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ABSTRACT

A key question to ask in determining whether a solution will be found to the current worldwide destruction of plant and animal life is whether people will learn to reconcile effectively the demands of environmental conservationists and developers. Probably the most immediate threat which ecological destruction poses to human welfare is shrinkage of the plant genepools available to agricultural scientists, farmers, and foresters. Additional problems are the extinction of species with economic or medical value and the ecological disturbances which result from the loss of any species. Demands for rapid economic and social development in Third World nations present particular problems for long-term environmental conservation. Unless national and international economic systems provide more opportunity for advancement, the dispossessed will naturally molest legally protected lands, trees, and animals. Environmental planners in all nations and foreign aid agencies in developed nations must incorporate concern for preservation of biological diversity into their policy decisions. A start toward the creation of needed ecological protectorates was made in 1978 when UNESCO designated 144 areas in 35 nations as part of a global network of Biosphere Reserves. The conclusion is that developers and conservationists must cooperate to develop policies to keep the biosphere in good order, slow the population growth, and satisfy people's basic needs. (Author/DB)

Disappearing Species: The Social Challenge

Erik Eckholm

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The Losses in Store

Once mainly the concern of animal lovers and bird-watchers, the worldwide loss of species now poses a major ecological and social challenge. If allowed to occur, the massive biological impoverishment projected for the next few decades will change the nature of life on this planet for all time

To most people, talk of "endangered species" evokes images of tigers under siege in Asia and cheetahs losing ground in Africa, of whales hunted to scarcity in the Antarctic and whooping cranes clinging to life in North America. For those who follow such matters, it may also bring to mind recent positive preservation developments whaling quotas, restrictions on trade in rare animal pelts, DDT bans, and international save-the-tiger campaigns, among others Even as such salvaging operations finally get under way, however, many leading biologists have begun sounding the alarm about an unsolved, unsung species problem of vaster proportions and wider implications. At risk, the scientists say, are not just hundreds of familiar and appealing birds and mammals. Examination of the survival prospects of all forms of plant and animal life—including obscure ferns, shrubs, insects, and mollusks as well as elephants and wolves—indicates that huge numbers of them have little future Not hundreds, but hundreds of thousands of unique, irreplaceable life forms may vanish by the century's end.

Within sight is the destruction of plant and animal species, and of the genetic heritage of eons they embody, on a scale that dwarfs the combined natural and human-caused extinctions of the previous millions of years. Should this biological massacre take place, evolution will

I wish to thank Thomas Lovejoy, Norman Myers, and Jacob Scherr for reviewing the manuscript

no doubt continue, but in a grossly distorted manner. Such a multitude of species losses would constitute a basic and irreversible alteration in the nature of the biosphere even before we understand its workings—an evolutionary Rubicon whose crossing *Homo sapiens* would do well to avoid.

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Estimates of the number of plant and animal species living on earth range from three million to more than ten million, with recent findings on the diversity of insects in particular supporting the higher approximation. Yet to date only about one-and-one-half million species—about 15 to 50 percent of the presumed total—have been recorded in the scientific literature, about most of these, little more is known than their appearance and location. It is likely that several million insects and plants—along with far fewer members of other animal classes—await discovery, mainly in the tropics. If current patterns of human activity continue, a good share of the unrecorded majority of species will vanish before their existence, much less their biological importance or economic utility, is established.[1]

Extinction is the ultimate fate of all species. In the late twentieth century, however, because of the accelerated spread of humans onto ever more habitats, the wide dissemination of toxic chemicals, and the callous exploitation of wildlife, the pace of species disappearance has risen sharply and undoubtedly surpasses the rate at which new species are evolving. More than half the known animal extinctions of the last 2,000 years—that is, since the first recorded extinction, which was of the European lion around 80 A.D.—have occurred just since 1900. An average of about one animal species or subspecies per decade is believed to have disappeared during the 350 years leading up to the mid-twentieth century. But currently, estimates the International Union for the Conservation of Nature and Natural Resources (IUCN), an average of one animal species or subspecies is lost each year. Overall, roughly 1,000 birds and mammals are now thought to be in jeopardy.[2]

Although endangered animals receive the greatest public attention, plant extinctions are often more significant ecologically. According to Peter H. Raven, Director of the Missouri Botanical Garden, a disappearing plant can take with it 10 to 30 dependent species such as in-

"Unknown numbers of unnamed species are disappearing in scientifically uncharted areas in the tropics."

sects, higher animals, and even other plants. Estimates of the past and current rates of plant extinctions are not available, but the IUCN's Threatened Plants Committee finds about 10 percent (20,000 to 30,000) of the world's flowering plants to be "dangerously rare or under threat." Coincidentally, in early 1978 the Smithsonian Institution listed close to 10 percent of the 22,200 plant species native to the continental United States as being "endangered" or "threatened." Half of Hawaii's native flora is thought to be imperiled; throughout the world, island plants and animals, having evolved in relative isolation, are especially vulnerable to disruption by human activities or the introduction of aggressive alien species.[3]

These estimates of species at risk understate the true problem, for they deal only with known life forms. All evidence indicates that sizable, if unknown, numbers of unnamed species are disappearing in scientifically uncharted or unmonitored areas in the tropics. In his forthcoming book, *The Sinking Ark*, wildlife specialist Norman Myers concludes that, right now, probably at least one species is disappearing each day in tropical forests alone—and that in a few more years there may well be a species lost each hour.[4]

Looking toward the century's end, Myers sees the elimination of one million species as "a not unlikely prospect." Similarly, biologist Thomas Lovejoy of the World Wildlife Fund, extrapolating current trends in population, land use, and the pollution of air and water, finds plausible a reduction in global diversity of at least one-sixth by the year 2000, which would mean the obliteration of 500,000 species based on the lowest estimates of total species numbers.[5] If these projections are even remotely close to correct, then no one can accuse the many alarmed scientists of crying wolf. The fabric of life will not just suffer a minor rip, sections of it will be torn to shreds.

