Conservation: Tactics for a Constant Crisis

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Is WILDLIFE CONSERVATION FAILING? IN THE UNITED STATES, species diversity appears to be declining at an accelerating rate (1). Even the Endangered Species Act of 1973 (ESA) has not significantly slowed the deterioration of the nation's biological estate, although this is largely the result of lack of support from the federal administration. Currently there are over 4000 species and subspecies recognized as candidates for endangered species status, but the listing process administered by the U.S. Fish and Wildlife Service is bogged down because of lack of funding. There are no recovery plans for nearly half of the 600 or so species in the United States that have been officially listed as threatened or endangered, and the score or so of recovering species is balanced by an equal number that may be extinct (2).

The situation is generally much worse in other nations. Biologists with extensive experience in developing countries are saying that by almost any quantitative standard conservation is failing, and that current approaches to conservation, such as traditional parks and reserves, are unlikely to succeed (3, 4). Worldwide, only about 3% of the land is set aside in 5000 nature reserves or protected areas (5), but many of these reserves are deteriorating (6). Because the moist tropics are far richer in species diversity than other biogeographic regions, and because deforestation will probably eliminate almost all of the tropical forests outside of protected areas by 2100 (7), biogeographers estimate that from 25 to 50% or more of tropical species will vanish in the next century or sooner (Fig. 1) (8). Even if humanity were to depart the earth, recovery of biotic diversity by evolutionary mechanisms would require millions of years, depending on how deep, taxonomically, the extinction crisis cuts (9).

Such dire predictions are now leading to a reappraisal of conservation's goals and tactics. In this article, I conclude that this reappraisal would be more fruitful if there were a deeper appreciation of the biological and social contexts of conservation actions, particularly how both biogeography and political geography dictate different conservation tactics in different situations. I also argue for an actuarial approach to the viability of protected areas—one that considers the social factors determining the half-life of nature reserves.

The Biospatial Hierarchy

Effective conservation is impossible without some knowledge of biotic (biological) diversity (biodiversity). For most scientific purposes, "life" is classified taxonomically, based on similarity and presumed evolutionary relationship. For purposes of protection, however, the living components of nature are usually classified in a "biospatial" hierarchy of nested sets. In practice, there are about five levels to this hierarchy: (i) whole systems at the landscape or ecosystems levels, (ii) assemblages (associations and communities), (iii) species, (iv) populations, and (v) genes (10). Place, not evolutionary relationship, is the basis for the biospatial hierarchy, because most conservation strategies are geographically anchored (11, 12).

The targets at the top of the biospatial hierarchy are ecosystems (or landscapes and seascapes making up interacting ecosystems), including such topographic features as entire drainages. A frequently cited example is the Yellowstone National Park region, including the adjacent Grand Teton National Park and other federally managed lands. Ideally, ecosystem conservation protects the contained biotic communities: habitats, species, populations, and genes, not to mention all ecological interactions, processes, and some of the traditional, human cultural practices that have been historically associated with the ecosystem.

At the second level, an arbitrary number of biotic assemblages can be defined within ecosystems, although the species themselves show little correlation in their distributions when climate changes (13). Nevertheless, state, federal, and international conservation programs often base their conservation strategies on the completion of the network of biotic community types—the so-called coarse-filter approach. The discovery of "gaps" in the network of assemblages is most often based on systems of biogeographic classification (12, 14).

The third biospatial level, species, is defined as groups of populations that routinely exchange genes or are phenotypically similar (15). The selection of protected areas is frequently based on the presence of one or more endangered species, often large-bodied or attractive ones. In addition, regions with high species diversity, such as tropical forests, coral reefs, or regions with large proportions of local endemic species, such as isolated mountain ranges or oceanic islands, are frequently identified as targets of conservation. Another reason for focusing on species is that the management of protected areas is often facilitated by attending to a relatively small number of so-called keystone or indicator species; these species may not be endangered themselves, but they are used to monitor the status of a much larger assemblage of species (16–18).

Next is populations. Populations, whether mobile or sedentary, are dynamic assemblages of individuals which maintain genetic and sometimes social information in lineages that may ramify and merge as individuals are born, reproduce, and die. Endangered populations, and those of species that mediate important ecological processes, are often targets of conservation, so that their viability is a major concern (18, 19). Theoretical treatments of population viability are influencing public policy, such as the debate over the spotted owl in the Pacific Northwest (20).

At the small end of the biospatial hierarchy of conservation targets are genes. Genes are sometimes conserved ex situ (21, 22) as seed collections, in tissue culture or germplasm collections, or as cryopreserved semen, ova, embryos, and tissues. The extraction of genes from nature annually produces multibillion dollar benefits for agriculture, biotechnology, and public health (23). In nature, genetic

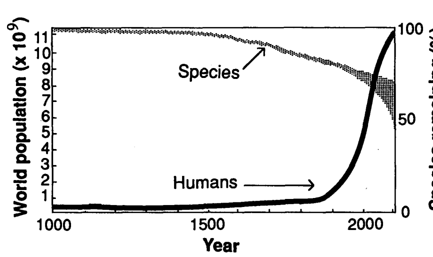

Fig. 1. The expected inverse correlation between human population size and the survival of species worldwide. Extinction rates depend on the size of the habitat fragment and occur at a decreasing rate as habitat fragments age. Anthropogenic extinctions before A.D. 1000 are ignored. The shape and width of the extinction curve reflect the uncertainty of the predictions; the curve is based in part on the assumption that most of the extinct species will be small organisms with geographically limited distributions.

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variation maintains the fitness and evolutionary flexibility of natural populations (*16*). Reserves in seminatural areas have been set aside to preserve the wild relatives of commercially important plants, especially to protect genes and gene combinations providing resistance to pests, drought, and other climatic factors (*24*).

