Human Carrying Capacity, Extinctions, and Nature Reserves

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Humanity has overshot Earth's long-term carrying capacity and is living "on capital," and simultaneously we are eliminating other organisms, heedless of the crucial role they play in supporting society. Only a change of paradigms leading to reduction of human numbers and impacts and a comprehensive system of reserves, can prevent catastrophe. *(Accepted for publication 16 February 1982)*

With present and foreseeable technologies, *Homo sapiens* has exceeded the long-term carrying capacity of Earth, which is especially evident in society's heavy dependence on a draw-down of nonrenewable resources. In order to maintain a population of about 4.5 billion people—many in a marginal existence—our species is squandering capital accumulated over hundreds of millions of years in a matter of decades (see Ehrlich et al. 1977 for overview).

When a politican or economist thinks of this destruction of capital, he or she normally thinks only of the rapid consumption of fossil fuels, especially of petroleum, and believes that humanity will find technological solutions to this problem with nuclear power, solar energy, synfuels, or other technologies. Most economists do not recognize the potentially serious problem of the dispersal of high-grade mineral resources because they have been taken in by a mythology of infinite substitutability (e.g., Barnett and Morse 1963)—the notion that "man largely creates his own environment and his own resources" (Anders et al. 1978, p. 39)—to provide a rationale for acting as if perpetual economic growth were possible. The most thoughtless and errant statement to be issued by this Western equivalent of a "cargo cult" (Catton 1980) so far was, curiously, published in *Science*. There, in June of 1981, an economist informed the world that "the quantity of copper that can be made available to humanity cannot be calculated even in principle" because "copper can be made from other metals" and that the theoretical limit on the amount of copper thus obtained would be "the total weight of the universe" (Simon 1980, p. 1435).

But the problems created by accelerating use of stocks of fossil fuels (Holdren 1981) and the impossibility of solving the problem of dispersing high-grade mineral resources by infinite substitution (Cook 1976, Ehrlich et al. 1977 for environmental constraints) are only the tip of the iceberg. Several centuries could pass before shortages of these resources brought on a crash of the human population. It is more likely that the depletion of another nonrenewable resource, the biological diversity of our planet, will be the prime factor in triggering a decline in human numbers so catastrophic that it could spell the end of industrial civilization.

WHY PRESERVE DIVERSITY?

There are three basic arguments for preservation of the stock of species that now inhabit Earth. One is an esthetic-ethical argument—that other species are beautiful, unique, and have a "right to exist" (e.g., Ehrenfeld 1978; Ehrlich and Ehrlich 1981). A second is that other organisms already provide humanity with a wide variety of direct economic benefits and have the potential for providing enormously greater benefits in the future (Myers 1979). But it is the third argument that is of greatest concern to us here: that other species are intimately involved in providing society with an array of indispensible, irreplaceable "ecosystem services" without which society in its present form could not persist (Ehrlich and Ehrlich 1979).

Ecosystem services (e.g., Bormann 1976) include maintenance of the quality of the atmosphere, amelioration of the weather and regulation of the hydrologic cycle, disposal of wastes and recycling of nutrients essential to agriculture, generation and maintenance of soils, provision of food from the sea, control of the majority of potential pests of crops and vectors of disease, and maintenance of a vast genetic "library" from which humanity can withdraw, among other things, some of the germ plasm required for the continuance of high-yield agriculture.

Few people are aware of these ecosystem services. Most do not understand that many human activities constitute assaults on ecosystems whose integrity must be preserved if those natural services are to continue being provided and industrial society is to persist. It is, for example, the necessity of preserving ecosystem integrity that places the fundamental constraints on human mobilization of materials—*not* the amounts theoretically available (Ehrlich et al. 1977). By using enough energy, the oceans could be boiled and granite mined to extract the trace elements in both. The energy could be mobilized, but the inevitable environmental side effects of its use on such a scale would be catastrophic.

