Science and environmental policy—making them compatible

by Richard V. Pouyat

During the Second World War and the initial post-war years, the physical sciences were the most influential of the sciences in shaping public policy in the United States. In the last 40 years, however, the biological sciences have come to surpass the physical sciences in influencing public policy. Rachel Carson's landmark book, *Silent Spring*, and mounting public concerns over the quality of the environment have promoted an increasing reliance on the biological sciences to uncover and solve environmental problems. Indeed, most of these problems were uncovered through the research of biologists. Solutions, however, have not been forthcoming, have confused the public, or have for various reasons been ignored in the political process (Herrick and Jamieson 1995, Wilson and Anderson 1997, Dietz and Stern 1998).

If the biological sciences are seen as incapable of solving problems, they will lose public and political support. Moreover, if biologists are unable or unwilling to attempt to integrate their science into the political process, nonscientific criteria will inevitably prevail in the making of environmental policy (Herrick and Jamieson 1995). At the extreme, it is conceivable that society would turn exclusively to the legal or regulatory arena to provide solutions to environmental problems.

If the biological sciences are to continue enjoying the support of the public and politicians alike, biologists must attempt to understand the difficulties inherent in integrating science with public policy making. My goal in this article is to identify and discuss the most challenging barriers separating science (in particular, ecology and related biological sciences) and public policy. I begin by presenting a brief historical context, one that spans the last 40 years, from which most existing federal environmental policy statutes arise. I then discuss the difficulties of integration. Finally, I conclude by proposing actions that ecologists and biologists can undertake to effectively integrate science with public policy. I developed these views based on experiences gained from a Congressional Science Fellowship that was coordinated by the American Association for the Advancement of Science (AAAS) and cosponsored by the American Institute of Biological Sciences (AIBS), the Ecological Society of America (ESA), and the Society for Conservation Biology (SCB).

Historical context

The biological sciences have done an admirable job of discovering environmental problems. These discoveries are often made well before the public, or even the environmental community, becomes aware of them (see Pace and Groffman [1998] for case studies in ecosystem science). Over the last 40 years, such environmental problems as the bioconcentration of toxins in food chains, the causes and consequences of eutrophication, the effects of acid deposition, and the links between human health and exposure to toxins were brought to the public's attention by the biological research community. In each case, the environmental community relied on science to effectively sway public opinion.

Beginning in the 1970s, the environmental movement led to the enactment, and later reauthorization, of the Clean Water and Clean Air Acts, the Endangered Species Act, the National Environmental Policy Act, and the Resource Conservation and Recovery Act, among other legislation. These statutes were political responses to what was known scientifically at that time about the causes and consequences of pollution. Certainly, industrial groups voiced their opposition to these statutes; however, business interests were not prepared to deal effectively with the science underlying these issues. Instead, they continued to employ the tried-and-true methods of political influence that had worked for them in the past.

In the early 1970s, the environmental community's efforts to influence the political process were made simpler because many environmental problems had become readily apparent to the public. Black smoke belching out of smoke stacks, green slime on lakes that were once blue, rivers catching fire—given such stark evidence of environmental degradation, the public readily accepted the connection between pollution and air and water quality. In reality, however, at that time there was much less data available linking pollution with health problems. For example, in 1970, when the Clean Air Act was enacted, and in 1977, when it was reauthorized, only a handful of studies were available from which to generate the National Ambient Air Quality Standards (NAAQS), compared to the hundreds now available to policymakers.

Today's environmental problems are somewhat less obvious to the public even as they are potentially more damaging; for example, it is difficult to visualize acid deposition. The subtlety of today's environmental problems has forced policymakers to rely even more than before on the scientific community for assessments and solutions. Moreover, both regulated industries and the environmental community have altered their approaches to influencing policy decisions by hiring scientists and

funding environmental research themselves. This increased sophistication by special interest groups has resulted in greater controversy over the interpretation and significance of published research findings. Whether this increased participation by special interest groups is viewed as a good thing depends in large measure on one's political opinions of the environmental issues at hand. In any case, the evolution of the political arena since the 1970s has increased the importance of active participation by the biological science community in the public policy process.

