

ENVIRONMENTAL LAW GROWS UP (MORE OR LESS), AND WHAT  
SCIENCE CAN DO TO HELP

by  
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*In this Article, Professor Rose assesses the role of science in a maturing modern environmental law. She describes this maturation process, beginning in the early 1970s with a first wave of “behavior-based” (BB) regulations. These regulations constrained the actions of resource-users, but generally they put to one side the very difficult task of linking particular legal constraints to direct impacts on environmental quality. BB regulations served a useful purpose in cutting back large pollution sources, but by the 1980s they came under increasing criticism for their inflexibility, inattentiveness to cost-effectiveness, and failure to confront small and diffuse sources that could be cumulatively more damaging than large or obvious sources.*

*To remedy these and other problems, a now-maturing environmental law has turned increasingly, although as yet incompletely, to quality-based (QB) approaches, which attempt to connect regulatory efforts directly to improvements in environmental quality. However, the newer QB approaches, including market-based programs, entail much greater reliance on measurement of the relationship between resource uses and quality changes. This pattern in turn puts new demands on scientific knowledge, especially for ways to measure or model (a) small and scattered sources and their impacts, (b) marginal or cumulative effects of differing amounts of the same kinds of resource uses, and (c) synergistic effects among different kinds of resource uses, particularly in connection with system-wide regulatory approaches. Policymakers need the scientific community to take these seemingly unglamorous but critical measurement tasks to heart—and also to be tolerant of the ways in which conditions of uncertainty necessarily affect policy decisions.*

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## I. INTRODUCTION

Sad to say, lawyers and scientists are not always the best of friends. In courtrooms, lawyers butcher scientific evidence—or at least so say their critics—hauling up any number of quacks to expound about the dangers of, say, celery, or, alternatively, to declaim how safe it really is.<sup>1</sup> Meanwhile, across the public square in the legislature, the lawmakers pass laws for all kinds of crazy reasons, among others because movie stars testify about the dangers of pesticides.<sup>2</sup> Like ordinary citizens, legislators do not have much of an idea about the difference between a risk that occurs at the rate of one in a million or one in a trillion. Both just seem very small. But then, when the one-in-a-trillion risk actually occurs, it seems huge. And so, wham! along comes more legislation to control it, in what seems to be a typical pattern of legislative overreaction.<sup>3</sup> All the same, lawmakers and regulators deserve some sympathy because they have difficult jobs. They often have to figure out what to do when they do not have a very clear idea what is going to happen, or what the danger zones and safety areas really are. This is true in many areas of legislation, e.g., in national defense expenditures or in energy policy; but in environmental areas the problem of decisionmaking under uncertainty is particularly acute. Environmental problems may take a long time to develop, and the causes for those problems may be numerous and inextricably mixed together. Thus, unlike pharmaceutical regulation, environmental law often does not allow for focused testing. Indeed, scientific findings about environmental problems sometimes give no firm answers, or raise as many questions as they provide answers.

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<sup>1</sup> See, e.g., PETER W. HUBER, *GALILEO'S REVENGE: JUNK SCIENCE IN THE COURTROOM* (1991) (decrying impact on jurors of evidence based on unsound scientific methods). But see Jeff L. Lewin, *Calabresi's Revenge? Junk Science in the Work of Peter Huber*, 21 HOFSTRA L. REV. 183 (1992) (criticizing Huber).

<sup>2</sup> Robert W. Hahn, *Toward a New Environmental Paradigm*, 102 YALE L.J. 1719, 1745 n.147 (1993) (reviewing ALBERT GORE, JR., *EARTH IN THE BALANCE: ECOLOGY AND THE HUMAN SPIRIT* (1992)) (noting "scare" over pesticide, Alar, enhanced by testimony of actress Meryl Streep).

<sup>3</sup> See generally Paul Slovic, *Perception of Risk*, 236 SCIENCE 280 (1987) (investigating differences between scientific and popular perceptions of risks of various eventualities). Some think, however, that what seem to be cognitive errors may be self-correcting, or at least evolutionarily useful. See Peter Strahlendorf, *Traditional Legal Concepts from an Evolutionary Perspective*, in *THE SENSE OF JUSTICE* 128, 147 (Roger D. Masters & Margaret Gruter eds., 1992), cited in Bailey Kuklin, "You Should Have Known Better," 48 U. KAN. L. REV. 545, 554 n.28 (2000).

Meanwhile, the results are a matter of acute political and economic significance to a great variety of interest groups.<sup>4</sup>

In the environmental area, however, legislators and regulators have at least gotten accustomed to regulating under conditions of ambiguity. In fact, much has been done, and at least some environmental regulatory ideas are identifiable as successes or mistakes. It is against this backdrop that we need to consider how science can interact fruitfully with environmental law.

In the pages that follow, I will devote a considerable amount of attention to characterizing the “First Wave” of environmental legislation beginning in the early 1970s, which focused on what I call “behavior-based” strategies. I will then take up the as-yet-incomplete efforts to shift focus to what I call “quality-based” approaches, using these characterizations as the frame for the question of the ways that science might be of assistance.

So, where are we now? Just where are we now with respect to environmental protective legislation? What is the current state of environmental law and where are the areas where science can be of help?

## II. THE FIRST WAVE: QUALITY-BASED APPROACHES CEDE TO BEHAVIOR-BASED CONTROLS

It is widely thought that, at least within the domestic United States, extensive legislation has already tackled many of the major environmental issues. There are exceptions, of course, notably in the very volatile area of global climate change. But with respect to many other areas of basic pollution control and resource conservation, environmental law is a mature area, or at least a maturing one.

This maturation should not be a surprise to those who have followed environmental legal scholarship. One of the important early scholarly works on environmental law, James Krier’s and Edmund Ursin’s study of air pollution control in California, argued that environmental law proceeds by a pattern of “exfoliation”; by this the authors meant a kind of trial and error process in which legislators try various solutions and shuck off the obvious mistakes.<sup>5</sup> And indeed, at least domestically, the Krier/Ursin analysis seems to have been vindicated. It may be the case that legislators have sometimes overreacted to perceived environmental crises or have gone off in the wrong directions, but the “exfoliation” process generally has later brought about some

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<sup>4</sup> A recent example of the uncertainties and pressures on science is the National Academy of Science’s (NAS) study of perchlorate, a chemical used in solid rocket fuel that has been linked to infant developmental disorders. After a contentious history pitting the defense establishment and the White House against environmentalists, the NAS panel concluded that drinking water can safely include 20 parts per billion (ppb), as opposed to the Environmental Protection Agency’s (EPA) proposed limit of 1 ppb. Some scientists and environmentalists complain that the NAS ignored other sources of the chemical. *See* Peter Waldman, *Pollution from Rocket Fuel*, WALL ST. J., Jan. 11, 2005, at A3; Peter Waldman, *Pentagon Backs Off Water-Test Plan*, WALL ST. J., June 20, 2003, at A5.

<sup>5</sup> JAMES E. KRIER & EDMUND URSIN, *POLLUTION AND POLICY: A CASE ESSAY ON CALIFORNIA AND THE FEDERAL EXPERIENCE WITH MOTOR VEHICLE POLLUTION 1940–1975*, at 1–3, 12 (1977).

reconsideration and adjustment, even if these readjustments are also imperfect. It is the exfoliation process that has matured environmental law—particularly in comparison to the early heady years and the great wave of legislation in the early 1970s.

The basic problem for environmental law is to constrain and channel adverse human impacts on natural resources. Obviously, this sentence is packed with questions: What is adverse to a natural resource? Which impacts are human? What exactly is a natural resource, or what is nature, for that matter? But I will operate on the theory that most readers will get the general idea even without an extensive discussion here of those deeper questions.