The ways in which humans undermine other species' prospects are legion. The excessive hunting or collecting of animals for food, profit, or recreation is a time-honored means of extermination. Indeed, considerable evidence suggests that the demise of the large Pleistocene mammals of North America, including the woolly mammoths, horses, camels, and mastodons, was caused by Stone Age hunters who filtered across the Bering Strait more than 11,000 years ago. Today,

hunters and collectors remain significant threats to many mammals, birds, reptiles, and fishes. Both legal hunters and poachers shoot endangered animals for their hides, heads, or tusks, oversized fishing
8 fleets deplete marine organisms of various sorts, and even some unscrupulous zoo suppliers imperil rarer species. Medical researchers' need for a human-like creature on which to test a hepatitis vaccine poses a new threat to Africa's dwindling chimpanzee population. Plant collectors and dealers, too, can wreak ecological damage: Arizona's cacti have been badly depleted as a result of the growing national taste for unusual houseplants.

Wildlife losses to hunters and collectors are deliberate and thus theoretically controllable through well-enforced national and international regulations. More difficult to identify and control are the inadvertent losses that result from the human pursuit of goals unrelated to plants and animals per se. The contamination of water and air with toxic chemicals, for example, presents a diffused and unmeasured but genuine threat to nature. Publicity about the effects of DDT on falcon eggs helped spur severe restrictions on the use of chlorinated hydrocarbons in North America and Europe. Yet persistent pesticides are increasingly and often profligately applied to Third World plantations.

Manifold other poisonous effluents of industrial society are infiltrating rivers, lakes, coastal zones, and the rich estuary ecosystems from which much sea life ultimately draws its sustenance. Meanwhile, air pollutants, either blowing directly across the countryside or raining down in the form of acids, are harming vegetation and fish in large areas of the United States and Europe and in scattered areas elsewhere.

A much broader long-term threat to flora and fauna may be posed by the combined effect of certain air pollutants and the widespread cutting of vegetation itself. Scientists now warn that continued massive burning of fossil fuels and leveling of forests will, by boosting the atmosphere's carbon-dioxide content and thus disrupting the heat balance, eventually cause global temperatures to rise and climates to change. Climatic shifts could in turn wipe out many species whose lives are closely attuned to particular environmental conditions. The

indirect ecological impact on humans of such a biological disaster might possibly rival the impact of the direct agricultural losses to which most attention has so far been devoted In a similar vein, the possible human-caused depletion of the stratospheric ozone layer that has recently generated so much concern could wreak more damage in the form of ecosystem disruption than in the better-publicized form of a rising skin-cancer rate [8]

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By far the biggest single cause of extinctions over the next few decades will be the destruction of habitats As both populations and economies grow, and human settlements sprawl, undisturbed natural areas shrink. Essential wildlife breeding zones, migration routes, and browsing and hunting domains are paved, inundated with water, grazed, or plowed Forest lands are denuded by farmers, timber companies, and firewood gatherers and then are given over to cattle, crops, or non-native tree species Plant species unique to a small locality can be erased from the earth by a single bulldozer, as can the animals that feed on them, predators dependent on a lengthy food chain may disappear once the wild area around them is compressed below a critical minimum

The problem of habitat destruction exists on every continent, but it is particularly serious in the humid tropics, which is where the major species losses are predicted Viewed in terms of biological diversity, the moist tropical forests of Africa, Asia, and Latin America hold an importance far beyond the land area they occupy Suffused with exceptional amounts of light, warmth, and moisture, the tropical rain forests house a remarkable variety of ecosystems and species A single volcano in the Philippines, for example, has a greater variety of woody plant species growing on its slopes than grow in the entire United States The Amazon Basin may contain a million plant and animal species, making it the biologically richest region on earth, with Southeast Asia not far behind [9]

Probably far fewer than half the species of the humid tropics have been seen or catalogued by scientists And among tropical regions, notes botanist Ghillean T Prance, scientific knowledge about the plant life is "inversely proportional to the species diversity, with the American tropics much more poorly known than the African and

Asian tropics." Even in Africa, the best-explored of the three regions, an average of more than 200 new plant species are still collected every year. Large areas of South America remain *terra incognita* to scientists. Botanists who collected 239 plant specimens on one recent expedition along the Panama-Colombia border found one in every five to be a new species. As Peter Raven observes: "Billions of dollars have been spent on the exploration of the moon, and we now know more about the moon than we do about the rainforests of, say, western Colombia. The moon will be there far longer than these forests."[10]

The blunt truth is that huge, perhaps inexorable, pressures to exploit the remaining virgin territories of the tropics are building. Many tropical forests lie within countries that, though biologically affluent, are economically poor, and whose governments are not inclined to value abstract, long-term ecological goals above immediate economic gains. Moreover, in many tropical countries, including some where significant numbers of people have relatively high incomes, land-tenure patterns are inequitable, population growth rates are high, and prevailing development patterns are not providing nearly enough jobs.

The consequences of poverty, inequality, and rapid population growth are land-hungry people desperately trying to carve a living out of the forest, and foreign exchange-hungry governments eager to promote the rapid logging of forests. Even affluent people in faraway lands, who demand wood and agricultural products, add to the pressures on tropical ecosystems, and international corporations are well equipped to facilitate the extraction and international transfer of tropical goods. A 1976 survey by Adrian Sommer concluded that, as of the early seventies, the world's original tropical moist forests had already been reduced by more than 40 percent to a total area of 935 million hectares, and that they were shrinking by about 11 million hectares (equal to the area of Bulgaria or Cuba) each year. Many experts believe the current annual loss to be considerably higher than that. These figures do not reflect the major additional disruptions that are occurring within standing forest ecosystems.[11]

Because of this combination of powerful social and political forces contributing to the settlement or disruption of hitherto unexploited

"Affluent people in faraway lands add to the pressures on tropical ecosystems."

tropical lands, many scientists fear that little untouched rain forest will be left by the year 2000. Certainly not all the forest lands will be inhabited or treeless—and some remote regions may remain pristine. But, once disturbed, the original balance of species in a given rain- 11
forest area may be forever lost. Unlike many temperate-zone trees, which can repopulate cleared areas with seeds blown from a few uncut specimens, many tropical trees can reproduce only under the environmental conditions of the original forest, which is why rain forests have been called a "nonrenewable resource." The eminent British botanist Paul W. Richards says that the original tropical rain forest, which has "for millions of years served as a factory and storehouse of evolutionary diversity from which plants and animals . . . have migrated to populate the subtropical, temperate and colder regions," will largely disappear if present usage patterns continue for many decades.[12]

Enormous are the worldwide biological losses in store, enormous are the tangible and intangible costs to humans that will result—and enormous, too, are the social forces driving the accelerated depletion of life forms. Rising numbers of people, virtually all of them seeking ever more material goods, will inevitably put massive pressures on both the quantity and quality of wildlife habitats everywhere. But large numbers of extinctions will result directly from the efforts of the Third World's economically dispossessed to eke out a living from the land. Slowing the loss of species must therefore entail much more than the ratification of international treaties, the passage of national conservation laws, and the policing of national park boundaries—essential as all these steps are. The future shape of the biosphere will depend in good measure on the shape of political and economic policies affecting employment, land tenure, income distribution, and population growth.

