Article

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On Purpose in Science, Conservation and Government

The Functional Integrity of the Earth Is at Issue not Biodiversity

The objectives of conservation have been focused ever more intensively for two decades on the preservation of "biodiversity." Emphasis has been on the losses of species through extinction. The cure has been the establishment of parks and reserves to protect "hot spots," especially in the tropics, where the diversity of species is high. The efforts in preservation have often extended to the development of connecting links among reserves to allow movements among them. The approach has been codified in law in the form of the Endangered Species Act in the United States and the Biodiversity Treaty, both of which address the issue species by species and each of which has obvious weaknesses. Such efforts may be appropriate but they are totally inadequate as the sum of activities in conservation in a world of 6 billion people with exploding technologies for exploiting virtually all of the earth for immediate human benefit. The biosphere is decaying rapidly as a habitat for all life, including people, not because of the extinction of species, but because of the progressive impoverishment of natural communities through human-induced chronic disruption that is now global and ubiquitous. The impoverishment leads to progressive environmental dysfunction that is cumulative, but only in its later stages leads to extinction of species. Long before extinction becomes important, genetically distinct, local ecotypes are lost and the natural communities in which they were developed become impoverished and dysfunctional. The most conspicuous disruption is that of climate, a global change in the environment of every ecosystem. The most elaborate and carefully interlinked array of natural reserves will succumb as climate is moved out from under them... and biodiversity will suffer the very extinctions the parks were established to avoid. But long before that, the human environment will suffer conspicuous and progressive impoverishment. The objective of conservation is the preservation of the integrity of function of landscapes (and waterbodies). Emphasis falls on forests in the normally naturally forested parts of the earth because forests are so large in area globally and have such a large influence on virtually every aspect of environment. Functional integrity requires structural integrity over 85% or more of the naturally forested zone in most areas. It also requires objective measurement and definition by the scientific community. Suddenly, conservation has become, not the preservation of biodiversity, honorable as that may be, but the preservation of the functional integrity of the human environment. That purpose is the central purpose that we assign to the governments that we establish in democracies to define and defend the public interest. It is past time for the scientific and conservation communities to recognize the urgency of this transition, join in defining competent new objectives for conservation, and to convey to the public the urgency of the need for governmental responsibility in protecting the public interest in a habitable biosphere.

OBJECTIVES IN CONSERVATION AND GOVERNMENT

Extensive efforts have been devoted over more than two decades to equate conservation to the protection of species from extinction (1). While no one wishes to suggest that extinction is acceptable, we do observe that long before extinction is an issue, human interests in environment have been greatly diminished through a general process of biotic impoverishment, and the potential for support of all life itself is in jeopardy. The survival of species is a last-ditch issue, long after the functional integrity of the landscape has been impaired. We call attention here to the importance of revising objectives in conservation to preserve, not species and not "hot spots of diversity," but the functional integrity of land and water universally.

One of several major scientific and political challenges of the post cold-war world is to define and defend a world that works as a biophysical system capable of supporting an expanding human population indefinitely. The issue has emerged full blown as global climatic disruption, but there has been ample warning over 50 years from experience with global contamination with radioactivity from nuclear weapons, agricultural poisons and other industrial products. We can no longer assume that the effects of human scarification and contamination of the earth's surface will be masked by a very large life-support system of infinite resilience. The political and economic models that have led us successfully until recently in developing a technologically driven civilization have been sufficient only because the world was large by comparison with human needs. The integrity of function of the globe as a biophysical system seemed assured until we discovered that the sum of human activities had reached a scale sufficient to disrupt climates globally and warm the earth as a whole, thereby changing the human environment out from under the human enterprise even as the demands on environment soared.

The world is full in the words of economist Herman Daly (2). Every resource is under increasing pressure and the public interest in common resources of clean air, clean water, and a place to live rises abruptly. The free market system does not set values on these communal properties and cannot be expected to. The values may in fact be very high, possibly beyond calculation in that they may be equivalent to life itself (3). Their protection through various forms of regulation is one of the central purposes of government. Perhaps, in this new world, it is the central purpose.

