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Which Science? Whose Science? How Scientific Disciplines Can Shape Environmental Law

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Environmental law fundamentally depends on the production of information by environmental science. However, the inevitable uncertainty in environmental science means that policy will necessarily intertwine with science, allowing for the concealment of value choices and trade-offs by agencies, interest groups, and politicians under a patina of science. Scholars and decision makers have struggled over how to resolve this "science charade." This Article proposes a new approach to the underlying challenge by closely examining the diversity of scientific disciplines in environmental law. Scientific disciplines each develop their own perspectives that are based in part on values and that shape the information they produce. Understood this way, the intersection of law and science can be greatly simplified. Instead of attempting to separate science and policy out for every significant individual decision, we can make generalizations about how science and policy will interact depending on the discipline that produces the relevant information. We can also understand scientific disciplines as essential components to the designing of any regulatory or management system. For instance, particular disciplines might be privileged in the legal or institutional structure to help advance specific policy goals; we might

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insulate the decision-making process from disciplines that interfere with the accomplishment of those goals; or, we might balance multiple disciplines in order to reduce the risk of disciplinary blind spots that interfere with policy making.

INTRODUCTION

The debate over climate change is, in part, about whether and how our planet has been growing warmer over the past century and a half of global industrial development. One group of scientists—generally called "climate scientists"—has developed complicated computer models that attempt to predict how the global climate will respond over the next ten to five-hundred years to a range of different human actions, such as increased concentrations of carbon dioxide, changes in deforestation rates, and increasing urbanization. These scientists have been the leaders of the international organizations that have sought to summarize and present the relevant science to policy makers through bodies such as the United Nations' Intergovernmental Panel on Climate Change (IPCC).

But there is another group of scientists (or at least, professionals who rely heavily on science) who often speak about matters related to climate, albeit on a very different scale: meteorologists, who try to forecast weather conditions in particular geographic locations in relatively short time frames, such as days to months. In the United States, meteorologists have a tremendous amount of public influence because they host many of the television weather forecasts.[1] Yet meteorologists are far more skeptical of climate change than climate scientists, and far more likely to believe that humans are not causing any climate change that is occurring, perhaps because of their own travails in dealing with the problems of forecasting weather in short time periods.[2] A recent study found that over one-quarter of meteorologists believe climate change is a "scam," and there are a number of high-profile meteorologists who have aggressively questioned climate change in public.[3]

The divide between climate scientists and meteorologists is an example of a much broader pattern in environmental law and policy: different scientific disciplines have very different perspectives and often reach very different conclusions about the state of the world and the need for policy intervention based on similar or identical information. While environmental law scholars have touched upon these issues, this Article builds on those initial insights to carefully examine the implications of the many disciplines and perspectives within environmental science.

There are substantial benefits to taking into account the diversity of disciplines and perspectives in environmental science. One of the intractable problems in environmental law has been the troubled boundary between science and policy. Scholars have criticized agencies, interest groups, and scientists for pursuing a science "charade" in which policy conclusions and value choices are hidden in complicated, technical models and analyses, primarily via

1 See Leslie Kaufman, *Consensus on Climate Change Ends at the TV Weather Desk*, NY Times A1 (Mar 30, 2010) (noting a study that found that 56 percent of Americans trusted weathercasters to inform them about climate change).

2 See Bill Dawson, *Why Are So Many TV Meterologists and Weathercasters Climate "Skeptics"?*, The Yale Forum on Climate Change & the Media (June 12, 2008), online at http://www.yaleclimatemediaforum.org/2008/06/why-are-so-many-tv-meteorologists-and-weathercasters-climate-skeptics/ (visited Dec 15, 2011).

3 See Kaufman, *Consensus on Climate Change*, NY Times at A1 (cited in note 1). In contrast, climatologists have developed a stong consensus that climate change is real, with 90 percent believing that climate change is real, and more than 80 percent agreeing that human activity is a significant contributing factor. See id, citing Peter T. Doran and Maggie Kendall Zimmerman, *Examining the Scientific Consensus on Climate Change*, 90 Eos AGU 20, 22 (2009).

assumptions and inferences.[4] The frequent response has been a call for greater transparency through a more explicit discussion of the policy conclusions and value choices necessarily part of regulatory decision making.[5] But given the complexity and dynamism of natural systems and therefore the large number of assumptions and simplifications necessary for tractable and informative analyses, it may be impossible (or at least extremely difficult) to ever fully identify all of the policy conclusions and value choices in regulatory science.

An alternative approach is to take into account the diverse range of values and perspectives already embedded in the scientific disciplines that are relevant for environmental law. In doing so, we can see that disciplines in fact often come as a "package" combining a range of perspectives that may be both methodological and value based. For instance, conservation biologists believe that biodiversity protection is an essential social goal, and the information they produce is shaped accordingly. It will often be much more feasible to identify the relevant discipline, its perspectives and values, and the likely way in which those perspectives and values might shape the ultimate conclusions of the relevant scientists, than it will be to painstakingly identify every assumption in every study and the policy implications of each assumption.

But there are larger benefits than simply making it easier to understand how policy and science intersect in environmental law. Once we understand scientific disciplines as bringing perspectives to the table that are relevant to policy making, we can also see them as legal- and institutional-design tools.[6] If we wish to accomplish particular policy goals in our regulatory- or management-design structures, then we may choose to embrace a particular discipline because its perspective will help advance those goals. Alternatively, we might seek to insulate the regulatory- or management-decision makers from a discipline that we believe will undermine those policy goals. Scientific disciplines may have particular promise as a precom-

4 See, for example, Ian Fein, Comment, *Reassessing the Role of the National Research Council: Peer Review, Political Tool, or Science Court?*, 99 Cal L Rev 465, 471–73 (2011). See also Alvin M. Weinberg, *Science and Trans-science*, 10 Minerva 209, 209 (1972).

5 See Fein, Comment, 99 Cal L Rev at 474 (cited in note 4).

6 For an overview of major issues in the design of administrative agencies, see generally Jacob E. Gersen, *Designing Agencies*, in Daniel A. Farber and Anne Joseph O'Connell, eds, *Research Handbook on Public Choice and Public Law* 333 (Edward Elgar 2010). One "designer" might be the legislature that establishes a statutory structure for regulatory or management decision making, though other parties (the President, the head of an agency) might play similar roles through other institutional mechanisms, such as the issuance of agency regulations.

mitment device by which environmental policy implementation can be protected against slippage as a result of pressure by powerful special interests or political myopia. Indeed, particular legal and administrative choices—such as statutory mandates that environmental agencies use the "best available science" in making regulatory decision making, or the embrace of particular disciplines by management agencies in terms of staffing and research—make more sense when understood in this way.

Understanding the importance of scientific disciplinary perspectives for environmental law can also lead us to consciously rely on a diversity of disciplinary perspectives when we are uncertain what our policy goal is. That diversity of perspectives might reduce the risk of "blind spots" in policy making that could cause serious political, technical, or economic problems in the course of policy implementation.

The exact choices regarding whether and how to use disciplines in these ways will depend on the particular goals that policy makers have for their regulatory or management programs. Given that contingency, my goal in this Article is not primarily to provide a normative assessment of the roles that scientific disciplines play in environmental science, or of the use of those disciplines in policy making. Instead, it is to provide a description of the ways in which disciplines do shape environmental science, and therefore environmental law today, and explore the implications of that fact for environmental policy making.

Thinking about scientific disciplines as including a package of science and values does not mean, however, that we give up hope on the ability of science to gain useful information from the natural world or the ability of the natural world to constrain the information that science produces. Nor does it mean that we give up on the ideal and goal of science as an endeavor that seeks to objectively determine the state of the natural world. Instead, building on the concept of "strong objectivity" developed by Sandra Harding,[7] it simply recognizes the limited but inevitable contribution of social factors to the development of science and information, and the limited but inevitable ways in which the perspectives of scientists and others shape the production of information from the natural world.

In Part I, I develop the basic interaction of science and policy in environmental law, the problems that environmental law has faced in

7 Sandra Harding, *Whose Science? Whose Knowledge? Thinking from Women's Lives* 138–63 (Cornell 1991); Sandra Harding, *After the Neutrality Ideal: Science, Politics, and "Strong Objectivity*,*"* 59 Soc Rsrch 567, 569–75 (1992).

balancing the two, and the weaknesses in existing proposals to "separate" science and policy. In Part II, I draw on science and technology studies literature to develop the concept of scientific disciplines and identify the primary factors that shape disciplines and their perspectives. I also present examples of the importance of values and perspectives in environmental science, focusing on fisheries science, marine ecology, conservation biology, and wildlife management. In Part III, I develop two main implications of the understanding of the diversity of scientific disciplinary perspectives in environmental law: the possible use of scientific disciplines as legal- or institutional-design tools, and the simplicity of relying on disciplinary perspectives as a proxy for understanding how science and policy interact in environmental law. I conclude by developing the implications of my analysis for other areas of law, such as forensic science in criminal law.

I. SCIENCE AND ENVIRONMENTAL LAW: A PROBLEMATIC, BUT INEVITABLE, PARTNERSHIP

Science is an essential input for environmental decision making. Regulatory standards for pollution depend on a number of questions: How much harm pollution will impose on human or natural systems? How effective are pollution-reduction systems? How much pollution actually is present in the natural environment?[8] Management decisions for natural resources depend on questions as to the status of the natural resources that are to be exploited or protected, the potential impacts on those resources from various management options, and the dynamic interaction of resources in response to human management decisions and changes in natural systems.[9] Answers to all of these questions will in turn depend on information produced by fields as diverse as epidemiology, toxicology, ecology, hydrology, and chemistry.

8 See, for example, 42 USC § 7408(a)(1)(A) (requiring regulation to control air pollutants that "may reasonably be anticipated to endanger public health or welfare"); 33 USC § 1316(a)(1), (b)(1)(B) (requiring regulation to control water pollutants "through application of the best available demonstrated control technology"); 33 USC § 1312(a) (requiring regulation to control pollutants where necessary to "assure protection of public health, public water supplies, agricultural and industrial uses, and the protection and propagation of a balanced population of shellfish, fish and wildlife" in waterways).

9 See, for example, 43 USC § 1732(b) (requiring the federal land management agencies to "take any action necessary to prevent unnecessary or undue degradation" of public lands); 16 USC § 1604(g)(3)(B) (requiring the Forest Service to issue regulations that will "provide for diversity of plant and animal communities" on national forests).

Environmental law often explicitly requires agencies to draw upon science. The Endangered Species Act of 1973[10] (ESA) and the Marine Mammal Protection Act of 1972[11] (MMPA) require administrative agencies to rely upon the "best available science."[12] The Clean Air Act[13] (CAA) requires the EPA to draw upon science advisory boards when making regulatory decisions.[14]

While science is essential to environmental law and policy, science often cannot provide clear answers to the questions that environmental decision makers ask.[15] This is in large part because of the significant uncertainties that surround environmental science.[16] Because of the complexity of the interaction of the large number of variables in environmental systems, the high rates of dynamic change in those variables, and the multiple levels of temporal and geographic scale at which change can happen, it is quite difficult to get high-quality information about environmental systems.[17] Simple measurement error and variability in the environment can lead to wildly different outcomes in the information produced from studies of environmental systems.[18] Statistical analysis of calculations estimating how much global temperatures will respond to changes in carbon dioxide concentrations in the atmosphere ("climate

10 Pub L No 93-205, 87 Stat 884, codified at 16 USC §§ 1531–43.

11 Pub L No 92-522, 86 Stat 1027, codified at 16 USC §§ 1361–1423.

12 See 16 USC § 1533(b)(1)(A); 16 USC § 1536(a)(2); 16 USC § 1373(a).

13 Pub L No 88-206, 77 Stat 392 (1963), codified as amended at 42 USC § 7401 et seq.

14 Clean Air Act § 1, 42 USC § 7417.

15 See, for example, Holly Doremus, *The Purposes, Effects, and Future of the Endangered Species Act's Best Available Science Mandate*, 34 Envir L 397, 438 (2004) (noting the problem in the context of the ESA).

16 See, for example, C.S. Holling, *Two Cultures of Ecology*, 2 Ecol & Socy (1998), online at http://www.ecologyandsociety.org/vol2/iss2/art4/ (visited Dec 15, 2011) ("In principle, . . . there is an inherent unknowability, as well as unpredictability, concerning ecosystems and the societies with which they are linked."); Holly Doremus and A. Dan Tarlock, *Science, Judgment, and Controversy in Natural Resource Regulation*, 26 Pub Land & Res L Rev 1, 6 (2005) ("The hard reality is that the scientific information available to support environmental and natural resource policy decisions is frequently incomplete, ambiguous, and contested.").

17 See, for example, Eric Biber, *The Problem of Environmental Monitoring*, 83 U Colo L Rev *3 (forthcoming 2012), online at http://ssrn.com/abstract=1680000 (visited Dec 15, 2011); Silvio O. Funtowicz and Jerome R. Ravetz, *Three Types of Risk Assessment and the Emergence of Post-normal Science*, in Sheldon Krimsky and Dominic Golding, eds, *Social Theories of Risk* 251, 253 (Praeger 1992); Naomi Oreskes, *Evaluation (Not Validation) of Quantitative Models*, 106 Envir Health Persp 1453, 1453 (1998) (noting that inherent uncertainty in natural systems makes it impossible to "demonstrate the predictive reliability of any model of a complex natural system in advance of its actual use").

18 Reinette Biggs, Stephen R. Carpenter, and William A. Brock, *Spurious Certainty: How Ignoring Measurement Error and Environmental Heterogeneity May Contribute to Environmental Controversies*, 59 BioSci 65, 69–73 (2009).

sensitivity") shows that reduction of the uncertainty range for those estimates is difficult or impossible, even with improved data inputs.[19]

There is therefore tremendous room, even need, for assumptions, inferences, and interpretations in the process of converting incomplete environmental data into conclusions on which environmental law and policy decisions can be based.[20] Those assumptions, inferences, and interpretations[21] will in turn depend on a range of value choices and positions, explicitly or implicitly.[22] Even when scientists can develop some consensus on which factors might be used to address the problems of underlying uncertainty,[23] there is little consensus on how to prioritize those factors, retaining ample space for the use of subjective preferences and value choices to affect the judgments drawn from ambiguous data.[24]

A simple but real example of this problem comes from the field of risk assessment, in which scientists and regulators attempt to determine whether and to what extent chemicals pose a health risk (particularly the risk of cancer) to humans. A common form of conducting risk assessment is to expose lab animals to high doses of the chemical over a relatively short period of time and then to observe whether any adverse health effects occur.[25] The results from high-dose testing on lab animals must then be extrapolated to the

19 Gerard H. Roe and Marcia B. Baker, *Why Is Climate Sensitivity So Unpredictable?*, 318 Sci 629, 629 (2007).

20 See, for example, Biber, 83 U Colo L Rev at *46–47 (cited in note 17); Steven Yearley, *The Green Case: A Sociology of Environmental Issues, Arguments and Politics* 119–32 (HarperCollins 1991).

21 Doremus and Tarlock, 26 Pub Land & Res L Rev at 9 (cited in note 16) (calling these the exercise of "judgment"). For other examples of the concept, see Elizabeth Fisher, *Drowning by Numbers: Standard Setting in Risk Regulation and the Pursuit of Accountable Public Administration*, 20 Oxford J Legal Stud 109, 110, 116–17 (2000); Steven Yearley, *Bog Standards: Science and Conservation at a Public Inquiry*, 19 Soc Stud Sci 421, 432–35 (1989).

22 See Holly Doremus, *Scientific and Political Integrity in Environmental Policy*, 86 Tex L Rev 1601, 1624–29 (2008) (noting that "scientific judgments and value judgments are often closely intertwined"); Holly Doremus, *Science Plays Defense: Natural Resources Management in the Bush Administration*, 32 Ecol L Q 249, 253 (2005); Sheila Jasanoff, *The Fifth Branch: Science Advisers as Policymakers* 7, 16–17, 230–31 (Harvard 1990).

23 See, for example, Douglas L. Weed, *Underdetermination and Incommensurability in Contemporary Epidemiology*, 7 Kennedy Inst Ethics J 107, 112–17 (1997) (listing factors used in epidemiology to evaluate whether ambiguous data has supported or refuted particular hypotheses).

24 See id at 117–19 (showing how different epidemiological review studies that relied on essentially identical evidence reached contrary outcomes, in large part because of different weighting of factors and noting possibility of "wish bias" in which "the results of the individual reviewers' studies match the conclusions reached in their respective reviews").

25 High doses are used in order to reduce the time and expense of the studies; ethical constraints prevent this sort of experimentation with humans. See Mark E. Rushefsky, *Making Cancer Policy* 21–58 (SUNY 1986).

impacts on humans from more realistic low-dose, chronic exposures. A key inference in this extrapolation is the nature of the "dose-response" curve, or how responses to the chemical in humans change as the dose levels decrease. The relationship might be linear, in which case if 1 gram of exposure causes a 1-in-100 risk of cancer, 0.01 grams of exposure should cause a 1-in-10,000 risk of cancer; or, the relationship might be non-linear, such that if 1 gram of exposure causes a 1-in-100 risk of cancer, 0.01 grams of exposure causes a 1-in-1,000,000 risk of cancer. Both curves are plausible given what we know about biology and chemistry.[26] But the different assumptions result in dramatic policy differences; the first relationship produces a much higher potential risk of cancer from low-dose exposures, and therefore a much stronger basis for regulatory intervention.[27] And of course, the underlying values and policy positions of the relevant risk assessors may, consciously or not, shape their choices among these various options.[28]

This inevitable intertangling of science and value judgments in environmental law (what some scholars have called "trans-science" problems[29]) leads to a series of problems. On the one hand, the public, scientists, and policy makers often fail to understand the importance of the value choices and preferences hidden in the assumptions, inferences, and interpretations needed to translate incomplete science into policy decisions. Instead, they assume a "linear" model of science and policy in which science determines facts that in turn determine policy options.[30] Each side identifies the information that best supports their position and accuses the other side of "bad science" by highlighting and undermining the key assumptions and uncertainties in the other side's chosen information.[31] Science becomes "a proxy for political battle," as each side tries to get the facts right so they can win the debate.[32]

26 See id at 48–49.

27 See Wendy E. Wagner, *The Science Charade in Toxic Risk Regulation*, 95 Colum L Rev 1613, 1626 (1995).

28 See Rushefsky, *Making Cancer Policy* at 22–27 (cited in note 25).

29 "[Q]uestions which can be asked of science and yet *which cannot be answered by science*." Weinberg, 10 Minerva at 209 (cited in note 5).

30 Roger A. Pielke Jr, *When Scientists Politicize Science: Making Sense of Controversy over* The Skeptical Environmentalist, 7 Envir Sci & Pol 405, 406 (2004).

31 Sheila Jasanoff, *(No?) Accounting for Expertise*, 30 Sci & Pub Pol 157, 158–60 (2003) ("[T]hose wishing to question a given scientific interpretation can generally find errors, hidden biases or subjective judgments that undercut their opponents' claims to truth and objectivity.").

32 Pielke, 7 Envir Sci & Pol at 412 (cited in note 30).

Of course, savvy policy makers and political actors sooner or later understand this dynamic.[33] If they are outside an administrative agency, they make take advantage of the inevitable uncertainty to raise doubts about the scientific justification for a particular government action or inaction, hiding their value choices in a critique of "bad agency science."[34] If they are decision makers within the agency, then they may take advantage of the uncertainty to hide value choices by contending that "science" mandates the outcome reached by the agency, without fully disclosing the assumptions, interpretations, and inferences that underpin the agency's decision and how they might advance particular political positions.[35] For instance, agencies may construct models to support decision making that depend on important, but unstated, assumptions for their functioning.[36] In this dynamic, which Wendy Wagner called the "science charade,"[37] in the context of toxic chemical regulation, "[s]cience . . . becomes a convenient and necessary means for removing certain options from a debate without explicitly dealing with disputes over values."[38]

One possible solution is for "better science" to reduce the uncertainty and the need for assumptions, inferences, and interpretations, and therefore to let the natural world resolve the political dispute.[39] Unfortunately, modern science often cannot successfully reduce uncertainty in a way that will fully resolve

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33 Michael S. Carolan, *The Politics in Environmental Science: The Endangered Species Act and the Preble's Mouse Controversy*, 17 Envir Polit 449, 449 (2008) ("Unfortunately, the banner of objective science is often waved by politicians to mask some very subjective beliefs and assumptions.").

34 See notes 268–71 and accompanying text.

35 Cary Coglianese and Gary E. Marchant, *Shifting Sands: The Limits of Science in Setting Risk Standards*, 152 U Pa L Rev 1255, 1262–73 (2004); Thomas O. McGarity, *Substantive and Procedural Discretion in Administrative Resolution of Science Policy Questions: Regulating Carcinogens in EPA and OSHA*, 67 Georgetown L J 729, 782 (1979) (proposing that "a regulator's open acknowledgement that result-oriented policy considerations will guide his resolution of science policy issues will simply ensure that the regulator will make the subjective decision instead of a scientist or low-level bureaucrat").

36 See, for example, Biber, 83 U Colo L Rev at *47 (cited in note 17); Orrin H. Pilkey and Linda Pilkey-Jarvis, *Useless Arithmetic: Why Environmental Scientists Can't Predict the Future* xii-xiv, 10, 20–21, 115–16 (Columbia 2007).

37 Wagner, 95 Colum L Rev at 1617 (cited in note 27).

38 Pielke, 7 Envir Sci & Pol at 409 (cited in note 30).

39 See, for example, Simon Shackley and Brian Wynne, *Representing Uncertainty in Global Climate Change Science and Policy: Boundary-Ordering Devices and Authority*, 21 Sci, Tech, & Hum Values 275, 282 (1996) (describing how "[a]ppeals and pledges to reduce uncertainties . . . are common" in climate science).

environmental disputes.[40] An underlying challenge in science is the underdetermination of theories from data: "There will always be more than one theory supported by the evidence, because for any piece of recalcitrant data, we always have two options: abandoning the . . . hypothesis being tested, or preserving the hypothesis, but abandoning" the claim that the test was informative as to the truth of the hypothesis.[41] As a result, decisions as to the implications of experimental results or investigations into the natural world will require "extraevidential considerations like symmetry, simplicity, and elegance, or personal, political, or metaphysical preferences."[42]

In the context of environmental science, this means that political actors can often develop new arguments to "explain away" inconvenient new factual data through claims about, for example, the exceptional circumstances of the time period in which the data were collected, alternative causal mechanisms, claims as to bias or error in the collection of data, and so forth. This allows the maintenance of the original claim as to the state of the world despite the new information, a claim that also (conveniently enough) supports that party's political position. The problem is particularly troublesome in the context of environmental decision making because the complexity, dynamism, and diversity of relevant scales in environmental science ensure that data will be especially incomplete and therefore that theories will be especially underdetermined.[43]

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40 See Dorothy Nelkin, *Science, Technology, and Political Conflict: Analyzing the Issues*, in Dorothy Nelkin, ed, *Controversy: Politics of Technical Decisions* 9, 11–14 (SAGE 1979); Sheila Jasanoff, *The Dilemma of Environmental Democracy*, 13 Issues Sci & Tech 63, 69 (1996).

41 Brian Leiter, *Why Quine Is Not a Postmodernist*, 50 SMU L Rev 1739, 1747 (1997) (describing the "so-called 'Duhem-Quine' thesis"). See also Naomi Oreskes, Kristin Shrader-Frechette, and Kenneth Belitz, *Verification, Validation, and Confirmation of Numerical Models in the Earth Sciences*, 263 Sci 641, 642 (1994); H.M. Collins and T.J. Pinch, *Frames of Meaning: The Social Construction of Extraordinary Science* 177–85 (Routledge & Kegan Paul 1982); Andrew Pickering, *Constraints on Controversy: The Case of the Magnetic Monopole*, 11 Soc Stud Sci 63, 66 (1981) (noting an "infinite number of potential interpretations" of experimental results). Underdetermination does not mean that useful scientific information cannot be produced based on observations and experiments. See Larry Laudan, *Science and Relativism: Some Key Controversies in the Philosophy of Science* 48–68, 76–86 (Chicago 1990) (discussing the problem of underdetermination and noting that the concept in some form is widely accepted in the philosophy of science but that it does not necessarily preclude the exercise of judgment in selecting among competing theories nor does it inevitably foreclose the elimination of hypotheses as a result of experiment in all circumstances). See also Leiter, 50 SMU L Rev at 1749–50 (cited in note 41) (rejecting the conclusion that the Duhem-Quine thesis forecloses the possibility that science can produce reliable information based on the natural world).

42 Oreskes, Shrader-Frechette, and Belitz, 263 Sci at 642 (cited in note 41); Pickering, 11 Soc Stud Sci at 65–66 (cited in note 41).

43 See Roger A. Pielke Jr, *The Honest Broker: Making Sense of Science in Policy and Politics* 67–70 (Cambridge 2007).

Indeed, given the high stakes around science in environmental decision making, and the problem of underdetermination, increasing the role of science in environmental decision making can make political conflicts worse, not better.[44] As the political stakes over an environmental decision and the supporting science rise, there are more incentives for those within and outside the scientific community to closely investigate the research, discover the inevitable ambiguities and uncertainties, and emphasize how the policy conclusions are underdetermined by the facts.[45] Thus, the unproblematic use of science in decision making may be easiest where there is consensus about the relevant policy goals.[46]

An alternative is to attempt to separate the science from the policy in environmental decision making—to try, as clearly as possible, to distinguish between the information or facts that we do know and the policy-laden assumptions, inferences, and interpretations that have been made.[47] Different methods have been proposed to accomplish this goal. J.B. Ruhl and James Salzman have argued for the use of "regulatory peer review" to increase transparency by identifying which parts of an agency's decision are science and which parts are

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44 Michael S. Carolan, *The Bright- and Blind-Spots of Science: Why Objective Knowledge Is Not Enough to Resolve Environmental Controversies*, 34 Critic Sociology 725, 731 (2008); Daniel Sarewitz, *How Science Makes Environmental Controversies Worse*, 7 Envir Sci & Pol 385, 397 (2004).

45 Sarewitz, 7 Envir Sci & Pol at 396 (cited in note 44) ("When political stakes associated with a controversy are relatively low, high certainty is more permissible than when the stakes are high."). See also Carolan, 34 Critic Sociology at 729–30 (cited in note 44); Naomi Oreskes, *Science and Public Policy: What's Proof Got to Do with It?*, 7 Envir Sci & Pol 369, 370–74 (2004); William R. Freudenburg, *Risky Thinking: Facts, Values and Blind Spots in Societal Decisions about Risks*, 72 Reliab Eng & Sys Safety 125, 126–27 (2001); Sheila Jasanoff and Brian Wynne, *Science and Decisionmaking*, in Steve Rayner and Elizabeth L. Malone, eds, 1 *Human Choice and Climate Change* 1, 30 (Battelle 1998).