Over the years, American environmental law has adopted two basic approaches to inducing constraints on human uses of resources: the first approach is to focus on overall environmental *quality*, while the second is to focus on environmentally-related *behavior* on the part of particular actors. Quality-based (QB) strategies direct their attention directly at the resource itself, and they aim at maintaining some optimum balance between consumption and preservation, however fraught the questions may be about the elements that go into that balance. An example of this approach appears in the National Ambient Air Quality Standards, which identify a set of major air pollutants and attempt to set overall air quality standards with respect to each.<sup>6</sup> These standards anticipate that some pollutants will get into the air from various economic activities, but they try to designate amounts that will attain an overall air quality compatible with health and welfare. Another example of a QB approach appears in the 1990 Amendments to the Clean Air Act, which set a total limit on the tons of sulfur dioxide (an acid rain precursor) that can be emitted by major coal-burning utilities.<sup>7</sup> In both examples, the primary object in view is the quality of the air, not the action or performance of any particular actor.

By contrast, behavior-based (BB) strategies look to something different: they focus on regulating the *activities* or *performance* of the various environmental players. Thus, regulations that prohibit the use of certain types of hunting or fishing gear are BB strategies, and so are requirements that pollution-emitting entities install end-of-the-pipe pollution control devices, such as catalytic converters on automobiles or scrubbers on coal-burning furnaces.

One schooled in philosophy might be tempted to describe these two different approaches as Utilitarian versus Kantian (or deontological), respectively, in that the first approach aims at a good outcome, whereas the second aims at inducing right behavior. Environmental ethicists might regard BB measures as primary because they might see rightful behavior as the

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<sup>6</sup> 42 U.S.C. §§ 7408–7409 (2000) (requiring national primary and secondary ambient air quality standards).

<sup>7</sup> 42 U.S.C. §§ 7651–7651o (2000) (acid rain deposition control sections). This subchapter also instituted an emissions trading program. See *infra* note 33 and accompanying text.

touchstone of ethics generally.<sup>8</sup> My own view, however, is that as a political matter, environmental law necessarily must look to quality in the final analysis, so much so that even controls on behavior are ultimately aimed not at rightful behavior in itself, but at improvements in environmental quality. This is why, in practice, BB and QB measures often appear in combination, with BB controls ultimately aiming at quality improvement. One example of this phenomenon appears in the history of water pollution control measures.

In this Article, I refer to the burst of new environmental legislation of the early 1970s as the “First Wave,” but in fact that legislative outpouring was preceded by more tentative efforts to contain harmful impacts on the environment, and many of the measures in this “pre-history” were QB strategies. Water pollution control efforts were among these. Even prior to the Clean Water Act (CWA), the states were supposed to set water quality standards for different bodies of water. But these QB approaches did not in fact work very well to improve water quality. The problem was that once the standards were set, nothing much happened. It was just too hard to connect deterioration in water quality to any particular responsible party.<sup>9</sup>

In the First Wave of environmental legislation in the early 1970s, Congress attempted to solve this kind of problem by shifting the focus to BB controls. That is, in a variety of areas environmental quality was to be improved through direct control on the players’ actions, without regard to the (almost unprovable) link between particular actions and quality deterioration. The Clean Air Act (CAA) was one of the most important of these new pieces of legislation. Here, Congress determined that the QB approach to air quality standards had to be buttressed by BB strategies, that is, direct regulation of polluting activities. The CAA set quality standards at a national level, but thereafter, when the states figured out ways to meet those standards, they were required to do so in part by specific limits on polluting activities—i.e., emissions limitations on specific sources, a kind of BB approach.<sup>10</sup> In addition, Congress passed a separate set of national BB controls on large industrial polluters, notably factories and the automobile industry. New factories were supposed to meet “New Source Performance Standards” to reduce the amounts of pollution that they produced.<sup>11</sup> Similarly, new automobiles also had to meet performance standards,<sup>12</sup> as did major new sources of hazardous air

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<sup>8</sup> See MARK SAGOFF, *THE ECONOMY OF THE EARTH: PHILOSOPHY, LAW AND THE ENVIRONMENT* 152–56 (1988) (referring to an ethical point of view with apparent reference to Kantianism); cf. Carol M. Rose, *Environmental Faust Succumbs to Temptations of Economic Mephistopheles, or, Value by Any Other Name is Preference*, 87 MICH. L. REV. 1631, 1633–35 (1989) (reviewing Sagoff, noting ambiguities of Sagoff’s “ethical” position).

<sup>9</sup> ROGER W. FINDLEY ET AL., *CASES AND MATERIALS ON ENVIRONMENTAL LAW* 386–87 (2003) (describing water quality standards and their problems prior to 1972 legislation).

<sup>10</sup> Clean Air Amendments of 1970, Pub. L. No. 91-604, § 110(a)(2), 1970 U.S.C.C.A.N. (84 Stat. 1676) 1954, 1959–60 (codified at 42 U.S.C. § 7410(a)(2) (2000)) (requiring that state implementation plans include emissions limitations).

<sup>11</sup> 42 U.S.C. § 7411 (2000) (performance standards for new stationary sources).

<sup>12</sup> 42 U.S.C. § 7521 (2000) (emissions standards for new motor vehicles).

pollutants.<sup>13</sup> In all cases, the performance or behavior standards were based on a version of “Best Available Technology”; that is, the polluting entity was supposed to perform at a level comparable to that of the best technology that could be applied to the activity, e.g., in the case of autos, tailpipe emission controls that were technically feasible even if not entirely developed.<sup>14</sup>

The idea was that these legal requirements to use better technology would force polluting sources to *perform* better, and in turn this behavioral improvement would mean that less “gunk”<sup>15</sup> went into the air, thus making environmental *quality* better. It is in that sense that these major new pollution control laws attempted to use Kantian principles (imposing uniform behavioral standards) to arrive at Utilitarian goods (better air quality).<sup>16</sup>

Much the same shift to BB approaches appeared in connection with water pollution. In 1972, the new Clean Water Act (CWA) slapped behavioral controls on the big polluters, notably through a technology-based permit system to limit polluters’ end-of-the-pipe discharges into the nation’s waters.<sup>17</sup> For example, a salmon cannery in Alaska had to meet a technology-based standard—even though not a terribly sophisticated one—to screen waste fish parts before dumping them in the sea.<sup>18</sup> To some degree the BB pattern held for the Endangered Species Act as well, with its stringent restriction on activities that “take” or otherwise harm endangered animals.<sup>19</sup> Once again, direct constraints on behavior would presumably help to attain a larger goal of improved environmental quality, in this case recovery of endangered species. The BB controls could operate without the cumbersome need to show the effect of particular actions on overall threats to the species.

In short, then, while behavioral controls, like temperance, can serve a moral good in their own right, from another perspective those controls can also have *results* in view—as in cutting down on the bad things that happen when too many people get too drunk.<sup>20</sup>

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<sup>13</sup> 42 U.S.C. § 7412 (2000) (performance standards for major new sources of hazardous air pollutants).

<sup>14</sup> A major case approving “technology-forcing” in principle, though granting a time reprieve to auto makers for pragmatic reasons, was *International Harvester Co. v. Ruckelshaus*, 478 F.2d 615, 648, 650 (D.C. Cir. 1973).

<sup>15</sup> *In re CMC Heartland Partners*, 966 F.2d 1143, 1145 (7th Cir. 1992) (describing waste material subject to environmental cleanup as “gunk”).

<sup>16</sup> Jon Elster argues that much conventional moral thinking is actually a variant of result-oriented Kantianism, which he calls “Everyday Kantianism,” i.e., doing the right thing so long as others do too. See JON ELSTER, *THE CEMENT OF SOCIETY* 192–95 (1989).