Unfortunately, just what is to be protected, how much, and how, remain a puzzle. The issue has become suddenly acute as the US, in an unaccountable reversal, has made a series of withdrawals from earlier international agreements under UN auspices in which the US had been a vigorous participant and stalwart supporter of international action in the common interest. This action has come despite major advances in science defining the contemporary challenges by agencies such as the Intergovernmental Panel on Climate Change (IPCC). Various other efforts such as the UNDP's Human Development Index offer objective appraisals of human welfare (4). Few address environment directly. The purpose of this essay is to consolidate some of the experience of ecology into a context useful in addressing just how we might keep the world functioning as a self-sustaining biophysical system. The consolidation engages a set of principles that supplement and modify the economic and political models we have learned to use in our daily lives.

The biophysical systems of the earth have maintained themselves and maintained a habitat suitable for life for a period far in excess of the period of human evolution. The entire process has operated using the special information coded in the genes of life itself, all of life from the newborn baby in search of a nipple to the oyster spat's search for a place for attachment. And virtually every organism that survives in the reproductive race can be shown to be an ecotype, especially adapted in various ways to that time and place. So it is that the biophysical world, made up entirely of survivors, operates to sustain itself. And it is not the diversity of species that counts in this scramble nearly as much as the genetic diversity within the species that assures the continuity of life in that place.

For advice on what to do now, we look to what worked before people became large in the world, skeptical as we are of our own capacity to manage the world's life-support systems (5). All other attributes of civilization become trivial if there is no suitable habitat for people on the planet. Dreams of technological salvation crumble as the biotic resources that technology is ultimately designed to exploit for human convenience and comfort disappear in an unwinnable struggle to support a continuously expanding human presence (6).

SUSTAINABILITY: IS IT A CURE?

The earth is not working properly at the moment and "sustainability" has been advanced as the cure (7). Lester Brown has succinctly revealed the fallacies in the current homage being paid to sustainability (8). He points out that no aspect of the human habitat can be said to be "sustainable" in a world subject to continuous expansion of the human population, a rapid and continuous warming that is global, and progressive losses of potential for support of living systems from multiple causes. If present trends are allowed to continue, the earth's capacity for sustaining people will be diminished rapidly over the next years, even as the numbers of people expand. The transitions promised by present trends make nothing but trouble—economic, political, and environmental. The speed of the changes is high and the changes will be seen as sudden reductions in human welfare, abrupt discontinuities in the human support system.

Such concerns have been decried recently by Easterbrook (9) and by such as Simon (10) and Rubin (11), and most recently Lomborg (12), who have become popular among editors of *The Wall Street Journal* by claiming that the warnings of scientists and others concerned with various aspects of the erosion of environmental quality are exaggerated. One would like to share their optimism about a resilient earth. Unfortunately, none of these writers, nor any of their publishers or admirers, has rescinded any of the laws of nature including especially the fundamentals of exponential growth, or the basic biophysics of the planet. The human population is twice what it was in 1955 and is still adding about 80 million people to the planet annually, about 200 000 daily. Fisheries have collapsed globally and the earth is warming rapidly, and is variously afflicted with cumulative impoverishment of expanding and threatening proportions. While the rich live well, the disparity between rich and poor is growing, a circumstance that alone has brought down civilizations in the past with frightening abruptness and consequences and is bringing down nations at the moment (13). And it is the poor who suffer first from progressive biotic impoverishment and the instabilities of environment thereby entrained.

The problem is conspicuously biological: the earth's great biological gyroscope is slowing and starting to wobble. It requires repair and restoration if it is to continue to provide a stable human habitat necessary for a complex civilization of 6 billion people. The most serious immediate failing is terrestrial, but there are problems with marine and aquatic systems as well. In postglacial time approximately 44% of the land area was at one time forested. The forested area of the earth has been reduced over the last two centuries to about 28%, according to recent appraisals, with consequences for the biophysics of the earth that are profound (14). There is evidence that the change may be significantly greater due to "cryptic impoverishment" within the remaining forests that is not conspicuous in the satellite imagery

used in many of these studies (15). Deforestation constitutes a change in color, in reflectivity, in energy budget, in evapotranspiration, in water flows, in nutrient flows, in the quality of coastal waters, and in the composition of the atmosphere. The topics have been addressed recently by the World Commission on Forests and Sustainable Development with a special emphasis on direct human effects. The Commission recommended the development of a method of measurement of the functional integrity of the 44% of the land that would be naturally forested in a normal world. Such a measure might be an "index of forest capital," recently advanced (16).