The Six Classes of Interference and the North-South Distinction

The five levels of the biospatial hierarchy—are being undermined by six major classes of human interference (*25*), as shown in Fig. 2. These six factors are (i) the loss of habitat; (ii) the fragmentation of habitat-producing deleterious area, edge, demographic, and genetic effects; (iii) overexploitation; (iv) the spread of exotic (introduced and alien) species and diseases; (v) air, soil, and water pollution; and (vi) climate change. These factors have all been discussed in great detail (*16, 19, 22, 26, 27*). The intensities of shading in the two parts of Fig. 2 are subjective, but suggest that the present and future hazards posed by the six factors are not equal in strength or concordant in rank across the range of conservation targets, or from economically poorer to economically richer nations.

Clearly the impact of a given factor depends on the time, the place, and the circumstances. As indicated in Fig. 2, economics, culture, as well as the temperate-tropical disparity in species diversity and other biogeographic patterns, explain the differences in biotic vulnerability between tropical, poor countries, and temperate, wealthier ones. The vastly greater number of species in the tropical nations, the much smaller geographic ranges of tropical species on average (*28*), in addition to the high rates of habitat destruction in most of these countries, means that species in the tropics are particularly vulnerable to habitat loss and fragmentation. Similarly, not all parts of the planet will be equally susceptible to the impacts of acid rain, ozone thinning, or greenhouse warming; for example, the effects of greenhouse warming will be much greater at high than low latitudes, except, perhaps, for marine systems (*29*). Other aspects of biogeography are relevant to geographic heterogeneity in biotic vulnerability; on oceanic islands, for example, introduced predators are typically more damaging than on continents (*16, 25, 30*), and introduced animals (goats, pigs, rats, mongooses, snakes, and predatory snails for instance) and plants may have catastrophic effects (*31*).

Although it is difficult to generalize, one can point to some rough principles about the global vulnerability of terrestrial biodiversity (*32*). Habitat loss, fragmentation, and the direct and indirect effects of exotic species are problems everywhere (Fig. 2A), but overharvesting of economically important species is now of greater concern in poorer countries. Pollution and climate pose major threats in the temperate zone nations (Fig. 2B). As discussed below, north-south differences in socioeconomic variables and biogeography mean that conservation tactics must be tailored to the location.

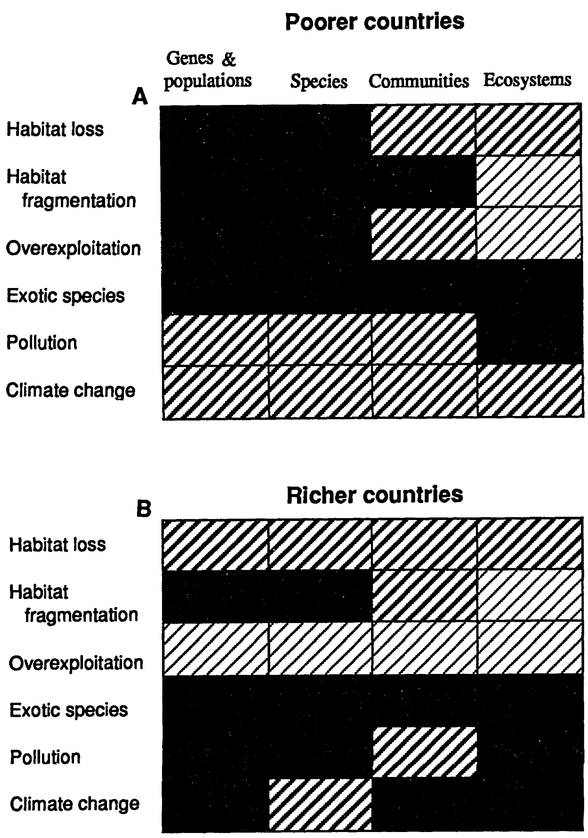

Fig. 2. Relative impacts of factors affecting terrestrial biotic diversity in (**A**) poor and (**B**) rich countries. Shading indicates intensity of impact: solid = highest; thick lines = intermediate; thin lines = lowest. Ecosystems refers to landscape level formations including, for example, mangrove habitats, coral reefs, riverine/riparian systems, forests, and savannas. The distribution of impacts on aquatic and marine systems differs somewhat from those shown here.

The Seven Sources of Biotic Degradation

The six classes of interference may constitute the most obvious proximal causes of biotic attrition, but the more fundamental causes are rooted in the contemporary human condition, especially as they are amplified by the explosive growth in human numbers in the last three centuries (Fig. 1). These more fundamental causes are listed in Table 1. The following brief descriptions of these factors are neither systematic nor exhaustive, but even this superficial treatment demonstrates why simple approaches (such as a network of protected areas alone) will fail.

Population growth. The continuous increase in human numbers exacerbates nearly every other environmental problem (*33, 34*). The population reached 1 billion about 1800, and appears to be headed toward 10 billion by 2046 and 12 billion by 2100, according to recent World Bank and United Nations projections. Ecologists argue that such numbers are incompatible with many ecological and evolutionary processes, including the persistence of large predators, the continuation of annual migrations of birds (*35*), speciation in large organisms (*36*), and the protection and maintenance of native biotas in the face of increasing pressure from human beings and

Table 1. Categories of fundamental human factors that contribute to the erosion of biological diversity.

