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Panarchy, Adaptive Management and Governance: Policy Options for Building Resilience

Environmental law plays a key role in shaping policy for sustainability. In particular, the types of legal instruments, institutions, and the response of law to the inherent variability in socio-ecological systems are critical.[1] Environmental protection has typically involved a command-and-control approach that is implemented in response to specific environmental problems.[2] Often the response is reactive and applied to crisis situations. Ruhl contends that command-and-control approaches to environmental problems have been very successful at dealing with air and water pollution, because the regulations were able to address the "low-hanging fruit" (e.g., point-source pollution, waste disposal) problems which are relatively easy to address.[3] The next wave of environmental challenges (e.g., cross-boundary water disputes, climate change) are not so easily addressed within the current law and policy framework, because although the problems may be easily identified, the solution requires frequent recalibration of the policy used to address the environmental issue.

Sustainability, one of the new wave of environmental issues, must occur via the institutions we have in place, combined with alterations in policy and regulation within the context of these institutions.[4] Hence, the shift to a sustainability paradigm cannot occur without

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1. *See* Benjamin J. Richardson & Stepan Wood, *Environmental Law for Sustainability*, *in* ENVIRONMENTAL LAW FOR SUSTAINABILITY 1, 2 (Benjamin J. Richardson & Stepan Wood eds., Hart Publishing 2006).
2. Stephen Dovers & Robin Connor, *Institutional and Policy Change for Sustainability*, *in* ENVIRONMENTAL LAW FOR SUSTAINABILITY, *supra* note 1, at 21, 29.
3. J.B. Ruhl, *Regulation by Adaptive Management—Is It Possible?*, 7 MINN. J. L. SCI. & TECH. 21, 21 (2005).
4. Dovers & Connor, *supra* note 2, at 23.

strong political support,[5] and the most effective approach is adaptive, in terms of both management and governance. In particular, there must be recognition that policy is not a linear process producing optimal results.[6] Rather, policy is an iterative process that requires constant monitoring and recalibration of the parameters driving the policy formulation. Policy is now often characterized by multiple policy systems and subsystems nested within organizations.[7] Policies are the product of non-linear combinations of laws and prior policies, and may lead to unanticipated consequences. Governments, as complex adaptive systems, possess emergent properties, such as resilience, non-linear response and discontinuous structure that vary across scales. This structure has been recently described as a panarchy, a nested set of adaptive cycles. An adaptive cycle describes the process of development and decay in a system.[8] The initial stage of development of short duration consists of a rapid exploitation and garnering of resources by system components. This stage has been termed the *r* stage or function. The *r* stage is followed by a *k* stage or function, a stage of longer duration characterized by the accumulation of capital or other system elements or energies and increasing connectivity and rigidity. Increasing connectivity and rigidity during the *k* phase leads to decreased resilience and eventual collapse. This stage of collapse, the omega, is rapid and unleashes the "energy" accumulated and stored during the *k* phase. Collapse during the omega phase is followed by reorganization during the alpha phase, a relatively rapid period of assembly of components, analogous to the pioneer stage in ecosystems.

How does panarchy differ from hierarchy? Unlike the top-down control envisioned in traditional hierarchies, connectivity between adaptive cycles in a panarchy can be from levels above or below. In a hierarchy, lower-level patterns and processes are dominated by higher levels in the hierarchy. Panarchy differs from this characterization of nesting, with respect to complex systems, in that conditions can arise that trigger "bottom-up" (i.e., cross-scale cascading) change in the system. This model of socio-ecological systems more accurately captures the "surprise" or uncertainty inherent in such systems. Further, levels in a panarchy are not static states, but rather adaptive cycles that are interconnected to other adaptive cycles in the panarchy. Each cycle operates over a discrete range of scale in both time and space and is connected to adjacent levels (adaptive cycles). It is impor-

5. John C. Dernbach, *Toward a National Sustainable Development Strategy*, 10 BUFF. ENVTL. L.J. 69, 83 (2003).
6. Dovers & Connor, *supra* note 2, at 23.
7. *Id*.
8. *See* C.S. Holling et al., *Sustainability and Panarchies*, *in* PANARCHY: UNDERSTANDING TRANSFORMATIONS IN HUMAN AND NATURAL SYSTEMS 63 (Lance H. Gunderson & C.S. Holling eds., Island Press 2002).

tant to note that adaptive cycles do not exist in isolation. Since adaptive cycles operate over specific ranges of scale, a system's resilience is dependent upon the interactions between structure and dynamics at multiple scales.

Complex systems with the capacity for evolution tend to evolve toward the edge of chaos in order to operate at maximum efficiency.[9] Positive and negative feedbacks operate to maintain a system within a basin of attraction, and reduce the likelihood of a regime shift.[10] Complex systems may have multiple regimes, and resilience is a measure of the amount of disturbance a system can absorb before crossing a critical threshold, undergoing a regime shift, and reorganizing to an alternative regime.[11] Resilience refers to the ability of a system to remain within a domain of attraction while exhibiting dynamic behavior. As such, it captures the richness of behavior in complex systems better than concepts such as stability. When a system is forced beyond the boundaries of a domain of attraction, a qualitatively different pattern of behavior may emerge. It is often quite evident when the resilient capacity of the system has been exceeded and the system qualitatively changed, such as when a lake flips from a clear to turbid state. A regime shift can be dramatic or subtle, depending upon the magnitude of the feedback between the agents and the system itself.[12] The characteristics of the new regime will depend upon the feedback between the basin of attraction that characterizes the new regime and driving variables in the system.[13] In ecosystems, the diversity of functional groups across and within scales contributes to the resilience of the system.[14] The ability for a system to reorganize into a new regime is the system's transformability.[15] A system transforms when the existing ecological, economic or social structures become untenable.[16] Within the context of panarchy, sustainability then is the ability to maintain or create the conditions necessary for the resilience of a

9. Brian Walker et al., *Resilience, Adaptability and Transformability in Social-Ecological Systems*, 9(2):5 ECOLOGY & SOC'Y, Dec. 2004, at 4, http://www.ecologyandsociety.org/vol9/iss2/art5/print.pdf.