Biological Impoverishment: The Human Costs

The extermination of a species seldom poses the obvious, immediate threat to human well-being that certain other kinds of environmental deterioration such as air pollution and the spread of deserts do. Yet, for a wide range of reasons, a decline in the diversity of life forms

should be of concern to everyone. Since the impending large-scale loss of species is without precedent and involves the disruption of ecological systems whose complexity is beyond human grasp, no means exist for quantifying the costs. But to be without a price tag is not to be without value. The biological impoverishment of the earth will certainly contribute to the economic, let alone the esthetic, impoverishment of humans. And what is irreplaceable is in some sense priceless

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Probably the most immediate threat to human welfare posed by the loss of biological diversity arises from the shrinkage of the plant gene pools available to agricultural scientists and farmers—a critical, if largely separable, aspect of the more general problem. While the global spread of modern agricultural methods and hybrid seeds has brought needed increases in food production, it has in many areas also entailed the substitution of relatively few seed varieties for the wide array of strains traditionally planted. At the same time, forest clearance, grazing, and the spread of cultivation onto unused lands may wipe out the wild relatives of domestic crops that still exist in some regions.[13]

Switching to more productive strains is usually necessary and socially desirable. Unaccompanied by adequate seed collection, however, such "progress" can involve the extinction of unique crop varieties that are closely adapted to the local environment and highly resistant to local pests. A half-century back, 80 percent of the wheat grown in Greece consisted of native breeds, today, more than 95 percent of the old strains have virtually disappeared, replaced by the products of modern plant science. The spread through the Middle East and Asia of new high-yielding wheat and rice varieties since the mid-sixties has inadvertently caused a drastic shrinkage of the gene pools in such traditional centers of crop diversity as Turkey, Iraq, Iran, Afghanistan, Pakistan, and India.[14]

Future agricultural progress is undermined as the diversity of genes on which plant breeders can draw declines. A locally evolved strain in some remote corner of the earth may hold the genetic key to an important agricultural breakthrough. Thus, in 1973, Purdue University scientists trying to develop high-protein sorghum examined more

than 9,000 varieties from all over the world before they discovered in the fields of Ethiopian peasants two obscure strains with the qualities they sought.[15] Who knows what other irreplaceable plant resources have quietly vanished?

Since pests, diseases, production technologies, and agricultural goals all tend to evolve over time, the maintenance of high-yield agriculture depends not only on major breeding breakthroughs but also on the routine development of new crop strains that incorporate needed traits. Yet countless locally evolved varieties, some undoubtedly with properties of huge value, are being obliterated. As British biologist J. G. Hawkes observes, the genetic diversity borne of some 10,000 years of local adaptation of ancient domestic crops such as wheat, barley, lentils, peas, maize, potatoes, and others "is now being swept away." What were once considered to be "inexhaustible gene pools are now beginning to dry up; indeed, in some cases the diversity for certain crops, such as wheat and barley in southwest Asia, African rice in west tropical Africa, and fruit trees in southwest and southeast Asia, has almost completely disappeared." Likewise, the wild relatives of many commercial crops are disappearing just as their use in plant breeding is accelerating.[16]

Even as it insidiously reduces the future options of plant breeders, the planting of large areas to genetically uniform crops also involves serious short-term risks. The more genetically homogeneous the fields, the higher their vulnerability to large-scale losses to pests, diseases, and weather abnormalities. The Irish potato famine of the 1840s provides the classic example of the dangers of monocultures; the decimation by corn blight of 15 percent of the U.S. corn crop in 1970 and repeated insect devastations of Southeast Asian rice crops over the last decade have underscored the continuing folly of reliance on a narrow genetic base in agriculture.[17]

The preservation of diverse crop strains is, in theory, one of the more manageable aspects of biological impoverishment. Huge numbers of seeds can, with proper care, be stored in seed banks and made available to breeders as the need arises. In response to the alarms sounded by Australian plant geneticist Otto H. Frankel and others, a start toward halting the erosion of the earth's crop genetic resources

has, in fact, been made in recent years. An International Board for Plant Genetic Resources, headquartered in Rome and funded by governments and U.N. agencies, is promoting a variety of regional seed-
14 collection, storage, [redacted]entation schemes. With the quickening of scientific interest [redacted]c diversity have also come new genetic salvaging efforts by various national governments. While the global problem is far from solved, and germ plasm already lost cannot be retrieved, the outlook for the conservation of varied crop genetic resources is now brighter than it was a decade ago.[18]

Some scientists have proposed the establishment of zones of crop diversity, farming areas within which cultivation of a traditional assortment of crop varieties would be maintained so that their evolution would continue. A potato-diversity preserve, for instance, could be established in the Andean highlands where the potato originated.[19] However desirable such on-farm conservation may be, though, it will be both expensive and socially difficult to implement and can, in any case, involve only a small portion of the extant crop varieties. Hence it cannot be relied upon as the primary means of protecting agriculture's genetic future.

The future of productive foresty, like that of agriculture, is undercut as the genetic resources on which tree breeders and planters can draw vanish. Unlike agriculture, most forestry still depends on trees growing in the wild. As expanding demands for lumber, firewood, and paper press against the shrinking forests, the areas planted to well-selected fast-growing species will have to increase rapidly. Yet land clearing, timber harvesting, and the spread of genetically homogeneous tree plantations are all contributing to the disappearance of tree varieties of potential value to foresters as they strive to boost forest-land productivity.

