CHAPTER 1

Regaining Healthy Ecosystems: The Supreme Challenge of Our Age

David J. Rapport

RECOGNIZING THE CONCEPT

The first sign of progress toward any goal is recognition that the goal is worthy of the effort. A decade ago, applying the concept of health beyond the individual and population level was deemed foolhardy. Ecologists in particular were adamant that ecosystems were not organized as organisms. Thus the concept of health, which applied to individuals and, later, populations, was inappropriate for ecosystems. They were partly right; indeed, ecosystems are not organized in the same manner as organisms. Ecosystems are not superorganisms. Ecosystems do, however, have organization, structure, and function. They constitute another level above that of populations — but below that of landscapes and biomes — in the biological hierarchy from cells to the biosphere. Thus, ecologists were wrong to assume that, because ecosystems are not organized in the same manner as organisms, the concept of *health* had no application to this level.

Clearly the concept of health — which at root refers to the capacity of a system (whether biological, social, or mechanical) to perform normal functions — is not restricted to the hierarchical levels in which the particular systems operate. There are healthy and unhealthy cells, tissues, organs, organisms, populations, biotic communities, ecosystems, and landscapes. When it comes to the biosphere, that all-encompassing dimension of life, its state of health also depends on the degree to which its functions are unimpaired.

Today the notion of healthy ecosystems, if not yet mainstream, has more than a toehold in the public domain. Numerous programs within government agencies are targeting the health of ecosystems as a key priority. For example, in a national audit of Australia, ecosystem health is one of the focus areas. In the guidelines for a recently launched project of the National Round Table on the Environment and the Economy (Canada) on indicators of sustainability, ecosystem health indicators with respect to natural resource systems are specified in the design. Major projects in managing forests, estuaries, and lakes around the world now focus on the degree to which the essential functions of these ecosystems have become compromised and how they may be restored. And, while species at risk are still major drivers of public concern about the environment, that concern has widened to consider ecosystems at risk.

The goal of managing for healthy ecosystems recognizes explicitly the human component. No longer is it tenable to consider ecosystems isolated from humans. Of course it has been recognized for decades — even made explicit in the writings of Aldo Leopold in the 1940s — that human

1-56670-612-2/03/$0.00+$1.50

activity has compromised ecosystem functions. However, the connections between humans and ecosystems go much deeper. True, humans have compromised ecosystem functions; but it is also true that ecosystem degradation has compromised humans physiologically, socially, economically, culturally, and psychologically.

How could it be otherwise? We are part of ecosystems and fully dependent on the functions of these systems for our very lives. We rely on the food, water, and shelter they provide, on their value for spiritual healing, and on the cultural aspects, particularly in those societies in which whole cultures co-evolved in intimate association with particular ecosystems. Destroy those ecosystems, and inevitably the cultures are destroyed as well.

Clarification of the concept and the role of culture in defining the meaning of healthy ecosystems are central to a number of the themes within this volume. It is particularly prominent in the section on Emerging Concepts (Part I). In a practical vein the CALFED Bay–Delta Program is building a broad consensus among the stakeholders as to what constitutes a healthy environment, bringing together landowners, farmers, natural resource managers, nongovernment organizations (NGOs), and others. At root the issues are political: what steps can be taken to rehabilitate the Bay Delta without undermining the economy or the social/cultural values of the area?

In a more theoretical vein, the issues of ecosystem health, quality of life, and ecological integrity are the topics of Section I.4, Setting Goals and Objectives in Managing for Healthy Ecosystems. Questions arise as to the appropriate use of ecosystem health concepts in public policy, whether the use of the concept should be the basis for federal and land use management, and the degree to which the concept relates to sustainability.

DEVELOPING THE INDICATORS

Management requires information, and information requires both data and understanding. Recognition is increasing about the importance of maintaining ecosystem functions and the high costs to society if these are impaired or lost (in terms of human health vulnerabilities, access to safe food and water, and the ensuing risks of civil disobedience). This increased recognition has led to a growing concerted effort to report on the state of health of major ecosystems: forests, coastal marine systems, great lakes, prairies, etc. Such reporting requires a judicious choice of indicators (Rapport, 1992). Obviously, when major ecosystems such as the San Francisco Bay or Lake Tahoe have become radically transformed as a consequence of chronic cumulative stress from human activities, there will be inevitable changes in nearly all of their biophysical, socioeconomic, human health, and cultural dimensions. What are the most sensitive and meaningful parameters to measure as indicators of the entire process of transformation? To what degree can one validate the indicators as correlating with the larger system change? In other words, which are the most informative parameters to track? Which are the most reliable groups of indicators that provide an overview of changes in the state of the ecosystem over time? This is one of the major challenges within the ecological indicator field.