46 See Yaron Ezrahi, *Utopian and Pragmatic Rationalism: The Political Context of Scientific Advice*, 18 Minerva 111, 114–15 (1980). See also Pielke, *Honest Broker* at 39–53 (cited in note 43).

47 See, for example, Thomas O. McGarity and Wendy E. Wagner, *Bending Science: How Special Interests Corrupt Public Health Research* 3 (Harvard 2008); Wendy Wagner and Rena Steinzor, *Introduction*, in Wendy Wagner and Rena Steinzor, eds, *Rescuing Science from Politics: Regulation and the Distortion of Scientific Research* 1, 9 (Cambridge 2006); E. Donald Elliott, *Strengthening Science's Voice at EPA*, 66 L & Contemp Probs 45, 51 (2003).

There is a third alternative, in which scientists and policy makers attempt to lay out the full range of uncertainty based on the different choices that might be made for each individual inference or assumption. The problem is that if there are a nontrivial number of inferences or assumptions, and each has a reasonably large range of possible outcomes, the spread of uncertainty for the final assessment very quickly becomes very large. We are then left in the same situation as before, where scientists that stick only to the particular data that they have are unable to provide useful information for policy makers. Of course, one could ask for only "reasonable" choices to be made for the inferences and assumptions to narrow the uncertainty, but then we return to the problem of the exercise of judgment by scientists.

policy.[48] Various scholars have argued that "[c]ourts could increase transparency by demanding clearer explanations of the policy judgments that necessarily underlie regulatory decisions, and deferring to those judgments when they are explained."[49] To reward agencies that (1) identify uncertainty, (2) explain how they resolved that uncertainty by making value choices, and (3) clarify what those value choices were, courts could uphold decisions that articulate those points, and remand decisions without such analysis.[50] Relatedly, "the unvarnished views of agency scientists or advisory panels" might be made publicly accessible to increase transparency, constraining the ability of political appointees to reject scientific advice without explicit policy rationales.[51]

The challenge to separating out the science from the policy is that it is unclear whether it is truly feasible to adequately separate the two components for the large number of environmental law and policy decisions that depend on environmental science.[52] Value choices are deeply embedded in much of the work of environmental science, so embedded that many policy makers and even scientists may not be aware of all of the implicit policy-based choices that they have made in developing and using scientific information.[53]

48 J.B. Ruhl and James Salzman, *In Defense of Regulatory Peer Review*, 84 Wash U L Rev 1, 43–47 (2006).

49 Doremus and Tarlock, 26 Pub Land & Res L Rev at 28 (cited in note 16). For other, similar proposals, see Kathryn A. Watts, *Proposing a Place for Politics in Arbitrary and Capricious Review*, 119 Yale L J 2, 32–33 (2009); Wagner, 95 Colum L Rev at 1712 (cited in note 27).

50 Doremus and Tarlock, 26 Pub Land & Res L Rev at 29 (cited in note 16).

51 Id at 30. Other proposals include creating an ombudsman for environmental agencies to address and investigate complaints about the blurring of science and policy. See Doremus, 86 Tex L Rev at 1645–46 (cited in note 22); Angus Macbeth and Gary Marchant, *Improving the Government's Environmental Science*, 17 NYU Envir L J 134, 160, 162 (2008), and developing a separate science agency.

52 See, for example, Robert G. Hetes, *Science, Risk, and Risk Assessment and Their Role(s) Supporting Environmental Risk Management*, 37 Envir L 1007, 1015 (2007) (noting that the "underlying assumptions and analytical approaches" necessary for the use of science in environmental law "are all informed by policy, judgment, and statute"); David E. Adelman, *The Art of the Unsolvable: Locating the Vital Center of Science for Environmental Law & Policy*, 37 Envir L 935, 938 (2007) (arguing that "thorny moral questions . . . are interwoven with methodological considerations" in environmental science and have exacerbated controversies); Deborah M. Brosnan, *Science, Law, and the Environment: The Making of a Modern Discipline*, 37 Envir L 987, 999 (2007) (arguing that individuals should recognize how science and law each are embedded in environmental decisions, as the two "cannot be easily separated out").

53 See Vern R. Walker, *Transforming Science into Law: Transparency and Default Reasoning in International Trade Disputes*, in Wagner and Steinzor, eds, *Rescuing Science from Politics* 165, 174 (cited in note 47). See also Stephen Bocking, *Nature's Experts: Science, Politics, and the Environment* 189 (Rutgers 2004); Doremus and Tarlock, 26 Pub Land & Res L Rev at 15 (cited in note 16); Doremus, 86 Tex L Rev at 1627–28 (cited in note 22).

For instance, by identifying a species, scientists create a category of knowledge that is used in the legal system to protect the environment through the ESA.[54] Yet many of the assumptions, inferences, and interpretations that must be made in the process of identifying a species do not on their face necessarily require policy choices: choices in methodology (for example, to rely heavily on the physical characteristics of individual animals or plants, as opposed to genetic information) will determine whether or not a particular population will be identified as a separate species.[55] But usually, methodological choices will not regularly correlate with consistently finding species more or less often; thus, one cannot consistently say that, for instance, relying on physical characteristics will result in identifying more species and therefore expanded regulatory protection under the ESA. There have been claims in the scientific community that some scientists have manipulated those methodological choices in order to identify new species that help advance the policy goals of protecting ecosystems or rare populations.[56] But this depends on the application of taxonomic analysis in a particular context—in other areas, identifying significant physical or genetic differences among populations might result in less regulatory protection for individual populations or members of a species (such as when there are claims that some members of a population are hybrids that do not warrant protection under the ESA).[57] Because of the interaction of the legal context with the diverse methodological choices, separating policy from science will have to be case by case.

Another example from the ESA context is the determination of whether a management or regulatory decision would lead to the extinction of a species, a central regulatory question that has been identified as an example of a "science" question.[58] But the question

54 David Takacs, *The Idea of Biodiversity: Philosophies of Paradise* 186 (Johns Hopkins 1996).

55 See Holly Doremus, *Listing Decisions under the Endangered Species Act: Why Better Science Isn't Always Better Policy*, 75 Wash U L Q 1029, 1089–1111, 1133–34 (1997).

56 See notes 288–95 and accompanying text.

57 For example, hybridization between coyotes and endangered red wolves might result in a determination that individual red wolves or red wolf populations no longer qualify for protection under the ESA because they have diverged from the pure red wolf populations. For a discussion of the various difficulties in mapping red wolves' genetic ancestry, see generally Craig R. Miller, Jennifer R. Adams, and Listette P. Waits, *Pedigree-Based Assignment Tests for Reversing Coyote (*Canis latrans*) Introgression into the Wild Red Wolf (*Canis rufus*) Population*, 12 Molecular Ecol 3287 (2003) (positing that "[t]he principal threat to the persistence of the endangered red wolf . . . in the wild is hybridization with the coyote").

58 See Ruhl and Salzman, 84 Wash U L Rev at 51 (cited in note 48) (identifying the assessment of the economic and other costs of designation of a group as an endangered species

whether a particular decision will lead to the extinction of a species is plagued with tremendous uncertainty. It requires significant assumptions and inferences to answer, and therefore again it will require judgments that will frequently implicate policy.[59] For instance, a scientist answering this question would have to decide (among other questions) which of the commercial or field data is "reliable" enough to warrant inclusion in any analysis, what additional factors (besides the management or regulatory decision at issue) might affect the species's viability in the future, how those factors will interact with the management or regulatory decision, and how those factors will vary in the future over time and space. Accordingly, the scientist will have to make judgment calls about whether to include or exclude data or factors, and how to characterize uncertainty—judgment calls that will surely affect the ultimate decision about whether the species's viability is threatened by the proposed decision.

Or take the process of risk assessment for chemicals. This is probably the area in which the interaction of science and policy has been most closely studied and best understood, and yet even now many observers question whether we have truly separated the science and policy questions and whether it is feasible to do so on an ongoing basis.[60]

Certainly the more sophisticated proposals to separate science and policy are aware of these obstacles, and attempt to address them. For instance, requiring the public disclosure of information produced by civil-service employees relies in part on the distinction between those employees (who presumably are more likely to have scientific training and be more involved in collecting scientific information) and political appointees (who presumably will be more focused on policy implications).[61] But it remains a difficult challenge, both

against the benefits to the designation as a "science" question). This is a question that the ESA requires to be answered based solely on the "best available science." 16 USC § 1533(b)(1)(A).

59 See Doremus, 75 Wash U L Q at 1112–28 (cited in note 55).

60 See, for example, Adelman, 37 Envir L at 937–39 (cited in note 52); Adam Babich, *Too Much Science in Environmental Law*, 28 Colum J Envir L 119, 165 (2003); Valerie Watnick, *Risk Assessment: Obfuscation of Policy Decisions in Pesticide Regulation and the EPA's Dismantling of the Food Quality Protection Act's Safeguards for Children*, 31 Ariz St L J 1315, 1333–36 (1999); Rushefsky, *Making Cancer Policy* at 41–44 & table 2.5, 180 (cited in note 25).

61 See Doremus, 86 Tex L Rev at 1644–45 (cited in note 22). See also Doremus and Tarlock, 26 Pub Land & Res L Rev at 30 (cited in note 16). But there may still be problems with political appointees "burying" themselves into the civil service. See Doremus, 86 Tex L Rev at 1643–44 (cited in note 22). And, as will be developed more fully below, the scientists themselves may have consciously or unconsciously already buried important policy implications into scientific work. See Part II. Another proposed structural solution is the establishment of independent advocates on behalf of science either within or outside the

because of the sheer number of stages at which the distinction must be drawn for any individual policy choice[62] and because of the potential difficulty of separating out science from policy at any given stage.[63]

Instead of trying to separate science and policy, we could try to understand how policy preferences manifest themselves through the diverse range of scientific disciplines. One reason this possibility hasn't been explored much to this date is that, in general, the environmental law and science literature has focused on relatively large-scale divisions in environmental science, primarily between "agency science," or "regulatory science," and "pure science," or "research science."[64] My goal here is to build on these basic distinctions and to explore how a more nuanced view of the range of scientific disciplines in environmental science might affect environmental law. As it turns out, that exploration will provide us with a number of options for

agency. See note 51. The problem remains, however, how to decide which aspects of a management or regulatory problem are "science" such that the independent voice should have primacy.

62 For example, there are many individual stages required to assess whether a species might be jeopardized by a regulatory or management decision, many of which will have policy implications. See notes 58–59 and accompanying text.

63 This is not to say that there are not a lot of (relatively) easy cases in which a particular component of an overall policy decision can be identified as science based or policy based. At one end of this spectrum, you might have the simple question of how many fish are actually present in the net that is used to sample the fish population. At the other end of this spectrum, you might have the question of whether your policy goal is to have a large or small population size for that fish population.

64 Emily Hammond Meazell, *Super Deference, the Science Obsession, and Judicial Review as Translation of Agency Science*, 109 Mich L Rev 733, 747–48 (2010); Jasanoff, *The Fifth Branch* at 75–77 (cited in note 22); Doremus and Tarlock, 26 Pub Land & Res L Rev at 27 (cited in note 16); A. Dan Tarlock, *Environmental Law: Ethics or Science?*, 7 Duke Envir L & Pol F 193, 215 (1996); Peter H. Schuck, *Multi-culturalism Redux: Science, Law, and Politics*, 11 Yale L & Pol Rev 1, 20 (1993). The former category is directed toward specific policy ends and is more focused on the synthesis and interpretation of knowledge, while the latter is directed by the interests of the scientists themselves. See Jasanoff, *The Fifth Branch* at 77–79 (cited in note 22).

There are a few scholars who have briefly touched on a diversity within science greater than the distinction between pure and applied science: David Adelman has noted that "[s]cience is . . . inherently pluralistic, as the different scientific disciplines attest, and a unitary conception of environmental science is neither a desirable end nor a viable goal." Adelman, 37 Envir L at 939 (cited in note 52). Holly Doremus has, in the context of discussing the role that science plays in identifying species for protection under the ESA, noted the existence of disciplinary diversity. Doremus, 75 Wash U L Q at 1066–71 (cited in note 55). See also Schuck, 11 Yale L & Pol Rev at 20 (cited in note 64) ("Although it is common to speak of the scientific 'community' (and I do so here), such usage is a rather quaint way to describe what has in fact become a fragmented profession."); Douglas A. Kysar and James Salzman, *Environmental Tribalism*, 87 Minn L Rev 1099, 1108, 1126–27 (2003) (noting disciplinary diversity in reaction to Bjørn Lomborg's book, *The Skeptical Environmentalist: Measuring the Real State of the World*).

dealing with the dysfunctions of science and environmental law. But first, I begin with what scientific disciplines are, their characteristics, and how they might affect the production of knowledge in environmental science.

II. SCIENTIFIC DISCIPLINES

The complexity of environmental science makes it difficult, if not impossible, for any one group of scientists to develop an effective, unified perspective of all of the various natural resources of interest to humans.[65] Instead, the range of perspectives is shaped and framed by different scientific disciplinary groups within environmental science, from epidemiology to toxicology, wildlife management to ecology, climate science to range science.[66]

Here I develop how external and internal forces shape the existence and structure of disciplines, and the perspectives or paradigms that frame the information that disciplines produce. I elucidate these points using examples from environmental science. The themes that I develop here—in particular, the peer-driven nature of much of science and the inevitable tension between external and internal pressures in shaping science—will be the basis for my analysis of the role of scientific disciplines in policy making in Part III.

In making these points, I do not mean to imply that environmental science faces no constraints from the natural world in reaching conclusions. In fact, the scientific method often does produce fairly clear results: chemicals have been identified as carcinogenic or toxic through lab experiments and epidemiology;[67] threats to species from hunting, chemical pollution, or habitat alteration have been identified and in some cases ameliorated;[68] the sources of many kinds of water pollution have been pinpointed and

65 Sarewitz, 7 Envir Sci & Pol at 390 (cited in note 44); Brian Wynne, *Knowledges in Context*, 16 Sci, Tech, & Hum Values 111, 114 (1991).

66 David Sarewitz has noted that "nature itself—the reality out there—is sufficiently rich and complex to support a science enterprise of enormous methodological, disciplinary, and institutional diversity." Sarewitz, 7 Envir Sci & Pol at 386 (cited in note 44). See also Bocking, *Nature's Experts* at 14–15 (cited in note 53); Carolan, 34 Critic Sociology at 726 (cited in note 44) ("The disciplines serve an important analytic purpose: namely, they break down into epistemologically manageable parts what is in reality an immensely complex world.").

67 See, for example, R.A. Lemen, J.M. Dement, and J.K. Wagoner, *Epidemiology of Asbestos-Related Diseases*, 34 Envir Health Persp 1, 2–7 (1980) (providing an overview of historical asbestos-related epidemiological studies and results).

68 See, for example, Nicole Strong, Comment, *The American Bald Eagle: Still a Protected National Symbol*, 12 Great Plains Nat Res J 232, 234–36 (2008) (describing impact of the pesticide DDT on raptors).

addressed.[69] My argument is instead that (1) there are nontrivial areas in environmental science for which the evidence from the natural world cannot—at least at this point in time—resolve all reasonable uncertainty; (2) in those areas of underdetermination, the perspectives of scientists and scientific disciplines can significantly shape the information that is produced; and (3) those perspectives are in turn shaped by a range of factors external and internal to the discipline. These three points are much more important in the context of "cutting edge" science that is more fallible—precisely the kind of science that is much more likely to be relevant for policy making. But as time proceeds and additional information is collected, the issues of underdetermination will often decrease. And while these issues are more prevalent in the fields of environmental science because of dynamism and complexity, those fields still frequently provide important conclusions informed by the natural world, just like the more paradigmatic hard science disciplines such as physics or chemistry.[70]

A. The State of Global Fisheries: An Example of How Disciplines Matter in Environmental Science

One example of how the different perspectives from different scientific disciplines can produce conflicts with significant policy implications is the conflict between marine ecologists and fisheries scientists over the state of global fisheries.[71] This is an issue of crucial importance for the people that depend on the oceans for food and livelihoods as well as for those concerned about the protection of marine species and ecosystems.

In 2003 and 2006, a relatively junior scientist, Boris Worm, published papers in *Nature* and *Science*, the two most prestigious scientific journals, contending that global fisheries were collapsing because of inadequate management, overfishing, and other human-

69 See, for example, John Harte, *Toward a Synthesis of the Newtonian and Darwinian Worldviews*, Physics Today 29, 32 (Oct 2002).

70 I am adopting the middle ground in the so-called science war between positivists and relativists. See D. Michael Risinger, *The Irrelevance, and Central Relevance, of the Boundary between Science and Non-science in the Evaluation of Expert Witness Reliability*, 52 Vill L Rev 679, 679–86 (2007) (noting that the debate is over "the proper proportion to be accorded to social construction factors in comparison to the external phenomena under examination"); John Ziman, *Real Science: What It Is, and What It Means* 234–36 (Cambridge 2000) (coming to the conclusion that "scientific knowledge is both found *and* made" since academic science gives great weight to the empirical findings of research, while still requiring the formulation of theories by scientists).

71 I am indebted to Holly Doremus for helping to identify this example.

caused impacts.[72] Given the policy importance of the conclusions for marine and fisheries management, the papers received significant press attention.[73] The papers also received significant criticism from numerous fisheries scientists who assailed Worm's methodologies and asserted that his doom-and-gloom statements were overstated.[74]

While the scientific debates appear highly technical to an outsider, at heart they are the result of different judgments being applied by scientists from different disciplinary backgrounds as to the appropriate data and methods to be used to understand the state of global fisheries given extremely limited information.[75] Worm "is a rising star among marine ecologists; soft-spoken and media-savvy, . . . a passionate conservationist."[76] His leading antagonist in the dispute, Ray Hilborn, is an award-winning fisheries scientist.[77] Marine ecologists generally study a wide range of natural marine systems, not just those that might be relevant for human exploitation (such as fish stocks); fisheries scientists have traditionally focused on

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72 Ransom A. Myers and Boris Worm, *Rapid Worldwide Depletion of Predatory Fish Communities*, 423 Nature 280, 282 (2003) ("Our analysis suggests that the global ocean has lost more than 90% of large predatory fishes."); Boris Worm, et al, *Impacts of Biodiversity Loss on Ocean Ecosystem Services*, 314 Sci 787, 790 (2006) (asserting that if present trends continue, all global fisheries will collapse by 2048).

73 Erik Stokstad, *Détente in the Fisheries War*, 324 Sci 170, 170 (2009).

74 See, for example, Ray W. Hilborn, *Biodiversity Loss in the Ocean: How Bad Is It?*, 316 Sci 1281, 1281 (2007); Steven Murawski, Richard Methot, and Galen Tromble, *Biodiversity Loss in the Ocean: How Bad Is It?*, 316 Sci 1281, 1281 (2007) (calling Worm's proxy for abundance "inadequa[te]"); John C. Briggs, *Biodiversity Loss in the Ocean: How Bad Is It?*, 316 Sci 1282, 1282 (2007); Ray Hilborn, *Faith-Based Fisheries*, 31 Fisheries 554, 554–55 (2006) (criticizing Myers and Worm's paper as an example of "faith-based" fisheries research); Tom Polacheck, *Tuna Longline Catch Rates in the Indian Ocean: Did Industrial Fishing Result in a 90% Decline in the Abundance of Large Predatory Species?*, 30 Marine Pol 470, 470 (2006); Franz Hölker, et al, *Comments on* Impacts of Biodiversity Loss on Ocean Ecosystem Services, 316 Sci 1285, 1285c (2007); John Hampton, et al, *Decline of Pacific Tuna Populations Exaggerated?*, 434 Nature E1, E1 (2005); Carl Walters, *Folly and Fantasy in the Analysis of Spatial Catch Rate Data*, 60 Can J Fish Aquat Sci 1433, 1433–34 (2003). See also Stokstad, 324 Sci at 170 (cited in note 73) ("Many fisheries scientists were appalled. Trained in quantitative techniques for determining the abundance of fish stocks, they questioned the methods used in Worm's global assessment, such as a reliance on the mass of fish reported caught.").

75 See Stokstad, 324 Sci at 170–71 (cited in note 73).

76 Id at 171.

77 Id (noting that Hilborn was awarded the Volvo Environment Prize in 2006). Other critics were also leading fisheries managers and scientists. See, for example, Hölker, et al, 316 Sci at 1285c (cited in note 74) (presenting a challenge to Worm's findings and conclusions brought by the authors, who are all European fisheries scientists); Walters, 60 Can J Fish Aquat Sci at 1433 (cited in note 74) (admonishing scientists who use "nonspatial" catch-per-effort data, an argument made by the author who has collaborated with Hilborn); Murawski, Methot, and Tromble, 316 Sci at 1281 (cited in note 74) (presenting commentary from three scientists at the National Marine Fisheries Service, the agency in charge of fisheries regulation in the United States); Briggs, 316 Sci at 1282 (cited in note 74) (presenting a critique of the Worm study brought by an author who is a fisheries scientist).

gathering data on fish species that are used for human benefit in order to manage them for maximum human use over the long run.[78]

A key part of the dispute was the use of "catch per effort" data. Fish are elusive and hard to count, given that their natural habitat is so inhospitable to humans. One way to estimate their population size is to measure how much effort commercial fishermen must exert to catch fish. The advantage of these data is that they are plentiful: commercial fishermen have been collecting these data for decades and for many of the fisheries around the world.[79] It allows for a global, historical overview of fisheries trends that is otherwise difficult to obtain.[80] This was the data that Worm relied upon in his two controversial papers.[81]

These data were the focus of the critics of Worm's papers.[82] They argued that "catch-per-effort" data necessarily require an understanding of the "effort" that commercial fishers put into fishing, and that therefore "catch-per-effort" data may give a misleading impression of the status of fish species.[83] For instance, "catch-per-effort" may decline substantially (in other words, it might require much more effort for fishermen to catch fish) but that may not necessarily reflect changes in the population of a fish species, depending on how the effort is distributed in space and time, and how the species reacts to greater fishing pressures.[84] Thus, one fishery scientist called the use of these data "folly" because of the need for significant assumptions to extrapolate the data across time and space.[85]

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78 Stokstad, 324 Sci at 170 (cited in note 73).

79 See Myers and Worm, 423 Nature at 280 (cited in note 72); Worm, et al, 314 Sci at 788 (cited in note 72).

80 See Myers and Worm, 423 Nature at 280 (cited in note 72).

81 See id at 280; Worm, et al, 314 Sci at 788 (cited in note 72). Worm and his coauthor provided detailed justifications for why they relied upon this data in the articles themselves and in technical appendices, and also provided some estimates of the uncertainty associated with their conclusions.

82 See, for example, Hilborn, 31 Fisheries at 554 (cited in note 74).

83 See, for example, Hampton, et al, 434 Nature at E1 (cited in note 74); Murawski, Methot, and Tromble, 316 Sci at 1281 (cited in note 74).

84 See Polacheck, 30 Marine Pol at 471–74 (cited in note 74).

85 See Walters, 60 Can J Fish Aquat Sci at 1433–34 (cited in note 74). Walters instead argued for "reasonable assumptions" that resulted in conclusions that fisheries were far less overexploited than Myers and Worm concluded. Id at 1434–35 & figure 1. Importantly, Walters conceded that both his approach and Worm's approach involved an element of "fantasy" and that Walters's approach (which rejected making simple assumptions about how known data might be representative of missing data) required "strong judgmental decisions about what assumptions to use." Id at 1434. For Walters, his "reasonable assumptions" contrasted with "unwise ones [that are] based on the mistaken notion that statistical rigor or scientific objectivity . . . can somehow substitute for judgment." Id. In short, the fisheries

Fisheries scientists instead emphasized an alternate source of information: fisheries assessments. These are complicated analyses of the status of particular fish stocks based, in part, on "catch-per-effort" data, but also on surveys conducted by research vessels and other data sources.[86] Fisheries scientists in their critiques emphasized that these sources are more accurate and reliable than simple "catch-per-effort" data alone.[87] The problem is, however, that only a few fish stocks around the world have had fisheries assessments conducted for them, and most assessments only go back for a very limited period of time.[88] Fisheries assessments therefore cannot provide a large-scale and long-term assessment of the status and trends of global fisheries.[89]

That is the heart of the conflict. Worm, as a marine ecologist, was interested in getting a global, long-term assessment of the impacts of human activities on the oceans. His concern was that looking only at the best-studied fish stocks for a relatively short period of time would greatly underestimate the negative impacts humans have caused on marine systems, since many of those impacts have occurred either on fish stocks that are not well studied (often in developing countries) or before fisheries assessments occurred. Underestimating negative impacts would, in turn, undermine the scientific case for the dramatic changes in marine policy that Worm believed were necessary to protect all marine biodiversity.[90]

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scientist critics of Worm did not, and could not, argue that there was a definitive reason why their conclusions were scientifically superior to those of Worm.

86 See Polacheck, 30 Marine Pol at 474 (cited in note 74); Murawski, Methot, and Tromble, 316 Sci at 1281 (cited in note 74).

87 See Polacheck, 30 Marine Pol at 474 (cited in note 74); Walters, 60 Can J Fish Aquat Sci at 1433–35 (cited in note 74). See also Hampton, et al, 434 Nature at E1 (cited in note 74); Murawski, Methot, and Tromble, 316 Sci at 1281 (cited in note 74).

88 See Polacheck, 30 Marine Pol at 470–71 (cited in note 74); Boris Worm, et al, *Biodiversity Loss in the Ocean: How Bad Is It?*, 316 Sci 1282, 1283 (2007).

89 See Stokstad, 324 Sci at 170–71 (cited in note 73).

90 These points are made clear in a book review that Worm wrote for *Science* shortly after his controversial 2006 article. See Boris Worm, Book Review, *Armageddon in the Oceans*, 314 Sci 1546, 1546 (2006). The reviewed book was a thriller that depicted a global ecological crisis based in the oceans that imminently threatened human societies. Worm approvingly cites the book for emphasizing the need for scientists to play a role now in saving oceans. Worm approves of criticism in the book that scientists are "shown to be slow to communicate their results, usually waiting for absolute certainty." Id. Worm emphasizes the importance of putting data together to get global, long-term perspective so we can understand how threatened oceans are:

> This is what emerges as the most interesting message from the book: that the oceans are changing on a global scale, that our understanding of these changes always lags behind them, and that too often we are too slow, too conservative, or simply too unimaginative to put all the pieces together.

Id (describing approvingly the book's mix of truth and fiction).