Factor	Example of impact on conservation
Population growth	Population pressures
Poverty	Hunger, deforestation, trade in rare and endangered species, failure of grass roots support
Misperception	Desire for quick results and denial of long-term failures
Anthropocentrism	Lack of support for nonutilitarian causes
Cultural transitions	Unsustainable resource management during colonization and rapid social change
Economics	Failure of planning because of internationalization of markets and erratic pricing of commodities
Policy implementation	Civil disruption, wars, corruption, failure of law enforcement

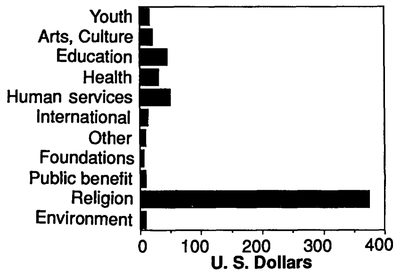

Fig. 3. Average charitable contributions per household in the United States. [Adapted from (*67*)]

introduced species. For nonhuman species, this "demographic winter" will last until human beings decide to reduce their numbers to levels compatible with the restoration of pre-explosion biotic processes (*37*). Human populations are already declining in many industrialized countries.

Poverty. The problem is not merely the shear magnitude of human numbers, however; it is compounded by poverty, the aspirations of people the world over for a better quality of life, and by social and political forces that impede the smooth transition to minimum (let alone "optimal") levels of prosperity, health, and justice (*38*). Disparities in income produce disparities of impacts. The per capita contribution to atmospheric pollution (and, hence, global climate change) is often orders of magnitude higher for citizens of the industrialized countries than for those in poorer nations (*34*), and economic pressures from the former contribute to unsustainable land use practices in the latter. Habitat destruction and extinction, however, will occur most rapidly in the tropics (Fig. 2A), where lack of economic opportunity, demographic momentum, and restrictions on reproductive choice are the engines that power the destruction of life.

It is probable that the price of raising human economic welfare to a standard similar to that in the wealthier countries will be biotic devastation in the tropics on a scale inconsistent with the persistence of wildlands except, perhaps, in remote, nonarable regions (*39*). Ehrlich and Wilson (*40*) point out that the magnitude of human aspirations, including demands on natural resources, if multiplied by the expected increases in human numbers, would require the human co-option of most remaining wildlands for grazing, farming, energy production, mining, transportation, and other uses. Therefore, the loss of most tropical wildlands in the next 50 years or so, an epochal catastrophe for earthly life, appears a virtual inevitability.

Misperception and time scale. Gradual environmental degradation goes almost unnoticed (*41*), whereas governments often overreact to sudden events of lesser overall impact. This short-term mentality is also reflected in current social mores and public policies favoring quick profits and results. The problem is that the benefits of conservation projects can only be measured on a scale of centuries. This difference in time scales between economic development projects and some conservation projects leads to conflicts because the business of conservation is keeping options open, whereas business as usual (economic development) often forecloses them.

Anthropocentrism. Many conservationists argue that current cultural values are antithetical to effective conservation policies, and that a new ethic or a revolutionary change in human consciousness is necessary before significant progress is possible (*42*). There are many calls for less human-centered, more biocentric economic policies. The anthropocentric orientation of most societies (*43*) however, augurs poorly for behavioral revolutions. If charitable donations reflect how Americans rank society's needs, it is evident that humanitarian concerns are dominant; money flows primarily to religious organizations and to medical, cultural, and social welfare causes. Figure 3 shows that only 1.5% of donated monies go to support environmental (nonhuman) groups and causes. This percentage is likely to increase, though, as donors learn about the environmental foundations of physical and social welfare.

Mindful of biases favoring our own species, nearly every book, report, or "strategy" written to promote or guide the conservation of biodiversity presents a list of utilitarian justifications, including the free services and amenities provided by nature (for example, water purification and storage, habitat for fish and livestock, vistas), and the promise of life-extending pharmaceuticals and agro-industrial products that are yet undiscovered in the tissues of organisms (*23*). Unfortunately, the political effectiveness of narrowly utilitarian arguments for large protected areas in the tropics and elsewhere is weak, in part because the promise of long-term economic and health benefits to society as a whole appears abstract to individuals and corporations more concerned with survival and short-term economic gains.

Cultural transitions. The most destructive cultures, environmentally, appear to be those that are colonizing uninhabited territory and those that are in a stage of rapid cultural (often technological) transition (*44*). The cultural groups that appear to be the least destructive to natural systems are those that have been occupying the same place for centuries or more (*45*). Overharvesting of wild animals, of aquatic and marine organisms, and of forests, is predictable, therefore, when human groups (i) have little or no experience in their current geographic setting or (ii) are undergoing integration into the world economy. Wealthy, well-educated, industrialized cultures may have the potential for minimizing environmental damage, but show little promise of this at present. Because most of the world's people are not only poor, but in a transitional phase between traditional agrarian self-sufficiency and a modern, high-input agricultural or industrial-urban society, relatively little value is placed on the protection of nature, and even where nature is highly valued, such valuation is often left out of economic calculus.

Economics. Environmental destruction and the erosion of biological diversity in the tropics and elsewhere is exacerbated by systems of commerce that create demands from the industrialized north for products, the production of which causes massive habitat destruction (*46*). The "cool chain" industry, for example, produces fresh produce such as fruit, vegetables, cut flowers, and mariculture produce (such as, shrimp) in the poorer countries and ships them in refrigerated carriers to the richer countries (*47*). This new industry contributes to the destruction of many habitats including lowland forests, mangrove, estuarine, and reef habitats. Better known are the coffee, sugar cane, banana, cacao, forest products, and cattle industries that account for the loss of a large proportion of tropical forests in developing countries (*23, 48*). In addition, a major contributor to forest and woodland destruction is the cutting of trees for the production of fuel wood and charcoal for domestic cooking and heating uses. Before the international price-fixing agreements among petroleum producers, most people in developing countries could afford to cook with kerosene. Now they must rely on wood, charcoal, and dung, contributing to the deterioration of forests and soils (*49*).

