Threats to Biodiversity

Habitat destruction, mostly in the tropics, is driving thousands of species each year to extinction. The consequences will be dire—unless the trend is reversed.

by Edward O. Wilson

The human species came into being at the time of greatest biologic diversity in the history of the earth. Today as human populations expand and alter the natural environment, they are reducing biologic diversity to its lowest level since the end of the Mesozoic era, 65 million years ago. The ultimate consequences of these biological collisions are beyond calculation and certain to be harmful. That, in essence, is the biodiversity crisis.

In one sense the loss of diversity is the most important process of environmental change. I say this because it is the only process that is wholly irreversible. Its consequences are also the least predictable, because the value of the earth's biosphere (the fauna and flora collectively) remains largely unstudied and unappreciated. Every country can be said to have three forms of wealth: material, cultural and biologic. The first two we understand very well, because they are the substance of our everyday lives. Biological wealth is much less serious. This is a serious strategic error, one that will be increasingly regretted as time passes. The biosphere is on the one hand part of a country's heritage, the product of millions of years of evolution centered on that place and hence as much a reason for national concern as the particularities of language and culture. On the other hand, it is a potential source for immense unappreciated material wealth in the form of food, medicine and other commercially important substances.

It is a remarkable fact, given the interdependence of human beings and the other species that inhabit the planet, that the task of studying biodiversity is still in an early stage. Although systematics is one of the two oldest formal disciplines of biology, the other is anatomy, we do not even know the nearest order of magnitude the number of species of animals on the earth. With the help of other specialists, I have estimated the numbernc number of species that have been formally described (given a Latinized scientific name) to be about 1.1 million. Even conservative guesses place the actual number of species at four million or greater, more than twice the number described to date.

Terry L. Erwin of the Smithsonian's National Museum of Natural History believes the number of species to be even greater. With the help of co-workers, he applies an insecticidal fog to the forest canopy at localities in Brazil and Peru in order to obtain an estimate of the total number of insect and other arthropod species in this rich but still relatively unexplored habitat. By extrapolating his findings to moist tropical forests around the world and by including a rough estimate of the number of ground-dwelling species, Erwin arrived at a global total of 30 million species. Even if this number proves to be a considerable overestimate, the amount of biodiversity in the world is certain to be projected sharply upward in other, compensatory ways.

TROPICAL RAINFORESTS, such as this one in northern Costa Rica, are among the most species-rich habitats on the earth. The extraordinary biological diversity found in these forests can be explained by the fact that the most species-rich groups on the planet, the invertebrates and flowering plants, are concentrated there. The vegetation, much of it broad-leaved evergreen, is extremely lush; the tallest trees tower as much as 100 meters (100 feet) above the rain-forest floor.

Groups such as the moths and fungi, for example, are extremely rich and also very underexplored, and habitats such as the forests of the deep sea are thought to harbor hundreds of thousands of species, most of which remain undescribed. Even the number of bacterial species on the earth is expected to be many times greater than the 3,000 that have been characterized to date. To take one example, an entirely new flora of bacteria has recently been discovered living as depths of 300 meters or more beneath the sea floor near Hilo, Hawaii. Even new species of birds continue to turn up at an average rate of two per year.

Systematists are in wide agreement that whatever the absolute numbers, more than half of the species on the earth live in moist tropical forests, popularly referred to as rain forests. Occupying only 6 percent of the land surface, these ecosystems are found in warm areas where the rainfall is in centimeters or more per year, which allows broad-leaved evergreen trees to flourish. The trees typically sort into three or more horizontal layers, the canopy of the tallest species being 30 meters (about 100 feet) or more from the ground. Together the tree crowns of the several layers admit light to the forest floor, inhibiting the development of undergrowth and leaving large spaces through which it is relatively easy to walk.

The belief that a majority of the planet's species live in tropical rain-forest habitats is not based on an exact and comprehensive census but on the fact that the two overwhelmingly species-rich groups, the arthropods (especially insects) and the flowering plants, are concentrated there. Other extremely species-rich environments exist, including the coral reefs and abyssal plains of the oceans and the heathlands of South Africa and southwestern Australia, but these appear to be outranked significantly by the rain forests.

Every tropical biologist has stories of the prodigious variety in this one habitat type. From a single leguminous tree in Peru, I once retrieved 33 species belonging to 26 genera, approximately equal to the plant diversity of all of the British Isles. In 10 selected one-hectare plots in Kalimantan in Indonesia, Peter S. Ashton of Harvard University found more than 700 tree species, about equal to the number of tree species native to all North America. The current world record for a single plot (700 species) was established in 1988 by Alwyn H. Gentry of the Missouri Botanical Gardens in Peru.