Who's to blame?

It is not just the politicians or special interest groups who have caused a disjunct between the biological sciences and environmental policy. Many biologists have felt frustrated by a political process that seems too inaccessible, politicians who seem too ignorant, environmentalists who seem too emotional, and industrialists who seem too interested in profit to integrate science into environmental policy. Indeed, many biologists think that the scientific community has done its job admirably: We publish in peer-reviewed journals, we teach undergraduate and graduate students, and we are advancing scientific knowledge at unprecedented rates. But, after working with policymakers and environmental and industrial groups, I have realized that they too are frustrated. I often heard criticisms that scientists were too removed from the "real world" of politics. Perhaps more important, I heard complaints about scientists' failure to provide solutions to environmental problems even after years of funding by the federal government.

Difficulties of integration

Based on my experience as a Congressional Science Fellow, I have identified seven problem areas relating to the integration of ecology and related biological sciences with policy. Although these problems are discussed primarily in the context of the federal government, many of them exist for the integration of science at all levels of government. This list is by no means complete, and readers may well have other problem areas to add to it.

Unrealistic expectations. In political debates about environmental policy, policymakers often have unrealistic expectations of science. Herrick and Jamieson (1995) propose that these expectations go so far as to make politicians believe science to be uniquely suited to identifying the "truth" and, furthermore, that these truths are value free and universal. Moreover, politicians believe that good science can always provide a "right" answer for environmental policy disputes.

However, the problem is not so much what politicians believe about science, but more what they hope to receive from science—the truth. If science provides the "truth," then politicians will not be relegated to finding the truth themselves—a perfectly reasonable desire. It is also understandable that policymakers expect science to provide the right answer to a policy-based environmental question. Scientists quantify phenomena, and what policymakers desire is a "bright line" from which to base their policy decisions.

Science, however, is not entirely value free, nor does it identify truth. Science is a human construct that is influenced by personal biases even though it attempts to minimize them. Furthermore, for most biological and ecological phenomena of interest to policymakers, the quest for the bright line may be unattainable or the data unavailable. For example, the Clean Air Act requires the Environmental Protection Agency (EPA) to establish air quality standards to protect all segments of the US population. Research on the human health effects of ozone, however, suggest that there is no bright line on which to base an exposure standard for ozone because the relationship between human lung performance and ozone concentration is essentially linear, with a y-intercept at background concentrations. In other words, some individuals exhibit sensitivity to background levels of ozone. Consequently, setting an ozone standard is strictly a policy decision (i.e., whose health gets protected and whose does not). At the time the Clean Air Act was written, policymakers assumed that the human response to ozone and other air pollutants would exhibit a threshold effect—a linear effect was not anticipated.

The ozone example is a case in which science "discovered" an environmental problem—that is, that ozone adversely affects human health—but was unable to address the question, "at what level is public health protected entirely?" and thus save policymakers from having to make a possibly unpopular policy decision. Moreover, from a scientific viewpoint, it was naïve for policymakers to assume a priori that there was a threshold level for the effects of air pollution on human health.

Scientific vs. political uncertainty. The basic nature of science is that there will always be uncertainty. Science does not discover "truth"; it brings us closer to truth by attempting to falsify hypotheses—a process of elimination that reveals which possible answers are wrong. As an ecologist recently explained, "we [scientists] disprove things, while lawyers prove things" (Ivan Valiela, Boston University Marine Program, personal communication).

Policymakers deal with uncertainty using a different set of rules than those with which scientists are familiar. Whereas scientists are accustomed to using a 5% rejection level for either accepting or rejecting a null hypothesis, politicians may be just as comfortable working with a much lower degree of certainty and are often satisfied with a better-than-even chance. The general public may similarly be willing to make decisions when a high degree of uncertainty exists. These include, for example, the purchasing of life insurance and investing in retirement plans (Weathers and Lovett 1998).