10. *See* Brian Walker & Jacqueline A. Meyers, *Thresholds in Ecological and Social-Ecological Systems*, 9(2):3 ECOLOGY & SOC'Y, Dec. 2004, http://www.ecologyandsociety.org/vol9/iss2/art3/print.pdf.

11. C.S. Holling, *Resilience and Stability of Ecological Systems*, 4 ANN. REV. ECOLOGY & SYSTEMATICS 1, 9 (1973).

12. *See* C. Perrings & B. Walker, *Biodiversity, Resilience and the Control of Ecological-Economic Systems: The Case of Fire Driven Rangelands,* 22 ECOLOGICAL ECON. 73 (1997); Carl Folke et al., *Regime Shifts, Resilience, and Biodiversity in Ecosystem Management*, 35 ANN. REV. ECOLOGY & SYSTEMATICS 557, 575 (2004).

13. *See* Walker et al., *supra* note 9.

14. Folke et al., *supra* note 12, at 575.

15. Walker et al., *supra* note 9, at 5.

16. *Id.*

favorable regime. In regards to governance, it is often not clear how policies or laws can enhance or erode resilience.

Legal systems are complex adaptive systems.[17] Within environmental law, single-trait maximization laws are elevated above all others, creating problems with managing other parts of the system, such as property rights.[18] Environmental laws have made significant inroads into protecting the environment, as command-and-control environmental policies rolled back many prior policies designed to capitalize upon natural resources as the United States emerged as a country.[19] Holling and Meffe contend that ecological systems become less resilient in response to command-and-control resource management that seeks to reduce the naturally occurring variability inherent in these systems.[20] They assert,

> Ecosystems do not have single equilibria, with functions controlled to remain near them. Rather, multiple equilibria, destabilizing forces far from equilibria, and absence of equilibria define functionally different stable states, and movement between states maintains an overall structure and diversity. . . . [O]n the one hand, destabilizing forces are important in maintaining diversity, resilience, and opportunity. On the other hand, stabilizing forces are important in maintaining productivity and biogeochemical cycles, and, even when these features are perturbed, they recover rapidly if the stability domain is not exceeded. . . .
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> Policies and management that apply fixed rules for achieving constant yields independent of scale (e.g., constant carrying capacity of cattle or wildlife or constant sustainable yield of fish, wood, or water) lead to systems that gradually lose resilience-systems that suddenly break down in the face of disturbances that previously could be absorbed. . . . Ecosystems are moving targets, with multiple potential futures that are uncertain and unpredictable. Therefore management has to be flexible, adaptive, and experimental at scales compatible with the scales of critical ecosystem functions.[21]

The problem is that the rigidity of current environmental law, laws that were so successful at protecting the environment for many years, is now the aspect of the law that does not allow it to confront emerging, cross-scale, and cross-boundary challenges.[22] Thus, Ruhl contends, environmental law must be re-designed to co-evolve with emerging environmental problems.[23]

For example, the Endangered Species Act of 1973 ("ESA") elevated species conservation over nearly every other consideration.[24] The

17. 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, 163 (1999).
18. *Id*. at 168.
19. *Id.* at 170.
20. C.S. Holling and Gary K. Meffe, *Command and Control and the Pathology of Natural Resource Management*, 10 CONSERVATION BIOLOGY 328, 328 (1996).
21. *Id*. at 332.
22. Ruhl, *supra* note 17, at 171.
23. *Id*.
24. *Id*. at 172.

ESA exhibited nearly zero tolerance with respect to endangering species, and was the ultimate "stick" in environmental law.[25] With time, the ESA has evolved with increased pressure from economic interests and property rights advocates. New policies associated with the ESA such as habitat conservation plans and "incidental take" have allowed the ESA to maintain species protection, while releasing some of the pressure placed upon the Act.[26] Environmental policy has often fallen into the "one-size fits all" trap that can lead to adverse policy outcomes.[27] There is no "best" scale for implementation of policy for linked socio-ecological systems. For example, within the context of endangered species protection, the federal government may be interested in preserving sea turtles because they are important for maintaining ecological functions in marine ecosystems. Although some local entities may support the imposition of federal law at the local level (e.g., southwest Florida), there are other local entities that will aggressively resist the imposition of federal authority over local interests. These local "resisters" may view sea turtles as a menace to their livelihoods, and view them as little more than a vehicle through which the federal government can take more control of environmental policy at local and state scales. In extreme cases, these "resisters" have been suspected of killing sea turtles in order to lessen pressure on their activities, since reducing the number of turtles would likely reduce the federal government's reach into environmental policy in southwest Florida. Thus, due to the fluid nature of socio-ecological systems, it appears that the most favorable policy outcomes are achieved via a combination of policies that have, at a minimum, some flexibility.[28] Ecosystem management is an approach that utilizes the full suite of policy instruments at its disposal.[29] The problem, as Ruhl asserts, is that the policy of ecosystem management has been applied within the outdated framework of the ESA.[30] Thus, Ruhl contends that ecosystem management can only be implemented via adaptive management.[31] The problem: In its current form, the ESA does not have the necessary flexibility in its regulatory language to effectively implement adaptive responses to changing environmental conditions.[32]

25. *Id*. at 173.
26. *Id*. at 175.
27. William A. Brock & Stephen R. Carpenter, *Panaceas and Diversification of Environmental Policy*, 104 PNAS 15206, 15206 (2007).
28. *Id*. at 15206–11.
29. J.B. Ruhl, *Taking Adaptive Management Seriously: A Case Study of the Endangered Species Act*, 52 U. KAN. L. REV. 1249, 1250 (2004).
30. *Id*.
31. *Id*. at 1263.
32. *Id*. at 1272.