AN EMPHASIS ON FUNCTION

The most conspicuous response of the scientific and conservation communities to the problem set forth so sharply by Lester Brown has been focused most intensively on taxonomy and insights from "island biogeography" as opposed to the systematic losses of structure and function of natural communities that precede the losses of species and may be equally irreversible. The result of an emphasis on species is an ostensible cure for that problem: the establishment of parks and reserves protecting "hot spots" as long advocated by Myers and more recently by Pimm et al. in 2001 and by various conservation agencies (17). Recommendations often include elaborate plans for corridors connecting major segments to assure the possibility of migration of species capable of migrating from a less suitable place to a more suitable one.

The problem is compounded by efforts at identifying and protecting areas of high biodiversity that are at special hazard, "hot spots," and by calls to use "triage" (18) in determining what to save, as though we know that we have a great excess of life on earth and are both wise enough and well enough endowed with life that we can decide what to keep and what to destroy.

The product of this somewhat strange deflection of emphasis is an Endangered Species Act in the United States that is a shadow of what it should be in conservation, an international Treaty on Biodiversity that deals primarily with rights to exploit species and not at all with the conservation of species, and an inability, even unwillingness, on the part of a significant fraction of recent US Congresses and other political representatives to address, or even understand, the seriousness of the destabilization of climate now underway.

A system of parks and reserves is essential to conservation, but it is only part of the solution. Debate and decisions concerning the current overpopulation of the earth and the uses of land and water, including the establishment of reserve systems, should take place within the framework of a broader agenda that addresses the systemic and universal forces that are driving the biosphere globally into impoverishment. In the absence of such a comprehensive approach, we have focused on reductionist approaches that draw attention away from these forces and defeat our purpose in conservation. Unless the larger context of preserving the functional integrity of landscapes is emphasized at every step, attention is drawn away from the far larger and more demanding immediate problem of restoring a world that will work in toto as a human habitat.

The issue has languished beneath the surface of conservation, science and government for centuries, erupting now and then locally to remind us momentarily that it is biotic functions that have been largely beyond human control that keep the earth habitable. Suddenly the challenge is global. Examples have emerged such as Haiti and Madagascar, eastern Europe, and segments of Indonesia, India, and China where the magic of the marketplace has been allowed to run free to the point where the core resources have been destroyed (19). The erosion of society and the landscape has proceeded to the point where there is little prospect of finding the resources for the reconstruction within the existing societies, at least at present. Massive aid from outside those nations will be essential to reconstruct functional landscapes, water supplies, to re-define patterns of land use that preserve agricultural land, forested drainage basins, forests for timber and fuel, and the integrity of lakes and streams. These steps are intrinsic to re-establishment even of a functional government, which requires a resource base to stand on. Such major projects in environmental restoration will displace people who now scratch survival for their families from tiny plots of marginal or sub-marginal agricultural land. Adequate provision must be made for such disruption, providing a living wage in the reconstruction or in other new, and probably subsidized, industry as part of the transition period of decades.

The World Commission on Forests and Sustainable Development, for example, has addressed the status of forests globally and the central role that they have in the stability of land, water, and climate. The topic has been elaborated recently under the term "ecosystem services" with great effectiveness by Gretchen Daily and co-workers of Paul Ehrlich at Stanford in an excellent book, *Nature's Services: Societal Dependence on Natural Ecosystems* (20). The point made in the title and elaborated in various ways over decades, however, has not yet gathered a clientele in the scientific and conservation communities sufficient to enter the mainstream of discussion and become the purpose in government that success demands (21).

THE BIOSPHERE AT HAZARD: BIOTIC IMPOVERISHMENT IS UBIQUITOUS

The human habitat is the earthly biosphere. Functioning properly it is a continuous matrix of natural communities of land and water that is the product of biotic evolution. Its functional preservation as an integral unit is necessary for the continued occupation of the earth by large human numbers living as we do with a high degree of social and technological potential. The objective of conservation and of governments in defending the public interest and the most elementary of civil rights is the biosphere itself, the whole earth, landscapes, not species alone, not hot spots, however endangered, not locales, but the entire earth.

The establishment of parks has little effect, despite the elaborations of shape and form of parks commonly advanced (22). The best designed parks, connected by scientifically designed and universally approved corridors to allow migration from one node to another, will fail as climatic changes measured in tenths to 0.5°C per decade accumulate (23). Parks, even at their maximal development under the most favorable of political regimes are certain to be limited in area to a fraction of what is required to stabilize a landscape. All of these conditions assume that an expanding human population, pressed for space and opportunity to glean a living from the earth, will allow parks to exist if their only purpose is to "preserve biodiversity."