Whatever a scientist's approach to dealing with uncertainty, the challenge occurs when scientists are forced to make decisions that go beyond the statistical outcomes of their research results, as is often the case in the making of public policy. Herrick and Jamieson (1995) suggest that when science is "hitched" to policy decision-making, its claims to being an objective, value-free in-

vestigative process are eroded. In other words, once scientists are forced to choose among interpretations ranging beyond their data, their decisions become explicitly value laden, which makes most scientists exceedingly uncomfortable. Adding to ecologists' burden of dealing with the contrasting scientific and political approaches to uncertainty is the inherent complexity of ecological systems. Ecological systems are greatly affected by chance events, thereby adding uncertainty to predictions based on empirical results.

Reaching scientific consensus. Policymakers often turn to the scientific community for consensus when making policy decisions. To reach consensus within the biological sciences, however, three inherent barriers must be surmounted.

First, scientists are trained to question the data and interpretations of other scientists through the peer-review process. This training, however, can hinder the reaching of consensus. Second, biological disciplines or approaches to investigating a question or problem can be in competition. These differences can lead to differing interpretations of the same phenomena. For example, the team of science advisors who evaluated the proposed NAAQS had divergent opinions on whether there was a need to change the standards. Toxicologists, who work with controlled laboratory and field experiments, were at odds with epidemiologists, who work with large databases and rely on statistical associations to determine the effects of pollution on human health (Wilson and Anderson 1997). These differing opinions between disciplines added greatly to the controversy of whether or not EPA should promulgate the standards.

Third, it is common to find inconsistencies between empirical results and results modeled across ecological systems and through time, in part because of the stochasticity of ecological systems. Moreover, models that are used to depict ecological systems often vary in their sensitivity to parameter modifications and are often developed using differing assumptions of how nature works.

These difficulties in reaching consensus on any particular scientific or environmental issue result in a range of scientific opinion, whose distribution, I believe, will often approximate a bell-shaped curve. That is, although scientists vary in their interpretations of the data, they generally agree on the body of theory from which they interpret their research results. The bell-shaped distribution is significant because science is usually called on to evaluate the weight of evidence concerning an environmental issue. Ideally, the range that encompasses the majority of scientific opinion would be the range of opinion weighted the most heavily in the policymaking process. Unfortunately, this process can be hampered by the media's tendency to amplify the most divergent opinions in an effort to produce an "objective" story. This amplification leads to the mistaken belief among the public and policymakers that there is no general scientific consensus on an issue and, often, to a legislative stalemate or a total disregard of the scientific evidence.

Other issues related to achieving scientific consensus need to be addressed by the scientific community. For example, who or what group decides the nature of the consensus process? Who gets included in the process? Who decides what issues require consensus?

Differing time scales. The political and scientific processes operate at different time scales. At the federal level, politicians work at 2-year (House of Representatives), 4-year (President), and 6-year (Senate) cycles, whereas the biological sciences work at various, and often much longer, time scales depending on the organism or process being investigated.

This disjunct in timing can cause frustration for both policymakers and scientists. A case in point is the National Atmospheric and Precipitation Assessment Program (NAPAP), a 10-year program that was established in the 1980s to investigate the effects of acid deposition on human-made structures and ecological systems. Much has been said about the successes and failures of NAPAP (see Likens 1992, Weathers and Lovett 1998); however, most scientists agreed that it was not realistic to expect science to solve the acid deposition issue within a 10-year period (from a political perspective, a long time span). Indeed, this expectation by policymakers was particularly unrealistic, given the paucity of long-term ecological data at the time of NAPAP's establishment (Pouyat and McGlinch 1998).