Ruhl contends that a fundamental limitation of environmental laws is that those with the greatest possibilities for cross-dimensional application have the least influence, while narrowly construed laws have great influence.[33] The difficulty with environmental law is that most regulations do not take into account the scale of the system to be affected. For instance, indicators of ecosystem health collected at a small-scale (e.g., 10–100 acres) are unlikely to be useful at larger scales (e.g., 1000–10,000 acres).[34] Up-scaling or down-scaling is difficult at best when the systems of interest behave and respond in a non-linear fashion. It would be best if strategies for sustainability could be dealt with on a case-by-case basis, as non-physical systems cannot be understood via characterization of only one scale.[35] Scale is the critical variable in monitoring and therefore policy associated with linked socio-ecological systems. Cumulative impacts have the capacity to "scale up" in terms of their effect.[36] As an illustration, large scale destruction and degradation of wetlands, and the ecological services associated with those wetlands, has occurred primarily as a result of innumerable, small conversions of wetlands for agricultural and urban development—a tyranny of many small decisions.[37] Within this context, no single conversion of a wetland appears to have much of an impact upon the delivery of ecosystem services.[38] However, the cumulative impact of small-scale wetland transformations has produced large-scale degradation of the ecological services associated with those wetlands.[39] Environmental law needs to be able to identify areas of concern and then react at the appropriate scale, because there is no "one size fits all" prescription for managing ecological complexity.[40]

Among the difficulties associated with a shift to sustainability as a policy paradigm, with respect to scale, is a lack of fit between governance boundaries and socio-ecological processes.[41] The problem is described by Conroy et al., for the Piedmont of the southeastern United States:

> Multiple scales of decision making also complicate policies, predictions, and understanding. Any given ecological system on the landscape is likely to overlap multiple ownership and jurisdictional boundaries and fall under at least

33. J.B. Ruhl, *Sustainable Development: A Five-Dimensional Algorithm for Environmental Law*, 18 STAN. ENVTL. L.J. 31, 48 (1999).
34. Reed F. Noss, *Some Suggestions for Keeping National Wildlife Refuges Healthy and Whole*, 44 NAT. RESOURCES J. 1093, 1105 (2004).
35. *See* Walker et al., *supra* note 9.
36. J.B. RUHL ET AL., THE LAW AND POLICY OF ECOSYSTEM SERVICES 54 (Island Press 2007).
37. *Id*.
38. *Id*.
39. *Id*.
40. 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).
41. Dovers & Connor, *supra* note 2, at 54.

three levels of administrative control, particularly in the eastern part of the Piedmont, where ownership parcels tend to be small and interspersed. Land management decisions themselves occur at multiple spatial scales driven by the scale of influence of the decision maker. For example, decisions may be made by individual homeowners, by private owners of larger parcels, by firms owning huge tracts of land, or by county or state officials. The appropriate scale for decision making, defined as the scale of a desired ecological outcome, often does not correspond with the scale of political or economic decision making. Finally, resource objectives may conflict when objectives are defined on a finer or coarser spatial scale or with respect to more specific resource components. A clear example comes from water resources, where, even at a watershed or county level, upstream users have conflicts with other upstream users, e.g., recreation vs. power generation in reservoirs, where downstream users have conflicts with other downstream users, e.g., irrigation demand vs. instream flows, and where, at the larger scale of the river basin, upstream and downstream users obviously disagree about water use.[42]

Legal certainty is an aspect of law that does not mesh well with environmental unpredictability. The real difficulty of managing linked socio-ecological systems is that often the aspects of a society that make it free (e.g., certainty of law) are not in concert with ecological realities (e.g., multi-regimes, non-linear systems and responses).[43] Thus, standard environmental research and rule-making, which has been geared around identifying a deterministic function of variables of interest (e.g., rainfall, climate), and then optimizing the management of that resource, is not the best strategy in light of our current understanding of socio-ecological systems.[44] Thus, it would be best if agencies could utilize a more flexible form of management that can evolve in response to changing environmental conditions.[45] The critical elements in the new environmental law paradigm are monitoring the implementation and management policies as rigorously as the initial formation of said policies, with an eye towards adaptively assessing responses in order to improve the implemented management or policy.[46]

There are significant differences in the ability of legal systems to innovate (e.g., the rate of statutory legal change, the development of new enforcement mechanisms, and the flexibility in environmental law).[47] The capacity for innovation in a particular legal system is spe-

42. Michael J. Conroy et al., *Landscape Change in the Southern Piedmont: Challenges, Solutions, and Uncertainty Across Scales*, 8(2):3 CONSERVATION ECOLOGY, Dec. 2003, at 9–10, http://www.consecol.org/vol8/iss2/art3/print.pdf.
43. *See* C. Folke et al., *The Problem of Fit Between Ecosystems and Institutions: Ten Years Later*, 12(1):30 ECOLOGY & SOC'Y, June 2007, http://www.ecologyandsociety.org/vol12/iss1/art30/ES-2007-2064.pdf.
44. *Id*.
45. Warren T. Coleman, Note, *Legal Barriers to the Restoration of Aquatic Systems and the Utilization of Adaptive Management*, 23 VT. L. REV. 177, 177 (1998).
46. *Id*. at 198.
47. Katherina Pistor et al., *Innovation in Corporate Law*, 31 J. COMP. ECON. 676, 676–694 (2003).

cific to that particular system. What is readily apparent in environmental law is that laws governing development and those governing conservation are often in conflict.[48] Futrell suggests that judges could use expanded liability to internalize externalities, as well as the use of the public nuisance doctrine for environmental protection.[49] Karkkainen argues that judicial destabilization is one possible mechanism by which the law can be made open to the type of creativity associated with the big, back loop in the adaptive cycle.[50] Another possible mechanism is litigation, or the possibility of litigation, acting as a perturbation to the system, which can result in collaboration and legal change.[51]