Why has life multiplied so prodigiously in a few limited places such as tropical rain-forest habitats? It was once widely believed that when large numbers of species coexist, their life cycles and food webs lock together in a way that makes the ecosystem more robust. This diversity-stability hypothesis has given way during the past 20 years to a cause-and-effect scenario that might be called the diversity-stability hypothesis: fragile superstructures of species interdepend upon when the environment remains stable enough to support their evolution during the circumstances of that environment. Biologists now know that biota, like houses of cards, can be brought tumbling down by relatively small perturbations in the physical environment. They are not robust at all.

The historical diversity of life is reflected in the standing diversity of marine animals, the group best represented by fossil record. The trajectory can be summarized as follows: after the initial "Big Bang" 570 million years ago, there was a swift rise in species number in the early Paleozoic era (570 million years ago), then plateaulike stagnation for the remaining 200 million years of the Paleozoic era and finally a slow but steady climb through
the Mesozoic and Cenozoic eras to
diversity's present all-time high [see illustration at right].
BALGOLICAL DIVERSITY has increased slowly over time, set back occasionally by mass extinctions. There have been five major mass-extinction events so far: at the close of the Ordovician, Devonian, Permian, Triassic, and Cretaceous periods. The last of these is by far the most famous, because it ended the age of dinosaurs, conferred hegemony on the mammals and ultimately, for better or worse, made possible the origin of our own species. But it is a sorry event when compared with the great Permian crash some 240 million years ago, which extinguished between 77 and 95 percent of all marine animal species. As David M. Raup of the University of Chicago has observed, "If these estimates are even reasonably accurate, global biology (for higher organisms, at least) had an extremely close call." It took five million years, well into Mesozoic time, for species diversity to recover.

What lessons can be drawn from this punctuation of life in geologic time? It is clear that recovery, given sufficient time, is sometimes possible. It is also clear that in the face of mass extinctions, species can be created rapidly. A large majority of flowering-plant species have originated in a single generation by polyploidy—a multiplication of chromosome sets, either within a single individual or following the hybridization of two previously distinct species. Even geographic speciation, in which whole species evolve after being separated by a barrier such as a strait or desert, can in extreme cases lead to the evolution of new species in as few as from 10 to 100 generations. Hence, it might be argued that when a mass extinction occurs the deficit can be made up in a relatively short time. But under such circumstances pure numbers of species mean little. What matters more, in terms of the spread of genetic codes and the multiple ways of life they prescribe, is diversity at the higher taxonomic levels. Thus, the number of genera, families and so on. A species is most interesting when its traits or its unique value as a whole help to illustrate my point. In western China a new species of muntjac deer was recently discovered, which appears to differ from the typical muntjac of Asia only in chromosome number and in a relatively minor modification of the trails. Human beings intuitively value this slightly differentiated species, of course, but not nearly so much as they value the giant panda, which is so distinctive as to be placed in its own genus (Ailuropoda) and family (Ailuropodidae).

Within the past 10,000 years, biological diversity has entered a wholly new era in the turbulent history of life on the earth. This new activity has had a devastating effect on species diversity, and the rate of human-induced extinctions is continuing to increase. The heaviest pressure has hitherto been exerted on islands, lakes and other isolated and strongly circumscribed environments. Fully one half of the bird species of Polynesia have been eliminated through hunting and the destruction of native forests. In the 1800's most of the unique flora of trees and shrubs on St. Helena, a tiny island in the South Atlantic, was lost forever when the island was completely deforested. Hundreds of fish species that are endemic to Lake Victoria, formerly of great local and cultural value as food and aquarium fish, are now threatened with extinction as the result of the careless introduction of one species of fish, the Nile perch. The list of such biogeographic disasters is extensive.

The problem of island biogeography, which has been substantiated at the macro level by experiments with alterations of island biotas and other field studies, holds that species number usually fluctuates around an equilibrium point and in a forested area. For example, the species number remains more or less constant over time because the rate of immigration of new species to the island balances the extinction rate of species already there, and so diversity remains fairly constant. The relation between the theory of island biogeography and global diversity is an important one. If the area of a particular habitat, such as a patch of rain forest, is reduced by a given amount, the number of species living in it will subside to a new, lower equilibrium. The rich forest along the Atlantic coast of Brazil, for example, has been cleared to less than 1 percent of its original cover; even in the unlikely event that no more trees are cut, the forest biota can be expected to decline by perhaps 75 percent, or to one quarter of its original number of species.