One serious constraint on the development of forest industries in the tropics, for example, has been the relative dearth of coniferous species—best suited for most construction and industrial purposes—in the world's lower latitudes. Highland Guatemala is one of the few tropical areas to sport an abundance of conifers, species whose study and dissemination could possibly open the door for lucrative forest industries elsewhere in the tropical world. But in view of the rapid de-

"Only a small fraction of the earth's plant species have been screened for medically useful ingredients."

struction of Guatemala's mountain forests, warns forester Thomas T. Veblen, "it is likely that the Guatemalan populations of several of these conifers will disappear before their potential as exotic plantation trees is ever tested . . . If the initiation of a program aimed at the preservation of this gene pool is delayed much longer, the options available to future generations for afforesting much of the world's tropical highlands will be tragically reduced "[20] As with food crops, the collection of the seeds of as many tree species and varieties as possible is essential. Given the length of time it takes to grow a tree and test its qualities, however, seed collections cannot provide anywhere near the research benefits that living forests can

In an age of plastics and moon shots, few people can appreciate the extent to which humans remain dependent on natural products. Although their harvest is seldom recorded in economic statistics, wild plants and animals are essential to the lives of many traditional peoples in Africa, Asia, and Latin America, this consideration alone justifies serious concern about the degradation of natural areas But in even the most technologically advanced societies, plants and animals serve a variety of crucial industrial, medical, and other purposes. Numerous industrial gums, oils, dyes, and pesticides come from natural sources and many additional uses for wild species are constantly being discovered. The nearly extinct manatee, a large aquatic mammal, provides by virtue of its prodigious appetite a means for clearing irrigation canals choked by the water hyacinths now proliferating in tropical waterways And in the lowly pokeweed has been found a snail-killing chemical of use in the battle against schistosomiasis, a snail-borne parasitic disease that debilitates more than 200 million people [21]

Some species of proven economic value are under acute pressure, but perhaps the greatest social costs of species destruction will stem from future opportunities unknowingly lost. Only a small fraction of the earth's plant species have been screened for medically useful ingredients. Nearly all the food humans eat comes from only about 20 crops, but thousands of plants are edible and some will undoubtedly prove useful in meeting human food needs In a 1975 publication, *Underexploited Plants with Promising Economic Value*, the U.S National Academy of Sciences drew attention to 36 little-known species with

tremendous potential utility. It is a statistical certainty that socially significant uses will be discovered for many tropical plants as more are studied.[22]

No one can confidently say that products of comparable significance to rubber (which following its discovery in South America became one of the world's most important commodities) or quinine (derived from cinchona bark and for the 300 years up to World War I the only effective remedy for malaria) remain to be discovered. But no one can confidently say they don't, either.

Medical researchers' interest in plant-derived or plant-inspired drugs has risen to new heights over the last few decades. The mid-twentieth century discovery of a series of "wonder drugs" from natural sources (some of which had been used for centuries by traditional folk healers) has "sparked a revolution," says Harvard botanist Richard Evans Shultes. "It crystallized the realization that the plant kingdom represents a virtually untapped reservoir of new chemical compounds, many extraordinarily biodynamic, some providing novel bases on which the synthetic chemist may build even more interesting structures." An analysis of American prescriptions written in 1967 revealed that 25 percent contained agents derived from higher plants, 12 percent were derivatives of microbes, and 6 percent had agents of animal origin. Hence, more than 40 percent of the modern pharmacopoeia originated in nature rather than in chemists' laboratories.[23]

Realizing that, as one observer put it, "the humblest bacterium can synthesize, in the course of its brief existence, more organic compounds than can all the world's chemists combined," scientists are stepping up their investigations both of ancient folk medicines and of hitherto unused plants with intriguing chemical properties. The plant kingdom is receiving special attention from cancer researchers, who hope to find tumor-inhibiting agents in nature that can provide prototypes or ideas for synthetic anti-cancer chemicals.[24] Tens of thousands of plant species have been screened for this purpose and a number have shown promise, but the search has really only just begun—and it is being undermined by the extermination of unexamined species.

One plant-derived class of compounds of particular medical value and promise is alkaloids. These biologically active chemicals include narcotics such as morphine (found in opium) and nicotine; hallucinogens such as LSD and mescaline, poisons such as that in Socrates' hemlock brew; and a host of medicines used as painkillers, antimalarials, cardiac and respiratory stimulants, blood-pressure boosters, pupil-dilators, muscle relaxants, local anesthetics, tumor inhibitors, and anti-leukemic drugs. Once extracted from plants, many alkaloids have served as models for synthesis by chemists, some, however, are still obtained solely from natural sources. A tropical periwinkle plant, for example, provides a chemical used to fight leukemia, the plant is becoming rare in some areas because its high commercial value has prompted over-collection. Curare, a muscle relaxant widely used by anesthesiologists in the operating room, is distilled from vines in Upper Amazonian jungles by Indians, who have long poisoned their arrow tips and blowgun darts with the concentrated extract. Curare is, now in short supply, perhaps—buyers theorize—because people have begun harvesting immature vines or perhaps because the Indians skilled at locating and processing the vines are themselves growing scarce.[25]

Only about 40 percent of the 4,350 alkaloids known as of 1970 had been chemically analyzed at that time. More significant, only a small proportion of the world's plants have yet been screened for alkaloid contents. Alkaloid-bearing plants appear twice as frequently in the tropics as in the temperate zones, so major losses of potentially valuable compounds are inevitable as tropical habitat destruction spreads.[26]

The extermination of a unique, unstudied organism or ecosystem involves an irreversible loss to science. Basic knowledge about living systems and ecological interrelationships, of which a great deal remains to be gleaned, is no mere academic concern, it underlies our understanding of how the world works and what our place in it is. Lost scientific opportunities, like lost economic opportunities, are by nature incalculable but they are nonetheless real. We cannot know how long our understanding of evolution would have been set back, for instance, had the unique fauna of the Galapagos Islands been destroyed before young Charles Darwin about to piece the mosaic

together under the visual stimulation of the isolated Galapagos life forms, visited the islands on H.M.S. *Beagle* in 1835.

18 Beyond particular economic or scientific losses caused by the destruction of particular species lies a more basic threat: the disruption of ecosystems on which human well-being depends. No matter how sophisticated modern technologies may seem, human livelihoods are ultimately grounded in biological processes, enmeshed in ecological webs so intricate that the consequences of destabilization cannot often be foreseen. Crushed by the march of civilization, one species is likely to take others with it, and the ecological repercussions and rearrangements that follow may well endanger people. One common result of ecosystem degradation, for example, is an increase in the prevalence of small, hardy, fast-reproducing plants and animals of the sorts usually considered pests. The consequences of an adverse change in an ecosystem, such as the overrunning of crops by pests or the sudden spread of a disease, may easily be perceived as matters of chance when in fact they are the direct results of human actions.