<sup>17</sup> Federal Water Pollution Control Act (Clean Water Act or CWA), § 301, 33 U.S.C. § 1311 (2000) (technology-based effluent limitations on point sources).

<sup>18</sup> *Ass’n of Pac. Fisheries v. EPA*, 615 F.2d 794, 816–18 (9th Cir. 1980).

<sup>19</sup> Endangered Species Act of 1973, 16 U.S.C. §§ 1531–1544 (2000); Endangered Species Act of 1973, § 9, 16 U.S.C. § 1538 (2000) (prohibiting “taking” of endangered fish or wildlife).

<sup>20</sup> The individual moral imperative of BB standards continues to exercise an appeal. See Wendy E. Wagner, *The Triumph of Technology-Based Standards*, 2000 U. ILL. L. REV. 83, 92–93.

### III. EMERGING SUCCESSES, EMERGING NEEDS, AND THE RETURN OF QUALITY CONSIDERATIONS

The First Wave approaches to environmental law clearly had some success, adding needed muscle to the exercise of setting quality-based goals. Without that muscle, little would have happened for the usual tragedy-of-the-commons reasons: even industries that wished to take environmentally friendly measures might not have done so, fearing that competitors would take the cheaper route of doing nothing, evading discovery, and ultimately gaining a competitive advantage. Uniform behavioral controls eliminated this competitive problem by imposing the same observable requirements on all relevant players. By the same token, there was a certain logic to another aspect of the First Wave's controls, that is, concentrating controls at the end of the pipe. The end of the pipe, or "point source" as it was called, was the place where pollution control performance could be measured easily.

Nevertheless, those subject to these controls (along with their academic supporters) had a point with some of their complaints. The mantra of all these complaints was that existing BB controls were costly and inflexible.<sup>21</sup> One version of this complaint was that environmental controls failed to operate efficiently: uniform BB controls subjected all actors to the same controls regardless of differences in their compliance costs and regardless of differences in actual effects on environmental quality.<sup>22</sup> For example, Honolulu has fought a long battle with the Environmental Protection Agency (EPA) to be relieved of the requirement of secondary treatment of city sewage; why spend the money on additional purification, the city asks, when a sufficiently long pipe takes the sewage out into the deep waters and strong currents, where the effluent scarcely matters?<sup>23</sup> Similarly, in the Alaska cannery case mentioned above, the canneries argued that the cost of screening fish remains was very much out of line with any environmental benefits to the receiving waters that would accrue from this process, as opposed to the cheaper process of grinding.<sup>24</sup>

A related version of the "flexibility" problem was that BB regulations lost sight of cumulative effects. In focusing on individual actors' behavior, BB measures were inattentive to the fact that even small amounts can add up. To be sure, each salmon cannery ship might have to do a better job in screening its fishheads, but this would not help the receiving waters much if ten more canneries started dumping fishheads. In reality, the issue was not canneries; it was cars. Each new auto might be performing better individually (at least the new ones), but as time went by, there were a lot more of them on the road, to some degree offsetting the BB controls that made every auto perform better

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<sup>21</sup> Bruce A. Ackerman & Richard B. Stewart, *Reforming Environmental Law*, 37 STAN. L. REV. 1333, 1335-40 (1985) (characterizing problems of one-size-fits-all technology-based regulation).

<sup>22</sup> *Id.* at 1336 (complaining of waste from regulatory failure to account for individual variations).

<sup>23</sup> See Johnny Brannon, *City Seeks New Permit for Sand Island Plant*, HONOLULU ADVERTISER, MAY 30, 2003, at 7B (describing Honolulu's request for continued exemption).

<sup>24</sup> *Ass'n of Pac. Fisheries v. EPA*, 615 F.2d 794, 806 (9th Cir. 1980).

individually. The problem basically is one of small sources: a lot of small things add up.

Another “flexibility” complaint focused on the end-of-the-pipe methodology of early BB regulation. In a famous incident that later became the centerpiece of an EPA reform effort, testing at an Amoco plant revealed that more serious benzene pollution was coming from the uncontrolled activities at a shipping dock than from the heavily-controlled “point sources” in the plant—and that the former could have been controlled at one-fourth the cost of the latter.<sup>25</sup> The trouble was that pollution from the point sources was easier to measure and hence to regulate, but in fact the less tractable nonpoint sources might be a bigger source of troubles. This issue has been especially noticeable in water pollution, where controls on point sources left more or less untouched the serious pollution from construction, agriculture, and city streets’ runoff—all “nonpoint” sources that are hard to measure and monitor. Nonpoint sources are small and inconvenient to regulate, but they not only add up, they can also interact in various deadly forms.

All these complaints of inflexibility and cost illustrated that our system of environmental law was already maturing by the end of the 1980’s. It made sense for the First Wave of environmental laws to impose uniform requirements on point sources because those were quick and dirty measures—not very fine-tuned, but useful to deal with gross problems. When individual acts of environmental degradation were indeed numerous and gross, it was easier and cheaper to pay less attention to individual cost differences, or the accumulation of small amounts, or the rising cost curve of ever-increasing regulation of the sources that were easy to find. But by the late 1980’s, once the grossest and most easily monitored problems had been addressed, it became increasingly less sensible to ignore the smaller and more difficult nonpoint sources while ratcheting up the regulatory burden on point sources—i.e. prohibiting smaller and smaller amounts of polluting substances from each and every pipe without corresponding improvement in environmental quality.<sup>26</sup> It was at this juncture that more attention to individual compliance costs made sense—and so did a shift of attention to other and now relatively more serious nonpoint sources of degradation, like agricultural runoff or evaporating fumes, even though controlling those sources is generally more difficult at the outset.

Notice that this shift of attention was ultimately based on attentiveness to environmental *quality*. It was because of quality considerations that we had to impose behavioral controls in the First Wave, deracinating those controls from hard-to-prove links between behavior and quality. But it is also because of

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<sup>25</sup> Caleb Solomon, *Clearing the Air: What Really Pollutes? Study of a Refinery Proves an Eye-Opener*, WALL ST. J., Mar. 29, 1993, at A1. For academic commentary, see, for example, J.B. Ruhl & James Salzman, *Mozart and the Red Queen: The Problem of Regulatory Accretion in the Administrative State*, 91 GEO. L.J. 757, 817 (2003) (using the Amoco experience as example of need to regulate at the “composite” level rather than that of individual operations).

<sup>26</sup> See, e.g., William F. Pedersen, Jr., *Turning the Tide on Water Quality*, 15 ECOLOGY L.Q. 69, 71–72 (1988) (noting that, as of 1984, more than half of U.S. water pollutants came from nonpoint sources and calling for regulation that requires attainment of quality standards).

quality considerations that, more recently, we have had to go beyond the first generation's fixation on behavior. To be sure, the first round of BB strategies has indeed done a great deal for environmental quality, and we should not forget it. Some scholars continue to think that behavioral controls should be central to our thinking, in large part because they still think that it is too difficult to prove a link between behavior and quality.<sup>27</sup> Some point out that even if we are to shift to more flexible approaches, the threatened club of behavioral regulation can keep the various actors "honest," forcing them to prove that their planned flexible approaches might perform better than uniform BB controls.<sup>28</sup> Certainly it is not to be expected that behavior-based approaches will vanish—"do this and don't do that"—but we might expect that newer generations of environmental laws are increasingly likely to treat these strictures as default rules, to which exceptions can be made on a regulatory or even on a contractual basis, ultimately with an eye to environmental quality.

