"STATIONARITY IS DEAD"† — LONG LIVE TRANSFORMATION: FIVE PRINCIPLES FOR CLIMATE CHANGE ADAPTATION LAW

*Robin Kundis Craig**

While there is no question that successful mitigation strategies remain critical in the quest to avoid worst-case climate change scenarios, we have passed the point where mitigation efforts alone can deal with the problems that climate change is creating. Because of "committed" warming — climate change that will occur regardless of mitigation measures, a result of the already-accumulated greenhouse gases in the atmosphere — what happens to coupled socio-ecological systems over the next decades, and most likely over the next few centuries, will largely be beyond human control. The time to start preparing for these changes is now, by making adaptation part of a national climate change policy.

American environmental law and policy are not keeping up with the need for adaptation. For example, environmental and natural resources law are currently based on assumptions of ecological stationarity and pursue goals of preservation and restoration. Neither those assumptions nor those goals fit a world of continual, unpredictable, and nonlinear transformations of complex ecosystems — but that is the world that climate change is creating.

This Article argues for a principled flexibility *model of climate change adaptation law to pursue goals of increasing the resilience and adaptive capacity of socio-ecological systems. In so doing, it lays out five principles and several subprinciples for the law of environmental regulation and natural resource management. Structurally, this Article also strongly suggests that climate change adaptation law must be bimodal: it must promote informed and principled flexibility when dealing with climate change impacts, especially impacts that affect baseline ecological conditions such as temperature and hydrology, while simultaneously embracing an unyielding commitment to precautionary regulation when dealing with everything else.*

†P.C.D. Milly et al., *Stationarity Is Dead: Whither Water Management?*, 319 SCIENCE 573, 573 (2008).

* Attorneys' Title Professor of Law & Associate Dean for Environmental Programs, Florida State University College of Law, Tallahassee, Florida. I would like to thank Hope Babcock, Alex Camacho, Dan Cole, Dan Farber, Shi-Ling Hsu, Andy Klein, John Leshy, Wayne Logan, Dave Markell, G. Tracy Mehan, John Nagle (and his students), Hari Osofsky, Melanie Rowland, and J.B. Ruhl for their suggestions in response to drafts of this Article. However, I remain responsible for the final product, and comments may be directed to me at rcraig@law.fsu.edu.

INTRODUCTION

On Halloween, 2008, PBS's nightly news program *The NewsHour* reported the plight of Montana's $300 million recreational fishing industry and $2.4 billion agricultural industry, both of which depend on Montana's rivers and streams. Trout fishing makes up a substantial component of the fishing industry, but the trout begin to die when water temperatures reach 78°F or higher.[1] Unfortunately for the trout, average spring air temperatures have been rising since the 1950s, at a pace consistent with projected climate change impacts, and will continue to increase.[2] Higher temperatures mean earlier snowmelt and hence less and slower-moving water in the summer, which in turn allows instream temperatures to rise above the trout's tolerance[3] — and temperatures are expected only to keep increasing.[4] As for agriculture, the decrease in the total volume of water available during the summer makes irrigation increasingly difficult.[5] Thus, climate change appears to be simultaneously putting at risk Montana's trout, fishing industry, agriculture industry, and the human communities dependent on all three.[6]

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[1] *The NewsHour with Jim Lehrer: Montana: Trout and Drought* (PBS television broadcast Oct. 31, 2008), *available at* http://www.climatecentral.org/video/montana-trout-drought/.

[2] *Id.*

[3] *Id.*

[4] *Id.*

[5] *Id.*

[6] Climate change–related water issues are not limited to the United States. The World Bank reported on February 16, 2009, that "[c]limate change could eliminate all of Colombia's glaciers by the year 2030," and "that by 2050 Colombia would also experience less rainfall and higher temperatures on its mountain peaks," reducing the area of the wetlands that supply the capital city of Bogota with water by about 50%. Mike Ceaser, *Climate Change: World Bank Report Says Colombia's Glaciers Could Succumb to Global Warming by 2030*, BNA INT'L ENV'T DAILY, Feb. 25, 2009, http://climate.bna.com/Home.html (search "Mike Ceaser") (on file with the Harvard Law School Library).

As Montana's trout streams demonstrate, climate change[7] is already altering the base conditions of ecosystems in the United States and hence is beginning to impact the human economies that depend on those ecosystems' services. To list three additional recent examples:

- *Climate change is altering hydrological regimes, creating new and exacerbating existing conflicts between species' and humans' needs for water.* In May 2007, the U.S. District Court for the Eastern District of California noted that the Delta smelt, "a small, slender bodied fish endemic to" the Sacramento–San Joaquin Delta and already at risk from the joint operations of the federally managed Central Valley Project and California's State Water Project ("CVP/SWP"), would likely be put further at risk by climate change–driven decreases in water volume and increases in water temperature in the Delta.[8] Because the U.S. Fish and Wildlife Service ("FWS") failed to consider the effects of these changing hydrological conditions on the smelt, its Biological Opinion issued pursuant to the federal Endangered Species Act ("ESA") was arbitrary and capricious.[9] The resulting injunction threatened to shut down water delivery to millions of southern Californians[10] — indeed, delivery of water to southern California in summer 2009 (the start of the dry season) was only forty percent of users' expectations, a result of both continued drought and species considerations.[11] To complicate the water delivery prob-

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[7] As the Intergovernmental Panel on Climate Change ("IPCC") explained in 2007, "climate change" means:

> [A]ny change in climate over time, whether due to natural variability or as a result of human activity. This usage differs from that in the Framework Convention on Climate Change, where *climate change* refers to a change of climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable time periods.

INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, CLIMATE CHANGE 2007: IMPACTS, ADAPTATION, AND VULNERABILITY: CONTRIBUTION OF WORKING GROUP II TO THE FOURTH ASSESSMENT REPORT OF THE IPCC 6 (2007) [hereinafter IPCC, ADAPTATION REPORT].

[8] Natural Res. Def. Council v. Kempthorne, 506 F. Supp. 2d 322, 328, 365–70 (E.D. Cal. 2007).

[9] *Id.* at 370.

[10] Immediately after the district court's decision, state officials shut down the pumps that deliver water from the Delta to protect the smelt. *See* Glen Martin, *Smelt Decline Turns Off Delta Water Pumps; Official Says Users Relying on State Project Will Be Okay*, S.F. CHRON., June 1, 2007, at B1. Pumping eventually resumed, but at significantly reduced levels. *See* Jeanne Marie Kerns, *California Cuts Water Supply by a Third to Protect Endangered Delta Smelt Fish*, ASSOCIATED CONTENT, Sept. 2, 2007, http://www.associatedcontent.com/article/366070/california_cuts_water_supply_by_a_third.html (on file with the Harvard Law School Library).

[11] Bettina Boxall, *State Water Deliveries Up*, L.A. Times Greenspace Blog, May 20, 2009, http://latimesblogs.latimes.com/greenspace/2009/05/water-deliveries.html (on file with the Harvard Law School Library) (noting that delivery to water contractors was down to forty percent). These contractors include wholesalers who provide water to Southern California.

lem still further, in June 2009 the National Marine Fisheries Service ("NMFS") concluded that CVP/SWP operations are likely to jeopardize five other species protected under the ESA — the endangered Sacramento River winter-run Chinook salmon, the threatened Central Valley spring-run Chinook salmon, the threatened Central Valley steelhead, the threatened southern distinct population segment of North American green sturgeon, and Southern Resident killer whales — especially considering shifting ecological baselines for these species as a result of climate change.[12]

- *Climate change is already allowing destructive pest species to invade new territory, threatening both ecosystems and commercial interests.* As is true of most insects, "[e]very aspect of [the mountain pine beetle's] lifecycle is dependent upon temperature."[13] This pest invades pines, particularly lodgepole pines, and kills them.[14] The beetle's territory is normally limited by cold winters, but since the 1970s, warming temperatures have expanded the beetle's potential range by more than seventy-five percent.[15] Mountain pine beetles have been taking advantage of this new habitat in British Columbia, Canada, and the northern Rockies in the United States (especially Colorado and Wyoming), and the expansion of the species can only be explained by changes in climate.[16] By the end of 2006, the beetle had infested 130,000 square kilometers of British Columbia and western Canada, an invasion that is an order of magnitude larger than any previous invasion.[17] Moreover, between 1997 and 2007, the beetle destroyed thirteen million hectares of pine in this part of Canada,[18] many areas of which are considered critical timber supply areas.[19] To deal with the economic disruption that the infestation

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Robert Krier, *State to Boost Water Deliveries to Wholesalers but S.D. Authority Won't See Increase*, SAN DIEGO UNION-TRIBUNE, May 21, 2009, at B4.

[12] SW. REGION, NAT'L MARINE FISHERIES SERV., NAT'L OCEANIC & ATMOSPHERIC ADMIN., BIOLOGICAL AND CONFERENCE OPINION ON THE LONG-TERM OPERATIONS OF THE CENTRAL VALLEY PROJECT AND STATE WATER PROJECT 575 (2009) [hereinafter NMFS, CVP/SWP OPINION], *available at* http://swr.nmfs.noaa.gov/ocap.htm.

[13] A.L. Carroll et al., *Impacts of Climate Change on Range Expansion by the Mountain Pine Beetle* 1 (Canadian Forest Serv. Mountain Pine Beetle Initiative, Working Paper No. 2006-14, 2006), *available at* http://warehouse.pfc.forestry.ca/pfc/26601.pdf.

[14] *Id.*

[15] *Id.* at 8.

[16] *Id.*

[17] Brian Hoyle, *Plight of the Pines*, NATURE REP. CLIMATE CHANGE, Apr. 24, 2008, http://www.nature.com/climate/2008/0805/full/climate.2008.35.html (on file with the Harvard Law School Library).

[18] *Id.*

[19] Under Canadian law, "[a] timber supply area is an area of Crown land designated by the minister of forests in accordance with the Forest Act and managed for a range of objectives including timber production." Forest Analysis & Inventory Branch, Ministry of Forests & Range, Gov't of British Columbia, Timber Supply Review, http://www.for.gov.bc.ca/hts/pubs/

and its effects on the Canadian logging industry have caused, the Canadian government "invest[ed] over $33 million in projects that support economic growth, job creation and future sustainability of communities adversely affected by the widespread beetle infestation."[20]

- *Climate change is creating positive feedback loops that may irreversibly push ecosystems over ecological thresholds, destroying coupled socio-ecological systems.* In January 2009, the U.S. Climate Change Science Program ("USCCSP") reported that the Arctic tundra represents a "clear example" of climate change pushing an ecosystem beyond an ecological threshold.[21] Warmer temperatures in the Arctic reduces the duration of snow cover, which in turn reduces the tundra's ability to reflect the sun's energy, leading to an "amplified, positive feedback effect."[22] The result has been "a relatively sudden, domino-like chain of events that result in conversion of the arctic tundra to shrubland, triggered by a relatively slight increase in temperature,"[23] and the consequences for people living in these areas have been severe. For example, the Inupiat Eskimo village of Kivalina, Alaska, is suing for the costs of moving elsewhere, in response to the steady erosion of the village itself.[24] Similarly, most Canadian Inuit live near the coast, on lands that exist only because of permafrost. Warming Arctic conditions threaten to deprive them of their homelands.[25]

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brochure/tsacopy.htm (last visited Dec. 27, 2009) (on file with the Harvard Law School Library). Areas of British Columbia impacted by the mountain pine beetle include vast timber supply areas. Western Economic Diversification Canada, Mountain Pine Beetle: Community Economic Diversification Initiative, http://www.wd.gc.ca/eng/9622.asp (last visited Dec. 27, 2009) (on file with the Harvard Law School Library). These areas are of critical economic importance to the entire country: "Canada's log export trade is clearly dominated by British Columbia," largely because the region "contains forests unique in North America." BILL DUMONT & DON WRIGHT, GENERATING MORE WEALTH FROM BRITISH COLUMBIA'S TIMBER: A REVIEW OF BRITISH COLUMBIA'S LOG EXPORT POLICIES 11 (Dec. 2006), *available at* http://www.for.gov.bc.ca/het/logexportreview(v36).pdf.

[20] Western Economic Diversification Canada, *supra* note 19.

[21] U.S. CLIMATE CHANGE SCI. PROGRAM, SYNTHESIS & ASSESSMENT PRODUCT 4.2: THRESHOLDS OF CLIMATE CHANGE IN ECOSYSTEMS 2 (2009) [hereinafter 2009 USCCSP ECOSYSTEM THRESHOLDS REPORT].

[22] *Id.*

[23] *Id.*

[24] Yereth Rosen, *Village in Alaska Sues Energy Companies Over Erosion Linked to Warming Climate*, BNA STATE ENV'T DAILY, Feb. 29, 2008, http://news.bna.com/sedm (search "alaska sues") (on file with the Harvard Law School Library).

[25] James D. Ford, *Supporting Adaptation: A Priority for Action on Climate Change for Canadian Inuit*, 8 SUSTAINABLE DEV. L. & POL'Y 25, 28 (2008). While Antarctica has no permanent human settlements, it too is being impacted by climate change. Although the IPCC projected no significant warming on that continent over the next 50 years, more recent science shows "that on average the entire continent warmed by 0.5°C between 1957 and 2006." Catherine Brahic, *Antarctica Is Now Feeling the Heat of Climate Change*, NEW SCIENTIST, Jan. 21, 2009, http://www.newscientist.com/article/dn16460-even-antartica-is-now-feeling-the-heat-of-climate-change (on file with the Harvard Law School Library).

Thus, a variety of natural systems and the humans who depend on them — what are termed socio-ecological systems[26] — are vulnerable to climate change impacts.

While developing and implementing successful mitigation strategies clearly remains critical in the quest to avoid worst-case climate change scenarios, we have passed the point where mitigation efforts alone can deal with the problems that climate change is creating.[27] Because of "committed" warming — climate change that will occur regardless of the world's success in implementing mitigation measures, a result of the already accumulated greenhouse gases ("GHGs") in the atmosphere[28] — what happens to socio-ecological systems over the next decades, and most likely over the next few centuries, will largely be beyond human control. The time to start preparing for these changes is now, by making adaptation part of a national climate change policy.

Nevertheless, American environmental law and policy are not keeping up with climate change impacts and the need for adaptation.[29] To be sure, adjustments to existing analysis requirements are relatively easy, as when the Eastern District of California ordered the FWS to consider the impacts of climate change in its Biological Opinion under the ESA.[30] Agencies and courts have also already incorporated similar climate change analyses into the National Environmental Policy Act's ("NEPA") Environmental Impact Statement ("EIS") requirement[31] and similar requirements in other statutes.[32]

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[26] *See infra* Part I.B. "Socio-ecological systems, social-ecological systems, and coupled human-environmental systems are commonly used in the literature to describe systems of human-environmental interactions." Elinor Ostrom, Marco A. Janssen & John M. Anderies, *Going Beyond Panaceas*, 104 PROC. NAT'L ACAD. SCI. 15,176, 15,176 n.‖ (2007) (endnotes omitted).

[27] *See, e.g.*, Rasmus Heltberg, Paul Bennett Siegel & Steen Lau Jorgensen, *Addressing Human Vulnerability to Climate Change: Toward a "No Regrets" Approach*, 19 GLOBAL ENVTL. CHANGE 89, 89 (2009) ("Adaptation — adjusting to address ongoing and future climate changes — is increasingly recognized as an urgent and necessary complement to greenhouse gas emissions reductions."); W. Neil Adger et al., *Socio-Ecological Resilience to Coastal Disasters*, 309 SCIENCE 1036, 1039 (2005) ("Clearly, the reduction of greenhouse gas emissions is necessary in this context [coastal impacts] but not sufficient in the management of hazards in coastal regions."). *See also* Mireya Navarro, *New York Must Prepare for Global Warming, Mayor's Panel Says*, N.Y. TIMES, Feb. 18, 2009, at A23 (reporting the advisory panel's findings that planning was necessary to deal with "higher temperatures, more rain and an increased risk of coastal flooding").

[28] Maximilian Martin & Andreas Ernst, *Climate Change: Enlarging the Toolbox*, VIEWPOINTS 35, 39 (2008), *available at* http://ssrn.com/abstract=1322306 ("Existing CO_2 levels will persist for at least a century, with average global temperatures predicted to rise by up to 2°C regardless of steps taken to reduce GHG emissions.").

[29] For a summary of national and international adaptation efforts, see generally Ira R. Feldman & Joshua H. Kahan, *Preparing for the Day After Tomorrow: Frameworks for Climate Change Adaptation*, 8 SUSTAINABLE DEV. L. & POL'Y 61 (2007).

[30] Natural Res. Def. Council v. Kempthorne, 506 F. Supp. 2d 322, 328, 367–70 (E.D. Cal. 2007); *see also* Greenpeace v. Nat'l Marine Fisheries Serv., 55 F. Supp. 2d 1248, 1261 (W.D. Wash. 1999) (upholding NMFS consideration of climate change effects in its Biological Opinion for pollock fishery).

[31] *See* 42 U.S.C. § 4332(2)(C) (2006) (establishing that federal agencies must produce an EIS for any major federal action that may significantly affect the quality of the human environ-

Even so, adapting law to a world of continuing climate change impacts will be a far more complicated task than addressing mitigation. When the law moves beyond analysis requirements to actual environmental regulation and natural resource management,[33] it will find itself in the increasingly uncomfortable world of changing complex systems and complex adaptive management — a world of unpredictability, poorly understood and changing feedback mechanisms, nonlinear changes, and ecological thresholds. As noted, climate change alters baseline ecosystem conditions in ways that are currently beyond immediate human control,[34] regardless of mitigation efforts. These baseline conditions include air, water, and land temperatures; hydrological conditions, including the form, timing, quality, and amount of precipitation, runoff, and groundwater flow; soil conditions; and air quality. Alterations in these basic ecological elements, in turn, are prompting shifts and rearrangements of species, food webs, ecosystem functions, and ecosystem services.[35] Climate change thus complicates and even obliterates familiar ecologies, with regulatory and management consequences.

Nor are these regulatory and management consequences an as-yet-still-hypothetical problem. In February 2008, a group of researchers noted in *Science* that current water resource management in the developed world is grounded in the concept of stationarity — "the idea that natural systems fluctuate within an unchanging envelope of variability."[36] However, because of climate change, "stationarity is dead."[37] These researchers empha-

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ment); Ctr. for Biological Diversity v. Nat'l Highway Traffic Safety Admin., 538 F.3d 1172, 1212–17, 1219–27 (9th Cir. 2008) (requiring agency to perform an adequate analysis of climate change effects to fulfill its NEPA responsibilities). *But see* City of Los Angeles v. Nat'l Highway Traffic Safety Admin., 912 F.2d 478, 485–90 (D.C. Cir. 1990) (upholding the agency's analysis of climate change and corporate average fuel economy ("CAFE") standards pursuant to NEPA).

[32] *See, e.g.*, Ctr. for Biological Diversity v. Brennan, 571 F. Supp. 2d 1105, 1130–36 (N.D. Cal. 2007) (finding the USCCSP in violation of the Global Change Research Act for failure to issue a climate change research plan); *see also* Found. on Econ. Trends v. Watkins, 794 F. Supp. 395, 396, 401 (D.D.C. 1992) (dismissing on standing grounds a suit seeking to force the Secretaries of the Interior, Energy, and Agriculture to analyze the effects of climate change on federal programs and actions pursuant to NEPA).

[33] Dan Farber, for instance, has pointed out that the EIS and other environmental assessments are purely reactive. Daniel A. Farber, *Rethinking the Role of Cost-Benefit Analysis,* 76 U. CHI. L. REV. 1355, 1400 (2009).

[34] For example, as National Geographic News recently reported, "[w]armer water can hold less oxygen compared with cooler waters," and "as Earth's icy poles gradually transform into open oceans, new organisms, from plankton to shellfish, will move in," further depleting the oxygen there. Ker Than, *Global Warming to Create "Permanent" Ocean Dead Zones?*, NAT'L GEOGRAPHIC NEWS, June 28, 2009, http://news.nationalgeographic.com/news/2009/01/090128-ocean-dead-zones.html (on file with the Harvard Law School Library).

[35] *See infra* Part I.B. Ecosystem services are the economically valuable services that functioning ecosystems supply to human beings. For example, watersheds capture sediments and other pollutants, protecting downstream water quality; riparian habitat "regulates water temperature" and wetlands "protect adjacent areas from the hazards of flooding." J.B. RUHL, STEVEN E. KRAFT & CHRISTOPHER L. LANT, THE LAW AND POLICY OF ECOSYSTEM SERVICES 5–6, 15 (2007).

[36] P.C.D. Milly et al., *Stationarity Is Dead: Whither Water Management?*, 319 SCIENCE 573, 573 (2008).

[37] *Id.*

sized that impacts to water supplies from climate change are now projected to occur "during the multidecade lifetime of major water infrastructure projects" and are likely to be wide-ranging and pervasive, affecting every aspect of water supply.[38] As a result, the researchers concluded that stationarity "should no longer serve as a central, default assumption in water-resource risk assessment and planning. Finding a suitable successor is crucial for human adaptation to changing climate."[39]

Further, these authors realized the critical question is what a successor regime to stationarity should look like.[40] With the onset of climate change impacts, humans have decisively lost the capability — to the extent that we ever had it — to dictate the status of ecosystems and their services. As a result, and perhaps heretically, this Article argues that, for adaptation purposes, we are better off treating climate change impacts as a long-term natural disaster rather than as anthropogenic disturbances,[41] with a consequent shift in regulatory focus: we cannot prevent all of climate change's impacts,[42] but we can certainly improve the efficiency and effectiveness of our responses to them. As this slow-moving tsunami[43] bears down on us, some loss is inevitable — but loss of everything is not. Climate change is creating a world of triage, best guesses, and shifting sands, and the sooner we start adapting legal regimes to these new regulatory and management realities, the sooner we can marshal energy and resources into actions that will help humans, species, and ecosystems cope with the changes that are coming.

The problem is, in this brave new world of climate change adaptation, there will be no panaceas — "one size fits all" solutions to environmental problems[44] — particularly in the realm of natural resource management. We

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[38] Specifically, they noted that climate change impacts will include "the means and extremes of precipitation, evapotranspiration, and rates of discharge of rivers," "atmospheric humidity and water transport," "flood risk," "contamination of coastal freshwater supplies" from sea-level rise, and "natural seasonal and interannual storage." *Id.*

[39] *Id. See also* Martin & Ernst, *supra* note 28, at 40 ("The management of water, air and other resources will become essential as the long-term impacts of warming become evident."); U.S. GLOBAL CHANGE RESEARCH PROGRAM, GLOBAL CLIMATE CHANGE IMPACTS IN THE UNITED STATES 49 (2009) [hereinafter USGCRP, IMPACT REPORT] ("Because climate change will significantly modify many aspects of the water cycle, the assumption of an unchanging climate is no longer appropriate for many aspects of water planning.").

[40] Milly et al., *supra* note 36, at 573–74.

