

Humanity Confronts Its Handiwork: An Altered Planet: Rio delegates ...

By WILLIAM K. STEVENS

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Humanity Confronts Its Handiwork: An Altered Planet

Rio delegates plan talks on preserving the web of life.

By WILLIAM K. STEVENS

HUMANS have always exploited nature in the belief that the all-encompassing biosphere — the seamless, wondrously resilient fabric of life, land, water and air — was so vast and enduring that people could never do it basic harm.

Events of the last decade have shattered that comforting perception. The moment of awakening may have come in the mid-1980's when governments finally accepted and acted on the evidence that waste industrial chemicals were weakening the stratospheric ozone shield that protects living things from biologically harmful ultraviolet rays.

But that is almost the least of it. People have now transformed the biosphere on so many fronts, scientists say, that Homo sapiens rivals grand forces like the movement of continents, volcanic eruptions, asteroid impacts and ice ages as an agent of global change.

The transformation has sharply escalated in both scale and pace since World War II. And it is raising serious questions not only about the ability of nature to sustain the global economy, but also about the health and future of the biosphere itself. That is why delegates from around the world are preparing to gather at an "Earth Summit" early next month in Rio de Janeiro.

There are many reasons for concern:

¶ People have transformed or manipulated ecosystems constituting about half the planet's ice-free land surface and have made a significant impact on most of the rest.

¶ They have appropriated to their own use about 40 percent of the photosynthetic energy produced by plants.

¶ They have steadily reduced the number of other species in the world through pollution, hunting and destruction of natural habitat. Now, as the inroads become deeper and more widespread, many biologists fear that human activity could bring about a mass extinction of epic scale, wiping out 25 percent of the world's remaining species in the next 50 years.

¶ By burning coal, oil, natural gas and trees they cut down, humans have altered the global flow of energy within the biosphere. Atmospheric concentrations of heat-trapping carbon dioxide have increased by 25 percent since pre-industrial times. That is well above levels recorded at any other time in the last 160,000 years, which is as far back as scientists have been able to track the trend. No end to the buildup is in sight. If it remains uncontrolled, scientists warn, a disruptive and possibly catastrophic warming of the earth could take place.

¶ Global population, which stood at 2.5 billion only 40 years ago, is expected to reach 6 billion by the year 2000 and swell to perhaps 10 billion 60 years from now.

Delegates to Rio hope to sign legally binding treaties to cope with the

threats of climate change and species extinction. The final round of talks on climate is to conclude at the United Nations in New York this week. The last round of biodiversity talks starts next week in Nairobi, Kenya.

The Rio delegates also hope to adopt a statement of principles and an agenda for action to prevent broad damage to the biosphere while accommodating the economic needs of the surging population.

The question of limits to economic and population growth has come to the fore once again in connection with the summit. But this time it has been joined by the newer and more pressing question of the degree to which the biosphere is in jeopardy. Scientists are still struggling toward an

answer in each case.

Until now, humans have always been able to push back the physical limits imposed on their expansion by the rest of the biosphere. When limited food supplies have threatened to check the proliferation of people, for instance, people have employed technology and social organization to