I have conservatively estimated that on a worldwide basis the ultimate loss attributable to rain-forest clearing alone (at the present 1 percent rate) is from 2 to 3 percent of all species in the forests per year. Taking a very conservative figure of two million species confined to the forests, the global loss that results from deforestation could be as much as from 4,000 to 5,000 species a year. That is about one in the order of 10,000 times greater than the naturally occurring background extinction rate that existed prior to the appearance of human beings.

Although the impact of habitat destruction is most severely felt in tropical rain forests, where species diversity is so high, it is also felt in other regions of the planet, particularly where extensive forest clearing is taking place. In the U.S. alone, some 60,000 acres of ancient forests are being cut per year, mostly for timber that is then exported to Japan and other countries in the Pacific rim. Most severely affected are the national forests of the Pacific Northwest, from which some 5.5 billion board-feet of timber were harvested in 1987, and Alaska's Tongass National Forest, where as much as 50 percent of the productive forestland has been logged since 1953. Although deforestation in these areas is possible, the process of regrowth may last 100 years or more.

How long does it take, once a species is relatively securely stored, for the species to live in it to actually become extinct? The rate of extinction depends on the size of the habitat patch left undisurbed. The time span of species extinction events, the number of bird species on several continents, has been estimated. About 10,000 years ago had part of the mainland but then became isolated when the sea level rose. By comparing the number of species per island with the number of species on the adjacent mainland, Diamond and Terborgh were able to estimate the number of species each island had lost and to correlate the rate of species loss with island size. Their model has been reasonably well supported by the data on local bird faunas, and the results are sobering: in patches of between one and 20 square kilometers, a common size for reserves and parks in the tropics and elsewhere, 20 percent or more of the species disappear within 50 years. Some of the birds vanish quickly. Other persist for a while longer, the "living dead," in regions where the natural habitat is highly fragmented, the rate of species loss is even greater.

These extinction rates are probably underestimates, because they are based on the assumption that the species are distributed more or less evenly throughout the forest being cut. But actual sampling shows that these large numbers of species are confined to very limited ranges; if the small fraction of each forested habitat occupied by a species is destroyed, the species is eliminated immediately. This is especially true for the ridge top in Peru was cleared recently, more than 90 plant species known only from that locality were forever. Ecologists have begun to identify that 'biological distance' is the measure that differentiates tars that are rich in species and also in imminent danger of destruction. Northerners, who are familiar with the effect of the widespread in the tropics, has compiled a list of threatened species. One of the world's plans, Ecologists, the Chocó of Western Colombia, the uplands of Western Amazonia, the
Atlantic coast of Brazil, Madagascar, the eastern Himalayas, the Philippines, Malaysia, northwestern Borneo, Queensland and New Caledonia. Other biologists have similarly classified certain temperate forest patches, heathlands, coral reefs, drainage systems and ancient lakes. One of the more surprising examples is Lake Malawi in Zambia, where large numbers of endemic crustaceans and other invertebrates are endangered by rising levels of pollution. The world's biota is trapped as though in a vice. On one side it is being swiftly reduced by deforestation. On the other it is threatened by climatic warming brought on by the greenhouse effect. Whereas habitat loss is most destructive to tropical biotas, climatic warming is expected to have a greater impact on those of the cold temperate regions and polar regions. A poleward shift of climate at the rate of 100 kilometers or more per century, which is considered at least a possibility, would leave behind on land, and whole species ranges behind, and many kinds of plants and animals might not migrate fast enough to keep up.

The problem would be particularly acute for plants, which are relatively immobile and do not disperse as readily as animals. The Engelmann spruce, for example, has an estimated natural dispersal capacity of from one to 10 kilometers per century, so that new plantings would be required to sustain the size of the range it currently occupies. Margaret Davis and Catherine Zahnleitner of the University of Minnesota predict that in response to global warming four North American tree-species—yellow birch, sugar maple, beech and hemlock—will be displaced northward by from 500 to 1,000 kilometers. Hundreds of thousands of species are likely to be similarly displaced, and many will adapt to the changing climate, not having to move at all, and many will become extinct is, of course, unknown.