Fisheries scientists, on the other hand, emphasized caution in their estimates and the need to avoid both over- and underestimating fish populations.[91] This perspective can be understood as coming out of the discipline's long history providing information to be used in assessing the population size of fish stocks so that appropriate harvest levels can be set by regulatory agencies.[92] In this context, risks exist in both directions: overestimating fish populations carries the risk of setting harvest levels too high and causing the collapse of a fish stock (the risk that Worm highlighted); but underestimating fish populations carries the risk of leaving a fish in the sea, unharvested, not benefiting humans, with resulting social and economic impacts.

Thus, a dispute over whose science was "better" or "worse" is actually a fundamental disagreement between two scientific disciplines over what factors are most important in making difficult judgments about data, methodologies, and interpretation of data. One discipline (marine ecology) values the importance of reaching conclusions that are broad in scale for both time and space, even if the result is higher uncertainty for those estimates; another discipline (fisheries science) values the importance of precision in estimates even at the expense of being very limited in making statements at larger levels of time and scale. These are judgment calls about when an answer is adequate to justify communicating it to a broader scientific or policy audience. It has epistemic implications, but it is affected by other factors, such as how the discipline values risks with respect to policy outcomes.[93] There is no right or wrong answer from

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91 See, for example, Walters, 60 Can J Fish Aquat Sci at 1434 (cited in note 74) (emphasizing the need for "reasonable assumptions" in fisheries science).

92 See, for example, Josh Eagle and Barton H. Thompson Jr, *Answering Lord Perry's Question: Dissecting Regulatory Overfishing*, 46 Ocean & Coastal Mgmt 649, 651–53 (2003); Ehsan Masood, *Fisheries Science: All at Sea When It Comes to Politics?*, 386 Nature 105, 106 (1997); Ray Hilborn, Ellen K. Pikitch, and Robert C. Francis, *Current Trends in Including Risk and Uncertainty in Stock Assessment and Harvest Decisions*, 50 Can J Fish Aquat Sci 874, 875 (1993).

93 Marine ecology or fisheries science are not unique in having a range of values shape their conclusions about what is an adequate answer worthy of communication in areas where there are high levels of uncertainty. At their heart, all decisions about statistical significance (that is, conclusions about whether results are statistically unusual enough that they warrant publication) are decisions of this sort, and they necessarily implicate policy. See, for example, Berry J. Brosi and Eric G. Biber, *Statistical Inference, Type II Error, and Decision Making under the US Endangered Species Act*, 7 Frontiers Ecol & Envir 487, 488 (2009). For discussions of these issues in other fields, see, for example, Scott D. Halpern, Jason H.T. Karlawish, and Jesse A. Berlin, *The Continuing Unethical Conduct of Underpowered Clinical Trials*, 288 J Am Med Assn 358, 359 (2002) (discussing the role that statistical analysis plays in decisions about ethical medical research); S.J.L. Edwards, et al, *Why "Underpowered" Trials Are Not Necessarily Unethical*, 350 Lancet 804, 807 (1997).

a scientific perspective in this dispute—instead, the dispute is about values and perspectives underlying the science.

B. Defining Scientific Disciplines

On an intuitive level, anyone who has spent a fair amount of time at a major research university understands the concept of scientific disciplines: the different departments (from economics to biology, from sociology to physics) are oriented around one level and conception of disciplines. While there is great diversity in the definitions of a scientific discipline,[94] for purposes of this Article I use a simple, general one: disciplines are epistemic subdivisions of science. My definition includes a wide range of scales for a discipline, from relatively large units (such as physics or chemistry), to smaller, more informal subunits (such as experimental nuclear physics or evolutionary biology).[95] My focus here is on the relatively larger units, though not necessarily those formally identified as university departments.

In my analysis, I will draw on two examples from environmental science: conservation biology and wildlife management. These fields are similar enough that a comparison helps illuminate many of my points about how scientific disciplines and their perspectives develop. Moreover, conservation biology is a new and specialized field that has not received formal recognition as a department at many institutions,[96] and using it as an example shows the possibilities and challenges of identifying relatively informal disciplinary structures.

Both conservation biology and wildlife management (or wildlife biology) focus on the management of populations of nondomes-

94 See, for example, Russel McCormmach, *Editor's Foreword*, 3 Hist Stud Phys Sci ix, ix (1971); Robert E. Kohler, *From Medical Chemistry to Biochemistry: The Making of a Biomedical Discipline* 1–2 (Cambridge 1982).

95 See Ziman, *Real Science* at 193 (cited in note 70) (adopting this defintion of "discipline"). Disciplines at varying scales are defined by sociologists, historians of science, and other scholars using a range of terms. Terms used to define disciplines include "epistemic communities," Peter M. Haas, *Introduction: Epistemic Communities and International Policy Coordination*, 46 Intl Org 1, 2–3 (1992), "invisible colleges," Diana Crane, *Invisible Colleges: Diffusion of Knowledge in Scientific Communities* 35 (Chicago 1972), and "specialties," Warren O. Hagstrom, *The Scientific Community* 159–62 (Basic Books 1965). For further examples of terms used to describe scientific disciplines, see Ludwik Fleck, *Genesis and Development of a Scientific Fact* 20–51, 94–95 (Chicago 1979) (developing the related concept of a "thought collective"); Thomas S. Kuhn, *The Structure of Scientific Revolutions* 177 (Chicago 3d ed 1996) (developing the concept of a "scientific community").

96 See Susan K. Jacobson, *Graduate Education in Conservation Biology*, 4 Conservation Bio 431, 431–32 (1990).

ticated species. The most obvious difference between the two is that wildlife management has historically focused on individual game species (what might be called "deer and ducks"),[97] seeking to identify the maximum number of animals an ecosystem could support ("carrying capacity") and to understand how to artificially manipulate "habitats and populations" to allow for larger "harvestable surpluses" of those species for hunting.[98] Conservation biology in contrast seeks to answer questions about how to protect biodiversity in all its forms (ecosystems, species, and populations).[99] It values protecting biodiversity for its own sake (not necessarily based on direct human use).[100] A useful simplification is that a wildlife biologist traditionally would publish a paper on the quality of white-tailed deer habitat in a particular county,[101] while a

97 See Thomas C. Edwards Jr, *The Wildlife Society and the Society for Conservation Biology: Strange but Unwilling Bedfellows*, 17 Wildl Socy Bull 340, 341–42 (1989); Paul R. Krausman, *Wildlife Management in the Twenty-First Century: Educated Predictions*, 28 Wildl Socy Bull 490, 490 (2000); Frederic H. Wagner, *American Wildlife Management at the Crossroads*, 17 Wildl Socy Bull 354, 356 (1989); Stanley A. Temple, et al, *What's So New about Conservation Biology?*, Trans 53rd N Am Wildl & Nat Res Conf 609, 610–11 & table 1 (1988). Studies of publications in wildlife journals have found a heavy historical bias toward game species. Robert A. Powell, et al, *Dynamics of Content and Authorship Patterns in the Wildlife Society Journals (1937–2007)*, 74 J Wildl Mgmt 816, 816 (2010); Mari N. Jensen and Paul R. Krausman, Conservation Biology*'s Literature: New Wine or Just a New Bottle?*, 21 Wildl Socy Bull 199, 201 table 1 (1993); Fred L. Bunnell and Linda A. Dupuis, Conservation Biology*'s Literature Revisited: Wine or Vinaigrette?*, 23 Wildl Socy Bull 56, 56 (1995); R. Douglas Slack and Nova J. Silvy, *Have the Wildlife Society's Publications Kept Pace with the Profession?*, Trans 55th N Am Wildl & Nat Res Conf 164, 167–70 (1990).

98 See Nathan F. Sayre, *The Genesis, History, and Limits of Carrying Capacity*, 98 Annals Assn Am Geographers 120, 125–26 (2008).

99 Temple, et al, *What's So New about Conservation Biology?* at 610–11 & table 1 (cited in note 97) ("Conservation biology has no taxonomic bias and, at least in principle, treats all taxa equitably.").

100 See Takacs, *The Idea of Biodiversity* at 6, 35, 114–15 (cited in note 54); Reed F. Noss, *Who Will Speak for Biodiversity?*, 3 Conservation Bio 202, 202 (1989) ("The fact that we are conservation biologists suggests that we value biodiversity."); Peter F. Brussard and John C. Tull, *Conservation Biology and Four Types of Advocacy*, 21 Conservation Bio 21, 22 (2007); Reed F. Noss, *Values Are a Good Thing in Conservation Biology*, 21 Conservation Bio 18, 20 (2007). For a discussion of how conservation biology is less focused on the utilitarian benefits to humans of wildlife conservation compared to wildlife biology, see Reed Noss, *Is There a Special Conservation Biology?*, 22 Ecography 113, 118 & table 1 (1999); Reed Noss, *Aldo Leopold Was a Conservation Biologist*, 26 Wildl Socy Bull 713, 717 (1998); Bruce A. Wilcox, *Editorial*, 1 Conservation Bio 188, 188 (1987); Jack Ward Thomas and Hal Salwasser, *Bringing Conservation Biology into a Position of Influence in Natural Resource Management*, 3 Conservation Bio 123, 125 (1989); Michael E. Soulé, *What is Conservation Biology?*, 35 BioSci 727, 728 (1985).

101 See Malcolm L. Hunter Jr, *Aardvarks and Arcadia: Two Principles of Wildlife Research*, 17 Wildl Socy Bull 350, 350 (1989).

conservation biologist would publish a paper on the conservation status of a cave spider.[102]

Wildlife management is the older discipline, having developed beginning in the 1930s,[103] while conservation biology was created in the 1980s.[104] Wildlife managers saw the rise of conservation biology in the 1980s as threatening; they asserted that conservation biology sought to answer the same questions wildlife management had been exploring for decades.[105] In the intervening decades, there have been claims that the two fields have converged, as wildlife managers have become more interested in questions about the conservation of a wider range of species and ecosystems, and less interested in maximizing game species populations to benefit humans.[106]

C. How Disciplinary Structures Are Created and Shaped

Disciplines are the products of a range of intellectual, political, economic, social, and institutional factors, and as those factors change, the structure of disciplines will also change over time, potentially creating new disciplines through the splitting or merging of existing fields.[107] For instance, the new field of tropical medicine developed in early-twentieth-century Britain as a result of internal

102 See, for example, Francis G. Howarth, *Ecology of Cave Arthropods*, 28 Ann Rev Entomology 365, 382 (1983).

103 See notes 182–85 and accompanying text.

104 See notes 163–65 and accompanying text.

105 Noss, 22 Ecography at 113 (cited in note 100) (noting that "wildlife and fisheries biologists, foresters, range managers, and other applied scientists . . . feel threatened by this ostensibly new 'metadiscipline' that has suddenly grabbed the spotlight of scientific and policy interest"); id at 114 ("[A] professional rivalry of sorts has developed between conservation biologists . . . and wildlife biologists."); James G. Teer, Book Review, *Conservation Biology: The Science of Scarcity and Diversity*, 52 J Wildl Mgmt 570, 571 (1988) (leading wildlife biologist questioning why conservation biologists felt the need to create a new society instead of joining "an already established professional society whose interests and emphasis have been and are on conservation of the natural world"); Reed F. Noss, *The Failure of Universities to Produce Conservation Biologists*, 11 Conservation Bio 1267, 1267 (1997) (asserting that wildlife resource "departments have successfully fought implementation of interdisciplinary programs in conservation biology, ostensibly because they already have the subject covered within their curricula. (I suspect the real reason may be the envy and fear among those in resource management fields that conservation biology has stolen the professional spotlight from them.)").

106 Robert D. Brown and Larry A. Nielsen, *Leading Wildlife Academic Programs into the New Millennium*, 28 Wildl Socy Bull 495, 497 (2000); Jack Ward Thomas and Daniel H. Pletscher, *The Convergence of Ecology, Conservation Biology, and Wildlife Biology: Necessary or Redundant?*, 28 Wildl Socy Bull 546, 547 (2000). See also notes 279–85 and accompanying text.

107 Gerard Lemaine, et al, *Introduction: Problems in the Emergence of New Disciplines*, in Gerard Lemaine, et al, eds, *Perspectives on the Emergence of Scientific Disciplines* 1, 16 (Mouton 1976).

intellectual changes (the development of the germ theory of disease, which made the study of the causes of disease much more tractable) and external social, political, and institutional pressures (the need for the development of a medical discipline that could allow Europeans to live in tropical regions for extended periods of time to run the colonial system and the need of the British Colonial Office to train doctors who could serve in the colonies).[108] I will discuss many of the external factors in the next Section, since they overlap with the factors that shape the perspectives of disciplines. What I will focus on here is how the disciplinary nature of science is a necessary outcome of the communication and specialization among scientists, and how that both shapes the structure of disciplines and allows an understanding of the borders of disciplines.

Patterns of communication among scientists are shaped by, and in turn shape, disciplines. At the larger, more formal levels, institutions such as university departments, PhD training programs, academic journals, and professional societies will provide structures for the sharing and certification of knowledge that also demarcate and develop borders between disciplines.[109] The intellectual history of a discipline (including the prior disciplines from which it developed) will shape patterns of communication among scientists, as communication is more frequent among closely related disciplines.[110] Subject matter will shape patterns of communication, as material that is seen as too distant or irrelevant will not be read, accepted for publication, or even understood.[111] Relatedly, the intellectual history of a discipline (that is, which prior disciplines it developed out of) will shape patterns of communication among scientists, as communication is more frequent among closely related disciplines.[112] Journals, peer review, and review articles function as gatekeeping devices that both create and maintain disciplinary borders by controlling what kinds of communications "count" within a

108 Michael Worboys, *The Emergence of Tropical Medicine: A Study in the Establishment of a Scientific Specialty*, in Lemaine, et al, eds, *Perspectives* 75, 93 (cited in note 107).

109 See, for example, M.J. Mulkay, G.N. Gilbert, and S. Woolgar, *Problem Areas and Research Networks in Science*, 9 Sociology 187, 189 (1975); S.W. Woolgar, *The Identification and Definition of Scientific Collectivities*, in Lemaine, et al, eds, *Perspectives* 233, 234 (cited in note 107); Crane, *Invisible Colleges* at 35 (cited in note 95).

110 See, for example, Kohler, *From Medical Chemistry* at 1–2 (cited in note 94); Crane, *Invisible Colleges* at 115–21 (cited in note 95); Hagstrom, *The Scientific Community* at 217–20 (cited in note 95).

111 See, for example, Crane, *Invisible Colleges* at 108, 115–21 (cited in note 95).

112 See, for example, Kohler, *From Medical Chemistry* at 214, 253–55 (cited in note 94) (noting deference in biochemistry to chemistry, the parent discipline).

particular field.[113] At smaller, more informal scales, patterns of citation and publication rates provide evidence of subdisciplinary borders and the emergence of new fields: citation networks are tighter within rather than across disciplines or subdisciplines, reflecting the underlying social relationships that help establish disciplines, such as collaboration, teaching, and citation.[114]

The importance of communication stems from the inevitable, even necessary, role that disciplinary specialization plays in the development of scientific information. Specialization—and accordingly, the development of disciplines—happens because of the limits on the amount of information that researchers can absorb, and the choices that researchers must make to "communicate with those who are concerned with problems similar in some way to their own."[115] In this way, disciplines are central to the functioning of science.[116]

Communication patterns and related institutional structures can therefore be used to help identify and distinguish disciplines. Researchers in information science have used these tools to study how disciplines and interdisciplinarity shape the production of knowledge. Techniques to determine whether a particular article is "interdisciplinary" range from simple ones based on the categorization of research by subject matter (such as keyword and classification headings for published articles), to the use of departmental affiliations for listed authors, to the publication and citations of articles by journals in different disciplines.[117]

113 Crane, *Invisible Colleges* at 115–22, 128 (cited in note 95); Hagstrom, *The Scientific Community* at 23, 210, 224 (cited in note 95); Saad Z. Nagi and Ronald G. Corwin, *The Research Enterprise: An Overview*, in Saad Z. Nagi and Ronald G. Corwin, eds, *The Social Contexts of Research* 1, 22 (Wiley 1972).

114 Crane, *Invisible Colleges* at 41 (cited in note 95) (discussing the influence of informal relationships, such as between students and teachers, in publication and evaluation).

115 Mulkay, Gilbert, and Woolgar, 9 Sociology at 189 (cited in note 109); Woolgar, *Definition of Scientific Collectivities* at 234 (cited in note 109); Ziman, *Real Science* at 46–49, 189–90 (cited in note 70); Derek J. de Solla Price, *Little Science, Big Science* 62–91 (Columbia 1963).

116 Specialization, by ensuring a diversity of perspectives and information in science, may also help produce scientific knowledge. See Philip Kitcher, *The Advancement of Science: Science without Legend, Objectivity without Illusions* 344 (Oxford 1993).

117 See Joachim Schummer, *Multidisciplinarity, Interdisciplinarity, and Patterns of Research Collaboration in Nanoscience and Nanotechnology*, 59 Scientometrics 425, 435–36 (2004) (describing some of the "scientometric approaches to measuring interdisciplinarity"); María Bordons, Fernanda Morillo, and Isabel Gómez, *Analysis of Cross-Disciplinary Research through Bibliometric Tools*, in Henk F. Moed, Wolfgang Glänzel, and Ulrich Schmoch, eds, *Handbook of Quantitative Science and Technology Research: The Use of Publication and Patent Statistics in Studies of S&T Systems* 437, 437 (Kluwer 2004); Mu-Hsuan Huang and Yu-Wei Chang, *A Study of Interdisciplinarity in Information Science: Using Direct Citation and Co-*

With these tools, even fields as similar as conservation biology and wildlife management can be distinguished to some extent. For instance, in terms of subject matter, as noted above, wildlife management historically has focused more on single-species game management that has direct connections to human use (such as hunting). In addition, conservation biology is generally more theoretical than wildlife management,[118] and answers questions at larger temporal and spatial scales.[119]

These differences reflect different intellectual pedigrees. Conservation biology developed out of the more theoretical field of ecology and related areas (such as evolutionary and population biology), while wildlife management developed out of the more applied fields of resource management, such as forestry.[120] The

authorship Analysis, 37 J Info Sci 369, 369 (2011); Thomas W. Steele and Jeffrey C. Stier, *The Impact of Interdisciplinary Research in the Environmental Sciences: A Forestry Case Study*, 51 J Am Socy Info Sci 476, 477 (2000); Jian Qin, F.W. Lancaster, and Bryce Allen, *Types and Levels of Collaboration in Interdisciplinary Research in the Sciences*, 48 J Am Socy Info Sci 893, 894–97 (1997); Powell, et al, 74 J Wildl Mgmt at 818 (cited in note 97); Sydney J. Pierce, *Boundary Crossing in Research Literatures as a Means of Interdisciplinary Information Transfer*, 50 J Am Socy Info Sci 271, 273–74 (1999).

118 See Krausman, 28 Wildl Socy Bull at 493 (cited in note 97); Jacobson, 4 Conservation Bio at 432 (cited in note 96); Edwards, 17 Wildl Socy Bull at 340–41 (cited in note 97); Thomas A. Gavin, *What's Wrong with the Questions We Ask in Wildlife Research?*, 17 Wildl Socy Bull 345, 345–46 (1989); Wagner, 17 Wildl Socy Bull at 358 (cited in note 97); Gregory H. Aplet, Richard D. Laven, and Peggy L. Fiedler, *The Relevance of Conservation Biology to Natural Resource Management*, 6 Conservation Bio 298, 299 & table 1 (1992); Tim W. Clark, *Developing Policy-Oriented Curricula for Conservation Biology: Professional and Leadership Education in the Public Interest*, 15 Conservation Bio 31, 33 (2001); Wilcox, 1 Conservation Bio at 188 (cited in note 100); Noss, 11 Conservation Bio at 1267 (cited in note 105). Studies of publications in wildlife and conservation biology journals have reached similar conclusions. See, for example, Jensen and Krausman, 21 Wildl Socy Bull at 201 table 1 (cited in note 97); Bunnell and Dupuis, 23 Wildl Socy Bull at 59–60 & figure 4 (cited in note 97); I. Fazey, J. Fischer, and D.B. Lindenmayer, *What Do Conservation Biologists Publish?*, 124 Bio Conservation 63, 71 (2005).

119 See, for example, Bunnell and Dupuis, 23 Wildl Socy Bull at 61 (cited in note 97); Noss, 26 Wildl Socy Bull at 718 (cited in note 100) (comparing conservation biology with similar fields and noting that "conservation biology emphasizes a long-term perspective, [and] focuses on several levels of biological organization (e.g., genes through ecosystems)"); Soulé, 35 BioSci at 728 (cited in note 100).

120 See, for example, David Ehrenfeld, *Editorial*, 1 Conservation Bio 6, 6–7 (1987) (listing relevant disciplines for conservation biology by the first editor in chief of *Conservation Biology* that includes ecologists, taxomonists, and population biologists, but not wildlife biologists); Joshua J. Lawler, et al, *Conservation Science: A 20-Year Report Card*, 4 Front Ecol & Envir 473, 474 table 1 (2006) (providing a list of journals surveyed for assessment of conservation science that focuses on applied ecology journals); Jacobson, 4 Conservation Bio at 431–32 (cited in note 96); Noss, 22 Ecography at 115–16 (cited in note 100); Curt Meine, Michael Soulé, and Reed F. Noss, *"A Mission-Driven Discipline": The Growth of Conservation Biology*, 20 Conservation Bio 631, 639 (2006) ("Conservation biology's scientific foundations lie at the interface of systematics, genetics, ecology, and evolutionary biology."); Gavin, 17 Wildl Socy Bull at 345 (cited in note 118) (arguing that conservation biology developed out of "basic"

different disciplinary origins are reflected to some extent in the institutional homes for conservation biology and wildlife management programs,[121] and to a lesser extent, the differences in educational backgrounds of faculty members in each program.[122]

Journals provide the clearest evidence of distinctions between wildlife management and conservation biology. Studies of the journals published by the leading wildlife management professional society—the Wildlife Society (TWS)—and the leading conservation

biological sciences); Noss, 26 Wildl Socy Bull at 718 (cited in note 100) (claiming that conservation biology "is clearly dominated by biologists, and especially by ecologists and geneticists"); Steven R. Beissinger, *On the Limits and Directions of Conservation Biology*, 40 BioSci 456, 456 (1990) ("In the past decade, the principles of population and ecosystem ecology, biogeography, and population genetics have been applied to the problems of preserving biological diversity. This synthesis has been termed *conservation biology*."); José Sarukhán, *Conservation Biology: Views from the Ecological Sciences*, 20 Conservation Bio 674, 674 (2006) ("If there is an area of science with which conservation biology has been intimately related, it is ecology. . . . Conservation biology is ecology applied to preserving species, populations, and communities."); Temple, et al, *What's So New about Conservation Biology?* at 610–11 & table 1 (cited in note 97) (contrasting conservation biology with wildlife management due to the fact that it "is a synthetic discipline whose practitioners hail from a diverse range of backgrounds, including population genetics, demography, community ecology, ecosystem ecology and evolutionary biology").

121 Wildlife management programs are somewhat more likely, for instance, to be located in "natural resources management" departments than in ecology departments compared to conservation biology programs. Of 414 wildlife undergraduate and graduate programs listed by the main wildlife management professional society, the Wildlife Society, 111 (26 percent) were located in departments that had "wildlife" or "natural resources" in their title, while 161 (39 percent) were located in biology departments, 88 (25 percent) were in environmental studies or science departments, and only 9 (2 percent) were in ecology or zoology departments. The Wildlife Society, *Table of Wildlife Degrees*, online at http://joomla.wildlife.org/documents /wildlife_degrees.xls (visited Dec 15, 2011). In contrast, of 99 conservation biology programs listed by the main conservation biology professional society, the Society for Conservation Biology that had accessible websites, 14 (14 percent) were in wildlife or natural resource departments, 40 (40 percent) were in biology departments, 19 (19 percent) were in environmental studies or sciences departments, and 21 (21 percent) were in ecology or zoology departments. Society for Conservation Biology, *University Program Database*, online at http:// www.conbio.org/Resources/Programs/Search/ps.cfm (visited Dec 15, 2011) (search keyword "conservation biology"). See also William J. Matter and Robert J. Steidl, *University Undergraduate Curricula in Wildlife: Beyond 2000*, 28 Wildl Socy Bull 503, 505 (2000) ("Most wildlife programs are housed in larger academic units that offer other natural resource curricula such as fishery, forestry, rangeland, and watershed science.").

122 Noss, 22 Ecography at 116 (cited in note 100); Temple, et al, *What's So New about Conservation Biology?* at 610–11 & table 1 (cited in note 97). A review of the faculty backgrounds from 25 conservation biology and 25 wildlife management programs (randomly selected from the lists provided by TWS and SCB) found that of 398 wildlife management professors, 38 (10 percent) had PhD degrees in wildlife science or natural resources, 73 (18 percent) in ecology or zoology, 182 (46 percent) in biology, 8 (2 percent) in environmental science and 97 (24 percent) did not fall in any of those categories, while for 529 conservation biology professors, 90 (15 percent) had PhD degrees in wildlife science or natural resources, 153 (32 percent) in ecology or zoology, 118 (22 percent) in biology, 8 (2 percent) in environmental studies, and 160 (30 percent) in other categories.

biology society—Society for Conservation Biology (SCB)—show striking differences in subject-matter and author affiliations.[123] Those differences are also replicated in the membership of the professional societies that publish the journals.[124]

The comparison of conservation biology and wildlife management shows how two fields that study very similar subject matter areas can nonetheless have important distinctions based on intellectual history and patterns of communication. But the comparison also demonstrates the challenges of distinguishing among disciplines, as shown by the data on the educational backgrounds of faculty members in the respective programs: the two fields have converged to some extent in terms of perspective, (primarily as wildlife managers have become more like conservation biologists and as communication between the disciplines has increased) and the lack of formal departmental identification for conservation biology (almost always) and wildlife management (frequently) makes line drawing more difficult. In Part III, I will draw on both the possibilities and challenges of distinguishing among disciplines when I discuss the use of scientific disciplines as legal- or institutional-design tools.