Indeed, the most serious downside to BB strategies may not be that they are inefficient or inflexible; instead, it may be that they can make us lose focus on the big picture of environmental quality—the receiving water quality, the receiving air quality, the total amounts of wildlife and habitat, and all the rest of environmental quality-related goals.<sup>29</sup> As a practical political matter, these issues of environmental quality, and the efforts and expenditures we are willing to make to attain different levels of environmental quality, are the things that really make a difference—more than the way any given environmental actor is behaving.

Notice that quality considerations were where we started in environmental thinking, even before the First Wave of federal environmental legislation in the early 1970s. In a sense, for environmental regulation to grow up has meant coming back to a qualitative focus and recognizing that even behavioral controls are not necessarily put in place for their own sake, but rather for the sake of a larger environmental good.

This shift of focus is as yet incomplete. It is in this context of incomplete transformation that we need to ask about the ways that science can help environmental law to grow up. But of course we do not write on a blank slate here. Environmental law has already moved beyond the First Wave; by 1990, regulators had already begun to deal with at least some of the issues raised by earlier legislation. They pinned high hopes on one new approach in particular: market-based tradeable environmental allowances, or so-called cap-and-trade programs. But these programs so far have had only fairly limited application. In the next few pages, I will not make a brief either for or against such trading

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<sup>27</sup> A consistent proponent of continued reliance primarily on behavioral standards is Howard Latin. See Howard Latin, *Ideal Versus Real Regulatory Efficiency: Implementation of Uniform Standards and "Fine-Tuning" Regulatory Reforms*, 37 STAN. L. REV. 1267, 1304 (1985) (arguing that regulatory reform based on cost and benefit comparisons requires too much information to be workable); see also Wagner, *supra* note 20, at 96 (same).

<sup>28</sup> Wagner, *supra* note 20, at 106.

<sup>29</sup> See Ackerman & Stewart, *supra* note 21, at 1353 (faulting behavior-based standards for deflecting attention to technological methods instead of quality goals).

programs; instead, I will use them to illuminate the kinds of assistance that our maturing environmental law needs from science.

#### IV. THE NEXT WAVE'S GAPS AND NEEDS: THE EXAMPLE OF CAP-AND-TRADE PROGRAMS

The call for market-based approaches to environmental law began with complaints about the inflexibility and inefficiency of early uniform BB approaches, and particularly complaints about those approaches' increasing marginal costs and decreasing marginal benefits. By the later 1980's, critics of BB approaches combined their critique with a proposed alternative: cap-and-trade programs, which seemed especially applicable to efforts to clean up sulfur dioxide, a byproduct of coal-burning plants and a precursor to acid rain.<sup>30</sup>

The first step in any cap-and-trade program is of course the *cap*: that is, the total usage of some resource is to be capped at an overall amount that is considered to be compatible with health and welfare. Thereafter, the total capped amount is divided into units that are convenient for individual resource users; they can purchase or trade for the number of units that they need at a price set by market demand.

The initial idea of an upper cap, be it noted, derives from a direct focus on environmental *quality* rather than on specific *behaviors* or activities. Indeed, at the trading stage, too, cap-and-trade programs are more or less indifferent to individual behavior. To take the acid rain program as an example, so long as you do not produce much pollution (i.e., consume the clean air resource by using it as a wastebasket), you do not have to do anything in particular—you do not need to install scrubbers or coal cleaners or any other particular kind of pollution reduction methods. Indeed, even if you *do* produce a lot of pollution, you do not have to do anything in particular. Cap-and-trade programs require only that for every unit of resource that you use, you must buy an entitlement—which is to say, you have to pay for someone else to stop polluting, in an amount equivalent to your pollution, so that the total capped usage of the air resource remains the same. But the method by which pollution is diminished is up to the users and their trading partners.

A system like this meets the demand for flexibility because it allows for any number of pollution-reduction methods to be used. Moreover, it encourages cost-effective pollution control, because it allows those with high costs of pollution reduction (normally older users with high retrofit costs) to pay to clean up lower-cost ones, ultimately resulting in better air quality for less money. In theory, the same kind of cap-and-trade regime can be used for a great variety of environmental subjects. And indeed, over the last several years, cap-and-trade regimes have been proposed in quite a variety of areas: water pollution trading, wetlands trading, fishing quota trading, and in the

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<sup>30</sup> See, e.g., Ackerman & Stewart, *supra* note 21, at 1353; T.H. TIETENBERG, EMISSIONS TRADING: AN EXERCISE IN REFORMING POLLUTION POLICY, 120-22 (1985); Robert W. Hahn & Gordon L. Hester, *Where Did All the Markets Go? An Analysis of EPA's Emissions Trading Program*, 6 YALE J. ON REG. 109, 110, 114, 127 (1989).

context of global warming, greenhouse gas trading.<sup>31</sup> Some have proposed trading regimes even for something as delicate as wildlife habitat: a developer presumably can destroy Habitat A so long as she pays for restoration or creation of equivalent or better Habitat B.<sup>32</sup>

But in practice, cap-and-trade regimes have had only a very modest number of applications. The Acid Rain trading regime of the 1990 Clean Air Act Amendments aroused great hopes, but it has seldom been replicated in other areas—some minor use in water pollution reduction; some fishing quota trading in New Zealand and Australia, among others; and some anticipatory trades in greenhouse gas reduction in Europe.<sup>33</sup>

Why are these seemingly promising mechanisms used so sparingly? There are many explanations, including a number that refer to the political entrenchment of established resource users,<sup>34</sup> but one major reason is an unsolved problem. That problem, in capsule form, is *measurement*, and it takes a variety of forms.

#### A. *Measuring Amounts*

The 1990 Acid Rain program applied only to big coal-burning utilities, whose emissions were themselves relatively easy to monitor. But this is not the case for producers of other kinds of air pollution, for example smog precursor gases: the latter result from large numbers of small and elusive sources, notably exhaust from autos but also evaporation from gas stations or decay from wood products, not to speak of flatulence from cows or termites. Water pollution is especially problematic. Some major polluters can be located easily, particularly those polluters already classed as point sources—the dye factories, the bleaching facilities, even the concentrated animal feedlots. But many discharges cannot be located easily, and hence they may be overlooked entirely in regulatory systems for water pollution control. Many discharges come from

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<sup>31</sup> See, e.g., Alan J. Krupnick, *Reducing Bay Nutrients: An Economic Perspective*, 47 MD. L. REV. 452, 476–79 (1988) (water pollution trades); Lisa A. Wainger et al., *Wetland Value Indicators for Scoring Mitigation Trades*, 20 STAN. ENVTL. L.J. 413, 414–15 (2001) (wetland trades); Shi-Ling Hsu & James E. Wilen, *Ecosystem Management and the 1996 Sustainable Fisheries Act*, 24 ECOLOGY L.Q. 799, 807 (1997) (fish quota trading); Margaret Kriz, *After Argentina*, 30 NAT'L J. 2848, 2851 (1998) (greenhouse gases).

<sup>32</sup> David Sohn & Madeline Cohen, *From Smokestacks to Species: Extending the Tradable Permit Approach from Air Pollution to Habitat Conservation*, 15 STAN. ENVTL. L.J. 405, 411–12 (1996).

<sup>33</sup> See, e.g., Thomas W. Merrill, *Explaining Market Mechanisms*, 2000 U. ILL. L. REV. 275, 281–86 (describing survey of relatively minor uses in U.S.); R. Quentin Grafton et al., *Private Property and Economic Efficiency: A Study of a Common-Pool Resource*, 43 J.L. & ECON. 679, 682 (2000) (tradable fishing quotas in Canada, New Zealand, Iceland, Australia, and the Netherlands); Thomas M. Kerr & Richard M. Saines, *International Climate Change and Corporate Action*, NAT. RESOURCES & ENV'T, Winter 2004, at 51, 53–54 (describing trades in expected European greenhouse gas markets).

