DEVELOPING A STRATEGY FOR PROTECTING AND REPAIRING SELF-MAINTAINING ECOSYSTEMS*

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INTRODUCTION

We are engaged in a global experiment in which we are the experimental animals. The rate of global change that life can accommodate is not well quantified. In this period of rapid global change, we are focusing on parts of the problem without integrating these parts into a strategy for the entire system. Fragmented decision making has produced a fragmented environment incapable of providing the necessary ecosystem services (e.g., carbon dioxide storage, degradation of wastes) produced a decade or two earlier. For sizable ecosystems, such as the Ohio River Drainage Basin, the cumulative impact of a series of individually minor (fragmented) decisions may be disastrous. Decision makers have focused on societal needs such as an extension of an airport runway through a wetland, the fragmentation of a wilderness area by access roads, the reduction of old growth forests to keep the lumbering industry economically viable, and a number of other similar considerations. Efforts to avoid this, such as the Endangered Species Act, assume that species can be protected one at a time while their overall habitat is being destroyed. This zoo mentality that assumes a wild thing can survive in an urbanized environment is simply wrong. The development of a strategy for maintaining, restoring, and protecting ecosystems must view the entire ecological landscape and must include more truly wild areas than the landscape now possesses.

The major question, then, is whether a civilization can be developed that *wildness* can endure. *Wildness* is used here in the sense that Thoreau used it; that is, a natural system unadjusted to the needs of human society by nature trails, parking lots, and concession stands. Environmentalists have often been accused of being closed to compromise that is so characteristic of reasonable people.

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Unfortunately, all the major environmental compromises possible have been made. These have resulted in less that 3% of the globe's land mass remaining in what Thoreau would have accepted in his most charitable mood as *wildness*. A world that runs itself is fading from memory. In its place is a "managed" environment supervised by governments that cannot balance budgets. If technology and biodiversity are to co-exist, the technology must be one that wildness can endure; *in other words, a clean technology*! Ecologists perpetually talk about the interdependence of nature, and lip service is given to this notion on Earth Day, but, in practice, environmental problems are approached one fragment at a time, not as a complex, multivariate, interdependent landscape. The co-existence of technology and biodiversity depends on switching from a fragmented to a landscape view.

The re-introduction of the wolf to a portion of its former range in the United States (even when this is designated a wilderness area) is an excellent illustration of this point. Despite the fact that the wolf is a relatively shy creature, fears of attacks on tourists, livestock, etc. may preclude the re-introduction or greatly restrict the number of sites for re-introduction. The fact that the wolf once occupied these wilderness areas and that, even after the re-introduction, the truly wild areas will be geographically small and ecologically widely spaced is not enough to convince the general public or the decision makers of its correctness and necessity.

The case of the spotted owl in the Pacific Northwest is an even better illustration of society's intolerance for wildness (Gup, 1990). The spotted owl cannot injure people or livestock or damage anything of commercial value. Unfortunately for the spotted owl, it requires old growth forests of substantial size (i.e., wildness) and is, therefore, an obstacle to the lumbering industry and the unions that wish to preserve a few lumbering jobs. The wildness will lose and so, ultimately, will human society, which values a short-term economic gain over the survival of a species.

The world's present population of somewhat over 5 billion people is likely to double early in the next century unless this extraordinarily rapid growth is arrested or reversed by disease, war, or starvation. Similarly, loss of ecological capital, such as the 24 billion tons of top soil lost from agricultural lands annually (Brown, 1988), clearly cannot continue endlessly since the rate of replenishment represents a tiny fraction of the rate of loss. Worse still, there is a synergy between many world events. For example, as the population expands beyond the capacity of the present agricultural system, more forests are destroyed, more farming occurs on steep hillsides, and the rate of topsoil loss is accelerated. Ehrlich and Ehrlich (1990) emphasize that the current global population is maintained at its present level of affluence only by destroying the earth's ecological capital such as fossil water (Ross, 1990), old growth forests, fossil fuels, topsoil, global biodiversity, and the atmosphere. The Ehrlichs also note that despite the present destruction of ecological capital, a huge portion of the world's population is inadequately fed, housed, and educated. An equilibrium must be reached on or before the year 2000 to prevent a net loss of ecological capital.