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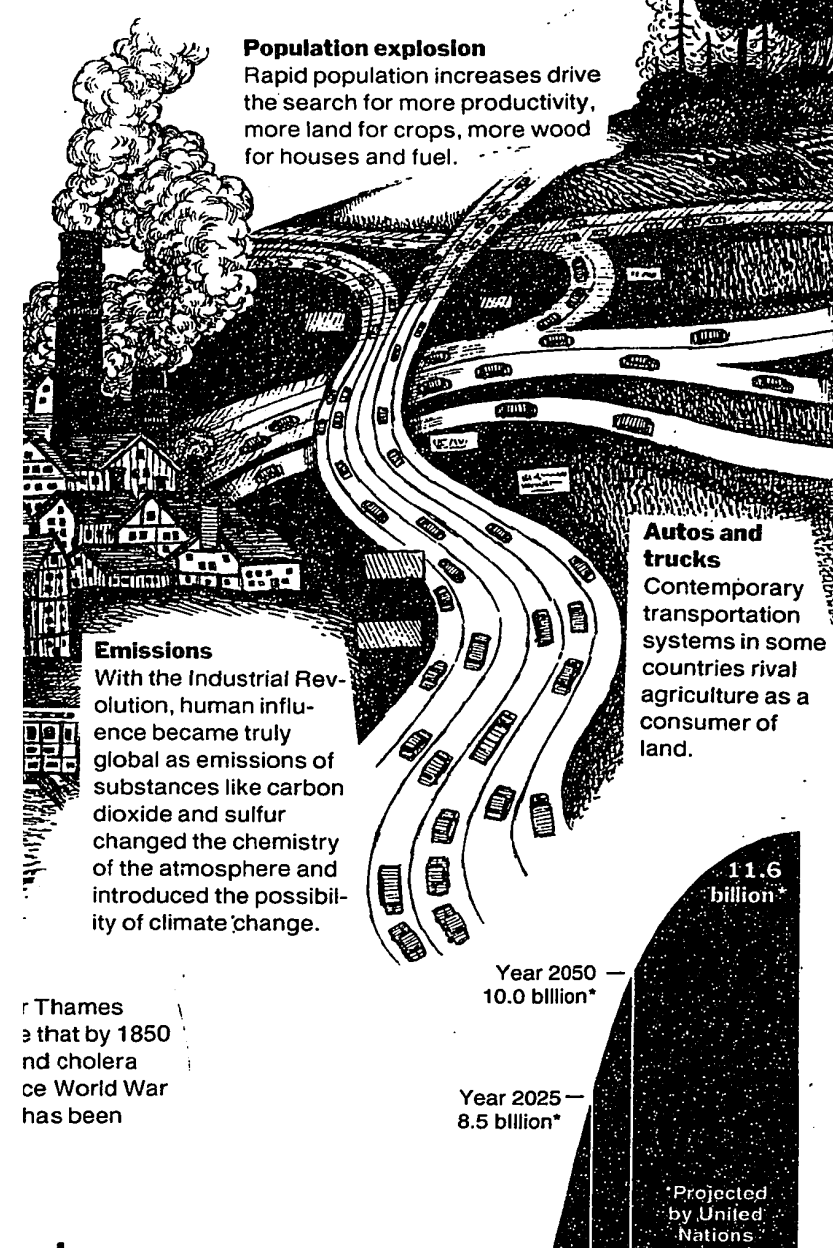
The growth of cities

In 1900, 16 cities had one million or more inhabitants. By 1990, 276 cities have reached that population.



Water pollution

So fetid had the River Thames become from sewage that by 1850 all the fish had died and cholera plagued London. Since World War II, however, the river has been restored to health.



Population explosion

Rapid population increases drive the search for more productivity, more land for crops, more wood for houses and fuel.

Autos and trucks

Contemporary transportation systems in some countries rival agriculture as a consumer of land.

Emissions

With the Industrial Revolution, human influence became truly global as emissions of substances like carbon dioxide and sulfur changed the chemistry of the atmosphere and introduced the possibility of climate change.

Year 2050 — 10.0 billion*

Year 2025 — 8.5 billion*

11.6 billion*

*Projected by United Nations

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grow crops and then clear forests, plow grasslands and, finally, harness science to agriculture. Humanity has not repealed the laws of ecology, but it has bent them; it continually expands to fill its ecological niche, then stretches the niche — at some cost to other elements of the biosphere.

Capacity for Growth

Is the capacity of the earth to accommodate human growth infinite? No, argue Donella H. Meadows, Dennis L. Meadows and Jorgen Randers, three authors of the "limits to growth" thesis propounded 20 years ago under the sponsorship of the Club of Rome, an informal group of academics, civil servants and business leaders. The thesis, based on computerized simulations of the workings of the global ecosystem, held that limits to growth on the planet would be breached within a century and that a sudden and uncontrollable decline of population and industrial capacity would ensue. Damage to the biosphere's natural resources were one element in the predicted collapse.

In a new book called "Beyond the Limits" (Chelsea Green Publishing Co.), based partly on updated computer simulations, the three authors argue that if human activity continues as at present, it will "overshoot" the carrying capacity of the biosphere and precipitate a collapse within the next few decades.