123 See, for example, Jacobson, 4 Conservation Bio at 432 (cited in note 96) (concluding that the *Journal of Wildlife Management* (the leading TWS publication) is dominated by articles about game species and that relatively few *Conservation Biology* (the leading SCB publication) articles are authored by researchers with wildlife manager affiliations); Temple, et al, *What's So New about Conservation Biology?* at 610 (cited in note 97) (reporting that "a review of the 889 papers published in *The Journal of Wildlife Management* (1982–87) revealed that only 75 (8 percent) were on topics that would be appropriate for publication in *Conservation Biology*"); Slack and Silvy, *Have the Wildlife Society's Publications Kept Pace with the Profession?* at 167–70 (cited in note 97) (concluding after a study of wildlife management journals from the 1930s through 1989 that a vast majority of articles are on game animals, and up to 40 percent of articles at times are on deer and waterfowl); Jensen and Krausman, 21 Wildl Socy Bull at 200 (cited in note 97) (finding *Conservation Biology* authors are more academic, much more likely to come from "basic" (biology) departments, and much more unlikely to come from wildlife departments); Powell, et al, 74 J Wildl Mgmt at 816, 819–23 (cited in note 97) (noting that despite a rise in conservation, nongame, and multiple species studies in wildlife journals, those types of studies are still a minority, and few articles study endangered species or invertebrates). But see Thomas and Pletscher, 28 Wildl Socy Bull at 547 (cited in note 106) ("Further, to scientists who have published in various journals, it seems obvious that often articles published in one journal could have just as readily appeared in another."); Noss, 22 Ecography at 120 (cited in note 100).

124 There is significant overlap among the members of TWS, SCB, and the ESA, the main professional society for ecologists. See Thomas and Pletscher, 28 Wildl Socy Bull at 547 (cited in note 106). However, a study of membership patterns found that many more ESA members are also members of SCB than of TWS. David M. Lawrence, Marjorie M. Holland, and Deborah J. Morrin, *Profiles of Ecologists: Results of a Survey of the Membership of the Ecological Society of America: Part I: A Snapshot of Respondents*, 74 Bull Ecol Socy Am 21, 31 table 14 (1993).

D. How Disciplinary Structures Shape the Production of Scientific Information

1. The importance of disciplinary perspectives.

The structure of disciplines within science is important because each discipline brings very different perspectives to scientific work.[125] (By perspectives, I mean attitudes about both how to describe and analyze the natural world, and how to value the natural world.) Those perspectives—sometimes called "paradigms," or "worldviews,"[126]—will shape (and in turn can be shaped by) the methodological tools used by a discipline, the interpretations of ambiguous data, the kinds of problems the discipline investigates, and the goals for research.[127] The contrasting viewpoints of marine ecologists and fisheries scientists toward the use and reliability of data demonstrate how important perspectives are in producing information.

Perspectives exist in part because they allow for easy communication within a discipline, "since all the fundamentals are agreed upon: what is a problem, what is a solution, what standards of

125 For a call for legal scholars to be more attentive to the ways in which values and perspectives in environmental science shape environmental law and policy, see William Boyd, *Ways of Seeing in Environmental Law: How Deforestation Became an Object of Climate Governance*, 37 Ecol L Q 843, 849–51, 916 (2010).

126 These terms were popularized by the work of Thomas Kuhn. See Kuhn, *The Structure of Scientific Revolutions* at x, 5–6, 111 (cited in note 95). In referencing the terminology, I do not endorse all of the statements by Kuhn in that work (or the interpretations of those statements) that paradigms might be "incommensurable" or that there is no basis for judging the truth or falsity of paradigms based on facts from the natural world. Laudan, *Science and Relativism* at 121–45 (cited in note 41) (noting adoption of incommensurability as justification for a radical relativist critique of science, and criticisms of the concept of incommensurability). My goal is much more limited. In the context of the complexity and dynamism of environmental science, the facts available to us from the natural world are more incomplete and less determinative of the truth or falsity of different hypotheses or perspectives. See notes 15–19 and accompanying text. Accordingly, in the context of environmental science, paradigms and perspectives will have greater role to play in determining the ways in which science develops information than in many other scientific areas. That does not mean that the natural world places no constraints on the development of environmental science, providing no basis for comparing different disciplines.

127 Crane, *Invisible Colleges* at 32, 136–37 (cited in note 95) (noting contingency as to whether a particular test can be seen as proof, depending on the intellectual environment of the relevant discipline); David Robbins and Ron Johnston, *The Role of Cognitive and Occupational Differentiation in Scientific Controversies*, 6 Soc Stud Sci 349, 353 (1976) (noting importance of a theoretical framework for shaping facts and their interpretation within a discipline); John Law, *The Development of Specialties in Science: The Case of X-ray Protein Crystallography*, in Lemaine, et al, eds, *Perspectives* 123, 124 (cited in note 107) (arguing that disciplines are based on paradigms, which constrain which problems can be worked on and which cannot); Doremus, 75 Wash U L Q at 1066 (cited in note 55); Carolan, 34 Critic Sociology at 728 (cited in note 44).

accuracy are appropriate, what techniques may and may not be used, what journals and text books are worth reading and what can safely be left on the shelf, and so on."[128] For instance, disciplines will develop "black boxes" of theories or claims that are presumed to represent truth.[129] These black boxes become the foundations for future intellectual progress within that field, by allowing scientists to focus on particular research questions, instead of questioning all of the necessary assumptions for any research to proceed.[130] But they also necessarily cabin to some extent the range of inquiry.

Until the 1980s, a dominant perspective in the field of ecology was an understanding of the natural world as governed by relatively simple models of the interactions among species, interactions that produced relatively stable outcomes in the natural environment.[131] Predator and prey species would interact in ways that would maintain each other's population levels within certain levels; a forest that had been cleared for agriculture or by a fire would eventually return to a "climax" state dominated by specific species. The underpinnings of this perspective were a series of assumptions about how the natural world operated and how it could be modeled. Those assumptions had not, in fact, been tested with real-world data more than a few times (and those few tests had found the assumptions wanting), but ecologists did not question the underlying assumptions because the models and general perspective were essential for pursuing productive field work.[132] Only when accumulating field data contradicted the predictions of the "balance of nature" perspective did ecologists begin to question those assumptions.[133]

The role that perspectives play in shaping knowledge is not comprehensive or even necessarily dominant; perspectives change in the face of the accumulation of evidence from experiments and

128 David Collingridge and Colin Reeve, *Science Speaks to Power: The Role of Experts in Policy Making* 19 (St Martin's 1986).

129 See Sheila Jasanoff, *Transparency in Public Science: Purposes, Reasons, Limits*, 69 L & Contemp Probs 21, 35, 37 (2006); Carolan, 34 Critic Sociology at 729 (cited in note 44); Oreskes, 7 Envir Sci & Pol at 370–72, 380 (cited in note 45).

130 See Kitcher, *Advancement of Science* at 80–82, 84–89 (cited in note 116). Variation within a discipline on important issues will nonetheless be significant and may be important for the development of new scientific knowledge. Id at 82 n 34, 306–08.

131 See Daniel B. Botkin, *Discordant Harmonies: A New Ecology for the Twenty-First Century* 27–49 (Oxford 1990).

132 Id at 33, 41–42.

133 Id at 37–41 (describing two studies that called into question the assumption of stability).

debates from within or outside the discipline.[134] The natural world will constrain the types of perspectives that can achieve consensus within a discipline.[135] But when it comes to interpreting and understanding ambiguous data and managing uncertainty, "[w]here reasonably possible, scientists tend to interpret their observations as consistent with whatever theory currently commands the most adherents, even if other interpretations are equally or even more plausible."[136]

These perspectives will often be influenced by the values of the members of the discipline.[137] The controversy over the global rate of extinction of species is an example of how values shape perspectives and how perspectives shape the production of information in conservation biology. There is no question that humans have dramatically shaped the world in the past century and a half. However, for conservation biologists, a key question is the implications for global biodiversity: How many species have gone extinct or will go extinct if current trends continue?

The problem is (again) that there are extremely limited data about even the total number of species on the planet, let alone how many of those species have gone extinct as a result of human activities (and will go extinct if present trends continue).[138] The question becomes even more complicated as conservation biologists attempt to understand how climate change might accelerate the loss of species over the next century.

To answer this question, conservation biologists have relied heavily on an equation that relates the area of intact habitat to the number of species that will persist over time: more intact habitat means more species persist.[139] This "species-area curve" analysis was

134 See generally Naomi Oreskes, *The Rejection of Continental Drift* (Oxford 1999) (describing the decades-long process by which argument and evidence accumulated in geology leading to a consensus around the theory of continental drift).

135 See Ziman, *Real Science* at 197–98 (cited in note 70).

136 Doremus, 75 Wash U L Q at 1066, 1068 (cited in note 55).

137 Sarewitz, 7 Envir Sci & Pol at 392 (cited in note 44) ("Even the most apparently apolitical, disinterested scientist may, by virtue of disciplinary orientation, view the world in a way that is more amenable to some value systems than others."); Michael S. Carolan, *Scientific Knowledge and Environmental Policy: Why Science Needs Values*, 3 Envir Sci 229, 230 (2006) ("In the end, environmental science rests, at least in part, on normative assumptions.").

138 See Paul Voosen, *Scientists Clash on Claims over Extinction 'Overestimates*,' NY Times (May 18, 2011), online at http://www.nytimes.com/gwire/2011/05/18/18greenwire-scientists-clash-on-claims-over-extinction-ove-96307.html?pagewanted=all (visited Dec 15, 2011) (describing the historic and renewed controversy over the uncertainty inherent in the calculations scientists use to estimate extinction).

139 See, for example, Stuart L. Pimm and Robert A. Askins, *Forest Losses Predict Bird Extinctions in Eastern North America*, 92 Proc Natl Acad Sci 9343, 9343 (1995).

used to estimate how many species might go extinct if deforestation rates in locations such as tropical rainforests continued.[140] It has since been extended to assess the implications of climate change for biodiversity. "Climate envelope" models use global-scale models estimating how climate will change across the planet in the next decades or century. They then compare the changed climatic regime to existing climate patterns to determine how much suitable habitat is gained or lost; reductions in habitat are then used (via the "species-area curve") to estimate how many species might go extinct as a result of climate change.[141]

"Climate envelope" models have proved quite controversial. A "climate envelope" study in 2004 tentatively predicted that 15 to 37 percent of global species would be "committed to extinction" as a result of climate change by 2050.[142] Critics challenged the significant assumptions entailed in the use of such models, such as the inability of species to adapt to new climates, or the relationship between climate and current distributions of species.[143] Critics also noted that the use of "climate envelope" models often assumes the worst-case scenario in terms of impacts of climate change on species.[144]

But even the fundamental relationship between species numbers and area has been challenged. Despite the relationship's widespread use by conservation biology, critics have argued that scientists still do not fully understand why the relationship exists.[145] Recent research

140 See, for example, Thomas M. Brooks, Stuart L. Pimm, and Joseph O. Oyugi, *Time Lag between Deforestation and Bird Extinction in Tropical Forest Fragments*, 13 Conservation Bio 1140, 1141 (1999).

141 See, for example, John W. Williams, Stephen T. Jackson, and John E. Kutzbach, *Projected Distributions of Novel and Disappearing Climates by 2100 AD*, 104 Proc Natl Acad Sci 5738, 5739 (2007); Wilfried Thuiller, et al, *Climate Change Threats to Plant Diversity in Europe*, 102 Proc Natl Acad Sci 8245, 8247 (2005); Chris D. Thomas, et al, *Extinction Risk from Climate Change*, 427 Nature 145, 145 (2004).

142 See Thomas, et al, 427 Nature at 145 (cited in note 141).

143 See, for example, Owen T. Lewis, *Climate Change, Species-Area Curves, and the Extinction Crisis*, 361 Phil Trans Royal Socy Bull 163, 167–68 (2006); Daniel Botkin, et al, *Forecasting the Effects of Global Warming on Biodiversity*, 57 BioSci 227, 230–31 (2007).

144 See Lewis, 361 Phil Trans Royal Socy Bull at 169 (cited in note 143); Botkin, et al, 57 BioSci at 228 (cited in note 143). But see Arndt Hampe, *Bioclimate Envelope Models: What They Detect and What They Hide*, 13 Global Ecol & Biogeography 469, 470 (2004) (arguing "climate envelope" models might *underestimate* the risks of climate change for biodiversity).

145 See Lewis, 361 Phil Trans Royal Socy Bull at 165–66 (cited in note 143) (describing the species-area relationship approach as deceptively simple in that it conceals a number of unfounded assumptions); Robert J. Whittaker, et al, *Conservation Biogeography: Assessment and Prospect*, 11 Diversity & Distributions 3, 12 (2005); Stephen Budiansky, *Extinction or Miscalculation?*, 370 Nature 105, 105 (1994); Voosen, *Scientists Clash*, NY Times (cited in note 138) (reporting that "[f]or decades, it has been an open secret among conservationists. An elegant equation widely used to calculate how many species will go extinct from deforestation and habitat destruction—one of the 'laws' of ecological theory—was a little shaky").

has questioned whether the relationship systematically overstates the impact of habitat destruction on species survival rates,[146] though that research has itself been criticized.[147]

My point here is not to resolve these disputes. Instead, I want to note that the significant reliance of conservation biologists on these tools, despite their acknowledged weaknesses, is the outcome of a discipline that places a strong value on biodiversity protection. There are other tools to assess the impacts of climate change and habitat destruction on biodiversity,[148] but those tools require tremendous amounts of data—data that exist only for a fraction of species.[149] If conservation biologists limited themselves to those other tools, they might make more precise estimates of the risks of species extinction for particular species, but they would be unable to make large-scale (in space and time) statements about the impacts of human activities on global biodiversity.[150] Such statements are crucial for a discipline that is focused on addressing the impacts of human activities on biodiversity at a global scale.[151] This is particularly true for a discipline that sees itself as responding to a "crisis" and therefore must produce information that is at a large enough scale that it can be useful for policy makers in decision making in the very near

146 See Fangliang He and Stephen P. Hubbell, *Species-Area Relationships Always Overestimate Extinction Rates from Habitat Loss*, 473 Nature 368, 368 (2011).

147 See Voosen, *Scientists Clash*, NY Times (cited in note 138); Stuart Pimm, *This Week's Claim that the Species Extinction Crisis Is Overblown Is a Sham*, Natl Geo News Watch (May 21, 2011), online at http://newswatch.nationalgeographic.com/2011/05/21/this-week%E2%80%99s-claim-that-the-species-extinction-crisis-is-overblown-is-a-sham/ (visited Dec 15, 2011); Bob O'Hara, *Species-Area Relationships Don't Overestimate Extinction Rates from Habitat Loss*, Deep Thoughts and Silliness Blog (Nature Publishing Group 2011), online at http://blogs.nature.com/boboh/2011/05/31/species-area-relationships-dont-overestimate-extinction-rates-from-habitat-loss (visited Nov 21, 2011) (providing a step-by-step analysis of He and Hubbell's conclusions to argue that they are incorrect); T.M. Brooks, *Extinctions: Consider All Species*, 474 Nature 284, 284 (2011).

148 See, for example, Botkin, et al, 57 BioSci at 230–32 (cited in note 143) (describing alternative models).

149 See Richard G. Pearson and Terence P. Dawson, *Predicting the Impacts of Climate Change on the Distribution of Species: Are Bioclimate Envelope Models Useful?*, 12 Global Ecol & Biogeography 361, 366–67 (2003) (noting that "climate envelope" models are much more useful for large numbers of species with limited data).

150 See Botkin, et al, 57 BioSci at 230 (cited in note 143); Lewis, 361 Phil Trans Royal Socy Bull at 165–66, 169–70 (cited in note 143); Antoine Guisan and Wilfried Thuiller, *Predicting Species Distribution: Offering More Than Simple Habitat Models*, 8 Ecol Let 993, 1004 (2005).

151 Thus, even those scientists who have questioned climate envelope and species-area curve models have emphasized that they do so out of a desire to ensure that more accurate information is available, both to improve conservation management and to reduce the risk that conservation biologists are seen as "crying wolf." See He and Hubbell, 473 Nature at 370 (cited in note 146); Lewis, 361 Phil Trans Royal Socy Bull at 164, 170 (cited in note 143).

future (and, ideally, inspire policy makers to action to protect biodiversity in the very near future).[152] Conservation biologists are comfortable accepting the uncertainty in these kinds of estimates for those reasons.[153] The discipline therefore relied on the species-area curve as a tool (and to some extent put it in a black box) despite its inevitable weaknesses, based in part on values (the importance of the protection of biodiversity) that contribute to the overall perspective of the discipline (understanding the status and trends of biodiversity as the primary goal of research).

2. How disciplines can shape the nature and content of their own perspectives.

Disciplinary perspectives are shaped both by the discipline itself and by forces outside the discipline. Perhaps the most important internal constraint is the training of scientists while graduate students, which acculturates them into the expectations of the discipline, including its fundamental precepts.[154] Even after training is completed, social or peer pressure from colleagues within a discipline (particularly leading figures) can deter scientists from publishing results that are inconsistent with the dominant perspective—particularly through peer-review gatekeeping mechanisms for publication, funding, hiring, and tenure decisions.[155] Positive peer reputation may be the most important factor in

152 For more on conservation biology as a crisis discipline, see, for example, Meine, Soulé, and Noss, 20 Conservation Bio at 635 (cited in note 120) (providing a brief historical overview of conservation biology's characterization a crisis discipline); Soulé, 35 BioSci at 727 (cited in note 100) (explaining why conservation biology is a crisis discipline). For more on the importance of generalizability, see, for example, Noss, 22 Ecography at 116 (cited in note 100) (arguing that "because case-specific information is always poorer than desired for conservation planning, empirical generalizations derived from prior experience often provide the only reasonable foundation for decision-making").

153 Soulé, 35 BioSci at 727 (cited in note 100) ("In crisis disciplines, one must act before knowing all the facts . . . . A conservation biologist may have to make decisions or recommendations about design and management before he or she is completely comfortable with the theoretical and empirical bases of the analysis. Tolerating uncertainty is often necessary.").

154 Cyrus C.M. Mody and David Kaiser, *Scientific Training and the Creation of Scientific Knowledge*, in Edward J. Hackett, et al, eds, *The Handbook of Science and Technology Studies* 377, 377–85 (MIT 3d ed 2008); H.M. Collins, *Changing Order: Replication and Induction in Scientific Practice* 142 (SAGE 1985); Hagstrom, *The Scientific Community* at 9–10 (cited in note 95).

155 See Steven P. Feldman, *The Culture of Objectivity: Quantification, Uncertainty, and the Evaluation of Risk at NASA*, 57 Hum Rel 691, 697 (2004); Mulkay, Gilbert, and Woolgar, 9 Sociology at 195 (cited in note 109); Sheila Jasanoff, *Science, Politics, and the Renegotiation of Expertise at EPA*, 7 Osiris 194, 196 (1992); Doremus, 75 Wash U L Q at 1062 & n 181 (cited in note 55).

professional advancement.[156] For instance, biologists who took the unpopular position of criticizing the species designation of a sea turtle population "felt considerable pressure to downplay or 'reinterpret'" the relevant data from "members of the international sea turtle research community" including "journal editors that were deciding the fate of [the biologists'] papers and program officers deciding the fate of [their] grants."[157]

Training and peer pressure can help perpetuate a discipline's perspective. Other internal factors might shape the content of that perspective. For instance, the methodological choices of a discipline may significantly affect the perspectives of the discipline. Meteorologists regularly work with complicated computer models to attempt to forecast weather at the local and regional level—producing predictions that can be quite unreliable.[158] As a discipline, meteorologists are all too aware of the flaws and foibles of models as forecasting tools. It is probably no surprise that meteorologists have been skeptical of the ability of global climate models to provide reliable predictions of future climate impacts from increases in atmospheric greenhouse gases.[159] On the other hand, the global nature of the information and the methods that most climate scientists use frame the policy questions that climate scientists believe are relevant to their work and create a focus on international, rather than local or domestic, solutions.[160]

There may be significant self-selection mechanisms by which perspectives are developed and maintained—scientists may enter into the study of a particular field because of personal preferences (for example, people who love birds may become ornithologists)—that in turn will inform their use of judgments about ambiguous data.[161] As one commentator has put it:

156 Hagstrom, *The Scientific Community* at 29–33 (cited in note 95); Mulkay, Gilbert, and Woolgar, 9 Sociology at 195 (cited in note 109).

157 Brian W. Bowen and Stephen A. Karl, *In War, Truth Is the First Casualty*, 13 Conservation Bio 1013, 1013–14 (1999).

158 This unreliability has led to an abundance of jokes about the predictive abilities of weather forecasters.

159 See text accompanying notes 1–3.

160 See, for example, Boyd, 37 Ecol L Q at 866–68 (cited in note 125); Paul N. Edwards, *Representing the Global Atmosphere: Computer Models, Data, and Knowledge about Climate Change*, in Clark A. Miller and Paul N. Edwards, eds, *Changing the Atmosphere: Expert Knowledge and Environmental Governance* 31, 33 (MIT 2001); Simon Shackley, *Epistemic Lifestyles in Climate Change Modeling*, in Miller and Edwards, eds, *Changing the Atmosphere* 107, 108–13 (MIT 2001).

161 Doremus, 75 Wash U L Q at 1073 (cited in note 55) (noting that intuitions and judgments of scientists may "be strongly influenced by subjective preferences").

> When it comes to evaluating conflicting evidence, people tend to trust evidence of the kind which they and their close colleagues have dedicated their lives to obtaining, in part for social reasons, and in part because they have an intellectual, aesthetic, or ethical affinity for that *kind* of scientific work, which helps to explain why they chose to pursue that kind of research in the first place. Often these commitments are both affective and epistemic. Field scientists *like* field work—they like being out in the fresh air and sunshine—*and* they also believe it to be more likely to capture the basic truths about the natural world, messy though it may be. In contrast, laboratory scientists enjoy working in the lab—they enjoy building and tinkering—and they also believe it to produce knowledge of greater specificity and rigor than field science. . . . Scientists may also choose a particular line of inquiry because it aligns with their normative commitments: (field biologists caring about nature, economists caring about the efficient management of monetary resources), in which case they are apt to defend their work strongly on (implicit) normative grounds.[162]

An example of these factors at work in shaping a discipline's perspective is the history of conservation biology.[163] The field's creation was part of a concerted effort by scientists concerned about the disappearance of species and ecosystems to increase their traction in the policy arena. For instance, the term "biodiversity" was created by scientists interested in protecting species, ecosystems, and other natural living resources. Their goal was to increase their political leverage to shape policy by emphasizing the importance of their expertise in making decisions about what should be protected and how to protect it.[164] It was first broadly used as part of the "National Forum on Biodiversity" in 1986, a political event intended to raise the profile of species conservation, and the organizers of the forum specifically coined the term as a "glitzy" one that could advance the political mission of conservation biology.[165]

The importance of internal factors means that science is often a very peer-driven enterprise.[166] Journals and government grant

162 Oreskes, 7 Envir Sci & Pol at 375 n 7 (cited in note 45).

163 Takacs, *The Idea of Biodiversity* at 35 (cited in note 54).

164 Id at 1, 5–8.

165 Id at 37–38.

166 See Nagi and Corwin, *The Research Enterprise* at 22 (cited in note 113); Law, *The Development of Specialties in Science* at 125 (cited in note 127).

funding are peer reviewed and disciplinary based,[167] and disciplinary associations are peer run. The collective imprimatur of scientists in a field is what ultimately determines what is "knowledge" and "truth" within the field, what work is valid, which scientists should be praised.[168]

The peer-driven nature of disciplines is an important basis for the public legitimacy and political power of science.[169] As a decentralized institution or social structure—a characteristic emphasized by disciplinary fragmentation—science is hard for outsiders to directly control.[170] The legitimacy of science when it is deployed in the political arena comes, in part, from the perception by the public that scientific information is often difficult for political actors to shape to achieve political goals,[171] and therefore as more likely to be authentic and trustworthy.[172] Thus, skeptics of climate science regularly attempt to discredit the field by pointing to government funding of climate scientists. The contention is that the government agencies use the threat of climate change and the need for additional research to justify larger budgets from Congress, and

167 The National Science Foundation grant-making process gives scientists a dominant role. See Steven Goldberg, *Culture Clash: Law and Science in America* 44–49 (NYU 1994). This peer-review process is usually organized by discipline. See Jasanoff, *The Fifth Branch* at 65–68 (cited in note 22).

168 Fleck, *Genesis and Development* at 118–25 (cited in note 95); Joseph Rouse, *Knowledge and Power: Toward a Political Philosophy of Science* 120 (Cornell 1987) (stating that "[i]n science, the standards of rational acceptability are not individual but social"); Kuhn, *The Structure of Scientific Revolutions* at 168 (cited in note 95); Hagstrom, *The Scientific Community* at 12–24 (cited in note 95).

While the peer-driven nature of scientific disciplines to some extent imposes conformity on scientists, there is a countervailing pressure—the dramatic rewards provided to those who develop new, original understandings of the world that become widely accepted within the discipline. See, for example, Ziman, *Real Science* at 40–41, 182–85 (cited in note 70). This pressure—and the desire of scientists for fame and recognition—might be an important factor driving the development of scientific information, including the development of challenges to scientific orthodoxy. See Kitcher, *The Advancement of Science* at 72–74 (cited in note 116).

169 See Pielke, *The Honest Broker* at 93 (cited in note 43).

170 See Daryl E. Chubin and Edward J. Hackett, *Peerless Science: Peer Review and U.S. Science Policy* 6 (SUNY 1990). But see Ziman, *Real Science* at 74–76, 177–81 (cited in note 70).

171 Sheldon Krimsky, *Publication Bias, Data Ownership, and the Funding Effect in Science: Threats to the Integrity of Biomedical Research*, in Wagner and Steinzor, eds, *Rescuing Science from Politics* 61, 67 (cited in note 47); Pielke, *The Honest Broker* at 88–89 (cited in note 43).

172 See Jasanoff, *The Fifth Branch* at 208 (cited in note 22) ("Knowledge generated by parties without a clear stake in its application might indeed be more resistant to the deconstructive pressures of U.S. regulation."); Fein, Comment, 99 Cal L Rev at 555 (cited in note 4).

the scientists exaggerate the risks of climate change to justify additional research that requires funding for themselves.[173]

3. How outside institutions can shape disciplinary perspectives.

Outside pressures shape both the creation of disciplines and their perspectives. Disciplines may be created or supported by institutions in order to increase their profile and improve their ability to obtain resources.[174] For instance, American "land grant" universities focused on the "services" they could provide to the local economy and society and so focused on "practical" disciplines such as agricultural sciences.[175] Those external forces will also shape the information produced by those disciplines they have created or nurtured by supporting work in some directions and deterring work in others.[176] In the development of biochemistry in the United States, the dominance of land grant universities meant that there was a focus on "applied" science.[177] Later, as biochemistry moved to medical schools, the focus changed to supporting clinical work and medical school service teaching and on research that could support medical practice.[178]

In the context of environmental science, industry is the main client for much of resource science such as forestry or fisheries science,[179] and that dominance might shape the values of those disciplines, which tend to assume that resources are to be used.[180] Foresters "use terms such as 'tree crops,' draw an analogy between farming and forestry, and often claim that undisturbed forests will

173 See, for example, Patrick J. Michaels, *Meltdown: The Predictable Distortion of Global Warming by Scientists, Politicians, and the Media* 221–35 (Cato 2004). I do not endorse this rather cynical view of climate science.