<sup>34</sup> Merrill, *supra* note 33, at 289.

run-off, i.e., the so-called nonpoint pollutants: sediment from construction, organic materials, pesticides from farms, and fertilizers from lawns.<sup>35</sup>

Some commentators have discussed the possibility of instituting trading regimes for nutrients in water, especially nitrogen-loading substances; these materials speed the growth of organic matter in the water, reducing available oxygen and leading to die-offs of other marine life.<sup>36</sup> The usual form of the nutrient-control proposals would pin responsibility on the point sources, i.e., those that can be located; and the usual practical measures would ratchet down the point sources' permit levels but allow those sources to meet the more stringent standards by finding nonpoint sources and controlling them, instead of installing more control equipment on the point source itself.<sup>37</sup>

A major problem with this idea, of course, is that it loads all the responsibility for cleanup on the point sources, largely because those are the sources we can identify. In that sense, these new cap-and-trade proposals replicate the way that First Wave behavior-based controls overloaded responsibility on point sources, even though, under trading regimes, the point sources have more flexible options for pollution reduction. But there are other problems too. Suppose we raise the requirements on a given point source—say, a sewage treatment plant—and then leave it to the sewage treatment plant to meet the new standard by finding a farm and cleaning up the farm's organic runoff. Quite aside from the problem of foisting all the costs on the plant, we do not know whether the solution actually works. The reason we do not know is that we do not have good measures of the farm's new and old pollution levels, and hence we do not know whether the trade matches or not.<sup>38</sup>

Here, then, is an area where a maturing environmental law really needs help from science: How can we trace small amounts of gunk coming from dispersed sources? How can we calibrate the impact of those small amounts in the relevant receiving waters? To be sure, regulators, economists, and legal thinkers have come up with the idea of trading regimes to solve some of the flexibility and efficiency problems of the First Wave of environmental legislation, but we cannot know whether the trades are really working to improve quality unless we have good measures of small and diffuse amounts of the relevant traded materials and good measures or models of their effects on the receiving media.

Notice that this measurement problem was exactly what drove the First Wave of environmental legislation toward BB strategies—simply ignoring the link between particular activities and hard-to-measure quality effects. Now that the easy-to-find sources have been more or less brought to heel, we are still

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<sup>35</sup> See Pedersen, *supra* note 26, at 71 (high percentage of water pollution from nonpoint sources).

<sup>36</sup> Thomas K. Ruppert, *Water Quality Trading and Agricultural Nonpoint Source Pollution: An Analysis of the Effectiveness and Fairness of the EPA's Policy on Water Quality Trading*, 15 VILL. ENVTL. L.J. 1, 2–4 (2004) (describing problems of nonpoint sources, particularly nitrogen and phosphorous loading, and proposals for trades).

<sup>37</sup> *Id.* at 19–20 (describing problems of allocating responsibility to point sources).

<sup>38</sup> *Id.* at 13–14 (noting the problem of measuring nonpoint source reduction effects and problems of “gaming” the system).

faced with the same issue that we had earlier, the link between activities and quality. While much has been done to investigate these links, environmental policy still very much needs the aid of science for closer measurement, especially of small and diffuse amounts and their effects on resources.

### B. *Measuring Interactions*

Measuring small quantities of pollutants is not the only arena in which a new generation of environmental regulation needs help from science. Another arena is the measurement of interactivities among pollutants. In turn, measuring interactivity takes at least two distinct forms: first, measuring the interactions of *like* substances, and second, measuring the interactivity of *unlike* substances or contexts.

It is useful here to compare sulfur dioxide (SO<sub>2</sub>), the major acid rain precursor that is the subject of the 1990 CAA amendments, with toxic air pollutants. Interactivity would *not* seem to be a major problem with SO<sub>2</sub>. This is because sulfur dioxide basically forms a big soup in the atmosphere. Whether the emissions come from Place X or Y, from Ohio or Pennsylvania, makes some difference to downwind states, but not a great deal of difference except in particular instances. For that reason, trading back and forth has little significance; if an Indiana plant buys up rights from a Pennsylvania plant, it will not matter a great deal in Massachusetts, where the soup ultimately comes down as acid rain.<sup>39</sup>

But by comparison, the location of toxic air pollutants may matter a great deal, and hence trading may matter too. A small amount of toxic material may be quite deadly, and if trades concentrate those materials in a given location, a serious danger threshold may be crossed there.<sup>40</sup> Similarly, trading in water pollutants may matter too, especially in smaller water bodies. A small amount of a given pollutant may be tolerable to marine life, but if trading results in a major shock in a particular location, the result may be a major fishkill.<sup>41</sup>

These kinds of issues have been labeled “hotspot” problems.<sup>42</sup> Hotspots signal a very simple form of interaction: they represent the interaction of a given pollutant with the same kind of pollutant in a pattern of rising marginal damage with increased concentrations. Small amounts of the pollutant may be harmless, but larger amounts may be dangerous, and even larger amounts may be deadly. The mirror image problem comes with resource extraction, where the use entails not an addition to the resource (as in pollution), but rather in taking something from it (as in mining or timbering). For example, a minor

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<sup>39</sup> Trades across airsheds do matter, however, if the pollutants are traded from downwind recipient locations to upwind locations. See James Salzman & J. B. Ruhl, *Currencies and the Commodification of Environmental Law*, 53 STAN. L. REV. 607, 638–40 (2000) (noting problems of these trades, which they describe generally as “spatial nonfungibilities”).

<sup>40</sup> Richard Toshiyuki Drury et al., *Pollution Trading and Environmental Injustice: Los Angeles’ Failed Experiment in Air Quality Policy*, 9 DUKE ENVTL. L. & POL’Y F. 231, 251 (1999) (criticizing emissions trading that concentrates toxics in low-income neighborhoods).

<sup>41</sup> Salzman & Ruhl, *supra* note 39, at 638 (noting failure of nitrogen trading in Long Island Sound due to concentration at the western end of Sound).

<sup>42</sup> See, e.g., Drury et al., *supra* note 40, at 252.

amount of groundwater extraction in a given location might not be harmful, since rain will replenish the loss, but a large extraction might cause the entire aquifer to collapse.<sup>43</sup>

Under those circumstances, trading can be highly problematic, because trading can cause concentrations of resource use in specific locations or contexts. What environmental regulators need is a system of indexing or “vintaging” to account for rising marginal costs of a given pollutant or extraction. The wide discussion of hotspot problems suggests that the indexing need is widely recognized. Fundamentally, this too is a need for measurement, and here too, environmental law very much needs help from science. The measurement issue here is not simply finding small amounts, but rather tracking the interaction of small amounts of a given substance with other small amounts of the same substance.

### C. *Measuring Synergies*

The interactions of one pollutant with another of the same kind is a species of synergy (i.e., twice the concentration of gunk X becomes more than twice as damaging to a given environmental resource). But other synergies are much more complex. For example, how do fish react to combinations of *different* pollutants in the water? Can they stand a larger volume of chlorine if oxygen has not been depleted by the discharge of organic wastes? How do they react if both types of pollutant are in slow streams instead of fast-moving ones, or in shallow streams as opposed to deep ones? In short, what are the effects of some amounts of X—even small amounts of X—given the presence of some other substance Y or context Z? If we do not know and account for those varying effects, trading a given amount of X from one location to another could be extremely problematic, because as James Salzman and J.B. Ruhl have convincingly argued, environmental issues are shot through with “nonfungibilities” that make supposedly equal trades have very unequal results.<sup>44</sup>

Here again, as with the tracing of small and diffuse amounts of resource use, if we do not understand the interactions and synergistic effects among pollutants or extractive activities, we cannot get very far with trading regimes. Without measurement and modeling of these synergies and interactions, we could permit trades that turn into disasters. Lawmakers and policymakers cannot come up with measures, markers, and models on their own. For this, they need the assistance of the sciences and a much more intensive effort in the measuring and modeling endeavors that already engage ecological scientists.