A framework for addressing this issue arises from the notion of an *ecosystem distress syndrome* (EDS) (Rapport et al., 1985). EDS comprises a group of signs commonly observed in ecosystems under stress, such as the loss of biodiversity, altered primary productivity, altered nutrient cycling, increased dominance of biotic communities by exotic (non-native) species, and the like. One of the common patterns in all of these changes is that the ecosystems under stress appear to have the characteristics of *retrogression* — that is, the appearance of a system moving to an earlier stage of succession. Under these conditions, terrestrial ecosystems lose accumulated nutrients (within the soils), while aquatic systems (lower in the landscape) tend to accumulate nutrients. In both cases, the biotic community tends to become dominated by a few opportunistic species and biodiversity within the ecosystem declines.

However, an important distinction separates a healthy ecosystem at an early stage of primary or secondary succession from an ecosystem that is in retrogression. In the healthy system, these early stages of colonization set the stage for later stages, characterized by increasing biocomplexity. In the unhealthy (stressed) system, retrogression is not often reversed without outside intervention (rehabilitation). Even with such interventions, success in restoring health is not a foregone conclusion (Rapport and Whitford, 1999).

Ecological (biophysical) signs of degrading ecosystems are now well documented in the literature (e.g., Hilden and Rapport, 1993; Vitousek et al., 1997). While a variety of specific mechanisms are involved in producing any one of the indicators (for example, many different ecological pathways may result in a decrease in nutrient availability to the biotic components of the ecosystem), the broad manifestations of ecosystem degradation are highly similar (Rapport and Whitford, 1999).

The question of indicators is, as one might expect, a central underlying theme in almost all of the chapters of this book, for obvious reasons: indicators are the basis for managing for ecosystem health or any other societal goal. Section I.5, Finding Indicators, includes indicators for forest ecosystem health, for the impact of ecological degradation on human health, for terrestrial and aquatic system function, and for ecological and economic sustainability.

The concrete application of indicators is the subject of Part II, Section II.1, in which environmental issues are the focus. These issues include biodiversity, climate change, and invasion of exotic species, among others. Each issue requires hard information upon which to make judgments, calling into play indicators of ecosystem health.

INTEGRATING THE DISCIPLINES

Ecosystem health is now emerging as a societal goal, and in this process it has become clear that the concept of healthy ecosystems extends well beyond the ecological domain. Ecosystem health assessments require an understanding of the social/cultural determinants of human health and of evolving systems of governance, ethics, and environmental management. Each of these dimensions has largely been a world unto itself. Integrative concepts, such as ecosystem health, however, force communication among the silos of disciplinary knowledge and the emergence of new, more effective transdisciplinary approaches to problems.

There are various possible levels of integration within a branch of science. For example, within ecology, integration among subdisciplines may bring together behavioral ecology with population ecology. Understanding changes in biological community structure may require integration across fields within a branch of science such as sociology, anthropology, and economics. Understanding the dynamics of human communities and the factors which interactively alter the health of ecosystems may call for integration of social, biological, and health sciences. There are even further possibilities in transcending disciplines, such as crossing the great divide between the arts and the sciences. Some fields are, by their nature, more naturally predisposed to integration than others. For example, medicine attempts to train physicians to integrate all the elements of medical education (a whole host of fields, e.g., immunology, physiology, anatomy, neurology) as well as ethics, and, to some extent, social factors.

Bringing these heretofore largely isolated silos into contact with one another is very much in evidence in the chapters that comprise this volume. For example, in the CALFED project to restore health to the San Francisco Bay, biotic communities, politics, culture, and tradition are viewed as interactive. In the case studies presented in Part III, particularly those on mining, forest health, and grazing animals/rangelands, long-overdue connections are being forged between the social sciences and natural sciences. People are not only part of (and not *apart from*) the ecosystem, but their views, values, and goals must also be central to any viable path for managing for ecosystem health.

MOVING THE CONCEPT TO PRACTICE

As amply illustrated within the present work, the notion of ecosystem health has now moved far beyond mere philosophical discussion. While still debated in terms of its fundamental meanings, it has entered the world of policy and practice (e.g., Lackey, 2001).

What is evident, even at this comparatively early stage, is that the link between healthy ecosystems and healthy people has begun to resonate within the body politic. As a consequence, ecosystem health is finding new academic homes within the health sciences and the associated professional schools, particularly human and veterinary medicine (e.g., Rapport et al., 2001) and public health (de Gruijl, 2000; Hales et al., 2000; Haines and Kammen, 2000).

One of the major factors providing the impetus to move ecosystem health into practice has been the support from the medical and public health fields. I have long puzzled over why ecosystem health found its initial acceptance within medicine and public health rather than within ecology. One reason, no doubt, is the fact that the terminology initially established for ecosystem health derived from medicine (Rapport et al., 1979; 1989). Description of ecosystem conditions in terms of health, pathology, and distress syndromes has a familiar ring to medical practitioners, but not to ecologists. Indeed, the notion that ecosystems have the property of *health* has been actively resisted by some ecologists. They contend that health implies value judgments (as to the desirable state of nature) and that, while this may be accepted with respect to individuals, it does not extend to higher levels of biological organization. If this argument were to be accepted, it would invalidate the entire field of public health and population medicine.