174 See Kohler, *From Medical Chemistry* at 7, 15–16, 211 (cited in note 94); Joseph Ben-David and Randall Collins, *Social Factors in the Origins of a New Science: The Case of Psychology*, 31 Am Sociological Rev 451, 458–61 (1966) (describing how institutional structures encouraged the development of psychology in Germany); Charles E. Rosenberg, *Factors in the Development of Genetics in the United States: Some Suggestions*, 22 J Hist Med 27, 28–29 (1967) (arguing that social and institutional context helps explain how genetics developed as a formal discipline in the United States); Joseph Ben-David, *Scientific Growth: A Sociological View*, 2 Minerva 455, 469–76 (1964).

175 Kohler, *From Medical Chemistry* at 4–5 (cited in note 94).

176 Schuck, 11 Yale L & Pol Rev at 16 (cited in note 64); Kohler, *From Medical Chemistry* at 324 (cited in note 94) (arguing that "[p]articular scientific styles flourish only where intellectual priorities are congruent with institutional structures and goals"); Robbins and Johnston, 6 Soc Stud Sci at 354 (cited in note 127).

177 Kohler, *From Medical Chemistry* at 96–97 (cited in note 94).

178 Id at 214, 216–17.

179 Bocking, *Nature's Experts* at 85–87 (cited in note 53).

180 Id at 86.

'deteriorate'—that is, become less productive."[181] Likewise, the mission of public agencies that are major clients of a discipline can also have a significant impact on a discipline's development.

Wildlife management provides an excellent example of how outside factors can shape a discipline's perspective. The field of wildlife management developed in the 1930s, with its own journals, societies, and departments in universities.[182] A primary impetus for its creation was the rise of state and federal agencies, such as the new federal Bureau of Biological Survey—the predecessor to the United States Fish and Wildlife Service (FWS)—that sought to restrict hunting and increase game populations.[183] The new federal agency in particular needed tools to monitor, count, and predict wildlife populations so that it could set quotas for duck and waterfowl hunting under a new regulatory system.[184] The new discipline could provide technical support for these goals, but perhaps even more important, "[t]he mantle of science gave game managers legitimacy."[185] Accordingly, the agency supported the development of the discipline: the Biological Survey encouraged its employees to join the new Wildlife Society, and its employees were 10 percent of the new organization's members.[186]

Given this institutional context, it is no surprise that the discipline was heavily oriented in a utilitarian, resource-maximizing direction. One of the founders of the field, Aldo Leopold, defined game management as "the art of making land produce sustained annual crops of wild game for recreational use" and the field was modeled on other "land-cropping arts" such as forestry and agricultural sciences.[187] Wildlife management heavily relied on the

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181 Id.

182 Thomas R. Dunlap, *Saving America's Wildlife* 76, 78 (Princeton 1988) (describing the development of game management as a separate academic discipline from ecology, noting that TWS was founded in 1936, with the Journal of Wildlife Management first published two years later in 1938); Thomas R. Dunlap, *Organization and Wildlife Preservation: The Case of the Whooping Crane in North America*, 21 Soc Stud Sci 197, 200–01 (1991); Samuel P. Hays, *Beauty, Health, and Permanence: Environmental Politics in the United States, 1955–1985* 19 (Cambridge 1987).

183 Dunlap, *Saving America's Wildlife* at 35–40 (cited in note 182); Hays, *Beauty, Health, and Permanence* at 19–20 (cited in note 182).

184 See Dunlap, *Saving America's Wildlife* at 37–38 (cited in note 182); Dunlap, 21 Soc Stud Sci at 200 (cited in note 182).

185 Dunlap, *Saving America's Wildlife* at 76 (cited in note 182).

186 Id at 78.

187 Id at 70–71, 76–77, citing Aldo Leopold, *Game Management* 3 (Scribner's 1933). See also Dunlap, *Organization and Wildlife Preservation*, 21 Soc Stud Sci at 201 (cited in note 182); Hays, *Beauty, Health, and Permanence* at 21 (cited in note 182); R. Ben Peyton, *Wildlife Management: Cropping to Manage or Managing to Crop?*, 28 Wildl Socy Bull 774, 776 (2000).

paradigms of "maximum production, efficiency, and expert management" that had dominated forestry.[188] The applied, agricultural focus of many American land grant universities also provided a welcoming home for such a utilitarian discipline.[189]

From the 1930s onward, academic wildlife science programs "worked hand-in-hand with agencies" to advance the dominant paradigm of managing wildlife populations for hunting and harvesting.[190] State wildlife agencies still hire the largest share of wildlife management program graduates, with federal agencies a close second, and together the two comprise the majority of employment opportunities.[191] Wildlife scientists regularly note (and sometimes bemoan) the heavy influence of these agencies on curricula and research programs.[192]

III. EXPLORING THE ROLE OF DISCIPLINES IN SHAPING ENVIRONMENTAL LAW

If the perspectives of disciplines are so integral to the development of information in environmental science, and if those perspectives interact with the governance institutions and politics of environmental law, then separating the "science" and the "policy" in environmental law is a challenging task. But what if we utilized the intertwinement of science and policy in the world of environmental law?

188 Dunlap, *Saving America's Wildlife* at 76–77 (cited in note 182).

189 Id at 77.

190 John F. Organ and Eric K. Fritzell, *Trends in Consumptive Recreation and the Wildlife Profession*, 28 Wildl Socy Bull 780, 781 (2000). See also Peyton, 28 Wildl Socy Bull at 774 (cited in note 187).

191 Robert M. Muth, et al, *Passing the Torch of Wildlife and Fisheries Management: Comparing the Attitudes and Values of Younger and Older Conservation Professionals, Trans 77th N Am Wildl and Nat Res Conf* 178, 183–84 (Wildlife Management Institute 2002).

192 See, for example, Brown and Nielsen, 28 Wildl Socy Bull at 499 (cited in note 106); Gavin, 17 Wildl Socy Bull at 348–49 (cited in note 118); J. Michael Scott, et al, *Conservation of Biological Diversity: Perspectives and the Future for the Wildlife Profession*, 23 Wildl Socy Bull 646, 650 (1995); James M. Peek, *A Look at Wildlife Education in the United States*, 17 Wildl Socy Bull 361, 361 (1989); Daniel M. Keppie, *To Improve Graduate Student Research in Wildlife Education*, 18 Wildl Socy Bull 453, 455 (1990); Brown and Nielsen, 28 Wildl Socy Bull at 496 (cited in note 106).

My discussion of the underlying values of the fields of conservation biology and wildlife management, and how those values shape the scientific output of those fields, is not a critique of those fields as scientific disciplines or of the scientists in those disciplines. Society (or at least important public and private organizations) decided that protection of endangered species and increasing the availability of game for sport hunters were both important social goals. These fields developed to serve those goals, and they have often performed well in achieving those goals.

Here I develop this possibility and how it might improve the relationship between science and law in the environmental context. By explicitly recognizing the ways in which value choices infuse various disciplines in environmental law, we can design our legal and institutional structures to take into account the disciplinary perspectives: either to embrace them (when those perspectives are thought to advance our overall policy goals in the area) or to offset them (when they instead interfere with our policy goals).[193] Alternatively, we can choose to rely on a more diverse range of perspectives in order to reduce the bias that might come from one particular discipline, if we believe that such bias is improper. The choice between embracing, offsetting, or balancing between different disciplines will often depend on whether the legal or institutional designer seeks to prioritize achieving a particular policy goal at the expense of a greater risk of lower quality information. Regardless of the specific design choice, being cognizant of the importance of disciplinary perspectives allows a potentially simpler way of understanding how policy and science frequently interact than trying, for every regulatory decision, to identify every assumption and inference and the implicit or explicit value choices that drive each of them.

A. Using Scientific Disciplines as Legal- or Institutional-Design Tools

Scientific disciplines can help us accomplish particular policy goals in a range of ways. We might privilege one discipline over another where both are seen as plausibly relevant for the policy process. For instance, a fisheries management program might privilege either the information produced by marine biologists or, alternatively, the information produced by fisheries scientists, depending on whether the policy goal prioritizes the protection of all forms of marine biodiversity, or the assurance of some level of human exploitation of particular fish stocks. But even when there

193 The concept of legal and institutional design is based on administrative law and political-science scholarship exploring how agency structures and procedures might be used by legislatures to shape implementation of a management or regulatory program by an administrative agency. See Gersen, *Designing Agencies* at 339–42 (cited in note 6) (discussing "structure and process" theory); Lisa Schultz Bressman, *Procedures as Politics in Administrative Law*, 107 Colum L Rev 1749, 1785 (2007) (providing overview of literature); Mathew D. McCubbins, Roger G. Noll, and Barry R. Weingast, *Administrative Procedures as Instruments of Political Control*, 3 J L, Econ, & Org 243, 248–53 (1987) (developing the concept of using administrative structure and process to solve principal–agent problems in government agencies, and considered a seminal political science article).

may be only one scientific discipline that is plausibly relevant, privileging that discipline in the policy making process can shape the information that is produced, and thus in turn the decisions that are based on that information. I develop an example of this shortly when I discuss the use of range science by the Forest Service.

In this Part, I explore four different choices for using scientific disciplines as legal- and institutional-design tools: (1) using a discipline to constrain administrative agency decision making, (2) using a discipline to legitimate administrative agency decision making, (3) insulating a discipline from administrative agency decision making, or (4) balancing the role of multiple disciplines in the decision-making process. These four examples help illuminate the possible ways in which disciplines might be used, but they are not exhaustive. My intent is also not to specifically endorse the use of any of these particular tools in general; the desirability of any of these options will depend on the particulars of any given regulatory or management program. I conclude with a discussion of some of the challenges to using specific scientific disciplines as legal- or institutional-design tools, such as the fluidity of the concept of a scientific discipline and the possibility that a discipline might change its perspectives over time—though it is important to keep in mind that these challenges may exist even if disciplines are not consciously or explicitly considered in the design of regulatory or management structures.

Throughout the following discussion, I draw on examples from statutes, regulations, and case law. However, I want to emphasize that my reliance on these examples is not necessarily intended to demonstrate that Congress, agency policy makers, or courts consciously chose to rely on disciplines as legal- or institutional-design tools. Instead, the examples are intended to show how some of the processes and possibilities that I explore might play out in the real world.

1. Option one: constraining.

We might use a discipline as an ex ante constraint on the implementation of an environmental statute by an administrative agency, drawing on the peer-driven independence of the discipline.[194]

194 By ex ante, I mean that the legal or institutional designer (for example, the legislature) sets up a system in advance (at the time the management or regulatory program is established) to constrain how the administrative agency implements the program, rather than attempting to control the agency through ongoing monitoring of the agency's performance. See Gersen, *Designing Agencies* at 334–42 (cited in note 6).

As long as a nontrivial number of members of the discipline are nongovernment employees, a direct mandate from the executive or bureaucratic leaders to those scientists to adopt a particular position on an issue is unlikely to succeed. Likewise, as long as at least some of the funding for a discipline comes from outside the government, it will be more difficult for the legislature to use its budgetary power to impose a consensus on a particular question, unlike how an agency might respond to similar sanctions.

Accordingly, if scientists from a particular discipline are given some sort of voice in the decision-making process—such as regulatory peer review, in which agency regulatory decisions are reviewed by scientists before being implemented—then they can provide effective ex ante control of bureaucracy.[195] Another possibility is that judicial review of agency decision making may pay special attention to a particular scientific discipline in examining an agency's decision.

This role for scientific disciplines has appeal for two reasons: (1) the tremendous need for flexibility in developing and responding to new information in the dynamic world of environmental science, and (2) the importance of using ex ante constraints to control the risk of future slippage in the implementation of environmental statutes by agencies.

Starting with the second point, slippage is particularly important in environmental decision making because there are good reasons to believe that psychological, economic, and political pressures will lead us to systematically implement environmental policy in ways which are socially suboptimal.[196] Many commentators have noted that the diffuse, subtle, and long-term nature of many environmental harms makes environmental law particularly vulnerable to public choice failures in the political process: the costs of organizing to achieve environmental benefits may be high, but any one individual will receive a relatively small share of the (socially quite large) overall benefit that is distributed among most or all members of the public, and free-riders cannot be excluded easily, if at all.[197] On the other side, those who pay for the environmental benefits will often (though not always) be relatively small in number, and their costs will be

195 For a discussion of the ability of peer-reviewed science to act as a neutral ex ante control on agency policies, see Stuart Shapiro and David Guston, *Procedural Control of the Bureaucracy, Peer Review, and Epistemic Drift*, 17 J Pub Admin Rsrch & Theory 535, 543 (2006).

196 See Richard J. Lazarus, *Super Wicked Problems and Climate Change: Restraining the Present to Liberate the Future*, 94 Cornell L Rev 1153, 1173–75 (2009).

197 Id at 1183; Richard J. Lazarus, *The Making of Environmental Law* 41 (Chicago 2004).

much higher per capita then the per capita benefits from the environmental amenities. As a result, there is a classic organizational advantage for the opponents of most environmental regulation.[198]

The obstacles are exacerbated by the subtle and long-term nature of environmental harms, which can take decades to manifest themselves. Myopia often leads us to overvalue short-term benefits and costs and undervalue long-term benefits and costs.[199] Moreover, the substantial uncertainty in environmental law helps encourage the avoidance of costly short-term choices to avoid long-term problems.[200] Myopia and procrastination might endlessly prevent individuals or communities from making the short-term sacrifices necessary to achieve long-term goals, particularly where short-term decisions not to sacrifice will result in "individually negligible" harms, but the accumulation of procrastination over time will result in "cumulatively devastating" outcomes.[201]

Some environmental protection statutes do get passed. The wave of environmental legislation passed in the early-to-mid-1970s has been explained either as a result of a "republican moment" in environmental law in which deliberation by the public led to a focus on the common good and political activism,[202] or as a result of an unusual convergence of public choice dynamics[203]—both explanations rely on the catalyzing influence of high-profile environmental catastrophes.[204] Whatever the story, the problem of long-term implementation still remains, even after the temporary conditions

198 See, for example, Steven P. Croley, *Public Interested Regulation*, 28 Fla St U L Rev 7, 35–38 (2000); Matthew D. Zinn, *Policing Environmental Regulatory Enforcement: Cooperation, Capture, and Citizen Suits*, 21 Stan Envir L J 81, 126–31 (2002); Eric Biber, *The Importance of Resource Allocation in Administrative Law*, 60 Admin L Rev 1, 40–49 (2008); Daniel A. Farber, *Taking Slippage Seriously: Noncompliance and Creative Compliance in Environmental Law*, 23 Harv Envir L Rev 297, 307–08 (1999).

199 See Lazarus, 94 Cornell L Rev at 1174–75 (cited in note 196); Lazarus, *The Making of Environmental Law* at 223 (cited in note 197); Cass R. Sunstein, *Endogenous Preferences, Environmental Law*, 22 J Legal Stud 217, 239 (1993).

200 See Lazarus, 94 Cornell L Rev at 1175 (cited in note 196).

201 See Chrisoula Andreou, *Environmental Preservation and Second-Order Procrastination*, 35 Phil & Pub Aff 233, 240 (2007).

202 See Daniel A. Farber, *Politics and Procedure in Environmental Law*, 8 J L, Econ, & Org 59, 66–67 (1992).

203 See Christopher H. Schroeder, *Rational Choice versus Republican Moment—Explanations for Environmental Laws, 1969–73*, 9 Duke Envir L & Pol F 29, 43–56 (1998).

204 See Farber, 8 J L, Econ, & Org at 67 (cited in note 202); Schroeder, 9 Duke Envir L & Pol F at 45–46 (cited in note 203). Another, more cynical, explanation is that politicians might respond to the public outcry with symbolic legislation that they have no intent of implementing, in which case they would not be interested in adopting the kinds of precommitment mechanisms discussed here. See Murray Edelman, *The Symbolic Uses of Politics* 22–29 (Illinois 1964).

that allowed for the enactment of legislation have disappeared:[205] "Subsequent legislative amendments, limited budgets, appropriations riders, interpretive agency rulings, massive delays in rulemaking, and simple nonenforcement are more than capable of converting a seemingly uncompromising legal mandate into nothing more than a symbolic aspirational statement."[206] For a sincere legislator seeking to ensure effective environmental policy, developing strong precommitments in environmental legislation that require effective future implementation is extremely important.[207]

An appealing precommitment tool is to specify the outcomes for future regulatory decisions. The problem is that environmental law is a highly dynamic field.[208] Thus, for precommitment to succeed in environmental law requires "institutional design features that allow for [ ] flexibility but insulate programmatic implementation to a significant extent."[209]

205 See Farber, 8 J L, Econ, & Org at 63, 72–73 (cited in note 202).

206 Lazarus, 94 Cornell L Rev at 1156 (cited in note 196). See also Farber, 23 Harv Envir L Rev at 298–99 (cited in note 198).

207 See Lazarus, 94 Cornell L Rev at 1197 (cited in note 196); Murray J. Horn, *The Political Economy of Public Administration* 53–54, 183 (Cambridge 1995) (arguing that commitment problems are central to institutional design, particularly when interest groups have disparate organizational strengths).

208 See Lazarus, 94 Cornell L Rev at 1180 (cited in note 196); Lazarus, *The Making of Environmental Law* at 192 (cited in note 197) ("Broad delegations of lawmaking authority are necessary . . . because of the sheer complexity of environmental standard setting, [which] requires deliberations based upon a vast array of informational inputs. . . . The relevant information . . . is constantly changing in light of new information and technology."). See also Daryl J. Levinson, *Parchment and Politics: The Positive Puzzle of Constitutional Commitment*, 124 Harv L Rev 657, 696 (2011). For examples of prespecified lists created by Congress, see 42 USC § 7412(b)(1) (listing 189 toxic substances to be regulated by the EPA under the Clean Air Act); 33 USC § 1317(a)(1) (identifying 65 toxic pollutants to be regulated by the EPA under the Clean Water Act). Such lists were often enacted by Congress as a frustrated response to perceived foot dragging by agencies. See, for example, Kenneth M. Murchison, *Learning from More Than Five-and-a-Half Decades of Federal Water Pollution Control Legislation: Twenty Lessons for the Future*, 32 BC Envir Aff L Rev 527, 552–55 (2005). They have been criticized, however, as inflexible, overambitious, and underinformed. See, for example, William Wombacher, Note, *There's Cologne in the Water: The Inadequacy of U.S. Environmental Statutes to Address Emerging Environmental Contaminants*, 21 Colo J Intl Envir L & Pol 521, 542–43, 554 (2010); John C. Dernbach, *The Unfocused Regulation of Toxic and Hazardous Pollutants*, 21 Harv Envir L Rev 1, 34, 51–53 (1997). See also Stephen Breyer, *Breaking the Vicious Circle: Toward Effective Risk Regulation* 39–42 (Harvard 1993); Richard H. Pildes and Cass R. Sunstein, *Reinventing the Regulatory State*, 62 U Chi L Rev 1, 96–99 (1995); R. Shep Melnick, *The Political Roots of the Judicial Dilemma*, 49 Admin L Rev 585, 586, 589–91 (1997); Robert L. Fischman, *The Divides of Environmental Law and the Problem of Harm in the Endangered Species Act*, 83 Ind L J 661, 681 (2008). In any case, such lists eventually become out of date. See Doremus and Tarlock, 26 Pub Land & Res L Rev at 24 (cited in note 16).

209 Lazarus, 94 Cornell L Rev at 1158 (cited in note 196).

Scientific disciplines might be a very useful solution to this problem:[210] they are flexible in that they develop and respond to new information through a decentralized, peer-based process; but if the values of the relevant disciplines are consonant with the underlying statutory goals, they can provide an important constraint on agency implementation in the future that is (relatively) immune to short-term political pressures.[211]

Consider the problem of global fisheries discussed in Part II.A. There is significant uncertainty about the status of those fisheries given the limited existing data. A legislature concerned about (for instance) the protection of marine biodiversity could rely upon the perspectives of marine ecologists (as opposed to fisheries scientists) in developing the regulatory and management structure. Marine ecologists will generally give the benefit of the doubt to protecting marine biodiversity in relying on data, developing methodologies, making assumptions, and drawing inferences. As shown in the example of the use of "catch-per-effort" data, they will be willing to tolerate uncertainty when making predictions that marine resources need additional protection.[212] That information will in turn be used by the regulatory and management process to reach outcomes that are more protective of marine resources than otherwise might occur. The legislature could even provide that an agency that ignored or overrode this information could be held accountable in court.

The ESA illustrates how courts might hold implementing agencies accountable for disregarding the perspectives of particular scientific disciplines. Science is obviously integral to the implementation of the ESA in order to inform agency decisions about what species are endangered and what steps are required to protect and restore those species. The implementation of the ESA is also extremely controversial—there are hundreds of court cases in which environmentalists, industry, and other parties have challenged the implementation of the statute by the relevant agencies.[213]

210 See Shapiro and Guston, 17 J Pub Admin Rsrch & Theory at 541 (cited in note 195) (arguing that regulatory peer review can constrain a shirking or corrupt agency that violates the legislature's preferences). Richard Lazarus has argued that one way to achieve this precommitment with flexibility is through "more neutral, objective scientific expertise" that gains access to the policy process through advisory bodies or reports. Lazarus, 94 Cornell L Rev at 1220–22 (cited in note 196).

211 See Levinson, 124 Harv L Rev at 680 (cited in note 208).

212 See notes 78–90 and accompanying text.

213 See, for example, *Tennessee Valley Authority v Hill*, 437 US 153, 161–64 (1978); *Miccosukee Tribe of Indians of Florida v United States*, 566 F3d 1257, 1262–64 (11th Cir 2008).

In those cases, courts often rely upon the perspectives of ecology, wildlife management, conservation biology, and related disciplines to determine whether an agency has failed to meet its ESA obligations. These are all disciplines that to one extent or another have perspectives that value the protection of wildlife and biodiversity.[214] Normally it is extremely difficult for a plaintiff to successfully challenge an agency's decision.[215] But plaintiffs do sometimes succeed in ESA litigation, and when they do, it is often because they are able to point to a conclusion within the fields of ecology, wildlife management, conservation biology, or other relevant biological disciplines that the agency is wrong.[216] In these cases, the reading of uncertain information that is given by particular disciplines is privileged by the courts over the interpretation by an administrative agency of the same information.

While there is no indication that Congress in enacting the ESA sought this kind of outcome,[217] a hypothetical legislator who wished

214 While there are differences among these disciplines, all place high value on the conservation of wildlife. See Parts II.B and II.C.

215 See, for example, *Marsh v Oregon Natural Resource Council*, 490 US 360, 377–85 (1989).

216 See, for example, *Western Watersheds Project v Foss*, 2005 WL 2002473, *15–16 (D Idaho 2005) (overturning the FWS's decision not to list plant species under the ESA in part because the agency's assessment ignored peer reviews by biologists and ecologists finding that listing was warranted and because the agency's conclusion that a 64–82 percent chance of extinction within 100 years did not warrant listing contradicted a guideline provided by the International Union for Conservation of Nature, a leading conservation biology professional and advocacy society, that a 10 percent risk of extinction in 100 years warrants protection); *Center for Biological Diversity v Kempthorne*, 607 F Supp 2d 1078, 1089–91 (D Ariz 2009) (scrutinizing the statements of a leading "jaguar expert . . . at the Wildlife Conservation Society" and rejecting an agency decision not to prepare recovery plan or designate critical habitat for jaguar based on the expert's statements since the statements did not support such a decision); *Defenders of Wildlife v Babbitt*, 958 F Supp 670, 676, 681–82 (DDC 1997) (overturning the FWS's refusal to list lynx for protection under the ESA where "not a single biologist or Lynx expert employed by the FWS disagreed with the recommendation" to list the species, state wildlife agency biologist studies supported listing, and where The Wildlife Society concluded that species population was in decline); *Northern Spotted Owl v Hodel*, 716 F Supp 479, 481–83 (WD Wash 1988) (overturning the agency's decision not to list owl species where experts on "population viability" and "the acknowledged founder of the discipline of 'conservation biology'" concluded that the species should be listed); *Western Watersheds Project v Fish and Wildlife Service*, 535 F Supp 2d 1173, 1178, 1180, 1186 (D Idaho 2007) (remanding the agency's decision not to list sage-grouse for ESA protection where the decision was contradicted by a report issued by a "group of State agency wildlife biologists who were experts on the sage-grouse" that was also "peer-reviewed by an independent group of scientists selected by the Ecological Society of America" and supported by the conclusions of a "panel of seven outside scientists with expertise in sage-grouse biology and ecology, sagebrush community ecology, and range ecology and management").

217 The ESA requires the FWS and the National Oceanic and Atmospheric Administration (NOAA) to use the "best scientific and commercial data available" in making many decisions. See 16 USC §§ 1533(b)(1)(A), 1536(a)(2). This language derives from a series of predecessor statutes: the 1966 Endangered Species Preservation Act, Pub L No 89-669

to reverse and halt the trend towards species extinction might indeed seek to use disciplines in this way. Such a legislator might understand that while Congress as a general matter might endorse the protection of all endangered species, when and if debates ever came down to the decision about whether to protect a particular species at the expense of particular interest groups or communities, the political support might be much weaker.[218] The general benefits of protecting species might be overridden regularly (at a socially undesirable rate) in the context of specific, concrete decisions. Such a legislator might also believe that Congress in 1973 knew so little about which species should be protected ten or twenty or thirty years in the future—or even how many species might require protection—that specific rules

§ 1(c), 80 Stat 926, repealed by the ESA § 14, 87 Stat at 903, required the implementing agencies to "seek the advice and recommendations of interested persons and organizations including, but not limited to, ornithologists, ichthyologists, ecologists, herpetologists, and mammologists" in making listing decisions. 1966 Endangered Species Preservation Act § 1(c), Pub L No 89-669, 80 Stat 926, repealed by the ESA § 14, 87 Stat at 903. In 1969, the best available science requirement was made explicit. Endangered Species Conservation Act of 1969 § 3(a), Pub L No 91-135, 83 Stat 275, 275, repealed by the ESA § 14, 87 Stat at 903. In the popular consciousness of the 1960s, ecology (mentioned in the 1966 Act) was strongly associated with the protection of the environment in general and the conservation of endangered species before the appearance of a distinct field of conservation biology in the 1980s. See Takacs, *The Idea of Biodiversity* at 11–30 (cited in note 54); Bocking, *Nature's Experts* at 56–58, 61–62 (cited in note 53); Roderick Frazier Nash, *The Rights of Nature: A History of Environmental Ethics* 55–86 (Wisconsin 1989); John Opie, *Nature's Nation: An Environmental History of the United States* 413–15 (Harcourt Brace 1998); Sylvia Noble Tesh, *Uncertain Hazards: Environmental Activists and Scientific Proof* 40–61 (Cornell 2000); Hays, *Beauty, Health, and Permanence* at 26–32 (cited in note 182). For instance, Washington State's environmental protection agency was created in 1970 and is still called the Department of Ecology. See Maria McLeod, *Historically Speaking: An Oral History in Celebration of the First 35 Years, 1970–2005* 5 (Washington State Department of Ecology 2005), online at http://www.ecy.wa.gov/pubs/0501006.pdf (visited Dec 15, 2011). Public surveys in this period identified a correlation between a "scientific approach" to resource management and a general support for environmental protection. Hays, *Beauty, Health, and Permanence* at 33–34, 256–58 (cited in note 182) (noting that "[f]rom the Mid-1960s on, ecology as a scientific discipline became central in environmental inquiry, and much of its perspective was adopted and adapted by environmentalists in their views as to what kinds of scientific knowledge and technologies should be advanced," including the need to protect biodiversity). However, we have almost no legislative history that could provide further insights into Congress's intent. Holly Doremus's extremely thorough review of that legislative history shows very little discussion of the topic in Congress. Doremus concludes that the legislative history shows that the best available science mandate was "generally intended to ensure objective, value-neutral decision making by specially trained experts." Doremus, 34 Envir L at 419 (cited in note 15). See also Doremus, 75 Wash U L Q at 1130 (cited in note 55) (expressing skepticism that Congress intended to privilege particular scientific disciplines through its use of the best available science concept).

