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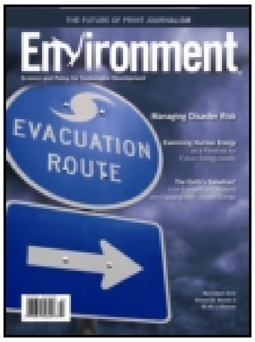

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Conditions for Sustainability Science

Baruch Fischhoff

As precursors of sustainability science, the three articles that comprise the "Our Hazardous Environment" series had several features that characterize the field.[1] One is that each article had contributors from multiple disciplines: geography, physics, psychology, geochemistry, and law. A second is that each article integrated knowledge of diverse types: theories, observations, principles, and preferences. A third is that each article bridged science and practice, seeking to satisfy the needs of both worlds. A fourth is that each article addressed the concerns of stakeholders with diverse, even conflicting, interests. A fifth is that each article was published in a peer-reviewed scientific journal, *Environment*. The conditions that allowed the work to have these unusual features are ones needed to nurture sustainability science:[2]

Collaboration. Multidisciplinary research requires scholars who recognize the limits to their own profession and the possibility of learning from others. Interdisciplinary research requires scholars who realize that those limits and possibilities are not properly understood until the knowledge of their own discipline has been integrated with that of others. That realization does not come easily to sciences dominated by a hegemonic theory (as with much economics) or focused on the experimental study of isolated factors in controlled settings (as with much psychology).

Significantly, each of the three articles is anchored by scholars from two inherently collaborative disciplines:


Tornado damage.

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geography and decision science. Operating across scales of time, space, social organization, and ecologies, geography has long sought to accommodate knowledge from diverse sources. Decision science characterizes problems in analytical terms that do not inherently privilege any concern, stakeholder, or kind of information. Absent such collaborative dispositions and methodologies, disciplinary pressures may overwhelm good intentions.

Integration. Each article adopts an analytical approach that seeks a balance between ambiguity and hyperprecision. On the one hand, each article defines terms clearly enough for others to verify any calculations and to identify the values embedded in its measures of cost, risk, or benefit, as well as in its selection of models or estimates—when those choices are known to favor particular interests. On the other hand, each article resists the temptation to reduce all valued outcomes to a common unit (e.g., net present economic value, quality-adjusted life years), so as not to obscure the trade-offs among those outcomes or neglect outcomes that are not readily quantified.

Thus, Harriss et al.[1] estimate the costs of natural and technological hazards separately, recognizing that different values and policies may pertain to each. They also estimate social costs and mortality separately, rather than trying to monetize human life. They use a broad measure of social cost, which includes losses to property and productivity, as well as investments in prevention and mitigation. They normalize each risk to national conditions (percent of GNP, percent of mortality), in order to treat developing and developed countries equitably. They note neglected items. Thus, the analyses emphasize computability over computation, in the sense that the elements of each analysis are specified clearly enough that one could "run the numbers" were the data requirements satisfied.[3] However, summary calculations are not required, lest they be dominated by factors that are readily quantified.

Science and practice. Practical concerns guide the science in each article, whether evaluating and improving the Consumer Products Safety Commission, identifying opportunities to interrupt accident sequences, or setting priorities for risk management. Commitment to that higher cause encouraged an engineering science approach, wherein participants recognize that

they need one another in order to make their science useful, just as structural engineers' expertise has little value in designing a bridge without material scientists' expertise to keep it from corroding away.

That faith is strengthened by the belief that science needs practice as much as the other way around. Alan Baddeley, when head of the Medical Research Council Applied Psychology Unit, argued that psychology's intellectual capital came, in large part, from two bridging enterprises.[4] Generalized to all disciplinary science, these enterprises are *applied basic* science and *basic applied* science. The former examines the ability of theories from basic science to predict events, or even to make predictions, in applied settings. The latter pursues basic science topics identified in those settings—rather than just topics that emerge endogenously from the science itself (e.g., when researchers pursue seeming anomalies in their data).

Diverse stakeholders. Any analysis embodies political and ethical judgments in its choice of outcomes to estimate, as well as in the units used to measure them.[5] As a result, an analysis can deliberately or unwittingly favor some stakeholders by choosing outcomes or measures that favor their cause. Each of the three articles seeks to reduce such bias by examining a wide range of outcomes, including those valued by diverse stakeholders. By leaving estimates in their natural units (e.g., deaths, lost species), the analyses do not prejudge the trade-offs among them.

Each article also seeks to increase the transparency of its analyses by translating them into terms meaningful to *Environment*'s broad readership. That translation includes using diagrams designed (implicitly) to fulfill the conditions proposed by Larkin and Simon for being worth ten thousand words: facilitating the three functions of search, recognition, and inference.[6] In the context of hazard management, *search* is locating relevant factors in the complex processes creating and controlling hazards; *recognition* is identifying options for manipulating those factors; *inference* is predicting the effects of those manipulations on valued outcomes.