[41] Of course, the distinction between "natural" and "anthropogenic" is often itself contested. *See, e.g.*, J.B. Ruhl, *The Myth of What Is Inevitable Under Ecosystem Management: A Response to Pardy*, 21 PACE ENVTL. L. REV. 315, 318–19, 320–22 (2004) (arguing that all ecosystems are influenced by humans); J.B. Ruhl, *The Pardy-Ruhl Dialogue on Ecosystem Management, Part IV: Narrowing and Sharpening the Questions*, 24 PACE ENVTL. L. REV. 25, 31 (2007) ("In short, naturalness is a human conception."). As this Article makes clear, however, I consider that contest to be unproductive and distracting for climate change adaptation efforts, including the implementation of climate change adaptation law.

[42] Again, this Article does not intend to undermine the critical role that mitigation can still play in reducing the severity and duration of climate change impacts. *See infra* notes 49–58 and accompanying text.

[43] My thanks to J.B. Ruhl for this metaphor, which I use with his permission.

[44] Ostrom et al., *supra* note 26, at 15,176 ("A core aspect of panaceas is the action or tendency to apply a single solution to many problems.").

need new ways of thinking about law, and a new legal framework that will allow a multiplicity of techniques to be brought to bear in crafting adaptation responses to particular local impacts while still promoting actions consistent with overall ecological and social goals.

Specifically, in formulating the law that will govern adaptation to ecological and socio-ecological impacts ("climate change adaptation law"), two issues are of most immediate consequence. First, existing environmental and natural resources laws are preservationist, grounded in the old stationarity framework that no longer reflects ecological realities.[45] In contrast, the new climate change adaptation law needs to incorporate a far more flexible view of the natural world, because both the identity of the regulatory objects — the things such as rivers that such statutes are trying to protect — and the regulatory objectives will themselves be continually transforming, especially at the ecosystem level.

Second, legal flexibility in the past has occasionally operated as the means for avoiding tough decisions and needed actions, as the Environmental Protection Agency's ("EPA") attempted ducking of carbon dioxide regulation under the Clean Air Act ("CAA") demonstrates.[46] Given the societal importance of climate change adaptation, however, increased legal flexibility should not become a mechanism for avoiding effective environmental regulation and natural resource management. To deal effectively with adaptation and climate change impacts, the law will need to differentiate aspects of flexibility and discretion. Specifically, the law will have to embrace flexibility and adaptive management in the implementation of specific adaptation measures. However, it will simultaneously need to limit actors' discretion to do nothing or to deviate materially from general regulatory and management precepts and goals. That is, the specific *means* of adaptation can reflect local circumstances and needs, but the *fact* of adaptation and the general *goals and policies* climate change adaptation law seeks to effectuate should not be subject to local veto or avoidance.

In other words, climate change adaptation law should be based on *principled flexibility*. As used in this Article, principled flexibility means that both the law and regulators (1) distinguish in legally significant ways uncontrollable climate change impacts from controllable anthropogenic impacts on species, resources, and ecosystems that can and should be actively managed and regulated, and (2) implement consistent principles for an overall climate change adaptation strategy, even though the application of those principles in particular locations in response to specific climate change impacts will

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[45] *See, e.g.*, Jonathan M. Verschuuren, Adaptation to Climate Change: Opportunities and Barriers 9 (May 2007) (unpublished manuscript), *available at* http://ssrn.com/abstract=1291183 ("[N]ature conservation law is aimed at conserving a certain habitat type, or certain species.").

[46] Notice of Denial of Petition, 68 Fed. Reg. 52,922, 52,925 (Sept. 8, 2003) (denying a CAA petition on grounds that EPA did not have authority to regulate greenhouse gas emissions under that statute).

necessarily encompass a broad and creative range of adaptation decisions and actions.

This Article takes a first step toward a new climate change adaptation regime for environmental regulation and natural resource management in the United States by suggesting an across-the-board shift in legal objectives, from preservation and restoration to the improvement of resilience and adaptive capacity.[47] Part I of this Article provides a basic introduction to the differences between climate change mitigation and climate change adaptation, as well as to the necessity of climate change adaptation. Part II then investigates the nature of climate change as *change* to argue that the paradigms of human-controlled preservation and restoration that currently saturate U.S. environmental and natural resources law are ill-suited to promoting efficient and effective adaptation to climate change impacts.

In Part III, the Article offers five principles (and several subprinciples) to guide climate change adaptation law. It acknowledges that these principles will have different implications for particular issues in environmental regulation and natural resource management. As one example, while natural resource management may need to become more flexible in key ways,[48] pollution control regulation may need to become more stringent and unyielding, perhaps even draconian. Nevertheless, this Article argues that, if employed with good faith in all of the relevant contexts, these principles will collectively increase the ability of species, ecosystems, and socio-ecological systems — and hence humans — to adapt more productively and efficiently to ongoing ecological changes in the United States.

I. Climate Change Adaptation Versus Climate Change Mitigation

A. *An Introduction to Climate Change Adaptation and Its Differences from Mitigation*

In the United States, much of the legal attention to climate change, whether expressed through litigation, legislation, or scholarship, has focused on *mitigation*[49] — that is, on the mechanisms for reducing global emissions of greenhouse gases, especially carbon dioxide,[50] and lowering the concen-

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[47] Similar shifts have been advocated in other contexts. For example, authors from the World Bank have presented "an integrated approach to *increase the capacity of society to manage climate risks with a view to reduce the vulnerability of households and maintain or increase the opportunities for sustainable development*." Heltberg et al., *supra* note 27, at 89.

[48] *See, e.g.*, Verschuuren, *supra* note 45, at 9 (arguing that "nature conservation law should be adapted to climate change, making it more flexible to deal with these changes, and at the same time making sure that authorities create and protect robust areas that can withstand the consequences of climate change").

[49] *See, e.g.*, Martin & Ernst, *supra* note 28, at 42 (lamenting that "the entire debate on climate change . . . remains focused on mitigation strategies").

[50] While carbon dioxide has received most of the attention, given the ubiquitous sources of that gas and its prominent role in climate change studies, several other greenhouse gases do

trations of those gases in the atmosphere.[51] For example, the *Massachusetts v. EPA*[52] litigation at the Supreme Court was about mitigation because it addressed EPA's authority and duty to regulate carbon dioxide emissions from motor vehicles.[53] Almost all of the climate change legislation and programs that the states, regional organizations, and Congress have been con-

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exist, including methane, chlorofluorocarbons, soot, and even water vapor. Cornelia Dean, *Emissions Cut Won't Bring Quick Relief, Scientists Say*, N.Y. TIMES, Jan. 27, 2009, at A21. However, carbon dioxide "is responsible for about half of greenhouse warming," and other greenhouse gases "are far less persistent in the atmosphere; if these emissions drop, their effects will decline relatively fast." *Id.*

[51] According to the U.S. Global Change Research Program, "[m]itigation refers to options for limiting climate change by, for example, reducing heat-trapping emissions such as carbon dioxide, methane, nitrous oxide, and halocarbons, or removing some of the heat-trapping gases from the atmosphere." USGCRP, IMPACT REPORT, *supra* note 39, at 10–11. The IPCC has adopted the mitigation goal of the 1992 United Nations Framework Convention on Climate Change ("UNFCCC"), namely:

> The ultimate objective of this Convention and any related legal instruments that the Conference of the Parties may adopt is to achieve, in accordance with the relevant provisions of the Convention, stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner.

INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, CLIMATE CHANGE 2007: MITIGATION 99 (2007) [hereinafter IPCC, MITIGATION REPORT] (quoting Article 2 of the Convention) (internal quotation marks omitted). The IPCC also has noted that "[t]he concept of 'mitigation potential' has been developed to assess the scale of GHG reductions that could be made, relative to emission baselines, for a given level of carbon price (expressed in cost per unit of carbon dioxide equivalent emissions avoided or reduced)." INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, CLIMATE CHANGE 2007: SYNTHESIS REPORT: SUMMARY FOR POLICYMAKERS 14 n.15 (2007) [hereinafter IPCC, SYNTHESIS REPORT: SUMMARY FOR POLICYMAKERS] (emphasis omitted).

[52] 549 U.S. 497 (2007).

[53] *Id.* at 528–35. *See also* Ctr. for Biological Diversity v. Nat'l Highway Traffic Safety Admin., 538 F.3d 1172, 1212–15, 1219–27 (9th Cir. 2008) (addressing climate change issues related to the CAFE standards for vehicles); City of Los Angeles v. Nat'l Highway Traffic Safety Admin., 912 F.2d 478 (D.C. Cir. 1990) (upholding the climate change NEPA analysis for CAFE standards); Lincoln-Dodge, Inc. v. Sullivan, 588 F. Supp. 2d 224 (D.R.I. 2008) (addressing Rhode Island's adoption of greenhouse gas emissions standards for motor vehicles); Cent. Valley Chrysler-Jeep, Inc. v. Goldstene, 529 F. Supp. 2d 1151 (E.D. Cal. 2007) (addressing California's regulations regarding emissions of greenhouse gases from vehicles); Green Mountain Chrysler Plymouth Dodge Jeep v. Crombie, 508 F. Supp. 2d 295 (D. Vt. 2007) (addressing Vermont's adoption of California's greenhouse gas emissions standards for vehicles); Cent. Valley Chrysler-Jeep v. Witherspoon, 456 F. Supp. 2d 1160 (E.D. Cal. 2006) (addressing California's adoption of greenhouse gas emissions standards for vehicles); Nw. Envtl. Def. Ctr. v. Owens Corning Corp., 434 F. Supp. 2d 957 (D. Or. 2006) (addressing emissions of greenhouse gases that allegedly violated the CAA and increased the risk of various injuries to the plaintiffs); Connecticut v. Am. Elec. Power Co., 406 F. Supp. 2d 265 (S.D.N.Y. 2005) (addressing a nuisance suit against electric utilities based on their greenhouse gas emissions); Ctr. for Biological Diversity v. Abraham, 218 F. Supp. 2d 1143 (N.D. Cal. 2002) (addressing a demand for more alternative fuel vehicles under the Energy Policy Act); Okeson v. City of Seattle, 150 P.3d 556 (Wash. 2007) (addressing a challenge to a utility's program for mitigating greenhouse gas emissions); In re Matter of Quantification of Envtl. Costs, 578 N.W.2d 794 (Minn. App. 1998) (upholding the agency's calculation of environmental cost values from carbon dioxide emissions associated with electricity generation).

sidering or implementing are mitigation measures designed to reduce total emissions of carbon dioxide and other greenhouse gases.[54] Legal scholars, in turn, have debated the merits of the litigation, legislative, and programmatic efforts to reduce greenhouse gas emissions.[55]

Climate change mitigation efforts remain crucial, and this Article does not intend to suggest otherwise.[56] In 2007, the Intergovernmental Panel on Climate Change ("IPCC") reported that "[u]nmitigated climate change would, in the long term, be *likely* to exceed the capacity of natural, managed and human systems to adapt."[57] Thus, without mitigation efforts, mass destruction of both natural systems and human societies becomes an increasingly likely eventuality.[58]

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[54] In the month of January 2009, for example, the new Congress proposed a number of mitigation-related bills, including: Right to Clean Vehicles Act, H.R. 609, 111th Cong. (2009); Save Our Climate Act of 2009, H.R. 594, 111th Cong. (2009); Heavy Duty Hybrid Vehicle Research, Development, and Demonstration Act of 2009, H.R. 445, 111th Cong. (2009); H.R. 391, 111th Cong. (2009) (declaring that the CAA cannot be used to regulate greenhouse gas emissions or climate change); Cleaner, Greener, and Smarter Act of 2009, S. 5, 111th Cong. (2009); 21st Century Energy Independence Act of 2009, H.R. 260, 111th Cong. (2009) (promoting cellulosic ethanol technology development); Greenhouse Gas Registry Act, H.R. 232, 111th Cong. (2009); Green Energy Production Act of 2009, S. 137, 111th Cong. (2009). In contrast, only three bills proposed during the same period even remotely addressed climate change adaptation: Water Use Efficiency and Conservation Research Act, H.R. 631, 111th Cong. (2009); Environment and Public Health Restoration Act of 2009, H.R. 585, 111th Cong. (2009); Integrated Coastal and Ocean Observation System Act of 2009, H.R. 367, 111th Cong. (2009). However, in House Concurrent Resolution 2, Congress did express its opinion that the FWS should consider global warming and sea level rise in its species and ecosystem decisions. H.R. Con. Res. 2, 111th Cong. (2009). *See also* Posting of Catherine Ho to L.A. Times Greenspace, http://latimesblogs.latimes.com/greenspace/2009/02/western-clima-1.html (Feb. 18, 2009, 6:44 PM) (on file with the Harvard Law School Library) ("If Western states don't substantially reduce greenhouse gas emissions, they could face billions of dollars in health care and other related costs by 2020 . . . .").

[55] For recent examples, see generally Jason Scott Johnston, *Climate Change Confusion and the Supreme Court*, 84 NOTRE DAME L. REV. 1 (2008); Paula J. Schauwecker, *Land Use to Address Global Climate Change*, 23 NAT. RESOURCES & ENV'T. 48 (2008); *Emission Not Accomplished: The Future of Carbon Emissions in a Changing World*, 33 WM. & MARY ENVTL. L. & POL'Y REV. 1 (2008); Jonathan Zasloff, *The Judicial Carbon Tax: Reconstructing Public Nuisance and Climate Change*, 55 UCLA L. REV. 1827 (2008); Cass R. Sunstein, *The World vs. The United States and China? The Complex Climate Change Incentives of the Leading Greenhouse Gas Emitters*, 55 UCLA L. REV. 1675 (2008); Cary Coglianese & Jocelyn D'Ambrosio, *Policymaking Under Pressure: The Perils of Incremental Responses to Climate Change*, 40 CONN. L. REV. 1411 (2008).

[56] Matthew Zinn has adeptly critiqued what he calls "adaptation-preferring climate policies," arguing that "[a]n adaptation-preferring climate policy . . . risks creating a perverse synergy by failing to moderate the severity of climate change and its stresses on natural systems and simultaneously requiring adaptations that produce their own severe, and in some cases synergistic, impacts on these systems." Matthew D. Zinn, *Adapting to Climate Change: Environmental Law in a Warmer World*, 34 ECOLOGY L.Q. 61, 64 (2007).

[57] IPCC, SYNTHESIS REPORT: SUMMARY FOR POLICYMAKERS, *supra* note 51, at 19. *See also Summary for Policymakers*, *in* IPCC, ADAPTATION REPORT, *supra* note 7 [hereinafter IPCC, ADAPTATION REPORT: SUMMARY FOR POLICYMAKERS] (noting that "[a]daptation alone is not expected to cope with all the projected effects of climate change, and especially not over the long term as most impacts increase in magnitude").

[58] *See, e.g.*, USGCRP, IMPACT REPORT, *supra* note 39, at 9 (noting that "[i]f emissions continue to rise at or near current rates, temperature increases are more likely to be near the upper end" of the projections for 2100, which range from 2 to 11.5°F); JULIAN CALDECOTT,

At the same time, however, the IPCC noted that "[a]daptation is necessary in the short and longer term to address impacts resulting from the warming that would occur even for the lowest stabilisation scenarios assessed."[59] In other words, adaptation must become a co-strategy with mitigation efforts for dealing with climate change, because "[r]isks associated with climate change could greatly increase vulnerability unless adaptation is stepped up."[60] Moreover, adaptation efforts may have immediate benefits for socio-ecological systems by decreasing vulnerability to future changes, "reducing sensitivity to climatic risks," and increasing the adaptive capacity of both humans and the ecological systems upon which they depend.[61]

According to the IPCC, climate change adaptation refers to "the adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities."[62] Ideally, these adjustments should "enhance resilience or reduce vulnerability to observed or expected changes in climate," such as "investment in coastal protection infrastructure to reduce vulnerability to storm surges and anticipated sea-level rise."[63] In practice, adaptation measures can be as broad-ranging as the scope of climate change impacts themselves; they can "include anticipatory and reactive actions, private and public initiatives, and can relate to projected changes in temperature and current climate variations and extremes that may be altered with climate change."[64]

Thus, whereas mitigation efforts focus on shaping human behavior to reduce the ultimate cause of climate change — increased greenhouse gas concentrations in the atmosphere — adaptation strategies must rely upon the (sometimes limited) abilities of species, ecosystems, and socio-ecological

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WATER: THE CAUSES, COSTS AND FUTURE OF A GLOBAL CRISIS 36 (2008) (citing a potential range of temperature increases of 1.1 to 6.4°C by the end of the century).

[59] IPCC, SYNTHESIS REPORT: SUMMARY FOR POLICYMAKERS, *supra* note 51, at 19.

[60] Heltberg et al., *supra* note 27, at 98. *See also* Verschuuren, *supra* note 45, at 1 ("Climate change is here to stay, at least for the time being. . . . So we have to adapt to the changing climate."); Thomas Lovejoy, *Mitigation and Adaptation for Ecosystem Protection*, 39 Envtl. L. Rep. (Envtl. Law Inst.) 10,072, 10,073 (2009) ("The adaptation part of the climate change agenda is only just beginning to get attention, and needs much more right away."); Paul Klemperer, What Is the Top Priority on Climate Change? 3 (Jan. 2009) (unpublished manuscript), *available at* http://ssrn.com/abstract=1328802 (noting that there is a greater than 20% probability that global warming will exceed 2°C — "the level that is commonly referred to as the threshold for 'dangerous' warming" — even if carbon dioxide levels in the atmosphere stabilize at 380 parts per million, a fairly ambitious goal); USGCRP, IMPACT REPORT, *supra* note 39, at 11 ("Mitigation and adaptation are both essential parts of a comprehensive climate change response strategy.").

[61] Ford, *supra* note 25, at 29.

[62] IPCC, ADAPTATION REPORT, *supra* note 7, at 6. *See also* USGCRP, IMPACT REPORT, *supra* note 39, at 11 ("Adaptation refers to changes made to better respond to present or future climatic and other environmental conditions, thereby reducing harm or taking advantage of opportunity."); Daniel H. Cole, *Climate Change, Adaptation, and Development*, 26 UCLA J. ENVTL. L. & POL'Y 1, 2 n.6 (2008) ("'Adaptation' is used to refer to efforts to deal with whatever consequences occur.").

[63] IPCC, ADAPTATION REPORT, *supra* note 7, at 720 (citations omitted).

[64] *Id.*

systems to respond to continuous alterations in baseline conditions.[65] Ecological literature describes these abilities through the closely related concepts of resilience and adaptive capacity. Resilience refers to the ability of a species, ecosystem, or socio-ecological system to cope with change. More precisely, resilience is:

> the capacity of linked socio-ecological systems to absorb recurrent disturbances such as hurricanes or floods so as to retain essential structures, processes, and feedbacks. Resilience reflects the degree to which a complex adaptive system is capable of self-organization (versus lack of organization or organization forced by external factors) and the degree to which the system can build capacity for learning and adaptation.[66]

Similarly, adaptive capacity refers to "the regenerative ability of ecosystems and their capability in the face of change to continue to deliver resources and ecosystem services that are essential for human livelihoods and societal development."[67] Resilience reflects a system's ability to absorb impacts and continue to function, while adaptive capacity refers to a system's ability to change to adjust to new conditions.

As a matter of international law, climate change adaptation is a component of the United Nations Framework Convention on Climate Change,[68] to which the United States is a party.[69] In particular, Article IV of the Convention requires parties to "cooperate in preparing for adaptation to the impacts of climate change."[70] While the parties to the Convention have pursued this duty less intensively than their duty to mitigate (as evidenced by the Kyoto

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[65] *See, e.g.*, USGCRP, IMPACT REPORT, *supra* note 39, at 10 ("Society and ecosystems can adjust to climatic changes, but this takes time. The projected rapid rate and large amount of climate change over this century will challenge the ability of society and natural systems to adapt.").

[66] Adger et al., *supra* note 27, at 1036. *See also* Stella Hurtley, *Editor's Choice: Ecology: Resistance and Resilience*, 293 SCIENCE 1731, 1731 (2001) (noting that an ecosystem's "'resilience' is the extent to which it can recover after the source of change is removed"); Emma L. Tompkins & W. Neil Adger, *Does Adaptive Management of Natural Resources Enhance Resilience to Climate Change?*, 9 ECOLOGY & SOC'Y 1 (2004), http://www.ecologyandsociety.org/vol9/iss2/art10/ (arguing "that a system's capacity for resilience, which involves its ability to absorb perturbations without being undermined or becoming unable to adapt and learn, is an important element of any sustainable response to climate change").

[67] Adger et al., *supra* note 27, at 1036.

[68] U.N. Framework Convention on Climate Change, *opened for signature* May 9, 1992, S. Treaty Doc. No. 102-38, 1771 U.N.T.S. 164 [hereinafter UNFCCC].

[69] *See* Cole, *supra* note 62, at 2 n.2 (discussing the United States' potential treaty obligations); Verschuuren, *supra* note 45, at 1–2 (discussing the UNFCCC obligations and the Kyoto Protocol with respect to adapation).

[70] UNFCCC, *supra* note 68, art. IV(1)(e).

Protocol[71] and post-Kyoto negotiations[72]), they are beginning to pursue adaptation measures.[73]

Nevertheless, climate change impacts also create particular problems for specific places and peoples.[74] As such, a global legal response is insufficient to deal with the localized details of climate change impacts, which will require legal reforms at the national, state, and local levels as well. The next section reviews the kinds of climate change impacts that are occurring and likely to occur with this local/state/national nexus in mind.

B. The Need to Turn Legal Attention to Climate Change Adaptation

Climate change adaptation will be necessary for at least the next several decades, and probably centuries.[75] As the examples at the beginning of this Article demonstrate, climate change effects are already being felt,[76] and such impacts will continue to increase through at least the twenty-first century even if atmospheric greenhouse gas concentrations are stabilized quickly,[77] which is unlikely.[78] Continued climate change impacts are inevitable be-

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[71] Kyoto Protocol to the U.N. Framework Convention on Climate Change, Dec. 10, 1997, 37 I.L.M. 32.

[72] Information about the post-Kyoto negotiations and meetings is available through the United Nations' web site for the UNFCCC. United Nations, Framework Convention on Climate Change: Meetings, http://unfccc.int/meetings/items/2654.php (last visited Dec. 27, 2009) (on file with the Harvard Law School Library).

[73] For more detailed discussions of these measures, see Cole, *supra* note 62, at 5–7; Ford, *supra* note 25, at 26–28.

[74] *See* Cole, *supra* note 62, at 4 ("The costs of climate change are expected to rise during the course of this century, but those costs will not be distributed uniformly or equitably."); Verschuuren, *supra* note 45, at 3 ("Adaptation differs enormously depending on the exact local situation."); *see also* Ford, *supra* note 25 (focusing on climate change impacts on the Inuit).

[75] IPCC, SYNTHESIS REPORT: SUMMARY FOR POLICYMAKERS, *supra* note 51, at 14 (noting that "additional adaptation measures will be required to reduce the adverse impacts of projected climate change and variability, regardless of the scale of mitigation undertaken over the next two to three decades"). *See also id.* at 20 ("Even the most stringent mitigation efforts cannot avoid further impacts of climate change in the next few decades, which makes adaptation essential, particularly in addressing near-term impacts."); Ford, *supra* note 25, at 28; USGCRP, IMPACT REPORT, *supra* note 39, at 11.