No one could claim that all existing species are ecologically essential to the viability of human culture. But scientists cannot yet say where the critical thresholds lie, at what level of species extermination the web of life will be seriously disrupted. Identifying and protecting those species whose ecological functions are especially important to human society are crucial tasks facing both scientists and governments. In the meantime, prudence dictates giving existing organisms as much benefit of the doubt as possible.

Apart from the direct social losses or ecological disruptions they may entail, species extinctions often signal other fundamental ecological or social trends meriting attention. At the broadest level, extinctions serve as markers of the general reduction in the capacity of the earth's biological systems to provide goods and crucial, if subtle, ecological services. Noted biologist George M. Woodwell calls this ongoing biological degradation "one of the great issues of our time, right up there with nuclear proliferation, the stability of government and health care. The ultimate resource is the biota—there is no other. And we are destroying it."[27]

"Prudence dictates
giving existing organisms
as much benefit of the doubt
as possible."

The disappearance of fish from New England lakes, for example, has served notice on Americans that pollutants spewed into the atmosphere can come back down to earth in the form of acid rain. The plight of the snail darter, a tiny fish that will disappear if a dam on the Little Tennessee River is completed, is a reminder that the last stretch of wild river in that part of the country could disappear—certainly a loss worth contemplating. On a more practical plane, multiple extinctions in the humid tropics herald a process of forest destruction that may affect the world's climate.

The disappearance of an individual species, then, may be less significant in itself than in what it says about our stewardship of resources. Ecologist Lee M. Talbot observes that "the status of wildlife tells us something about how well we manage our environment. Through work in some 90 nations I have come to the conclusion that the status of a nation's wildlife resource is a good indicator of the status of that nation's lands and natural resources in general." The way people treat nature may even provide an indication of the way people treat one another, as Daniel Oduber Quiros, then President of Costa Rica, argued while accepting an international conservation award in early 1977. "I believe that when nations have shown little or no respect for the environment and where the natural environment has been ruined or lost in an over-hasty and uncoordinated exploitation of the Earth's resources, human relations inside those nations are also likely to be characterized by a lack of respect for individuals and for human rights."[28]

The array of economic, scientific, and ecological arguments for biological conservation together build an indisputable utilitarian case for alarm over current trends. Still, many situations are bound to arise in which human activities threaten species of little, if any, currently provable material importance. Conservationists need not give up such struggles but, if their credibility is to be preserved, they must be frank about their motivations and realistic in their assessments of the probable costs of extinction. Charles Warren, Chairman of the Council on Environmental Quality, points out that "we do not really have to reach into left field" to defend species-protection measures, "the current rate of species depletion is so totally without precedent in the

[illegible]ory of evolution as to evoke concern in any thoughtful, scientifically aware person."[29]

20 In the long run, philosophical considerations may prove as potent as economic considerations as a force for species preservation. Biologist David W. Ehrenfeld of Rutgers University, noting that "practical" arguments on behalf of a species sometimes fail to hold water, calls for an explicitly *non-economic* approach to the issue: "Long-standing existence in nature is deemed to carry with it the unimpeachable right to continued existence. Existence is the only criterion of value. . . ." Ehrenfeld dubs this ethical justification for preservation the "Noah Principle," after its first known executor.[30] Faced with an endangered species problem of unparalleled dimensions, Noah took into his ark "everything that creepeth upon the earth." No animal was excluded because it lacked economic value—though Noah apparently did not appreciate the biological importance of plants.

Otto Frankel has urged the worldwide adoption of an "evolutionary ethic"—a determination to "try to keep evolutionary options open so far as we can" without forcing "undue deprivations on those least able to bear them."[31] The alternative to living by such a creed is destroying many of those habitats and species that do not seem immediately useful; humans would appoint themselves as the ultimate arbiters of evolution and determine its future course on the basis of short-term considerations and a great deal of ignorance. When the issue is framed this way, as it should be, how many will dispute the desirability of such an ethic?

Conservation and Social Justice

The descent from the airy summit of evolutionary ethics to the everyday human landscape of the tropical world is a jarring one. Sad but true, to be rich in birds, insects, trees, and fungi is not necessarily to be rich in food and consumer goods. Far from it many of the countries in which the great species wipeout will soon unfold are burgeoning with the destitute. Alongside biological wealth live hundreds of millions of people who get by on no more than a few hundred dol-

lars' income a year, who watch three or four of every ten babies die by age five because their families cannot afford a decent diet and proper sanitation; whose opportunities for a better life are choked off by rigid structures of political and economic privilege; and whose numbers are likely to double over the next quarter-century. As long as it exists, their social deprivation will corrode the foundations of even the best-designed species-preservation structures.

For governments of countries at every income level, immediate economic gains hold greater political appeal than any long-term, unquantifiable values that might be sacrificed as a result of their pursuit. When nations are poor, the temptation to choose short-term material benefits regardless of future ecological costs often proves irresistible. Local entrepreneurs or multinational companies who offer to turn standing forests into salable timber, and unoccupied lands into beef-producing pastures, are seldom turned down by governments eager to acquire foreign exchange. Likewise, besieged by restless legions of the jobless and the landless, governments are naturally inclined to transform remaining pristine areas into agricultural settlements—and, in fact, often lack the ability to prevent such transformations even when they want to.

Consider, for example, the fate of the Kutai Nature Reserve in East Kalimantan, Indonesia, which constitutes one of the last redoubts of the orangutan. Since 1970, one logging firm has opened its concession in the eastern third of the 3,000 square kilometer "reserve," while another has begun cutting four access roads through the forest. Logging disturbs the rain-forest ecosystem directly, but, equally important, jobs and roads attract people: the number residing within the reserve's boundaries jumped from 1,000 in 1968 to some 8,000 in 1977. Logging concessions have been granted within designated nature reserves elsewhere in Indonesia, too.[32]

Despite the countervailing pressures, a few tropical countries including Colombia, Costa Rica, Peru, Thailand, and Venezuela have already established sizable, if not yet adequate, natural reserves. Leaders in wildlife-rich Kenya and Tanzania have also initiated farsighted conservation policies. Kenya has gone so far as to ban all sales of animal-derived souvenirs. Encouraged and assisted by private inter-

national conservation organizations and U N. agencies, other Third World countries have taken first steps toward the preservation of their biological heritages by designating limited areas for protection.

