



## Science and the Pursuit of a Sustainable World

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## SCIENCE AND THE PURSUIT OF A SUSTAINABLE WORLD<sup>1,2</sup>

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While it is true that overexploitation of biotic resources is common, it does not follow that greed and its "accomplice" science are equally culpable when management strategies lead to resource collapse or extinction. In their provocative article on conservation policy, Ludwig et al. (1993) argue that relying upon scientists to predict optimal levels of resource exploitation is likely to be a futile, if not a dangerous, process. In their view scientists rarely understand the dynamics of the simple ecological systems, even those with which they can experiment; they are unable to generalize from these systems to those of the "real world" where complexity precludes reductionism. Thus they cannot predict anything with confidence.

The desire to accumulate wealth may ultimately drive humans to overexploit resources. And scientists when faced with a complicated natural world may make contradictory and at times erroneous predictions about the functioning of ecological systems. This lack of consensus is not too surprising given that scientists are armed with a universal skepticism and caution on the one hand and a diversity of perspectives, values, and hence assumptions, on the other. Scientists may lack political clout, but to rely on scientists only to "recognize problems, but not to remedy them" (Ludwig et al. 1993: 36), is to cast scientists in the role of proverbial good little children that are there to be seen, but not to be heard. Is this the appropriate role for scientists to play? Is it true, as Ludwig et al. state, that only "once we free ourselves from the illusion that science or technology (if lavishly funded) can provide a solution to resource or conservation problems, appropriate action becomes possible" (1993:36)?

I contend that the answer to both questions is no, and that effective management can only take place when the best available scientific information is used to inform decision making. Effective policy, however, rarely comes from the "top down" even when based upon rigorous and complete optimality analyses because they are limited to one set of assumptions or one set of goals. As Ludwig et al. (1993) contend, human motivation should be incorporated explicitly into the decision-making process, and waiting for the perfect set of facts or for scientists in the abstract to reach consensus should be avoided. And of course uncertainty

should be incorporated into decision-making theory that considers a variety of plausible alternative management options. But even if these prescriptions are followed, using optimality modelling to find a sustainable solution to a problem is only as good as one ivory tower's or government ministry's understanding of both the biotic and human dimensions of the problem. And even if the assessments prove to be correct, it is unlikely that scientists will be empowered to implement the management directives as indicated by the models.

Perhaps a better approach is to encourage the best solution to emerge from a "bottom-up" process. Most resources are shared by a variety of stakeholders having differing motivations and differing views as to how the resources should be used to enhance their wealth. Information about key biological features of the resource can only help each stakeholder formulate the most effective strategy consistent with its values. By this approach the management plan that ultimately emerges as best will not be based upon any particular view of what constitutes the optimal hypothetical alternative. Because it will be negotiated by parties with conflicting perspectives, including those for and against managing the resource sustainability, it is likely to be a composite. Under either scenario model building, optimality analyses, and the simulating of alternatives will guide individuals when making policy decisions. Only in the latter case, however, is human motivation explicitly included and as a result there is the potential for finding a solution that all parties are likely to accept and uphold. In either the "omniscient modelling" or the "stakeholder trading" case science and the concept of sustainability play central roles in the decision-making process.

Sustainable development has different meanings for different people. Here I use the term in its broadest sense to mean that the abundance and the genotypic diversity of individual species comprising an ecosystem, as well as the species composition of the overall ecosystem itself, are not significantly reduced by human intervention. Ludwig et al. (1993) contend that claims of sustainability should be distrusted in part because the track record of fisheries seeking to maintain a maximum sustainable yield has been dismal. There will always be some intractable systems where either gathering scientific information, accounting for risk when developing policy, or enforcing sanctions will prove too difficult, thus hindering the sustainable use of a resource. Yet there is at least one "real world"

<sup>1</sup> Manuscript received 2 June 1993.

<sup>2</sup> For reprints of this Forum, see footnote 1, p. 545.

situation, African grasslands, where it should be possible to manage biotic resources in a sustainable fashion because enough is known about the biology of these systems and the conflicting economic needs of the ever increasing human populations inhabiting them. Problems of managing African wildlife in the past have been many, but they were the result of faulty policy or ineffective governmental control, not of faulty science. Scientists have long recognized the pressures that competing demands have placed on grasslands, and through their data-gathering efforts have encouraged multiuse development of these landscapes, in part as a means of limiting population growth and of improving the quality of life.

It is well known that Africa's grazing ungulates fall into two categories: those that occupy year-round home ranges and those that migrate over vast geographical areas. Wherever migrants occur they dominate the biomass and thus comprise the major biotic force affecting the habitat. Decades of study by McNaughton (1979, 1984, 1985, 1990), Belsky (1983, 1986, 1987, 1989), Sinclair (1979), and others have not only chronicled the pattern and timing of the movements of the massive herds of the Serengeti, but have identified many of the causes and consequences of these movements. In general, the timing, magnitude, and location of rainfall governs the movements of these large herbivores. Shortly after the rains begin ungulates move southward to the drier areas where plants contain the highest levels of minerals. They do so even though primary productivity is higher and water is more abundant elsewhere. After the rains cease the herds typically travel westward and then northward to the more mesic and productive areas. Environmental uncertainty, however, does alter this pattern, but in predictable ways. When rainfall is sporadic, or when it fails completely, movements are altered as males and nonlactating females move directly north to the dry season range, while females with young move to the transitional regions where forage contains high levels of essential nutrients.