Perhaps the overriding reason why ecosystem health has more readily found acceptance in the health sciences than in ecology is that the health sciences are, by their nature, caring professions and mission oriented. Their mission of restoring function, alleviating suffering, etc. is not unlike the mission of ecosystem health — restoring functions to degraded landscapes and ecosystems. Thus, ecosystem health and medicine do have a similar orientation. Another connection between these fields is that interventions aimed at restoring ecosystem functions serve directly to enhance human health (e.g., by enhancing the availability of such basic amenities as water and food). Permanent solutions to certain public health problems may demand a different perspective. For instance, New York City recently suffered an increased risk to public health from declining water quality due to land use changes in the drainage system. The solution may be found not by technical interventions (i.e., by building a bigger and better sewage treatment plant), but rather by managing the Catskill watershed (that supplies New York City with its water) in a manner that restores health and the ecological services that healthy watersheds provide.

Since the Stockholm Conference on the Environment (1972) and the United Nations Conference on Environment and Development (Rio Declaration, 1992), it is also recognized that economic development (and more generally the health of economies) is also dependent on maintaining healthy ecosystems. The Rio Declaration on Environment and Development was explicit on this point and committed the parties to develop a new legal framework that integrates resource management, protection of the environment, and future economic growth (Cicin-Sain, 1993). This mandate calls for a comprehensive approach to human futures, integrating economic policies with full recognition of environmental constraints. Principle 7 of the Rio Declaration calls upon nation states, individually and collectively, to take responsibility to "conserve, protect and restore the health and integrity of the Earth's ecosystems" (Rio Declaration, 1992). It is this declaration that has given rise to the so-called Agenda 21, the action plan to achieve the goals of the Rio Declaration. In effect, the action plan details through treaties and accords (such as the Kyoto Protocol) the means of achieving healthy ecosystems.

In Part III of this work, case studies illustrate how the concepts of ecosystem health are applied to practical efforts to restore function to some of the world's most damaged environments. Five studies ranging from the Colorado River delta to the Canadian prairies to the Langat Basin of Malaysia all demonstrate the potential for improving the health of large-scale ecosystems by taking

a broad systems approach. These studies also suggest that times are changing, and that today one finds teams of applied ecologists that are adopting an ecosystem health perspective. An additional study also found in this section (on the impacts of a motor fuel additive on human health and the economics of the transport industry) further illustrates the potential applications of an ecosystem health perspective in action.

NEW GOALS FOR ENVIRONMENTAL MANAGEMENT

The history of environmental management dates to times of antiquity, when it was observed that humans impact their surroundings and that some practices are more deleterious than others. The earliest applications were undoubtedly in agriculture, where, particularly in dry or relatively infertile regions, managing the environment has long been practiced and continues to this day.

Over the past half century it has became apparent that many agricultural and industrial activities have cumulatively rendered ecosystems and landscapes less functional. These deleterious changes have often had dramatic and negative impacts on the human community through loss of income, medicinal plants, and culture, and increased threats or risks to human health. It has also become apparent that neighboring ecosystems, particularly aquatic systems, have become degraded as a consequence of certain management practices, such as agriculture and urbanization. As the interconnections of human activity, ecosystem dynamics, human health, international trade, and sustainable economic development have become better articulated, many new concerns are coming to light. Among these are the likely role of antibiotics (used as growth promoters in poultry, swine, and cattle production) in directly and indirectly increasing the prevalence of antibiotic resistance in certain human pathogens, especially those that invade the gut. Climate change increases human health vulnerabilities by spreading the range of vector-borne diseases as well as contributing to a greater frequency of extreme weather events.

These realities are encouraging a rapid evolution in the practice of environmental management, from protection of the environment from various sources of contamination — the focus being on clean air and clean water — to protection of the vitality, organization, and resilience of whole ecosystems, of which humans are an integral part. The new approach to environmental management goes well beyond crisis-driven management. No longer are single factors identified as the likely sole cause; rather, the search is for multiple stresses that singly and interactively degrade major ecosystems over time. Efforts at restoration are increasingly directed toward reestablishing critical ecosystem functions rather than one particular species.