Notwithstanding the grave moral, social, and geopolitical implications of current economic disparities, the redress of such imbalances is unlikely to occur in time to save most seminatural biological systems from massive attrition. Few would question the goals of economic and social justice or their fashionable surrogate, sustainable development, but the premise that a new economic order would, alone, solve the biodiversity crisis (*50*) is suspect. The North American, let alone the Costa Rican experience (*4*), suggests that social justice and other progressive changes cannot protect biological diversity in the face of rapidly changing economic conditions including the internationalization of markets, increasing human numbers, the loss of cultural and ecological traditions, not to mention ethnic and religious conflicts. Even wealthy countries such as the United States and Canada justify the removal of the last remnants of ancient forests on the grounds of economic necessity; attempts to save that remaining 15% of original forests in the Pacific Northwest have yet to prove successful (*18*). In addition, corruption and bureaucratic inefficiency appear to be virtually indelible.

Policy implementation. There are many reasons for the inability of modern states to enforce laws and implement conservation policies, especially policies that require short-term sacrifices for the sake of long-term benefits. For example, the setting aside and long-term protection of land from the national estate is improbable in societies with many poor or landless people, powerful oligarchies, or corruptible judges and bureaucrats.

In countries where adequate resources are lacking for the protection and management of protected areas, even relatively secure reserves are subject to the removal of trees and to the poaching of game. Most poor nations simply lack the resources to preserve biotic diversity in situ (*51*). Such attrition is frequent during "normal" times (*52*), but during periods of social unrest, the loss of biodiversity can be catastrophic (*53*).

Many conservation and development projects are destined to fail in a statistical sense, given their unstable social or political contexts. Wars and the breakdown of civil administration can undermine decades of successful policy implementation. In Africa, recent wars in Ethiopia, Sudan, Liberia, Libya, Morocco, Somalia, South Africa, Zimbabwe, Uganda, Chad, Angola, Mozambique, Rwanda, Burundi, and other countries have led to the partial or complete collapse of nature reserves, the destruction of habitat, and the local extinction of endangered species (*53*). The frequency of events such as wars should be built into the planning processes of responsible agencies and organizations. This is not to say that we should abandon reserves in regions where civil chaos is frequent. Rather, expectations and policies must be tuned to appropriate distributional parameters—for example, to the mean and variance of persistence times of protected areas in similar situations and to the kinds of damage that protected areas are likely to suffer, including the killing of most large animals. The lower the mean and the higher the variance, the greater the emphasis there must be on redundancy, on alternative approaches, and on backup, ex situ projects. It would be prudent, in other words, to think of nature reserves as ephemeral islands, and to plan accordingly.

The human condition is dynamic and unpredictable and will remain so for at least a century, if for no other reasons than the momentum of the population explosion and the unsatisfactory economic and social status for billions of people during the 21st century. The "biotic condition," therefore, will also be tenuous during this interval. Fortunately, conservationists have an increasing number of tools with which to deal with the crisis.

Tactics and Conflicts

The eight paths to biotic survival. What tools are available to protect living nature from humanity? Table 2 presents a brief survey of eight conservation tactics or systems (*5*). The tactics are defined roughly in order of least to most artificial or intrusive.

1) *In situ* refers to those conservation systems based on bounded wild areas with relatively little human disturbance; it includes most protected areas, from wilderness parks to the core areas of biosphere reserves (*54*). Persistence may depend to some extent on the economic benefits, as generated, for example, by tourism, but protected areas tend to degrade, even in the best of circumstances, and few, if any are large enough to maintain viable populations of large predators and omnivores without ex situ supplementation (*16, 19, 26, 55*).

2) *Inter situ* refers to conservation systems or activities in regions where native species still persist, but which are outside the boundaries of established protected areas. Most of the lands belonging to this category are nonarable; typically, they are relatively infertile, cold, steep, rocky, or arid. In the United States, most such regions are administered by the Bureau of Land Management and the U.S. Forest Service.

3) *Extractive reserves* permit certain kinds of resource harvesting on a (theoretically) sustainable basis. Examples include rubber tapping, the collection of edible fruits and nuts, thatch grasses, and, perhaps, even limited logging and hunting. Sustainability of such practices, however, depends on a low population density, a stable economy, and careful management (*56*). In practice there may be little difference between extractive reserves and inter situ projects, except that the latter are more circumscribed.

4) *Ecological restoration projects* refers to intensive management activities intended to increase species richness or productivity in degraded habitats. Among the necessary conditions for such activities are political and institutional stability.

5) *Zooparks* refers to facilities in secure locations where a mix of local and exogenous species can be maintained under seminatural conditions—in other words, sanctuaries for sensitive species of diverse provenance (*57*). The assumptions underlying the establishment of such reserves are that protected areas, in many places, are not viable for social

Table 2. The relative potential significance of eight different conservation systems for the protection and maintenance of natural biological diversity. The "0" indicates little or no role; "X, XX, and XXX" indicate low, moderate, and high significance, respectively. The order of the systems does not imply a ranking of value.

Targets of conservation	Conservation system							
	In situ	Inter situ	Extractive reserves	Restoration projects	Zooparks	Agroecosystems & agroforestry	Living ex situ	Suspended ex situ
Entire systems (ecosystems)								
Processes or functions	XXX	XX	XX	XX	XX	X	0	0
Biosocial (traditional human uses)	X	XX	XXX	XX	X	X	0	0
Biogeographic assemblages	XXX	XX	XX	X	XX	0	0	0
Indigenous and endemic species	XXX	XX	XX	X	XX	X	XX	X
Local populations of species	XXX	XX	XX	X	XX	X	X	X
Genetic variation within species								
Wild relatives of domesticates	XXX	XX	XX	X	X	X	XXX	XX
Traditional domesticated varieties	X	X	X	0	X	XX	X	XXX
Noneconomic genetic variation	XXX	XX	XX	X	X	0	X	X
Ownership	Public & private	Private & public	Public & private	Private & public	Private	Private	Private & public	Private & public

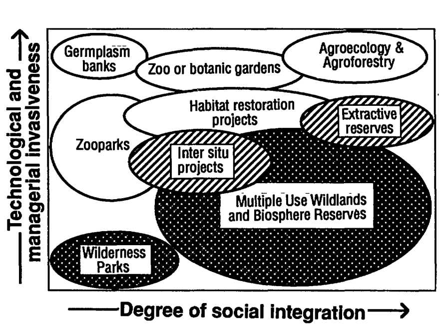

Fig. 4. Descriptive distribution of conservation tactics according to the degree of social integration at the local level, and the degree of technological input or management intensity. Shading indicates relative degree of human interference with natural processes; darker shades indicate less interference. The positions shown for each tactic are meant to suggest the center of the probable zone of action for the tactic. The term "Biosphere Reserves" refers to multiple use, production-oriented projects, with a relatively sacrosanct core protected area.