In addition, although science tends to advance slowly when compared to political cycles, there are periods when major paradigm shifts may occur. Wilson and Anderson (1997) suggest that when science changes rapidly, even reversing previously held beliefs (e.g., the existence of threshold effects for carcinogens in humans), environmental legislation has difficulty adapting at the same rate. Acid deposition legislation is another example of a situation in which an existing legislative solution (Clean Air Act Amendments of 1990) was recognized as inadequate in light of later scientific evidence (Pouyat and McGlinch 1998). In other words, once a legislative solution appears at hand for a particular environmental problem, policymakers will concentrate on other legislative needs, with the assumption that the problem has been fixed (at least for the time frame of the political cycle). Moreover, it is politically difficult to take into account new scientific advances or understanding after years of negotiating a legislative compromise.

Uniqueness of ecological systems. All assemblages of plants and animals are unique at some scale, which makes it difficult to develop environmental regulations across ecological systems. However, the foundation of most federal environmental statutes is broad-based environmental regulations. The ecological sciences are not well suited to determining and adapting to one-size-fits-all political solutions, unlike the chemical and physical sciences, in which generalizations are more easily made across systems. It is important to remember that the physical sciences dominated public policy during and immediately after World War II, and the public and policymakers may therefore have unrealistic expectations of the ways in which the biological and ecological sciences can contribute to developing public policy. Indeed, ecology

may be more suited to make its mark at the local level, where intensive investigations can yield solutions to environmental problems on a case-by-case basis.

Cultural differences. A subtle but important difficulty of integration lies in the cultural differences between the political and scientific communities. For instance, when I began my Congressional Fellowship, I immediately purchased several suits because I was advised that on Capitol Hill (as in business) such attire is required if one wants to be taken seriously. Imagine, for example, a senator participating in an annual meeting of AIBS, ESA, or SCB—what would his or her impression be of the science given that most attendees wear shorts and sandals?

Another significant cultural difference lies in the training for the two professions. Advanced training in the sciences often necessitates asking narrowly focused questions or specializing in one area of study. Moreover, ecologists and some biologists tend to think in the long term, expecting that the systems under study will change over time. Biologists and ecologists are, therefore, generally open to new understanding and reevaluation of previous thought. Training in public policy, by contrast, encourages taking a broad view, with a great deal of effort put into determining what is best for the public in the short term. In other words, scientists are much more concerned with detail, whereas policymakers are concerned primarily with a more immediate "bottom line."

Professional conduct also differs and sometimes clashes between the two professions. Congressional staffers are generally young (in their 20s) and, although bright, usually have limited scientific training. Nevertheless, it is these young staffers who usually communicate with individual, probably older and well-known scientists. My own experience working in Congress showed me that this situation can be frustrating for both the scientist and the staffer. For one thing, it is common for staffers to not return phone calls, which for a well-established and busy scientist can be frustrating. Likewise, Congressional staffers often feel frustrated when they try to untangle a web of scientific jargon.

Although these cultural differences may appear to be overstated, I found that it takes personal interactions and relationships to effectively transfer information and knowledge in the political arena. If scientists avoid these interactions because of cultural differences, then they cannot expect policymakers to readily heed their advice.

Perceptions of biology and ecology. One of the most serious difficulties of integration is the way in which policymakers perceive biology, in particular ecology. Policymakers often confuse ecologists and environmentalists (see definitions by Likens 1992), which is not surprising because it is the environmental community and regulated industry, not the scientific community, that has often "interpreted" biological and ecological research for the public and policymakers. But special interest groups have incentive to selectively present facts that are consistent with their political agendas (Herrick and Jamieson 1995), and policymakers sometimes confuse the advocacy message for the science.

This confusion came home to me during my fellowship when my colleagues first referred to me, albeit with good humor and affection, as a "tree hugger." Later, the realization became more significant—not one biologist or ecologist was asked to testify in a Senate Environment and Public Works Committee hearing on proposed legislation to reform the Endangered Species Act. The reason, a committee staff member told me, was that biologists and ecologists have a political agenda and there was no need to hear their views because the Committee already had testimony from several environmental groups.

The fault here does not lie with the environmental community or the regulated industry, neither of whom should be criticized for their attempts to use science to advocate their position. But if biologists and ecologists wish to be taken seriously in the policymaking process, they must work at being viewed as members of the scientific community rather than as part of the advocacy community. This goal will be achieved only if biologists and ecologists make an effort to interpret and translate their own research results for policymakers and the public.