The result, they write, would be "a permanently impoverished environment and a material standard of living much lower than could have been possible had the environment never been overstressed."

The new analysis puts more emphasis on deterioration of the biosphere, and Dennis Meadows said that it convinced him that less time is available to halt the expected collapse than had earlier been thought. Twenty years ago, he said, "it seemed to us there was a period out to 2030 or 2040 in which to fashion a sustainable society." Now, he said, it looks as if a new set of attitudes and policies are not in place in the next 20 years, it will be too late to avoid an eventual collapse.

Are Limits Real?

The original limits-to-growth thesis drew sharp criticism and dissent, and the updated one is likely to provoke argument as well. Indeed, Allen Sinai, chief executive officer of the Boston Company Economic Advisors, an economic analysis group, took issue with its forecast of overshoot-and-collapse in a debate on the subject a few weeks ago in Cambridge, Mass. The debate was organized by Earthwatch, a Boston-based scientific research and education organization. The earth's carrying capacity is "roughly infinite over the time span of relevance to most of us, which would be 50 to a hundred to 150 years," Dr. Sinai said.

He did not discount "the very real effects" of population and economic growth on the physical world in the short term. But "again and again," he said, the market system has "stretched limits which appear finite to roughly infinite," frustrating Malthusian predictions of disaster.

But no one knows the capacity of the biosphere to sustain humanity's expansion. "We have yet to see a cogent analysis of what the real, sustainable carrying capacity of the earth is for people," said Dr. Daniel

Botkin, an ecologist at the University of California at Santa Barbara.

Scholars have a better fix on the ways in which human activity is transforming the biosphere, even though they have only recently begun looking at the question systematically.

No Immediate Danger

Contrary to widespread popular perception, they say, the earth itself is in no danger at the hands of humanity, and life itself is not about to be wiped out. Grand movements of the continents, shifts in the earth's position relative to the sun that bring on ice ages, global temperatures higher than any contemplated in the foreseeable future, bombardment of the planet by debris from space — all have transformed the earth in the past without destroying the planet or extinguishing all life.

Nor are humans the only species that has altered the biosphere. The earth's original atmosphere, for instance, was far different from today's. But about 2 billion years ago, photosynthesizing microbes that lived on hydrogen began to break down water and expel oxygen as a byproduct. Oxygen was toxic to most other organisms then alive, and they perished as atmospheric oxygen built up. The ultimate result was the creation of a new, oxygen-rich atmosphere that supports today's animal kingdom.

Nevertheless, the extent of change wrought by humans "is enormous; you can't get away from it," said Dr. B. L. Turner 2d, a geographer at Clark University in Worcester, Mass., who directs a new program based at Clark on human transformation of the earth. The most recent and comprehensive inventory of biospheric changes caused by humans was published in 1990 under the auspices of Clark. In it, a wide range of experts in the physical and social sciences from around the world described the last 300 years of change.

"Humankind has altered or transformed virtually every element of the biosphere," Dr. Turner, Dr. Robert W. Kates of Brown University and Dr. William C. Clark of Harvard University wrote in the first chapter of the voluminous report, "The Earth as Transformed by Human Action" (Cambridge University Press, 1990).

The face of the earth, the 1990 report said, bears the most visible and oldest marks of change, although the more recent and more subtle changes in the flows of the biosphere's energy and chemicals may be more profound.

Alterations to the face of the earth have been going on "a bit longer than most people realize," Dr. Turner said. For instance, one quarter of the deforestation that has now taken place in the world had taken place by 1700, and 75 percent by 1915.

But in most cases, at least half the biospheric change caused by humans has taken place since World War II. This is especially true of the byproducts of the consumption-oriented industrial societies: emissions of carbon dioxide and other gases that trap heat in the atmosphere, chlorofluorocarbons that weaken the protective ozone layer, nitrates that alter patterns of plant growth and sulfates that cause heat-reflecting clouds to form and acid to pollute water and soil.