### D. *Measurement and System-Wide Approaches*

The First Wave of environmental law tended to treat environmental issues in a kind of modern version of the Cartesian method: divide everything into

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<sup>43</sup> Kenneth A. Hodson, Note, *The Dormant Commerce Clause and the Constitutionality of Intrastate Groundwater Management Programs*, 62 TEX. L. REV. 537, 541 (1983).

<sup>44</sup> Salzman & Ruhl, *supra* note 39, at 612–13.

parts and then attack each part separately. Thus we find the Clean Air Act, the Clean Water Act, the groundwater protections of RCRA<sup>45</sup> and CERCLA,<sup>46</sup> pesticide control in FIFRA,<sup>47</sup> and so forth and so forth, each concentrating on a different type of pollutant or medium. One unfortunate result has been cross-media pollution, as, for example, when pollutants “scrubbed” from factory smokestacks get carted off to the hazardous waste site; once there they must be kept from polluting the groundwater.<sup>48</sup> Since various environmental issues and media ultimately need to be considered in conjunction, clearly a new generation of environmental law needs to pay attention to the coordination of environmental efforts.

In some ways, the calls for system-wide approaches raise questions that are simply a more complex variant on the other measurement issues: system-wide approaches are supposed to manage the interactions and synergies among a whole range of environmental initiatives. One approach to wider coordination has received a considerable amount of attention: what has been called “ecosystem management,” which generally involves areawide planning and coordination through public participation and intergovernmental cooperation.<sup>49</sup>

Less noticed is the fact that cap-and-trade programs could also provide for system-wide environmental coordination—at least in theory, and the exploration of that theory is again enlightening about the needs of a maturing environmental law. The most ambitious imaginable trading programs would allow the trading of different kinds of resource uses against one another: If A’s new production of widgets releases more carbon monoxide, A might trade her way out of her cleanup obligations by paying to reduce some amount of B’s sulfur dioxide (or perhaps C’s arsenic, or D’s chlorofluorocarbons). A will presumably choose to clean up the pollutant that can be most cheaply controlled, taking into account a universal index that determines the equivalent harmfulness of each pollutant by comparison to each of the other pollutants, and, of course, taking amounts into consideration.

Given such a universal index of relative harms, the “cap” in question would presumably be a sort of “everything cap,” encompassing every kind of

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<sup>45</sup> Resource Conservation and Recovery Act, 42 U.S.C. §§ 6921–6939e (2000) (regulating treatment, transportation, storage and disposal of hazardous waste).

<sup>46</sup> Comprehensive Environmental Response, Compensation, and Liability Act of 1980, 42 U.S.C. §§ 9601–9675 (2000) (providing for emergency response to releases of hazardous materials).

<sup>47</sup> Federal Insecticide, Fungicide, and Rodenticide Act, 7 U.S.C. §§ 136–136y (2000).

<sup>48</sup> See, e.g., Uwe M. Erling, *Approaches to Integrated Pollution Control in the United States and the European Union*, 15 TUL. ENVTL. L.J. 1, 11–12 (2001) (describing the air pollution and hazardous waste cross-media problem in U.S. law); see also William L. Andreen, *Environmental Law and International Assistance: The Challenge of Strengthening Environmental Law in the Developing World*, 25 COLUM. J. ENVTL. L. 17, 36 (2000) (describing U.S. law as taking a “sectoral” approach, with certain practical advantages, and the disadvantage of inattentiveness to cross-media pollution); cf. Ruhl & Salzman, *supra* note 25 at 814, n.193 (discussing the cross-media problem but remarking that regulators are now more aware of it).

<sup>49</sup> See, e.g., Symposium, *Ecosystem Management: New Departure for Land and Water*, 24 ECOLOGY L.Q. 619 (1997).

environmental resource use and all environmental risks, and allowing all to be traded against all.<sup>50</sup> The idea here is the eminently sensible one of getting the most for the environmental dollar: that the most dangerous and cheapest-to-control risks should be cut back first through trades against less dangerous or more costly ones, and so on in order down the line. Thus, a universal market would allow the market mechanism to coordinate system-wide environmental protection, and would do so in a way that maximizes flexibility and minimizes costs.

There are obviously very sharp policy issues here, of course. If a pesticide pollutant A causes stomach upsets while pollutant B kills rainbow trout, how much credit (in the form of more stomach-irritating A) should I get for reducing some amount of trout-killing B? Should these substances be traded against each other at all? These kinds of questions suggest some of the limits on science: it is not at all clear that science can tell us that it is worth it to have more live fish, even at the cost of more stomach aches—particularly when the persons interested in the fish may not suffer the stomach aches themselves. But science *could* assist in describing the effects of pollutant A and B, so that policymakers could at least intelligently discuss whether they wanted to make tradeoffs between A and B, and if so, how those tradeoffs might be calibrated.

And so, here again, policymakers desperately need science. Without that scientific knowledge, without understanding synergies, interactions, and tradeoffs, policymakers cannot even begin to make informed decisions about system-wide management. Notice that this is not just a problem for market-based approaches. Market approaches make the knowledge problem obvious. But direct regulatory or command approaches to system-wide ecosystem management must face the same kinds of issues. Command systems require coordination as much as trading systems do, and one cannot have well thought out coordination without knowledge of synergies and tradeoffs.

In sum, then, the second wave of environmental legislation consciously foregrounded overall environmental quality, but it grew out of demands for “flexibility”—a thinly veiled call for more efficiency and greater attentiveness to the differential costs and benefits of regulation. Cap-and-trade regimes were one of the chief theoretical advances in attempting to deal with the demands for flexibility and quality considerations, but cap-and-trade regimes have turned out to have a much more limited practical reach than some had hoped. One reason is that cap-and-trade programs have pulled the veil away from a set of unsolved measurement problems. Without solutions, cap-and-trade simply cannot work well—but then, neither can more *dirigiste* regulatory programs, like ecosystem management. We need adequate measures or models for small and diffuse sources, for interactions between various amounts coming from those sources, and for interactions among sources of different types and across media of different types. If we cannot solve these measurement problems, we

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<sup>50</sup> See Richard B. Stewart, *The Role of the Courts in Risk Management*, 16 ENVTL. L. REP. 10208 (1986) (proposing that courts should facilitate a “risk portfolio” approach, which would reduce the most dangerous and easily controlled risks first). While this Article was directed to the courts, Stewart is very much an advocate of market-based approaches, presumably on the basis of a “risk portfolio” approach.

are not going to make much further progress along the road to a more mature environmental law, one that returns the focus to environmental quality. And indeed we cannot solve those problems without the help of science. This of course leads to a further question: *Will science help?*

## V. SCIENCE IN THE NEW WAVE

From one perspective, the answer to the question, “will science help,” seems obvious. Yes, it will, and in fact it already has. Considerable progress in measuring and modeling has already been made, spurred by environmental laws in general and perhaps enhanced by the interest in the use of cap-and-trade approaches.<sup>51</sup> On the other hand, there are many reasons why science tends to lag in environmental areas. One important reason is that environmental resources are by their nature diffuse and unowned; because no one in particular has a property-based concern for such resources, environmental research often fails to attract the concentrated attention, funding, and political lobbying that accrues to more money-making scientific research.<sup>52</sup> This systemic problem may even result in the conscious suppression of environmental scientific findings by those who find such findings unwelcome.<sup>53</sup> Given this structural problem, it is a tribute to science—and to the policymakers that fund it—that so much has already been accomplished in environmental research.

