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Ecosystem health concepts as a management tool

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Abstract

Arguably, no ecosystems on the planet are unaffected by human society. Airborne contaminants are circulated globally; trash is left even on Everest; and the world's oceans contain oil and plastic, not to mention a variety of other wastes from human society. However, ecosystems are more than depositories for the waste of human society. Ecosystems furnish a variety of services that benefit human society, such as maintaining the atmospheric gas balance and water quality. As the human population approaches 10 billion, the amount of space available for occupancy by non-domesticated species will be greatly diminished per capita. If ecosystem services are to be maintained, the areas occupied by non-human, non-domesticated species will have to be managed so that, at the very least, services necessary to maintain the quality of human life will not diminish and, optimally, little additional biotic impoverishment (extinction of species) occurs. From the anthropocentric viewpoint, ecosystem health could be viewed as the maintenance of biological integrity necessary for the delivery of ecosystem services necessary for human society. This manuscript discusses the barriers to the use of ecosystem health concepts, which diminish risks to natural systems and the ways in which the integrity of these systems can be maintained. Maintenance of integrity will ensure the sustainable use of these ecosystems as sources of services upon which human society is dependent.

1. Implementing ecosystem health concepts in an age of fragmented information

Determining the health of complex, multivariate systems requires a holistic view in which a diverse array of information is integrated over significant spatial and temporal scales, as well as at different levels of biological organization. The globalization of economies and marketplaces is already well underway. In addition, we are already well into the information age which generates mind-boggling amounts of information available to anyone with modest electronic technology. However, the ways in which this information is used in the aggregate often appear much less effective than when much less information was available for complex decisions. In his book, *Amusing Ourselves to Death*, Postman (1986) contends that television, even its news segments, is a form of entertainment and that public discourse in the age of show business is fragmented rather than contextual. MacNeil (1983) describes the secret of success for the basic idea in television news:

> ... keep everything brief, not to strain the attention of anyone but instead to provide constant stimulation through variety, novelty, action, and movement. You are required ... to pay attention to no concept, no character, and no problem for more than a few seconds at a time.

In addition, Postman (1986) has three commandments for teachers: (1) thou shalt have no prerequisites, (2) thou shalt induce no perplexity, and (3) thou shalt avoid exposition like the ten plagues visited upon Egypt.

2. Re-establishing the context for environment information

Context is defined in *Webster's Third New International Dictionary* as "the interrelated conditions in which something exists or occurs e.g. environment or historical." Environmental information reaches professionals in fragments and not in a contextual format. The use of ecosystem health concepts as management tools will require an avoidance of the fragmented delivery pattern, together with an entirely new set of assumptions. Some of the present assumptions that will require re-examination if we are to manage for ecosystem health follow, not necessarily in order of importance.

(1) The absence of deleterious symptoms in organisms in laboratory tests is sufficient to ensure ecosystem health.

The U.S. Environmental Protection Agency (USEPA, 1991) routinely uses three test organisms (the crustacean *Ceriodaphnia*, the fathead minnow, and an alga) to evaluate environmental risks from industrial waste discharges. The assumption is made that, if these organisms show no deleterious effects at ambient effluent concentrations over a period of time, the ecosystem receiving the waste is adequately protected and in good health. In fact, comparisons have been made using the results of these tests to the ecological condition of the receiving systems (see Parkhurst, in press, among others). However, existing evidence is limited in time scale and effect inclusiveness. In addition, the rigor of correspondence found between these tests and ecological conditions has been modest (Niederlehner & Cairns, 1995). So far, the evidence accumulated has not provided a definitive basis for continued reliance on this assumption.

(2) Fragmentation of ecosystems is not as injurious to ecosystem health as toxic chemicals.

It may well be that on the planet as a whole there is a greater impairment of ecosystem health through fragmentation than by toxic chemicals. The USEPA's rankings of environmental problems conclude that habitat alteration and destruction are higher risks than toxics (USEPA, 1990). Our techniques for assessing these risks, data bases on habitat destruction, and governmental instruments for preventing or ameliorating fragmentation are in their infancy. The USEPA and other government agencies have neither significant enforcement procedures to prevent fragmentation, nor any robust data base to provide a minimum threshold for particular ecosystems beyond which further fragmentation will seriously impair ecosystem health.

(3) Defining environmental protection as an absence of deleterious effects is more cost effective than managing for robust ecosystem health.

The USEPA and its counterparts worldwide have focused primarily on absence of deleterious effects because it is obvious environmental damage that arouses public ire. However, if the focus changes to ecosystem services, which are also of economic benefit to human society, then the accounting system for establishing cost-benefit ratios would be dramatically altered. What would be the cost to agriculture if greenhouse gases increased significantly and caused a marked change in global weather patterns? Some ecosystems act as sinks for carbon dioxide and methane, two of the most important greenhouse gases. Removing these from the atmosphere is an ecosystem service for which society pays nothing and yet which is of considerable economic value. The protection and enhancement of ecosystem services are primary justifications for going beyond mere ecosystem protection to ensuring ecosystem health! It is likely that the value of the ecosystem services can, if well documented, be readily understood and appreciated by the general public and its representatives.