[76] USGCRP, IMPACT REPORT, *supra* note 39, at 9 (noting that such changes "include increases in air and water temperatures, reduced frost days, increased frequency and intensity of heavy downpours, a rise in sea level, and reduced snow cover, glaciers, permafrost, and sea ice"); IPCC, SYNTHESIS REPORT: SUMMARY FOR POLICYMAKERS, *supra* note 51, at 9.

[77] IPCC, SYNTHESIS REPORT: SUMMARY FOR POLICYMAKERS, *supra* note 51, at 12.

[78] Indeed, the IPCC projects continued increases in greenhouse gas emissions of 25% to 90% from 2000 to 2030. *Id.* at 7. It also notes that:

> Future energy infrastructure investment decisions, expected to exceed US$20 trillion between 2005 and 2030, will have long-term impacts on GHG emissions, because of the long lifetimes of energy plants and other infrastructure capital stock. The widespread diffusion of low-carbon technologies may take many decades, even if early investments in these technologies are made attractive. Initial estimates show that returning global energy-related CO2 emissions to 2005 levels by 2030 would require a large shift in investment patterns, although the net additional investment required ranges from negligible to 5 to 10%.

Id. at 15.

cause carbon dioxide persists in the atmosphere for "'a few centuries, plus 25 percent . . . lasts essentially forever,'" and "[t]he warming from our . . . emissions would last effectively forever, too."[79] Thus, even if the world immediately implements comprehensive efforts to significantly reduce emissions of carbon dioxide and other greenhouse gases, there will be a substantial time lag between implementation of those efforts and either actual stabilization of greenhouse gas concentrations in the atmosphere or cessation of climate change impacts.[80] As a result, the world is probably already committed to a 2°C increase in average global temperature.[81]

One example of delayed climate change impacts will be sea level rise. Increased greenhouse gas concentrations in the atmosphere cause increased average global air temperatures. Much of this heat is transferred to the oceans, causing a slow expansion of their volume. At the same time, warming temperatures cause land-based ice and glaciers to melt, increasing the total amount of water in the seas. As a result, according to the IPCC:

> Sea level rise under warming is inevitable. Thermal expansion would continue for many centuries after GHG concentrations have stabilised, for any of the stabilisation levels assessed, causing an eventual sea level rise much larger than projected for the 21st century. . . . The long time scales of thermal expansion and ice sheet response to warming imply that stabilisation of GHG concentrations at or above present levels would not stabilise sea level for many centuries.[82]

Other climate change–driven alterations in ecological, meteorological, and climatic conditions will also be facts of life, at least until the end of this century and almost certainly much longer.[83]

Climate change adaptation is not only a long-term problem; it is a complex problem.[84] First, climate change is affecting atmospheric, land, freshwater, and ocean temperatures[85] — but not uniformly. Temperatures toward the poles are increasing faster than temperatures near the equator, and land temperatures are rising faster than temperatures in the ocean.[86] These temperature changes are already altering weather patterns, leading to fewer cold

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[79] Mason Inman, *Carbon Is Forever*, NATURE REP. CLIMATE CHANGE 156, 156–57 (2008) (quoting oceanographer David Archer). *See also* Dean, *supra* note 50 (noting that "the effects of carbon dioxide persist").

[80] Inman, *supra* note 79; Dean, *supra* note 50.

[81] CALDECOTT, *supra* note 58, at 37.

[82] IPCC, SYNTHESIS REPORT: SUMMARY FOR POLICYMAKERS, *supra* note 51, at 20. *See also* USGCRP, IMPACT REPORT, *supra* note 39, at 11 (noting that "the Earth's vast oceans have absorbed much of the heat added to the climate system due to the increase in heat-trapping gases, and will retain that heat for many decades").

[83] Inman, *supra* note 79; Dean, *supra* note 50.

[84] J.B. Ruhl & James Salzman, *Massive Problems in the Administrative State: Strategies for Whittling Away*, 98 CAL. L. REV. (forthcoming 2010) (manuscript at 4–6, 17, 19, 28–29), *available at* http://ssrn.com/abstract=1280896.

[85] IPCC, SYNTHESIS REPORT: SUMMARY FOR POLICYMAKERS, *supra* note 51, at 2.

[86] *Id.*

nights and frosts and more frequent hot days and hot nights, heat waves, heavy precipitation events, and "intense tropical cyclone activity in the North Atlantic."[87] As a result, climate change impacts will vary from location to location, necessitating different specific adaptation strategies in different places.[88]

Second, many of these climate change–driven ecological changes are likely to become both worse and more complex in the coming decades, because even the IPCC's fairly conservative analysis projects changes of 0.1°C to 0.2°C *per decade* for the rest of this century.[89] Contraction of snow- and ice-covered areas, increasing extreme heat events, increased intensity of tropical cyclones, and a poleward shift of such storms, are all likely results.[90] Water supplies are especially vulnerable:

> There is *high confidence* that by mid-century, annual river runoff and water availability are projected to increase at high latitudes (and in some tropical wet areas) and decrease in some dry regions in the mid-latitudes and tropics. There is also *high confidence* that many semi-arid areas (e.g. Mediterranean Basin, western United States, southern Africa and north-eastern Brazil) will suffer a decrease in water resources due to climate change.[91]

Moreover, as noted, changes in glacial, Arctic, and Antarctic ecosystems have already been observed as a result of changes in snow, ice, and frozen ground, while other areas are experiencing alterations in hydrological patterns and shifts of species poleward and upward, to higher elevations.[92] The IPCC concluded in 2007 that many other ecosystems are also likely to experience significant stresses and alterations as a result of climate change.[93]

Third, climate change impacts all sectors of socio-ecological systems. The changes in water resource availability alone will directly affect agriculture in low-latitude regions[94] and human health throughout the world.[95] Temperature impacts create a multiplicity of problems for humans and are already affecting several important economic and social activities, including: (1) agriculture, particularly with respect to the timing of spring planting and

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[87] *Id.*

[88] *See* USGCRP, IMPACT REPORT, *supra* note 39, at 107–52 (describing the differing regional changes in the United States).

[89] IPCC, SYNTHESIS REPORT: SUMMARY FOR POLICYMAKERS, *supra* note 51, at 7. *See also* IPCC, ADAPTATION REPORT: SUMMARY FOR POLICYMAKERS, *supra* note 57, at 19 ("Past emissions are estimated to involve some unavoidable warming (about a further 0.6°C by the end of the century relative to 1980–1999) even if atmospheric greenhouse gas concentrations remain at 2000 levels. . . .").

[90] IPCC, SYNTHESIS REPORT: SUMMARY FOR POLICYMAKERS, *supra* note 51, at 8.

[91] *Id. See also* USGCRP, IMPACT REPORT, *supra* note 39, at 41–52 (describing impacts to water resources and potential conflicts about water in the United States).

[92] INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, SYNTHESIS REPORT 33 (2007) [hereinafter IPCC, SYNTHESIS REPORT].

[93] IPCC, SYNTHESIS REPORT: SUMMARY FOR POLICYMAKERS, *supra* note 51, at 9.

[94] *Id.* at 9.

[95] *Id.* at 13 tbl.SPM.3.

the availability of a summer irrigation supply; (2) forest management, especially with respect to fires and pests; and (3) public health efforts, especially with regard to heat-related mortality, changes in infectious disease vectors such as mosquitoes, and changes in allergenic pollens.[96]

Climate change impacts operate on complex ecosystems and set in motion feedback loops and nonlinear changes, neither of which are entirely (or even mostly) predictable through existing knowledge and modeling. For example, one of the consequences of the mountain pine beetle's spread through Canada, with the resulting death of millions of acres of trees, is an increase in carbon dioxide emissions from the decaying trees and a decreased ability of the remaining forest to act as a carbon sink.[97] Researchers predict that the beetle's expansion and ravages — which are themselves almost certainly the result of early climate change impacts — may release 270 megatonnes of carbon dioxide by 2020, an amount that equals Canada's emission reduction commitment under the Kyoto Protocol.[98] This is an example of a positive feedback loop: increasing greenhouse gas concentrations in the atmosphere result in warming temperatures that allow the mountain pine beetle to expand its range, killing trees and resulting in increasing concentrations of carbon dioxide in the atmosphere, which will warm temperatures further and, at least for a while, allow the beetle to expand even farther northward.

Differential sensitivities of ecosystems add another layer of complexity to climate change impacts, and hence to adaptation strategies. Tundra, boreal forests, mountain regions, and the sea ice biome are primarily sensitive to warming, but Mediterranean-type ecosystems and tropical rainforests are most likely to be impacted by reductions in precipitation, while coastal ecosystems are most vulnerable to sea level rise and more severe storm events.[99] The most complex problems may occur in coral reefs, mangroves, and salt marshes, which will be impacted by several climate change–induced stresses — increased temperatures, sea level rise, and changes in water quality — simultaneously.[100]

Moreover, the crossing of ecosystem thresholds, like those in the Arctic tundra, and the conversion of ecosystems to new and probably irreversible states of being (e.g. the Arctic shrubland) is not only possible, but a source of real concern for the future. As the IPCC rather cautiously acknowledged, "[a]nthropogenic warming could lead to some impacts that are abrupt or irreversible, depending upon the rate and magnitude of the climate change."[101] More dramatically, but with a necessary sense of urgency, Ted Nordhaus and Michael Shellenberger have opined that:

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[96] *Id.* at 3.

[97] W.A. Kurz et al., *Mountain Pine Beetle and Forest Carbon Feedback to Climate Change*, 452 NATURE 987, 987 (2008).

[98] Hoyle, *supra* note 17.

[99] IPCC, SYNTHESIS REPORT: SUMMARY FOR POLICYMAKERS, *supra* note 51, at 9.

[100] *Id.*

[101] *Id.* at 13.

> To describe these challenges as problems of pollution is to stretch the meaning of the word beyond recognition. Global warming is as different from smog in Los Angeles as nuclear war is from gang violence. The ecological crises we face are more global, complex, and tied to the basic functioning of the economy than were the problems environmentalism was created to address forty years ago. Global warming threatens human civilization so fundamentally that it cannot be understood as a straightforward pollution problem, but instead as an existential one. Its impacts will be so enormous that it is better understood as a problem of *evolution*, not pollution.[102]

Given what we already know about climate change impacts, adaptation requires a constructive legal and social response to continuous, interacting, often unpredictable, and perhaps irreversible changes in multiple sectors. These changes affect the most basic elements of human support systems: water supply, agriculture, public health, ecosystem stability, and in some areas like the Arctic and coastal regions, the very existence of land to live on.[103] Nevertheless, comparatively little attention has been paid in the United States to the legal principles that should inform and govern climate change adaptation. Legal institutions need to begin to address adaptation challenges, and the sooner they do so, on a reasoned basis, the more proactive, rational, and cost-effective climate change adaptation measures can be. Moreover, while climate change adaptation efforts will need to pervade all aspects of law and society, a logical and manageable place to begin the discussion of climate change adaptation law is to set out principles for environmental regulation and natural resource management.

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[102] TED NORDHAUS & MICHAEL SHELLENBERGER, BREAK THROUGH: FROM THE DEATH OF ENVIRONMENTALISM TO THE POLITICS OF POSSIBILITY 8 (2007).

[103] IPCC, SYNTHESIS REPORT: SUMMARY FOR POLICYMAKERS, *supra* note 51, at 18 ("Key vulnerabilities may be associated with many climate-sensitive systems, including food supply, infrastructure, health, water resources, coastal systems, ecosystems, global biogeochemical cycles, ice sheets and modes of oceanic and atmospheric circulation."); *see also* Ford, *supra* note 25, at 28 (noting that "[t]he majority of Inuit cultural sites . . . and current settlements are located on the coast and/or on permanently frozen land (i.e., permafrost). Climate change threatens to violate Inuit rights to their homelands through sea level rise, coastal erosion, permafrost thaw, and more active slope processes."). The IPCC in 2007 identified five key "reasons for concern" related to adaptation: (1) "Risks to unique and threatened ecosystems"; (2) "Risks of extreme weather events"; (3) "Distribution of impacts and vulnerabilities"; (4) "Aggregate impacts"; and (5) "Risks of large-scale singularities." IPCC, SYNTHESIS REPORT: SUMMARY FOR POLICYMAKERS, *supra* note 51, at 19. *See also* IPCC, ADAPTATION REPORT, *supra* note 7, at 11–12 (detailing the potential climate change effects on freshwater resources and management; ecosystems; food, fiber, and forest products; coastal systems and low-lying areas; industry and human settlement; and human health); *id.* at 14–15 (detailing projected effects in North America).

C. Mitigation Versus Adaptation as a Legal Problem

Recognizing that environmental regulation and natural resource management should address the need for climate change adaptation is just the first step in adapting the relevant laws to the realities of climate change. As the previous discussion suggests, adaptation is inherently a far more complex legal problem than mitigation.[104] Despite some proposals (many sounding as though they came straight from science fiction) for short-term technological "fixes" to the problem of increasing greenhouse gas concentrations,[105] climate change mitigation efforts have one clear and essential regulatory goal: substantially reduce overall emissions of greenhouse gases worldwide, preferably sooner rather than later.[106] Even the basic regulatory mechanisms available to accomplish this goal are fairly limited in number: mandated reductions for each regulated emitter ("command-and-control" regulation), cap-and-trade programs, mandated changes in manufacturing processes, taxes and other economic incentives such as subsidies, or some combination thereof.[107]

Of course, the conceptual simplicity of mitigation law does not mean that creating and implementing such law will be easy. Indeed, the almost two decades of international negotiations on the subject and the failures of many nations to adopt mitigation laws attest to the numerous political, economic, technological, and practical difficulties in establishing a functional mitigation legal regime.[108] Participating nations have been less than success-

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[104] *See* Zinn, *supra* note 56, at 64 (discussing the complexities of climate change adaptation).

[105] Proposals have ranged, for example, from enlisting the ability of bony fish to produce calcium carbonate "gut rocks" to setting off volcanoes. *See* Catherine Brahic, *Fish 'an Ally' Against Climate Change*, NEW SCIENTIST, Jan. 16, 2009, http://www.newscientist.com/article/dn16432-fish-an-ally-against-climate-change.htm# (on file with the Harvard Law School Library); *EPA Official: We May Need to Stimulate Volcanoes to Slow Down Global Warming*, ENVTL. NEWS NETWORK, Feb. 16, 2009, http://www.enn.com/top_stories/article/39320 (on file with the Harvard Law School Library). These measures, however, do not address the root cause of climate change. To use a medical analogy, they treat the symptoms but not the disease itself.

[106] *See* IPCC, MITIGATION REPORT, *supra* note 51, at 99.

[107] *See* Shi-Ling Hsu, Nine Reasons to Adopt a Carbon Tax 2–3 (May 8, 2009) (unpublished manuscript), *available at* http://ssrn.com/abstract=1405944.

[108] These difficulties include ongoing debates over which sources of greenhouse gas emissions to regulate, how severely and how quickly to regulate them, what other activities also need to be regulated, and what to do about global inequalities and the developing world, among others. These debates also reveal a multiplicity of perspectives regarding economic and social effects, technological capabilities, and equitable considerations in climate change mitigation efforts. For example:

> China and India long ago rejected any approach to addressing climate change that would constrain their greenhouse gas emissions or their economic growth . . . . The governments and the people of China and India are increasingly concerned about global warming, to be sure, but they are far more motivated by economic development, and to the extent that the battle against global warming is fought in terms of ecological limits rather than economic possibility, there's little doubt which path these countries will take.

ful in achieving their Kyoto Protocol commitments,[109] demonstrating that inertia remains an important practical limitation to mitigation progress and that new technologies and social norms are probably necessary before mitigation efforts can be successful.[110]

Even so, climate change adaptation law will be dealing with complexity at another order of magnitude because, as noted, the effects of climate change will themselves be complex — ever-changing, often unpredictable, and subject to feedback mechanisms that may not be completely understood and that may change over time, often leading to nonlinear alterations of ecosystems and their services. Moreover, adaptation law will have to cope with multiple layers of governmental interest, since many adaptation strategies will have to be intensely local in implementation, while adaptation principles and goals may need to operate on a larger state, watershed, regional, or national scale.

The complexity of climate change adaptation makes it both a more interesting and a more vexing legal problem than climate change mitigation. In the broadest perspective, adaptation measures must embrace all aspects of human society simultaneously, from national security to changes in economic productivity; from energy production and distribution to national and regional infrastructure redevelopment; from food production, distribution, and agricultural practices to water supply; from local government planning and land use regulation to environmental regulation and natural resource management.[111] Equally important, governments must implement whatever adaptation measures they choose while the ground is figuratively and literally shifting under society's feet — that is, while the focus of the adaptation measures itself may no longer have a stable identity.

NORDHAUS & SHELLENBERGER, *supra* note 102, at 12. As for other activities besides greenhouse gas emissions, "even if we were to drastically limit the greenhouse gas emissions produced by power plants and automobiles, we would still need a strategy to slow the rapid rate of deforestation." *Id.*

[109] As Ted Nordhaus and Michael Shellenberger have noted, "those developed nations that ratified the Kyoto treaty on global warming have made little headway in actually reducing their own emissions. In late 2006, the United Nations announced that, since 2000, the emissions of the forty-one wealthy, industrialized members of Kyoto had gone up, not down, by more than 4 percent." *Id.*

[110] *Id.* at 15 ("There is simply no way we can achieve an 80 percent reduction in greenhouse gas emissions without creating breakthrough technologies that do not pollute.").

[111] As the IPCC noted in 2007:

> The array of potential adaptive responses available to human societies is very large, ranging from purely technological (e.g., sea defences), through behavioural (e.g., altered food and recreational choices), to managerial (e.g., altered farm practices) and to policy (e.g., planning regulations). While most technologies and strategies are known and developed in some countries, the assessed literature does not indicate how effective various options are at fully reducing risks, particularly at higher levels of warming and related impacts, and for vulnerable groups. In addition, there are formidable environmental, economic, informational, social, attitudinal and behavioural barriers to the implementation of adaptation. For developing countries, availability of resources and building adaptive capacity are particularly important.

IPCC, ADAPTATION REPORT: SUMMARY FOR POLICYMAKERS, *supra* note 57, at 19.

Therefore, it is worth emphasizing that climate change adaptation law and policy, by definition, cannot be preservationist. The point should not be — and in many areas and sectors, *cannot* be — to preserve as much of the current status quo as possible, or even to make a shift to a new and stable status quo.[112]

Instead, even if we restrict our focus to environmental and natural resources law, as this Article does, climate change adaptation law will often require both a new way of thinking about what regulation is supposed to accomplish and different kinds of legal frameworks for accomplishing those new goals.[113] While I am less pessimistic than Matthew Zinn about the adaptability of environmental and natural resources law to climate change impacts (in part because I envision mitigation and adaptation as being simultaneous approaches), I agree with his conclusion that adaptation challenges both the existing capacity of legal institutions and continued public will to engage in environmental protection.[114] Environmental and natural resources law in a climate change adaptation era require fundamental re-visioning, because both regulatory goals and the legal mechanisms for accomplishing them will have to be centered on the concept of *change* itself. Responding effectively to the specific local and regional alterations occurring as a result of the global phenomenon of climate change requires a different paradigm for thinking about environmental, natural resource, and ecosystem "change" than those currently pervading most environmental and natural resources

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[112] *See, e.g.*, Farber, *supra* note 33, at 1401 (noting that in climate change adaptation, "the whole point is that the status quo will become unsustainable due to climate change"). *See also* J.B. Ruhl, *Climate Change and the Endangered Species Act: Building Bridges to the No-Analog Future*, 88 B.U. L. REV. 1, 18–23 (2008) [hereinafter Ruhl, *Building Bridges*] (describing how climate change is leading us to a "no-analog" future); 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, 940, 968–75 (1997) [hereinafter Ruhl, *Complex Adaptive System*] (arguing that environmental law inappropriately engages in uniformitarianism).

Nevertheless, while "[p]ublic opinion has largely accepted that climate change is occurring," "climate change is not yet considered irreversible and its long-term implications have not been accepted." Martin & Ernst, *supra* note 28, at 41. This lack of acceptance is obvious in the thrust of many of the few climate change adaptation articles that have been written, most of which adopt, consciously or unconsciously, a preservationist approach. *See, e.g.*, David Takacs, *Carbon Into Gold: Forest Carbon Offsets, Climate Change Adaptation, and International Law*, 15 HASTINGS W.-NW. J. ENVTL. L. & POL'Y 39, 43–44 (2009) (describing "ecological resiliency" as "*protecting and preserving* the natural ecosystems that help human communities survive through buffering from floods, filtering drinking water, stabilizing soil, providing sustainable forest products, and *preserving* a host of other ecosystem services necessary for human survival" (emphasis added)); William S. Eubanks II, *The Life-Altering Impacts of Climate Change: The Precipitous Decline of the Northeastern Sugar Maple and the Regional Greenhouse Gas Initiative's Potential Solution*, 17 PENN ST. ENVTL. L. REV. 81, 81 (2008) (arguing that "the public must first realize the scientific and economic necessity of *preserving* the sugar maple in the northeastern United States" (emphasis added)).

[113] IPCC, ADAPTATION REPORT, *supra* note 7, at 729–30, 731 (discussing the role of social processes in adaptive capacity, the potential role of regulation in building adaptive capacity, and the role of social policy in enhancing adaptive capacity).

[114] *See* Zinn, *supra* note 56, at 64–65, 81–101.

law. Thus, it is to our conceptualizations and theories of change that this Article now turns.

II. THINKING ABOUT CLIMATE *CHANGE*: SHIFTING PARADIGMS FROM PRESERVATION AND RESTORATION TO INCREASING ADAPTIVE CAPACITY

A. The Current Preservation and Restoration Paradigms

At its most basic, "change" is the emergence of difference over time. Thus, acknowledgment of change almost by definition posits an initial or baseline state (or states) against which humans can measure the amount of difference that has accumulated over a particular period of time. Acknowledging change, in other words, is always an exercise in making comparisons.

More subtly, however, recognition of change also problematizes identity: how is it that we can identify the present "it" that has changed as being the same "it" that existed in a different state at some previous time? The point here is not to indulge in a philosophical inquiry into the nature of identity but rather to emphasize that climate change impacts can blur or obliterate the relevant identity of regulatory objects, particularly at the ecosystem scale.[115] Climate change impacts are metamorphic and transformative: Montana's trout streams become too warm to support trout; the Arctic tundra becomes the Arctic shrubland. As a result, climate change means that regulatory objectives based on the pre–climate change characteristics of particular places can and will become increasingly obsolete. Climate change adaptation law must be able to accommodate the transforming ecological realities of particular places and not attempt to freeze ecosystems and their components into some prior state of being.