It has been argued that adaptive management is the best policy instrument for dealing with dynamic socio-ecological systems. Adaptive management has been characterized by three types of learning necessary to make corrections in management policies: incremental learning, episodic learning and transformational learning.[52]

> Incremental learning occurs as plans, models, and policies are implemented and evaluated. Models or schemas are assumed to be correct, and learning is characterized by collecting data or information to update those models. In bureaucratically dominated resource systems, the learning is carried out largely by self-referential professionals or technocrats, who view dealing with this type of change and learning mainly as problem solving. Passive forms of adaptive management promise this type of learning.
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> Episodic learning is discontinuous in time and space. It can be generated by ecological regime shifts that reveal the inadequacies of the underlying models or policies. This type of learning occurs after environmental crises in which policy failure is undeniable. In this case, the learning is described as double-loop, in which the underlying model or schema is questioned and rejected. This is also characterized as problem reformation. In bureaucratic resource systems, this type of learning is facilitated by outside groups or charismatic integrators.
>
> Transformational learning is the most profound form of learning. Cross-scale surprises or the emergence of novelty characterize this type of change. In these cases, learning requires the reframing of problem domains. Transformational learning involves several levels in a social-ecological panarchy, not simply one level of a social system responding to ecological surprises.[53]

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48. J. William Futrell, *The Transition to Sustainable Development Law*, 21 Pace Envtl. L. Rev. 179, 184 (2003).
49. *Id*. at 192.
50. Bradley C. Karkkainen, *Panarchy and Adaptive Change: Around the Loop and Back Again*, 7 Minn. J. L. Sci. & Tech. 59, 68 (2005).
51. *Id*.
52. Lance H. Gunderson et al., *Water RATs (Resilience, Adaptability, and Transformability in Lake and Wetland Social-Ecological Systems*, 11(1):16 Ecology & Society, June 2006, at 4, http://www.ecologyandsociety.org/vol11/iss1/art16/ES-2005-1556.pdf.
53. *Id.*

Adaptive management is linked with monitoring of the response of natural resource systems to differing policies, and can be either active or passive:

> [A]daptive management need not involve a loss of objective utility in favor of learning, but rather can involve the simultaneous striving for optimal system return with information feedback along the way. This approach should avoid the problems inherent in approaches that seek to stabilize the delivery of ecological goods and services at maximum sustainable yield or some other static target but also fail to exploit learning opportunities. In addition, such static approaches often alter the previous disturbance regime of the system, invalidating the model on which they are based and leading to a higher likelihood of ecological surprise. In general, an adaptive decision-making and monitoring scheme would entail several components, including:
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> 1. assessment of the current state of the resource system. This includes the "information state" as measured by prior relative belief among alternative system models;
> 2. prediction of the expected impact of each action among the set of feasible alternative actions or decisions, taking into account environmental, demographic, structural, statistical, and other sources of uncertainty, and selecting as the best action the one that leads to the greatest expected gain, or least expected loss, in system return;
> 3. collection of monitoring data to assess the new current system state and compute the statistical likelihood under each alternative model, either after the action is taken if it was implemented landscape-wide, or concurrently if it was implemented on some spatial units but not others. This information would be used together with the prior model weights to compute a new posterior information state; and
> 4. repetition of steps 1–3 with the posterior information state as the new prior belief.

The above description may be characterized as "passive adaptive management," in that learning is a "by-product" of optimal decision making. That is, no deliberate attempt is made to gain information as part of the decision-making process. "Active adaptive management" occurs when decisions are made partly in anticipation of learning to reduce structural uncertainty and derive a greater long-term benefit. Either approach should be superior to "nonadaptive" decision making, in which either system uncertainty is ignored or learning, if it occurs, is not formally incorporated into decision making.[54]

Ruhl has argued that adaptive management is fundamentally incompatible with our current legal framework.[55] Karkkainen demonstrates that the U.S. Fish and Wildlife Service ("FWS") uses adaptive management within the context of Habitat Conservation Plans ("HCP").[56] Unfortunately, the manner in which FWS applies "adaptive management" is not that as advocated by Holling. Rather, according to Karkkainen, FWS's adaptive management does not allow for learning and experimentation, which are at the heart of what adap-

54. Conroy et al., *supra* note 42, at 14–15 (citations omitted).
55. Karkkainen, *supra* note 50, at 69 (citing Ruhl, *supra* note 3, at 51–52 nn. 98–99) .
56. *Id*. at 71.

tive management (*sensu* Holling) requires.[57] However, this situation is changing, and the U.S. Department of Interior has recently adopted an adaptive management approach to resource management, that, if followed, offers an opportunity to greatly enhance our ability to learn from both policy and management decisions, and enhance our management of natural resource systems.[58] A recent case indicates that the courts are now giving attention to adaptive management:

> The Final EIS and the 2004 Master Manual describe the "adaptive management" process. Adaptive management is an approach to natural resources management, in which policy choices are made incrementally. As each choice is made, data on the effects of these choices are collected and analyzed in order to assess whether to retain, reverse, or otherwise alter the policy choice. Missouri maintains that this adaptive management approach violates NEPA because it permits the Corps to circumvent the NEPA process when policy choices are modified. Missouri takes issue with the potential flow changes that the Corps may undertake in the future. Missouri fails to point to any evidence that indicates that the Corps intends to avoid its NEPA obligations by implementing this adaptive management approach. To the contrary, the Corps acknowledges that in the event a major policy change results, the Corps will be required to comply with NEPA. (Final EIS at D1-69; Corps AR 1970 at 3.) Absent evidence that the adaptive management process actually results in the Corps' evasion of NEPA obligations, the Court declines to declare this approach invalid.[59]

The fundamental constraint to adaptive management is the current state of administrative law.[60] Having to operate in an atmosphere where each policy is evaluated on the "front-end", in anticipation of public and legal scrutiny, has squelched agencies' appetite for adaptive management.[61] As Ruhl notes,