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Yet even in countries with excellent conservation laws and ample nature reserves—let alone in countries where political leaders lack enough appreciation of biological diversity to act on its behalf—the permanent protection of large natural areas will be feasible only if the deeper socioeconomic forces that imperil them are dispelled. Whatever the proclamations from national capitals, and whatever the economic progress registered in aggregate GNP accounts, as long as large numbers are denied the means to make a decent living the nature reserves will be in jeopardy Illustrating this point even as he stressed his own commitment to the preservation of African wildlife, Chief Gatsha Buthelezi, political leader of the KwaZulu "Homeland" in South Africa, recently said, "More and more of my people . . . see my enthusiasm for the wilderness getting less and less relevant to the major issue of their survival "[33]

Reviewing the outlook for Venezuela's tropical rain forests, Lawrence S. Hamilton of Cornell University describes well the preservation dilemmas faced there and in many other much poorer countries In the face of rapid population growth, high unemployment, and rising numbers of landless peasants, Venezuela's remaining virgin woodlands are falling fast. Shifting cultivation, the extension of grazing by large landowners, and government-sponsored land settlement are the primary means of "planned" destruction. But since authorized conversions of forest lands into agriculture cannot keep up with the demand, illegal land clearing by shifting cultivators is rampant. According to a Venezuelan analyst, "there are 30,000 campesino families living within the National Parks, Forest Reserves, Wildlife Refuges and Protected Zones. This illegal squatting then becomes *de facto* agricultural land and is subsequently legalized " The problem of land protection is intensified by an unstoppable influx of land-hungry Colombian squatters.[34]

Adequate protection of Venezuela's preserves is not likely to be achieved, notes Hamilton, with "stiffer fines, more laws, and more wardens. The laws are adequate, and there are fines mandated for the

illegal *conuco* [shifting cultivator]. But the illegality is seldom faced, and for very compelling reasons." The integrity of the preserves could be enforced only at gunpoint. Neither the local officials, who know that the invader "is not really an evil fellow, but is simply trying to feed his family and make a living," nor national politicians, who cannot relish the political repercussions of massive, violent land evictions, are likely to carry out such a task. And who is to say that they should so long as the economic system offers the squatters no alternative means of making a living?

Current socioeconomic trends likewise imperil the spectacular wildlife of the East African savannas—the zebras, elephants, lions, and gazelles that symbolize Africa's biological richness to many. While great international attention has been accorded the threats posed by ivory and skin poachers, a far greater, more insidious threat to African wildlife is the continuous loss of habitat to human settlements. The large game parks of Kenya and Tanzania do not cover sufficient areas by themselves to prevent the depletion of many species, yet humans are closing in around their boundaries. And, more ominous, considerable popular sentiment exists within those countries to reduce the size of the protected areas. Future national leaders may well lack the present leaders' determination (or ability) to resist such pressures. Noting the exceptionally high rates of population growth and unemployment and the severe overcrowding of traditional farmlands in East Africa, Norman Myers writes that "much wildlife outside the parks could be diminished by 1980, many parks themselves could be impoverished by 1990, and few parks could survive at all by the year 2000." Unless some fairly drastic changes in the region's development and demographic patterns occur, a wild community that constitutes one of the world's great treasures may simply be overwhelmed by human activities.[35]

Beyond hand wringing about the population explosion, many conservationists distraught over Third World species losses have paid little attention to the socioeconomic structures and human plights underlying current nature destruction. Some tend to perceive wildlife prospects largely in terms of the degree to which governments legislate proper conservation laws. While such legal measures are obvi-

ously essential, an accurate long-range perspective must also incorporate analysis of the economic policies affecting human prospects.

24 Accustomed to perceiving species-protection battles in North America and Europe as battles against mindless development, many may find it hard to devote attention and energy to the Third World battle for rapid economic development—albeit development of an ecologically sustainable, socially sensitive sort. However, the ultimate fates of thousands of plant and animal species will turn not only on what happens in the comparatively tidy worlds of scientific research and Presidential decrees, but also on what happens in the confused, conflict-ridden arenas of social and economic change.

Unless national and international economic systems provide many more people with land or jobs, the dispossessed will naturally covet and molest "legally protected" lands, trees, and animals. Similarly, if rapid population growth in tropical countries is not soon slowed, human pressures to exploit virgin territories will overwhelm even the most stalwart conservation efforts. Success in bringing down birth rates, however, is also at least partly dependent on more general social progress. Immediate human survival needs will always take precedence over long-term environmental goals. Clearly, the struggle to save species and unique ecosystems cannot be divorced from the broader struggle to achieve a social order in which the basic needs of all are met.

"In wildness is the preservation of the world," sermonized Henry David Thoreau in 1851, encapsulating a philosophy that has suffused Western nature-conservation efforts since then. Reflecting on the psychic anomie of an acquisitive society estranged from its natural roots, he observed that "the mass of men lead lives of quiet desperation." Today's Third World, of course, bears little resemblance to blooming nineteenth-century America, the quiet desperation suffered by hundreds of millions is of a more basic sort, one not much salved by the contemplation of turtles and ants. Even so devout a nature disciple as Aldo Leopold (himself a patron saint of modern wildlife conservation) admitted that "wild things had little value until mechanization assured us of a good breakfast."[30] Present circum-

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stances necessitate a complement to Thoreau's dictum. In broadly shared economic progress is the preservation of the wilderness

Setting Priorities and Paying the Price

Considering the geography of imperiled species, of human poverty, and of human demography, one thing is clear: some level of species extinction is inevitable, particularly in the tropics. The urgent tasks confronting those who care about such things are the setting of global preservation priorities and the marshaling of resources to insure that the more critical species and ecosystems are protected. Thomas Lovejoy laments that "limited resources of manpower and money are in fact forcing us into employing on a planetary scale an environmental form of triage, the practice evolved by Allied forces in World War I of sorting the wounded into three groups: those likely to die despite medical care, those so lightly injured as to probably recover without care, and the remainder on whom medical resources were concentrated."[37] Galling as it sounds to anyone steeped in the mysteries of biology, consciously writing off some life forms in order to save many more may be the best among unpleasant alternatives.

