Trans-Amazon Highway being cut through the rain forest near Altamira, Brazil—one example of the deforestation that takes place along with traditional frontier expansion. *Photo courtesy of Nigel J. H. Smith.*

CHAPTER

2

THE LOSS OF DIVERSITY
Causes and Consequences

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Discussions of the current extinction crisis all too often focus on the fates of prominent endangered species, and in many cases on deliberate overexploitation by human beings as the cause of the endangerment. Thus black rhinos are disappearing from Africa, because their horns are in demand for the manufacture of ceremonial daggers for Middle Eastern puberty rites; elephants are threatened by the great economic value of ivory; spotted cats are at risk because their hides are in demand by furriers; and whales are rare because, among other things, they can be converted into pet food.

Concern about such direct endangerment is valid and has been politically important, because public sympathy seems more easily aroused over the plight of furry, cuddly, or spectacular animals. The time has come, however, to focus public attention on a number of more obscure and (to most people) unpleasant truths, such as the following:

- The primary cause of the decay of organic diversity is not direct human exploitation or malevolence, but the habitat destruction that inevitably results from the expansion of human populations and human activities.
- Many of the less cuddly, less spectacular organisms that *Homo sapiens* is wiping out are more important to the human future than are most of the publicized endangered species. People need plants and insects more than they need leopards and whales (which is not to denigrate the value of the latter two).
- Other organisms have provided humanity with the very basis of civilization in the form of crops, domestic animals, a wide variety of industrial products, and many important medicines. Nonetheless, the most important anthropocentric reason for preserving diversity is the role that microorganisms, plants, and animals

play in providing free ecosystem services, without which society in its present form could not persist (Ehrlich and Ehrlich, 1981; Holdren and Ehrlich, 1974).

- The loss of genetically distinct populations within species is, at the moment, at least as important a problem as the loss of entire species. Once a species is reduced to a remnant, its ability to benefit humanity ordinarily declines greatly, and its total extinction in the relatively near future becomes much more likely. By the time an organism is recognized as endangered, it is often too late to save it.
- Extrapolation of current trends in the reduction of diversity implies a denouement for civilization within the next 100 years comparable to a nuclear winter.
- Arresting the loss of diversity will be extremely difficult. The traditional "just set aside a preserve" approach is almost certain to be inadequate because of factors such as runaway human population growth, acid rains, and climate change induced by human beings. A quasi-religious transformation leading to the appreciation of diversity for its own sake, apart from the obvious direct benefits to humanity, may be required to save other organisms and ourselves.

Let us examine some of these propositions more closely. While a mere handful of species is now being subjected to purposeful overexploitation, thousands are formally recognized in one way or another as threatened or endangered. The vast majority of these are on the road to extinction, because humanity is destroying habitats: paving them over, plowing them under, logging, overgrazing, flooding, draining, or transporting exotic organisms into them while subjecting them to an assault by a great variety of toxins and changing their climate.

As anyone who has raised tropical fishes knows, all organisms require appropriate habitats if they are to survive. Just as people cannot exist in an atmosphere with too little oxygen, so neon tetras (*Paracheirodon innesi*) cannot survive in water that is 40F (4.4C) or breed in highly alkaline water. Trout, on the other hand, cannot breed in water that is too warm or too acid. And the bacteria that produce the tetanus toxin cannot reproduce in the *presence* of oxygen. In order to persist, Bay checkerspot butterflies (*Euphydryas editha bayensis*) must have areas of serpentine grassland (to support the growth of plants that serve as food for their caterpillars and supply nectar to the adults). Whip-poor-wills, red-eyed vireos, Blackburnian warblers, scarlet tanagers, and dozens of other North American birds must have mature tropical forest in which to overwinter (see Terborgh, 1980, for example). Black-footed ferrets (*Mustela nigripes*) require prairie that still supports the prairie dogs on which the ferrets dine.

This utter dependence of organisms on appropriate environments (Ehrlich, 1986) is what makes ecologists so certain that today's trends of habitat destruction and modification—especially in the high-diversity tropical forest (where at least one-half of all species are believed to dwell)—are an infallible recipe for biological impoverishment. Those politicians and social scientists who have questioned the extent of current extinctions are simply displaying their deep ignorance of ecology; habitat modification and destruction and the extinction of populations and species go hand in hand.

The extent to which humanity has already wreaked havoc on Earth's environments is shown indirectly by a recent study of human appropriation of the products of photosynthesis (Vitousek et al., 1986). The food resource of the animals in all major ecosystems is the energy that green plants bind into organic molecules in the process of photosynthesis, minus the energy those plants use for their own life processes—growth, maintenance, and reproduction. In the jargon of ecologists, that quantity is known as the net primary production (NPP). Globally, this amounts to a production of about 225 billion metric tons of organic matter annually, nearly 60% of it on land.