Peer review. One vital difference between science and consultancy (or punditry) is its insistence on peer review. Scientists need the support of their disciplinary peers to ensure that their claims are consistent with the evidentiary record and properly qualified in terms of their strength and generalizability. However, that quality control can come at the price of a kind of mind control, if satisfying their colleagues makes authors more loyal to the discipline than to the problem. Such loyalty might encourage authors to elide limits to their science, fearing that the admission would undermine its influence and break faith with their colleagues. Thus, experimentalists

Pollution in the Tinto River in Huelva, Spain.

A man wears protection while spraying crops with pesticides.

may hesitate to acknowledge that they create conditions that exaggerate the effects of factors that interest them, so as to see better how they work. Computational modelers may hesitate to acknowledge that they omit factors that are not readily quantified.

Environment has long provided a home for authors willing to reach across disciplines and connect science and practice. In fulfilling its duty to them, the journal has recruited and trusted reviewers and editors able to exercise the professional judgment needed to help authors accomplish those tasks. As such, it is the rare journal seeking wisdom, as well as accuracy and innovation.

Creating These Conditions

Scientists who share these predispositions still need places to work. Although the authors of these articles had disciplinary training, none wrote from

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Genetically modified seeds.

a disciplinary department. Rather, they were in innovative programs at Clark University (including its renowned Graduate School of Geography), federal government offices (Commerce, NASA), and an independent research institute (Decision Research). Their funding came from a National Science Foundation program that supported scientists whose commitment to applied problems drew them outside their disciplinary folds, both to work together and to maintain the sustained relationships needed to understand stakeholders' problems and perspectives.

Such boundary organizations are unstable.[7] They need to overcome the centripetal forces that keep institutions circling around their traditional pursuits. They need funders and researchers willing to take these gambles. Those conditions are perhaps most likely to be met when impelled by the urgency of a problem. The Medical Research Council Applied Psychology Unit arose from its invaluable service during World War II. Yet, after a half century of working on a broad suite of problems, it was replaced by a unit with a more focused, conventional mission.[8] The American Soldier Project, also prompted by the war effort, transformed American social science, and then was closed.[9]

However frustrating, these struggles for survival may be productive, if they attract people committed to cause over career (while recognizing that they do still need to make a living). Although sustainability issues are with us for the duration, their identify will change—and, with it, the skills needed to address them. As a result, the health of sustainability science may depend on its ability to recruit new people from traditional disciplines for applied basic research projects—and then return them to their home disciplines with exciting basic applied research ideas, thereby convincing their colleagues that such excursions are good for science, as well as for the world.

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NOTES

1. The three articles referred to are: T. Bick and R. E. Kasperson, "Pitfalls of Hazard Management," *Environment*, 20, no. 8 (1978): 30–42; B. Fischhoff, C. Hohenemser, R. E. Kasperson, and R. W. Kates, "Handling Hazards," *Environment* 20, no. 7 (1978): 16–20, 32–37; and R. C. Harriss, C. Hohensemser, and R. W. Kates, "Our Hazardous Environment," *Environment* 20, no. 7 (1978): 6–15, 38–41.

2. These issues also arise in two later articles in this series: B. Fischhoff, P. Slovic, and S. Lichtenstein, "Weighing the Risks," *Environment* 21, no. 5 (1979): 17–20, 32–38; and P. Slovic, B. Fischhoff, and S. Lichtenstein, "Rating the Risks," *Environment* 21, no. 4 (1979): 14–20, 36–39.

3. B. Fischhoff, W. Bruine de Bruin, U. Guvenc, D. Caruso, and L. Brilliant, "Analyzing Disaster Risks and Plans: An Avian Flu Example," *Journal of Risk and Uncertainty* 33, no. 1 (2006): 133–51.

4. A. D. Baddeley, "Applied Cognitive and Cognitive Applied Research," in L.-G. Nilsson, ed., *Perspectives on Memory Research* (Hillsdale, NJ: Lawrence Erlbaum Associates, 1979): 367-388.

5. B. Fischhoff, "The Realities of Risk-Cost-Benefit Analysis," *Science* 350, no. 6260 (2015): 527, http://dx.doi.org/10.1126/science.aaa6516; and B. Fischhoff and J. Kadvany, *Risk: A Very Short Introduction* (Oxford, UK: Oxford University Press, 2011).

6. J. H. Larkin and H. A. Simon, "Why a Diagram Is (Sometimes) Worth Ten Thousand Words," *Cognitive Science* 11, no. 1 (1987): 65–99.

7. J. Parker and B. Crona, "On Being All Things to All People: Boundary Organizations and the Contemporary University," *Social Studies of Science* 42, no. 2 (2012): 262–89.

8. http://www.mrc-cbu.cam.ac.uk/history (accessed October 16, 2015).

9. P. F. Lazarsfeld, "The American Soldier—An Expository Essay," *Public Opinion Quarterly* 13, no. 3 (1949): 377–404.