(4) Increased population growth, increased per capita affluence, and environmental destruction can continue indefinitely.

Given limited quantities of land, arable soil, potable water, and both renewable and fossil fuels, it seems logical to believe that there are limits to the numbers of people the earth can support while maintaining any level of per capita affluence. Some people argue that technological innovations will continue to overcome these limits. However, quantities of ecosystem services per capita are falling as the rates of both population growth and ecosystem destruction increase. One example of this decline can be found in the Worldwatch Institute's report of decreased, rather than increased, grain production per capita worldwide for several years (Brown *et al.*, 1989).

(5) Management for ecosystem health can be carried out with the responsibility divided among a plethora of agencies, all engaged in a portion of environmental management.

In the United States, one agency might be attempting to optimize recreational activities, another flood control, another hydroelectric power generation, and yet others water for agricultural, municipal, and industrial use. Clearly, all of these cannot be optimized simultaneously, and the attempt to satisfy a substantial portion of the needs of each group might severely strain ecosystem health. There is no process in place for working out conflicts between simultaneously desirable, but mutually exclusive, goals. Some form of integrated environmental management provides a framework for resolving these conflicts.

(6) Ecosystem health can be maintained without major restructuring of the present practices of human society.

Persuasive anecdotal evidence indicates that human societies that failed to consider the integrity of the ecological systems upon which their societies depended suffered greatly as a consequence (e.g., Diamond, 1994; Yoffee & Cowgill, 1988). Ornstein & Ehrlich (1989) speculate that there has been no selective advantage to societal farsightedness in developing an awareness for long-term environmental catastrophe. This contrasts sharply with the immediate selective pressure exerted when an organism lacks sufficiently quick reflexes necessary to avoid being eaten by a large predator. Platt (1973), Brockner & Rubin (1985), and Costanza (1987) have discussed the social traps that prevent the resolution of conflicts between the perceived needs of human society and the degree of nurture necessary for robust ecosystem health, self-maintenance, and the possibility for long-term, sustainable use by human society. In the introduction to the National Academy of Engineering (1994) book, Richards, Allenby, and Frosch point out that "A mature natural ecological community operates as a waste minimization system." This minimization progresses from individual facilities to the society as a whole. They also note that in the 1930s and 1940s in the United States, there was an economically viable paper recycling industry that was not motivated by environmental concerns. Perhaps, the most important statement is their excellent definition of sustainable development.

> Sustainable development represents the quest for an economy that exists in equilibrium with the earth's resources and its natural ecosystems. Sustainable development brings environmental quality and economic growth into harmony, not conflict. It is a concept that recognizes that economic activities and environmental considerations need to be integrated for humanity's long-term well-being.

Cairns (1995) notes that there is a coevolution between human society and natural systems that can be either hostile or constructive. The hostile co-evolution scenario assumes a continuing disregard for the health of natural ecosystems with a concomitant belief that human society cannot eradicate all species (e.g., cockroaches, the gypsy moth, and fruit flies). In the hostile coevolution scenario, society will be coevolving with species highly resistant to control measures by human society. These species are often designated pests. In constructive or benign coevolution, human society acknowledges its dependence upon the ecosystem services provided by natural systems and adjusts its behavior and practices so that these services are protected and suitable for long-term sustained use. Our belief is that constructive coevolution is possible but will not be implemented unless a major change occurs in both human society's environmental literacy and its attitude toward natural ecosystems.

Developing an ecosystem health management program

Norman Myers (personal communication) has noted, "Obviously the world outside the window does not run in segmented compartments, conveniently labeled 'soil', 'vegetation', 'water', and so forth. Equally obvious is the fact that such labels must be attached in order to make the world manageable. Problems arise when the labels imply a degree of discrete separateness that is not justified by 'things on the ground'." Obviously, the connections must be there because the ecosystem is, in a very real sense, seamless. It is only the disciplines that create the seams or discontinuities. The big problem is to take advantage of the methods and quality control system that have become well-established within the disciplines without creating barriers that do not exist in natural systems.