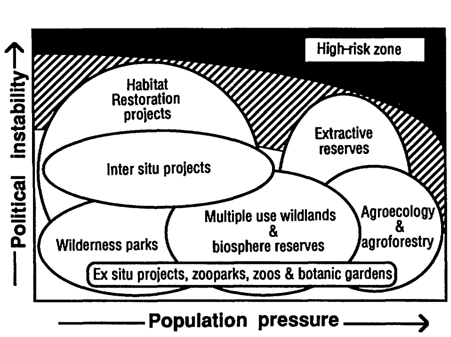

Fig. 5. Prescriptive distribution of conservation tactics based on the probability of increasing population pressure and the likelihood of political instability or violent conflicts. Backup, ex situ facilities are placed in relatively secure, politically stable locations.

or political reasons and the inevitability of highly recombined biotic communities in the future given current rates of species introductions (*58*). This category differs from in situ reserves because of the conscious introductions of target species.

6) *Agroecosystems and agroforestry projects* are highly managed, production-oriented systems with a wide range of dependence on artificial chemical and energy inputs (*59*). The number of native species that can survive in such systems is highly variable, depending mostly on the proximity of garden, farm, and plantation to wildlands, the use of artificial chemical inputs, and the tolerance of farmers to wildlife (*60*).

In addition to zooparks, there are two kinds of ex situ tactics or backup systems (*14*). These are essential where particular reserves are likely to fail or lose significant numbers of their species.

7) *Living ex situ* programs refers to botanical gardens, zoos, aquaria, and similar institutions that maintain and propagate living organisms for noncommercial (education, research, conservation) purposes in a highly controlled, usually urban, context.

8) *Suspended ex situ* programs are completely artificial; living material is metabolically slowed or arrested. Among these projects are germplasm storage facilities such as seed banks, tissue culture collections, and cryopreserved collections of gametes, zygotes, and embryos.

As shown in Table 2, this typology of tactics manifests a current trend—the privatization of conservation. For many reasons, nonprofit groups and individuals increasingly are complementing if not supplanting government agencies in protecting biodiversity. Private zoos, botanical gardens, and others are taking responsibility for the captive propagation of endangered species. Responsibility for the restoration of degraded forest, pastures, and farmlands on both public and private lands is being assumed by private groups. Organizations like The Nature Conservancy and Conservation International are acquiring new sites for protected areas (*61*), though governments are usually the ultimate owners.

Social Context and the Debate over Tactics

Current discussions have tended to oversimplify the diversity in conservation approaches by exaggerating the differences between the so-called species approaches and ecosystem approaches. The former emphasizes the protection, both in situ and ex situ, of endangered, often charismatic vertebrates, whereas the objective of the latter is to set aside and manage natural areas based on systems of landscape classification that will capture as much species and ecological diversity as possible (*62*). Critics of species-level approaches have emphasized the shortcomings of the Endangered Species Act and point out that most of the federal dollars are directed at a few birds and mammals (*62*). Some of these critics argue that success in captive breeding and cryopreservation will lead to complacency about the need for more and better protected areas. Supporters of endangered species might counter that if it were not for the charismatic species, the public appeal of conservation would be much less, that endangered species justify many of the larger protected areas in the United States and elsewhere, and that endangered species legislation is providing the economic leverage to bring developers and government agencies into negotiations about the preservation of large areas of habitat for general biodiversity conservation in the United States (*63*).

Such adversarial discussions, however, often ignore social context. As shown in Fig. 4, conservation tactics can be ranked according to the degree each is integrated into the local human community and the degree that each is dependent on artificial (technological) means and invasive management practices. Implicit is idea that different tactics require different degrees of social and technical sophistication.

A more prescriptive classification is shown in Fig. 5. It distributes the tactics in a plane of human population pressure and political stability. It is based on the untested assertion that the persistence of conservation projects, particularly protected areas, is related to the frequency and degree of political unrest and the rate of population growth. The combination of the two figures suggests that the choice of tactics should be influenced by the probable impact of demographic, economic, and social conditions as discussed above. For example, ex situ tactics are prescribed where political instability is frequent and where population pressure is building.

Much of the debate in the United States over approach and tactics stems from uncertainty and bias about landscape and geography, the importance of socioeconomic conditions and the stability of political structures, confidence in new legislative and legal remedies, and the identity of target organisms. For example, conservationists with experience in the species-rich tropics—where infrastructure is fragile at best, episodes of social chaos inevitable, human populations are doubling every few decades, laws are ignored, and hunting of rare animals and deforestation are a way of subsisting—should support a pluralistic approach that includes ex situ backup for protected areas. On the other hand, those with experience in wealthy, stable, temperate zone regions—where most species have wide geographic ranges and where there exists extensive areas of low productivity, government-owned lands—are more likely to promote systems of protected areas linked by corridors in multiple use zones that can be managed for conservation and sustainable forms of exploitation (*64*). They will also have more faith in legislative remedies and law enforcement. Figure 5 illustrates this tactical pluralism.