Some changes analyzed in the study are decelerating even while others speed up. Humans increasing-

Pollution and deforestation are changing how the planet works.

ly alter the distribution of water in the biosphere by withdrawing more and more of it for their own use, for instance, and carbon dioxide continues to build up in the air. But some changes are decelerating because awareness of harmful impacts has led to regulation. One example is the successful effort to reduce emissions of lead, sulfur and carbon tetrachloride. Now that the world has formally agreed to phase out the manufacture of ozone-destroying chlorofluorocarbons, they are expected in time to diminish as a problem.

Moreover, the global pattern of biospheric transformation is uneven. Much land in the industrialized countries has reverted to forest, for example, as those countries have moved toward zero population growth and the area devoted to farming has declined. But in the developing countries, where population is surging and industrialization is only now taking hold, forests are being cleared at an increasingly rapid rate to provide both farmland and lumber.

The effects of the changes are also

expected to vary regionally, with winners and losers emerging. If the human population were ever to plunge sharply because there were no longer enough resources to sustain it, "you wouldn't see a global crash," Dr. Botkin said. "You'd see it in one region or another." The Clark study warns that "regional population declines are possible, potentially brutal and even likely accompaniments" to the achievement of zero population growth globally.

Similarly, some cold regions might benefit, or suffer less, from global warming while others would suffer catastrophic drought or flooding from rising sea levels. Developing countries would be hardest hit in both instances, experts believe.

What of the future? Demographers do not expect the global population to stabilize until it reaches 11 billion to 12 billion more than a century from now, and even this projection assumes that fertility rates eventually stabilize at replacement level — an insecure assumption. Some analysts say the increase would be accompanied by a tripling or quadrupling of agricultural production and a sixfold to eightfold increase in energy use. Dr. Turner and his colleagues say that this analysis suggests that "the enormous transformations of the last three centuries will be doubled, trebled or more in the centuries to come."

But surprises are virtually assured.

"The very best scientists of any time," they wrote, "may only poorly understand the fundamental processes governing nature, society and the relationships between them."

And even if fears about the biosphere's health are genuine, they said, "the gloomiest of forecasts may not be realized because society takes them seriously and acts upon them."

Population

Pressure Is Building

THROUGHOUT most of history, humans have been a quite minor presence on the planet. Only 200 million people were alive at the time of the birth of Christ. By the time Europeans first settled in America 1,600 years later, the world population had grown to 500 million. But the human population spurted to 1 billion in 1850, more than doubled by 1950 and then more than doubled again, to 5.3 billion, in just the next 40 years. This post-Industrial Revolution expansion — and especially the last 50 years — is generally held responsible for most of the stress humans have put on the biosphere.

Demographers say that though

women have been having fewer children since 1950, improved health and control of disease have caused death rates to plummet, so that global population increased. At the same time, population growth feeds on itself: more people means more women of childbearing age.

The United Nations now projects that if fertility ultimately stabilizes at a replacement rate of about 2.06 births per woman, the global population will reach 10 billion in the year 2050 before leveling off and stabilizing at around 11.5 billion soon after 2200. But those numbers could vary greatly if fertility rates turn out to be higher or lower. At a rate of 2.5 births per woman, the U.N. calculates, world population would reach 28 billion in 2150. At a rate of 1.7, which a few industrialized countries have achieved, it would reach 7.8 billion in 2050 but then fall to 4.3 billion a century later.

Economics and Population

According to conventional wisdom, a country's population will stabilize as its economy develops and living standards rise. This "demographic shift," as it is called, has already taken place in industrialized countries, where the fertility rate is generally at or below replacement level.

But the shift is only starting in developing countries of the Southern

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... Whose Vast Resilience Is Stretched to the Limit

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Hemisphere, where fertility rates, while dropping in many instances, are still double and even triple those, in the affluent countries of the North. As a result, the developing countries in 1990 accounted for 77 percent of the global population; by 2025, they are expected to account for about 85 percent. The U.N. projects that more than 60 percent of these will be urban dwellers, as compared with 37 percent in 1990.

Because the rural dwellers of developing countries rely for their direct sustenance largely on ready-at-hand renewable resources like trees, soil and water, growing population puts increasing pressure on the local biosphere. Forests are cut for wood, soil is depleted, water is withdrawn at ever-rising rates. In an anxious quest for income, many of these countries are also cutting some of their forests for commercial sale.

