Critical Challenges for Sustainability Science

KATES *ET AL.* ADVOCATE THE DEVELOPMENT of a new "sustainability science" ("Sustainability science," *Science*'s Compass, Policy Forum, 27 Apr. 2001, p. 641). As world development moves in unsustainable directions, it is indeed timely to expand the structure and focus of the scientific enterprise to effectively address emerging questions. The urgency for a transition to sustainability and the associated need for new directions in science had earlier been stressed by the Board on Sustainable Development of the U.S. National Academy of Sciences (*1*). However, although the proposed core research questions of sustainability science are apt, they are insufficient.

Kates *et al.* list four methodological challenges: (i) spanning the range of spatial scales; (ii) accounting for temporal inertia and urgency; (iii) dealing with functional complexity and multiple stresses on human and environmental systems; and (iv) recognizing the wide range of outlooks. We would expand this list of challenges to include (v) linking themes and issues (e.g., poverty, ecosystem functions, and climate); (vi) understanding and reflecting deep uncertainty; (vii) accounting for human choice and behavior; (viii) incorporating surprise, critical thresholds, and abrupt change; (ix) effectively combining qualitative and quantitative analysis; and (x) linking with policy development and action through stakeholder participation.

Sustainability science will need to transcend the determinism and incremental responses to perturbation that still dominate much research on the dynamics of combined socio-ecological systems. The evolution of methods that can adequately and rigorously capture uncertainty, the capacity for system discontinuity, and the normative content of sustainability problems defines a rich and urgent research agenda. In this regard, participatory scenario development offers one approach for systematically addressing many of the core challenges identified above. This method has been used in various contexts, such as the work of the Global Scenario Group (*2*), which has been used for UNEP's Global Environmental Outlook (*3*), and the work of the Intergovernmental Panel on Climate Change (*4*), and at a regional scale in the Georgia Basin Futures project (*5*). Such exercises have proven successful in bridging gaps between science and policy by engaging a wide range of experts and stakeholders in a systematic exploration of diverse global futures.

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Response

WE THANK SWART *ET AL.* FOR THEIR INTEREST in elaborating on the scientific core questions of sustainability science and the challenge of

appropriate methods and approaches. We agree with many of their arguments and, indeed, addressed several of them as substantive (rather than methodological) challenges in our Policy Forum. More importantly, however, the meeting reported in our Policy Forum catalyzed a process of consultations on science, technology, and sustainability that, over the past year, has engaged more than 300 scientists and technologists from more than 40 countries in locally organized workshops on every continent except Antarctica. These consultations have reviewed the relevance of the core questions and challenges posed in our Policy Forum to the most urgent sustainability problems of specific regions. A synthesis workshop, organized in collaboration with the International Council for Science (ICSU) and the Third World Academy of Sciences in May, sought to integrate these regional perspectives and identify priority measures for harnessing science and technology in support of sustainability. The report of that meeting has been taken forward by ICSU as a contribution to the World Summit on Sustainable Development.

Results of this continuing process of revision and elaboration can be found on the Forum on Science and Technology for Sustainability at sustainabilityscience.org. Each of the core questions initially raised in our Policy Forum now has a separate Web page with introductory essays, commentary, links, and resources. Emerging thinking on a number of related issues, including several of those raised by Swart *et al.*, is also addressed. Finally, the Forum supports a growing network of scientists and technologists interested in specific questions of science, technology, and sustainability.

We invite all *Science* readers to peruse these discussions on the Forum, join the network, comment on any or all of the many papers and documents posted, and further the development of the virtual community of sustainability science and technology.

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Does the Sun Know What Day It Is?

I WAS AMUSED BY THE RANDOM SAMPLES item "Sun burp" (12 July, p. 189), in which it is stated, "The sun jumped the gun on Independence Day fireworks, belching out a massive curling cloud of flaming gas more than 30 times Earth's diameter on 1 July." Do you have some unreported evidence that the sun is American? Many countries celebrate their national day with fireworks, and several do so on July 1, including your neighbor to the north. Perhaps the sun is really Canadian, eh?

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Making a Case for Conservation

I THINK IT'S IMPORTANT WHEN SCIENTISTS with the credentials of *Science*'s Editor-in-Chief Donald Kennedy make an effort to portray scientific evidence in terms the public can understand, as he did in his recent Editorial "POTUS and the fish" (26 July, p. 477) about President Bush and daughter Jenna's striped bass capture during a Maine vacation this summer.

I have absolutely no quarrel with Kennedy's comments regarding the extension of species' ranges as a result of climatic change, but I'm not sure the striped bass incident he cites is a case in point. *Morone saxatilis* is a broadly distributed species. Old ichthyology texts list its range from Louisiana in the Gulf of Mexico up to the New Brunswick coast of Canada—well within the area of the Bush expedition. In the 1950s, I worked as a mate on a charter boat that fished in huge schools of stripers in Cape Cod (now Massachusetts) Bay, north of the Cape. By the time I began doing research at the Marine Biological Laboratory in Woods Hole in the late 1960s, not only were stripers in decline north of Cape Cod, as Kennedy indicates, but by the late 1980s, only the old salts were able to catch stripers south of the Cape, and then not reliably. The North Atlantic population of *M. saxatilis*, most of which originates in the Chesapeake and Delaware Bays, had entered a period of steep decline. There were few striped bass anywhere along the Atlantic coast, outside of hatcheries.

President Bush and daughter Jenna catching a striped bass in Maine this summer.

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While I'm not sure if the problem causing the decline was actually ever identified—there were the usual handwringings and accusations of pollution versus overfishing (both likely to blame)—in 1981, a massive striped bass conservation effort was undertaken by the Atlantic States Marine Fisheries Commis-