Conclusions

Today, the conservation of biodiversity is virtually equivalent to the ex situ protection of wildlands. In the future, however, such reserves will come to be seen actuarially, their life times dependent on many biogeographic, social, and political factors. Unless a much denser and more secure network of protected areas is established soon, the importance of less appealing alternatives will be greater than conservationists would wish.

This awareness has led some observers to call for a greater emphasis on adjunctive approaches, including inter situ projects—the management of wildlife in nonarable lands outside of traditional reserves (*65*). Though appropriate in certain places, these lands are not immune to overexploitation, desertification, and to other forms of abuse, as the recent history of Tibet, the Sahel of Africa, and the American Southwest have shown. The inter situ tactic is an important backup, however, especially in socially and demographically stable nations and regions. The point is that every tactic has its limitations; sole reliance, for instance, on ecological restoration or on cryopreservation technologies would be premature, if not immoral, because these technologies could protect only a tiny fraction of species diversity for the foreseeable future, especially in tropical seas and forests.

Progress in conservation is hampered by the lack of a clearly articulated public policy on biodiversity. The United States and many other countries lack a coherent conservation strategy. In part, this may stem from confusion about tactics, as discussed above. The United States should join the nations that have developed a national conservation or biodiversity strategy. There is also a need for new institutions such as a National Institutes of the Environment (similar to the National Institutes of Health) to provide intellectual leadership and sustainable funding for planning and research in biodiversity. In addition, a high level review of federal agencies is necessary so that either the authority for the protection of biodiversity is vested in a new agency with clear directives, or the organic acts (if any) of the agencies should be restructured, making conservation a prime directive of the U.S. Forest Service, the Bureau of Land Management, and the National Wildlife Reserve System.

Everywhere, nature reserves must be defended and bolstered by social experimentation in "sustainability." But there is too much at risk to gamble on any one social ideology, theory, or approach. All human institutions are transient expedients, and the conservation systems that are fashionable today will certainly undergo many changes in the next century. Opportunism and tolerance must be the watchwords of the science, the politics, and the art of nature protection (*66*). The issue, therefore, is not the "failure" of conservation; it is whether it can stay the course. During the construction of cathedrals in the Middle Ages, planners and artisans were not dismayed that "success" might require centuries. Like those workers, conservation scientists and practitioners must accommodate their objectives to the social complexity and temporal scale of their enterprise (*67*).

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9. Many millions of years are required to replenish taxonomic diversity at the family level or higher (D. Jablonski, *Science* **231**, 129 (1986); *ibid.* **253**, 754 (1991); D. M. Raup, *ibid.* **231**, 1528 (1986). Not only is the current rate of extinction many orders of magnitude higher that the historical average rate of speciation, but contrary to intuition, the process of speciation for large organisms is now severely compromised by habitat loss and fragmentation [see M. E. Soulé, in *Conservation Biology: An Evolutionary-Ecological Perspective*, M. E. Soulé and B. A. Wilcox, Eds. (Sinauer, Sunderland, MA, 1980)].
10. Individual organisms are rarely considered to be targets of conservation. Their conservation status, if any, usually derives from their potential genetic and generative contribution to the lineage or population, not because of their value or rights as individuals per se, a premise that distinguishes the conservation movement from the animals rights movement. For a discussion of the "rights" argument, see T. Regan, *The Case for Animal Rights* (Univ. of California Press, Berkeley, 1983). Regan considers the conservation argument to be fascistic (pp. 361–362) on the grounds that conservation emphasizes aggregative (population and community) considerations which, he says, cannot be reconciled with the animals rights view. Even so, a single individual can have instrumental value in conservation; habitat and species diversity is often maintained by natural disturbance [see S. T. A. Picket and P. S. White, Eds., *The Ecology of Natural Disturbance and Patch Dynamics* (Academic Press, Orlando, FL, 1985); L. D. Harris, *Environ. Manage.* **12**, 675 (1988)].
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12. J. M. Scott, B. Csuti, J. D. Jacobi, J. E. Estes, *ibid.* **37**, 782 (1987); J. M. Scott, B. Csuti, K. Smith, J. E. Estes, S. Caicco, in (*1*), pp. 282–297.
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14. Office of Technology Assessment, *Technologies to Maintain Biological Diversity* (U.S. Congress, OTA-F-330, U.S. Government Printing Office, Washington, DC, 1987).
15. Information on endangered species issues is available in *The Endangered Species UPDATE* (School of Natural Resources, University of Michigan, Ann Arbor, MI 48109-1115) and *Species* (Species Survival Commission, c/o Chicago Zoological Society, Brookfield, IL 60513).
16. O. H. Frankel and M. E. Soulé, *Conservation and Evolution* (Cambridge Univ. Press, Cambridge, 1981).
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18. D. S. Wilcove, *Trends Ecol. Evol.* **4**, 385 (1989).
19. M. E. Soulé, *Viable Populations for Conservation* (Cambridge Univ. Press, Cambridge, 1987).
20. J. W. Thomas *et al.*, *A Conservation Strategy for the Northern Spotted Owl* (U.S. Department of Agriculture, Forest Service, Portland, OR, 1990).
21. Conservation tactics that focus on life in natural place are called in situ and those that conserve it elsewhere are ex situ. For information on ex situ conservation, see W. G. Conway, in (*4*), pp. 199–209; A. H. D. Brown, O. H. Frankel, D. R. Marshall, J. T. Williams, Eds., *The Use of Plant Genetic Resources* (Cambridge Univ. Press, New York, 1989).
22. E. O. Wilson and F. M. Peter, Eds., *Biodiversity* (National Academy Press, Washington, DC, 1988).
23. N. Myers, *The Primary Source: Tropical Forests and Our Future* (Norton, New York, 1984).
24. H. H. Iltis, in (*22*), pp. 98–105; J. T. Williams, in *ibid.*, pp. 240–247.
25. J. Diamond, in (*4*), pp. 37–41, has used a more compact classification—"the evil quartet."
26. M. E. Soulé, *Conservation Biology: Science of Scarcity and Diversity* (Sinauer, Sunderland, MA, 1986).
27. D. Simberloff, *Annu. Rev. Ecol. Syst.* **19**, 473 (1988); C. M. Shonewald-Cox, S. M. Chambers, B. MacBryde, W. L. Thomas, *Genetics and Conservation* (Benjamin-Cummings, Menlo Park, 1983); D. Western and M. C. Pearl, Eds., *Conservation for the Twenty-First Century* (Oxford Univ. Press, New York, 1989); M. E. Soulé and B. A. Wilcox, Eds., *Conservation Biology: An Evolutionary-Ecological Perspective* (Sinauer, Sunderland, MA, 1980).
28. J. Terborgh and B. Winter, in *Conservation Biology: An Evolutionary-Ecological Perspective*, M. E. Soulé and B. M. Wilcox, Eds. (Sinauer, Sunderland, MA, 1980), pp. 119–134; A. H. Gentry, in *Conservation Biology: Science of Scarcity and Diversity*, M. E. Soulé, Ed. (Sinauer, Sunderland, MA, 1986).
29. R. L. Peters and T. Lovejoy, Eds., *Consequences of Greenhouse Warming for Biological Diversity* (Yale Univ. Press, New Haven, in press).
30. I. Atkinson, in (*4*), pp. 54–75; J. A. Savage, *Ecology* **68**, 660 (1987).
31. S. L. Pimm, *Trends Ecol. Evol.* **2**, 106 (1987); P. M. Vitousek, in (*22*), pp. 181–189.
32. Similar analyses might be useful for aquatic and marine systems.
33. P. R. Ehrlich and A. H. Ehrlich, *Extinction: The Causes and Consequences of the Disappearance of Species* (Random House, New York, 1981).
34. ______, *The Population Explosion* (Simon & Schuster, New York, 1990).
35. See, for example, J. Terborgh, *Where Have All the Songbirds Gone?* (Princeton Univ. Press, Princeton, NJ, 1989).
36. M. E. Soulé, in *Conservation Biology: An Evolutionary-Ecological Perspective*, M. E. Soulé and B. M. Wilcox, Eds. (Sinauer, Sunderland, MA, 1980), pp. 151–170.
37. M. E. Soulé, M. E. Gilpin, W. G. Conway, T. Foose, *Zoo Biol.* **5**, 101 (1986).