Perhaps a billion people remain desperately poor in these circumstances of mismatched resources and population, slowing the onset of the demographic shift. Many of these are moving to increasingly overcrowded and misery-racked cities in their search for sustenance.

Agriculture

Revolution Has Slowed

TEN thousand years ago in the Middle East, humans first freed themselves from dependence on what they could glean from the wild. By cultivating grains for the first time, they were able to expand food supplies so that an unprecedented growth in population was made possible.

For millennia, farmers sustained population growth mainly by clearing and cultivating new lands. The clearing escalated about three centuries ago, and since then there has been a 450 percent increase in the world's cultivated acreage, from a total area equivalent to Argentina to an expanse as large as South America.

Almost all prime agricultural land is now under cultivation. And although forests are being cleared at a rapid rate, scientists say, the land now being freed for farming is of marginal productivity and will have relatively little impact on future food production.

Moreover, since World War II, agriculture, deforestation and overgrazing have left an area about the size of China and India combined with moderately to severely diminished soil quality, reducing overall productivity.

The Green Revolution, based on higher-yield seeds and fertilizer, largely overcame these limitations starting in the 1960's and 1970's, enabling the world's farmers to sustain the doubling of the global population that began after World War II.

High-yield strains of wheat and rice bred in the world's agricultural laboratories doubled and tripled harvests in much of the developing world. So abundant did the harvests become that world food prices declined by more than 20 percent in the 1980's.

Sub-Saharan Africa is the main exception to the rule. It is the only region in the world with declining food production. It relies most heavily on imported food and a higher proportion of its people are malnourished than for any other region.

But out-and-out famine as a result of underproduction has largely disappeared. World hunger today is caused mostly by political upheaval, ineffective distribution of food and inability of the poor to buy it.

Yet the demand for basic food grains could double by 2020, and the ability of agriculture to keep pace with the demand is being called into question. Some neo-Malthusians insist that mass starvation is on the horizon, while some economists counter that human ingenuity will come through as it always has.

Even some who have brought the Green Revolution about, however, acknowledge that it has made its biggest and easiest gains, and that the challenge ahead appears formidable.