WHAT HAS WORKED IN THE PAST?

David Ehrenfeld suggests in *Beginning Again* that the key to success in "management" of the biosphere, a concept that he deplores, lies in allowing the biosphere to "manage" itself (5). The issue is not the "muddling through" that Rubin (11) advocates, but an active program of correcting the presently threatening trends by removing the causes of the disruption and turning back to a reliance on the information derived from past experience and coded in the genes of the biota. There is no other body of information, no library, no higher authority, no other model of success. Failure to acknowledge that experience leads to incremental but inevitably progressive biotic impoverishment (24).

In 160 000 years of most recent glacial advances and retreats the carbon dioxide (CO_2) concentration of the atmosphere never exceeded 284 ppm, although it fluctuated with temperature

throughout that time (25). At present, as a result of intensive use of the biosphere by humans, the CO_2 content of the atmosphere is more than 365 ppm and rising at about 1.5 ppm yr^{-1}. We are looking now at global changes over a few decades that are as great, or greater than, any change in several thousand years of human history. Our interests are in the times of our lives and the lives of our children, not millennia. We assume, falsely, that the biosphere is sufficiently resilient to accommodate the full range of current human activities, however disrupting. The time for "beginning again" is here. We might begin by examining the biotic integrity of the planet and figuring out how to preserve it while defending the interests of 6 billion people. The method is classical in ecology (26); it is also unexceptionable.

A WORLD THAT IS NOT WORKING: WHAT WILL WORK?

The trends, however obvious and threatening, are not easily controlled. They are not measured, not defined quantitatively, not expressed as a cost of current business, and the corrective action is not clear beyond the need to reverse a trend. The impoverishment includes the replacement of forests by agriculture, even though human wealth may be created in the process. Turning all forests to agricultural land is neither desirable nor possible. But how much forest, and in what stage of preservation, is necessary for a stable human habitat? How much savanna? Swamp? Marsh? How far can the process of earthly transformation be allowed to proceed before the human habitat becomes vulnerable to what might be considered autolysis, a cascading series of changes that assure accelerating degradation of both terrestrial and marine systems with a systematic loss in the global capacity for support of people? There are abundant examples already underway in densely populated agrarian societies such as Haiti where agriculture has been pushed by necessity to slopes that will not support tillage but for a short time under very intensive control.

Unfortunately, the biosphere operates with a series of feedback systems that do not always favor stability. With respect to the warming of the earth there is a clear possibility that a change in the temperature of the earth entrains a series of changes in the metabolism of plants and soils and in the surface waters of the oceans that accentuate the trend (27). The biosphere does not necessarily stabilize itself. There are, moreover, other changes that may occur suddenly to bring major changes in climate to the earth as a whole (28). Anticipating such hazards is the business of the scientific community; avoiding them is one of the responsibilities we relegate to government, in fact, establish governments to address. But the intellectual and scientific leadership lies with the scholarly community simply because of its business of sorting out the biophysical details of nature.

CRITERIA FOR APPRAISING THE STATE OF THE BIOSPHERE: AN INDEX OF BIOTIC INTEGRITY

A world that works as a biophysical system in support of human interests will be comprised of local ecosystems that also work, that retain their self-sufficiency in basic functions. We might consider that self-sufficiency as "biotic integrity" (29). Biotic integrity ought to be measurable and usable in appraising the degree to which that self-sufficiency remains intact. An Index of Biotic Integrity (IBI) can be assigned locally and summed regionally to gain a perspective on the extent to which capital resources have been consumed and continue to be consumed in the expansion of the human enterprise. The use of the index would be completely consistent with current interests in determining the full costs of putatively profitable economic development.

Such an index has been suggested for the normally naturally forested zones of the earth (30). The Forest Capital Index offers an objective basis for appraising the degree of functional maturity of a unit of landscape based on its successional stage as modified by chronic disturbance. It does not incorporate in its present form any appraisal of commercial value which can be added as a separate index. It does, however, call attention to the necessity for the stabilization of landscapes, current trends, causes and costs of impoverishment.

The tools of ecology are many. More can be invented as experience accumulates. They include direct measurements of succession and successional status, of flows of carbon and energy and water, species lists, species abundance, and a variety of input-output measurements and ratios having to do with the basic chemistry of environment.