There is a false paradox about conservation programs and time scale. A critic might ask, "Why the haste if conservation projects must last centuries?" The problem is the that the current rate of biotic destruction demands immediate actions. This is not inconsistent with the objective that they persist a long time.
38. R. Repetto, Ed., *The Global Possible: Resources, Development, and the New Century* (Yale Univ. Press, New Haven, 1985); H. E. Daly and J. C. Cobb, Jr., *For the Common Good: Redirecting the Economy Toward Community, the Environment, and a Sustainable Future* (Beacon, Boston, 1989).
39. P. M. Vitousek, P. R. Ehrlich, A. H. Ehrlich, P. A. Matson, *BioScience* **36**, 368 (1986).
40. P. Ehrlich and E. O. Wilson, *Science* **253**, 758 (1991).
41. R. Ornstein and P. R. Ehrlich, *New World, New Mind* (Doubleday, New York, 1989).
42. B. Devall and G. Sessions, *Deep Ecology* (Gibbs M. Smith, Layton, UT 1985); A. Leopold, *A Sand County Almanac and Searches Here and There* (Oxford Univ. Press, Oxford, 1948); *World Conservation Strategy: Living Resources Conserved for Sustainable Development* (International Union for the Conservation of Nature, Nairobi, Kenya, 1980).
43. D. Ehrenfeld, *The Arrogance of Humanism* (Oxford Univ. Press, New York, 1981); C. Birch and J. C. Cobb, Jr., *The Liberation of Life: From Cell to the Community* (Cambridge Univ. Press, Cambridge, 1986).
44. P. S. Martin and R. G. Klein, Eds., *Quarternary Extinctions: A Prehistoric Revolution* (Univ. of Arizona Press, Tucson, 1984); S. T. Olson, in *Conservation for the Twenty-first Century*, D. Western and M. C. Pearl, Eds. (Oxford Univ. Press, New York, 1989), pp. 50–53.
45. P. M. Chandler, *Agriculture and Human Values* **8**, 59 (1991); T. H. McGovern, G. Bigelow, T. Amorosi, D. Russell, *Human Ecology* **16**, 225 (1988).
46. R. B. Norgaard, in *Biodiversity*, E. O. Wilson and F. M. Peter, Eds. (National Academy Press, Washington, DC, 1988), pp. 206–211.
47. D. E. Goodman and W. H. Friedland, personal communication.
48. P. H. Raven, in (*22*), pp. 119–122; M. J. Plotkin, in *ibid.*, pp. 106–118.
49. S. Postel in *State of the World* (Norton, New York, 1989), pp. 21–40.
50. For example, S. Hecht and A. Cockburn, *The Fate of the Forest: Developers, Destroyers and Defenders of the Amazon* (Harper Perennial, New York, 1990); to this extent, the working principle of some international conservation organizations that economic development is a necessary, let alone sufficient, precondition for conservation is untested.
51. H. H. Iltis, *Environment* **25**, 55 (1983).
52. G. E. Machlis and D. L. Tichnell [*The State of the World's Parks* (Westview, Boulder, CO, 1985)] report that 95% or tropical reserves report poaching of wildlife.
53. For example, F. Kayanja and I. Douglas-Hamilton, in *National Parks, Conservation and Development: The Role of Protected Areas in Sustaining Societies*, J. A. McNeely and K. R. Miller, Eds. (Smithsonian Institution Press, Washington, DC, 1984), pp. 80–86.
54. The Biosphere Reserve concept of Unesco's Man and the Biosphere Program is, in part, an attempt to integrate economic development and conservation by sharing the management and benefits of protected areas with local peoples. It attempts to avoid the extremes of banishing people to save nature and banishing nature for the sake of people. It has been difficult to apply in practice [see D. Hales, in (*4*), pp. 139–144]; M. Batisse, *Nat. Resour.* **22**, 1 (1986); S. R. Kellert, *Environ. Conserv.* **13**, 101 (1986).
55. U. S. Seal, in *Endangered Birds: Management Techniques for Preservation of Threatened Species*, S. A. Temple, Ed. (Univ. of Wisconsin Press, Madison, WI, 1978), pp. 303–314; W. D. Newmark, *Nature* **325**, 430 (1987); P. F. Brussard, *Ecol. Appl.* **1**, 6 (1991); R. L. Peters and J. D. Darling, *BioScience* **35**, 707 (1985).
56. L. Silberling, *BioScience* **41**, 284 (1991); J. R. Browder, *ibid.* **40**, 626 (1991); J. R. Browder, *ibid.* **41**, 286 (1991).
57. An example is North American ranches harboring African ungulates. Entrepreneurs might consider the purchase of strategically located islands and other real estate where secure facilities could be located. See also M. E. Soulé, in *Conservation of Threatened Natural Habitats*, A. V. Hall, Ed. (South African National Science Programmes Report 92, CSIR Foundation for Research Development. P.O. Box 395, Pretoria, South Africa), pp. 46–65; M. E. Soulé, in (*4*), pp. 297–303.
58. M. E. Soulé, *Conserv. Biol.* **4**, 233 (1990).
59. M. A. Altieri and L. C. Merrick, in (*22*), pp. 361–369.
60. Although the vast majority of native species currently are unable to survive in intensively managed agricultural zones, especially in the tropics, sound agroecological practices create a healthy environment and contribute to self-sufficiency and the maintenance of crop genetic resources, especially if practiced in an economically and political stable environment. In addition, they may effectively reduce wood-collecting, hunting, and other pressures on nearby wildlands [see M. A. Altieri and D. K. Letourneau, *Crop Protect.* **1**, 405 (1982); S. R. Gliessman, E. R. Garcia, A. M. Amador, *Agro-Ecosystems* **7**, 173 (1982)].
61. Among the most recent and impressive acquisitions by The Nature Conservancy is the purchase in 1990 of the 130,000-ha Gray Ranch in southwestern New Mexico, which includes an entire mountain range (Las Animas).
62. J. M. Scott, B. Csuti, K. Smith, J. E. Estes, S. Caicco, in (*1*), pp. 282–297. See also Part IV of (*1*).
63. See L. A. Greenwalt, in (*1*), pp. 31–36; M. J. Bean, in *ibid.*, pp. 37–42; D. D. Murphy, in *ibid.*, pp. 181–198.
64. R. Reed, *Nat. Areas J.* **7**, 2 (1987); L. D. Harris and J. Eisenberg, in (*4*), pp. 166–181.
65. D. Western, in (*4*), pp. 158–165.
66. Others have called for greater respect for pluralism [D. Western, in (*4*), pp. vi–xv; R. F. Noss, in (*1*), pp. 227–246].
67. *Giving and Volunteering in the United States: Summary of Findings* (Independent Sector, 1828 L Street, NW, Washington, DC, 1988).
68. The manuscript was much improved thanks to the comments of D. B. Botkin, P. R. Ehrlich, D. Goodman, W. P. Gregg, Jr., R. E. Grumbine, D. F. Hales, J. A. McNeely, P. Romans, J. M. Scott, D. Wilcove, and G. Zegers.