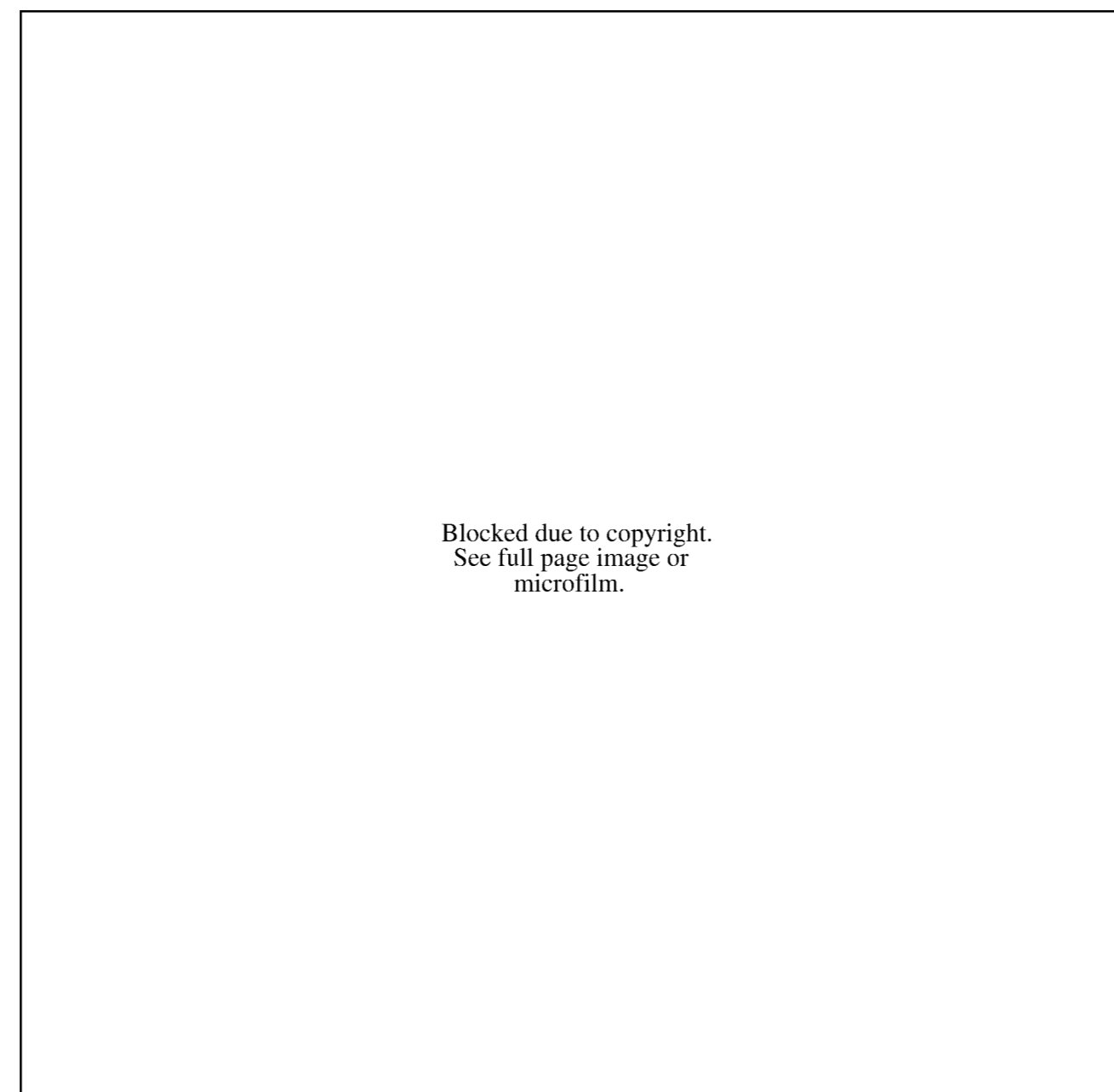
Side Effects of Production

"The task will not be an easy one," said Dr. Donald L. Winkelman, the director-general of the International Maize and Wheat Improvement Center in Mexico, where the Green Revolution's "miracle wheat" was developed. The Green Revolution has entered a new and slower phase, he said, one in which increased production will depend on relatively simple measures like more intensive use of fertilizers, more efficient water use and fast-maturing varieties of plants that allow multiple crops.

Intensive use of synthetic chemicals runs the risk of further polluting water supplies through runoff, and a number of advocates urge the adoption of alternative methods of cultivation that rely on organic fertilizers and natural pest controls. But alternative agriculture is making inroads slowly.

Many scientists say that a variety of highly productive new strains of crops might be developed, but there are widespread fears that the natural genetic material from which they might be created is rapidly disappearing.

Farmers, as they embrace the Green Revolution, are abandoning traditional crop strains that constitute part of this genetic capital. And the United Nations Food and Agriculture Organization warned recently that global agriculture could be threatened by the extinction of 40,000 important plant species in the next 60 years unless conservation measures are immediately stepped up.



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Species

The Signs Of Danger

IN THE last 600 million years, the earth has experienced five big extinctions of life, usually linked to climatic change, in which 35 percent to 95 percent of all species then on the planet disappeared. Scientists know from fossil records that in each case it took 10 million years or more for the earth to regain its biological diversity.

Humans may now be precipitating an extinction of comparable scale, many biologists fear. Some economists argue that the fears are based on insubstantial evidence, and a few biologists say they may be exaggerated. But most biologists who have studied the situation believe the threat to species diversity is a clear and present danger.

As people alter or obliterate natural ecosystems to plant crops, harvest trees and build cities and towns, they destroy species habitat. Eventually a species that lives in a given kind of habitat will be doomed to extinction if enough patches of habitat disappear.

Globe-traveling humans have also introduced countless species into new habitats around the world, where they tend to choke out native species. Few areas on earth have been unaffected by this redistribution of plants and animals. Many animals have already been hunted to extinction. Others, like the rhinoceros and the African elephant, are threatened by hunting today. The Mediterranean Sea and parts of the Pacific and Indian Oceans are so heavily fished that fish populations can no longer withstand the pressure, the United Nations Food and Agriculture Organization says, and pressure is nearly as heavy in some other oceanic areas.