Nevertheless, humans being humans, neutral valuations of the fact of change are rare, particularly when the articulation of "change" becomes interlaced with conceptions of "natural" and "unnatural" or "progress" (cleaner, restored) and "regression" (dirtier, degraded). In particular, natural changes, such as the cycles of seasons or the growth of babies, are generally good, or at least comfortingly predictable, and the histories of both science and literature reveal attempts to fit new discoveries and social developments into these comfortable tropes.[116] In contrast, anthropogenic changes

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[115] Ruhl, *Building Bridges*, *supra* note 112, at 17–26; Robin Kundis Craig, *Climate Change, Regulatory Fragmentation, and Water Triage*, 79 U. COLO. L. REV. 825, 878–83 (2008).

[116] In science, for example, the evolution of the tropes of evolutionary theory are revealing, moving from the nineteenth-century conception of evolution as "progress" to the much more chaotic twentieth-century "punctuated equilibrium" view of species change. In literature, the English Romantic poets — arguably the first generation to have to cope with readily visible, non-natural environmental change, as a result of the Industrial Revolution — reached repeatedly for both mythological tropes of cyclical change and renewal and scientific notions of "progress" to explain and cope with the various "revolutions" of their day —

to the natural world, at least since the Industrial Revolution, are often portrayed as bad, from the English and American Romantic poets to Rachel Carson's *Silent Spring*,[117] in part because humans upset the "balance of nature."[118]

Thus, in general, human institutions in the Anglo-American tradition impose values on different types of change, and American environmental and natural resources law is no different. Indeed, one of the assumptions that pervades these laws is that anthropogenic change is unnatural and degrading, but also nontransformative and hence (generally) reversible. This assumption sets up the most basic paradigms of environmental and natural resource regulation and management: preservation and restoration. Laws implementing these paradigmatic goals, whether within the context of cleanups pursuant to the Comprehensive Environmental Response, Compensation or Liability Act[119] ("CERCLA," also known as "Superfund") or the establishment of marine protected areas,[120] attempt either to preserve an ecosystem in a desired, more "natural" state, or to reverse the human-induced changes in an area or ecosystem back to some more "natural" baseline.[121]

The restoration paradigm is perhaps clearest in pollution regulation, where the largely internalized baseline or assumed "pristine" condition is an area's preindustrial status, even though the relevant laws generally allow for some postindustrial compromise in the actual regulatory goal. For example, the federal Clean Water Act ("CWA") states a lofty (if unrealistic) "national goal that the discharge of pollutants into the navigable waters be eliminated by 1985."[122] However, its actual regulatory requirements are keyed to "best available" existing technological capabilities (in the form of technology-based effluent limitations)[123] and pragmatic water quality standards based on

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Industrial, French, and American. Robin Kundis Craig, Romantic Transformations: The Poetics of Change and History in a Context of Mythography and Science 1–13 (March 17, 1993) (unpublished Ph.D. dissertation, University of California, Santa Barbara) (on file with the Harvard Law School Library).

[117] RACHEL CARSON, SILENT SPRING (1962).

[118] *See, e.g.*, DANIEL B. BOTKIN, DISCORDANT HARMONIES: A NEW ECOLOGY FOR THE TWENTY-FIRST CENTURY 8–13 (1990) (tracing a history of views of nature and the variety of metaphors used to described natural workings).

[119] 42 U.S.C. §§ 9601–9628 (2006).

[120] Of course, choosing the baseline can require consideration of practicalities and politics. *See* Robin Kundis Craig, *Taking Steps Toward Marine Wilderness Protection? Fishing and Coral Reef Marine Reserves in Florida and Hawaii*, 34 MCGEORGE L. REV. 155, 167–79 (2003). Nevertheless, the basic paradigm remains the same: return a changed (degraded) site or ecosystem to some previous state. *See id.* at 179–83.

[121] *See* NORDHAUS & SHELLENBERGER, *supra* note 102, at 24–26 (describing the model of pollution regulation in these paradigmatic terms and noting that most environmentalism operates off the metaphor that "[n]ature has been unjustly violated by mankind"). *See also* Richard J. Hobbs & Viki A. Cramer, *Restoration Ecology: Interventionist Approaches for Restoring and Maintaining Ecosystem Function in the Face of Rapid Environmental Change*, 33 ANN. REV. ENV'T & RESOURCES 39, 40 (2008) ("The practice of ecological restoration is becoming an increasingly important tool in humanity's attempt to manage, conserve, and repair the world's ecosystems in the face of an increasing legacy of environmental damage").

[122] 33 U.S.C. § 1251(a)(1) (2006).

[123] *Id.* §§ 1311(b), 1316, 1317(a).

the actual uses of particular waterbodies.[124] Nevertheless, the CWA's overall goal remains to "*restore and maintain* the chemical, physical, and biological integrity of the Nation's waters."[125]

Similarly, both CERCLA and the Oil Pollution Act[126] allow governments and tribes to collect natural resources damages for ecosystems impaired by releases of hazardous substances and oil spills, respectively, and the basic measurement of those damages is the cost of restoring the area to pre-spill or pre-release conditions.[127] Treatment, storage, and disposal facilities regulated under the Resource Conservation and Recovery Act ("RCRA") must undertake corrective actions if their activities contaminate land or groundwater,[128] restoring those sites to pre-contamination status; similarly, the Surface Mining Control and Reclamation Act seeks to ensure that mining operations restore the disturbed landscape to something approaching its pre-mining condition.[129] Finally, while the CAA less explicitly indulges in restoration rhetoric, it nevertheless seeks "to protect and enhance the quality of the Nation's air resources so as to promote the public health and welfare and the productive capacity of the population,"[130] fairly explicitly recognizing that industrialization can turn clean air into something unhealthy.

No one disputes that reducing pollution is generally a good thing. However, harnessing pollution regulation to goals formulated under a restoration paradigm creates a conceptual discontinuity with the realities of climate change impacts. Restoration is an attempt to return a resource to a prior ("normal" or "natural") state of being, a goal that climate change is likely to make impossible in many places. If increasing temperatures heat Montana's streams to the point where trout cannot survive, regulation of thermal pollution to restore the prior water quality is useless. This is the danger of the restoration paradigm: it can make environmental regulation appear futile in a climate change era, which it most decidedly is not. Indeed, as discussed below, reducing the amount of pollution entering the environment — particularly toxic pollution — should remain a critical component of the new law for climate change adaptation, but to serve different goals.

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[124] *Id.* §§ 1312, 1313.

[125] *Id.* § 1251(a).

[126] 33 U.S.C. §§ 2701–2762.

[127] *See* 42 U.S.C. § 9607(a)(4)(C) (2006) (creating liability for damage to natural resources caused by hazardous substances); 33 U.S.C. §§ 2702(b)(2)(A), 2706(b)(2)(A) (creating liability for damage to natural resources and allowing the President to name trustees to enforce such liability for the public good); 33 C.F.R. § 136.211(a) (2009) (noting that natural resources damages for the Oil Pollution Act include "the cost of restoring, rehabilitating, replacing, or acquiring the equivalent of the damaged natural resources"); 43 C.F.R. § 11.10(e)(3) (2008) (using the same language for natural resources damages under CERCLA).

[128] 42 U.S.C. § 6924(u), (v); 40 C.F.R. §§ 257.21–.28; 258.50, 258.51 (2009).

[129] 30 U.S.C. § 1265(a), (b)(2) (2006) (requiring mining permittees to "restore the land affected to a condition capable of supporting the uses which it was capable of supporting prior to any mining").

[130] 42 U.S.C. § 7401(b)(1).

Reducing pollution reduces ecosystem stress and vulnerability, increasing resilience — even if we cannot have exactly the same ecosystem that we had before.

Natural resources laws, in turn, tend to incorporate the preservation paradigm more prominently, generally through a focus on minimizing or mitigating destructive human change to ecosystems and species. Thus, NEPA forces federal agencies to think long and hard about any federal activity that might significantly affect the environment and to consider alternatives to the initial proposal that might be less environmentally damaging.[131] Reduction and mitigation of wetlands destruction are (or are supposed to be) a routine part of Section 404 permitting under the CWA,[132] while the overall goals of the ESA are to prevent the extinction of imperiled species and to restore them to populations that ensure that each species will thrive.[133] Multiple-use public lands management is more complex precisely because it anticipates and promotes continued human uses of public resources; nevertheless, the paradigm remains (legally, at least) to minimize human destruction of these resources.[134] Moreover, public lands managers have been moving toward an ecosystem management approach, with the goal of preserving ecosystem functions and services.[135] Similarly, management of water resources ("water law") generally anticipates continued human use of those resources, but the law increasingly imposes ecological restrictions on such uses through in-stream flow requirements, public interest requirements, and the public trust doctrine.[136]

Like the restoration paradigm, the preservation paradigm incorporates an expectation that ecosystems are or should be stable and that managers can sustain one particular historical ecological state of being. Thus it, too,

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[131] 42 U.S.C. § 4332(2)(C).

[132] 33 U.S.C. § 1344(a); 40 C.F.R. § 230.10(d).

[133] 16 U.S.C. §§ 1531(b), 1532(3) (2006); *see also* Ruhl, *Complex Adaptive System*, *supra* note 112, at 968–75 (discussing the "uniformitarian" approach of the ESA).

[134] *See, e.g.*, 43 U.S.C. § 1701(a)(8) (2006) (declaring a national policy that public land management "protect the quality of scientific, scenic, historical, ecological, environmental, air and atmospheric, water resource, and archeological values," "preserve and protect certain public lands in their natural condition," "provide food and habitat for fish and wildlife and domestic animals," and "provide for outdoor recreation and human occupancy and use"); *id.* § 1702(a) (defining "areas of critical environmental concern" to be public lands "where special management attention is required . . . to protect and prevent irreparable damage to important historic, cultural, or scenic values, fish and wildlife resources or other natural systems or processes, or to protect life and safety from natural hazards"); *id.* § 1702(c) (defining "multiple use" in part to be the "harmonious and coordinated management of the various resources *without permanent impairment of the productivity of the land and the quality of the environment*," paying attention to "the relative values of the resources and not necessarily to the combination of uses that will give the greatest economic return or the greatest unit output" (emphasis added)).

[135] *See, e.g.*, Robert L. Fischman, *The Significance of National Wildlife Refuges in the Development of Conservation Policy*, 21 J. LAND USE & ENVTL. L. 1, 14–22 (2005) (describing the 1997 conversion of National Wildlife Refuge management to an ecosystem-based approach).

[136] *See* Craig, *supra* note 115, at 835–36 and sources cited therein (discussing developments under both riparian and prior appropriation systems).

threatens to dislocate the goals of natural resources law from the ecological realities of a climate change era. Preserving natural resources implies an attempt to keep them in a particular state of being — another losing proposition as baseline conditions shift in response to climate change. Thus, goals based on a preservation paradigm, like those based on a restoration paradigm, threaten to render natural resources law futile. Instead, the new law of climate change adaptation needs goals that acknowledge and allow for ecosystem change.[137]

B. The Mismatch of the Preservation and Restoration Paradigms with Climate Change Adaptation

The preservation and restoration paradigms that currently pervade environmental and natural resources law assume that ecological change is predictable and that human impacts are generally reversible. Predictability is what makes human use of natural resources manageable and ecological preservation possible. If regulators can predict how a species, resource, or ecosystem will respond to changes in human impacts (more or less pollution, more or fewer people, more or fewer vehicles, more or less habitat destruction), they can manage that species, resource, or ecosystem to the human-determined functionality or productivity goal. Thus, we require drinking water contamination to be below maximum contaminant levels, manage fisheries for maximum sustainable yield, regulate air pollution to eliminate human health risks, and manage public lands to achieve sustained yield of several products and services. Reversibility, in contrast, presumes that undesirable ecological change can be undone. While some of the exceptions to this assumption are obvious — extinction of species, for example — the whole concept of environmental restoration depends upon it.

Neither of these regulatory and management assumptions holds true in a world of transformative climate change. As J.B. Ruhl has noted with respect to predictability, "even as we learn more about the highly coupled, tightly interacting processes that comprise the climate, the likelihood is that we will realize with even greater clarity that it is inherently unpredictable."[138] As for reversibility, the IPCC has emphasized that "[i]rreversibility is an important aspect of the climate change issue, with implications for mitigation and adaptation responses. The response of the climate system . . . is likely to be irreversible over human time scales, and

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[137] USGCRP, IMPACT REPORT, *supra* note 39, at 11 (noting that "society won't be adapting to a new steady state but rather to a rapidly moving target. Climate will be continually changing, moving at a relatively rapid rate, outside the range to which society has adapted in the past.").

[138] Ruhl, *Building Bridges*, *supra* note 112, at 19; *see also id.* at 19–20 and sources cited therein; Heltberg et al., *supra* note 27, at 94 (emphasizing that historical data will provide no basis for predicting climate change impacts); Tompkins & Adger, *supra* note 66, at 1 ("The likely geographical distribution of impacts and the probabilities of particular future scenarios are much less clear.").

much of the damage is likely to be irreversible even over longer time scales."[139]

It might be argued that climate change merely exacerbates an existing problem in natural resource management: the law and managers assume stationarity and ignore how human impacts interfere with the natural dynamics of ecosystems, while the ecological reality has always been one of complex change.[140] Moreover, in some respects, the law has already been changing to reflect the dynamic complexity of natural systems. For example, Robert Fischman has explored in detail the evolution of the National Wildlife Refuge system to an ecosystem management framework in the context of refuges that are often undergoing systemic changes.[141] Finally, this dynamism means that species and ecosystems already possess some intrinsic ability to adapt to climate change.

However, the fact that the ecological dynamism/legal stationarity problem has been recognized before does not diminish the urgency to adopt climate change adaptation law and policy. First, while natural dynamism is indeed the rule, climate change–driven ecological transformations will almost certainly outpace natural dynamism in several respects — faster and greater accumulation of greenhouse gases than has ever occurred before; faster melting of polar ice and glaciers; more rapidly increasing air and water temperatures; abruptly changing air and ocean currents — with results that will be more dramatic and visible than "normal" ecosystem dynamics. Moreover, as a legal matter, the impacts of climate change on baseline ecological conditions extend far beyond endangered species and public lands management into environmental regulation (pollution control), energy law, agriculture law, and land use law. Thus, the dynamism/stationarity problem is arguably broader in a climate change era than has been fully acknowledged previously.

Second, while it is true that dynamism means that species and ecosystems have an intrinsic adaptive capacity, it is also true that (1) existing human impacts have already undermined that adaptive capacity and (2) ecological changes from climate change are already outstripping whatever adap-

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[139] IPCC, MITIGATION REPORT, *supra* note 51, at 102; *see also* Heltberg et al., *supra* note 27, at 94 (noting that irreversible damages are likely for both natural and human assets).

[140] *See, e.g.*, Robert L. Glicksman, *Ecosystem Resilience to Disruptions Linked to Global Climate Change: An Adaptive Approach to Federal Land Management*, 87 NEB. L. REV. 833, 836–37, 852–56 (2009) (describing the paradigm shift in ecology away from the equilibrium model and the mismatch of public lands laws, NEPA, and the ESA with the new dynamism); BOTKIN, *supra* note 118, at 4 (arguing that our perspective on nature must change to include "the recognition of the dynamic rather than the static properties of the Earth and its life-support system"); Ruhl, *Complex Adaptive System*, *supra* note 112, at 940, 954–67, 968–75 (explaining the dynamic qualities of ecosystems and other complex systems and exploring the uniformitarian nature of the ESA).

[141] Robert L. Fischman, *From Words to Action: The Impact and Legal Status of the 2006 National Wildlife Refuge System Management Policies*, 26 STAN. ENVTL. L.J. 77, 82–84 (2007); Fischman, *supra* note 135, at 14–22.

tive capacity remains.[142] Thus, humans cannot punt even the problem of species and ecosystem adaptation to climate change, especially if we acknowledge socio-ecological systems and our dependence on ecosystem services.

Third, and most importantly, although the dynamism/stationarity problem has been recognized,[143] the law has not changed significantly to acknowledge it. Problem recognized does not mean problem solved. Even though American courts are beginning to require regulators to discard the assumption of stationarity in the face of climate change, as in the Delta smelt case,[144] the preservation and restoration paradigms remain embedded in current environmental and natural resources law. Moreover, the perpetuation of these paradigms — both in the laws themselves and in the regulators' minds — impedes the rational development of climate change adaptation law and policy because they encourage decision makers to view ecological change as a matter of human choice: how much degradation will we choose to allow, and for what reasons? In the climate change era, in contrast, ecological change will result from both controllable human activities and the uncontrollable consequences of two centuries of greenhouse gas accumulation, and the law needs to reflect those new realities.

As noted, this regulatory perspective also indulges in yet another assumption, that ecological change is nontransformational. More specifically, current law assumes that, whatever humans do, the baseline attributes of the system — temperatures, precipitation and hydrology, soil conditions, air quality, species assemblage — will remain more or less intact. As this Article has discussed, however, climate change calls this basic assumption into question because it impacts precisely those baseline ecological attributes. We are moving into an era when ecological change may not be predictable and "when external factors, positive feedbacks, or nonlinear instabilities in a system cause changes to propagate in a domino-like fashion that is potentially irreversible."[145] As land, air, and water temperatures generally increase, patterns of precipitation change in terms of both amount and timing, and species shift as best they can to cope. As a result, "restoration" and even "sustainability" have the potential to become close to meaningless concepts. We are moving along an at least somewhat unpredictable path to an as yet unpredictable final destination — what J.B. Ruhl has called the "no-analog future."[146] Fundamental metamorphosis of the natural world,

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[142] IPCC, SYNTHESIS REPORT, *supra* note 92, at 65 ("There is *high confidence* that the ability of many ecosystems to adapt naturally will be exceeded this century. . . . Unmitigated climate change would, in the long term, be *likely* to exceed the capacity of natural, managed and human systems to adapt.").

[143] Ruhl, *Complex Adaptive System*, *supra* note 112, at 980–1000.

[144] Natural Res. Def. Council v. Kempthorne, 506 F. Supp. 2d 322 (E.D. Cal. 2007); *see also supra* notes 8–10 and accompanying text.

[145] 2009 USCCSP ECOSYSTEM THRESHOLDS REPORT, *supra* note 21, at viii.

[146] Ruhl, *Building Bridges*, *supra* note 112, at 17, 23.

and of the ecosystem services upon which human societies depend, is becoming our largely uncontrollable reality.

Thus, as was true more specifically for water resources management, stationarity is dead. If the law is to deal effectively with climate change, it must declare, at least with respect to climate change impacts, "Long live transformation."

And that leads to the last mismatch between the current legal paradigms of preservation and restoration and climate change adaptation law: our valuation of climate change–driven ecological change. From the adaptation perspective (but, importantly, *not* from the mitigation perspective), climate change impacts confound our normal understanding of what is "natural." Human industrialization may have set climate change in motion, but the planet's systems are responding in ways that we do not fully understand and at spatial and temporal scales that far exceed the scope of existing regulatory mechanisms. Impacts from climate change, for the next several decades at least, are largely beyond human control, regardless of human mitigation efforts. Obsessing about their "unnaturalness" is an unhelpful approach to formulating adaptation law.

Therefore, as heretical as it may sound, climate change adaptation law (but importantly, again, *not* climate change mitigation law) will almost certainly be more effective if it treats climate change impacts as though they were arising entirely from natural causes. Refusing to expend time, money, and analysis to figure out which changes are natural and which are not will keep climate change adaptation law focused on what is actually occurring with respect to species, water supplies, ecosystem functions and services, agriculture, disease vectors, and so on. Such a perspective will also keep society's limited resources directed toward productive responses to those changes, rather than ineffective and expensive attempts to restore a set of conditions that can no longer exist or inefficient efforts to address mitigation through adaptation's regulatory back doors.

As a corollary, I agree with J.B. Ruhl's conclusion that the ESA should not be used to attempt to address greenhouse gas emissions.[147] And I would extend that conclusion to all laws that do not directly focus on emissions of pollutants into air. That is not to say that legal arguments for doing so cannot be constructed — they can, and often easily. For example, under the CWA it would take no great effort to define greenhouse gas emitters as nonpoint sources contributing to temperature violations in Montana's trout streams and thus to include them within the ambit of any resulting total maximum daily load ("TMDL") regime.[148] That does not change the fact,

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[147] *Id.* at 29–31, 59.

[148] *See* 33 U.S.C. § 1313(d) (2006) (setting up the TMDL requirement for waterbodies that violate water quality standards); *see also* Robin Kundis Craig, *Climate Change Comes to the Clean Water Act: Now What?*, 1 J. ENERGY, CLIMATE & ENV'T (forthcoming 2010), *available at* http://ssrn.com/abstract=1366065; Robin Kundis Craig, *The Clean Water Act on the Cutting Edge: Climate Change and Water Quality Regulation*, NAT. RESOURCES & ENV'T, Fall 2009, at 14 [hereinafter Craig, *The Cutting Edge*].

however, that the CWA TMDL process, like species protection regulation under the ESA, is a grossly inefficient mechanism for dealing with greenhouse gas emissions and the mitigation regulatory problem. Instead, policymakers, courts, and regulators should acknowledge that mitigation law and adaptation law address separate, if ultimately related, regulatory problems and need different sets of tools to do so.

C. The New Paradigm: Increase Resilience and Adaptive Capacity

Regulators' increasing inability to define regulatory goals in terms of previous (or even desired) ecosystem states and functions does not eliminate the role of environmental and natural resources law in the United States, nor should it become an excuse for an exploitative free-for-all. Instead, the more we acknowledge pervasive uncertainties regarding what climate change actually means at all levels — local, state, regional, or national; social, political, and natural — the more we should restructure environmental and natural resources law to give as many species and systems as possible the best chance to survive and adapt to whatever changes come. As the USCCSP recently concluded, "[I]t is essential to increase the resilience of ecosystems . . . and to employ adaptive management strategies to deal with new conditions, new successional trajectories and new combinations of species."[149]

As such, the new paradigm for environmental and natural resources law in an era of climate change adaptation must be to increase the continuing capacity of the natural world, human society, socio-ecological systems, and legal institutions to adjust to continual transformation. In other words, the overall goal of climate change adaptation law should be to increase humans', other species', society's, and ecosystems' *adaptive capacity*.[150]

The details of what this new paradigm means for particular statutes is beyond the scope of this Article, although some implications will be obvious. Instead, this Article seeks to establish a set of general principles that, individually and collectively, will help to promote adaptive capacity regard-

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[149] 2009 USCCSP ECOSYSTEM THRESHOLDS REPORT, *supra* note 21, at ix.

[150] According to the IPCC:

> Adaptive capacity is the ability or potential of a system to respond successfully to climate variability and change, and includes adjustments in both behaviour and in resources and technologies. The presence of adaptive capacity has been shown to be a necessary condition for the design and implementation of effective adaptation strategies so as to reduce the likelihood and the magnitude of harmful outcomes resulting from climate change. Adaptive capacity also enables sectors and institutions to take advantage of opportunities or benefits from climate change, such as a longer growing season or increased potential for tourism.

IPCC, ADAPTATION REPORT, *supra* note 7, at 727 (citation omitted). *See also* Heltberg et al., *supra* note 27, at 90 (advocating, as a new approach to adaptation management for households, "the explicit goal to *increase the capacity of society to manage climate risks with a view to reduce the vulnerability of households and maintain or increase the opportunities for sustainable development*" (emphasis added)).

less of the particular regulatory regime at issue. The next Part thus presents starting principles for legislatures and policymakers working to adopt climate change adaptation law.