Years of working with interdisciplinary teams have provided abundant evidence that specialists are inclined to emphasize their disciplinary strengths and to avoid venturing outside their areas of specialization where their weaknesses might become glaringly apparent. One of us (Cairns) is presently engaged in an attempt to summarize the crucial information in a series of specialized reports written by highly competent scholars of national and international stature. The specialists all knew that the exercise was to be a holistic one before their individual contributions were prepared. They assembled several times to hear what the other contributors had to offer, as well as to acquaint the others with their contribution. Nevertheless, in none of the individual contributions does substantive reference to the interfaces of components appear. These scholars delivered the material in the form eminently suited to scholarly journals in their discipline, and, presumably, they felt that their professional responsibility ended with this effort. It seems unlikely at this point that a synthesis manuscript will result because the interfaces between the superb individual components were not identified. As a consequence, one might call this type of activity a *multi-disciplinary* approach, in that all of the participants are giving different views of a single ecosystem, but from a wide variety of disciplinary viewpoints, including historical, anthropological, geological, ecological, and so forth. It is a *Rashomon* approach. However, in the absence of a sustained and systematic effort by the specialists to go beyond the boundaries of their areas of specialization to see the connections among the components of the system, it is not an *interdisciplinary* or a *trans-disciplinary* approach. The term *interdisciplinary*, in theory, should require a synthesis or integration of the evidence and analyses of the different specialties but, in fact, even in the so-called interdisciplinary activities, the 'shifting of gears' when one moves from one speciality to another is quite evident. One might even call this a clashing of gears. The term *trans-disciplinary* suggests that the focus is on the problem and not on the disciplines, and examples of this sort of activity are exceedingly rare, although Worldwatch is definitely a good model. Myers (personal communication) suggests that one way of determining whether any environmental activity is truly interdisciplinary is to determine the percentage of time spent within discrete disciplines and the time spent engaging in cross-sectrol analyses. Myers believes that the proportion should be 70% on cross-sectrol analyses and 30% on discrete disciplines if the discussions and analyses are to reflect the real world. There are few examples of this process in educational institutions, in government, or in the private sector, although the latter has undoubtedly provided the best models.

It is unlikely that effective management practices involving ecosystem health can be developed and implemented until reliance on some assumptions has markedly diminished. Undoubtedly, going from the reductionist to the holistic point of view will require an extended transition involving at least two generations, but a start can at least be made by focusing on the health or condition of the ecosystem itself.

3. Ecosystem health and the courts of law

One of the major problems in the United States, and in a number of other countries as well, is the tendency to use courts of law to address primarily scientific problems. Yet, legal proceedings have definitions of causation, reasonableness, and burden of proof that are incompatible with accepted scientific methods (e.g., Rankin, 1991). In addition, in many environmental matters, delaying a decision is, in fact, making an irreversible decision about the fate of an ecosystem. Often when ecosystem health is endangered, immediate corrective action is required if health is to be maintained. For any quality control system, signals of inadequate condition require immediate effective response. Unquestionably, there will be some situations where the evidence is somewhat ambiguous and the uncertainty of the outcome higher than most decision-makers would like. All quality control systems have these difficulties and work best when a series of qualified professionals examine the evidence immediately after it is generated and can make quick course corrections when the flow of information indicates that judgments were in error. An alternative to the courts of law would be science courts, that would not attempt any judgment on legal matters, but which would judge matters where scientific skills are required. These science courts should probably be regional and should be staffed by scientists with very strong credentials who are not permanent appointees but rather serve for a limited period of time. The reason for this is that they should have exemplary, first-hand experience with complex multivariate systems, which can only come from working with them.

4. Concluding remarks

Brundtland (1987) notes that human society is dependent on uses of the biosphere that are sustainable. Clearly, human values are an integral part of the human society/natural ecosystem relationship, but the values are fragmented, not contextual, and expressed primarily as short-term rather than long-term objectives. The focus on short-term human *needs*, even such simple things as fuel wood (e.g., Samuels & Betancourt, 1982), may have profound effects on human society.

As spatial and temporal scales increase for complex, multivariate systems such as ecosystems, the uncertainty about the accuracy of measurements of condition or health increases. There are a number of reasons for this, including the fact that obtaining replicate samples on a number of large, individually unique ecosystems is extraordinarily difficult, particularly when the ecosystems are undergoing succession. In addition, it is highly improbable that the *sequence* of meteorological, biological, and ecological events will precisely ever occur again. An additional difficulty is the fact that universities and research organizations are poorly structured to engage in interdisciplinary research on complex problems with large temporal and spatial scales. Furthermore, the higher educational system has serious impediments to transcending disciplinary boundaries (e.g., Cairns, 1993). As a consequence, if a constructive relationship is to be established with the environment to permit sustainable use, not only the social system but the educational system must change dramatically. This view is supported by such mainstream organizations as the National Research Council (1993). The National Research Council is the operating arm of the U.S. National Academy of Science and the U.S. National Academy of Engineering. Although the tools to implement the management of ecosystem health are lacking, much can be done with presently available knowledge. As a start, the greening of industrial systems makes economic sense as well as ecological sense. Making more efficient use of resources inadvertently benefits the environment.

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