Dynamical Law-and-Society System,"[47] Ruhl consciously applied complexity theory to the problem of how society influences law and vice-versa, specifically arguing against the reductionist approaches taken by legal theorists to that point. Thus, according to Ruhl:

> [L]ike classical science, the major schools of American legal theory have been so mired in reductionist thought that they have failed to see the system behaviors that throughout time have denied legal theorists the Holy Grail of a predictive model of law. And it is precisely the failure of American legal theory to produce a predictive model, and legal institutions' fear of what that means, that has promoted the rise of an administrative state built on layer

45. Flournoy, *supra* note 39, at 822-23.

46. *Id.* at 824.

47. J.B. Ruhl, *Complexity Theory as a Paradigm for the Dynamical Law-and-Society System: A Wake-Up Call for Legal Reductionism and the Modern Administrative State*, 45 DUKE L.J. 849 (1996).

> upon layer of reductionist premises. The point of this Article, therefore, is not to espouse a theory that will allow absolute prediction of law's impact on society, or vice versa, as either goal is no longer scientifically rational. Rather, the exercise is intended to allow a greater appreciation of the forces at play in the interaction of law and society, and which, ultimately, doom any reductionist, prediction-oriented theory of law and legal administration.[48]

A more realistic approach, he concluded, must acknowledge that:

> [L]aw and society interact together, and can be thought of as doing so in a nonlinear dynamical manner. The law-and-society system model in this sense exhibits qualities similar to those which scientists have observed in other natural and social systems. For legal theory and legal institutions to ignore the findings of dynamical systems theory, therefore, is to remain ignorant of the underlying qualities and evolution of the law-and-society system model.[49]

Ruhl has continued to work diligently toward integrating complexity theory into legal theory generally and into environmental, natural resources, and administrative law in particular[50] – but so,

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48. *Id.* at 853.

49. *Id.* at 927.

50. *See generally* J.B. Ruhl, *Reconstructing the Wall of Virtue: Maxims for the Co-Evolution of Environmental Law and Environmental Science*, 37 ENVTL. L. 1063, 1073-78 (2007); J.B. Ruhl, *The Co-Evolution of Sustainable Development and Environmental Justice: Cooperation, Then Competition, Then Conflict*, 9 DUKE ENVTL. L. & POL'Y F. 161 (1999) (applying the theory of complex adaptive systems to the relationships between sustainable development and environmental justice); J.B. Ruhl, *Sustainable Development: A Five-Dimensional Algorithm for Environmental Law*, 18 STAN. ENVTL. L. J. 31 (1999) (applying complex adaptive systems theory to sustainability); J.B. Ruhl, *The Endangered Species Act and Private Property: A Matter of Timing and Location*, 8 CORNELL J.L. & PUB. POL'Y 37, 44 (1998); 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 HOUSTON L. REV. 933 (1997); 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*

now, are a number of other environmental and natural resources law scholars. Indeed, 1996 might be considered the watershed year for complexity theory vis-à-vis environmental and natural resources law scholarship, spurred not only by Ruhl's article, but also by a Duke Law School symposium.[51] Ever since, such scholarship has proceeded with ever-increasing recognition that these areas of law need to catch up with complexity theory.[52]

Are we to the point where the complexity of ecosystems and socio-ecological systems is accepted as a given by environmental and

Society, 30 U.C. DAVIS L. REV. 405 (1997); J.B. Ruhl, *Thinking of Mediation as a Complex Adaptive System*, 1997 BYU L. REV. 777; J.B. Ruhl, *The Fitness of Law: Using Complexity Theory to Describe the Evolution of Law and Society and Its Practical Meaning for Society*, 49 VAND. L. REV. 1407 (1996).

51. *E.g.*, George Frampton, *Ecosystem Management in the Clinton Administration*, 7 DUKE ENVTL. L. & POL'Y F. 39, 46-47 (1996) (emphasizing the importance of the new theories regarding complex adaptive systems).

52. *E.g.*, Jonathan P. Scoll, *Flood Control on the Red River as a Complex Environmental Decision System*, 26 NATURAL RESOURCES & ENVT. 24 (2012); Barbara Cosens, *Resolving Conflict in Non-Ideal, Complex Systems: Solutions for the Law-Science Breakdown in Environmental and Natural Resource Law*, 48 NATURAL RESOURCES J. 257 (2008); Gregory Todd Jones, *Sustainability, Complexity, and the Negotiation of Constraint*, 44 TULSA L. REV. 29 (2008); Hope M. Babcock, *Chumming on the Chesapeake Bay and Complexity Theory: Why the Precautionary Principle, not Cost-Benefit Analysis, Makes More Sense as a Regulatory Approach*, 82 WASH. L. REV. 505, 523-31 (2007); Mary Jane Angelo, *Embracing Uncertainty, Complexity, and Change: An Eco-Pragmatic Reinvention of First-Generation Environmental Law*, 33 ECOLOGY L.Q. 105, 109, 136-37 (2006); Erin Ryan, *New Orleans, the Chesapeake, and the Future of Environmental Assessment: Overcoming the Natural Resources Law of Unintended Consequences*, 40 U. RICH. L. REV. 981, 986-87 (2006); Jeffrey Rudd, *J.B. Ruhl's "Law and Society System": Burying Norms and Democracy Under Complexity Theory's Foundation*, 29 WM. & MARY ENVTL. L. & POL'Y REV. 551 (2005); Donald T. Hornstein, *Complexity Theory, Adaptation, and Administrative Law*, 54 DUKE L.J. 915 (2005); Lee P. Breckenridge, *Can Fish Own Water? Envisioning Nonhuman Property in Ecosystems*, 20 J. LAND USE & ENVTL. L. 293, 298-304 (2005); Daniel A. Farber, *Probabilities Behaving Badly: Complexity Theory and Environmental Uncertainty*, 37 U.C. DAVIS L. REV. 145 (2003); Bradley C. Karkkainen, *Adaptive Ecosystem Management and Regulatory Penalty Defaults: Toward a Bounded Pragmatism*, 87 MINN. L. REV. 943, 944 (2002); David W. Burnett, *New Science but Old Laws: The Need to Include Landscape Ecology in the Legal Framework of Biodiversity Protection*, 23 ENVIRONS: ENVTL. L. & POL'Y J. 47, 51-52 (1999); Philip Garone, *The Tragedy at Kesteron Reservoir: A Case Study in Environmental History and a Lesson in Ecological Complexity*, 22 ENVIRONS: ENVTL. L. & POL'Y J. 107 (1999).