Protecting self-maintaining ecosystems as discussed above is the initial step toward a world that runs itself. The second step is to repair the self-maintaining ecosystems presently damaged by hazardous waste, clear-cutting, and other anthropogenic activities so that they are capable of a level of essential self-maintenance that is presently not possible. These damaged ecosystems probably cannot be restored to their predisturbance conditions, but they certainly can be restored to ecologically superior conditions than their present damaged states. The third step then becomes the establishment of a quality control monitoring system that prevents ecological damage or, at least, gives an early warning of deleterious change.

Although this conference is focusing on the Ohio River Basin, attendees must ponder Rene Dubos' injunction "Think globally, act locally." The People's Republic of China or India may achieve their energy goals of essentially doubling the per capita energy consumption by the year 2000 (a real possibility since they are starting from such a low per capita base). The sheer number of individuals in either country is so large that, in order to offset the increase in contributions of carbon dioxide to the atmosphere by either nation, the United States would essentially have to abandon its use of coal. Of course, although it now appears likely that the People's Republic of China, with abundant supplies of coal, will reach the goal with that fuel, it might be less ecologically damaging for it to do so with the second generation of nuclear power plants if the United States gives its assistance in this costly and high technology endeavor. Until predictive models for global warming are more robust (Mikolajewicz, 1990; Shulman, 1990), keeping at least a no-net increase in atmospheric greenhouse gases globally is prudent. This raises a very important point: unless developing nations are persuaded to cooperate, the most important global environmental problems will not be solved. But what reasonable person would expect developing nations to cooperate with the United States when American per capita energy consumption is a global scandal! Ecological efforts in the Ohio Valley could easily be negated by global climate change. Americans must change if others are to be successfully persuaded to do so (Anonymous, 1990).

Another example of interconnectedness of regions is the restoration of prairie potholes in the midwestern United States. Of course, prairie potholes have a regional importance as part of a local ecological mosaic. In addition, however, they are extremely important, though not continually used, ecological "stepping stones" for migratory birds, particularly water fowl. Here, the time scale becomes important because a particular pothole might not be used every year, or at least not used heavily every year. However, given the patchiness of regional conditions, localized droughts or other episodic events may make an infrequently used pothole of exceptional importance in a particular year. *The mosaics* *under discussion, both social and ecological, have both time and spacial scales that are invariably larger than ecologists feel comfortable examining*! In fact, the present migratory flyways may be vastly constricted from their original breadth, due perhaps to the major alterations made in the hydrologic cycles, including the filling in of wetlands and the translocation of water from its original drainage basin to other regions.

THE HACKENSACK MEADOWS

Recently I was privileged to visit the restored areas of the Hackensack Meadows, New Jersey, which offers a stunning mixture of urbanization and wildlife. An area that had been an unsightly, unsanitary, and ecologically devastated wetland has sizable flocks of blue-winged teal, large and small white egrets, heron, and a variety of other birds. The once nearly fishless water almost seethed with abundant shrimp being chased by fish, and vegetation was robust. Moreover, the odors were characteristic of a tidal wetland, not a garbage dump. Yet, in the not-too-distant horizon were 18-wheeled trucks, trains, buildings, and even the New York Giant's stadium. Planes from Newark and other airports were almost always visible in the sky.

Among the many services provided by this wetland is its role as a nutrient/toxics sink so that the Newark River is purified to some extent before reaching the nearby ocean. Not far from this restored wetland are both the New Jersey Turnpike and a locus where many of the rail lines in New Jersey headed toward New York converge. A tentative proposal has been made to build a parking facility and some associated structures on a part of the restored wetland so that people visiting New York City could then leave their cars in the parking facility and take the train to downtown New York. This, of course, would improve air quality in the city, reduce vehicular congestion, and save energy, and offer other associated benefits such as reduced possibility of theft or damage to the vehicle and the greater peace of mind in not having to face the kamikaze driving habits of native New Yorkers. However, if the wetland alone is considered, the decision makes little sense. Why spend all the money to restore the wetland to its present level of ecological integrity, and then impair it (if only slightly)? Furthermore, once one facility has encroached, surely excuses will be found to permit further encroachment. Interesting tradeoffs emerge if this problem is viewed in a landscape context, encompassing traffic control, energy conservation, and landscape ecology. Mitigation of the ecological effects of the parking lot might include adding a much larger ecological compartment elsewhere in compensation for both monetary and ecological loss on the parking site. This could also serve migratory waterfowl, temporarily store flood waters, recharge groundwater aquifers, etc. Reducing fossil fuel consumption would benefit the planet; reducing traffic congestion would improve the quality of life locally; and there would be a net increase in ecosystem area regionally.