Humanity is now using directly (e.g., by eating, feeding to livestock, using lumber and firewood) more than 3% of global NPP, and about 4% of that on land. This is a minimum estimate of human impact on terrestrial systems. Since *Homo sapiens* is one of (conservatively) 5 million species, this may seem an excessive share of the food resource. But considering that human beings are perhaps a million times the weight of the average animal (since the overwhelming majority of animals are small insects and mites) and need on the order of a million times the energy per individual, this share might not be too unreasonable.

Yet human beings can be thought of as co-opting NPP not only by direct use but also by indirect use. Thus if we chalk up to the human account not only the NPP directly consumed, but such other categories as the amount of biomass consumed in fires used to clear land, the parts of crop plants not consumed, the NPP of pastureland (converted from natural habitat) not consumed by livestock, and so on, the human share of terrestrial NPP climbs to a staggering 30%. And if we add to that the NPP foregone when people convert more productive natural systems to less productive ones (such as forest to farm or pasture, grassland to desert, marsh to parking lot), the total *potential* NPP on land is reduced by 13%, and the human share of the unreduced potential NPP reaches almost 40%. There is no way that the co-option by one species of almost two-fifths of Earth's annual terrestrial food production could be considered reasonable, in the sense of maintaining the stability of life on this planet.

These estimates alone both explain the basic causes and consequences of habitat destruction and alteration, and give reason for great concern about future trends. Most demographers project that *Homo sapiens* will double its population within the next century or so. This implies a belief that our species can safely commandeer upwards of 80% of terrestrial NPP, a preposterous notion to ecologists who already see the deadly impacts of today's level of human activities. Optimists who suppose that the human population can double its size again need to contemplate where the basic food resource will be obtained.

A standard fool's answer to that question is that indefinite expansion of the human population will be supported by the immeasurable riches of the sea. Unhappily for that notion, the riches of the sea have been quite carefully measured and found wanting. People now use about 2% of the NPP of the sea, and the prospects even for doubling that yield are dim. The basic reason is that efficient harvesting of the sea requires the exploitation of concentrated pools of resources—schools of fishes and larger invertebrates. People cannot efficiently harvest much of the NPP that resides in tiny phytoplankton (the green plants of the sea) or in the zooplankton (animals too small to swim against the currents). Humanity appears to be already utilizing about as much of oceanic NPP as it can on a sustainable basis.

This discrepancy in the ability of *Homo sapiens* to exploit terrestrial and oceanic NPP is reflected in the general lack of an extinction crisis in the seas. Except for such organisms as some whales and fishes that are threatened by direct exploitation, animals that spend their entire lives in the open sea are relatively secure. Aside from some limited environments, such as certain coral reefs, the effects of habitat destruction are relatively small away from shorelines and estuaries. This situation could, of course, change rapidly if marine pollution increases—a distinct possibility.

The extirpation of populations and species of organisms exerts its primary impact on society through the impairment of ecosystem services. All plants, animals, and microorganisms exchange gases with their environments and are thus directly or indirectly involved in maintaining the mix of gases in the atmosphere. Changes in that mix (such as increases in carbon dioxide, nitrogen oxides, and methane) can lead to rapid climate change and, in turn, agricultural disaster. As physicist John Holdren put it, a carbon dioxide-induced climatic change could lead to the deaths by famine of as many as a billion people before 2020. Destroying forests deprives humanity not only of timber but also of dependable freshwater supplies and furthermore increases the danger of floods. Destruction of insects can lead to the failure of crops that depend upon insect pollination. Extermination of the enemies of insect pests (a usual result of ad lib pesticide spraying) can terminate the pest control services of an ecosystem and often leads to severe pest outbreaks. The extinction of subterranean organisms can destroy the fertility of the soil. Natural ecosystems maintain a vast genetic library that has already provided people with countless benefits and has the potential for providing many, many more.

These examples can be multiplied manyfold—the basic point is that organisms, most of which are obscure to nonbiologists, play roles in ecological systems that are essential to civilization. When a population playing a certain role is wiped out, ecosystem services suffer, even if many other populations of the same organism are still extant. If the *population* of Engelmann spruce trees (*Picea engelmanni*) in the watershed above your Colorado home is chopped down, you could be killed in a resulting flood, even though the *species* of spruce is not endangered. Equally, if that were the last population and it were reduced to just a dozen trees (so that, technically, the species still existed), you would not be spared the flood, and chance events would likely finish off the Engelmann spruce eventually anyway.