[218] See *Tennessee Valley Authority*, 437 US at 152–53, 184 (noting that the original legislative intent of Congress in enacting the ESA was to "halt and reverse the trend toward species extinction, whatever the cost," but the Supreme Court also noted that Congress subsequently appropriated funds for the completion of a dam that might drive a species into extinction).

(for example, protect these species now, or protect at least fifty species a year) are inadequate. But by legally privileging particular scientific disciplines, a legislator can draw on a decentralized, peer-based social organization that is outside the direct control of future legislators or the executive branch, that has expertise in developing the relevant information needed to resolve uncertainty in the future and respond to dynamic, complex change, and that has underlying values that will lead it to push for implementation of the statute consistent with the legislator's purposes.

2. Option two: legitimation.

A different choice would be to closely tie the relevant scientific discipline to the administrative agency structure and use the discipline to legitimate and advance that agency's implementation of the relevant statutes.

From the agency's perspective, it can use science to provide the benefits of legitimacy, as discussed earlier.[219] But in addition, limiting the political or legal scope of discussion to a particular discipline may make it easier for the agency to frame the information relevant for its decisions, and therefore make the agency's decision-making process simpler. The larger the scope of the relevant science, the more diverse viewpoints are available, the easier it is to find dissenters; the harder it is to meet whatever legal standard might exist to change the legal status quo, the easier it is to argue to wait until the "science is clearer." On the other hand, by privileging a particular disciplinary perspective, agencies can cabin the range of scientific information and arguments that are available for a policy debate and therefore help shape and advance particular outcomes. Disciplinary restrictions can be an important way to tame what is otherwise the very decentralized and peer-driven social structure of science—but in a subtle way that appears to endorse, rather than conflict with, science.

From an institutional or legal design perspective, legitimation of agency decision making may be a desirable goal because the agency may be seen as necessary for the long-term implementation of the relevant policy. The institutional power and structure of a major regulatory or management agency might be essential to offset other important interest groups (such as regulated industry) in future implementation. A sympathetic scientific discipline can provide that

[219] See notes 29–38, 169–73 and accompanying text. See also Jasanoff, 7 Osiris at 194, 203, 215 (cited in note 155).

agency with additional political and legal heft that it needs for future political battles.

An example of how disciplines can provide legitimacy for an administrative agency, and how an agency might use a discipline to shape the information relevant for its decision making, is the interaction between the discipline of range science (the study of the impacts of grazing on grasslands) and the Forest Service. While range science has roots that go back to the nineteenth century, the discipline was nurtured in its formative years by the Forest Service.[220] From the beginning, the Forest Service did not limit itself to managing the timber on its lands. It also looked to manage the grazing of livestock on those lands—something that hitherto had been regulated by the states, if at all.[221] Grazing regulation was immediately controversial, requiring two decisions by the Supreme Court to confirm the agency's regulatory powers,[222] and that controversy never disappeared, as the Forest Service found itself regularly locked in battles with grazers and their congressional allies whenever it sought to reduce permitted grazing levels.[223]

In fighting those battles, the Forest Service concluded that data produced by scientists would provide a formidable political and legal ally.[224] In the early twentieth century, government scientists developed estimates of the maximum grazing capacity for rangelands, estimates that were then used by the Forest Service to create systematic estimates of whether rangelands were being grazed in excess of their "carrying capacity."[225] As historian William Rowley put it:

> [I]n order for its officers in the field to administer with confidence and professionalism, the Forest Service needed to

220 See N.F. Sayre and M. Fernandez-Gimenez, *The Genesis of Range Science, with Implications for Current Development Policies*, in N. Allsopp, et al, eds, *Proceedings of the VIIth International Rangelands Congress* 1976, 1978 (2003); Nathan F. Sayre, Eric Biber, and Greta Marchesi, *Social and Legal Effects on Monitoring and Adaptive Management: A Case Study of National Forest Grazing Allotments, 1927–2007*, Socy & Nat Resources (forthcoming 2012). Thanks to Nathan Sayre for assistance in the research of this history.

221 See *Omaechevarria v Idaho*, 246 US 343, 352 (1918) (upholding state regulation of grazing on federal land); *Light v United States*, 220 US 523, 529, 535 (1911) (noting historic regulation of grazing by states and absence of federal regulation).

222 *United States v Grimaud*, 220 US 506, 511 (1911); *Light*, 220 US at 535.

223 See Nancy Langston, *Forest Dreams, Forest Nightmares: The Paradox of Old Growth in the Inland West* 206–16 (Washington 1995); William D. Rowley, *U.S. Forest Service Grazing and Rangelands: A History* 180–87 (Texas A&M 1985).

224 Sayre and Fernandez-Gimenez, *The Genesis of Range Science* at 1978–79 (cited in note 220).

225 See Rowley, *U.S. Forest Service Grazing and Rangelands* at 99, 101 (cited in note 223); Sayre, et al, *Monitoring as a Social Process* (cited in note 220).

> make decisions rooted in information derived from objective, scientific study. . . . [T]he professional manager could speak much more authoritatively if he could show that 'studies have been conducted.' On the basis of this research, decisions could be made in the interests of professional management of the forest and its resources. If the administrators of the range were to professionalize themselves and their tasks, they needed a body of knowledge from which they could derive authority. . . . Range science was the unspoken but necessary source of authority for aggressive range-management policies.[226]

Accordingly, the Forest Service adopted the field of range science as the basis for its grazing-management program, in part because the field promised a quantifiable estimate of how much grazing a rangeland could sustainably support and of whether a particular pasture was exceeding that carrying capacity. Through its research stations and management actions, the Forest Service helped guide the field of range science to adopt the very "carrying capacity" perspective that would be most useful to the agency.[227] Over the decades, the Forest Service increasingly adopted quantitative estimates of range condition based on range science and hired more and more range scientists ("range conservation" personnel in the bureaucracy) to conduct estimates of grazing conditions in order to continue its struggles with recalcitrant permittees.[228]

One epoch in the 1940s helps demonstrate the pattern: Congress had held hearings in which grazing permittees expressed their unhappiness with federal management and threatened to divest the Forest Service of its grazing lands.[229] The resulting political environment meant that the agency had to tread carefully.[230] It was no coincidence that in the late 1940s, the Forest Service turned to a leading range scientist "to develop a system for measuring range conditions and trends, usable throughout national forests as a

226 Rowley, *U.S. Forest Service Grazing and Rangelands* at 111 (cited in note 223). See also Thomas G. Alexander, *From Rule-of-Thumb to Scientific Range Management: The Case of the Intermountain Region of the Forest Service*, in Char Miller, ed, *American Forests: Nature, Culture, and Politics* 179, 179–80 (Kansas 1997).

227 Sayre and Fernandez-Gimenez, *The Genesis of Range Science* at 1980 (cited in note 220) (noting that the "practical exigencies of management and administration determined the research agenda—and thus indirectly the findings—of range science").

228 See Sayre, et al, *Monitoring as a Social Process* (cited in note 220); Sayre and Fernandez-Gimenez, *The Genesis of Range Science* at 1978 (cited in note 220).

229 See William Voigt Jr, *Public Grazing Lands: Use and Misuse by Industry and Government* 110–21 (Rutgers 1976); Rowley, *U.S. Forest Service Grazing and Rangelands* at 173–230 (cited in note 223).

230 See Rowley, *U.S. Forest Service Grazing and Rangelands* at 188 (cited in note 223).

management tool that would be uncomplicated, scientifically sound, and acceptable to permittees who owned livestock using national forest rangeland."[231] That system has become the basic methodology for range monitoring for national forests and many other rangelands in the United States.[232] These developments occurred just as the discipline of range science was developing its institutional structures, such as the formation of the Society for Range Management in 1948, and the creation of masters and doctoral programs in range science in many universities between 1930 and 1950.[233]

The Forest Service also shaped how range science developed information. Range science emphasized the notion of a fixed carrying capacity for rangelands, based on ecological theories that held that any ecosystem that was protected from disturbance would naturally proceed towards a climax state ("successional" theory).[234] In the context of rangelands, this meant that any difference between the "natural" state of a grassland and its existing state was more likely to be the result of overgrazing, and reduction of grazing was the appropriate solution.[235]

However, early range scientists working in the American Southwest observed that rangeland conditions varied tremendously from year to year, often regardless of grazing pressures. Carrying capacity in these rangelands did not appear to be fixed, but instead highly variable depending on climatic conditions.[236] Yet despite these observations, these range scientists eventually embraced the concept of fixed carrying capacity, in part because of the legal and

231 Lloyd W. Swift, *Kenneth William Parker, 1904–1973*, 1 Wildl Socy Bull 153, 153–54 (1973).

232 Sayre, et al, *Monitoring as a Social Process* (cited in note 220).

233 See Sayre, *The Genesis of Range Science* at 1980 (cited in note 220). See also Clinton H. Wasser, Elbert H. Reid, and Arthur D. Smith, *A History of the Society for Range Management, 1948–1985* 1–3 (Society for Range Management 1987), online at http://www.rangelands.org/pdf/SRM%20History%201948-1985.pdf (visited Dec 15, 2011).

234 National Research Council, *Rangeland Health: New Methods to Classify, Inventory, and Monitor Rangelands* 52–62 (National Academy 1994); Society for Range Management, *New Concepts for Assessment of Rangeland Condition*, 48 J Range Mgmt 271, 272–73 (1995).

235 See Nathan F. Sayre, *Ranching, Endangered Species, and Urbanization in the Southwest: Species of Capital* 76–77 (Arizona 2002).

236 Nathan F. Sayre, *Recognizing History in Range Ecology: 100 Years of Science and Management on the Santa Rita Experimental Range*, USDA Forest Service Proceedings RMRS-P-30 1, 5 (2003) (describing how an early researcher's "reports contain numerous remarks, however, that suggest he had doubts about the concept of carrying capacity when applied 'in a region where the seasons, the altitude, the slope, and the rainfall are so variable'"); id at 6 ("[B]oth of [the leading range science researchers in the Southwest] expressed reservations, tacitly or explicitly, about the central premise of the system of rangeland administration institutionalized over the following decades.").

bureaucratic needs for such a concept.[237] It would take decades for range science (and other disciplines, such as ecology) to question this concept.[238] The choice of a particular discipline, and the perspective that the discipline took (shaped in significant part by the administrative agency it was allied with), resulted in a significant change in how the natural world was viewed.

The Forest Service's interactions with range science provide an excellent example of the way in which an administrative agency's reliance on a particular scientific discipline not only provides legitimacy for the agency directly, but can also shape the production of information in ways that supports the agency's political and legal goals and narrows the range of information available for political and legal debate. Range science, under the influence of the Forest Service, developed a concept of carrying capacity that downplayed other influences on rangeland conditions (such as climatic variability) and emphasized the role played by active management of grazing levels by the Forest Service. This in turn provided political and legal support for the agency to take steps to manage grazing levels on Forest Service allotments.

3. Option three: insulation.

A legal or institutional designer might be concerned that a discipline could interfere with future implementation, perhaps because the perspective of the discipline could undercut achievement of desired policy goals. Legislators might accordingly try to reduce the influence of that discipline. They might impose high public-participation requirements, heavy involvement of political appointees in the decision-making process, explicit statutory language mandating that courts not defer to the agency on technical questions, or explicit efforts to force the development and use of

237 See id at 12–13 (describing how "[r]ange scientists generated carrying capacity estimates that aspired to be independent of fluctuating rainfall, and economic and political constraints compelled ranchers and agencies to interpret proper stocking in terms of static carrying capacities," and noting that "highly variable carrying capacities might have [been] economically and administratively impractical"); Sayre, *Ranching, Endangered Species, and Urbanization* at 62–65 (cited in note 235) (noting early work that recognized the extreme variability of Southwest rangelands, but that carrying capacity was "the conceptual foundation [of] leasing, the cornerstone of range reform," and therefore fixed carrying capacities had to be determined); Nathan F. Sayre, *Climax and "Original Capacity": The Science and Aesthetics of Ecological Restoration in the Southwestern USA*, 28 Ecological Restoration 23, 27–28 (2010) (noting that fixed carrying capacity was needed if range science was to be useful for management).

238 See National Research Council, *Rangeland Health* at 62 (cited in note 234).

competing scientific disciplines in the decisionmaking process, among other tools.

One possible example of how disciplines might have been used in this way is the effort to reform the Forest Service in the 1970s.[239] Historically, there was a tight relationship between the Forest Service and the discipline of forestry.[240] Graduates from forestry programs provided the vast majority of professional employees for the Forest Service for many years.[241] The discipline of forestry emphasized the measurement and classification of forests to maximize timber production,[242] just as the Forest Service emphasized those goals in its management.[243] The Forest Service had significant influence on forestry research on questions such as whether fire helped or hindered timber management.[244]

In the 1960s and 1970s there was a significant public movement to try and reorient the Forest Service around a wider range of goals besides timber production. During that time frame, Congress instructed the Forest Service to manage for a wider range of goals and to ensure that minimum environmental standards were met on Forest Service lands.[245] One tool that Congress relied upon was instructing the agency to draw on a wide range of disciplinary

239 See Eric Biber, *Too Many Things to Do: How to Deal with the Dysfunctions of Multiple-Goal Agencies*, 33 Harv Envir L Rev 1, 18 (2009).

240 The founder of the Forest Service, Gifford Pinchot, also helped found the Society of American Foresters and the Yale School of Forestry—the first major forestry school in America—in 1900. See Samuel Trask Dana and Sally K. Fairfax, *Forest and Range Policy: Its Development in the United States* 84 (McGraw-Hill 1980). See also Char Miller, *Gifford Pinchot and the Making of Modern Environmentalism* 117, 196, 279 (Island 2001).

241 See Paul W. Hirt, *A Conspiracy of Optimism: Management of the National Forests since World War Two* xxxvii, 59–60 (Nebraska 1994); Henry Clepper, *Professional Forestry in the United States* 2, 49 (Johns Hopkins 1971).

242 As a select committee of university professors of forestry concluded in a congressional report, "The core of forestry professionalism, the central tenent [sic] of professional dogma, is sustained yield timber management." In other words, managing forests in order to maximize the amount of timber that can be produced in perpetuity from the forest. *Select Committee of the University of Montana, A University View of the Forest Service*, S 91–115, 91st Cong, 2d Sess 22 (1970). See also Hirt, *A Conspiracy of Optimism* at 6 (cited in note 241); Nancy Langston, *Environmental and Human Change in Old-Growth Forests*, 7 Rsrch Soc Probs & Pub Pol 253, 260 (1999).

243 For instance, the agency made aggressive efforts after World War II to convert "decadant old growth" forests into rapidly growing, young forests that would provide much greater levels of timber production under active Forest Service management. See Langston, 7 Rsrch Soc Probs & Pub Pol at 253, 258–60 (cited in note 242).

244 See Ashley L. Schiff, *Fire and Water: Scientific Heresy in the Forest Service* 15–50 (Harvard 1962).

245 See Biber, 33 Harv Envir L Rev at 18–20 (cited in note 239).

perspectives in conducting its planning and decision making.[246] Over time, this has resulted in a greater diversity of scientific disciplines among the staff of the Forest Service, which in turn appears to have had a significant effect on the agency's decision making, causing it to consider environmental impacts of timber production to a much greater degree.[247]

246 See, for example, 16 USC § 1604(b) (requiring agency to use a "systematic interdisciplinary approach" in planning); 16 USC § 1604(f)(3) (requiring agency to use an "interdisciplinary team" to prepare planning documents). The provision was originally enacted in 1974 as part of the Forest and Rangeland Renewable Resources Planning Act of 1974 (RPA) § 5(b), Pub L No 93-378, 88 Stat 476, 477. It was part of a forest reform bill introduced by Senator Hubert Humphrey to provide more balance and environmental protection in Forest Service decision making. See National Forest Environmental Management Act of 1973, S 2296, 93d Cong, 1st Sess, in 119 Cong Rec S 26797 (daily ed July 31, 1973); 119 Cong Rec S 27174 (daily ed Aug 1, 1973) (statement of Sen Lee Metcalf). Much of the rest of the original bill was substantially changed in response to industry pressure, eliminating substantive restrictions on timber cutting, for example, and making it more of a procedural, planning statute that was in part intended to alleviate a perceived timber shortage. See Amendment No 641, 93d Cong, 1st Sess, in 119 Cong Rec S 36106 (daily ed Nov 7, 1973) (statements by Sen Humphrey); *Forest and Rangeland Environmental Management Act of 1974*, S Rep No 93-686, 93d Cong, 2d Sess 5, 8–9; *Forest and Related Resources Planning Act of 1974*, HR Rep No 93-1163, 93d Cong, 2d Sess 1–2. Nonetheless, the interdisciplinary provision remained and became part of the final law. There was relatively little discussion of the provision itself during the legislative process, and what references there were emphasized that the provision could improve balance in agency decision making. See S Rep No 93-686 at 12 (cited in note 246) ("The further requirement that such plans shall use a systematic interdisciplinary approach to achieve integrated consideration of physical, biological, economic and other sciences, is designed to assure that a balanced, comprehensive methodology will be employed."). Timber industry representatives who testified at hearings for the bill indicated no opposition and claimed that interdisciplinary work was already standard practice in the Forest Service. See *National Forest Environmental Management Act, Hearing on S 2296 before the Subcommittee on Environment, Soil Conservation and Forestry of the Committee on Agriculture and Forestry*, 93d Cong, 1st Sess 78 (1973) (statement of William E. Towell, Executive Vice President, American Forestry Association); id at 99 (statement of Arnold D. Ewing, Executive Vice President, North West Timber Association). Interestingly, the Society of American Foresters explicitly endorsed the provision, perhaps because the society asserted that it already represented a wide range of practitioners in addition to foresters, and therefore the provision would provide additional employment opportunities. *Forest and Rangelands Environmental Management Act, Hearings on HR 11320 before the Subcommittee on Forests of the Committee of Agriculture*, 93d Cong, 1st Sess 67–68 (1973) (statement of H.R. Glascock Jr, Executive Vice President, Society of American Foresters).

247 See Biber, 33 Harv Envir L Rev at 22 (cited in note 239). The RPA provision requiring a reliance on a range of disciplines makes it difficult for courts applying the statute to use the conclusions of particular disciplines to constrain agency decision making. For instance, in *Sierra Club v Marita*, 46 F3d 606 (7th Cir 1995), the court rejected claims by environmental groups and conservation biologists that the Forest Service was legally required to use conservation biology principles because conservation biology provided the most relevant science for shaping agency management plans to achieve the goal of biodiversity protection. Id at 617, 619–24. The court concluded that the agency had great discretion to draw on a range of scientific tools and was not required to rely specifically on conservation biology. Id at 619–24. *Marita* shows that the use of disciplines in one way under a statute may exclude the use of

4. Option four: balancing.

So far the analysis has assumed that there is a particular policy goal—conservation of endangered species, or active management of forests to maximize output—that the legal or institutional designer seeks to achieve and the designer selects particular disciplines to help achieve that goal, perhaps to offset other political pressures. But there may be many situations in which the policy goal is not so specific or where the concern about political pressures is not so severe. Here, the legal and institutional designer might be more concerned about trying to get the "best" information (however defined) to identify the relevant problems and possible solutions.

In this context, drawing on a diverse range of scientific disciplines may be a good option. A wide range of disciplinary perspectives will ensure that a wide range of values will be brought to bear, that the biases or blind spots of any one discipline are more likely to be identified by individuals in other areas, that important aspects of a particular problem will be identified, or that interdisciplinary debates might provoke a broader range of creative solutions.

Blind spots might be technical or methodological. For instance, the EPA has been criticized for relying too heavily on experimental toxicology data (for example, tests on lab animals) for determining health risks from chemicals or pollution and too little on observational epidemiological data.[248] The concern is that this narrow focus means that the EPA has ignored useful information that could help with regulation in the context of high levels of uncertainty.[249] It appears that one of the reasons why environmental review documents did not accurately identify the risks of a massive oil spill from deepwater drilling in the Gulf of Mexico (as occurred with the Deepwater Horizon disaster) is the lack of appropriate scientific expertise in reviewing agencies, such as engineers who might have properly evaluated the risks from a blowout.[250] In the example of the

disciplines in other ways under that statute. This is a specific example of a more general point: statutes may limit the ability of agencies to use scientific disciplines in particular ways.

248 See Mark R. Powell, *Science at EPA: Information in the Regulatory Process* 64, 123, 194–95 (Resources for the Future 1999) (giving an example from an EPA air regulatory program).

249 Id at 64, 123. In some contexts, reliance on toxicology is seen as being more "risk-averse" in terms of avoiding harms from potentially toxic chemicals, and therefore more likely to result in regulation, than reliance on epidemiology. See Rushefsky, *Making Cancer Policy* at 28, 32, 41, 45–46 (cited in note 25).

250 See Holly Doremus, *Through Another's Eyes: Getting the Benefit of Outside Perspectives in Environmental Review*, 38 BC Envir Aff L Rev 247, 261–69, 274 (2011).

conflict between fisheries scientists and marine ecologists discussed in Part II.A, a détente was reached between the two sides with an effort to work together to develop mutually acceptable methodologies for assessing global fisheries; the result was a series of papers that both sides could agree upon as accurately reflecting the status of the world's marine biological resources.[251]

Blind spots may also involve important social goals or values. If all of our information is gathered and applied within the framework of a single discipline, and we are not conscious about the value choices that the discipline is based on, then we may be blind to the inevitable tradeoffs that those implicit value choices force us to make. For instance, the definition of a species for conservation purposes necessarily "requires the making of value judgements."[252] Statistical genetics tests intended to determine whether two populations are separate subspecies or species worthy of protection under the ESA necessarily require prior assumptions as to (a) what types of errors we are more willing to accept and (b) what level of risk of each error we are willing to accept. Are we more willing to accept a 5 percent chance that we conclude a population is not a separate subspecies when in fact it is one (a Type II error), or a 5 percent chance that we conclude a population is a separate subspecies when in fact it is not one (a Type I error), and which of the two is the more important decision criterion?[253]

In a recent scientific fight over whether a population of jumping mice in the Front Range of Colorado and Wyoming was a subspecies that warranted legal protection, different scientists took different positions based on the outcomes of their studies, but few recognized that at the heart of their disagreement was a difference of opinion about which risks were more problematic. Those that believed that the Preble's jumping mouse was not a separate subspecies emphasized the risk of Type I errors in their analyses, while their opponents emphasized the risk of Type II errors.[254] But the problem is even worse because the statistical tests used by the scientists (particularly those that attempt to estimate the risk of Type II error) also implicitly require an understanding of what should be the minimum genetic difference between populations that justifies calling them species or subspecies—without such an understanding,

251 See Stokstad, 324 Sci at 170–71 (cited in note 73).

252 Carolan, 17 Envir Polit at 450–51 (cited in note 33).

253 Id at 455–56. See Brosi and Biber, 7 Front Ecol & Envir at 493 (cited in note 93).

254 Carolan, 17 Envir Polit at 456–57 (cited in note 33).

one simply cannot conduct the relevant tests.[255] The scientists involved in the controversy had hardly considered this question.[256] In other words, bias and blind spots as to crucial (implicit) value choices inevitable in this kind of work meant that important policy questions were predetermined (unconsciously) by the researchers.[257]

Because of the disciplinary blind spots, taxonomists and conservation biologists have not yet developed a concept of a "minimum level of change or difference" that needs to be met in order for a species or subspecies designation to be made.[258] The problem, however, is that identification of species or subspecies for regulatory protection necessarily implies the expenditure of scarce societal resources at the expense of other social goals—in other words, a tradeoff. Biologists who take the value of protecting biodiversity as a given are not well-placed to identify such tradeoffs,[259] and accordingly have not developed analytic tools that would require identifying tradeoffs, making decisions about those tradeoffs, and translating them into (for instance) an assessment of how much genetic difference between populations society should value and therefore identify as worthy of protection as a protected species or subspecies. It will require outsiders—perhaps economists, perhaps judges, perhaps scientists from other disciplines—with different perspectives to force such a process to occur.[260] These are the reasons Sheila Jasanoff has called for diversity of disciplines to be used in expert advisory bodies that agencies or policy makers rely upon.[261]

255 See Brosi and Biber, 7 Front Ecol & Envir at 493 (cited in note 93). See also Carolan, 17 Envir Polit at 449–50 (cited in note 33).

256 See Brosi and Biber, 7 Front Ecol & Envir at 488–89 (cited in note 93).

257 Funtowicz and Ravetz, *Three Types of Risk Assessment* at 265 (cited in note 17) (noting the inevitable value choices implicated by choices as to statistical significance and statistical analysis tools).

258 See Brosi and Biber, 7 Front Ecol & Envir at 488–89, 492–93 (cited in note 93).

259 Doremus, 86 Tex L Rev at 1617–19, 1627 (cited in note 22) (arguing that "if scientists do not recognize their values as such, and fail to concede the possibility that others might hold different values, they cannot consciously monitor the extent to which their values influence their scientific work," and noting that "the assumption that there can be only one view about the relative value of conservation is widespread among [conservation biology graduate students]").