GOING BEYOND NO-NET ECOLOGICAL LOSS

The embryonic field of landscape ecology has already persuasively demonstrated that ecologists generally are looking at fragments that are too small—whether they be space, time, or levels of biological organization. Ecologists have focused primarily on populations and rarely, even in journals described as ecological, are system-level problems discussed (Harte, in press). Scientists feel uncomfortable examining landscapes or systems because they cannot engage in studies at the same level of detail that is possible when studying fragments. This is not to denigrate the reductionist approach but to merely point out that attention to too fine a level of detail may miss important attributes of a larger system. A choice need not be made between the reductionist and integrative approaches, but, rather, they should be used effectively in concert. The Rene Dubos injunction mentioned early—"Think globally, act locally"—indicated that local action, even in a system as large as the Ohio River Basin, will not be appropriate in a larger context unless the decisions made in the Ohio River Basin are compatible, insofar as is possible, with events elsewhere. This is not to say that localities should not proceed until the large system is ready; otherwise, for example, the Hackensack Meadows restoration would not have occurred. However, the continued survival of a project such as the Hackensack restoration depends upon the perception of its role in a larger context than its own limited geographic area.

NO-NET LOSS OF SPECIES

Aldo Leopold and others have pointed out that a good watch repairman never discards any parts, however insignificant they may appear, until he knows what they do. The comparison of ecosystems to watches has both strengths and weaknesses. Some ecosystems (e.g., tropical rain forests) have more components than other ecosystems (e.g., Arctic tundra). Ecosystems function well despite anthropogenic onslaughts because of the functional redundancy of the system, which is not the case for watches. In ecosystems a number of species may be transforming detritus, although they may not all do so in identical ways. As a consequence, the loss of one component is not as critical as it is in a watch. On the other hand, ecosystems adjust to change because there is a species X more suited to the new conditions than was species Y, the original inhabitant of that particular ecological niche. The successional process requires that the replacement species becomes available when particularly favorable (to them) environmental changes occur. Ecological islands (e.g., the tops of mountains) are also required where these species may persist in small numbers until their "ecological time" comes again. Furthermore, when these new conditions develop, the species best suited for them must be able to get there from the ecological islands they now inhabit. In the Hackensack Meadows, for example, small patches of appropriate vegetation remained, which subsequently invaded the newly suitable areas. Migratory birds, of course, are quite adept at finding newly created habitats. But, recovery does not always proceed as well as it did in the Hackensack Meadows where a relatively simplified ecosystem had some components already in place in patches and other components that were highly mobile.

The strategy for both protecting and repairing self-maintaining ecosystems requires both that a pool of suitable species (e.g., widely varied genetic information) be available to occupy a wide variety of habitats and that the species be able to get to the habitats when favorable conditions develop.

Ecosystems that are protected to some degree, such as national parks, national forests, nature conservancy tracts, and similar such areas occupy less than 3% of the land masses of the planet. This is simply not an adequate species pool to fill the requirements just described. Action must be taken with the other 97% of the land mass. Sufficient species must be saved from the rapidly disappearing pool for establishing truly self-maintaining systems capable of responding to changes, such as global warming. Society knows the costs, both in energy and labor, of attempting to maintain ecosystems not capable of maintaining themselves. Some fisheries, for example, would cease to exist for all practical purposes if they were not "subsidized" by hatcheries. Agricultural systems, the ultimate in managed ecosystems, are notoriously unstable at times, even when they are heavily subsidized with fertilizers, pesticides, and fossil fuel energy. However, the most important factor is that ecology as a predictive science is not sufficiently robust so that ecologists can assume the maintenance of natural systems and expect them to perform as dependably as they did when they were self-maintaining. For example, much of the rain that falls in tropical rain forests originates from the forests themselves. This is not only true in South America, but in parts of Asia where it has been noted by natives unskilled in ecology or climatology. The forests affect the meteorological conditions necessary for their survival in significant ways. Remove the rain forests and the whole climatological picture changes—usually for the worse, as has been seen in the desertification of much of Africa.