III. Five Principles for Climate Change Adaptation Law

Altering the basic paradigms of environmental and natural resources law from preservation and restoration, based on assumptions of stationarity, to a paradigm of increasing resilience and adaptive capacity, based on assumptions of continuing, unpredictable, and nonlinear change, will necessarily require different kinds of legal amendments, and perhaps even new laws, for different regulatory contexts. Nevertheless, certain key principles should undergird the entire legal adaptation endeavor, regardless of the specific statute or level of government involved.

This Part lays out five key principles for climate change adaptation law. It presents those principles roughly in order of implementation. Because climate change impacts will occur over decades and probably centuries, governments cannot and should not develop complete adaptation strategies overnight, especially given current uncertainties regarding mitigation strategies and the particular climate change impacts likely to occur at the local level. Indeed, irreversible commitment too early to particular strategies as opposed to taking a more cautious, "no regrets" approach at the outset is more likely to create path dependencies[151] that could actually impede future adaptation and even survival.

Principle #1: Monitor and Study Everything All the Time

In general, "[e]nvironmental governance depends on good, trustworthy information about stocks, flows, and processes within the resource systems being governed, as well as about the human-environment interactions affecting those systems."[152] However, the unfortunate current reality is that we have very little idea what climate change impacts will actually be, especially at the local level.[153] Moreover, we have little understanding of "the com-

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[151] *See infra* text accompanying notes 305–15.

[152] Thomas Dietz, Elinor Ostrom & Paul C. Stern, *The Struggle to Govern the Commons*, 302 Science 1907, 1908 (2003). As one example, these researchers detailed how wrong information contributed to the collapse of cod stocks in Canada. *Id.*; *see also* Glicksman, *supra* note 140, at 871 ("Planning and project level decisions are only as good as the information on which they are based.").

[153] As researchers from the World Bank have described the climate change adaptation knowledge problem:

> There is a great deal of uncertainty about when, where, and how much predicted climate changes will manifest. Few problems confronted by social scientists and policy makers entail such complex long-term implications and this much uncertainty. Uncertainty complicates decision-making and cost-benefit analyses — should crop research, for example, target widely consumed staples or instead shift toward drought-tolerant varieties whose importance may grow? Uncertainty extends into

plex, multivariable, nonlinear, cross-scale, and changing [socio-ecological systems]" that exist even *prior* to climate change impacts.[154] Thus, Principle #1 for climate change adaptation law should be to increase requirements and funding for continual monitoring and basic scientific and economic research to promote understanding of climate change impacts at all scales and across sectors. This will help policymakers avoid overly simplistic "solutions" to, and panaceas for, climate change adaptation.

Anticipatory planning and actual responses to climate change impacts should be based on a solid scientific understanding of how ecological baseline conditions and ecosystem functions and services are changing, and on valid projections of such changes into the future (i.e., modeling).[155] Lack of knowledge about the nature, scope, and extent of climate change effects, particularly at the level of specific resources and ecosystems and local communities, limits citizens' and governments' abilities and willingness to make rational choices regarding adaptation strategies, thus undermining adaptive capacity.[156] In contrast, Lawrence Brown and Lawrence Jacobs have argued that "[w]hen faced with concrete threats, most Americans . . . expect government to intervene," creating more politically fertile ground for debate and creative solutions.[157] Nevertheless, solid information regarding both climate change impacts[158] and the costs and benefits of adaptation[159] remains quite limited.

One particular knowledge gap about which both the IPCC and the USCCSP have expressed deep concern is the potential crossing of ecological "thresholds" as a result of climate change.[160] As noted, one observed example of such threshold crossing has been the "conversion of the arctic tundra

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> the policy arena: levels of funding, implementation arrangements, and effectiveness of proposed adaptation interventions are all uncertain and contested. *Uncertainty, however, should not delay action.* When confronted with other risks such as health, food security, or the threat of terrorism, the response to uncertainty is not inaction as policy makers realize they need to minimize the risk of catastrophic losses. The same should be the approach to climate change.

Heltberg et al., *supra* note 27, at 94 (emphasis added). *See also* T.P. Hughes et al., *Climate Change, Human Impacts, and the Resilience of Coral Reefs*, 301 SCIENCE 929, 932 (2003) (calling for more research on coral reefs and noting that "most coral reef research is parochial and short-term, and provides little insight into global or longer-term changes").

[154] Ostrom et al., *supra* note 26, at 15,181.

[155] Elinor Ostrom has described a nested framework for studying the complexity of socio-ecological systems that could be helpful in the climate change adaptation context. *See id.* at 15,181–86.

[156] IPCC, ADAPTATION REPORT, *supra* note 7, at 719 (noting that barriers to the adoption of successful adaptation strategies include "significant knowledge gaps for adaptation as well as impediments to flows of knowledge and information relevant for adaptation decisions").

[157] LAWRENCE D. BROWN & LAWRENCE R. JACOBS, THE PRIVATE ABUSE OF THE PUBLIC INTEREST: MARKET MYTHS AND POLICY MUDDLES 130 (2008) (citation omitted).

[158] IPCC, ADAPTATION REPORT: SUMMARY FOR POLICYMAKERS, *supra* note 57, at 20.

[159] IPCC, ADAPTATION REPORT, *supra* note 7, at 724, 727.

[160] 2009 USCCSP ECOSYSTEM THRESHOLDS REPORT, *supra* note 21, at 1 ("[A]n ecological threshold is the point at which there is an abrupt change in an ecosystem quality, property, or phenomenon, or where small changes in one or more external conditions produce large and persistent responses in an ecosystem." (emphasis omitted)).

to shrubland, triggered by a relatively slight increase in temperature" and propelled by an "amplified positive feedback effect" that accelerates loss of snow cover.[161]

Such ecological thresholds represent limitations to the resilience and adaptive capacity of both ecosystems and coupled socio-ecological systems.[162] Indeed, the IPCC identifies threshold crossings as potential hard limits on both humans' and ecosystems' abilities to adapt to climate change,[163] and it cites the 2006 Millennium Ecosystem Assessment for the proposition that "[t]he loss of keystone species may cascade through the socio-ecological system, eventually influencing ecosystems services that humans rely on, including provisioning, regulating, cultural, and supporting services."[164]

Unfortunately, as has been noted, ecosystems and their responses to climate change are complex and difficult to predict.[165] Given the multiple complex interactions between climate change impacts and ecosystem function, the USCCSP has concluded that "[c]omplex situations like those involving ecological thresholds . . . tend to be beyond the limits of existing predictive capabilities."[166]

As a result, the USCCSP has strongly recommended monitoring and increased research as two means of identifying and hopefully avoiding these ecological thresholds.[167] Monitoring of "the key factors controlling adaptive capacity and resilience" is especially critical, and changes in monitoring priorities may be necessary.[168]

More generally, uncertainty regarding climate change impacts is a significant source of political and popular resistance to initiating climate change adaptation measures, particularly when such measures involve costly

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[161] *Id.* at 2.

[162] IPCC, ADAPTATION REPORT, *supra* note 7, at 733.

[163] *Id.*

[164] *Id.* at 734 (citing MILLENNIUM ECOSYSTEM ASSESSMENT, ECOSYSTEMS AND HUMAN WELL-BEING: SYNTHESIS (2006)).

[165] *See* Dietz et al., *supra* note 152, at 1908 ("Scientific understanding of coupled human-biophysical systems will always be uncertain because of inherent unpredictability in the systems and because the science is never complete."). The USCCSP has recently emphasized both that "[e]cosystems are not simple, and complex interactions between multiple factors and feedbacks can lead to even greater nonlinear changes in their dynamics" and that "climate change will alter not only the landscape, but it will also affect the disturbance mechanisms themselves." 2009 USCCSP ECOSYSTEM THRESHOLDS REPORT, *supra* note 21, at 3. The report continued, "[a]dding additional complexity to already-complex systems, human actions also interact with natural drivers of change, producing multifaceted ecosystem changes that have important implications for the services provided by those ecosystems." *Id.* at 3–4.

[166] *Id.* at 5.

[167] *Id.* at 6 ("Reliable identification of thresholds across different systems should be a national priority because of the potential for substantive surprises in the management of our natural resources.").

[168] *Id.* In particular, "[c]onsideration should be given to monitoring indicators of ecosystem stress rather than the resources and ecological services of management interest." *Id.*; *see also* W. GOVERNORS' ASS'N, WESTERN WILDLIFE HABITAT COUNCIL ESTABLISHED 29–30 (2008), *available at* http://www.westgov.org/wga/publicat/wildlife08.pdf (emphasizing the need for better data regarding wildlife species).

dislocations, changes in lifestyle or business conduct, or limitations on growth and sprawl. Increased knowledge bases — from increased monitoring of ecological conditions, improved modeling, and information sharing — will be necessary for a whole range of adaptation issues.[169] Even the IPCC has acknowledged that uncertainty regarding climate change impacts creates barriers to adopting and implementing effective adaptation measures,[170] and "[c]onflicting understandings can impede adaptive actions."[171]

Thus, increased knowledge about what climate change is doing to particular resources and ecosystem services can increase adaptive capacity by allowing specific changes to be identified and observed and hence making particular social impacts, especially economic impacts like those in Montana, more certain. Such knowledge can help to overcome political impediments to identifying and implementing adaptation measures.[172]

Principle #2: Eliminate or Reduce Non–Climate Change Stresses and Otherwise Promote Resilience

Principle #2 encompasses immediate, "no regrets" changes that legislatures and regulators can make to environmental and natural resources laws, even in the absence of detailed information about climate change impacts, that will nevertheless improve resilience and adaptive capacity. They are "no regrets" measures because, regardless of actual climate change impacts, they will reduce the toxicity of the environment, improve human health, and contribute to sustainability.

As the IPCC noted in 2007, "vulnerability to climate change can be exacerbated by other stresses."[173] In other words, ecosystems that are already coping with other problems, such as pollution, habitat destruction, and loss of biodiversity, are more vulnerable to climate change impacts than systems not already suffering from such stresses.

Many of these other stresses do not derive from climate change but instead from standard human-controlled activities, such as development and polluting industrial activities. These activities are amenable to the same "plain vanilla" regulation that currently characterizes environmental and natural resources law. Thus, by more stringently addressing these directly

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[169] *See* Milly et al., *supra* note 36, at 574 (calling for improved modeling and "[r]apid flow of such climate-change information from the scientific realm to water managers").

[170] IPCC ADAPTATION REPORT, *supra* note 7, at 735 (citations omitted).

[171] *Id.* at 736.

[172] The IPCC has identified four such impediments: (1) the failure of increased knowledge about the causes and effects of climate change to lead to the adoption of adaptation strategies; (2) differing perceptions of climate change risks; (3) varying perceptions of vulnerability and adaptive capacity, which influence a person's willingness to undertake adaptation measures; and (4) the fact that guilt and fear do not work to motivate the initiation of adaptation responses. *See id.* at 735.

[173] IPCC, ADAPTATION REPORT: SUMMARY FOR POLICYMAKERS, *supra* note 57, at 19. More specifically, "[n]on-climate stresses can increase vulnerability to climate change by reducing resilience and can also reduce adaptive capacity because of resource deployment to competing needs." *Id.*

anthropogenic, non–climate change stressors, climate change adaptation law can do much to increase the resilience of ecosystems. Ecosystems so protected will generally have increased capacity to adapt to *climate change* impacts — to changes in temperature and other baseline ecological conditions — that humans will *not* be able to effectively regulate. In other words, while a pure restoration paradigm would unproductively encourage futile goals, climate change adaptation law should nevertheless seek to reduce or eliminate all of the existing stressors that it can in order to increase socio-ecological systems' resilience to climate change impacts that cannot be blunted.

The IPCC in 2007 identified coral reefs as one example of already overstressed ecosystems. Reefs suffer from both non–climate change stressors such as overfishing, marine pollution, and chemical runoff from agriculture, and climate change-related stressors such as increases in water temperature and ocean acidification.[174] Thus, coral reefs are textbook examples of ecosystems where regulable stressors are compromising the systems' resilience to climate change impacts.

Marine biologists have emphasized that "the direct and indirect effects of overfishing and pollution from agriculture and land development have been the major drivers of massive and accelerating decreases in abundance of coral reef species, causing widespread changes in reef ecosystems over the past two centuries."[175] Fishing pressure disrupts coral reef food webs. Moreover, both removal of plant-eating fish through overfishing and nutrient pollution in agricultural runoff can promote the growth of destructive marine algae. Even before climate change impacts, therefore, these stressors "have caused ecological shifts, from the original dominance by corals to a preponderance of fleshy seaweed."[176] Seventeen marine scientists thus argued in *Science* that improving coral reefs' resilience in the face of climate change impacts "requires a strong focus on reducing pollution, protecting food webs, and managing key functional groups (such as reef constructors, herbivores, and bioeroders) as insurance for sustainability."[177] In other words, humans can greatly enhance coral reefs' ability to adapt to climate change by regulating and managing human-controlled non–climate change stressors.

In other systems as well, the existence of multiple stressors can undermine socio-ecological systems' adaptive capacities. In the IPCC's example, "farming communities in India are exposed to impacts of import competition and lower prices in addition to climate risks; marine ecosystems overexploited by globalised fisheries have been shown to be less resilient to climate variability and change."[178] In contrast, as the USCCSP has recently empha-

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[174] *Id.* (discussing the effect of temperature on coral reefs).

[175] Hughes et al., *supra* note 153, at 929 (citations omitted).

[176] *Id.* at 929, 932 (citations omitted). *See also* Adger et al., *supra* note 27, at 1037 (describing the same shift on some reefs).

[177] Hughes et al., *supra* note 153, at 932 (citations omitted).

[178] IPCC, ADAPTATION REPORT, *supra* note 7, at 719.

sized, reducing known stresses can "make ecosystems healthier and more resilient as climate changes."[179]

Several subprinciples follow from Principle #2.

1. *Decontaminate Land, Water, and Air, and Reduce New Pollution as Much as Possible*

Principle #2 strongly suggests that federal and state pollution control laws are important components of climate change adaptation law. By reducing the amount of pollution added to or left in land, water, and air, these regulatory regimes already reduce ecological stressors and hence contribute to overall resiliency.

As coral reefs demonstrate, however, pollution control laws do not yet adequately regulate all types and sources of pollution known to cause ecological harm. As one well-known example, nutrient pollution from agriculture not only damages coral reefs but also is the primary cause of the hypoxic zone ("Dead Zone") in the Gulf of Mexico and contributes to ongoing water quality and biodiversity problems in the Chesapeake Bay. Thus, amendments to the existing pollution control laws may be warranted to increase their contributions to socio-ecological systems' adaptive capacity. For example, some pollution control regulatory goals currently assume the ability of ecosystems and media to absorb certain amounts of pollution up to a human-determined qualitative standard, such as air quality requisite to protect human health under the CAA or the designated uses incorporated into CWA water quality standards. A goal of increasing adaptive capacity may prompt a shift in focus towards reducing new pollution to the greatest extent possible, and eliminating particular kinds of discharges and emissions to reduce pollution stressors even further.[180]

Numerous specific amendments should follow from this shift in focus. First, pollutants that are known to be stressors but that currently largely escape effective regulation, such as nutrient pollution of water,[181] should be brought within the ambit of the relevant regulatory regimes. Second, sources of pollution that are not being regulated effectively or comprehensively, such as nonpoint and agricultural sources of water pollution and minor stationary sources of air pollution, should be incorporated into the relevant regulatory regimes. Finally, instead of allowing pollution control requirements based on lesser standards of technological capability, such as the CWA's "best conventional control technology"[182] and the CAA's "rea-

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[179] 2009 USCCSP ECOSYSTEM THRESHOLDS REPORT, *supra* note 21, at 7.

[180] For example, Dan Farber has recommended radical reform of the federal Toxic Substances Control Act to follow the European model. *See* Farber, *supra* note 33, at 1358, 1374–79.

[181] NAT'L RESEARCH COUNCIL, MISSISSIPPI RIVER WATER QUALITY AND THE CLEAN WATER ACT: PROGRESS, CHALLENGES, AND OPPORTUNITIES 36–45, 126–28 (2008).

[182] 33 U.S.C. § 1311(b)(2)(E) (2006).

sonably available control technology,"[183] legislatures might incorporate both more demanding standards based on the best available technologies and incentives for continual innovation in pollution control technologies and manufacturing processes with technology-forcing regulatory requirements. Similarly, EPA could make greater use of its existing authorities to reduce or ban releases of toxic pollutants into the environment, as through CWA effluent standards[184] and CAA revisions of maximum achievable control technology-based emissions standards.[185]

On the other side of pollution regulation, the new goal of increasing adaptive capacity suggests that governments should direct more money and effort toward cleaning up existing contamination on land and in waterbodies, particularly along coasts, in floodplains, and in likely corridors of ecosystem shifting and adjustment. I have already discussed, for example, how reducing coastal contamination will both improve efforts to adapt to sea level rise and decrease the damage to coastal areas from Hurricane Katrina–like storms.[186] However, CERCLA's cleanup program has faltered recently.[187] Recent bills introduced in Congress to revive the Superfund tax to fund CERCLA cleanups[188] are thus a step in the right direction.

2. *Convert "Maximum Sustainable Yield" and Similar Regulatory Standards to "Clearly Sustainable Even Under Climate Change" Standards*

Regulatory standards based on "sustainable yield" or "sustained yield" pervade U.S. natural resources law. For example, fisheries management under the Magnuson-Stevens Fishery Conservation and Management Act seeks to achieve "maximum sustainable yield."[189] Federal land agencies such as the U.S. Forest Service and Bureau of Land Management ("BLM") manage national forests and other public lands under "multiple-use sustained-yield" legal regimes, including the Multiple-Use Sustained-Yield Act

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[183] 42 U.S.C. § 7502(c)(1) (2006).

[184] 33 U.S.C. § 1317(a).

[185] 42 U.S.C. § 7412(d)(2).

[186] *See* Robin Kundis Craig, *A Public Health Perspective on Sea-Level Rise: Starting Points for Climate Change Adaptation*, 15 WIDENER L. REV. (forthcoming 2010) (manuscript at 21–28), available at http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1119563.

[187] The Public Interest Research Group ("PIRG") reported in 2004 that:

> [Superfund] cleanups have fallen by 50 percent during the Bush administration compared with the pace of cleanups between 1997 and 2000. Site listings have slowed down as well; the Bush administration has listed an average of 23 Superfund sites a year compared with an average of 30 sites from 1993 to 2000, a drop of 23 percent.

JULIE WOLK, U.S. PIRG EDUC. FUND, THE TRUTH ABOUT TOXIC WASTE CLEANUPS: HOW EPA IS MISLEADING THE PUBLIC ABOUT THE SUPERFUND PROGRAM 1 (2004), *available at* http://www.uspirg.org/home/reports/report-archives/toxic-free-communities.

[188] *E.g.*, Superfund Polluter Pays Act, H.R. 832, 111th Cong. (2009); Superfund Reinvestment Act of 2009, H.R. 564, 111th Cong. (2009).

[189] 16 U.S.C. §§ 1802(33), (34), 1852(g)(1)(B), 1853(a)(3) (2006).

of 1960,[190] the Forest and Rangeland Renewable Resources Planning Act of 1974,[191] and the Federal Lands Policy and Management Act.[192] "Sustained yield" under these statutes, like "maximum sustainable yield" in fisheries, promotes "high-level annual or regular periodic output" of timber and other renewable resources.[193]

However, one of the more troubling legacies of natural resource management in the United States is that "sustainable yield" standards tend to err on the side of more human harvest or extraction rather than institutionalizing any kind of precautionary principle or margin of error in favor of the species or ecosystem. Thus, even before climate change, these natural resource management regimes rarely achieved true "sustainable" use of the relevant resources. Instead, "maximum sustainable yield" and similar standards allow more harvest and taking than is truly sustainable. Indeed, U.S. fisheries are widely acknowledged to suffer from overfishing,[194] and Julian Caldecott has recently noted that "[c]atastrophic over-fishing worldwide is rooted in our trying to achieve 'rational' use, based on an inadequate understanding of wildlife populations and ecology."[195] He has also described in detail the pervasive flaws that help to ensure "that the [maximum sustained yield] approach will result in exhausted fisheries and a largely dead ocean."[196] Similarly, Robert Fischman has concluded that, for national forests, multiple use sustained yield "tilted toward maintaining commodity outputs at the expense of ecological integrity."[197]

As in coral reef ecosystems, overharvest of living resources creates additional stress for the ecosystems of which they are a part, impairing or destroying ecosystem functions and services and increasing the ecosystem's vulnerability to climate change impacts. In contrast, "[b]iodiversity enhances resilience if species or functional groups respond differently to environmental fluctuations, so that declines in one group are compensated by increases in another."[198] As such, making harvest standards *truly* sustainable would increase ecosystems' resilience and decrease their vulnerabilities, even in the absence of climate change impacts.

Climate change impacts further problematize the whole concept of "sustainable yield." How do regulators decide what a sustainable take might be when species are rearranging and ecosystems are transforming all

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[190] *See id.* § 529.

[191] *Id.* § 1604.

[192] 43 U.S.C. § 1701(a)(7) (2006).

[193] 16 U.S.C. § 531(b); 43 U.S.C. § 1702(h).

[194] *See, e.g.*, Peter Schikler, *Has Congress Made It Harder to Save the Fish? An Analysis of the Limited Access Privilege Program (LAPP) Provisions of the Magnuson-Stevens Fishery Conservation and Management Reauthorization Act of 2006*, 17 N.Y.U. ENVTL. L.J. 908, 910 (2008) (noting that American fisheries management is unsustainable).

[195] CALDECOTT, *supra* note 58, at 79.

[196] *Id.* at 81–83.

[197] Robert L. Fischman, *Forestry*, *in* STUMBLING TOWARD SUSTAINABILITY 327, 331 (John C. Dernbach ed., 2002).

[198] Adger et al., *supra* note 27, at 1037.

the time? The regulatory pitfall, of course, is the muddling of causation: did a species collapse in one area because of overharvest or because of climate change? Given that we are dealing with complex adaptive systems, the answer is likely to be that climate change impacts and human extraction will interact synergistically to produce ecological results that neither would have produced on its own.

Given past failures and these new uncertainties in defining sustainability, climate change adaptation law should promote increased resilience by reenvisioning "sustained yield" and "sustainable yield" management directives to something far more precautionary than has been employed in the past. For example, more protective standards might become more likely, and burdens on public lands managers already struggling with ambiguous definitions of "sustainable yield" perhaps reduced, if natural resources laws presumed that all take, harvest, or extraction in the climate change era is unsustainable until proven otherwise, shifting the burden of proof for appropriate standards to those who wish to take natural resources for their own profit. Similarly, instead of seeking "maximum" and "high-level" sustainable yields, law- and policymakers should consider the alternative of "clearly sustainable" standards that require incorporation of projected climate change impacts and modeling, with revisions as better information becomes available.