Even fewer people realize that billions of genetically distinct populations and millions of species of organisms are functional (and often noninterchangeable) elements in ecosystems. To the degree that people *are* aware of endangered

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species, they are conscious of the threat to prominent organisms like the blue whale, black rhino, and California condor. Their concern is born of compassion for and interest in such creatures, not of a well-grounded fear that in assaulting them society is sawing off the limb on which it is perched.

THE DECAY OF DIVERSITY

Until the last century or so, the imapct of *Homo sapiens* on Earth's biota was little noted. Many populations were, of course, exterminated, possibly including much of the Pleistocene megafauna (e.g., Ehrlich et al. 1981, pp. 109–114, Martin and Wright 1967, Van Valen 1969). Greek scholars before the time of Christ were well aware of the deterioration of local ecosystem services resulting from deforestation (Hughes 1978), but the disappearance of other species only began to attract attention with the loss or near loss of widespread and well-known animals like the great auk, northern right whale, passenger pigeon, and American bison. Such animals were endangered directly by overexploitation, and thus an early focus of conservationists was to protect animals from overhunting and overfishing. Parallel to this there developed a great concern for the degradation of the landscape (e.g., Marsh 1864), but the wide recognition of habitat destruction as the prime source of the loss of organic diversity has been slower in coming.

It has been estimated (Ehrlich et al. 1977, p. 192) that in the closing decades of the twentieth century the rate of species extinction will be some 40 to 400 times the rate that has prevailed through most of geological time. One can guess that the rate of extinction of genetically distinct populatons will be disproportionately higher. The decline of Earth's biota can be viewed as an extremely rapid depletion of a nonrenewable resource. Speciation mechanisms are not capable of replenishing the stock at a rate of interest to us, any more than geological processes are capable of restoring depleted stocks of fossil fuels or high-grade mineral resources. Furthermore, there is reason to believe that, overall, human activities are slowing the rate of speciation itself (Ehrlich and Ehrlich 1981, Soulé 1980).

The decline of diversity contributes to a dismal prospect for humanity. Only the rapidly increasing threat of thermonuclear war darkens our future more. As nonrenewable (stock) energy and materials resources are depleted, people will be increasingly forced to depend on renewable (flow) resources for sustenance. The outlook is all the more unfortunate as human behavior in the terminal years of what sociologist William Catton (1980) calls "the age of exuberance" seems bound to become ever more destructive of the very systems that are involved in supplying flow resources, such as solar energy, fresh water, food, timber, medicines, fibers, and various industrial products from plants and animals (e.g., Myers 1979).

THE TIDE OF HABITAT DESTRUCTION

Increased human population growth and per capita consumption lead to habitat destruction in diverse ways. Natural areas are paved over for housing, roads, industry, and shopping centers. More and more marginal land is put to the plow, destroying entire communities for often short-lived agricultural operations. Those vast storehouses of species diversity, the tropical rainforests, are being cut down to yield beef for cheap hamburgers, to provide packaging for Japanese electronic gadgets, and to supply firewood and farm sites for burgeoning human populations (Myers 1980). At the other end of the spectrum from the moist forests, many arid regions in North America are being chewed up by off-road vehicles. Industrial society also degrades environments globally with its effluents—from chlorinated hydrocarbon pesticides and industrial chemicals that concentrate in food chains to air pollutants that generate the acid rains that destroy aquatic communities wholesale and may have serious deleterious effects on terrestrial ecosystems.

THE ROLE OF NATURE RESERVES

In any tactical solution to the problem of accelerating extinctions, nature reserves clearly must play a central role. The technology of reserve design, unfortunately, is in its infancy (e.g., Gilpin and Diamond 1980, Frankel and Soulé 1981, Wilcox 1980), and the applicability of some of the principles of its mother science, island biogeography (MacArthur and Wilson 1967) are still in dispute (e.g., Simberloff and Abele 1975). But, both because of what we do know and because of what we do not know, it is clear that every attempt must be made to increase the number and size of nature preserves.