natural resources law scholars? Probably. In a recent interview, for example, Laurie Ristino and Sam Kalen reported to the American Bar Association's Section on Environment, Energy, and Resources that:

> It's not that environmental problems are suddenly more complex; rather, it's that we are waking up to their complexity. It is worth noting that several legal scholars in the past decade have applied complexity and systems theories from science to critique environmental law and suggest new paradigms for developing environmental solutions. Likewise, I'm suggesting that we'll need to move beyond old avenues to make progress in addressing environmental protection. To do this, I think we first need to step back and take a hard look at what parts of our legal framework are working and which ones aren't.[53]

Other scholars in recent works similarly accept uncertainty and complexity as baseline environmental realities with which environmental and natural resources law (and politics) must simply learn to deal.[54]

Nevertheless, work remains to be done. While scholars may accept the new realities of complexity theory, much of environmental and natural resources law remain based in paradigms of complicatedness, predictability, and stationarity – always a bad fit to ecological reality,

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53. Laurie Ristino & Sam Kalen, *Is Environmental Law Serving Society?*, 26 NAT. RESOURCES & ENVT. 52 (2012).

54. *E.g.*, Craig Antony (Tony) Arnold, *Fourth Generation Environmental Law: Integrationist and Multimodal*, 35 WM. & MARY ENVTL. L. & POL'Y REV. 771, 780-83 (2011); Eric Biber, *Which Science? Whose Science? How Scientific Disciplines Can Shape Environmental Law*, 79 U. CHI. L. REV. 471, 487 (2012); Keith H. Hirokawa, *Sustaining Ecosystem Services Through Local Environmental Law*, 28 PACE ENVTL. L. REV. 760, 779 (2011); Sherry A. Enzler, *How Law Mattered to the Mono Lake System*, 35 WM. & MARY ENVTL. L. & POL'Y REV. 413, 511 (2011); Robin Kundis Craig, *Legal Remedies for Deep Marine Oil Spills and Long-Term Ecological Resilience: A Match Made in Hell*, 2011 BYU L. REV. 1863, 1886-96; Wes Nicholson, *Getting to Here: Bioregional Federalism*, 40 ENVTL. L. 713, 716-19 (2010); Douglas A. Kysar, *Ecologic: Nanotechnology, Environmental Assurance Bonding, and Symmetric Humility*, 28 UCLA J. ENVTL. L. & POL'Y 201, 212 (2010).

and an increasingly problematic mismatch in a climate change era.[55] Complexity theory and its related theories, especially resilience theory, are much better theoretical foundations for environmental law and natural resources law in an era of climate change.[56] As I have argued elsewhere, climate change has thrown law into a world of undeniable, continuous, and often unpredictable changes to ecosystems and the social systems that depend on them: "Stationarity is dead."[57] This continual change, and the perpetual threat of threshold crossings, not only delivers the death blow to the continuing viability of traditional structures of environmental and natural resources law, but it also at least severely undermines, if not outright destroys, goals of sustainability adopted world-wide, coincidentally, twenty years ago.[58] Complexity theory and resilience thinking offer the brightest hope for the future of environmental and natural resources law and policy in this climate change era, and so we should all hope that they continue to inspire transformative scholarship.

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55. Craig, *supra* note 13, at 10-18, 31-39.

56. *See, e.g.*, Jonathan H. Adler, *Water Rights, Markets, and Changing Ecological Conditions*, 42 ENVTL. L. 93, 108-09 (2012) ("Climate change, like environmental change more broadly, requires the adoption of complex adaptive systems. Specifically, there is a need for systems that can respond relatively rapidly to unforeseen and unpredictable changes; systems that are capable of discovering, dispersing, and accounting for time and place-specific information about new and emerging demands, needs, and availabilities; and systems that allow for the reallocation of resources in response to new challenges and opportunities. In short, the sort of system that is required is that provided by a well-functioning market."); Ari Bessendorf, *Games in the Hothouse: Theoretical Dimensions in Climate Change*, 28 SUFFOLK TRANSNAT'L L. REV. 325, 329 (2005) ("Climate change involves a dynamic link between the planet's ecosystem and the human socioeconomic system, two vast and complex systems. It will take decades to implement the fundamental change in our economic systems needed to substantially reduce carbon emissions."); *see also* Daniel Schramm & Akiva Fishman, *Legal Frameworks for Adaptive Natural Resource Management in a Changing Climate*, 22 GEO. INTL. ENVTL. L. REV. 491, 502 (2010).

57. Craig, *supra* note 13, at 10-18, 31-39.

58. *See generally* Robin Kundis Craig & Melinda Harm Benson, *Replacing Sustainability*, 46 AKRON L. REV. (forthcoming 2013), *available at* http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2168345 (arguing that climate change means the death of sustainability as a regulatory and policy goal).