What can be done?

Despite these difficulties, the biological sciences can influence environmental policy for the better and have indeed done so. However, more effective integration is achievable, and with this integration the public will get the most value from its investment in biological research. This return would be manifested in more scientifically based policy actions that are made with clear goals, are implemented efficiently, and achieve the desired policy result.

The need for cultural change. To be more effective in influencing the policy process, biologists must be more involved in it. Such involvement, however, requires time and, ultimately, a reward system that recognizes contributions to public policy and environmental management and planning. The current tenure system does not reward scientists for these services. Moreover, biologists are not trained to interact with politicians, managers, planners, or the media. In fact, many, if not most, established scientists and academic administrators still maintain that young scientists in tenure-track positions should be building their research programs rather than involving themselves with "public service." Indeed, not only has working with the public been discouraged by the academic community, but it has often been viewed negatively in tenure evaluations or in the granting of scientific awards.

Part of the problem is that there is no recognized process by which to evaluate public service. Contributions to science, such as the number of publications and the amount of grant money received, are more easily quantified. What is needed for public service to be recognized in the sciences is a model for evaluating these services. Such a model would help tenure and award committees more comfortably accept public service as they evaluate an individual scientist for tenure and promotion. Moreover, if graduate students had

more public-service training, they would bring to biology more familiarity with public service as they move into academic positions and subsequently into positions on tenure and award committees.

Finally, encouraging the participation of biologists in public service would not only help to integrate biology with public policy but actually help biology to advance. For example, Weathers and Lovett (1998) argue that public policy and science, rather than being antagonistic, were actually synergistic in dealing with the problem of acid deposition. Certainly there were difficulties with the process, as I have already mentioned; however, Weathers and Lovett (1998) suggest that the policy debates and ensuing funding for acid deposition research increased the understanding of ecosystem functioning in unexpected ways. My point is that, although investigator-generated questions are important for advancing science, problem-initiated questions can advance science just as well and perhaps in ways that would not have been possible with basic research alone.

The need to build consensus. Perhaps the most important action biologists can take in the movement toward integration is to build consensus around emerging environmental policy issues. Obviously, consensus building takes time and energy, adding to the already heavy work load of most scientists. I propose, however, that just as professional societies (such as those sponsoring my Congressional Fellowship) have enhanced interaction among scientists, they can also enhance interactions between scientists and policymakers. And institutions such as the National Center for Ecological Analysis and Synthesis (NCEAS), which is funded by the National Science Foundation, facilitate integrative research in an effort to synthesize existing data and information. Consensus building should be included as an important function of professional scientific societies and other institutional structures, such as NCEAS.

To reach consensus, scientists must first synthesize the most current scientific knowledge available on a particular issue. It is important to remember, however, that consensus does not necessarily resolve all conflicting viewpoints; consensus allows room for participants to "agree to disagree" as well.

A laudable example of the importance of achieving scientific consensus is the series of reports by the Intergovernmental Panel on Climate Change (IPCC). These reports were the result of intensive discussions and review by the world's leading scientists, who were charged with identifying the potential global effects of increasing concentrations of greenhouse gases. Beginning with the first IPCC report, in 1988, each successive report has built on those previous by chronicling the scientific community's growing consensus about the global effects of greenhouse gases. The latest IPCC report has had a strong influence on members of Congress, who are trying to sort out the often-conflicting media reports on global environmental change.

The need to overcome uncertainty. Biologists and ecologists need to present the uncertainty of their results in ways that policymakers and the general public can understand. They must also keep in mind that policymakers are willing to accept a much higher degree of uncertainty then scientists are. Given the difficulties involved with uncertainty, the issue can be addressed in two ways. First, scientists need to develop both quantitative and qualitative descriptors of uncertainty that are easily understood by policymakers and the public. For example, in briefings to Congress on the issue of global environmental change, scientists who participated in the IPCC used a scale of 1 to 10 to explain the uncertainty associated with specific questions related to this issue. This approach allows scientists to avoid taking a stand on an issue, instead leaving the decision making to the policymakers. Other approaches to help convey scientific uncertainty to the public are to use risk assessment and likelihood principles.