A very different kind of reason for a lag concerns the prestige that comes from different kinds of scientific research. From reading popular or journalistic descriptions of modern science, one could easily get the impression that scientific work in general is getting smaller and smaller. The “hot” subjects in the biological sciences would seem to be studies of ever smaller bits of the genetic code—DNA, RNA, proteins, and so forth. This trend, if it exists, would not appear to bode well for the kind of science that will be of most serious practical use to our maturing environmental law, where the issues are to devise rather prosaic markers of chemicals and other materials, to test their characteristics at different concentrations, to learn about their interactions with other substances, and to model how similar interactions might occur in different contexts. Nevertheless, one might suspect that even the molecular biologists might well take a turn toward the synergistic before long, if they have not already, and to address such questions as, “How does genetic material A interact with genetic material B and C? How do A, B, and C all interact with some environmental factor K?”<sup>54</sup>

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<sup>51</sup> Camille V. Otero-Phillips, Comment, *What's in the Forecast? A Look at the EPA's Use of Computer Models in Emissions Trading*, 24 RUTGERS COMPUTER & TECH. L.J. 187, 204–12 (1998) (describing the EPA's computerized air pollution models and their uses).

<sup>52</sup> Carol M. Rose, *Scientific Innovation and Environmental Protection: Some Ethical Considerations*, 32 ENVTL. L. 755, 759–60 (2002).

<sup>53</sup> See Robert R. Kuehn, *Suppression of Environmental Science*, 30 AM. J.L. & MED. 333, 333–34 (2004) (detailing instances).

<sup>54</sup> See, e.g., Matt Ridley, *The DNA Behind Human Nature: Gene Expression and the Role of Experience*, DEADALUS, Fall 2004, at 89, 90–91, 98 (describing behavioral consequences of different interactions between genes and nearby “switches” of bases, and interactions of all with environmental factors); see also Keith Humphreys & Sally Satel,

A grown-up environmental law definitely needs scientists who are interested in large-scale issues and the interactions among the parts. Of course, the biggest picture of all at the moment is the issue of human-induced climate change. Climate change conferences all over the globe have focused on reducing human-created carbon dioxide (CO<sub>2</sub>), but there are other global warming gases as well, and some are more potent greenhouse precursors than CO<sub>2</sub>, for example methane. How does the reduction of CO<sub>2</sub> from automobile combustion interact with the greater amount of methane emitted by termites that digest construction waste? How do both interact with the deforestation in some parts of the globe (e.g., Amazonia) and the reforestation in others (e.g., New England)? International environmental lawyers would be grateful for even tentative answers. They would be equally grateful for further research on other measurement issues: Are there markers through which synergistic or interdependent activities can be noticed? Are there really keystone species? Are there other signals that a whole ecosystem requires attention, on an ecosystem-wide basis? These are very large questions, and a mature environmental law needs scientific help with them, just so that policymakers can make educated guesses where to put their efforts, and how efforts in place A might affect place B.

Something else that policymakers need from scientists is *tolerance*. In a policy world, decisionmakers have to make up their minds on the basis of very incomplete information. Scientists, unlike legislators, do not have to make decisions while their findings are still in doubt, but legislatures do. Doing nothing is a decision too, and—like doing the wrong thing—it can be a decision that makes environmental problems much worse.

What this means is that policymakers fall back on a number of proxies or heuristics that people steeped in the sciences would eschew. One such heuristic is consensus, particularly consensus about information, including scientific information. Consensus is not necessarily a way to do good science in the first instance, since it can lead to an undue narrowing of the scope of inquiry. A classic example is the refusal of the eighteenth century British scientific academy to take seriously the comparison of timepieces to calculate longitude—but that is the method that ultimately prevailed.<sup>55</sup> But policymakers are not doing science in the first instance; instead, they are trying to figure out what to do on the basis of the best information available at any given time. This is not to say that policymakers should not attempt to get the best scientific advice they can,<sup>56</sup> it is just to say that policymakers may have to act before the scientific community comes to a definitive conclusion. Take issues of global warming: Some scientists may not agree that human actions have a significant

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*Some Gene Research Just Isn't Worth the Money*, N.Y. TIMES, Jan. 18, 2005, at D5 (comparing genetic to environmental factors in disease and arguing against genetic research where environmental changes are more effective).

<sup>55</sup> DAVA SOBEL, *LONGITUDE: THE TRUE STORY OF A LONE GENIUS WHO SOLVED THE GREATEST SCIENTIFIC PROBLEM OF HIS TIME* (1995).

<sup>56</sup> For a survey of the ways that scientific advice to policymakers has been organized, see Lynn E. Dwyer, *Good Science in the Public Interest: A Neutral Source of Friendly Facts*, 7 HASTINGS W.-NW. J. ENVTL. L. & POL'Y 3, 15 (2000).

impact on the pattern of global climate change, and in the end their views may even prevail. But the current consensus among scientists is that human actions have influenced the pattern of warming, and this fact explains the widespread view—shared by many scientists—that at a minimum, policymakers need to consider possible constraints.<sup>57</sup> Consensus does not make a scientific answer right, but policymakers cannot wait until they know they are right. Scientists need to be tolerant of this unpleasant circumstance of political decisionmaking. This is why calls for environmental policy based on “good science” can be disingenuous delaying tactics, equating “good science” with the absence of doubt; in the face of the many uncertainties about environmental issues, the relevant science is rarely likely to meet that test.<sup>58</sup>

Another type of proxy that policymakers use involves extrapolation from large quantities to small, or from small to large. The small-to-large extrapolation is widely known; many of us treat our individual experiences as characteristic of a whole class of phenomena.<sup>59</sup> Precisely because so many of us do this, we are aware of the pattern, and we can guard against its excesses to some degree. More problematic is the large-to-small extrapolation, but this kind of extrapolation is especially common in environmental policy. Suppose that an herbicide causes one of every ten mice to die when administered in teaspoon-sized doses for a short time. A teaspoon is a lot for a mouse; how should one extrapolate back to the much smaller doses that a real mouse is likely to encounter in the real world?<sup>60</sup> One answer is to assume that a linear reduction in dosage brings about a linear reduction in incidence of mortality; another answer is to take the view that there is some likely threshold at the low end—that is, that smaller doses are likely to reduce toxicity more than linearly.<sup>61</sup> Among environmental regulators and commentators, there has been much debate over this dose-response issue (even before extrapolating from mice to humans). Unfortunately, environmental researchers cannot often run the “megamouse” experiments that would give us better answers about low dosages.<sup>62</sup> But policymakers have to make choices anyway. Some

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<sup>57</sup> See Patrick Parenteau, *Anything Industry Wants: Environmental Policy Under Bush II*, 14 DUKE ENVTL. L. & POL’Y F. 363, 365–71 (2004) (describing scientific consensus on global warming and criticizing the Administration for manipulating science).

<sup>58</sup> Wendy E. Wagner, *Congress, Science, and Environmental Policy*, 1999 U. ILL. L. REV. 181, 230.

<sup>59</sup> See, e.g., Adam J. Hirsch, *Default Rules in Inheritance Law: A Problem in Search of Its Context*, 73 FORDHAM L. REV. 1031, 1071 n.160 (2004) (describing this logical error as the “representativeness heuristic,” first described by Amos Tversky & Daniel Kahneman, *Belief in the Law of Small Numbers*, in JUDGMENT UNDER UNCERTAINTY: HEURISTICS AND BIASES 23 (Daniel Kahneman et al. eds., 1982)).