STEPS TOWARD REESTABLISHMENT OF SELF-MAINTAINING ECOSYSTEMS SUITABLE FOR LONG-TERM SUSTAINABLE USE

All of the steps outlined above must be implemented immediately to reestablish self-maintaining ecosystems. But, even then, total self-maintenance might not be possible in our lifetimes. The alternative is to wait until the ecosystems collapse, and an expensive and even more uncertain restoration project is undertaken. While large numbers of species are rapidly being lost now globally, if the numbers increase, the uncertainty for restoration will even be higher. Because governments worldwide, with some notable exceptions such as Switzerland, have shown themselves incapable of debt management, these restorative steps must be a "grassroots" undertaking carried out at local and regional levels by concerned citizens. Implementation will require cooperative interactions among all components of society, including the disadvantaged. Poor nations as well as comparatively wealthy ones must cooperate (National Science Foundation, 1990). In all cases, the strongest stimulus will be the consequences of failure to take action now. The United States has seen the results of over-utilizing ecosystems, which created the dust bowl in Oklahoma and some other states in the 1930s. Comparable dust bowl and erosion situations have also occurred in such distant nations as Australia (from over grazing), Columbia (from deforestation), and Africa (from over grazing, deforestation, and excessive population densities). The planet Earth cannot afford to have these ecological mistakes repeated until the human population learns that the resiliency of natural systems is not infinite. When ecosystems collapse, conditions are obviously much worse than they were prior to their breakdown. Furthermore, recovery to pre-excessive use condition is not always possible and, when it is, takes substantial amounts of time, energy, and money.

At the recent conference Biodiversity and Landscapes (Pennsylvania State University, October 22-25, 1990), several speakers noted that United States legislators feel that ecologists have gone too far in protecting the environment. They feel that protecting natural systems to a degree that requires personal and societal adjustments is not "practical." The relics of numerous civilizations that did not woo nature and respect her needs persuasively demonstrate the fallacy of this view. Human society can destroy natural systems, leaving them barren and eroded. However, the ultimate irony is that these civilizations that ignored natural law in turn were destroyed. Society can, and is, destroying the ecological capital built on nature's great productive fertility. When the natural capital is exhausted and the fertility is gone, the society responsible will perish and nature will begin the slow process of recovery without the destructive forces.

Step 1-Stabilization and Ultimate Reduction of Global Human Population Size

Ehrlich and Ehrlich (1990) calculate that for everyone on the planet to receive an adequate number of calories and various nutrients, given our present agricultural output, all humans would have to vegetarians. They also point out that even this is barely possible because society is wasting its ecological capital (e.g., topsoil and fossil water). If a sustainable yield could be managed, the number supported would be much lower. Furthermore, Ehrlich and Ehrlich note that the absolute amount of food produced in the world has declined in recent years and that the per capita amount has declined even more since the population keeps growing. Clearly, as Brown (1988) notes, adding 90 million people annually to the planet's population cannot be continued while losing 24 billion tons of agricultural topsoil per year. These two trends are not compatible over even relatively short periods of time. If the global population is not stabilized between now and early in the next century, the race to save the planet will probably be lost. An alternative is that parts of the planet might be saved—

if tremendous numbers of deaths occurred elsewhere. This alternative does not seem probable in an interdependent world.

Step 2-Developing a Civilization That Wildness Can Tolerate

For several centuries, ecosystems have had to adjust to human needs. Their capacity for adjustment is now diminished. Huge volumes of tropical rain forests are disappearing daily, and the global loss of species may be equal to or exceed the worst extinctions of the past (Wilson, 1988). Furthermore, the rate of loss is much more rapid than any of the past extinctions are thought to have been, and global climatic changes, such as global warming, may occur at a rate unprecedented in the planet's history (Schneider, 1989). It is well worth remembering that colossal experiments are being carried out in our living space. We can catch another plane if routine checks determine that the maintenance has not been adequate, but we cannot "catch" another planet. It is virtually certain that the predictions of harm will be grossly inaccurate since substantial data on both unprecedented degree of change and unprecedented rate of change are unavailable. Under such circumstances, it would not be surprising if some effects were overestimated and others underestimated. Since some of the possible effects are truly catastrophic, underestimating even one could have serious consequences for society as it exists. For example, anything that would drastically diminish the agricultural productivity of Egypt, a stabilizing force in an unstable area, could easily cause further disruption of oil production and flow and, therefore, disrupt the global economy. Therefore, it is in our interest to protect the self-maintaining functions of our life support system until we have a better understanding of how it works.