Even a triage strategy of nature conservation, however, is merely a holding action, a means of buying time until the fundamental threats to species are brought under control. Until population growth rates plunge, until ecologically reckless consumption and production patterns are curbed, and until the fruits of economic growth are more widely shared, the world conservation cause will remain imperiled. On the other hand, realistic, socially sensitive conservation, development, and population policies can conceivably hold the ultimate losses to a level that, though not desirable, is at least not likely to prove disastrous.

To recognize the inevitability of further human-caused extinctions is not to sanction their blithe acceptance. Given the extent of our scientific ignorance, practical as well as ethical reasons exist for a presumption of value for every species, however obscure. Furthermore, richer countries can afford to virtually halt exterminations within their borders without imposing serious hardships on anyone,

if only they can muster the will to do so. The U.S. experience with its 1973 Endangered Species Act, which forbids any federal action that would destroy a species listed as imperiled, well illustrates the feasibility of such a pro-life approach. Of some 4,500 federal projects scrutinized in accordance with the Act, about 200 have involved potential conflicts with species preservation, but, in nearly every case the conflict has been readily defused through simple modifications in project plans. Only three cases have not been resolved administratively and have gone to court, and in only one case—that pitting the snail darter against the partially constructed Tellico Dam in Tennessee—has a serious impasse developed. Though this latter conflict and the potential for more like it have received great publicity, overall the Act has worked smoothly and without imposing great social burdens.[38]

Certainly conflicts between planned economic activities and the habitat needs of seemingly useless species are bound to occur from time to time in developed countries. But such cases will be relatively unusual and can be judged as they arise; by and large, richer countries can easily afford to give every species the benefit of the doubt as a matter of course.

It is in the Third World, where massive disruptions of wild habitats are unavoidable, that the most difficult choices must be made. Scientists and governments need somehow to identify the endangered areas and species of greatest importance to humanity and then do what is necessary to preserve them. The World Conservation Strategy being prepared by the IUCN, with the assistance of the U.N. Environment Program and the World Wildlife Fund, represents an initial step toward this goal. The economic and ecological significance of various species and ecosystems must, despite the awesome knowledge gaps, be weighed in order to rationalize the allocation of conservation resources.

Although scientists have long recognized the need for a broader concern with habitat preservation, most protection efforts in the past have been pursued on a species-by-species basis. Considerable resources and, in some cases, worldwide public attention have been devoted exclusively to the salvation of, for example, the tiger or the

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bald eagle. In regions where few animals are in jeopardy, or in cases of species of great esthetic, economic, or ecological importance, such an approach may still make sense. Campaigns centered on a well-known animal can generate sizable public donations and interest, and can lead to governmental conservation policies that in turn help preserve the domains of countless species with less popular appeal.

Plants or animals endangered by hunters, collectors, or fur and ivory traders can only be protected on a species-by-species basis. Improper exploitation of wildlife within countries must, in the first place, be controlled by national governments. However, the Convention on International Trade in Endangered Species of Wild Fauna and Flora, which came into effect in 1975, is potentially a powerful tool against biologically myopic practices. The Convention, now signed by nearly 50 countries, prohibits or regulates trade in live specimens and product derivatives of listed plants and animals. Unfortunately, however, dozens of countries whose participation matters have not yet ratified the Convention. The delinquent nations include many species importers such as Italy, Japan, the Netherlands, and Spain, and many potential species exporters such as Colombia, Kenya, Mexico, Sudan, Thailand, and Uganda.[39]

While a special conservation focus on important individual species will and should continue, the inadequacy of that approach in the face of today's challenge must be recognized. Worldwide, the number of jeopardized species is simply too great for the standard protection methods to be applied effectively. The major threat to most species today—the destruction of habitats supporting large numbers of interdependent species—cannot be analyzed or halted using a species-by-species approach. Moreover, because they live near the top of food chains, the larger animals that enjoy the greatest public affection may be less vital to the fates of other species than are many less visible plants and animals. The overriding conservation need of the next few decades is the protection of as many varied habitats as possible—the preservation of a representative cross section of the world's ecosystems, especially those particularly rich in life forms.

A start toward the creation of the needed ecological protectorates has been made under the auspices of UNESCO. As of mid-1978, 144

areas in 35 countries had been officially recognized by UNESCO as part of its global network of Biosphere Reserves. These areas, which are managed by individual countries, are intended to include a representative array of the world's biotic communities, including both untouched and modified zones. The reserves will help protect biological and genetic diversity while providing scientists with opportunities for basic research and comparisons of environmental trends among regions.[40]

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While an encouraging development, the Biosphere Reserve system is far from complete. Even in the United States, where 29 areas have been declared reserves under the program, the coverage of ecosystems is wanting and should, many involved scientists feel, be extended to some 20 additional areas. In general, the humid tropical forests are badly underrepresented in the UNESCO program as well as among other types of reserves.[41] Now needed is a forward strategy by which reserve needs are identified country by country and then governments are encouraged to establish them. Otherwise, this or any other reserve program could wind up merely putting an international stamp on preexisting national parks and on the accidental remnants of ill-planned land-use patterns.

Although it could stand as a bulwark against extreme biotic impoverishment, even a well-conceived and protected system of Biosphere Reserves would not be sufficient to prevent widespread extinctions; additional reserves of various sorts will be needed in most countries. Protection policies need both to set aside samples of unique ecosystems and to preserve large numbers of species, and striving toward these two goals can require different strategies. The protection of species inhabiting small enclaves as part of unique local ecosystems may depend on the establishment of numerous relatively small protectorates. Thus, a Venezuelan botanist has identified 64 areas in his country's rain forests alone that he thinks are sufficiently unique to merit preservation. At the same time, the survival of most tropical species may be better served by setting aside fewer, larger areas within which thinly spread plants and animals exist in numbers large enough to insure reproduction and continuing evolution.[42]

Given the mounting socioeconomic and demographic threats to conservation, biological reserves cannot be successfully established and managed in isolation from local society. Rather, they must be planned within the context of broader regional development. In many cases, reserves can be demarcated in areas that ought to be set aside anyway for other good reasons, such as watershed management, the protection of indigenous tribal cultures, or city folks' recreation. To the extent compatible with biological goals, economic uses such as selective forestry, game cropping, or tourism can be allowed; where more pristine conditions are necessary, unused zones can be surrounded by lightly exploited buffer areas. Ecologically sound uses of forests by native peoples can often be allowed to continue without sacrificing conservation goals. The use of nature reserves by nearby school systems can be encouraged, perhaps thereby helping schools to perpetuate rather than eradicate the extensive botanical and zoological knowledge of traditional tropical cultures. Overall, the more that natural areas are integrated into regional economic and cultural life, the more the underlying pressures to destroy them will be dissipated.