260 See Brosi and Biber, 7 Front Ecol & Envir at 492 (cited in note 93) (suggesting the role that courts could play in forcing this development in the ESA listing process); Holly Doremus, *Using Science in a Political World: The Importance of Transparency in Natural Resource Regulation*, in Wagner and Steinzor, eds, *Rescuing Science from Politics* 143, 160–64 (cited in note 47) (calling for disclosure of agency scientific reports as part of this process).

261 Jasanoff, 30 Sci & Pub Pol at 161 (cited in note 31). See also Doremus and Tarlock, 26 Pub Land & Res L Rev at 32 (cited in note 16); Doremus, 32 Ecol L Q at 302 (cited in

An example of the use of a diversity of disciplines in this way in environmental policy making is the National Environmental Policy Act of 1969[262] (NEPA). NEPA requires the federal government to conduct a review of the relevant environmental impacts before conducting any major action that might significantly impact the environment.[263] NEPA further requires any such review to use an "interdisciplinary approach."[264] One of the goals of NEPA was to force consideration of a wider range of values in governmental decision making, particularly environmental values;[265] imposing a requirement for interdisciplinary review of the impacts of proposed projects can be seen as an effort to reduce disciplinary blind spots that might ignore important environmental values.[266]

There is a significant tension in any choice between privileging or distancing particular disciplines and balancing a diversity of disciplines. In the first case, scientific disciplines are being used to stabilize the policy-making process (through constraint, legitimation, or insulation) against political or economic pressure in order to ensure that the implementation process will be more likely to achieve a particular goal. In the second case, a diversity of disciplines is being used to increase the chances that important values are not ignored, that important policy options are not overlooked, and that important facts or information are not excluded.[267] In general,

note 22); David E. Winickoff and Douglas M. Bushey, *Science and Power in Global Food Regulation: The Rise of the Codex Alimentarius*, 35 Sci, Tech, & Hum Values 356, 372 (2010).

262 Pub L No 91-190, 83 Stat 852 (1970), codified at 42 USC §§ 4332–35.

263 See NEPA § 102, 83 Stat at 853.

264 See NEPA § 102(A), 83 Stat at 853.

265 See Biber, 33 Harv Envir L Rev at 35–41 (cited in note 239) (describing the history and purposes of NEPA).

266 Id at 38–39 (suggesting that scientists hired by agencies to put its projects in compliance with NEPA may be sequestered in institutional "cul de sacs" where their perspectives are not given attention for decision-making purposes). The success of NEPA in achieving these results is unclear.

NEPA and RPA both can be seen as using interdisciplinary decision-making requirements to achieve different goals (balancing versus insulation), demonstrating how the same policy tool might serve different goals in terms of using disciplines in institutional and legal design.

267 Developing the process of balancing across disciplines may require some complex institutional design choices as well. A simple balancing process might just aggregate estimates or preferences from different disciplinary representatives. But simple aggregation will only result in a better approximation of the objective truth in the natural world if the distributions of those perspectives are roughly symmetric (that is, their errors are equally distributed around whatever the true value of the natural world is) and independent of each other (that is, their errors are not correlated). These conditions might not be satisfied in many cases (for example, disciplines might influence each other). If we know that these conditions are not satisfied, we might want to give some disciplines a greater representation in the decision-making process (to offset skewed distributions) or ensure that disciplines that are relatively independent of other disciplines have representation in the process. Moreover, we may not know if either of these

balancing disciplines might be the choice that is preferable when we are less concerned about public choice failures or political or economic pressures on the decision-making process. The choice of balancing a diversity of disciplines can be seen as prioritizing getting "better" information and a more inclusive decision-making process, but with less of a focus on a particular, specific policy outcome. The first three options instead can be seen as prioritizing accomplishing predetermined goals, with the attendant risk of using "worse" information in the decision-making process, and at the risk of excluding particular values.

5. Limits to using disciplines as institutional- or legal-design tools.

The discussion above lays out the ways in which scientific disciplines might be useful institutional- or legal-design tools. But there are also limits to using them in this way. Some of those limits have to do with the external pressures that might shape disciplines, reducing their utility; others have to do with the internal instability of disciplines, the possibility that they may change, fracture, or merge with other disciplines and therefore may not be predictable in the future. Finally, there is the question of whether explicitly relying on disciplines as policy tools undermines their effectiveness as policy tools.

a) Outside pressures. Science is not immune to political pressures, as the Forest Service's shaping of forestry and range science shows. Scholars have regularly bemoaned the ability of interest groups or agencies to shape the production of scientific information in the environmental arena. For instance, the differential ability of various interest groups to mobilize effective challenges to new scientific information (with regulated industry often portrayed as having a substantial advantage[268]) might result in the skewing of scientific outcomes in a systematic way.[269] In response to unfavorable studies, interest groups might marshal criticisms of the

conditions are satisfied, in which case we might choose to rely on other, less mechanistic approaches, such as deliberation among a group of disciplinary representatives. Similar problems can arise if our goal is to achieve some level of representation of a variety of social values and goals through disciplinary balancing.

268 For instance, industry historically dominated the scientific advisory process for pesticide regulation in EPA because of little opposition from other groups. See Jasanoff, *The Fifth Branch* at 40, 143–45 (cited in note 22).

269 William R. Freudenburg and Robert Gramling, *Scientific Expertise and Natural Resource Decisions: Social Science Participation on Interdisciplinary Scientific Committees*, 83 Soc Sci Q 120, 120, 128 (2002).

methodologies or interpretations, reanalysis of the data, or other tools to discredit the results and, perhaps, keep the unfavorable research out of the peer-reviewed literature.[270] The inevitable existence of assumptions and inferences allows any such critic to undermine results by deconstructing science.[271] Interest groups can actively sponsor research in efforts to shape outcomes as well, reaching the desired results through hidden use of inferences, assumptions, and study design choices.[272] Research results can often correlate with the origin of funding—a study of Bisphenol A (BPA) research found that industry-supported research was much less likely to find a correlation between BPA exposure and cancer than non-industry-supported research.[273] If disciplines are so vulnerable to outside pressures, then they may not be very useful in constraining an administrative agency from bowing to outside forces itself. If the discipline is very vulnerable to outside pressure, then we might be better off insulating decision making from the discipline to avoid future implementation problems.

These are real problems, but the questions are always relative ones:[274] For instance, in using disciplines to constrain agencies, are the political pressures on scientific disciplines less than the political pressures that might be brought to bear on administrative agencies? The answer here will not be straightforward. For example, given its history, range science might be less successful than conservation biology at constraining the Forest Service but more successful at legitimating it. Many disciplines have fundamental commitments that will make them resistant to shaping by outside forces on particular questions—it seems unlikely that outside pressure would (for instance) result in conservation biology abandoning its strong commitment to protecting biodiversity. The level of underdetermination on particular questions or particular topics will also affect malleability; the higher the underdetermination, the more malleable the outcomes and the more susceptible to pressure a

270 McGarity and Wagner, *Bending Science* at 128–56 (cited in note 47).

271 See id at 133.

272 See id at 61–95. See also William R. Freudenburg, *Seeding Science, Courting Conclusions: Reexamining the Intersection of Science, Corporate Cash, and the Law*, 20 Sociological F 3, 13–21 (2005) (describing efforts by a major corporation to support the publication of a sociological article that might have been supportive of their position in high-stakes litigation).

273 McGarity and Wagner, *Bending Science* at 96 (cited in note 47), citing Frederick S. vom Saal and Claude Hughes, *An Extensive New Literature Concerning Low-Dose Effects of Bisphenol A Shows the Need for a New Risk Assessment*, 113 Envir Health Persp 926, 928 (2005).

274 See Neil K. Komesar, *Imperfect Alternatives: Choosing Institutions in Law, Economics, and Public Policy* 5 (Chicago 1994).

discipline might be. The particular answer for any particular case will depend on the history and structure of the relevant discipline: what kinds of intellectual and economic influences outsiders have on that discipline, the nature of the research questions being asked, the kinds of interest groups involved, and other factors.

b) Disciplinary dynamism, diversity, and distinctions. For some choices in using disciplines as design tools,[275] the management or regulatory process is predicated on the perspectives of particular disciplines that guide the production of information in particular ways. That production of information, in turn, guides regulatory or management outcomes.

But, as noted earlier, disciplines are not fixed monoliths; instead, they are flexible, diverse, and changing structures. Disciplines might well change their values and perspectives independently even if they do resist outside political pressures. If legal or institutional designers build a regulatory or management structure based on discipline A taking a consensual position X on a key issue, they may be sorely disappointed when discipline A's position on X changes, is unclear, or when discipline A no longer clearly exists as an institution. These problems are exacerbated when diversity and dynamism occur in multiple disciplines that might each be relevant for the particular regulatory or management question.

(i) *Disciplinary dynamism.* Disciplinary dynamism includes the possibilities that the discipline as a field may disappear or change so significantly that it can no longer be usefully relied upon as an institutional or legal design mechanism (*structural changes*), or that a discipline might itself change its central values or perspectives such that its role in the regulatory and management process fundamentally changes (*paradigm shift*).

Structural changes are not unusual.[276] Biochemistry emerged from the prior discipline of physiology; conservation biology from the field of ecology. In both cases, what was once one discipline became two. Other fields disappear,[277] and fields might merge as well. If the legal or institutional structures depend, explicitly or implicitly, on underlying scientific disciplines that might themselves change, then this may upset those legal or institutional structures.

275 The option in which a discipline constrains policy making by an agency in the future, and the option in which a discipline provides support for agency decision making in the future.

276 See Ziman, *Real Science* at 199 (cited in note 70).

277 See, for example, Charles S. Fisher, *The Death of a Mathematical Theory: A Study in the Sociology of Knowledge*, 3 Arch Hist Exact Sci 137, 139 (1966) (describing the death of the field of invariant theory in mathematics).

Paradigm shifts (or "epistemic drift") occur when a disciplinary field's perspective or knowledge strongly changes over time. From the point of view of a legal or institutional designer, the problem is that if one is counting on the discipline to provide a particular perspective, the changed perspective or knowledge thus will undermine (or at least alter) the discipline's utility as an institutional or legal design tool.[278]

Such paradigm shifts are also not uncommon. An example is the gradual shift of wildlife management away from managing primarily or exclusively for maximizing output of desired game species and towards management for a wide range of game and "non-game" species. The state regulatory systems established to control hunting beginning in the early twentieth century were generally designed to entrench a particular vision of wildlife management: maximizing hunting opportunities for sport or recreational hunters. One way this was accomplished was through state professional wildlife management agencies staffed by professionals from the new field of wildlife management, sympathetic to the goals of maximizing game numbers for hunting.[279] Most wildlife managers saw "their primary responsibility as providing resources (fish and game) to their clients—anglers, hunters, and trappers."[280]

But today, younger wildlife scientists are much less focused on management for the purposes of providing a crop for hunters and much more focused on managing for the full range of native species, whether valuable for game or not.[281] Survey data of wildlife management professionals shows that younger ones are more likely to embrace ecosystem management and biodiversity protection at the expense of managing for high levels of game species.[282] Wildlife management scientists in nonprofits and universities are also less likely than those working in agencies to support hunting as the

278 See Shapiro and Guston, 17 J Pub Admin Rsrch & Theory at 544–45 (cited in note 195).

279 See text accompanying notes 182–92. See also Robert M. Muth and Wesley V. Jamison, *On the Destiny of Deer Camps and Duck Blinds: The Rise of the Animal Rights Movement and the Future of Wildlife Conservation*, 28 Wildl Socy Bull 841, 843 (2000) (describing the "North American Wildlife Conservation Model" that emphasizes "intensive management" of wildlife "based on professional training and scientific research"); Thomas D.I. Beck, *Citizen Ballot Initiatives: A Failure of the Wildlife Management Profession*, 3 Hum Dimensions Wildl 21, 23 (1998) (noting how wildlife management follows an "agricultural model" in which deer are "harvest[ed]" and wetlands become managed as "production units" for waterfowl).

280 Martin Nie, *State Wildlife Policy and Management: The Scope and Bias of Political Conflict*, 64 Pub Admin Rev 221, 223 (2004).

281 Muth, et al, *Passing the Torch* at 178 (cited in note 191).

282 Id at 185 table 5, 189 table 7.

dominant goal of the profession.[283] Curricula in wildlife management departments at universities have changed to include "more rare-species conservation" and "more multidisciplinary management" and less "species harvest management."[284]

This paradigm shift caused substantial policy changes in Colorado in the mid-1990s, when the state wildlife agency became more open to other goals and imposed stricter regulations on the trapping of furbearing animals, many of which were predators of livestock. Agricultural and trapping interests responded by getting the legislature to move regulatory power over "predator management" to the commissioner of agriculture, seen as much more friendly to trapping and livestock interests. Animal rights groups responded with a successful initiative to prohibit trapping.[285] What had been a decision-making process contained within a regulatory agency and guided by disciplinary perspectives to advance a particular policy outcome had been transferred to competing agencies and decision-making structures where the voice of the discipline was much less influential, and where outcomes were much more fluid.

(ii) *Disciplinary diversity*. Relying on disciplines in the regulatory or management process can be problematic if the disciplines themselves have diverse perspectives on important regulatory or management questions and therefore cannot provide clear answers to those questions. The diversity of opinion on an important question might be widely shared within a discipline (*dissensus*),[286] or there may be significant, vocal individuals within a discipline that dispute the dominant position within the field (*heretics*).[287] Either way, a decision-making structure predicated on a discipline providing a predictable answer to particular questions may break down.

An example of dissensus is the dispute within biological disciplines about how to define taxonomic groups such as species and subspecies—a concept that is integral to the regulatory program under the ESA, since it requires the identification of species that require protection under the Act. The problem is that the "ESA's

283 Organ and Fritzell, 28 Wildl Socy Bull at 784 (cited in note 190).

284 Id at 783.

285 Susan Cockrell, *Crusader Activists and the 1996 Colorado Anti-trapping Campaign*, 27 Wildl Socy Bull 65, 67 (1999).

286 See Robert Ackermann, *Consensus and Dissensus in Science*, 1986 Proceedings Biennial Meeting Phil Sci Assn 99, 100.

287 See Steve Fuller, *The Elusiveness of Consensus in Science*, 1986 Proceedings Biennial Meeting Phil Sci Assn 106, 113.

definition of 'species' is singularly uninformative."[288] Moreover, the basic concept of species is not one about which biologists have a consensus: there is great variation across taxonomic groups and across geographic areas in terms of number of species that are identified, and that variation appears to be based on different standards among taxonomists, not on the biology of those different taxonomic groups.[289] This is in part because there is a great deal of subjectivity in the definition of a species, with up to two dozen different definitions in the scientific literature.[290] This subjectivity allows for a wide variety of ways to draw the line between what counts and doesn't count as a species.[291] The differences can be substantial—adoption of one definition (for instance, the phylogenetic species concept) might result in a 48 percent increase in the total number of species recognized worldwide.[292]

Given the definitional importance of the species concept for the regulatory scope of the ESA, these disputes have tremendous policy importance. Indeed, critics have argued that this ambiguity has been used for policy purposes by various scientists, purportedly through the creation of additional species in order to provide additional political or legal support for conservation measures.[293]

288 Doremus, 75 Wash U L Q at 1089 (cited in note 55).

289 See Emma Marris, *The Species and the Specious*, 446 Nature 250, 251 (2007); Paul-Michael Agapow, et al, *The Impact of Species Concept on Biodiversity Studies*, 79 Q Rev Bio 161, 168–69 (2004); Nick J.B. Isaac, James Mallet, and Georgina M. Mace, *Taxonomic Inflation: Its Influence on Macroecology and Conservation*, 19 Trends Ecol & Evol 464, 464–65, 467 (2004).

290 See Marris, 446 Nature at 251 (cited in note 289). See also Peter C.H. Pritchard, *Status of the Black Turtle*, 13 Conservation Bio 1000, 1000 (1999); Agapow, et al, 79 Q Rev Bio at 163 (cited in note 289).

291 See Isaac, Mallet, and Mace, 19 Trends Ecol & Evol at 464 (cited in note 289) (noting that ant taxonomists are much more amenable to identifying new species than butterfly taxonomists); Doremus, 75 Wash U L Q at 1102 (cited in note 55) (noting different professional traditions in taxonomy across different categories of animals and plants, and distinction between "lumpers" who group taxa together and "splitters" who identify many different species).

292 Agapow, et al, 79 Q Rev Bio at 62, 64 (cited in note 289).

293 See, for example, Bowen and Karl, 13 Conservation Bio at 1013 (cited in note 157); James Mallet, Nick J.B. Isaac, and Georgina M. Mace, *Response to Harris and Froufe, and Knapp* et al.*: Taxonomic Inflation*, 20 Trends Eco & Evol 8, 8 (2005); Robert M. Zink, et al, *Genetics, Taxonomy, and Conservation of the Threatened California Gnatcatcher*, 14 Conservation Bio 1394, 1402–03 (2000); Doremus, 75 Wash U L Q at 1102–03 (cited in note 55) (recounting quote from a FWS biologist that there was a bias towards identifying species in order to increase protection).

The problem is even worse for the definition of subspecies, another category within the ESA's legal definition of "species." Here there are no consistently applied definitions, leading to even greater subjectivity. See, for example, Carolan, 17 Envir Polit at 449 (cited in note 33); Susan M. Haig, et al, *Taxonomic Considerations in Listing Subspecies under the U.S. Endangered Species Act*, 20 Conservation Bio 1584, 1586 (2006).

To the extent that a range of biological disciplines constrains agency decision making under the ESA, the dissensus eliminates that constraint—where there is such a divergence of opinion, it is possible for the agency to justify a decision either way it comes out, making any legal challenges extremely difficult.[294] That is the case even where the agency's application of the concept has been highly inconsistent over time, as Holly Doremus documented in the 1990s.[295]

Heretics are individual members of a discipline that contest fundamental values or principles of that discipline. For instance, conservation biologist Rob Roy Ramey[296] has challenged the focus of the discipline on protecting the full range of biodiversity, including subspecies and genetic diversity within species, and has argued instead that biodiversity policy should practice triage and focus on species that represent significant elements of evolutionary change.[297] Such heretics can be drawn upon by interest groups who seek to challenge the ability of the discipline to stabilize, legitimize, or constrain decision making. For instance, Ramey conducted research challenging whether a subspecies of jumping mouse in Colorado and Wyoming was, indeed, a valid subspecies; developers and state and local officials who opposed the impacts of ESA regulatory protections for the jumping mouse drew upon this work in arguing for development of previously-protected areas.[298]

Given the underdetermination in much of environmental science and the stakes of many environmental regulatory and management decisions, there is tremendous potential and motive for

294 See, for example, *Alabama–Tombigbee Rivers Coalition v Kempthorne*, 477 F3d 1250, 1255–62 (11th Cir 2007) (upholding agency decision to list an endangered species based on the conclusion that it was separate from related fish species, despite conflicting evidence). For an exception in which the agency's conclusion was overturned, see *Center for Biological Diversity v Lohn*, 296 F Supp 2d 1223, 1230, 1236–40 (WD Wash 2003). In this case, the court noted that when there are extreme practical difficulties in affirmatively establishing evidence of different taxa, such as the case for whales, consensus is an unreasonable standard. But as noted above, in many circumstances there will be significant disagreement about species status among scientists. In such situations, courts are likely to defer to the agency's conclusion.

295 Doremus, 75 Wash U L Q at 1103–12 (cited in note 55).

296 David Holthouse, *Building a Better Mousetrap*, Denver Westword (Jan 20, 2005), online at http://www.westword.com/2005-01-20/news/building-a-better-mousetrap/ (visited Dec 15, 2011). Ramey has a doctorate in ecology and evolutionary biology, and self-identifies as a conservationist. See also Rob Roy Ramey II and Laura MacAlister Brown, *About WSI* (Wildlife Science International), online at http://www.wildlifescienceintl.com/WSI,_Inc/About_WSI.html (visited Dec 15, 2011) (describing Ramey's consulting firm and noting that Ramey has "been working on endangered species conservation issues for 28 years").

297 Holthouse, *Building a Better Mousetrap* at 6 (cited in note 296).

298 Id. Ramey explicitly justified his position in the jumping mouse controversy based on his preferences for prioritizing protection of major elements of biodiversity.

interest groups to encourage this kind of heresy.[299] As philosopher of science Imre Lakatos put it, "A brilliant school of scholars (backed by a rich society to finance a few well-planned tests) might succeed in pushing any fantastic programme ahead, or, alternatively, if so inclined, in overthrowing any arbitrarily chosen pillar of 'established knowledge.'"[300] Dissenters always exist, but they become a lot more important when the political or economic stakes of a decision that might depend on science are very high. For instance, disputes over climate science have risen because the political and economic stakes became so high (particularly after the Kyoto Protocol) and because the necessary uncertainty and ambiguities in climate science allow for dispute to occur.[301]

(iii) *Disciplinary distinctions*. Finally, it will not always be easy to distinguish among disciplines in a regulatory or management program. First, if the particular discipline to be relied upon has not been specifically identified, then more than one discipline might be relevant for important policy decisions, creating the potential for conflict.

Disciplinary conflict[302] is exemplified by an ongoing dispute over how to restore and manage the San Joaquin River and Sacramento River delta in California, a major source of drinking and irrigation water for the state, as well as a vital hub for fisheries and home to other native species. After 2000, the population of a number of

299 See Brian Martin, *Suppression of Dissent in Science*, in William R. Freudenburg and Ted I.K. Youn, eds, 7 *Research in Social Problems and Public Policy* 105, 106 (JAI 1999) (stating that "[a] few dissenting experts are sometimes all it takes to turn unanimity into controversy" and that "[t]he existence of controversy . . . usually serves to undercut the legitimacy of the dominant position").

300 Imre Lakatos, *Falsification and the Methodology of Scientific Research Programmes*, in Imre Lakatos and Alan Musgrave, eds, 4 *Criticism and the Growth of Knowledge: Proceedings of the International Colloquium in the Philosophy of Science, London, 1965* 91, 187–88 (Cambridge 1970). While I do not fully embrace a strong interpretation of Lakatos's statement in all fields of knowledge, in the context of environmental science, where underdetermination is particularly important, it has a great deal of force. See also Carolan, 34 Critic Sociology at 727 (cited in note 44); Jasanoff, 69 L & Contemp Probs at 38 (cited in note 129). See generally Freudenburg, 20 Sociological F 3 (cited in note 272). See also Donald Ludwig, Ray Hilborn, and Carl Walters, *Uncertainty, Resource Exploitation, and Conservation: Lessons from History*, 260 Sci 17, 17 (1993) (discussing how the fishing industry relied upon dissenting scientists to argue that overfishing was impossible for oceanic species in order to resist regulation of California sardine harvests prior to the collapse of the fishery). Nonetheless, even in environmental science there are limits to the extent to which outside funding can question established principles. See Seth Borenstein, *Skeptic Finds He Now Agrees Global Warming Is Real*, Boston Globe A2 (Oct 30, 2011).

301 See Carolan, 34 Critic Sociology at 730 (cited in note 44).

302 See James V. Spickard, *Disciplinary Conflict in the Study of Religion: Anthropology, Sociology, and "Lines in the Sand*,*"* 14 Method & Theory Stud Relig 141, 142 (2002).

native fish species, including the delta smelt, crashed. Pursuant to the ESA, the FWS has proposed restrictions on the pumping of water from the delta for irrigation. Irrigators challenged in court the FWS's Biological Opinion (BiOp) that imposed the pumping restrictions.[303]

A major source of controversy over the BiOp was whether the FWS's analysis of the status of the delta Smelt, and the impacts of water pumping on it, was adequate. Water districts challenging the BiOp obtained declarations from several fisheries biologists who contended that the BiOp had improperly relied too much on qualitative analysis, instead of developing a comprehensive, quantitative "life-cycle model" for the smelt which would have allowed for a more precise understanding of how water pumping was affecting the species.[304] During court hearings, fisheries biologists testified on behalf of the water districts that development of a quantitative "life-cycle model" is "standard operating procedure" for fisheries management agencies,[305] and asserted that such a modeling exercise could have been completed within a matter of hours to at most months.[306]

FWS experts and a National Research Council expert panel responded that given the lack of monitoring data, the agency had done the best that it could do, and that a quantitative model based on inadequate data ran the risk of producing inaccurate and misleading numbers that might lead to decisions that could irreversibly harm the smelt.[307] In the end, the court agreed that a life-cycle model is a "standard tool used by fisheries scientists to evaluate population-level impacts,"[308] but nonetheless upheld the FWS's

303 See *Consolidated Delta Smelt Cases*, 717 F Supp 2d 1021, 1024–25 (ED Cal 2010).

304 See, for example, Declaration of Dr. Richard B. Deriso, *Consolidated Delta Smelt Cases*, Docket No 401, *2–4, 5, 11 (ED Cal filed Mar 23, 2010) (recording the statements of Dr. Deriso, an expert in fisheries management, asserting that life-cycle models are necessary for adequate status assessments); Declaration of Dr. Ray Hilborn in Support of Plaintiffs' Motion for Summary Judgment, *Consolidated Delta Smelt Cases*, Docket No 393, *2–3, 6 (ED Cal filed Mar 23, 2010) ("Hilborn Declaration") (recording the statements of Dr. Hilbornon on the importance of life-cycle models for determining a species protection status, similar to Dr. Deriso's declaration, and noting Dr. Hilborn's expertise in fisheries management).

305 *Consolidated Delta Smelt Cases*, 717 F Supp 2d at 1048.

306 Id at 1048–50.

307 See National Research Council, *A Scientific Assessment of Alternatives for Reducing Water Management Effects on Threatened and Endangered Fishes in California's Bay–Delta* 3, 25–26, 39 (National Academies 2010); Declaration of Ken B. Newman, *Consolidated Delta Smelt Cases*, Docket No 484, *4–6 (ED Cal filed Jan 8, 2010).

308 *Consolidated Delta Smelt Cases*, 717 F Supp 2d at 1048.

conclusions on this issue because the plaintiffs had not submitted their own models during the administrative process.[309]

The choice of disciplines in this case had the potential to change any evaluation of the FWS's BiOp. From the perspective of fisheries scientists, heavily reliant on modeling in their work, the FWS's choice was flawed. From the perspective of conservation biologists, however, there is much greater skepticism of model use; for instance, conservation biologists have expressed caveats about the use of the most frequent form of quantitative models in their discipline—population viability analysis (PVA).[310] Conservation biologists emphasize that, given the often large gaps in the data record from which any model might be constructed, researchers should be skeptical of the use of models such as PVAs because of the risk that limited data, processed unthinkingly through models, might produce predictions that are insufficiently conservative and protective of species, the primary goal in the discipline.[311] With this type of sharp disciplinary conflict, the ability of any one discipline to either constrain or legitimate an agency is greatly reduced, as partisans on either side can point to an alternate source of scientific information.