Finally, monitoring for ecosystem health is far broader in scope than simply monitoring biophysical attributes. A watchful eye is also required to identify the socioeconomic, cultural, and human health manifestations of dysfunctional ecosystems (Maffi, 2001). Clearly the great challenge ahead in applying ecosystem health to environmental management is to make use of new methods that allow continuous monitoring (particularly from remote sensing) of biophysical conditions of large-scale ecosystems (Rapport et al., 1995) and to integrate these findings with socioeconomic, cultural, and human health trends. Further, if ecosystem health is to be maintained — and restored where it has been lost — what is needed above all else is the recognition that the politics of the environment inevitably must change. The current stance of *politics as usual* that applies to events that seem of no particular consequence must change to one of *politics of urgency* that applies to extreme threats to the future of humanity. While the insidious erosion of ecosystem health has none of the public appeal aroused by the September 11 crisis, it may well cost ultimately far more in lives. If ecosystem health is to be restored, it is time to back away from politics as usual and play hardball with the environment. Toward this end, the present volume provides abundant evidence not only that ecosystem health is a worthy goal for environmental management, but also that the concept finds ready application in solutions to real-world problems. In the past few years a multitude of new programs in ecosystem health (and ecosystem approaches to human health) have been

initiated in the U.S., Canada, Australia, South America, and elsewhere, both within academic institutions and within government programs. Increasingly, there is recognition that healthy ecosystems perform services upon which humans and other biota are dependent. Thus, actions that threaten ecosystem health and threaten the continued supply of ecosystem services are coming under more intense scrutiny. The public and decision makers are becoming aware that, unless the health of the world's ecosystems is restored and maintained, socioeconomic aspirations will become increasingly compromised.

REFERENCES

Cicin-Sain, B., Sustainable development and integrated coastal management, *Ocean Coastal Manage.,* 21:11–43, 1993.

De Gruijl, F.R., Health effects from the sun's ultraviolet radiation and ozone as a stratospheric sunscreen, *Global Change Hum. Health,* 1:26–40, 2000.

Haines, A. and Kammen, D.M., Sustainable energy and health, *Global Change Hum. Health,* 1:78–87, 2000.

Hales, S., Kovats, S., and Woodward, A., What El Niño can tell us about human health and global climate change, *Global Change Hum. Health,* 1:66–77, 2000.

Hildén, M. and Rapport, D.J., Four centuries of cumulative cultural impact on a Finnish river and its estuary: an ecosystem health approach, *J. Aquat. Ecosyst. Health,* 2:261–275, 1993.

Lackey, R.T., Values, policy, and ecosystem health, *BioScience,* 51:437–444, 2001.

Maffi, L., *On Biocultural Diversity: Linking Language, Knowledge and the Environment*, Smithsonian Institution Press, Washington, D.C., 2001.

Rapport, D.J., What constitutes ecosystem health? *Persp. Biol. Med*., 33: 120–132, 1989.

Rapport, D.J., Evolution of indicators of ecosystem health, in McKenzie, D.H., Hyatt, E.D., and McDonald, J.V. Eds., *Ecological Indicators,* Elsevier, Amsterdam, 1992, pp. 121–134.

Rapport, D.J. and Whitford, W.G., How ecosystems respond to stress: common properties of arid and aquatic systems, *BioScience,* 49:193–203, 1999.

Rapport D.J., Thorpe, C., and Regier, H.A., Ecosystem medicine, *Bull. Ecol. Soc. Am.,* 60: 180–182, 1979.

Rapport, D.J., Regier, H.A., and Hutchinson, T.C., Ecosystem behavior under stress, *Am. Nat.,* 125: 617–640, 1985.

Rapport, D.J., Gaudet, C., and Calow, P., Eds., *Evaluating and Monitoring the Health of Large-Scale Ecosystems*, Springer-Verlag, Heidelberg, 1995.

Rapport, D.J., Howard, J.M., Lannigan, R., Angema, C.M., and McCauly, W., Strange bedfellows: ecosystem health in the medical curriculum, in *Ecosyst. Health* 7(3): 155–162, 2001.

Rio Declaration on Environment and Development, 1992, in Johnson, S., Ed., *The Earth Summit: The United Nations Conference on Environment and Development*, Graham and Troutman/Martinus Nijhoff, London, 1993, 118.

Stuart, L.P., Márcio, A., Balmford, A., Branch, G., Brandon, K., Brooks, T., Bustamante, R., Costanza, R., Cowling, R., Curran, L.M., Dobson, A., Farber, S., da Fonseca, G.A.B., Gascon, C., Kitching, R., McNeely, J., Lovejoy, T., Mittermeier, R.A., Myers, N., Patz, J.A., Raffle, B., Rapport, D., Raven, P., Roberts, C., Rodríguez, J. Paul, Rylands, A., Tucker, C., Samper, C., Stiassny, M.L.J., Safina, C., Supriatna, J., Wall, D.H., and Wilcove, D., Can we defy nature's end, *Science,* 293:2207–2208, 2001.

Vitousek, P.M., Mooney, H.A., Lubchenco, J., and Melillo, J.M., Human domination of earth's ecosystems, *Science,* 277:494–499, 1997.