<sup>60</sup> Bert P. Krages II, *Rats in the Courtroom: The Admissibility of Animal Studies in Toxic Tort Cases*, 2 J. ENVTL. L. & LITIG. 229, 239–44 (1987) (describing difficulties of scaling).

<sup>61</sup> Cass R. Sunstein, *Beyond the Precautionary Principle*, 151 U. PA. L. REV. 1003, 1026–27 (2003) (discussing various dose-response choices and controversies over them).

<sup>62</sup> Krages, *supra* note 60, at 241 n.71 (describing the expense of “megamouse” experiments); cf. Janet L. McQuaid, Note, *Risk Assessment of Hazardous Air Pollutants Under the EPA’s Final Benzene Rules and the Clean Air Act Amendments of 1990*, 70 TEX. L. REV. 427, 454 n.175 (1991) (describing an actual “megamouse” experiment that still failed to find a threshold for a toxin).

commentators believe that the only cautious thing to do is to assume linearity; others think it wiser to assume safe thresholds; but neither method is pure science.<sup>63</sup> Pure science under the circumstances is simply not feasible.

Still another proxy that policymakers use is the technique of “minimax,” that is, choosing a solution that minimizes the maximum trouble.<sup>64</sup> Suppose that the policymaker gets two studies of a toxin, but they suggest radically different effects on human health. The policymaker might choose to split the difference between them, even though there is no evidence for the middle ground.<sup>65</sup> The policymaker chooses the middle ground for a different reason: to minimize the worst mistake.

None of these methods would make scientists happy, but in the policy world, decisionmakers do not have a lot of options. They are not necessarily playing fast and loose with science or manipulating data; they may simply be doing the best they can under circumstances of uncertainty. Where the science is inconclusive, policymakers have to choose their science on the basis of other considerations—such as leaving margins of safety, taking cost into account, minimizing worst-case errors, or all of these.

Moreover, in a mature environmental law, problems of uncertainty are likely to increase, not decrease. This is because in a mature legal system, the largest and easiest things have been done, that is, the quick-and-dirty controls. The problems that are left are simply *hard*, and despite the exhortations of this Article for better measures and models, it is not to be expected that scientists will come up with definitive answers to all, or even many, of them.

But in the meantime, there is something else that science can do for a mature environmental law. Science can help to make environmental issues interesting. A mature environmental law is not pretty. It is past the stage of grand theory and well into the stage of acronyms and statutory sections. It bristles with code numbers and code names: among the important ones there are sections 111 and 112 of the CAA, along with section 404 of the CWA; there are CERCLA, RCRA and EPCRTKA (itself a part of SARA);<sup>66</sup> there is SMCRA<sup>67</sup> and FLPMA,<sup>68</sup> and TSCA.<sup>69</sup> None of this makes the environmental

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<sup>63</sup> See, e.g., Sunstein, *supra* note 61, at 1026–27 (arguing that linear extrapolation is not necessarily “precautionary”). Professor Wendy Wagner is a strong proponent of the view that science is unable to answer many environmental policy questions. See Wagner, *supra* note 58, at 230 (arguing that policymakers try too hard to treat policy decisions as science).

<sup>64</sup> Sunstein, *supra* note 61, at 1033–34 (describing the “minimax” principle).

<sup>65</sup> For a somewhat similar example, see Bob Davis, *What Price Safety? Risk Analysis Measures Need for Regulation, But It's No Science*, WALL ST. J., Aug. 6, 1992, at A1 (describing the OSHA process for proposing cadmium regulations, given highly varied experimental results).

<sup>66</sup> SARA stands for Superfund Amendments and Reauthorization Act of 1986; its Title III includes disclosure requirements officially named the Emergency Planning and Community Right-to-Know Act, Pub. L. No. 99–499, 1986 U.S.C.A.N. (100 Stat. 1613) (codified as amended in scattered sections of 42 U.S.C.).

<sup>67</sup> Surface Mining Control and Reclamation Act of 1977, 30 U.S.C. §§ 1201–1328 (2000).

<sup>68</sup> Federal Land Policy and Management Act of 1976, 43 U.S.C. §§ 1701–1785 (2000).

<sup>69</sup> Toxic Substances Control Act, 15 U.S.C. §§ 2601–2692 (2000).

novice happy. She wants to keep the air sparkling, and what she finds are the PSD<sup>70</sup> requirements. She wants to save the whales, and all she gets is the MMPA.<sup>71</sup>

On the other hand, environmental science *is* interesting. The author once encountered a husband and wife who were both engaged in marine biology; their major study area was worms that lived in saltwater marsh muds. They had started with scuba diving and went from the beauties of the reef fish to mudworms. But after their studies, they were every bit as fascinated by mudworms. Similarly, one need only see the computer versions of geologic formations to get a glimpse of the aesthetic pull of geology as a scientific pursuit.

Policymakers need environmental scientists to talk about this aspect of their work—that is, about the aesthetic aspects of scientific research. Perhaps this could help to overcome the structural reasons for the inattentiveness to environmental issues mentioned above. Section 404 of the Clean Water Act concerns wetland regulations, but taken alone it will never get many people interested in wetlands; most people would have to be interested in wetlands already before they tried to fathom section 404. Indeed, all other things being equal, those most likely to look at section 404 might well be the property owners most fearful of the legislation and least inclined to appreciate the wetlands it protects. But the guts of a mudworm might bring some interest to wetlands protection, even among affected property owners, and so might the way that a freshwater mussel opens and closes. Knowing something about those natural phenomena might get a person to read section 404 with real interest and a positive attitude. The Kyoto Protocols alone will not get anyone interested in climate change, but news of a glacier melt might. It is the scientists who are often the first to know about matters of this sort and to have access to an aesthetic and dramatic appreciation that can help make people interested in policy. Those on the policy side need scientists to open the eyes of the world to this information, so that section 404 and the Kyoto Protocols have a chance.

## VI. CONCLUSION

What, then, does a mature environmental law need from science? This Article has argued that most centrally, a mature environmental law is likely to take greater account of the relationships between controls and overall quality; but to address quality concerns, the law especially needs help with measurement and modeling. Understood broadly, this includes measurement of small and diffuse resource changes, interactions, and synergies. The history of our own environmental law also teaches that in shifting back to quality concerns, more mature regulatory systems need to become more flexible and more attentive to costs and benefits. But those goals cannot be reached without

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<sup>70</sup> 42 U.S.C. §§ 7470–7492 (2000) (describing requirements for “prevention of significant deterioration” in air quality).

<sup>71</sup> Marine Mammal Protection Act, 16 U.S.C. §§ 1361–1421 (2000).

measurement and modeling of the resource uses, and of the effectiveness *vel non* of more flexible devices.

Secondarily, a mature environmental law faces even greater uncertainties as the problems it addresses become less tractable. For this reason, a mature environmental law needs tolerance from science. This is because, more than ever, policymakers cannot wait until scientific evidence is conclusive; instead, they often have to make up their minds while the data is still tentative. Here, the appropriate criteria to judge policymaking are not just attentiveness to scientific findings, and certainly not accord with some dreamed-for and settled “good science,” but rather fairness, openmindedness, and transparency—all of which, after all, are scientific values in themselves.

Finally, a mature environmental law necessarily becomes complicated, not to say impenetrable. This brings us to a somewhat more subtle way that science can help environmental law, especially as environmental law matures: science can engage the interest of ordinary citizens, bringing us to see the beauty and aesthetic pleasure in the whole intertwining knot of our ecological surroundings.