> Indeed, recent NEPA decisions by the Supreme Court highlight the perverse disincentives in conventional administrative law that hinder adaptive decisionmaking of the kind the Corps has flirted with. In *Norton v. Southern Utah Wilderness Alliance* and *Department of Transportation v. Public Citizen*, the Court established in no uncertain terms that if an agency lacks discretion over some aspect of an action, or has reached a decision within its discretion and divested itself of further discretion to alter the decision, NEPA does not apply. This principle benefits an agency in a "front-end" world of administrative law, allowing it to dodge the NEPA bullet, but it provides a strong disincentive to establishing and retaining long-term adaptive management programs. After all, continuing discretion to alter a decision is the essence of adaptive management. Thus, the clear message to agencies under conventional administrative law is that they adopt adaptive management at their own peril. Adopting adaptive management may be an agency's dream; prac-

57. *Id*. at 72.
58. Byron K. Williams et al., Adaptive Management: The U.S. Department of the Interior Technical Guide (2007).
59. *In re* Operation of the Mo. River Sys. Litig., 363 F. Supp. 2d 1145, 1163 (D. Minn. 2004).
60. Ruhl, *supra* note 3, at 34.
61. *Id*. at 36.

> ticing it is a nightmare. This sobering conclusion is confirmed by the HCP experience.[62]

Karkkainen does not dispute Ruhl's contention that the adversarial character of administrative law, combined with the need for certainty (e.g., procedural rules) in the larger realm of American law, is likely incompatible with adaptive management (*sensu* Holling).[63] Thus, as Karkkainen contends, environmental law is at odds with science, as the certainty required for socio-political stability makes it very difficult to apply a novel approach to ecosystem management (e.g., adaptive management) that requires institutional flexibility.[64] Karkkainen argues that administrative law should proceed on two trajectories: (1) a fixed rule track that will apply unless an agency can justify otherwise; and (2) an adaptive management track, where a new set of administrative law standards specific to adaptive management would hold precedence.[65] Karkkainen concedes that this proposed process is rife with bureaucracy, which is a negative, but contends that this type of system is likely the best we can do to reconcile science and law.[66]

How then does environmental law need to evolve in order to become more capable of adapting to "surprise"? Should it evolve in the manner Karkkainen has described? The answer may be in distributing power amongst institutions that manage environmental policy at scales that are best matched to institutional ability to adapt to surprise. At its root, this new policy is best characterized as a panarchy for dealing with uncertainty in socio-ecological systems. There is no absolute guarantee of success when managing socio-ecological systems. Consider the following example:

> Both government ownership and privatization are themselves subject to failure in some instances. For example, Sneath shows great differences in grassland degradation under a traditional, self-organized group-property regime versus central government management. A satellite image of northern China, Mongolia, and southern Siberia shows marked degradation in the Russian part of the image, whereas the Mongolian half of the image shows much less degradation. In this instance, Mongolia has allowed pastoralists to continue their traditional group-property institutions, which involve large-scale movements between seasonal pastures, while both Russia and China have imposed state-owned agricultural collectives that involve permanent settlements. . . . About three-quarters of the pasture land in the Russian section of this ecological zone has been degraded and more than one-third of the Chinese section has been degraded, while only one-tenth of the Mongolian section has suffered

62. *Id*. at 38–39.
63. Karkkainen, *supra* note 50, at 73.
64. *Id*. at 74.
65. *Id*. at 75.
66. *Id*. at 75–76.

equivalent loss. Here, socialism and privatization are both associated with more degradation than resulted from a traditional group-property regime.[67]

Thus, it is best to have a variety of policies in place that are specific to the intended scale of the policy. And to maximize learning and the reduction of response uncertainty, those policies should be treated as hypotheses and put at risk with monitoring data.

How can the shift to environmental policy based upon a scale-specific management paradigm occur? Several commentators have advocated that organizational leadership (e.g., policy entrepreneurs) is critical for agenda setting.[68] An effective leader can set policy and then generate the support necessary to implement the desired trajectory.[69] The role of a strong leader cannot be discounted in agenda setting. Consider the following example:

> [W]e analyzed the emergence of a governance system for adaptive co-management of the wetland landscape of Kristianstad in southern Sweden, a process whereby unconnected management by several actors in the landscape was mobilized, renewed, and moved into a new configuration of ecosystem management within about a decade. . . . A key individual provided visionary leadership in directing change and transforming governance. The transformation involved four phases: (a) preparing the system for change, (b) the opening of an opportunity, (c) navigating the transition, and (d) charting a new direction for management while building resilience of the new governance regime. . . . The shift was facilitated through broader scale crises, such as seal deaths and toxic algal blooms in the North Sea, which caused environmental issues to become top priority on the national political level, at the time of a search for a new identity at the municipality level. Hence, a window of opportunity at the political level opened, which made it possible to tip and transform the governance system into a trajectory of adaptive co-management of the landscape with extensive social networks of practitioners engaged in multilevel governance. The transformation took place within the existing institutional framework.[70]

For policy integration, finding the "common ground" between law, economics and ecology has proven most difficult.[71] It is critical to have sustainability policy developed so that when a policy window opens, the policy can be implemented.[72] Within the context of panarchy, policy windows can be viewed as thresholds, where the system undergoes a fundamental shift to emerge within a different policy regime. This characterization is especially appropriate when viewed from the policy perspective of "unpredictable change", which is synonymous with "surprise" in ecology.[73]

67. Elinor Ostrom et al., *Revisting the Commons: Local Lessons, Global Challenges,* 284 SCI. 278, 278 (1999).
68. Carl Folke et al., *Adaptive Governance of Social-Ecological Systems*, 30 ANN. REV. ENV'T & RESOURSES 441, 451 (2005).
69. *Id*.
70. *Id.* at 457.
71. *See* Dovers & Connor, *supra* note 2, at 54.
72. *Id.* at 58.
73. *Id.* at 59.