Political resistance to these changes is inevitable. Almost by definition, the species subject to sustainable yield standards are economically valuable — worth the time and investment to catch, cut, or harvest. For precisely that reason, however, these are species for which interested parties should want to significantly improve resilience and long-term survival, especially if climate change is already affecting the species' availability. Properly cabined, therefore, existing profit motives and self-interest could provide political palatability for legal reforms.

3. *Stop Subsidizing or Otherwise Encouraging Maladaptive Behaviors, and Provide Incentives for Adaptive Behaviors*

As part of efforts to increase resilience, governments should carefully reevaluate the incentives that laws currently create. Perverse incentives are a recognized if generally unintended consequence of environmental and natural resources law. The CAA's new source review provisions, designed to ensure that existing emitters upgrade their pollution control technology as they upgrade other aspects of the facilities, have instead motivated owners to extend the working life of the facility at less stringent emissions requirements.[199] The ESA's connection of habitat modification to species protection can encourage landowners to destroy protected species before the FWS

[199] Jonathan Remy Nash & Richard L. Revesz, *Grandfathering and Environmental Regulation: The Law and Economics of New Source Review*, 101 Nw. U. L. Rev. 1677, 1713–14 (2007).

knows that they are present.[200] Agencies and legislatures should eliminate these known perverse incentives as part of efforts to increase adaptive capacity.

Additionally, employing existing environmental and natural resources laws in a world of climate change is likely to illuminate other maladaptive incentives not yet obvious. Regulators and legislatures should be alert to such problems and willing to realign incentives when they become apparent.[201]

The laws governing agriculture are a particularly significant source of perverse incentives that climate change adaptation law should address. As Craig Cox has noted, "The environmental implications of U.S. agricultural conservation policy, programs, and institutions are enormous. Cropland, pasture, and rangeland make up more than 50 percent of the land area in the continental United States."[202]

As just one example, subsidies and market realities have encouraged widespread monocropping in both agriculture[203] and forestry, undermining crop species' abilities to cope with new pests and diseases. One result, aided by warm winters, has been the pine beetle's spread through large stands of lodgepole pine in Canada. Another has been increased use of pesticides and

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[200] Stephen J. Dubner & Steven D. Levitt, *Unintended Consequences: The Case of the Red-Cockaded Woodpecker*, N.Y. TIMES MAG., Jan. 20, 2008, at 18–19.

[201] With respect to sea-level rise, for example, Jim Titus has provided a fairly comprehensive overview of how governments, especially the federal government, can change the incentive structures of their various coastal-related programs and laws. *See* James G. Titus, *Does the U.S. Government Realize that the Sea Is Rising? How to Restructure Federal Programs so that Wetlands and Beaches Survive*, 30 GOLDEN GATE U. L. REV. 717, 734–39, 752–71 (2000).

An example of an incentive problem in environmental law that already has largely been realigned to increase adaptive capacity is the problem of ownership of contaminated sites and brownfields under CERCLA. CERCLA's strict, retroactive, and joint and several liability made ownership of contaminated properties financially risky for both lenders and prospective purchasers, even when they clearly bore no responsibility for that contamination. As a result, CERCLA liability obstructed transactions that might otherwise have led to the cleanup and redevelopment of such properties and instead promoted the development (and potential contamination) of "greenfield" sites. Juha Siikamäki & Kris Wernstedt, *Turning Brownfields into Greenspaces: Examining Incentives and Barriers to Revitalization*, 33 J. HEALTH POL. POL'Y & L. 559, 561 (2008). Such perverse incentives applied even to lightly contaminated industrial properties ("brownfields") destined for the foreseeable future for industrial use. *Id.* at 561–62. Through a series of amendments to CERCLA, Congress provided reasonable protections to lenders, 42 U.S.C. § 9601(20)(E) (2006), and made it easier for "bona fide prospective purchasers" to purchase and redevelop "brownfield sites," *id.* §§ 9601(35), 9601(39), 9607(b)(3). While these amendments have not yet perfectly realigned incentives to make redevelopment of contaminated sites the clearly more attractive option to developing "virgin sites," they have nevertheless removed many barriers to reusing contaminated sites. *See, e.g.*, Siikamäki & Wernstedt, *supra*, at 586 (noting that the fact of contamination continues to impede conversion of brownfields to greenspace).

[202] Craig Cox, *U.S. Agriculture Conservation Policy & Programs: History, Trends, and Implications*, *in* U.S. AGRICULTURAL POLICY AND THE 2007 FARM BILL 113, 113 (Kaush Arha et al. eds., 2007).

[203] *See, e.g.*, William S. Eubanks II, *The Sustainable Farm Bill: A Proposal for Permanent Environmental Change*, 39 Envtl. L. Rep. (Envtl. Law Inst.) 10,493, 10,494–95 (2009).

fertilizers,[204] many of which derive from petroleum and hence contribute to our dependence on fossil fuels and to increased greenhouse gas emissions. Moreover, these pesticides and fertilizers become sources of surface and groundwater pollution,[205] stressing downstream aquatic ecosystems such as coral reefs and jeopardizing water supplies. While successive Farm Bills have incorporated incentives for farmers to protect water quality,[206] this legislation has also been much criticized[207] — and incentives on the back end do little to address the core sources of the problem.[208]

As another example, biofuels subsidies have created multiple perverse incentives in the agricultural sector. These subsidies incentivize farmers to convert food crops to fuel crops during a period of worldwide crop failure; to switch to more pesticide- and fertilizer-intensive crops, increasing demand for and application of those products; and to take farmlands out of conservation programs,[209] reducing habitat[210] and increasing threats to water quality.

In contrast, a host of agricultural techniques already exist that would better promote resiliency of crops, agricultural lands, and affected terrestrial and aquatic ecosystems. These include precision farming, organic farming, companion planting and crop rotation, no-till agriculture, buffers in riparian zones, and the cultivation of heirloom species.[211] Rebecca Goldman, Barton

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[204] Rebecca L. Goldman, Barton H. Thompson & Gretchen C. Daily, *Managing for Ecosystems Services on U.S. Agricultural Lands*, *in* U.S. AGRICULTURAL POLICY AND THE 2007 FARM BILL, *supra* note 202, at 97, 99 ("Pesticide use more than doubled in just over 30 years on about 70 percent of current cropland acreage," and "[c]ommercial fertilizers are prevalent on many U.S. farms. In just over 20 years, nitrogen fertilizer use increased 335 percent; over 12 million nutrient tons were being used in 1998.").

[205] *Id.* at 100.

[206] *See* Cox, *supra* note 202, at 115–21 (providing a history of farm environmental programs).

[207] *See, e.g.*, Jonathan Cannon, *A Bargain for Clean Water*, 17 N.Y.U. ENVTL. L.J. 608, 626–27 (2008) (acknowledging that Farm Bill subsidies can themselves create perverse incentives); Cox, *supra* note 202, at 113 (noting that the 2002 Farm Bill spent $4 billion per year on conservation programs but provided crop and farm income subsidies of between $10 and $20 billion per year); Kaush Arha et al., *Conserving Ecosystem Services Across Agrarian Landscapes*, *in* U.S. AGRICULTURAL POLICY AND THE 2007 FARM BILL, *supra* note 202, at 207, 208 (noting that "the present set of farm conservation programs — though successful in part — fails to articulate and execute a conservation strategy that accounts for the full range of ecosystem services across all agricultural landscapes").

[208] Daniel A. Sumner, Kaush Arha & Tim Josling, *Commodity Policy and the 2007 Farm Bill*, *in* U.S. AGRICULTURAL POLICY AND THE 2007 FARM BILL, *supra* note 202, at 5, 14 ("At best commodity programs can be configured to contribute less environmental damage. But it takes other types of programs — those tied directly to environmental outcomes, not those tied to commodity production — to effectively deal with the rural environment.").

[209] *See* Cox, *supra* note 202, at 133 (noting the importance of more permanent land reserves and the great vulnerability of such land reserves to "changes in market conditions, budget pressures, and policy priorities").

[210] *Id.* at 127 (noting that the Conservation Reserve Program in particular had "produced great benefits to wildlife populations — particularly grassland nesting birds and migratory waterfowl").

[211] *See, e.g.*, Goldman et al., *supra* note 204, at 98–100, 106 (discussing precision farming, organic farming, no-till, crop rotation techniques, and means of reducing water pollution in the U.S.).

H. Thompson, and Gretchen C. Daily have recently advocated for "ecological agriculture" to support biodiversity and ecosystem services, including "broad scale landscape vision and management" and "[r]ewards for services rather than just food and fiber."[212] In addition to reducing or eliminating the perverse incentives discussed above, such revised agriculture policies could also promote farms' abilities to provide many ecosystem services that would contribute both to the productivity of the farmland itself and to the resiliency of socio-ecological systems, including water purification, pollination, soil fertility, sequestration of greenhouse gases, flood mitigation, and biodiversity enhancement.[213] Reworking[214] and rescaling[215] the legal incentives for agriculture thus could yield widespread benefits by increasing the resilience and adaptive capacity of many sectors and ecosystems.

Although not directly a component of environmental regulation and natural resource management, insurance also provides important incentives relevant to both mitigation and adaptation law.[216] In particular, government-subsidized insurance programs can provide either adaptive or maladaptive incentives to insured parties. The National Flood Insurance Program, for example, has already been widely criticized for the incentives it provides property owners to develop and rebuild in floodplains and along coasts.[217] This is a highly maladaptive incentive in the face of projected increased flooding, coastal storms, and rising sea levels.

4. *Preserve and Expand Open Space and Ecosystem Connectivity*

As noted, climate change is likely to outstrip, or at the very least challenge, species' and ecosystems' intrinsic capacities to adapt, even if those capacities are not already diminished by anthropogenic stressors. As the IPCC noted in 2007, one of the potential barriers to climate change adaptation is "the inability of natural systems to adapt to the rate and magnitude of climate change."[218] Given that one of the most damaging existing stressors

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[212] *Id.* at 97; *see also* Arha et al., *supra* note 207, at 207 (arguing that "conserving ecosystem services across the agrarian landscapes should deservedly be recognized as one of the major goals of the U.S. agricultural policy").

[213] Goldman et al., *supra* note 204, at 100–05, 106–07.

[214] *See, e.g.*, Cox, *supra* note 202, at 129 (advocating that the U.S. "[r]etool conservation programs and institutions for environmental management and enhance the environmental performance of the conservation programs we already have in place" and provide "'[g]reen' crop subsidy, insurance, and related programs designed to support income, stabilize price, or manage risk").

[215] *See, e.g., id.* at 131 (advocating a change in focus from individual farms to the watershed or landscape scale); Goldman et al., *supra* note 204, at 107 (noting that managing agriculture for certain ecosystem services, such as flood mitigation, biodiversity conservation, and water quality requires "looking at the agricultural system as a landscape").

[216] *See, e.g.*, Sean B. Hecht, *Climate Change and the Transformation of Risk: Insurance Matters*, 55 UCLA L. REV. 1559 (2008).

[217] *See, e.g.*, Jim Blackburn & Larry Dunbar, *Houston's High Water Problems*, 46 HOUSTON LAWYER 18, 22–23 (2008); Kelley M. Jancaitis, *Florida on the Coast of Climate Change: Responding to Rising Seas*, 31 ENVIRONS: ENVTL. L. & POL'Y 157, 186 (2008).

[218] IPCC, ADAPTATION REPORT, *supra* note 7, at 719.

for many species is loss of habitat,[219] one of the most effective adaptation measures humans could implement may be to preserve as much connected and varied open space as is physically and politically possible and let species and ecosystems sort themselves out in response to climate change impacts.[220]

Lending support to this subprinciple, the USCCSP has suggested that coastal management programs that already preserve open space along the coast "may also help coastal ecosystems adapt to rising sea level,"[221] recognizing that, "[u]nder natural conditions, habitats are continually shifting, and species generally have some flexibility to adapt to varied geography and/or habitat type."[222] Jonathan Verschuuren at Tilburg University, the Netherlands, has recommended an adaptation strategy focused on "making protected areas climate proof by making sure that these areas are large enough and stable enough to adapt to the changed climate":

> Protected areas should be able to live through flooding in winter, wild fires in the summer, [and] storm damage and should have enough variety in habitat types to host new species. This for many protected areas means an enormously intensified protection measures [sic], for instance by enlarging sites or connecting existing sites into one much larger site.[223]

Similarly, seventeen marine scientists have declared that networks of no-take marine reserves and better management of the areas surrounding them are "essential" to coral reef resilience and survival in an era of climate change.[224]

Assisted migration for species is a much-debated adaptation strategy that might limit the need for additional protected areas.[225] While acknowl-

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[219] Eric W. Seabloom, Andy P. Dobson & David M. Stoms, *Extinction Rates Under Nonrandom Patterns of Habitat Loss*, 99 PROC. NAT'L ACAD. SCI. 11,229, 11,229 (2002).

[220] *See* Zinn, *supra* note 56, at 87–88 (describing the potential "death by a thousand cuts" from habitat loss).

[221] U.S. CLIMATE CHANGE SCI. PROGRAM, SYNTHESIS AND ASSESSMENT PRODUCT 4.1: COASTAL SENSITIVITY TO SEA LEVEL RISE: A FOCUS ON THE MID-ATLANTIC REGION 6 (2009).

[222] *Id.* at 5.

[223] Verschuuren, *supra* note 45, at 6. *See also* Adger et al., *supra* note 27, at 1037 ("Spatial heterogeneity can also confer resilience . . . ."); CALDECOTT, *supra* note 58, at 204–05 (describing the importance of expanding protected areas, while simultaneously emphasizing that non-protected areas are not then "expendable").

[224] Hughes et al., *supra* note 153, at 932. *See also* Moises Velasquez-Manoff, *Parks That Can Move When the Animals Do*, CHRISTIAN SCI. MONITOR, Mar. 4, 2009, at 13 ("[F]ew — and maybe none — of the more than 4,500 marine protected areas (MPAs) established worldwide have been explicitly designed to cope with climate change . . . [but experts] are already thinking about how to design MPAs that still function as climates change. Maybe they're bigger, say scientists, or spaced like stepping stones . . . . Perhaps they're not tied to a geographic location at all . . . .").

[225] *See, e.g.*, Julie Lurman Joly & Nell Fuller, *Advising Noah: A Legal Analysis of Assisted Migration*, 39 Envtl. L. Rep. (Envtl. Law Inst.) 10,413 (2009); Glicksman, *supra* note 140, at 889–91; John Kostyack & Dan Rohlf, *Conserving Endangered Species in an Era of Global Warming*, 38 Envtl. L. Rep. (Envtl. Law Inst.) 10,203, 10,209 (2008); Ruhl, *Building Bridges*, *supra* note 112, at 53, 61–62; Jason S. McLachlan et al., *A Framework for Debate of Assisted Migration in an Era of Climate Change*, 21 CONSERVATION BIOLOGY 297, 298–99 (2007).

edging that debate and the potential value of assisted migration in certain circumstances — as well as the probable necessity for seed banks, botanic gardens, and zoos as stopgap measures to save otherwise doomed species — this Article consciously adopts an attitude of humility in the face of ecological responses to climate change and assumes that, given enough room and enough options, Nature will generally do a better job of adapting ecosystems to new baseline conditions than humans will. As the IPCC has pointed out, "Human intervention to manage the process of adaptation in biological systems is also not well understood, and the goals of conservation are contested."[226]

Hobbs and Cramer acknowledge that the new reality of climate change adaptation and the "no-analogue future" suggest the need "for a new approach in which ecological restoration focuses on the future as much as, if not more than, on the past" and that "the pathway toward this new formulation is not yet clear and requires new ways of thinking and clearer insights regarding the dynamics of ecosystems under novel conditions."[227] As a result, "it remains important to question the extent to which humanity can meddle with nature, albeit in an increasingly intelligent way, given the legacy of problems from past attempts."[228]

Principle #3: Plan for the Long Term with Much Increased Coordination Across Media, Sectors, Interests, and Governments

As decision makers acquire reliable information about local and regional climate change impacts, planning for future climate change adaptation will become increasingly important at all levels of government.[229]

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[226] IPCC, ADAPTATION REPORT, *supra* note 7, at 737. More generally, humans' ability to restore ecosystems has been limited, even in contexts where we have a good idea of what's missing or what went wrong; what restoration abilities exist are likely to be substantially reduced as the ecosystems themselves reshuffle components. As restoration ecologists Richard Hobbs and Viki Cramer have noted, however, "[d]eciding on what type of intervention, if any, is required for the effective restoration of an ecosystem (or particular components or processes) presupposes a clear understanding of how the ecosystem works and what the outcomes of the intervention are likely to be." Hobbs & Cramer, *supra* note 121, at 42. Furthermore, "[t]he more degraded an ecosystem is, and the more fundamentally the basic ecosystem processes have been altered, the more difficult and expensive restoration will be." *Id.* at 43. Thus, Hobbs and Cramer recently summarized, "[i]t is becoming increasingly apparent that the theoretical and practical underpinnings of restoration have to be reconsidered in the light of rapid environmental changes, which can act synergistically to transform ecosystems and render the likelihood of returning to past states more unlikely." *Id.* at 50.

[227] *Id.* at 51.

[228] *Id.* at 54–55.

[229] Heltberg and fellow researchers concluded that:

> [W]hile most adaptation will necessarily take place at the local level, global efforts are required. What we mean is that most successful adaptation efforts are likely to be local as communities and other subnational actors respond to the localized manifestations of emerging climate risks. However, local actors will increasingly need external support because the risks — large, covariate, and possibly with irreversible damages — can overwhelm local adaptive capacity.

However, to reduce redundancies, increase efficiency, and avoid conflicting adaptation measures, planning must be coordinated, and where possible integrated, within and among those various levels. Thus, Principle #3 calls for planning that is both longer term and better coordinated than what currently exists, with adjustments to relevant institutional structures as necessary.

Adaptation measures can be classified along a number of variables, but two of the most important for law and planning are the temporal variable and the spatial scale variable. With respect to temporal variability, regulatory adaptation efforts can respond to three basic and overlapping levels of climate change effects: current variability; medium- and long-term trends that have actually been observed in the relevant locality; and predicted longer-term changes based on modeling.[230] Measures that respond to current variability — observed changes — are often the most politically palatable because they address acknowledged and often relatively limited changes in circumstances.[231] Regulation to adapt to longer-term and especially predicted changes may be prudent in the long run,[232] but it is also far more likely to raise political obstacles as a result of greater uncertainties in the effects, greater immediate costs to implement, potentially greater displacement from the status quo, and the frequent mismatch of ecological and political timescales. Thus, climate change adaptation law must have mechanisms that both allow for and encourage adaptation planning and implementation of adaptation measures on a variety of timescales.

The spatial scale variable acknowledges that climate change impacts, and the means of adapting to them, can occur at several spatial scales. For example, the decreasing ability of Delta smelt to survive in the Sacramento–San Joaquin Delta or of farmers in Montana to have adequate water supplies for summer irrigation are fairly local effects, while the pine beetle infestation is an impact of national importance, and the conversion of Arctic tundra to Arctic shrubland is a change of regional and arguably international scale. Complicating the legal aspects of this spatial dimension is the fact that laws potentially applicable to any one of these impacts can exist at several levels of government simultaneously, leading to potential fragmentation of regulatory purpose.[233] Laws relevant to the Delta smelt and Montana's rivers, for example, include city or county land use planning requirements, state water law and environmental policies, state-federal interactions such as contracts governing irrigation projects or cooperative federalism arrangements under the CWA or CAA,[234] and purely federal regulation, as through the ESA.[235] Coordinating levels of regulation to generate appropriate adap-

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Heltberg et al., *supra* note 27, at 95.

[230] IPCC, ADAPTATION REPORT, *supra* note 7, at 720.

[231] *See id.* at 720–21 (discussing such measures as promoting existing development goals).

[232] *Id.* at 721.

[233] *See generally* Craig, *supra* note 115 (discussing the regulatory problems of protecting coastal estuaries and the probability that climate change will make regulatory coordination even more difficult).

[234] 33 U.S.C. § 1342(b) (2006).

[235] 16 U.S.C. §§ 1536, 1538 (2006).

tive responses at the relevant spatial scale is one of the great challenges for the law of climate change adaptation.[236]

The subprinciples in this section offer initial suggestions for acknowledging and effectively incorporating these multi-scalar aspects of climate change adaptation.

1. *Acknowledge and Avoid Potential Conflicts Between Human and Species/Ecosystem Adaptation*

As the IPCC pointed out in 2007, most of the literature regarding socio-ecological systems' responses to climate change has focused on the limitations that ecological changes may impose on humans' capacities to adapt.[237] In a particularly dramatic example of this perspective, researchers at the World Bank recently argued "that serious — even catastrophic and irreversible — damage to natural systems from climate change need not result in catastrophic and irreversible damage to humans. In contrast, catastrophic and irreversible damage to humans can result even from modest changes in natural systems."[238]

In contrast to this anthropocentric point of view, not enough attention has been paid to the fact that reverse influences are also likely — that is, that human adaptations to climate change will interfere with species' and ecosystems' capacities to adapt.[239] For example, coastal populations in the United States may start moving inland in response to rising sea levels, building new homes and businesses on previously undeveloped land and almost certainly putting additional stress on the species trying to survive in those same spaces. Californians and other residents of an increasingly water-strapped West may migrate in mass numbers to wetter areas, shifting their demand to new water resources.

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[236] *See generally* Craig, *supra* note 115; Ruhl & Salzman, *supra* note 84 (creating a typology of various kinds of "wicked" regulatory problems and suggesting strategies for regulatory agencies in addressing them); Hari M. Osofsky, *Is Climate Change "International"? Litigation's Diagonal Regulatory Role*, 49 VA. J. INT'L L. 587, 587 (2009) (noting that "[c]limate change is an individual, local, state, national, regional, and international problem" and proposing the concept of "diagonal regulation" as a means of coordinating these various regulatory spheres). My thinking on the spatial and governance issues involved in climate change has benefited greatly from conversations and correspondence with Alex Camacho, Hari Osofsky, and J.B. Ruhl, and I thank them for that engagement.

[237] IPCC, ADAPTATION REPORT, *supra* note 7, at 734; *see* Ford, *supra* note 25; Farber, *supra* note 33, at 1394 ("Adaptation planning requires an assessment of how climate will impact human activities and how to respond to those changes."); *World's Fisheries Face Climate Change Threat*, ENVTL. NEWS NETWORK, Feb. 23, 2009, http://www.enn.com/top_stories/article/39359 (on file with the Harvard Law School Library) (warning "that millions of people dependent on fisheries in Africa, Asia and South America could face unprecedented hardship as a consequence of climate change").

[238] Heltberg et al., *supra* note 27, at 89.

[239] *See* Zinn, *supra* note 56, at 66 ("The direct environmental changes caused by unabated climatic warming will put new pressure on human communities to which they will need to adapt, either proactively or retroactively. In turn, those adaptations will produce secondary environmental effects scarcely discussed in the climate change literature."); *id.* at 67–81 (describing a variety of these secondary impacts).