An Evolutionary Basis for Conservation Strategies

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CONSERVATION STRATEGIES HAVE BEEN REMARKABLY ANthropocentric from their inception in the Middle Ages to the present (*1, 2*). During dynastic and feudal times, parts of kingdoms were set aside as hunting grounds for the aristocracy, thus preserving everything that dwelled therein. This, plus severe natural and cultural control of human populations resulted in environmental protection for centuries. Today, with a burgeoning and expanding human population of 5.3 billion, no more than 4500 areas are protected globally (*1*); that is equivalent to a mere 3.2% of our planet's landmass. National parks, wildlife refuges, biosphere reserves, military reserves, Indian reservations, and other forms of legally protected areas have been established for aesthetic, political, or practical purposes in the last 150 years. Many reserves in less-developed nations are paper parks only; many in the more developed are lamentably endangered by touristic herds, and certain wilderness parks are threatened by short-sighted national energy policies.

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Today, conservation strategy is based on a perceived impending loss of biodiversity due to tropical deforestation or disappearing habitats where populations of "interesting" species, subspecies, or even varieties (especially in temperate areas) reside. Campaigns usually focus on loss of potentially useful resources, such as plants with pharmaceutical properties or large animals that capture human interest. In practice, this results in saving fauna and flora in a few "available" acres where a well-known target taxon lives. Science has been too slow in providing inventory data to do much more; thus, what should be a major collective effort between conservation and science is often nonexistent, or in some cases, discord.

In the past 3 billion years, more species and their natural assemblies with their particular interactions have come and gone than are now present on Earth (*3*). One fact of evolution is that species go extinct, and others come into existence. Today, because of unprecedented human impact, species are increasingly going extinct and the speciation process, which creates future biodiversity, is being severely pressured through the removal of contiguous related biotic habitats. The pattern of continental habitats, often vast biomes, is being reduced to one of scattered island-like habitats and, just as on real islands, major extinctions are destined to occur. If this disruption of natural systems continues into the 21st century, we can expect the evolutionary process as we know it to become degraded and retarded.

There is no unified scientific method behind conservation strategy that addresses the nature and quantity of biodiversity, nor what it means environmentally either to save it or lose it outside direct