

Interdisciplinary research for managing ecosystem services

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Like all good assessments, the Millennium Ecosystem Assessment (MA) provided a state-of-the-art summary of relevant knowledge, in this case, of the state and trends of the world's ecosystems. The MA went further by developing a novel framework for analyzing the fundamental relationship between the well-being of human societies and the ecosystem services on which we depend (1). In this issue of PNAS Carpenter *et al.* (2) build on the innovative nature of the MA even further by proposing an impressive research agenda that challenges a very broad range of disciplines to build a new type of knowledge base oriented around social-ecological systems and the services they derive from the ecosystems in which they are embedded.

By focusing on the concept of ecosystem services and their ongoing provision, Carpenter *et al.* (2) immediately focus a wide array of disciplines on common problems that require integration and, furthermore, effectively bridge the divide between research and management. Thus, of the many exciting research challenges that they outline, one of the most important, and one that is not implemented often enough, is to learn from existing management programs. Although much can be gained by a post facto analysis of the success or failure of various projects aimed at improving management, a related, complementary approach is to embed research and its evaluation as an interactive part of the policy and management process from its initiation (3, 4).

Fig. 1 illustrates one type of adaptive management approach. The critical feature is the continuous loop involving experiments specifically designed to inform policy and management, the implementation of new or modified policy and management tools and measures based on the experiments, and the periodic monitoring and evaluation of the success, or not, of the new or modified approaches. The process triggers questions about whether we understand enough about the dynamics of the social-ecological system that we are trying to manage or about the types of socioeconomic instruments that could deliver desired outcomes. These questions, in turn, drive research in the relevant disciplinary areas of expertise.

The processes are challenging, and perhaps even confronting, to both the research and policy/management com-

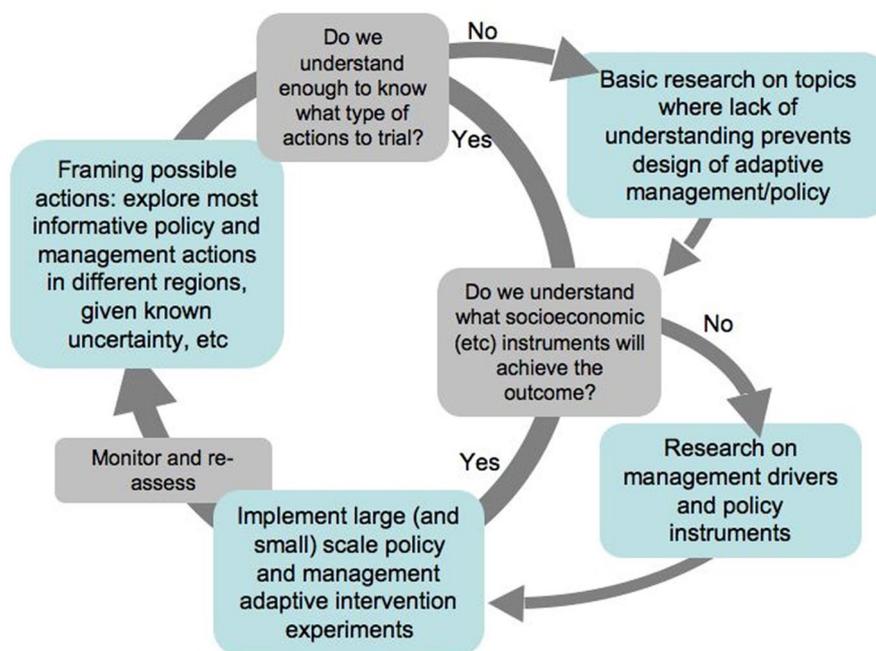


Fig. 1. A visual representation of adaptive management, an iterative approach built around explicit, experimentally-based development of plausible management options [image courtesy of M. Stafford Smith (Commonwealth Scientific and Industrial Research Organization, Sustainable Ecosystems, Canberra, Australia) (5)].

munities. For the former, the questions invariably drive interdisciplinary research that frequently involves stakeholders in the design and evaluation of the work, features that often push researchers out of their comfort zones. For the policy and management communities, trying new approaches to on-ground management with no guarantee of success can be threatening to risk-averse people who have a (perhaps well justified) fear of failure. Failure, however, is only truly failure if we do not learn from the experience (6), a perception that will require a change of attitude for many in the public and the media.

An adaptive management approach is particularly relevant to the challenge of developing a research agenda to support the flow of ecosystem services to enhance human well-being. For example, Carpenter *et al.* (2) have highlighted several areas where basic research is required on the dynamics of social-ecological systems: nonlinear and abrupt changes, the links between ecosystem structure and functioning and the provision of ecosystem services, and the role of biodiversity in ecosystem functioning and the delivery of ecosystem services.

All of these topics demand a systems approach, which by nature is highly interdisciplinary. Without improved knowledge of the dynamics of social-ecological systems, it is almost impossible to design appropriate management tools or even the adaptive intervention experiments needed to inform policy and management.

Another of the more immediate research challenges highlighted by Carpenter *et al.* (2) is the need to quantify tradeoffs among ecosystem services. The issue has escalated in importance with proposals to use landscapes for climate mitigation (7); the potential competition between food production and biofuel production is a recent well-known example, but more subtle tradeoffs may arise with proposals to store more carbon in terrestrial ecosystems (an important ecosystem service), but with possible implications for biodiversity, recreation, food production, and water resources.

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