In contrast to human efforts to adapt to climate change, biological adaptation — the adaptation of species and ecosystems — is purely reactive, not anticipatory.[240] Thus, humans should do the anticipating and provide other species with space to adapt, underscoring both the need for comprehensive adaptation planning and the importance of Subprinciple 4 of Principle #2.

The litigation that has required federal agencies to consider climate change impacts as part of their existing assessment duties under NEPA and Section 7 of the ESA provides one step toward incorporating this subprinciple into law.[241] Indeed, in June 2009, in a Section 7 Biological Opinion, NMFS actively incorporated climate change impacts into its description of the ecological baseline for six ESA-listed species potentially affected by the Central Valley Project/State Water Project in California.[242] It concluded that "[t]he historic hydrologic pattern . . . can no longer be solely relied upon to forecast the future" and that "[c]limate change will affect the entire life cycle of salmonids and sturgeon through warmer ocean periods, changes in age and size at maturity, decline in prespawn survival and fertility due to higher stream temperatures, and a loss of lower elevation habitat."[243] Models and the latest scientific information "indicate[ ] that climate change will negatively affect the Central Valley listed species and their proposed or designated critical habitats."[244] As a result, NMFS incorporated anticipated climate change impacts into its "Reasonable and Prudent Alternatives" recommendations.[245]

States are also beginning to anticipate the need to accommodate wildlife in human adaptation. In June 2008, the Western Governors' Association established the Western Wildlife Habitat Council.[246] Among other duties, the Council is tasked to "[c]oordinate and implement steps that foster establishment of a 'Decisional Support System' (DSS) with each state," including "[p]rioritization of the process for identifying wildlife corridors and crucial habitats, and taking steps accordingly to support adaptation to climate change."[247] The Council is also working "to establish policies that ensure information from state-led Decisional Support Systems is considered early in planning and decision-making processes, whether federal, tribal, state or local, in order to preserve these sensitive landscapes through avoidance, minimization, and mitigation."[248]

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[240] IPCC, ADAPTATION REPORT, *supra* note 7, at 720.

[241] *But see* Zinn, *supra* note 56, at 85 (questioning the efficacy of the NEPA EIS for climate change adaptation).

[242] NMFS, CVP/SWP OPINION, *supra* note 12, at 172–74.

[243] *Id.* at 173 (citation omitted).

[244] *Id.* However, NMFS also noted that "[u]ncertainties abound at all levels. We have only the crudest understanding of how salmonid habitats will change and how salmonid populations will respond to those changes, given a certain climate scenario." *Id.*

[245] *Id.* at 579.

[246] W. GOVERNORS' ASS'N, *supra* note 168, at 1.

[247] *Id.* at 2. *See also id.* at 5 (detailing climate change impacts to wildlife in the context of other anthropogenic impacts).

[248] *Id.* at 2.

Acknowledging the coadaptation of species and ecosystems with humans has obvious implications for land use planning, growth management, and agriculture law, as well. For example, efforts to apply this subprinciple may create yet another incentive to incorporate New Urbanism approaches to city planning, concentrating human settlements into densely settled and self-sufficient neighborhoods and towns, with limited connections between such neighborhoods and towns.[249] Such a strategy could simultaneously increase humans' adaptive capacity by reducing energy consumption and demand and improving human health.[250]

However, this subprinciple may also challenge policy makers' assumptions about the scales of planning relevant to climate change adaptation.[251] Local land use planning, for example, operates at the wrong scale to deal with mass migrations. Moreover, the potential for mass migrations may create a demand for national-level cost-benefit analyses of adaptation strategies and lead to changes in assumptions about who controls what resources. For example, despite the general presumption that water law and water allocation are state prerogatives, it may be that, at the national level, everyone is better off if the nation as a whole finds ways to reliably supply California's almost thirty-four million people with sufficient water, and hence encourage them to remain in California cities, rather than do nothing and experience a reverse–Dust Bowl mass migration to relatively unsettled plains regions.

2. *Acknowledge Climate Change in All Levels of Governmental Planning*

Despite the potential for climate change to impact water resources, agricultural productivity, forest productivity, and coastal management, climate change considerations have yet to be widely incorporated into governmental planning and assessment at any level.[252] As the IPCC recognized in 2007,

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[249] For information about New Urbanism, see generally Online NewsHour, *New Urbanism: What Is New Urbanism?*, http://www.pbs.org/newshour/newurbanism/keypoints.html (last visited Dec. 27, 2009) (on file with the Harvard Law School Library).

[250] *See* New Urbanism, Sprawl and Health, http://www.newurbanism.org/newurbanism/sprawlhealth.html (last visited Dec. 27, 2009) (on file with the Harvard Law School Library); New Urbanism, Green Transportation, http://www.newurbanism.org/transport.html (last visited Dec. 27, 2009) (on file with the Harvard Law School Library) (noting that employment of these principles leads to less dependence on cars and foreign oil).

[251] For example, Emma Tompkins and Neil Adger have argued that:

> [T]he imposed impacts of climate change are manifest at particular localities. In some political systems, although the appropriate institutional scale for adaptation is often that of municipal or local resource management institutions, the interaction between institutions across scales is constrained by the power relationships among these bodies. In effect, the diversity of impacts of climate change means that the most appropriate adaptation responses will often be on multiple levels.

Tompkins & Adger, *supra* note 66, at 3 (citation omitted).

[252] *See, e.g.*, Glicksman, *supra* note 140, at 866–68 (recommending that the federal public lands agencies "make climate change a priority in the planning process").

such planning is critical.[253] Moreover, the IPCC labels this integration of climate change planning into existing regulatory programs and structures as "mainstreaming," and it considers mainstreaming important for all levels of government, from the international to the local.[254]

In general, "mainstreaming" refers to the incorporation and prioritization of climate change adaptation considerations into all areas of government regulation and planning for development.[255] Mainstreaming thus prevents climate change adaptation from being relegated to an afterthought and instead integrates adaptation considerations into existing procedures and decision making. In Least Developed Countries, for example, mainstreaming generally requires that climate change adaptation be incorporated "within the national policy making processes in those countries."[256]

In the United States, New York City provides one fairly comprehensive example of climate change mainstreaming at the municipal level. The City has adopted a Climate Change Initiative, a strategy that addresses land, water, transportation, energy, and air issues.[257] Indeed, the climate change strategy "is the sum of all the initiatives in this plan."[258] While the City focused first on climate change mitigation and reducing its greenhouse gas emissions, it is now beginning "a long-term effort to develop a comprehensive climate change adaptation strategy, to prepare New York for the climate shifts that are already unavoidable."[259] Such comprehensive mainstreaming needs to occur in all governments in the United States — local, state, and federal.

3. *Consider a Range of Possible Long-Term Futures When Planning*

The IPCC has emphasized that the effects of climate change on human society depend significantly on which development pathway individual societies and the world at large decide to follow.[260] Because many of these decisions are currently outside of any one government's complete control, planners need to consider a range of potential future events and ecological states. In addition, the unpredictability of climate change effects and especially of those impacts' interactions and feedback loops counsels governments and other decision makers to consider a wide range of possible futures

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[253] IPCC, ADAPTATION REPORT: SUMMARY FOR POLICYMAKERS, *supra* note 57, at 20.

[254] *Id.* at 731–33.

[255] *See* ORGANISATION FOR ECON. CO-OPERATION & DEV., POLICY BRIEF: PUTTING CLIMATE CHANGE ADAPTATION IN THE DEVELOPMENT MAINSTREAM 1 (2006), *available at* http://www.oecd.org/dataoecd/57/55/36324726.pdf (indicating that mainstreaming works to "[b]ridg[e] the gap between the climate change adaptation and development communities").

[256] SALEEMUL HAQ ET AL., MAINSTREAMING ADAPTATION TO CLIMATE CHANGE IN LEAST DEVELOPED COUNTRIES (LDCs) 7 (2003), *available at* http://www.un.org/special-rep/ohrlls/ldc/LDCsreport.pdf.

[257] PLANYC, *Climate Change*, http://nyc.gov/html/planyc2030/html/plan/climate.shtml (last visited Dec. 27, 2009) (on file with the Harvard Law School Library).

[258] *Id.*

[259] *Id.*

[260] HAQ ET AL., *supra* note 256, at 19–20.

when planning adaptation strategies, especially over the longer term. Daniel Farber has emphasized this point recently, arguing that "[r]ather than searching for economically efficient strategies to address climate change, we should focus . . . on adaptation strategies that are robust across a broad range of scenarios."[261]

To find such robust strategies, however, planners must first describe and incorporate a broad range of potential futures. As the IPCC acknowledged in 2007, "climate change poses novel risks often outside the range of experience, such as impacts related to drought, heatwaves, accelerated glacier retreat and hurricane intensity."[262]

Thus, an important tool for adaptation planning will be scenario building. Scenario building aids long-term planning by considering multiple plausible futures, without predicting the "most likely" future conditions.[263] Instead, the goal of scenario building is to "challenge assumptions and foster strategic thinking about possible responses to different futures."[264] The National Park Service, for example, is already using scenario building to plan for climate change.[265] Ideally, climate change adaptation scenario building would make use of the information gathered and models produced in pursuit of Principle #1.

4. *Increase Regulatory Coordination Across Media and Objects*

American environmental and natural resources law tends to create different regulatory regimes for different media and regulatory objects, with limited requirements for coordination among those regimes. With respect to pollution regulation, for example, federal law creates the CAA, the CWA, and, for land, RCRA and CERCLA. Forests are managed under different statutes than other public lands, while endangered species, migratory birds, fish, and marine mammals each have their own governing federal statutes.

Links between such statutes are limited, leaving certain problems unresolved. For example, mercury emitted into the air by sources regulated under the CAA falls out of the sky, often making its way into bodies of water.[266] Nevertheless, the CAA's emission requirements for mercury do not require EPA to set emissions standards sufficient to prevent water pollution.[267]

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[261] Farber, *supra* note 33, at 1357.

[262] IPCC, ADAPTATION REPORT, *supra* note 7, at 719.

[263] Leigh Welling, *Climate Change Scenario Planning: A Tool for Managing Resources in an Era of Uncertainty* 3 (2008), *available at* http://www.fs.fed.us/psw/cirmount/meetings/mtnclim/2008/talks/pdf/Welling_Talk2008.pdf (on file with the Harvard Law School Library).

[264] *Id.* at 4.

[265] *See generally id. See also* W. GOVERNORS' ASS'N, *supra* note 168, at 30 (recommending changes in wildlife corridor planning accounting for projected climate change impacts).

[266] Craig, *supra* note 115, at 857–61, 885–87.

[267] 42 U.S.C. § 7412(d)(2) (2006) (requiring only that the EPA Administrator "tak[e] into consideration . . . any non-air quality health and environmental impacts," among other factors, when setting the technology-based National Emissions Standards for Hazardous Air Pollution).

Climate change adaptation law needs to recognize and fill the gaps between existing regulatory regimes to ensure that regulation under one law does not undermine the resilience and adaptive capacity of another medium or regulatory object. For pollution control statutes, such coordination can most easily be incorporated into the existing regulation of the source. In natural resource management, coordination may more often require legislatures to decide which management regime takes priority and then require overlapping regimes to acknowledge that priority. For example, Congress has coordinated certain aspects of endangered species and marine mammal regulation so that endangered or threatened marine mammals receive the most stringent of the protections that either the ESA or the Marine Mammal Protection Act offers them.[268]

5. *Increase Regulatory Coordination Among Governmental Bodies*

According to the IPCC, responses to climate change should include "actions at all levels from the individual citizen through to national governments and international organizations."[269] Such multilevel efforts, however, will be most effective if they are coordinated or, at the very least, not working at cross-purposes.

Regulatory fragmentation, however, is a prominent feature of environmental and natural resources law, interfering with government coordination toward a common goal of increasing resilience and adaptive capacity.[270] Celebrating the fact that states and the federal government operate in overlapping, rather than distinct, spheres of regulatory authority, the expanding literature of dynamic federalism is already suggesting new productive possibilities for the interactions of those two levels of government.[271] These explorations may bear fruit for climate change adaptation law.[272]

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[268] 16 U.S.C. § 1536(b)(4)(C) (2006).

[269] IPCC, ADAPTATION REPORT: SUMMARY FOR POLICYMAKERS, *supra* note 57, at 20.

[270] Glicksman, *supra* note 140, at 873–75; Craig, *supra* note 115, at 834–61, 866–78, 884–90; Zinn, *supra* note 56, at 83, 86–87; William W. Buzbee, *Recognizing the Regulatory Commons: A Theory of Regulatory Gaps*, 89 IOWA L. REV. 1, 27–36 (2003). As the Western Governors' Association concluded:

> Wildlife do not observe political boundaries or land ownership. Conservation of wildlife corridors and crucial habitats must therefore be coordinated across government, including the federal land management agencies (BLM & Forest Service), federal agencies responsible for water delivery and flood control (Bureau of Reclamation and the Corps of Engineers), federal wildlife agencies (Fish and Wildlife Service and [NMFS]), tribal governments, states; and local governments.

W. GOVERNORS' ASS'N, *supra* note 168, at 6.

[271] *See, e.g.*, David E. Adelman & Kirsten H. Engel, *Adaptive Federalism: The Case Against Reallocating Environmental Regulatory Authority*, 92 MINN. L. REV. 1796, 1799–1802 (2008) (arguing for an ecosystem-like model of adaptive federalism in environmental law); Kirsten H. Engel, *Harnessing the Benefits of Dynamic Federalism in Environmental Law*, 56 EMORY L.J. 159, 174–77 (2006) (arguing that the old model of dual federalism is not the reality in environmental law and extolling the benefits of dynamic federalism).

[272] Scholars are certainly already considering its benefits for climate change mitigation. *See, e.g.*, Daniel P. Schramm, *A Federal Midwife: Assisting the States in the Birth of a Na-*

Other mechanisms are also likely to be helpful. For example, overcoming regulatory fragmentation may require legislatures to align and prioritize statutory mandates. In addition, new coordinating bodies may prove helpful in avoiding inefficient fragmentation of climate change adaptation efforts. I have suggested elsewhere, for example, that watershed-level entities could provide comprehensive oversight of the various navigation, damming, water allocation, agricultural, pollution regulation, species protection, recreation, estuary, and coastal decisions made within that watershed.[273] Daniel Farber, in turn, has suggested that a new Sustainability Office is needed within the Office of Management and Budget to coordinate the current Office of Information and Regulatory Affairs, the Council on Environmental Quality, and parts of the National Oceanic and Atmospheric Administration and the FWS.[274]

6. *Give Meaningful Weight to Public Rights and Values in Private Property*

As the IPCC has acknowledged, there are significant "financial, cognitive and behavioural, and social and cultural constraints" on the implementation of adaptation measures.[275] In the United States, one source of resistance to significant adaptation measures is likely to be popular conceptions of private property rights as "absolute,"[276] while fear of constitutional "takings" liability is likely to inspire at least some governments to drag their proverbial feet in implementing necessary measures.[277] In addition, as Lawrence Brown and Lawrence Jacobs have noted, American culture has tended to "embrace[ ] minimal government and maximal individual liberty."[278] None of these proclivities are well suited to climate change adaptation, which is likely to require a community-based valuation system.[279] Climate change

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tional Greenhouse Gas Cap-and-Trade Program, 22 TUL. ENVTL. L.J. 61, 86 (2008) (extolling the virtues of dynamic federalism in a cap-and-trade program over picking one level of government).

[273] Craig, *supra* note 115, at 925–27.

[274] Farber, *supra* note 33, at 1397–99.

[275] IPCC, ADAPTATION REPORT, *supra* note 7, at 719.

[276] Christine A. Klein, *The New Nuisance: An Antidote to Wetland Loss, Sprawl, and Global Warming*, 48 B.C. L. REV. 1155, 1158–67 (2007).

[277] *See, e.g.*, Darren Botello-Samson, Lawsuits, Property, and the Environment: Measuring the Impact of Regulatory Takings Litigation on Surface Coal Mining Regulations 42–43 (Aug. 31, 2006) (unpublished manuscript), *available at* http://www.allacademic.com/meta/p151975_index.html (suggesting that regulatory takings litigation can have a chilling effect on environmental and natural resources regulation).

[278] BROWN & JACOBS, *supra* note 157, at 128.

[279] Tompkins and Adger write that:

> Although not a panacea, community engagement may offer a means of reducing vulnerability to the natural hazards associated with climate change. Critiques of how participatory planning is applied have highlighted its frequent lack of consideration for ecosystem heterogeneity and intracommunity dynamics as well as the differential access to resources inherent in some community-based management.

Tompkins & Adger, *supra* note 66, at 2 (citations omitted).

adaptation law should thus anticipate the need for several alterations in cultural norms,[280] much as World War II required several layers of pervasive domestic cultural adjustments, including in the workforce, in consumption patterns, and in acceptable and desirable behaviors.

Notably, when the IPCC reported on climate change adaptation measures in the United States, it emphasized state land acquisition programs[281] that facilitate the conversion of private land to public land, which makes the implementation of land-based adaptation measures easier.[282] Moreover, within the United States, the public interest–private rights tug-of-war has been engaged in repeatedly in the context of coastal protection measures; it is no accident that one of the most prominent regulatory takings cases in the U.S. Supreme Court involved restrictions on coastal development.[283]

As Christine Klein has recognized, "[i]n a healthy society, there is a rough give-and-take between individual autonomy and community well-being."[284] In an unhealthy, stressed, or war-ravaged society, in contrast, the balance tends to tip sharply in favor of preservation of the community, allowing for measures such as quarantine, rationing, and the suspension of habeas corpus.

Like war and epidemic diseases, climate change adaptation could well become a matter of community survival. As such, it warrants rebalancing of public and private interests. As this Article has argued throughout, climate change impacts will alter the basic parameters of ecosystems, which in turn provide ecosystem services[285] to human communities, creating complex coupled socio-ecological systems. Climate change threatens to transform these

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[280] *See, e.g.*, *id.* at 10 ("Adaptation to climate change requires a broader conceptualization of equitable, legitimate, and sustainable development in effective and resilient response."); *id.* at 11 ("Action to adapt and maintain resilience in the face of climate change requires adjustments by governments, by individuals acting as citizens and through market exchange, and by civil society through collective action."); *id.* at 12 ("[N]ot all ways of adapting to climate change are in harmony with existing social norms, institutions, and structures.").

[281] IPCC, ADAPTATION REPORT, *supra* note 7, at 722 tbl.17.1. Specifically, the Report highlighted:

> Land acquisition programmes taking account of climate change (e.g., New Jersey Coastal Blue Acres land acquisition programme to acquire coastal lands damaged or prone to damages by storms or buffering other lands; the acquired lands are being used for recreation and conservation); establishment of a 'rolling easement' in Texas, an entitlement to public ownership of property that 'rolls' inland with the coastline as sea-level rises; other coastal policies that encourage coastal landowners to act in ways that anticipate sea-level rise.

Id. *See also* W. GOVERNORS' ASS'N, *supra* note 168, at 6 ("Wildlife conservation on private lands is best accomplished through the use of incentives and tools that encourage and facilitate private landowners and private industry to achieve conservation objectives.").

[282] *See also* Glicksman, *supra* note 140, at 877–81 (discussing the federal government's potential uses of the Property Clause and condemnation authority to protect public lands and their ecosystems in an era of climate change).

[283] Lucas v. S.C. Coastal Council, 505 U.S. 1003 (1992).

[284] Klein, *supra* note 276, at 1158.

[285] *See generally, e.g.*, NATURE'S SERVICES: SOCIETAL DEPENDENCE ON NATURAL ECOSYSTEMS (Gretchen C. Daily ed., 1997); COMM. ON ASSESSING & VALUING THE SERVS. OF AQUATIC & RELATED TERRESTRIAL ECOSYSTEMS, NAT'L RESEARCH COUNCIL, VALUING

systems, rendering human societies vulnerable. As a legal matter, that threat alone should be sufficient to prompt revitalized legal attention to the public and community values of private property and to the legal doctrines that give cognizance to those values: nuisance,[286] the public trust doctrine,[287] and public necessity.[288]

Principle #4: Promote Principled Flexibility in Regulatory Goals and Natural Resource Management

Given the complex nature of ecosystems, long-term planning, even when based on robust adaptation strategies or better scientific information about climate change impacts, is unlikely to eliminate all surprises. Moreover, climate change adaptation planning and implementation by definition address continual, not one-time, change, and that change will often be nonlinear. Therefore, Principle #4 is to adapt the law itself to allow principled flexibility to become a reality.

1. *Interpret or Amend Existing Laws to Allow Principled Flexibility Regarding Environmental Management Goals to Reflect Changing Baseline Conditions*

Environmental laws, particularly pollution control laws, have often been inflexible in certain respects. For example, anti-backsliding requirements are important components of many pollution control permits.[289] Principled flexibility does not require the elimination of these provisions, particularly where such measures prevent or reduce regulable (non–climate change–caused) anthropogenic stresses in accordance with Subprinciple 1 of Principle #2. Moreover, many existing laws already contain provisions that are sufficiently flexible to address climate change impacts to baseline ecological conditions.[290]

ECOSYSTEM SERVICES: TOWARD BETTER ENVIRONMENTAL DECISION-MAKING (2005); RUHL ET AL., *supra* note 35.

[286] *See, e.g.*, Michael C. Blumm & Lucus Ritchie, Lucas*'s Unlikely Legacy: The Rise of Background Principles as Categorical Takings Defenses*, 29 HARV. ENVTL. L. REV. 321, 331–41 (2005) (describing the role of public nuisance as a limitation on private property rights).

[287] *See, e.g.*, California v. Super. Ct. Placer County, 625 P.2d 256, 260 (Cal. 1981) (upholding the public interest in public trust protections for shore lands and noting that "[p]reservation of the public trust in the shore zone will allow the state the flexibility in determining the appropriate use of such land").

[288] *See, e.g.*, John Alan Cohan, *Private and Public Necessity and the Violation of Property Rights*, 83 N.D. L. REV. 651, 690–733 (2007) (outlining the various kinds of public necessity and the right of public needs to impinge on private property rights and noting that no compensation is required if private property is destroyed to avoid a "public calamity").

[289] *See, e.g.*, 33 U.S.C. § 1342(o) (2006) (providing the CWA's anti-backsliding provision for National Pollutant Discharge Elimination System permits).

[290] *See* Craig, *The Cutting Edge*, *supra* note 148, at 17 (discussing the value of the CWA's water quality criteria and water quality-based effluent limitation provisions for climate change adaptation).

Nevertheless, existing law does occasionally restrict flexibility in ways that could undermine climate change adaptation. For example, the water quality standards provisions of the CWA include an antidegradation requirement, which prohibits states from allowing existing uses of water bodies to degrade.[291] Because water quality standards must incorporate existing uses as designated uses,[292] climate change–driven changes to baseline water conditions can both put a state in violation of the antidegradation policy and, more importantly, trigger the Act's TMDL provisions,[293] designed originally to ensure that waters would eventually meet and maintain the applicable water quality standards.[294]

The TMDL provisions are an important tool for protecting the nation's waters from standard anthropogenic sources of water pollution, and this Article does not advocate their repeal. However, when violations of water quality standards derive solely or most significantly from climate change impacts, restoring pre–climate change water quality is likely to be practically impossible. For example, Montana's streams, pre–climate change, supported healthy trout populations. If climate change impacts continue to raise water temperatures, those existing trout uses may become unsupportable. However, forcing Montana into the expensive and time-consuming process of drafting and implementing a TMDL is sheer waste, because no immediately regulable sources of effluent or runoff can bring stream temperatures back down. Incorporating a "climate change adaptation exemption" into such provisions would avoid inefficient and expensive inflexibility in the face of climate change impacts that alter baseline ecological conditions.