Policies that address the cross-scale nature of processes associated with the management of socio-ecological systems are necessary.[74] In order for this to happen, a methodology must be developed that examines the nested attributes of systems and the resource units generated by those systems that affect the interested parties.[75] Ostrom contends that a multi-tier nested framework will allow for increased understanding of what level a particular sustainability issue resides within a panarchy.[76] Scale is the critical variable and so it is imperative that policy be implemented at the appropriate scale. Characterizing the resilience of a regime favorable to human existence is critical to sustainability. Sustainability proscriptions must be applied at the appropriate scale:

> For example, in 2002, a moratorium on all fishing for northern cod was declared by the Canadian government after a collapse of this valuable fishery. An earlier near-collapse had led Canada to declare a 200-mile zone of exclusive fisheries jurisdiction in 1977. Considerable optimism existed during the 1980s that the stocks, as estimated by fishery scientists, were rebuilding. Consequently, generous total catch limits were established for northern cod and other ground fish, the number of licensed fishers was allowed to increase considerably, and substantial government subsidies were allocated for new vessels. What went wrong? There were a variety of information related problems including: (i) treating all northern cod as a single stock instead of recognizing distinct populations with different characteristics, (ii) ignoring the variability of year classes of northern cod, (iii) focusing on offshore-fishery landing data rather than inshore data to "tune" the stock assessment, and (iv) ignoring inshore fishers who were catching ever-smaller fish and doubted the validity of stock assessments. This experience illustrates the need to collect and model both local and aggregated information about resource conditions and to use it in making policy at the appropriate scales.[77]

Environmental problems that can be effectively dealt with at a small scale (e.g., forest stand management) can result in global crises (e.g., rapid species loss) when the problem "scales up".[78] Management must occur at the appropriate scale; thus environmental issues are best dealt with via a nested set of institutions, diverse in scope and size, but exerting influence only upon the corresponding scale of the natural resource system.[79] Dietz et al. also argue that government must employ multiple, nested institutional variations to implement scale-specific policies for the management of shifting socio-ecological systems.[80] Why? Because local governments and grassroots organi-

74. *See* J.M. Anderies et al., *Panaceas, Uncertainty, and the Robust Control Framework in Sustainability Science*, 104 PNAS 15194 (2007).
75. Elinor Ostrom, *A Diagnostic Approach for Going Beyond Panaceas*, 104 PNAS 15181, 15181 (2007).
76. *Id.* at 15186.
77. Thomas Dietz et al., *The Struggle to Govern the Commons*, 302 SCI. 1907, 1908 (2003).
78. *Id*.
79. *Id*. at 1910.
80. *Id*.

zations often operate at smaller scales in socio-ecological systems, and are more nimble and reactive to public opinion.[81] Legislatures and federal and state agencies operate at larger scales, and should be used to implement policies that encourage sustainability.[82] The interaction between different levels of organization should allow for a more diverse set of management options when change occurs at different scales.[83]

Lance Gunderson, C.S. "Buzz" Holling and Steve Light, in their book, *Barriers & Bridges to the Renewal of Ecosystems and Institutions*, highlight the importance of panarchy for the management of linked socio-ecological systems.[84] Numerous case studies document the management failures that manifested from focusing upon a single scale, which resulted in crises that may have otherwise been avoided.[85] Since a degree of uncertainty is inherent in socio-ecological systems, the generation of adaptive capacity in management entities is a good "insurance policy" for sustainability.[86] Adaptive capacity in socio-ecological systems is characterized by past history and local knowledge, as well as open and frequent lines of communication between institutions at multiple scales.

One of the most critical aspects in the panarchy appears to be a bridging organization that can monitor the status of the socio-ecological system, and manifest rapid change, if conditions are deteriorating.[87] In order for management entities operating at discrete scales to improve communication channels and create opportunities for collaboration, intermediate level entities may serve to facilitate these cross-scale linkages. Brown contends that bridging organizations have the capacity to fulfill this role, and organize cooperation between stakeholders across scales.[88] Bridging organizations must formulate strategies, coordinate joint action, address uncertainty, and link diverse stakeholders in a world of increasing complexity.[89] In his study, Brown investigated bridging organizations from across the world, and

81. Nancy P. Spyke, *Heeding the Call: Making Sustainability a Matter of Pennsylvania Law*, 109 PENN ST. L. REV. 729, 753 (2005).
82. *Id*.
83. Folke et al., *supra* note 68, at 449.
84. BARRIERS AND BRIDGES TO RENEWAL OF ECOSYSTEMS AND INSTITUTIONS (Lance H. Gunderson et al. eds., 1995).
85. Lance H. Gunderson, *Stepping Back: Assessing for Understanding in Complex Regional Systems*, *in* BIOREGIONAL ASSESSMENTS: SCIENCE AT THE CROSSROADS OF MANAGEMENT AND POLICY 27, 34 (K. Norman Johnson et al. eds., 1999).
86. *Id*. at 35–37.
87. Ann Kinzig et al., *Coping with Uncertainty: A Call for a New Science-Policy Forum*, 32 AMBIO 330 (2003).
88. L. David Brown, *Development Bridging Organizations and Strategic Management for Social Change*, *in* ADVANCES IN STRATEGIC MANAGEMENT 381, 381 (Paul Shrivastava et al. eds., 1993).
89. *Id*. at 382.