Second, as mentioned before, when scientists are asked to make predictions that go beyond their data, they should explicitly articulate this fact. Gene Likens, of the Institute of Ecosystem Studies (personal communication) uses the metaphor of wearing different hats to indicate a scientist's value system when presenting an opinion to the public or policymakers. If scientists are interpreting their results within the bounds of their statistical procedures, then they are wearing their "scientist" hat, but if they are asked to predict beyond their data, then they should make it clear that this judgment was made while wearing their "citizen" hat. Of course, a scientist's judgment as a citizen should not be discounted; indeed, their judgment, although value laden, is based on a tremendous amount of knowledge and experience.

The need to educate ourselves and the public. When asked what is the most important task in integrating science with public policy, most scientists would answer, "to educate the public and policymakers better about science." Only a few would say that scientists themselves need to be educated in policy and communication skills. But in fact, the education "arrow" should point in all directions among scientists, policymakers, and the general public. Indeed, scientists should "seek first to understand, then to be understood" (Covey 1990).

To both educate and be educated, the biological community must become more engaged with policymakers and the general public. There are many ways to accomplish this task. First, AIBS, ESA, SCB, and other scientific societies should continue to sponsor Congressional Science Fellows and similar fellowships. A fellow's year on Capitol Hill should be followed by the opportunity to work as a staffer in the headquarters of these societies because the fellows have already established contacts in Congress. Second, scientists should be encouraged and supported to carry out some form of public service during their sabbaticals. By "public service," I include providing scientific input to local and federal policymakers, teaching at the grade-school or high-school level, and contributing to community revitalization efforts, such as increasing environmental awareness in inner-city neighbor-

hoods. Finally, graduate students should be trained in at least one communication skill, such as media relations, nontechnical science writing, or public speaking. A two-way education process will be an inevitable result of biologists interacting in various capacities with politicians, journalists, educators, and the general public.

The need to become involved at the local level. Perhaps the most convenient and comfortable way for the majority of biologists to participate in public service is by becoming personally involved with local environmental and other science policy issues. Local issues provide numerous opportunities to participate in stakeholder deliberations, provide technical advice to governmental and nongovernmental groups, and so on. Working locally in this capacity will help scientists to build and maintain the personal relationships that are necessary to gain the trust of the public and policymakers and, therefore, their willingness to use scientific information in their decision-making process. Moreover, in many cases biologists have collected data within the vicinity of the places they live or teach—it is these data that are the most appropriate for use in making local environmental policy decisions.

The need to develop institutional interfaces. Many of my proposals would require a large amount of time and energy from individual scientists—time and energy that can be costly for a young scientist trying to obtain tenure. One way to lessen the burden on individual scientists is to develop institutional interfaces between scientists, policymakers, and the media. In this way, the institution can "bridge" the cultural divide separating science and policy.

Many scientific societies are developing personal relationships with congressional members and their staff, setting the stage for the efficient transfer of scientific information to Congress. For example, ESA has a Public Affairs Committee and staff that sponsor visits by ecologists to congressional members, and AIBS is sponsoring "roundtable discussions" on emerging scientific issues. What is needed at a minimum is the establishment of institutional interfaces, and the continuance of the work being done by staff at both AIBS and ESA.

A final word

I do not mean to be too hard on biologists for not doing their part in engaging policymakers and the general public. We are all faced with balancing a personal life with the multiple and often stressful demands of academic life. But I am proposing that biologists cooperate as a community and share the responsibility of ensuring the effective transfer of scientific knowledge for the betterment of society. Biologists do not all have to be in the trenches on Capitol Hill or some state capital to transfer their knowledge. At the least, what is needed is for the biological community to accept, respect, and support the involvement of some scientists to effectively integrate science with public policy making.

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