Of course, increasing regulatory flexibility always opens the door to potential abuse.[295] However, there are ways to cabin climate change adaptation exemptions to minimize misuse. For example, such exemptions should require the relevant regulatory or management agency to show to some standard of proof that climate change processes were the proximate cause of alterations in baseline ecological conditions — air, land, or water temperature; hydrology or precipitation patterns; sea level; air quality — that made compliance with the regulatory mandate through the normal regulatory mechanisms impossible. Principled flexibility is just that: flexibility to deal with the climate change impacts that are beyond human control in a principled way to achieve general adaptation goals, not abdication of all environmental regulation and management.

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[291] 40 C.F.R. § 131.12 (2009).

[292] *Id.* § 131.12(a)(1).

[293] 33 U.S.C. § 1313(d)(1).

[294] *Id.* § 1313(d)(4).

[295] *See, e.g.*, Glicksman, *supra* note 140, at 862 (describing problems with federal lands agencies having too much discretion).

2. *Be Serious About Using Adaptive Management — and Change Both Natural Resources and Administrative Laws to Allow for It*

Especially with respect to natural resources and public lands management, climate change adaptation is the quintessential adaptive management problem, and both scientists and governments (at all levels) have acknowledged that adaptive management is a necessary approach to climate change adaptation.[296] Adjusting to climate change impacts and feedback loops will require regulatory and management agencies to respond to changing ecological conditions and shifting goals on a more or less continuous basis, preferably — per Principle #1 — in response to continuous informational inputs regarding exactly what is occurring. Legislatures and policymakers should thus incorporate comprehensive and pervasive adaptive management requirements and procedures into natural resource management statutes.[297]

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[296] For instance, Joshua J. Layler writes:

> What is new is a turning toward a more agile management perspective. To address climate change, managers will need to act over different spatial and temporal scales. The focus of restoration will need to shift from historic species assemblages to potential future ecosystem services. Active adaptive management based on potential future climate impact scenarios will need to be a part of everyday operations. And triage will likely become a critical option.

Joshua J. Lawler, *Climate Change Adaptation Strategies for Resource Management and Conservation Planning*, ANNALS N.Y. ACAD. SCI., Apr. 2009, at 79, 79. *See also* Glicksman, *supra* note 140, at 868–71; AUSTL. DEP'T OF ENV'T. & HERITAGE, CLIMATE CHANGE IMPACTS AND RISK MANAGEMENT: A GUIDE FOR BUSINESS AND GOVERNMENT 19–21 (2006), *available at* http://www.climatechange.gov.au/impacts/publications/pubs/risk-management.pdf (recommending adaptive management strategies in a risk management approach to adapting to climate change); Int'l Council for Local Envtl. Initiatives (ICLEI) Oceania Secretariat, Adaptive and Resilient Communities Program: Local Government Climate Change Adaptation Toolkit, http://www.iclei.org/index.php?id=adaptation-toolkit (last visited Dec. 27, 2009) (recommending the Australian Government's risk management/adaptive management approach); Tony Prato & Dan Fagre, *Coping with Climate Change*, ACTIONBIOSCIENCE, Oct. 2006, http://www.actionbioscience.org/environment/prato_fagre.html (on file with the Harvard Law School Library) ("Adaptive management (AM) is a science- and information-based approach that is well suited for managing natural resources for climate and landscape change."); Tompkins & Adger, *supra* note 66. One state agency described its approach this way:

> The uncertainty surrounding the extent and potential impacts of climate change requires a flexible management approach that can be continually revised and adapted. The Department's adaptive management strategies are iterative processes where monitoring and assessment continually refine our policies and management decisions. By closely linking research and management we are better able to anticipate and respond to the effects of climate change.

Commonwealth of Mass. Dep't of Fish & Game, Adapting to Climate Change, http://www.mass.gov/dfwele/climatechange.htm (last visited Dec. 27, 2009) (on file with the Harvard Law School Library).

[297] *See, e.g.*, Lara Whitely Binder, *Preparing for Climate Change in the U.S. Pacific Northwest*, 15 HASTINGS W.-N.W. J. ENVTL. L. & POL'Y 183, 189–90 (2009) (calling for adaptive planning in climate change adaptation policy); Ruhl, *Complex Adaptive System*, *supra* note 112, at 996 (advocating adaptive management as the proper process for regulating complex adaptive systems like ecosystems).

As several scholars have pointed out,[298] effective incorporation of adaptive management almost certainly requires adjustments to administrative law as well. Standard procedures for agency rulemaking are cumbersome and hence can discourage frequent amendment.[299] By demanding front-end justification for all measures proposed and taken, existing standards for judicial review can stifle an agency's willingness to experiment.[300]

With the exception of a few constitutional principles, however, administrative law requirements are statutory, subject to amendment. There has long been an assumption that the same basic administrative procedural requirements should apply to all agencies and in all regulatory contexts, regardless of the regulatory program or objective. In reality, most administrative law already imposes substantially different requirements in adjudications and in rulemakings, and Congress has already tweaked the basic requirements of the federal Administrative Procedure Act[301] in the ESA[302] and the CAA.[303] Climate change adaptation may productively become the occasion for the next generation of administrative law, the twenty-first century's answer to the mid-twentieth century's original administrative law revolution.

This is not an argument for wholesale repeal of public participation, judicial review, or any of the other safeguards that administrative law provides. Indeed, retaining current administrative procedures will be warranted and appropriate for many kinds of agency decisions, even in the climate change era. For example, current rulemaking requirements will remain useful in pollution regulation, especially with regard to technology-based limitations on emissions or effluent discharges, because getting the regulatory standard "right" is more important than the need to build capacity for flexible responses to changing conditions. These standards apply to facilities and reflect the technologies available to industries, not ecological conditions. Moreover, as Robert Glicksman has argued, effective enforcement against agencies remains critical for climate change adaptation measures.[304]

Nevertheless, this is a call for scholars and lawmakers to think creatively about how to restructure those legal safeguards and allow administrative agencies more breathing room to deal with climate change adaptation. For example, public lands managers may need some form of general plan-

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[298] Alfred R. Light, *Tales of the Tamiami Trail: Implementing Adaptive Management in Everglades Restoration*, 22 J. LAND USE & ENVTL. L. 59, 96–98 (2006); J.B. Ruhl, *Regulation by Adaptive Management — Is It Possible?*, 7 MINN. J. L. SCI. & TECH. 21, 30–31, 35–38, 53–57 (2005); John H. Davidson & Thomas Earl Geu, *The Missouri River and Adaptive Management: Protecting Ecological Function and Legal Process*, 80 NEB. L. REV. 816, 859–60 (2001). The discussion in this section has also benefited from my correspondence with Alex Camacho regarding one of his works in progress.

[299] Ruhl, *supra* note 298, at 36–37.

[300] *Id.* at 34–36. *See also* Farber, *supra* note 33, at 1399 (arguing that climate change requires increased incentives for agencies to act).

[301] 5 U.S.C. §§ 551–559, 701–706 (2006).

[302] 16 U.S.C. § 1533(a), (b) (2006).

[303] 42 U.S.C. § 7607 (2006).

[304] Glicksman, *supra* note 140, at 884–85.

ning requirements coupled with abbreviated administrative procedures for specific implementation decisions, periodic rather than continual judicial review for rationality, the ability to rely on postdecisional evaluations rather than predecisional justifications, or increased emergency authorities in order to achieve true capacity for adaptive management in the face of climate change impacts to resources and ecosystems.

3. *Prefer "No Regrets" Management Options First, Especially in the Face of Scientific Uncertainty*

One of the advantages climate change adaptation strategies often have is the ability to pursue two or more socially useful goals simultaneously.[305] These overlaps mean that governments can often choose, especially in the early stages of implementation, "no regrets" adaptation strategies — that is, measures that will increase resilience and the capacity to adapt to particular climate change impacts if those impacts actually occur, but will still enhance overall social welfare even if they do not materialize.[306]

As one example, I have argued that coastal areas can undertake many measures to adapt to climate change–driven sea level rise that will also enhance those communities' responses to hurricanes, storm surges, and storm- and sea-related public health problems.[307] Such dual- and triple-purpose measures minimize the political fallout that could occur from expenditures that the public might perceive as wasted or unnecessary while governments at all levels attempt to figure out what a locality's or region's actual climate change impacts are likely to be.

4. *Engage in Robust Decision Making with Respect to More Permanent or Expensive Adaptation Strategies to Help Retain Flexibility and Avoid Path Dependence*

Social scientists have noted that global climate change creates a key challenge for policymakers and scientists alike: "decision making under pervasive uncertainty associated with complex socio-ecological processes."[308]

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[305] For example, according to the IPCC, "[m]any actions that facilitate adaptation to climate change are undertaken to deal with current extreme events such as heatwaves and cyclones. Often, planned adaptation initiatives are also not undertaken as stand-alone measures, but embedded within broader sectoral initiatives such as water resource planning, coastal defence and disaster management planning." IPCC, ADAPTATION REPORT, *supra* note 7, at 719.

[306] *See* Heltberg et al., *supra* note 27, at 89 (defining "'no regrets' adaptation interventions" as "actions that generate net social benefits under all future scenarios of climate change and impacts"). As these authors further explain, "[n]o-regrets interventions are useful for hedging climate exposure because of the uncertainty over climate scenarios. They seek to build a general resilience that does not depend overly on detailed climate projections. However, 'no-regrets' does not mean cost-free: no-regrets options have real or opportunity costs or represent trade-offs." *Id.* at 95 (citations omitted).

[307] *See* Craig, *supra* note 186.

[308] John M. Anderies et al., *Panaceas, Uncertainty, and the Robust Control Framework in Sustainability Science*, 104 PROC. NAT'L ACAD. SCI. 15,194, 15,194 (2007).

One tendency in the face of such uncertainty and mounting pressure to "do *something*" is for decision makers to quickly and unadvisedly adopt simple "solutions" or panaceas that cannot reflect the true complexities of the problem,[309] then consider the problem "resolved." Failure to acknowledge the complexity and changing understanding of climate change impacts, however, will not lead to effective climate change adaptation strategies at any level.

Instead, decision makers should be cognizant that retaining as much flexibility as possible is itself an important adaptation strategy. This strategy is especially important during the early stages of climate change, while information regarding impacts and effects in particular locations and adequate models to generate future predictions are still being developed. Climate change adaptation law should thus encourage or require robust decision-making processes that identify adaptation measures that will be helpful under a variety of climate change scenarios for many adaptation decisions. These processes would be especially important for any decisions that involve significant investments in relatively permanent adaptation measures.

Adaptation to sea level rise is likely to be one of the first testing grounds for this subprinciple, especially in communities where residents call for expensive investments in dikes and sea walls to hold back the sea. However, reliance on robust decision making will also be relevant in decisions to site and construct sewage treatment plants, drinking water treatment plants, and hazardous waste treatment, storage, and disposal facilities; decisions whether to invest in new electric power generation, and what kind; decisions whether to invest in desalination plants, and where; decisions to allow new residential and industrial developments; decisions whether to construct new or replace old roads and highways; and decisions whether to construct new or replace old water infrastructure — in sum, in any decision regarding whether, where, and how to invest substantial capital in long-lasting infrastructure. This subprinciple thus also underscores the importance of Principle #3 and the general need for more coordinated decision making and planning.

Climate change adaptation decision making may thus require new tools that allow for flexibility in designing strategies. As one approach to flexibility, the IPCC has acknowledged "the value of a portfolio or mix of strategies that includes mitigation, adaptation, technological development (to enhance both adaptation and mitigation) and research (on climate science, impacts, adaptation and mitigation). Such portfolios could combine policies with incentive-based approaches . . . ."[310] More specifically on point for robust decision making, John M. Anderies and colleagues have described a "robust control" methodology for natural resource management, which "expos[es] how [management] policies distribute robustness and vulnerability across a given system" and "highlight[s] the importance of continual learning," as

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[309] *Id.*

[310] IPCC, ADAPTATION REPORT: SUMMARY FOR POLICYMAKERS, *supra* note 57, at 20.

well as the inevitability of trade-offs.[311] For the legal and policy realms, Daniel Farber has noted the potential of Robust Decision Making ("RDM")[312] as a tool for identifying particularly robust adaptation strategies — that is, "policies that perform well over many possible situations."[313] RDM is a computer-aided, statistical analysis of multiple future scenarios that helps planners both "to determine which characteristics of the scenarios are critical to the success or failure of particular strategies" and to generate increasingly robust adaptation policies.[314] Farber notes that RDM may be particularly useful for the types of large-scale, long-term infrastructure decisions discussed here.[315]

Principle #5: Accept — Really *Accept* — *That Climate Change Adaptation Will Often Be Painful*

Perhaps the most difficult aspect of climate change adaptation law, policy, and planning will be the acceptance of loss. Principled flexibility will require means of acknowledging ecological loss — the inability to save certain species in a "natural" environment or to preserve all existing ecosystem functions and services in particular locations. As the scientific journal *Nature* reported in 2004:

> Many plant and animal species are unlikely to survive climate change. New analyses suggest that 15–37% of a sample of 1,103 land plants and animals would eventually become extinct as a result of climate changes expected by 2050. For some of these species there will no longer be anywhere suitable to live. Others will be unable to reach places where the climate is suitable.[316]

Similarly, even with a massive effort to reduce non–climate change stressors to coral reefs, "the available evidence indicates that, at a global scale, reefs will undergo major changes in response to climate change," and even though they may not "disappear entirely," "[t]here is, nonetheless, great uncertainty whether the present economic and social capacity of coral reefs can be maintained."[317] Moreover, as the coral reef example illustrates, loss

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[311] Anderies et al., *supra* note 308, at 15,198, 15,199.

[312] Farber, *supra* note 33, at 1395.

[313] *Id.* at 1396.

[314] *Id.*

[315] *Id.*

[316] *Feeling the Heat: Climate Change and Biodiversity Loss*, NATURE HIGHLIGHTS, Jan. 8, 2004, http://www.nature.com/nature/links/040108/040108-1.html (on file with the Harvard Law School Library). Indeed, an international panel of marine scientists concluded that ocean acidification alone "may render most regions chemically inhospitable to coral reefs by 2050." Cornelia Dean, *Rising Acidity Is Threatening Food Web of Oceans, Science Panel Says*, N.Y. TIMES, Jan. 31, 2009, at A12.

[317] Hughes et al., *supra* note 153, at 932.

of biodiversity can reduce "an ecosystem's ability to deliver goods and services for human well-being."[318]

With regard to individual species, protections in the wild can be supplemented by programs to preserve species in captivity, in hope of reintroducing them somewhere at some future date. With regard to ecosystems and their services, however, as with adaptation measures in general, "[d]ifficult choices will have to be made."[319] I have suggested elsewhere that a triage model of decision making — figuring out what is likely to survive with little or no human intervention, what is likely to be lost regardless of human effort, and what species and ecosystems would benefit most from human intervention — may prove helpful in responding to climate change impacts on water resources.[320] Other models, such as RDM, may prove more helpful in other climate change adaptation contexts, such as deciding among multiple proposed development plans or among different overall adaptation strategies.

The larger point for environmental and natural resources law, however, is that climate change adaptation presents lawmakers and policymakers with a difficult balancing act. Climate change adaptation law must incorporate an acceptance that some losses are inevitable while avoiding a morose complacency about losses that may be preventable. The law should not make the sacrifice of species, ecosystem function, and ecosystem services too easy. On the other hand, in the climate change era, comprehensive preservation is impossible. For this reason, climate change adaptation law must empower regulators and managers to cope with climate change–driven loss without automatically violating some legal requirement or otherwise incurring legal liability. Attempting to place blame for unavoidable losses simply wastes resources, reducing society's collective adaptive capacity to pursue more productive management and regulatory measures.

CONCLUSION

The climate change era is upon us, and phenomena such as the changing Arctic tundra, expanding pine beetle infestations, and Montana's warming trout streams are harbingers of the growing need for effective adaptation strategies. As in any situation that mixes scientific uncertainty, politics, and potentially large shifts in economic, social, and socio-ecological well-being, conflicts regarding how to proceed are inevitable.

Such conflicts, however, will only delay necessary decisions. The local character of many climate change impacts may assuage certain kinds of po-

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[318] SWEDISH BIODIVERSITY CTR., FACT SHEET NO. 2: CLIMATE CHANGE AND ECOSYSTEM SERVICES 1, *available at* http://www.swedbio.com/dokument/fact%20sheet%20climate-en.pdf (last visited Dec. 27, 2009) (on file with the Harvard Law School Library).

[319] Binder, *supra* note 297, at 195.

[320] Craig, *supra* note 115, at 920–21.

litical conflicts — but they may also exacerbate conflicts among the various levels of government and subject-matter-based regulatory authorities.

This Article suggests, first and foremost, that two necessary steps in successful climate change adaptation will be (1) to adopt shared and overarching principles for climate change adaptation that can apply in a variety of scenarios, and (2) to change the law to remove existing barriers to, and to actively promote the implementation of, those principles in adaptation strategies. To those ends, this Article has argued for a principled flexibility model of climate change adaptation law to pursue goals of increasing the resilience and adaptive capacity of species, ecosystems, and socio-ecological systems. It has laid out five principles and several subprinciples for the climate change adaptation law of environmental regulation and natural resource management. Structurally, however, this Article also strongly suggests that climate change adaptation law must be bimodal: it must promote informed and principled flexibility when dealing with climate change impacts, especially impacts that affect baseline ecological conditions, while simultaneously embracing an unyielding commitment to stringent precautionary regulation when dealing with almost everything else. The five principles articulated in this Article give shape and content to that bimodality and can be applied in environmental regulation and natural resource management at all levels of government.

For example, consider again Montana's trout streams. Under current law, climate change impacts are likely to lead to forced and expensive establishment of TMDLs under the CWA in a futile attempt to achieve temperature standards that can no longer be achieved; listing of the trout species under the ESA, with consequent heroic (and again expensive) efforts to preserve viable populations in streams where survival is becoming impossible; curtailment of farmers' irrigation rights as a result of legal battles to preserve the trout; and takings litigation over those water rights. In many respects, California is already traveling this path, as the Delta smelt controversy highlights. Climate change adaptation dictates hard choices, but climate change adaptation law should not require this kind of futile and expensive attempt to preserve ecosystems in formations that can no longer exist.

Application of principled flexibility, in contrast, would prompt managers to acknowledge that Montana's trout streams are in fact changing and to adapt their use and management to evolving ecological realities. Under the first principle, relevant agencies at all levels of government should be gathering and sharing information regarding the flows and temperature of streams containing trout and other vulnerable species. Such investigations should be seeking answers to the following questions: How fast are temperatures rising? Where and how are water flow regimes changing? When, where, and to what extent are trout threatened? Do other stressors, such as thermal discharges regulated under the CWA or sediment runoff, increase the risks to trout in certain streams? Could land use changes to reduce sediment runoff or to increase the number of trees shading the stream bed reduce those vulnerabilities? If so, to what extent and for how long? What other

impacts would such land use changes have? Where and when are withdrawals of water for agriculture already exacerbating threats to the trout? Where are conflicts likely to emerge in the near future? Where are trout likely to be extirpated, regardless of human effort?

As decision makers gather this information, they should begin to consider short- and long-term actions. If sediment runoff is exacerbating stream temperature increases, for example, Montana might consider enacting more stringent controls on nonpoint source pollution. A statewide project to plant trees along streambeds to shade the water might well be identified early as a "no regrets" adaptation measure for trout that might also produce ancillary benefits, such as stabilization of stream banks and creation of biodiversity-increasing riparian habitat. Similarly, given projected decreases in water supply, the various levels of government might choose to encourage farmers to install more efficient irrigation systems to reduce water demand. Nevertheless, the state should simultaneously consider the legal implications and perverse incentives such encouragement could have with respect to farmers' water rights, perhaps offering to pay for infrastructure improvements in exchange for farmers agreeing to return most of the newly "excess" water to the public domain. In addition, for budgetary reasons, such exchange programs might be adaptively phased in both temporally and geographically to match the progression of temperature impacts. On the trout side of the adaptation plan, fisheries managers should be adaptively managing the recreational trout fisheries, shifting fishing activity away from trout populations approaching extirpation thresholds. Throughout these first phases, coordination among the water quality, water allocation, fish and game, agriculture, tourism, recreation, and business sectors should be tight and transparent, with trade-offs among the various interests made publicly and explicitly.

Over the long term, of course, Montana might still lose a significant percentage — maybe all — of its coldwater trout, as well as all the livelihoods that trout used to support. Principled flexibility counsels the interested parties to try to make the best of this possible eventuality. For example, decision makers and the affected public at all levels of government should begin to think about whether the loss of trout should become the occasion to give in to the probably increasing pressures to allow Montana's streams to be drained for human water supply. Principled flexibility counsels "no," at least not without serious reflection on the implications of that wholesale elimination of riparian habitat for further adaptation and human well-being. Even if all trout are extirpated, streams with water left *in situ* are highly unlikely to remain uncolonized by other species, especially if managers are not actively trying to fight these changes but instead have plans and programs in place to opportunistically adapt to them. Continued monitoring will probably reveal continuing evolutions in the assemblage of species, some of which may end up being as economically valuable to residents as the trout had been. At the very least, the new assemblages are likely to provide humans with some ecosystem services that dry streambeds cannot, if only in terms of recreation and tourism. Ex ante commitments to

water withdrawal, in other words, can maladaptively foreclose opportunities for human benefits while simultaneously increasing the adaptation stress on other species.

Principled flexibility thus encourages a climate change adaptation process that is immediate, pervasive, and, in some respects, draconian — but also staged, progressive, and adaptive. As researchers at the World Bank have noted, "The time lag until the full impacts of climate change unfold allows for sequencing responses . . . . While some adaptation responses must begin now, others can wait, allowing some room for experimentation and learning."[321] Caution is particularly warranted in making long-term infrastructure commitments, redesigning cities, planning relocations, and similar efforts — that is, in any decision that requires substantial economic investment and potentially creates path dependence. Moreover, robust strategies should be greatly preferred to non-robust ones.[322]

The new climate change adaptation law must similarly recognize and give legal effect to the critical differences between "no regrets" measures that should be undertaken immediately, such as information gathering and reductions in pollution, and longer-term adaptation plans and strategies, which should be based on greater understanding of the actual climate change impacts to particular socio-ecological systems than we currently possess. There are no panaceas for climate change adaptation, and there will be no final solution for some time to come.

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[321] Heltberg et al., *supra* note 27, at 94.

[322] *See id.* at 95 (arguing that "investments in infrastructure and physical structures with a long expected life should be climate proofed").