In most cases, numerous genetically diverse populations are necessary to ensure the persistence of a species in the face of inevitable environmental changes that occur naturally. The existence of many populations spreads the risk so that unfavorable conditions in one or a few habitats do not threaten the entire species. And the presence of abundant genetic variation within a species (virtually assured if its populations are living in different geographic areas) increases its potential for successfully evolving in response to long-term environmental changes. Today, this genetic diversity *within* species is declining precipitously over much of Earth's land surface—an unheralded loss of one of humanity's most vital resources. That resource is largely irreplaceable. Along with fossil fuels, rich soils, ancient groundwater, and mineral deposits, genetic diversity is part of the inheritance of capital that *Homo sapiens* is rapidly squandering.

What then will happen if the current decimation of organic diversity continues? Crop yields will be more difficult to maintain in the face of climatic change, soil erosion, loss of dependable water supplies, decline of pollinators, and ever more serious assaults by pests. Conversion of productive land to wasteland will accelerate; deserts will continue their seemingly inexorable expansion. Air pollution will increase, and local climates will become harsher. Humanity will have to forego many of the direct economic benefits it might have withdrawn from Earth's once well-stocked genetic library. It might, for example, miss out on a cure for cancer; but that will make little difference. As ecosystem services falter, mortality from respiratory and epidemic disease, natural disasters, and especially famine will lower life expectancies to the point where cancer (largely a disease of the elderly) will be unimportant. Humanity will bring upon itself consequences depressingly similar to those expected from a nuclear winter (Ehrlich, 1984). Barring a nuclear conflict, it appears that civilization will disappear some time before the end of the next century—not with a bang but a whimper.

Preventing such a denouement will prove extremely difficult at the very least; it may well prove to be impossible. Earth's habitats are being nickeled and dimed to death, and human beings have great difficulty perceiving and reacting to changes that occur on a scale of decades. Our nervous systems evolved to respond to short-term crises—the potential loss of a mate to a rival, the sudden appearance of a bear in the mouth of the cave. For most of human evolutionary history there was no reason for natural selection to tune us to recognize easily more gradual trends, since there was little or nothing one could do about them. The human lineage evolved in response to changes in the ecosystems in which our ancestors lived, but individuals could not react adaptively to those changes, which usually took place slowly. The depletion of organic diversity and the potential destruction of civilization may, ironically, be an inevitable result of our evolutionary heritage.

If humanity is to avoid becoming once again a species consisting of scattered groups practicing subsistence agriculture, dramatic steps will be necessary. They can only be briefly outlined here. Simply setting aside preserves in the remaining relatively undisturbed ecosystems will no longer suffice. In most parts of the planet such areas are too scarce, and rapid climatic changes may make those preserves impossible to maintain (Peters and Darling, 1985). Areas already greatly modified by human activities must be made more hospitable for other organisms; for example, the spewing of toxins into the environment (leading to intractable problems like acid deposition) must be abated.

Above all, the growth of the human population must be halted, since it is obvious that if the scale of human activities continues to increase for even a few more decades, the extinction of much of Earth's biota cannot be avoided. Indeed, since *Homo sapiens* is now living largely on its inherited capital and in the future will have to depend increasingly on its income (NPP), one can argue persuasively that the size of the human population and the scale of human activities should be gradually *reduced* below present levels. Reducing that scale will be an especially difficult task, since it means that the environmental impacts of the rich must be enormously curtailed to permit the poor a chance for reasonable development.

Although improvements in the technologies used to support human life and affluence can of course help to ameliorate the extinction crisis, and to a limited extent technologies can substitute for lost ecosystem services, it would be a dangerous miscalculation to look to technology for the answer (see, for example, Ehrlich and Mooney, 1983). In my opinion, only an intensive effort to make those improvements and substitutions, combined with a revolution in attitudes toward other people, population growth, the purpose of human life, and the intrinsic values of organic diversity, is likely to prevent the worst catastrophe ever to befall the human lineage. Curiously, scientific analysis points toward the need for a quasi-religious transformation of contemporary cultures. Whether such a transformation can be achieved in time is problematic, to say the least.

We must begin this formidable effort by increasing public awareness of the urgent need for action. People everywhere should understand the importance of the loss of diversity not only in tropical forests, coastal zones, and other climatically defined regions of the world but also in demographically delineated regions such as areas of urbanization. The geological record can tell us much about catastrophic mass extinctions of the past. That, and more intensive studies of the living biota, can provide hints about what we might expect in the future. At the present time, data on the rates and direction of biodiversity loss remain sparse and often uncertain. As a result, estimates of the rate of loss, including the number and variety of species that are disappearing, vary greatly—in some cases, as pointed out by E. O. Wilson in Chapter 1, by as much as an order of magnitude. Moreover, scientists have also differed in their predictions of the eventual impact that will result from the diminishing biodiversity. Some aspects of these challenges are explored in the following five chapters comprising this section and are reflected throughout this volume.

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