The consequences of these movements are equally dramatic as high levels of productivity attract herds, stimulate consumption, which in turn enhance fecal deposition and hence nutrient recycling. As a result the energy and nutrient fluxes in the ecosystem are elevated by the presence and action of these roving ungulates. Moreover, the dynamics of both predators (Sinclair 1985) and parasites (Dobson and Carper 1992) that both thrive on and influence the birth and death processes of the ungulates are also well enough understood so that models of both the behavioral and population dynamics of the various species can be constructed.

It is from such models that the consequences of hypothetical management schemes for the Serengeti, as well as for more arid African grasslands or even temperate ones such as those in Yellowstone, could be explored. For example, thought experiments, such as what would happen if arable areas were to be denied

to herbivores but were made available to farmers, or what would happen if cattle herds were increased substantially, or what would happen if a certain percentage of particular wildlife species were harvested, could be performed. Yet even such simulations would only be informative if they were based on realistic models that incorporated fundamental ecological, behavioral, and life history principles.

Since these three "what if" scenarios are likely to be real concerns for three very different but competing interest groups, determining the best and most effective policy will depend on whether stakeholders with conflicting goals are allowed to negotiate a workable solution, or whether an omniscient consultant is called upon for an answer. If the former, then horticulturalists, pastoralists, ranchers, ecotourism operators, hunters, and government ministers must be brought into the process. If the latter, then as Ludwig et al. (1993) suggest, accounting for the differing perspectives of these groups must be incorporated into the models. In either case, without a detailed understanding of the biological processes both among species and across trophic levels it would be difficult to decide how cows, sheep, and goats, for example, compare to elephants, wildebeest, and zebras with respect to their traveling, harvesting, and fertilizing abilities. Only by knowing these equivalencies can the differential effects on the dynamics of the vegetation and hence the energy and nutrient fluxes of the entire ecosystem be measured. When armed with an understanding of these types of dynamics, making predictions becomes possible and the consequences of alternative management schemes can be compared. Large-scale experiments incorporating elements of realism can then be established and outcomes having some robustness can be monitored.

Keeping ecologists and their science in the loop, from start to finish, is the best way of insuring that all stakeholders, or omniscient consultants, have access to the best available information. In this way science can continually inform policy. But some environmental scientists will have to change their ways. First, calls for more funding across the board on the grounds that all ecological research somehow will improve our understanding of how to use resources sustainably overstates the case and puts all ecologists in a position where it will be difficult to deliver on such promises. Second, ecologists when directly addressing real world problems will have to build into their models safety factors that minimize either the risk of underestimating fluctuations in key factors or of omitting critical features pertaining to the human dimension. And third, if ecologists really want their scientific knowledge to be taken seriously and to be used in policy making, then ecologists will have to stay involved throughout the decision-making process, from the monitoring of experimental systems, to the revising of models, to the updating of assessments. By following these three principles ecologists can become integral participants, help-

ing pursue ways of managing resources in a sustainable fashion.

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## SUSTAINABILITY NEEDS MORE THAN BETTER SCIENCE<sup>1,2</sup>

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Two issues raised by Ludwig et al. (1993) regarding changes underway in the management of natural resources will have profound effects in all resource management fields. First is the concept of sustainable development and how it differs from the traditional scientific concept of sustained yield: it integrates biology, economics, and politics more directly than did sustained yield and it allows for goals and approaches to change over time. Vestiges of the sustained yield concept will, however, remain around for some time. Second is the role of science and scientists in the full process of resource management, including design, decision making, monitoring, and adaptation of policies, plans, and programs: the historic role of science as an outside observer and sometimes contributor without accountability for results is disappearing. But here also, we will continue to see scientists in traditional roles for some time.

The concepts of maximum sustained yield, and its mirror image, minimum viable population, are attractive to sectoral resource advocates, scientists, and policy makers because they offer the prospect of a scientifically valid solution to questions of (1) how much can be removed from a renewable resource without depleting the stock capital, or (2) what conditions of a

stock, i.e., amount and distribution, are necessary to approach a high likelihood that the stock will persist for an infinitely long time. Both maximum sustained yield and minimum viable population are useful general concepts and have certainly generated much scientific and policy activity over recent years. But both ideas fail in practical application for some of the reasons Ludwig et al. (1993) identify, such as uncertainty, fluctuating stocks, and lack of feedback information to managers. They also fail for some reasons Ludwig et al. do not identify, such as the complex dynamics of ecosystems that set the context for renewable natural resources and the complexity of values and uses that humans need or expect from other aspects of those ecosystems, some of which come into direct conflict.

Because population stocks of species that humans exploit as resources are integral to the structure, composition, and function of ecological systems, changes in species stocks as a result of exploitation can and often do affect changes in the rest of the ecosystem. These changes may alter other resource stocks or other human uses and values of these ecosystems. In extreme cases endangerment or extinction of species in ecosystems being exploited for other resources, such as the northern subspecies of Spotted Owl (*Strix occidentalis occidentalis*) in old forests of the Pacific Northwest being managed for timber values, can result from pursuing a policy based on sustained yield of a single re-

<sup>1</sup> Manuscript received 10 June 1993.

<sup>2</sup> For reprints of this Forum, see footnote 1, p. 545.