from a variety of scopes (e.g., regional economic policy in the U.S.; small-scale irrigation projects in Indonesia; agricultural productivity in Zimbabwe).[90] He found that bridging organizations are independent of stakeholders in a socio-ecological system, which allows them to negotiate with other stakeholders and advocate their own positions to other stakeholders.[91] This unique role in the management of socio-ecological systems affords bridging organizations the capacity to catalyze the formation of policies that are flexible and reflective of the panarchy.[92] In addition, bridging organizations have the capacity to reduce transaction costs, and provide a mechanism to enforce adherence to desired policies, despite their lack of regulatory authority.[93] Another critical aspect to matching management institutions with natural systems is the need to develop alternative policy options in order to prepare for a variety of potential "surprises".[94] These policy options (i.e., scenarios) explore the uncertainty associated with the dynamics of tailoring policies for complex adaptive systems.[95]

Examples of bridging organizations include: (1) assessment teams, which are made up of actors across sectors in a socio-ecological system; (2) non-governmental organizations, which create an arena for trust-building, learning, conflict resolution and adaptive co-management; and (3) the scientific community: which acts as a "watchdog," as well as a facilitator, for adaptive management. For purposes of environmental management, an example of a successful bridging organization is that of Ecomuseum Kristianstads Vattenrike ("EKV"), a small, municipal organization that facilitated progressive ecosystem management in southern Sweden.[96] EKV was tasked with managing water resources at a regional scale in Sweden, and it was successful largely because it employed organizational flexibility that allowed for EKV to respond quickly to "surprise".[97] This was achieved through leadership, a core inter-disciplinary staff, and the facilitation of connections between individuals and organizations (i.e., the panarchy of institutions) in the socio-ecological system.[98] EKV was able to improve the social capacity to respond to "surprises" and create the trust necessary

90. *Id*. at 385.
91. *Id*. at 384.
92. *Id*. at 384–86.
93. Thomas Hahn et al., *Trust-Building, Knowledge Generation and Organizational Innovations: The Role of a Bridging Organization for Adaptive Comanagement of a Wetland Landcape Around Kristianstad, Sweden*, 35 HUM. ECOLOGY 573, 586 (2006).
94. Gunderson, *supra* note 85, at 32–38.
95. *See* Garry D Peterson et al., *Scenario Planning: A Tool for Conservation in an Uncertain World*, 17 CONSERVATION BIOLOGY 358 (2003).
96. Hahn, *supra* note 93, at 573.
97. *Id*. at 580.
98. *Id*. at 580–81.

to push the socio-ecological system towards improved adaptive management of resources.[99]

The challenge, therefore, is that of developing methodologies suitable for adaptive sustainable management of the environment which are applicable across a panarchy, and yet retain sufficient certainty and clarity to form the basis of effective law and regulation. This is no easy task because it calls for developing a practical connection between the two cultures of Western thought.[100] As first discussed by the British physicist and novelist C.P Snow in his famous Rede lecture at Cambridge,[101] Western scholarship tends to diverge into two distinct cultures: that of science and that of the humanities, with precious little communication between the two. For example, Snow wrote,

> A good many times I have been present at gatherings of people who, by the standards of the traditional culture, are thought highly educated and who have with considerable gusto been expressing their incredulity at the illiteracy of scientists. Once or twice I have been provoked and have asked the company how many of them could describe the Second Law of Thermodynamics, the law of entropy. The response was cold: it was also negative. Yet I was asking something which is about the scientific equivalent of: Have you read a work of Shakespeare's? I now believe that if I had asked an even simpler question—such as, What do you mean by mass, or acceleration, which is the scientific equivalent of saying, 'Can you read?'—not more than one in ten of the highly educated would have felt that I was speaking the same language. So the great edifice of modern physics goes up, and the majority of the cleverest people in the western world have about as much insight into it as their Neolithic ancestors would have had.[102]

Legal scholarship, at least in Western cultures, is steeped in a humanistic tradition reaching back to the time of the classical Greeks and Romans, while scientific scholarship is the child of the scientific revolution of the last two hundred years. Clearly, much progress has been achieved since Snow's Rede lecture in 1959 towards the integration of the different areas of scholarship, but a significant challenge remains, and the theme of this Article is a reflection of that still-present challenge.

There is no simple solution to the dilemma posed by the existence of two different scholarly cultures and essentially two separate systems of thought. But a possible avenue for making progress exists, at least in the area of environmental management for sustainability. The requirement of any viable adaptive management regime is that it be both flexible and enforceable under the law and associated regulations. It may be possible to characterize such a regime based on the use of metrics of sustainability applicable at the scale of interest.

99. *Id*. at 573.
100. *See* C.P. SNOW, THE TWO CULTURES AND THE SCIENTIFIC REVOLUTION (1959).
101. *Id*.
102. *Id*. at 15–16.

There is some experience with such metrics, and much exploratory research within the realm of science[103] and other disciplines.[104] Essentially, these metrics establish requirements or processes that must be maintained in order to preserve the sustainability of a system. Fortunately, the number of such requirements and processes for these evolutionary systems seems to be relatively small. For example, at a minimum, the following requirements and processes must be preserved: (1) energy flowing through the system must be balanced, neither accumulating nor being depleted because the system uses this flow of energy to create structure and order, such as functioning ecosystems, stable economies, and orderly societies, (2) the burden that the human population imposes on its supporting ecosystem must be modest and must not be increasing with time because it will otherwise overwhelm the capacity of the ecosystem, (3) the economy on which human society depends for its livelihood must be sufficiently strong to provide employment and other basic human needs, and (4) the socio-ecological system must be able to maintain its self-organization and ability to function. There are computable aggregate metrics that can represent these requirements and processes, and the legal standards for adaptive management could be based on how the value of these metrics changes over time. For example, the human burden on the environment can be represented by ecological footprint,[105] and the legal standard for sustainable adaptive management could mandate an ecological footprint appropriate to the scale of interest. These metrics, including an ecological footprint, can be computed at multiple scales, which allows for flexibility and for the entrepreneurial nature of human beings to search for novel solutions. That is, maintaining an ecological footprint that does not increase is required, but the actual methods by which this is accomplished are not prescribed, thus allowing for flexibility and adaptation. Further, the target level for a specific sustainability metric would need to be set to the appropriate scale for the effect intended, as uniform standards will likely not promote sustainability.[106] Likewise, it may be possible to develop similar metrics and corresponding legal standards for the other processes and requirements. The point is that part of environmental policy could potentially be based on these metrics, which could serve to preserve the fundamental aspects of socio-ecological systems without over-prescribing the path by which sustainability is attained. For as Ruhl con-