The scientific community has accumulated profound experience with the circulation and effects of toxic substances and with toxic effects of changes in the acidity of atmosphere and soils and the relative abundance of nutrient elements. Direct measurements of the details of the chemistry and physics of environment are now sufficiently sensitive and reliable to offer a short-term appraisal of both direct and indirect biotic hazards as suggested recently in a landmark paper by Collins (31). What is lacking is any general appraisal of the normal chemistry of environment and its importance. Such an appraisal is long overdue and will establish far more demanding and effective controls on human activities than criteria based on hazards to human health alone (32).

GLOBAL BIOTIC INTEGRITY

There can be little question as to the global hazard of accelerating biotic impoverishment as measured at the moment directly through appraisals of changes in species presence, the accumulation of impoverished land through erosion and salinization, the losses of productivity of land and sea, and indirectly through such global changes as the warming of the earth. When the issue was nuclear Armageddon, scientists and others had no difficulty seeing the potential for the destruction of civilization and the difficulty of restoring it (33). The potential of cumulative biotic impoverishment for searing the earth over a period only slightly more protracted is clear. The scientific community carries a responsibility that is as urgent and clear as the responsibility assumed repeatedly in warning against assumptions that nuclear weapons are merely slightly larger explosives.

THE POTENTIAL FOR SURPRISES

The expansion of the human enterprise globally has effects that appear, not as the product of mere growth in numbers of people, but as the product of that growth and the technology they control. The doubling time of the human population globally is widely thought to lie in the range of 35–40 years. The spread of technology is even more rapid and the combined effect measured on the surface of the earth as demands for air, water and land must have a doubling time measured in a few years. Suddenly, the fish are gone, the water is dirty, the highways are full, the air, stifling. The effects integrate the growth in human numbers, the accumulating demand on a *per capita* basis, and the surge of technological development, all aimed at increasing the human undertaking. The issue of growth is urgent; the effects only partially reversible; the consequences, devastating.

The speed of the transitions and the consequences will require severe limitations on the extent of exploitation of the biosphere. The limitations will have to take various forms but one of the forms will be zoning, decisions as to the intensity of use of nature with restrictions on the extent to which the surface of the earth can be transformed. The fact of the need is no longer a question. The questions lie in the basis of determining an ac-

ceptable intensity of use. Commercial pressures will always seek more intensified use and the political pressures to accommodate such wishes will be high.

Without prejudging the capacities of governments to defend the public interest in the face of greed and accelerating change, the scientific community has an obligation to set forth the issues as clearly as possible and to see that they are addressed effectively. The most urgent issues are those that are most conspicuous globally, the progressive disruption of climate and soaring rates of biotic impoverishment. The action required is obvious: address first the issue of global climatic disruption. The Framework Convention on Climate Change has been ratified by virtually all nations, more than 180, including the United States. The Convention offers all that is needed for each nation to neutralize its contribution to the annual net accumulation of between 3 and 4 billion tonnes of carbon to the atmosphere. The US contribution to the total release is approximately 1/3 of the 6.5 billion tonnes released globally each year. The US share of the responsibility for stabilization is 1/3 of 3–4 billion tonnes of annual accumulation or about 1.17 billion tonnes, approximately a 50% reduction in current use of fossil fuels nationally. Such a change is beyond equivocation, a major challenge to the nation, but entirely possible over the course of a few years if addressed immediately and straightforwardly.

Second, replace the emphasis in conservation on biodiversity with a pervasive local interest in the functional integrity of every landscape. The process can start immediately using simple criteria such as the Forest Capital Index applied to 10 000 ha tracts globally. There is every reason to explore more comprehensive and generally applicable indices that might include economic and other considerations but must retain the dominance of the functional integrity of the landscape in the context set forth recently for a segment of the Brazilian Amazon Basin by Nepstad et al. (34).

At issue is the potential of the earth for support of us and our children. The objective is restoration of the biosphere to a condition that might approach "sustainability" as defined in the Report of the Brundtland Commission. The ready availability of computer-based geographic information systems makes such an approach even more promising as a window on the status of life-support globally. Efforts in that direction are not underway.

It is time for an expression of intensive interest and urgency from the scientific community, from those agencies of government charged with the protection of the public interest in environment and human rights, and from the public.

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