In addition, all ecologists, I include myself among them, would argue that every species extinction diminishes humanity. Every microorganism, animal and plant contains the order of one from 10 to 100 billion bits of information in its genetic code, hammered into existence by an astronomical number of mutations and episodes of natural selection over the course of thousands or millions of years of evolution. Biologists may eventually come to read the entire genetic codes of some individual strains of a few of the vanishing species, but I doubt that we can hope to measure, let alone replace, the natural species and the great array of genetic strains comprising them. The rate of evolution by natural selection may be too great even to conceive, let alone duplicate, without diversity there can be no selection (either natural or artificial) for organisms adapted to a particular habitat that then undergoes change. Species diversity—the world's available gene pool—is one of our planet's most important and irreplaceable resources. No artificially selected genetic strain is, to my knowledge, ever outcompeted wild variants of the same species in the natural environment. It would be naive to think that humanity need only wait while natural selection refills the diversity void created by mass extinctions. Following the great Cretaceous extinction (the latest such episode), from five to 10 million years passed before diversity restored to its original levels. As species are exterminated, largely as a result of habitat destruction, the capacity for natural genetic regeneration is greatly reduced. In Norman Myers' phrase, we are causing the death of birth.

Wild species in tropical forests and other natural habitats are among the most important resources available to humanity, and so far they are the least utilized. At present, less than one tenth of 1 percent of naturally occurring species are exploited by human beings, while the rest remains untapped and fellow. In the course of history people have utilized about 7,000 plant species for food, but today they rely heavily on about 20 species, such as wheat, rice and maize—plants for the most part that Neolithic man encountered hap hazardly at the dawn of agriculture. Yet at least 75,000 plant species have edible parts, and at least some of them seem demonstrably superior to crop species in prevalent use. For example, the winged bean, Psophocarpus tetragonolobus, which grows in New Guinea, has been called a one-species supermarket: the entire plant—roots, seeds, flowers, leaves—is edible, and a coffee-like beverage can be made from its juice. It grows rapidly, reaching a height of 15 feet in a few weeks, and has a nutritional value equal to that of soybeans.

Wild plants and animal species also represent vast reservoirs of potentially valuable products as fibers and petroleum substitutes. One example is the banana palm, Cordyline australis, from the Amazon basin, a palm that produces about 25 barrels of oil a year. Another striking example is the royal poinciana, Caesalpinia pulcherrima, from Java, whose leaves yield 750 gallons of oil annually. Another striking example is the royal poinciana, Caesalpinia pulcherrima, from Java, whose leaves yield 750 gallons of oil annually. (The story of cutting down tropical forests in order to grow crops or graze cattle is that after two or three years the nutrient-poor topsoil can no longer support the agricultural activity for which it was cleared.)

Thomas Elster of Cornell University has suggested that in addition to the compilation of biological inventories, programs should be established to promote chemical prospecting around the world as part of the search for new products. The U.S. National Cancer Institute has begun to do just that: that their natural products branch is currently screening some 10,000 substances a year for activity against cancer cells and the AIDS virus. It has become equally clear that biological research must be tied to zoning and other land-use planning designed not only to conserve and promote the use of wild species but also to make more efficient use of land previously converted to agriculture and monocrop timber. More efficient land use includes choosing commercial species well suited to local climatic and soil conditions, planting mixtures of species with yields higher than those of monocultures and retaining a wider range of local traits. In addition, the focus of research should move to crops and plants that are adapted to local conditions, and to crops and plants that are adapted to local conditions, and to the use of existing species, rather than to the use of existing species, rather than to the use of new species. In the end, the use of new species is likely to be less successful than the use of existing species, because of the difficulty of adapting new species to local conditions.

Effective against Hodgkin's disease and acute lymphoblastic leukemia. The income from these two substances alone exceeds $100 million a year. Five other species of Catharanthus occur on Madagascar, none of which have been carefully studied. At this moment one of the five is close to extinction due to habitat destruction.

Biological diversity is eroding at a swift pace, and massive losses can be expected if present rates continue. Can steps be taken to slow the extinction process and eventually bring it to a halt? The answer is a guarded "yes." Both developed and developing countries need to expand their taxonomic inventories and reference libraries in order to map the world's species and identify hot spots for priority in conservation. At the same time, conservation efforts must be closely coupled with economic development, especially in countries where poverty and high population densities threaten the last of the remaining wildlands. Biologists and economic planners now understand that merely setting aside reserves, without regard for the needs of the local population, is but a short-term solution to the biodiversity crisis. Recent studies indicate that even with a limited knowledge of wild species and only a modest effort, more calories can often be extracted from sustained harvesting of natural forest products than from clear-cutting for timber and agriculture. The irony of