Step 3-We Must Preserve and Protect What We Cannot Create

For well over two decades, I have been studying the restoration of damaged ecosystems. Persuasive evidence (Cairns, 1989) indicates that a damaged ecosystem cannot be restored to a precise replica of its predisturbance condition, although sometimes close approximations are possible. Even if the ecological clock could be reset to predisturbance conditions, the particular restored patch would not be as integrated into the larger ecological landscape as it would if no damage had occurred. We do not presently know how to reset the ecological clock of a damaged area so that it will correspond to the ecological clocks of the adjacent areas. Change is characteristic of all ecosystems, but the *rates* of change vary. Resetting the ecological clock of the damaged area *to where it would have been had no damage occurred* is presently a goal with a highly uncertain outcome. Still, it is a goal well worth achieving. The ability to reset the ecological clock so that a restored ecosystem is in a harmonious and beneficial interactive state with the larger landscape in which it occurs is far less robust than the rather unlikely possibility of resetting the ecological clock to predisturbance condition for a damaged patch. The task of resetting the ecological clock is made even more difficult because sources of recolonizing species are being lost literally by the hour (as mentioned above). Furthermore, if global climate changes occur at a relatively rapid rate, we must face the problem of altering the entire global ecosystem to accommodate these unprecedented climatic changes. The pioneering and rapidly developing field of landscape ecology has already demonstrated that most studies involve too small an area. Ecological interactions may occur over relatively vast areas. Not only would it be helpful to have some pristine, or at least relatively undisturbed, areas to use as templates for reconstruction of damaged systems, but it would also be helpful to have sufficiently large undisturbed areas so that: (1) ecological interactions that occur over a heterogeneous and widely dispersed landscape could be studied; (2) portions of populations of certain species could be removed for recolonizing damaged areas elsewhere; and (3) the attributes that make self-maintenance possible could be determined.

Step 4-The Maintenance of Ecosystem Integrity Must Be the Primary Determinant for all Social and Political Actions

We may have pushed the environment beyond its limits and almost certainly have lost some of the attributes that make it self-maintaining (Diamond, 1990). Nevertheless, this is an incremental process and some of the lost attributes may be restored. The fragmentation of the ecological landscape itself makes it highly likely that some of the interactive attributes necessary for long-term self-maintenance have been lost at least temporarily. Restoring corridors between ecological fragments may restore the original attributes or at least partially offset the loss. However, when jobs are at stake and a developing nation has aspirations for its citizens of a lifestyle comparable to that in the United States, we must stop to consider that the Earth's natural systems simply cannot survive further destruction. Americans will be more persuasive in leading the world in preserving our planet if they alter their own lifestyles to be more compatible with natural systems. Politicians, as well as unions, etc., in this country, should not be able to say "We are in favor of the environment but not at the cost of jobs." This merely reflects their inflexibility or lack of planning, because maintaining the environment properly, in fact, will create *new* jobs. We must go from a exploitative society to a maintenance society, which does not result in fewer jobs, just *different* jobs.

Step 5-Development and Utilization of Clean Technology

Developing and utilizing clean technology may be the key to preserving and enhancing the integrity of natural ecosystems. Clean technology reduces the rate of social change and personal sacrifice. More important, it is far less damaging to our life support system. In addition, clean technology offers the prospect of sustainable long-term use of the planet's ecosystem services and amenities.

CONCLUSIONS

If we manage environmental change in the Ohio River Basin and in the Earth of which the Basin is a part as badly as we have done throughout most of this century, the self-maintaining quality of the ecosystems will be lost forever. Merely having a fragment of a relatively undisturbed ecosystem here and there throughout the Ohio River Basin, or globally, will not result in the self-maintaining quality of the past. Just as agriculture is beginning to learn that a mosaic of crops rotated is preferable in many ways to monoculture and human medicine is becoming more holistic, we must do the same with the environment. Landscape ecology shows that, invariably, the scale of ecological studies is simply too small; that is, neither the spatial, temporal, or level of detail dimensions are adequate to develop the robust predictive models nor to determine the factors that lead to self-maintenance. Fragmentation of decision making at all levels of government has lead to a fragmented approach to environmental management which, at worst, pits one agency against another and, at best, results in optimization of one use above all others. Since we are clearly incapable of managing the environment both politically and scientifically, we should endeavor to protect the self-maintaining capabilities of natural systems not yet lost. To do this will require that society adjusts to the needs of nature rather than saying that it is not "practical" to protect either ecosystems or species. Otherwise, future archaeologists may study another civilization that thought it was exempt from natural law.

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