We do know that many reserves today are almost certainly too small to permanently support the large animals they were designed to maintain. Michael Soulé and his colleagues (1979), for example, deduced that most of the large animals will be lost from present day African game parks in a matter of a few hundred years, even if the parks are flawlessly protected. Although this may seem like an incredibly long time in the high-discount world of economists, it is a mere instant in evolutionary time and a brief interlude in the history of our species.

Perhaps more disturbing, recent work by our group (Ehrlich et al. 1980, Murphy and Ehrlich 1980) indicates that previous estimates of the amount of undisturbed area required to guarantee the persistence of butterfly populations were not sufficiently conservative. Butterflies, because of their popularity with amateur naturalists, are probably the best indicator group available for assessing the status of a myriad of herbaceous plants, insects, and other obscure organisms that play crucial roles in delivering those all-important ecosystem services. If the butterflies' requirements turn out to be more or less typical of herbivorous insects, then the long-term value of smaller reserves (which predominate in Great Britain) will diminish greatly, especially if they become islands in what are, in essence, biological deserts. Although with intensive management (e.g., Duffey 1968) it may prove possible to maintain species on undersized reserves, extinctions will still occur (Duffey 1977); the management practices themselves, however, may eliminate the possibility of regenerating diversity (Soulé 1980).

It is clear, then, that great efforts must be made to avoid the development of substantial new tracts of land anywhere. Wherever suitable areas still exist, they should be converted into reserves and the resources found to protect and manage them properly so that the impacts of humans are minimized. Violation of existing reserves is a worldwide problem and is especially severe in some tropical areas (e.g., Hamilton 1976). Sadly, the current Secretary of the Interior, James Watt, is determined not to expand wilderness areas and to open up much of the current system of reserves "for the people." Little does he realize the ultimate consequences for people of such an approach to the stewardship of America's land!

Furthermore, everything possible should be done to make nonreserve areas more hospitable to other species. Native vegetation should be planted to replace lawns and manicured parks, concrete lining of streams should cease, herbiciding of rights-of-way should be forbidden, hedgerows should be planted between farm fields (Elton 1958), and so on. Ideally, in many cases, corridors of restored habitat should be established to allow migration between reserves, even if it is necessary to condemn the needed land. Programs of ecosystem reestablishment should be started everywhere, returning to nature marginal farmland, overgrazed range, deserted slums, old railroad tracks, deserts churned by off-road vehicles, and so on.

All of this, of course, would solve the problem only in a context of human population control and a great reduction in the release of pollutants into the biosphere. Humanity must move promptly toward a slow reduction in its population size and quickly find ways to limit per capita impacts on environmental systems. Failing this, Earth will suffer a catastrophic loss of species and genetically distinct populations, and civilization will have committed what E. O. Wilson recently described as "the folly our descendants are least likely to forgive us."

THE STRATEGY OF CONSERVATION

How could such plans, essential for the survival of our society, be implemented? Obviously they cannot be in a world now dominated by "growth-mania" and "supply-side economics"—a world in which Western commentators complain if the Saudi Arabians are not pumping their oil "fast enough." The situation is especially difficult since tropical moist forests are the most critical ecosystems because they are the greatest reservoir of diversity (e.g., Raven 1976). These forests generally lie in poor nations where, quite naturally, conditions are not favorable to development of a "land ethic" (Leopold 1949). Furthermore, conservation movements in rich nations tend to have a local focus. There is too little knowledge or concern over the impact of the rich nations on the tropical forests. Few Americans, for example, are aware that the assault on those forests is reflected in the cheapness of their hamburgers and the many layers of cardboard in which their Japanese radios come packed.

What is required to save the remaining biotic diversity of Earth is nothing less than a dramatic paradigm shift—a transition to a "sustainable" or "steady-state" society (see summary in Ehrlich and Ehrlich 1981, pp. 242–250). Not surprisingly, the solution to this problem is intertwined with the solutions to other major human problems—economic inequity, racism, and, above all in the short term, the avoidance of nuclear war. Those who claim that all this is too idealistic must carefully consider the alternatives.

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