103. *See* Audrey Mayer et al., *The Multidisciplinary Influence of Common Sustainability Indices*, 2 Frontiers in Ecology & Env't 419 (2004).
104. *See* H. Cabezas et al., *Sustainability: Ecological, Social, Economic, Technological, and Systems Perspectives*, 5 Clean Techs. & Envtl. Pol'y 1 (2003).
105. *See, e.g.*, Mathis Wackernagel & William Rees, Our Ecological Footprint: Reducing Human Impact on the Earth (1996).
106. Bradley C. Karkkainen, *Collaborative Ecosystem Governance: Scale, Complexity and Dynamism*, 21 Va. Envtl. L.J. 189, 198–99 (2002).

tends, "The full range of financing mechanisms should be made available (e.g., taxes, fees, surcharges, bonds) and the full range of compliance instruments should be capable of being used effectively as appropriate (e.g., regulatory and market-based incentives, reporting and information requirements, planning requirements, voluntary actions)."[107]

Furthermore, this would create simple, clear, and scale-specific policy at the level of aggregate metrics, where such simplicity is possible, while respecting the underlying complexity of the system. Karkkainen has called this a "rolling rule" approach to ecosystem management.[108] The key is for a bridging organization to operate within the context of a panarchy of management entities, and for monitoring of a system to generate the most current data on that system's dynamics.[109] These results will allow for management to set new target levels, and modify policy to reach those target levels, as new information is generated on scale-specific system attributes.[110] In summary, this framework could serve as one scenario in the suite of policy options for actualizing sustainability. The "big picture" is eloquently stated by Karkkainen:

> In addition to the functional division of labor between a central coordinating body and specialized committees, effective ecosystem governance typically involves a nesting of governance institutions and responsibilities at different spatial scales. A large, complex ecosystem usually exhibits characteristic systemwide properties and processes, requiring that its parts be understood in relation to the whole. On the other hand, the biotic components, physical and chemical properties, and ecological processes that comprise the larger system are typically not distributed uniformly and homogeneously across the entire system; the larger system has spatially distinct subsystems. Consequently, while one set of basin-wide governance institutions may be needed to address systemwide problems and processes, and to coordinate the efforts of spatially differentiated parts, another level of more localized institutional arrangements may be necessary to address locally varying conditions.[111]

The reality is that the institutions we have in place are likely to persist barring a large scale perturbation to socio-ecological systems. So, we must operate within the limitations of these institutions, which complicates matters somewhat, but does not make the situation intractable. The key appears to be in developing bridging organizations that catalyze cross-scale communication across the panarchy of institutions and ecosystems, and explicit recognition of the underlying cross-scale structure and non-linear interactions of these linked sys-

107. J.B. Ruhl et al., *Proposal for a Model State Watershed Management Act*, 33 ENVTL. L. 929, 935 (2003).
108. Karkkainen, *supra* note 106, at 201.
109. *Id*. at 201–02.
110. *Id.* at 202.
111. Bradley C. Karkkainen, *Transboundary Ecosystem Governance: Taking Stock*, 19 PAC. MCGEORGE GLOBAL BUS. & DEV. L.J. 209, 235 (2006).

tems, by both policy and policy makers. The lack of communication and cooperation between institutions at even small scales further illuminates that bridging organizations can help bring about effective management of natural resources at multiple scales.[112] Thus, bridging organizations should act as mini think-tanks that facilitate communication between institutions, incubate new ideas for environmental management, and provide a forum for coming to agreements on contentious issues.[113]

Ecosystems have traditionally been managed via anticipatory management, which is based on the belief that it is possible to collect enough information on the system to essentially reduce uncertainty to zero.[114] Our understanding of ecosystems has led us to now understand that these systems are characterized by an inherent degree of unpredictability. Given this, do we despair and give up? Of course not, but this improved understanding of ecosystem dynamics requires a new management paradigm. Is it adaptive management? Likely a variation of adaptive management, couched within panarchy, that has the ability to fit within the constraints of the legal framework of the United States. Given the capacity for "surprise" in ecosystems and other complex systems such as economies (witness the extreme volatility in global markets during 2008), monitoring becomes critical to understanding system behavior, identifying uncertainties, and development of new policies associated with the system of interest.[115] The type of analysis needed to manage socio-ecological systems is an "ongoing, open, public process of deliberation, experimentation and further deliberation. . . ."[116]

"Panic," a word derived from the "pan" in panarchy, comes closer to capturing nature as it is: characterized by high variability, unpredictability and non-linear interactions and surprise.[117] Thus, sustainability is not an end, but rather a journey; a journey that requires an acceptance of a degree of uncertainty—no easy task for *Homo sapiens*.[118]

112. Allison H. Roy et al., *Impediments and Solutions to Sustainable, Watershed-Scale Urban Stormwater Management: Lessons from Australia and the United States*, 42 Envtl. Mgmt. 344, 349 (2008).
113. *See* L. David Brown et al., *Globalization, NGOs, and Multi-Sectoral Relations*, in Governance in a Globalizing World 271 (Joseph S. Nye, Jr. & John D. Donohue eds., 2001).
114. M. Boyle et al., *Monitoringin Support of Policy: An Adaptive Ecosystem Approach*, *in* 4 Encyclopedia of Global Environmental Change 122 (T. Munn ed., 2001).
115. *Id*. at 123.
116. Bryan G. Norton, Sustainability 427 (2005).
117. Jim Chen, *The Midas Touch*, 7 Minn. J. L. Sci. & Tech. 1, 8 (2005).
118. *Id*.