Disciplinary conflict is part of a broader problem in relying on scientific disciplines as legal- or institutional-design tools. Even where a discipline has been specifically identified as relevant in the statutes, regulations, or court decisions, it can be quite difficult to draw lines between what are admittedly fuzzy concepts. As the discussion of conservation biology and wildlife management in Part II.B showed, it will not always be easy to distinguish between an ecologist and a conservation biologist, or a fisheries scientist and a conservation biologist, for example. An individual scientist might be a member of multiple professional organizations (for example, both the Ecological Society of America and the Society for Conservation

309 Id at 1050 (finding that no party who commented on the public review drafts of the BiOp had submitted a life-cycle model).

310 See J. Michael Reed, et al, *Emerging Issues in Population Viability Analysis*, 16 Conservation Bio 7, 14–15 (2002); Barbara L. Taylor, *The Reliability of Using Population Viability Analysis for Risk Classification of Species*, 9 Conservation Bio 551, 552, 557 (1995); J. Michael Reed, Dennis D. Murphy, and Peter F. Brussard, *Efficacy of Population Viability Analysis*, 26 Wildl Socy Bull 244, 245–46 (1998); Steven R. Beissinger and M. Ian Westphal, *On the Use of Demographic Models of Population Viability in Endangered Species Management*, 62 J Wildl Mgmt 821, 832–33 (1998). But see Hilborn Declaration at *7, 13 (describing PVA as a risk assessment tool that is commonly used by conservation biology), citing Wikipedia, *Population Viability Analysis*, online at http://en.wikipedia.org/wiki/Population_viability_analysis (visited Dec 15, 2011) (relying on Google searches to contend that such quantitative analyses are the "accepted scientific standard" in ESA analysis).

311 See Taylor, 9 Conservation Bio at 557 (cited in note 310).

Biology); the name of the department at which they are located might not clearly identify their institutional home (for example, both fisheries scientists and conservation biologists might be trained in an ecology department); the borders between disciplines might be disputed and movable (for example, conservation biologists might claim for themselves the research of all endangered species including fish, while fisheries scientists might claim for themselves the research of all fish species, regardless of whether they are endangered). The problem might be much worse if there are significant legal and political stakes involved in deciding who is part of a particular discipline.

(iv) *Addressing the challenges raised by disciplinary diversity, dynamism, and distinctions*. These are all nontrivial problems or costs to the explicit use of disciplines in this way, but they do not lead to the conclusion that disciplines cannot be used this way. First, again the comparison must be a relative one: Compared to the regulatory and management system we would otherwise have, would reliance on disciplines improve outcomes? The prior use of disciplines by institutions such as the Forest Service to provide significant legal and political support provides some strong evidence that disciplines are not necessarily so unstable that they cannot serve as useful structures to build management or regulatory systems upon. Indeed, range science proved to be stable enough to provide decades of support for the agency. There are a number of factors that might cut against the legal or institutional instability caused by disciplinary dynamism and diversity. While disciplines do change, they do have substantial inertia as a whole; while one individual may change their perspective quickly, a discipline as a whole may move much more slowly, with change primarily driven by generational turnover.[312] While there may be dissensus or even heresy on important points, many of the most fundamental assumptions and perspectives will not be questioned and will be taken for granted. For instance, even Ramey concurs with the importance of preserving some forms of biodiversity; the debate is over whether to prioritize and how.[313]

Second, there are ways to ameliorate the problem, and the ways in which courts have relied upon scientists in reaching decisions in ESA cases shed some light on these tools. One might look to the conclusions of established professional organizations and societies, which might be more stable as institutional entities, less dynamic

312 Wildlife management exemplifies this gradual transformation process. See notes 279–85 and accompanying text.

313 See Holthouse, *Building a Better Mousetrap* at 6 (cited in note 296).

compared to individuals, easier to define and identify, and harder to manipulate (at least if their membership is substantial). It is significant that in many cases where courts have overturned agency decisions implementing the ESA, the basis has been conclusions reached by leading professional organizations.[314] One might resort to "nose-counting," looking at the weight of the published literature in the leading journals of the field, which also will be relatively stable as institutional entities and easier to define and identify.

Using in part these tools, courts in a significant number of cases appear to have been able to reach judgments about which scientists are relevant for their analysis of ESA decisions.[315] The risk of error might be small in many of these cases; after all, the perspectives of related fields may be similar on many points (for instance, ecologists, wildlife managers, and conservation biologists all have similar attitudes towards many of the underlying issues in biodiversity policy).[316]

Third, and perhaps most important, the challenges that disciplinary diversity, dynamism, and distinctions pose to environmental law are not limited to situations where we privilege or distance any one particular discipline. The establishment of a "balanced" decision-making process that represents a range of disciplines will necessarily require addressing the question of which disciplines to represent, which decision makers represent which disciplines, and how the perspectives of each represented discipline will interact. All of these assessments can be upset by the problems of diversity, dynamism, and disciplinary line drawing.

And even if we try to avoid the problem by not explicitly or consciously taking into account disciplines in our regulatory or management process, the problem still will arise. Science still has to be used in environmental law; there are often a range of relevant disciplines, each with different perspectives that might result in the production of different information. Even if only one discipline appears relevant, its perspective will still often shape the information produced (as shown by the example of range science and the Forest Service). If we ignore these problems, then we will be blindly drawing upon disciplinary perspectives, perhaps producing

314 See note 216.

315 See note 216.

316 These options are not perfect; for instance, there is evidence that industry has created or shaped professional organizations and journals to provide legitimacy for its policy positions. See generally McGarity and Wagner, *Bending Science* (cited in note 47). And to the extent that we are relying on lower levels of scientific disciplinary structures, where there are far fewer formal institutions, it will be much harder to undertake this kind of line drawing.

unintended consequences. And surely the interest groups, agencies, and other actors in the decision-making process will not blind themselves to the role that disciplines play, as shown by the skillful use of disciplines by the Forest Service for decades. We are thus forced to at least consider the role that disciplines play in policy, and, in so doing, face the challenges posed by disciplinary diversity, dynamism, and distinctions.

c) Undermining the legitimacy of disciplines. A third major problem is that explicitly relying on scientific disciplines as legal- or institutional-design tools in certain ways might be self-defeating. If policy makers specifically rely on disciplines to shape policy, that might undermine the legitimacy or public standing of disciplines by eroding their perceived neutrality or independence. The problem here may be less serious when using disciplines to constrain agencies: here the discipline still remains autonomous from the administrative agency or political process. The problem also may be less serious in the context of insulating disciplines from the policy process, since the insulation will itself also emphasize the discipline's independence. Similarly, balancing disciplines might still imply independence among the various groups. But where a discipline is used to provide legitimacy for an agency, the very process of identifying the disciplines as connected with and supportive of an administrative agency may undermine its perceived independence and neutrality, and therefore the legitimacy it can provide.

On the other hand, it is not as if disciplines have not been drawn upon in this way in the past. As the US Forest Service's history with both range science and forestry makes clear, scientific disciplines have been recruited, shaped, and utilized in policy making for decades, and yet scientific disciplines still have significant amounts of public legitimacy and still can provide significant legitimacy to regulatory and management decisions. Again, the question is the relative utility of disciplines for this goal as opposed to other ways of increasing agency legitimacy and authority.

6. Assessing the use of disciplines as legal- and institutional-design tools.

This Article suggests four ways that scientific disciplines may be used as institutional- and legal-design tools. There are surely other combinations and options: for instance, disciplines might be used in combination with institutions other than agencies (for instance, a discipline might be used to constrain or empower decision making by courts). Across the diversity of ways in which legal and institutional designers might want to account for disciplines, each option might draw differently on the tension between internal and external forces in shaping scientific disciplines.

The details will vary depending on the particular goals of a regulatory or management program, the nature of the relevant disciplines that will plausibly be drawn upon, the political or economic context for decision making, and the underlying realities of the natural world. One might even reject explicitly relying on particular disciplines because of the problems that disciplinary dynamism, diversity, and distinctions create. The important point is that wise institutional and legal design in environmental law has to take into account the paradigms and values of the scientific disciplines that will produce the information used in the regulatory or management process if it is ultimately to be fully effective. Whether we consider disciplines consciously or not, they shape the information used in environmental law.

B. Seeing Science and Law in a New Way

Even if in the end we do not rely on disciplines as an explicit legal and institutional design tool, understanding scientific disciplines as part of the policy process in environmental law helps us understand the problematic relationship of environmental law and science in a new, more effective way. Instead of trying to separate the science from the policy for each stage in a complicated environmental policy question, it may be much easier in many cases to simply understand the likely perspective of the scientific community that is involved in the decision-making process and therefore the likely policy valence of the assumptions and judgments made by that scientific community in its analyses and models.[317]

[317] There are in fact two relevant dimensions of scale for the analysis of the interaction of policy and science. One dimension is the scale of the relevant policy decision-making process: Do we investigate each individual decision (for example, individual risk assessments for particular chemicals) or the general process for decision making (for example, risk assessment as a category)? The second dimension is the scale of our analysis of the interaction of science and policy: Do we examine each individual application of science mixed with policy to determine the scope of each category (for example, in developing this dose-response curve, what elements are science-based and what are policy-based), or do we rely upon disciplines (for example, was it toxicologists or epidemiologists who are involved in constructing the dose-response curve)? As described in Part I, prior scholarship has focused on examinations of individual applications of science mixed with policy but applied that analysis to both levels of scale for policy decision making (individual decisions or general processes). See notes 25, 27, 33, and 35. However, there may be limits to the ability to generalize about how individual applications of science mixed with policy consistently correlate with policy conclusions for general policy decision-making processes. See text accompanying notes 53–57. My disciplinary approach can also be applied at both levels of scale (individual decisions, or general decision-making processes), though it is more amenable to extrapolation to larger levels of scale and

Choosing a scientific discipline involves choosing a package of interrelated policy perspectives and scientific facts and methodologies.[318]

Recognizing the role of different scientific disciplines in bringing values to environmental law and policy and the need for a choice among disciplines and their values might be controversial among those who believe that "neutral" science, or at least the perception of neutral science, has given environmentalists a powerful public rhetorical weapon against industry and other interest groups that otherwise have heavy advantages in the political arena. Giving up the neutrality of science—or at least recognizing its limits—might be opposed as unilateral disarmament.[319]

But first of all, there are many situations in which environmentalists have found themselves on the opposite side from the dominant perspective of important scientific disciplines, and yet have still successfully won important political battles. For example, for many years, the nuclear industry and government agencies enjoyed support from a public consensus among the relevant physicists and engineers about the safety of nuclear power, but

therefore may be less costly to apply. More generally, there may be circumstances in which fine-grained analyses are not particularly difficult or might be easily generalizable across multiple decisions, in which case there may not be as great of an appeal for a discipline-based analysis.

One weakness of relying on scientific disciplines is that, unlike fine-grained, particular analyses of individual policy and science judgments for specific decisions, this method will be less able to detect bad-faith efforts by agencies or interest groups to bury policy choices within science. In such situations, the bad-faith actor might purport to rely on information from a discipline with one perspective but adjust the relevant policy and science judgments to reflect very different perspectives. Thus, my disciplinary approach is not a complete substitute for efforts to separate science and policy.

318 See J.B. Ruhl, *Reconstructing the Wall of Virtue: Maxims for the Co-evolution of Environmental Law and Environmental Science*, 37 Envir L 1063, 1080–82 (2007) (arguing that environmental law and environmental science should be seen as co-evolved fields that are interdependent and cannot be fully separated, and calling for greater attention to the interconnection of law and science in training environmental lawyers, policy makers, and scientists). See also Brosnan, 37 Envir L at 1005–06 (cited in note 52) (suggesting that greater integration of science, law, and policy would lead to superior decisions, since "when anyone enters into the messy realm of science, law, and policy they will, at some point, address topics and make judgments beyond their expertise"). The understanding of disciplines as a "package" of perspectives and knowledge has similarities to the "co-production" concept of science that Sheila Jasanoff has developed. See, for example, Sheila Jasanoff, *Ordering Knowledge, Ordering Society*, in Sheila Jasanoff, ed, *States of Knowledge: The Co-production of Science and Social Order* 13, 19–36 (Routledge 2004) (describing how scientific knowledge is created through a process of "co-production" by the physical reality of the world and the social organization by scientists of that reality into an orderly and recognizable system of knowledge).

319 The same concerns or arguments might be relevant for those who oppose greater regulation on economic or other grounds. My responses here apply with equal force to them as well.

environmentalists successfully challenged a range of controversial proposals for nuclear power plant locations by effectively developing new sources of information from other scientific disciplines.[320] In the 1970s and 1980s, it was industry that pushed for greater use of "science" in regulatory decisions (such as in the context of the assessment of the risks of potentially carcinogenic chemicals) while environmental groups pushed to open the decision-making process to more public involvement.[321] Industry has called for the greater use of scientific panels for pesticide regulation, in part because the view of scientists in the relevant disciplines (such as pathology or epidemiology) of what is "good science" often correlates well with a skepticism of identifying negative health impacts from chemicals.[322]

There is therefore no necessary reason why plainly recognizing the role that values play in environmental science will consistently privilege one side of the debate or another. Even in the area of biodiversity protection, where conservation biology has been tightly allied with efforts to increase regulatory protections,[323] this is the case. As Holly Doremus has well documented, the George W. Bush administration skillfully used the rhetoric of science to argue for delaying or denying protection to endangered species: "[T]he rhetoric of science is just as suited to blocking conservation measures as it is to facilitating them."[324]

And in the long run, efforts to disguise the role that assumptions, inferences, and values play in environmental science

320 See Brian Balogh, *Chain Reaction: Expert Debate and Public Participation in American Commercial Nuclear Power, 1945–1975* 257–62 (Cambridge 1991).

321 Jasanoff, *The Fifth Branch* at 15–16, 20–38 (cited in note 22); Ted Greenwood, *Knowledge and Discretion in Government Regulation* 265 (Praeger 1984) (noting the call by industry for more use of scientific advisory panels by OSHA).

322 Jasanoff, *The Fifth Branch* at 123, 133, 145 (cited in note 22) (describing how pressure from the agricultural lobby encouraged adoption of scientific adivisory panels for pesticide regulation under the EPA, and noting pressure from industry for the FDA to use more science advisory panels and push from industry for the EPA to use science advisors in developing carcinogen guidelines). Industry has also tried to invoke reviews by the National Research Council to undermine regulatory decisions it disagrees with. See Fein, Comment, 99 Cal L Rev at 468–69 (cited in note 4).

323 See Takacs, *The Idea of Biodiversity* at 112, 115–16, 121 (cited in note 54).

324 Doremus, 32 Ecol L Q at 258 (cited in note 22). See also Carolan, 17 Envir Polit at 458–60 (cited in note 33) (noting how industry groups have framed the question as whether "sound science" proves the "hypothesis" that regulation is required, which places a steep statistical burden on the advocates of environmental regulation); Charles N. Herrick and Dale Jamieson, *Junk Science and Environmental Policy: Obscuring Public Debate with Misleading Discourse*, 21 Phil & Pub Pol Q 11, 15–16 (2001) (noting use of "junk science" rhetoric by those who challenge environmental regulations); Doremus and Tarlock, 26 Pub Land & Res L Rev at 17–18 (cited in note 16) (noting that opponents of regulation also call for "sound science").

are likely to backfire because they will lead to a fundamental suspicion of scientists and the work they produce by large sections of the public. For instance, in the wake of the deposition of radioactivity by the Chernobyl catastrophe on the Lake District of England, government scientists assured local sheep farmers and the larger public that there would not be long-term impacts on the soil or the sheep. Once the scientists were forced to admit the uncertainties in their assessments, backtrack on their assurances, and reveal that assumptions they had made in their earlier assessments were inaccurate, the farmers became extremely suspicious and cynical towards scientists in general.[325] Efforts to disguise values and assumptions and to rely on boilerplate rhetoric in which doubters are called "anti-science" and "irrational" can instead eliminate trust in the policy making and scientific processes, and harden opponents' positions.[326]

Explicit recognition by scientists of their values, preferences, and interests and how those might shape the research they conduct and the conclusions they draw can reduce, rather than exacerbate, that lack of trust. The public in the Lake District already interpreted the information provided by the scientists through this lens—acknowledgment of that possibility and efforts to respond to those concerns (rather than denial of them) might have improved the receptiveness of the audience to the relevant information.[327]

325 Brian Wynne, *Misunderstood Misunderstandings: Social Identities and Public Uptake of Science*, in Alan Irwin and Brian Wynne, eds, *Misunderstanding Science? The Public Reconstruction of Science and Technology* 19, 21–44 (Cambridge 1996); Bocking, *Nature's Experts* at 8–9, 173 (cited in note 53) (describing how overly assuring statements or scientific cover-ups of politically sensitive issues may undermine the public's ability to trust science as a whole).

326 See Freudenburg, 72 Reliab Eng & Sys Safety at 125, 127 (cited in note 45) (noting the inherent nature of policy choices in technical decision making, and arguing that use of "irrationality" or "anti-science" arguments destroys trust, hardens opposition, and eliminates "common ground" on which discussion might occur). See also Kristin Shrader-Frechette and Earl D. McCoy, *Molecular Systematics, Ethics and Biological Decision Making under Uncertainty*, 13 Conservation Bio 1008, 1012 (1999) (noting that if scientists are not transparent about how policy is affecting their conclusions, "the public will find out, and the misrepresentations will not be successful anyway"); Fisher, 20 Oxford J Legal Stud at 121 (cited in note 21) (noting a lack of trust in Britain of risk assessment process in wake of the "mad cow" disease crisis, where assurances of safety by government officials proved incorrect).

327 See Wynne, *Misunderstood Misunderstandings* at 38–39, 42–44 (cited in note 325); Bocking, *Nature's Experts* at 154, 169–74 (cited in note 53) (arguing that the public perceives risk information provided by scientists through a lens that is shaped by the institutional and political context within which the scientists work, the interests that they might have in shaping the information, and the degree to which the public trusts the scientists); Doremus, 34 Envir L at 447 (cited in note 15).

The transparent, explicit recognition that scientists have values and perspectives, and that these will shape the information they produce in a world filled with uncertainty, dynamism, and complexity, does not mean that we fall into the trap of complete relativism, abandoning the effort to try and develop information based on the reality in the natural world. Instead, it simply recognizes the necessary imperfections in all human endeavors, including science, and seeks to provide for a better decision-making process by recognizing, compensating for, or even building on those imperfections.

Here I am drawing on Sandra Harding's concept of "strong objectivity,"[328] in which "by recognizing the societal and disciplinary cultures in which each of us is positioned, and that therefore cannot help but mold our scholarship, we can take steps to becoming more objective, . . . more self-aware," and potentially even more powerful epistemologically.[329] Harding's contention is that we have allowed the ideal of neutrality in science to obscure the inevitable biases in the scientific process,[330] "includ[ing] the judgments scientists make about interpretation or reliability of data" and "the decisions scientists make about which problems to pursue or when to conduct an investigation."[331]

In the end, Harding argues that "[s]cience is politics by other means, and it also generates reliable information about the empirical world."[332] If that is the case, and if the goal is to achieve as much truth as possible as quickly as possible, then scientists, decision makers, and institutional and legal designers should not demand perfect neutrality from scientists—surely an impossible, perhaps even undesirable, task—but instead should draw on as wide a range of perspectives in "economic, political, and cultural diversity that is necessary to enable those who count as peers to detect the . . . values and interests" that may be otherwise dominant in the relevant scientific community.[333] Being cognizant of the standpoints that

328 See note 7.

329 Takacs, *The Idea of Biodiversity* at 43, 122 (cited in note 54) (applying Harding's theory of "strong objectivity" to conservation biology). See also Bocking, *Nature's Experts* at 43 (cited in note 53) (noting that "it can be most productive to acknowledge explicitly the political nature of knowledge"); N. Katherine Hayles, *Searching for Common Ground*, in Michael E. Soulé and Gary Lease, eds, *Reinventing Nature? Responses to Postmodern Deconstruction* 47, 48 (Island 1995) (calling for understanding "positionality" of scientists in trying to provide an understanding of reality).

330 Harding, 59 Soc Rsrch at 568–69 (cited in note 7).

331 Id at 578.

332 Harding, *Whose Science? Whose Knowledge?* at 10 (cited in note 7).

333 Harding, 59 Soc Rsrch at 578 (cited in note 7).

researchers come from can make it easier to understand their assumptions and biases, ones that might otherwise remain hidden, and thereby allow us to better approach truth.[334]

CONCLUSION

This Article has focused on the role that the different perspectives of natural scientific disciplines have and could play in shaping environmental law, but the issues I have raised are not limited to either natural science or environmental law. While there may be a number of ways in which social science disciplines might differ from natural science disciplines, the underdetermination of theories from data, and the resulting importance of perspectives in shaping information, is surely not among them. Economists certainly have their own perspectives, such as emphasizing the importance of efficient use of resources, and there are significant variations of perspectives within economics.[335] Moreover, there are important examples of the use of social science disciplines as design tools within environmental law.

For instance, in the early 1980s, the ESA was amended to require that certain agency decisions under the Act could be made "solely" on the best available science; the provision was intended by Congress, and has been applied by the courts, to prevent the consideration of economic costs in making relevant implementation decisions, a form of insulation of particular agency decisions from the field of economics.[336]

In contrast, the role of regulatory review by the White House Office of Management and Budget (OMB) shows the use of economics as a discipline to shape decision making in favor of the consideration of economic costs. Beginning with the Carter Administration and waxing and waning with other Presidents depending on the ideological perspective, the OMB has had the ability to at least delay, and sometimes veto, the issuance of major regulations by environmental agencies in order to require an analysis of the costs and benefits of the regulations. The result has been a

334 See id at 580–81, 583 ("[S]tandpoint theory demands acknowledgment of the sociological relativism that is the fate of all human enterprises including knowledge claims, but rejects epistomological relativism."). See also Oreskes, 7 Envir Sci & Pol at 380 (cited in note 45) (arguing that science can never be invoked, in making political decisions, as providing one concrete and universally accepted answer).

335 See, for example, Peter A. Hall, *Policy Paradigms, Social Learning, and the State: The Case of Economic Policymaking in Britain*, 25 Comp Polit 275, 288 (1993) (describing the distinction between Keynesian and monetarist macroeconomists).

336 See Doremus, 75 Wash U L Q at 1049–56 (cited in note 55).

greater weight on economic costs in environmental regulation. The relevant office in the OMB is heavily staffed by economists, and the process can be seen as an effort to privilege economists (this time in an internal regulatory review program) in order to ensure that their perspective helps shape the regulatory process.[337]

Likewise, there are many other areas of law that depend on scientific information in the context of high levels of uncertainty and underdetermination, and where the perspectives and values of the scientific practitioners might significantly shape the information that is produced.

As an example, consider the controversial history of the forensic sciences, in particular the disciplines (such as fingerprint identification, voice identification, and handwriting identification) in which investigators purport to be able to identify individuals from physical characteristics.[338] These disciplines are incredibly central to much of modern criminal law, as prosecutors often depend heavily on identification from forensic scientists in building a case against a criminal defendant at trial or in deciding which suspect to pursue in an investigation.[339] But criminal law scholars have noted the weaknesses of the disciplines: There is in fact significant uncertainty in the identifications that are made, although when forensic scientists testify as witnesses, they usually frame their answers in terms of absolute certainty. The clients of forensic scientists are almost uniformly prosecutors and police investigators, creating at least the possibility of external pressure to reach outcomes that are supportive of the goals of those groups. Institutionally, forensic scientists often work for law enforcement organizations, producing similar pressures. And, it is at least plausible that individuals who work in these disciplines do so at least in part because of a personal motivation to help combat crime.[340] All of these factors might lead to a particular perspective on the part of these disciplines, focused on identifying

337 See Biber, 33 Harv Envir L Rev at 49 (cited in note 239).

338 For an overview of the fields, see Michael J. Saks, *Merlin and Solomon: Lessons from the Law's Formative Encounters with Forensic Identification Science*, 49 Hastings L J 1069, 1080–94 (1998).

339 Id at 1090–94.

340 See id at 1091–94; Risinger, 52 Vill L Rev at 712 (cited in note 70); Michael J. Saks, *The Past and Future of Forensic Science and the Courts*, 93 Judicature 94, 95–97 (2009); Susan Haack, *What's Wrong with Litigation-Driven Science? An Essay in Legal Epistemology*, 38 Seton Hall L Rev 1053, 1078–80 (2008); D. Michael Risinger and Michael J. Saks, *Rationality, Research and Leviathan: Law Enforcement-Sponsored Research and the Criminal Process*, 2003 Mich St L Rev 1023, 1037–40; D. Michael Risinger, et al, *The* Daubert/Kumho *Implications of Observer Effects in Forensic Science: Hidden Problems of Expectation and Suggestion*, 90 Cal L Rev 1, 27–41 (2002).

criminals, helping to solve cases, and ensuring that the clients or colleagues succeed in their goals of identifying a suspect and obtaining a successful conviction in an adversarial trial. As a result, it is no surprise that the methodologies of forensic scientists often seem better suited to winning an argument than conducting a (relatively) dispassionate analysis. As noted above, the disciplines appear to completely ignore the inevitable uncertainty in their conclusions;[341] there has been little or no effort to apply standard scientific techniques to validate the methodologies used. Indeed, open hostility has often been the response to those who question the disciplines (although that may be changing).[342]

None of this would come as a surprise to anyone who understands that disciplines are shaped by their external environment and internal perspectives and values. And seen that way, a range of solutions becomes clear: perhaps we should create more institutional separation between forensic scientists and law enforcement, in hopes of changing the external pressures on the discipline; perhaps we should broaden the client base, so that scientists work as much for defense attorneys as they do for law enforcement; or perhaps courts should take a more skeptical eye towards the information produced by forensic scientists through legal doctrines such as exclusion under *Daubert v Merrell Dow Pharmaceuticals, Inc*.[343] Maybe we might do nothing at all, but even if that is our option, it should be a choice that is made with an understanding of the perspectives of the relevant disciplines and how that shapes the information they are providing to decision makers.

341 See notes 338–40.

342 See, for example, Risinger, 52 Vill L Rev at 712 (cited in note 70); Haack, 38 Seton Hall L Rev at 1078–80 (cited in note 340); Saks, 49 Hastings L J at 1080–90 (cited in note 338); Risinger, et al, 90 Cal L Rev at 27–41 (cited in note 340).

343 509 US 579 (1993). For explications of many of these proposals, see the sources cited in note 340.