Both national planners and foreign aid agencies need to incorporate concern for the preservation of biological diversity into their decisions. Endangered species are too often solely the province of scientists, while economists and politicians go about their work oblivious to the hidden ecological costs of agricultural, forestry, and other development schemes. Regional development plans need to include provision for the protection of natural diversity from the beginning. Also, formal procedures by which aid and planning agencies can scrutinize proposed projects for possible impacts on endangered species, and can modify plans to minimize such impacts, are needed everywhere.[43]

Because so much responsibility for preserving the earth's genetic heritage falls to poorer countries, the possibility of distributing the costs of conservation among nations has naturally arisen. The general need for cost-sharing in cases of local environmental measures that have global benefits was aired at the 1972 Stockholm Conference on the Human Environment. More recently, the need to apply this principle to the species problem has been articulated.[44]

In a general sense, of course, a development process protective of natural diversity is likely to bring the greatest lasting benefits to a nation; biological conservation is enlightened self-interest. Furthermore, some of the destruction of tropical trees and animals is simply a consequence of the greed of well-off entrepreneurs, such destruction requires law enforcement, not international compensation. Yet specific conflicts between development imperatives and conservation needs do arise, and where large numbers of people are desperately poor, the eventual benefits of conservation may understandably lie beyond the horizon of public perception. To a hungry person, a loaf of bread today is worth far more than the theoretical future rewards of biological diversity.

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Those concerned about the depletion of species will sometimes, in effect, be asking tropical countries to leave untapped the economic potential of sizable areas, and to pass up possible development projects such as a dam that would inundate a unique habitat but would produce needed power and food. In the United States, the recent halt in construction of the Tellico Dam (which is of slight economic importance) out of concern for the snail darter has engendered widespread public resentment. Can it be surprising, then, if people living at subsistence level in Thailand or Zaire do not happily forsake the benefits of a new dam, road, or plantation simply because some plant or animal species might perish?

This predicament could be at least partially untangled through the international sharing of the costs of habitat protection, by which wealthier nations would contribute to conservation-related expenses in poorer countries. If the world's extant species and gene pools are the priceless heritage of all humanity, then people everywhere need to share the burdens of conservation according to their ability to do so. Not only do people in developed countries share the long-term benefits of tropical conservation, but they also, because of their penchant for consuming tropical agricultural and forest products, share responsibility for tropical ecosystem destruction. Moreover, international corporations and investors are major agents and beneficiaries of tropical forest exploitation. Foreign capital accounts for more than two-thirds of the investment in Amazonian land development.[45]

"People everywhere need to share the burdens of conservation according to their ability to do so."

Calling for the internationalization of conservation costs is, of course, easier than devising realistic measures for doing so. Means for assisting countries with the direct expenses of nature protection—research, training, land purchases, administration of parks and preserves—are not hard to identify. Already a variety of private organizations such as the World Wildlife Fund, the IUCN, the Nature Conservancy, and the New York Zoological Society are helping countries with research and the development of conservation infrastructure. Official governmental aid for nature conservation also exists to some degree. The U.S. Fish and Wildlife Service assists wildlife projects in several developing countries, as does the Peace Corps, while United Nations and bilateral aid agencies have occasionally supported wildlife and forest conservation projects. But biological diversity has not yet become a customary concern of major aid agencies.

Effective and fair measures for offsetting the broader development potentials lost when large, usable areas are set aside are more difficult to imagine. International tourism can sometimes help parks pay their way, but its contribution is likely to be significant in only a few regions that enjoy spectacular scenery or wildlife. Sometimes, moreover, the economic benefits of tourism may be captured by too few local people to compensate the majority for lost opportunities.

In the long run, the only workable answer lies in the wider arenas of economic progress and reform. If international aid and trade policies, and local social policies, can promote broad-based development without destroying the natural environment in the process, then the need for international conservation aid will gradually disappear. Equitable economic progress will provide alternative livelihoods for people who might otherwise endanger nature reserves. It will also allow people to take a farsighted view of the importance of biological diversity—and only a local public that cares and that can afford to act on behalf of its concern can save a nation's biological heritage.

Once priority areas for protection are identified and demarcated, the rapid, socially equitable development of other areas must be pursued. If undertaken within the context of a sound regional development plan, measures often anathema to conservationists such as agricul-

tural intensification, the planting of fast-growing trees, and even industrial development may all serve the long-term interest of biological preservation. Similarly, international trade policies that boost employment and incomes in tropical countries can, when buttressed by proper land-use planning, serve the conservation cause.

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All over the world, developers and conservationists have long been at loggerheads, but this will have to change. Economic progress and stability are threatened by the degradation of the earth's living resources. Yet keeping the biosphere in good order will not be possible unless people's basic needs are satisfied and population growth is quickly slowed. The eventual tripling in human numbers projected by many demographers would simply be incompatible with the preservation of needed natural diversity. Locally and internationally, economic orders must be created that are at once ecologically and socially sustainable. Developers and conservationists need each other if the ultimate goals of either are to be met, for biological impoverishment and human impoverishment are inextricably intertwined.

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44. Yvonne I. Nicholls, *Source Book Emergence of Proposals for Recompensing Developing Countries for Maintaining Environmental Quality* (Morges, Switzerland: IUCN, 1973), Scott MacLeod, *Financing Environmental Measures in Developing Countries The Principle of Additionality* (Morges, Switzerland IUCN, 1974), Norman Myers, "An Expanded Approach to the Problem of Disappearing Species," *Science*, July 16, 1976.

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45. Prance, "The Phytogeographic Subdivisions"

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