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Management and the Problem of Scale

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Gordon Baskerville's thoughtful piece makes a number of points, explicit and implicit, that must underlie any efforts at management. Ecological science, indeed, most often is focused only on one scale at a time, and the problem of relating phenomena on different scales is too rarely addressed. Efforts to predict responses of forests and grasslands to global change, for example, ultimately depend on understanding how individual plants respond to changing environments, but we do not understand well enough how to scale up from such information to the responses of ecosystems. The dynamics of marine ecosystems, as another example, emerge from the interactions among individuals and with their local environments, on scales of the order of the sizes of those individuals. I do not agree with Baskerville that the pressures of good science forbid work from being carried out at the relevant levels for management. The powerful decades of research by Bormann and Likens and their associates at Hubbard Brook, the elegant whole−lake manipulations of Schindler, and the classic studies of Paine in the intertidal all provide evidence of long−term studies carried out at the level of whole systems, and using the experimental method that is a necessary corollary of the importance of exploring far−from−equilibrium dynamics. Yet all of these investigators would agree that whole−system studies must be related to processes mediated at lower levels of integration, and that one of the greatest challenges for management is in relating dynamics across scales. The fishery manager need look no further than his or her own system, in which conflicts between actions and interactions at the level of individuals and consequences at the level of the whole fishery create paradoxes and challenges that have been acknowledged since the dawn of fisheries management. The "Tragedy of the Commons" is the eloquent caricature of this very situation.

It also follows from Baskerville's arguments that we must recognize that ecological and socioeconomic systems are highly nonlinear and dynamic, and hence, that path dependency is a fact of life. Buzz Holling properly, therefore, turned our attention to the notion of domains of attraction and resiliency, rather than simply to maintaining an equilibrium. However, one must be aware that resiliency is a synonym for resistance to change, and that path dependency may mean that state−dependent approaches that are too local in perspective may keep systems locked in suboptimal configurations. Managers, even if they recognize this fact of life, may be chary of shifting systems from one basin to another, since such shifts invariably must be accompanied by painful travels through even less desirable regions of dynamic space.

I agree with Baskerville that attention must be directed at understanding the processes underlying pattern, and that those mechanisms are more important than the details of pattern. Indeed, the search for exact prediction is an impossible and dangerous dream, because of the dynamic nature of systems and the unsurprising fact, again emphasized by Holling, that there always will be surprise. We must seek to learn what aspects of system dynamics are robust, what are the critical details at the mechanistic level that control domain shifts, and how to manage systems adaptively in the face of uncertainty. Levels of precision, realism, and generality are not mutually exclusive, as suggested by Baskerville. The assertion is not technically accurate, because levels are, after all, just levels. The essential point, made earlier by Levins, that there are trade−offs among these characteristics that limit the degree to which one can improve the three simultaneously, is valid and pungent. Lorenz showed years ago that exact prediction was impossible in models of the weather at certain scales, and that this characteristic, tied up with chaotic and other irregular fluctuations, was certain to hold for a wide range of complex, nonlinear systems. The lesson applies in spades in ecological systems, and increases the importance of our understanding exactly what is predictable and what is not. Ecologists have perhaps failed to make clear to managers the fundamental nature of this lesson and the implications for management. Ralph Gomory (1995) has recently emphasized the importance of this in a more general context, imploring us to distinguish between the known, the unknown, and the unknowable.

I part company somewhat with Baskerville on his initial premises, which, I argue, do not benefit from the arguments that he later develops. The explanation of our current environmental crises as due to a combination of poor models and/or poor attention to good models is, I fear, simplistic, or at least limited to a too narrow range of examples. When a set of narrowly defined objectives may be defined for a bounded system, these points may hold sway. Too often, however, the issue is one of the multiple uses to which any single system can be put, and of the interrelationships among systems. The goal of sustainability requires a balancing of intergenerational and intragenerational equity; an agreement of sorts concerning the valuation of any system, which requires, in particular, a better understanding of the ecosystem's services to humanity; and hence, some sense as to trade−offs and ways to discount the future. That is, managers too often have a limited view, focusing on one scale or one set of objectives without attention to the heterogeneity in objectives that characterizes the broader body of stakeholders. The manager's own powers are limited, and to varying degrees, management may imply achieving consensus (of sorts) among those stakeholders, who include the broader public, while achieving adequate representation of the underrepresented, especially including future generations. Addressing such conflicts raises much deeper issues regarding management than those already identified, and presents us with perhaps the greatest challenge for the future.

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Literature Cited

Gomory, R. E. 1995. The known, the unknown, and the unknowable. *Scientific American***272**(6):120.

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