Diversity of Life

No one can say for sure how many species are being doomed. But Dr. E. O. Wilson, a Harvard University biologist, has determined on the basis of field observations that when a patch of habitat is reduced by 90 percent, the number of species living in it eventually declines by about half. Using this formula, Dr. Wilson has calculated that at the rate at which tropical rain forests are being destroyed, 10 percent to 22 percent of rain forest species will be lost in the next 30 years because of habitat destruction alone.

The rain forests contain about half the plants, animals and microbes on earth. A quarter or more of the planet's species could be eliminated in 50 years, Dr. Wilson said.

How many species this amounts to is unknown, for the simple reason that the vast majority of all living species have yet to be discovered. About 1.4 million have been named, but biologists say there may be as many as 10 million, or even 100 million undiscovered species. The overwhelming majority are not charismatic species like elephants and whales but obscure but essential invertebrates and microbes that undergird the web of life. "The life of this planet," Dr. Wilson said, "is largely unexplored." If he and others are right, much of life could vanish before scientists can even name it.

What does it matter? Apart from the value attached to life in general, natural ecosystems provide the materials of human sustenance. That is where crops originally came from. Forests contain untapped riches in the form of medicines. But more than that, scientists say, natural ecosystems are such an essential part of the biosphere that mass extinctions could undermine its functioning. It is now widely recog-

nized, for instance, that the diversity of life interacts with the oceans and the atmosphere in regulating climate, that it is essential in creating soils and holding them in place, that it cleanses waters of pollution and maintains a microbial standoff that keeps harmful pathogens under control.

Scientists do not know at what point a gradual loss of species results in the disintegration of ecosystems, or at what point the loss of ecosystems begins to affect the overall health of the biosphere. But many argue that it is dangerous to take chances.

Forest

Chain-Saw Progress

OF ALL the differences humans have made in the face of the Earth, perhaps none is so striking as the disappearance of forests. People have long been cutting down trees, but only in recent decades have they become alarmed at the scope and rate of deforestation.

Trees play a vital role in the maintenance of the biosphere. They hold soil in place, preventing erosion and the silting of rivers. They absorb water and give off moisture, helping to recycle water. They absorb vast amounts of heat-trapping carbon dioxide and lock it up in their cells. And they contain a disproportionate share of the world's living species.

Estimating the extent of forest cover and of deforestation is chancy, since many forests regenerate and are in constant flux.

In fact, deforestation of temperate-zone forests in the industrialized countries has reversed in this century as marginal farm land is taken out of production and trees reclaim it. There were an estimated 7.7 million square miles of forest in the developed nations in 1900, and about 8 million in 1985.

Pressure on Forests

But the population explosion in the developing countries has intensified the pressure on forests there, which are one of the last sources of fuel and of new pasture and arable land, however marginal. The advent of the chain saw, truck and tractor have made it immeasurably easier to clear trees. As a result, according to United Nations estimates, an area of tropical forest larger than the state of Florida is disappearing each year.

Scientists estimate that about half the forest cover of the developing world has vanished in this century, and the rate of tropical deforestation is believed to have increased by 50 percent in the 1980's.

Worldwide, scientists say, there has been a net loss of more than 3 million square miles of forest, an area roughly equal to the 48 contiguous states of the United States. About half the loss has come since 1850. Figures on deforestation vary somewhat, but experts agree that trees are being destroyed on a large scale, and many believe the rate in the tropics is accelerating.

Assuming that about 3 million square miles of forest have been lost, that would be 12 to 13 percent of the pre-agricultural worldwide total. Forests may therefore cover an area 85 to 90 percent as large as they did 10,000 years ago. Scientists nevertheless raise two main alarms.

First, some 25 percent of the heat-trapping carbon dioxide released into the atmosphere as a result of human activity has come from deforestation. While the burning of fossil fuels will continue to be the main source of carbon dioxide buildup, accelerating deforestation adds substantially to the atmospheric total.

als are used for agriculture, about 25 percent for industrial use and the rest for domestic purposes. Experts expect withdrawals for farming to increase slightly by the end of this century and withdrawals for industrial use to double. Most of the increase will be in the developing countries. Water use is stabilizing in the industrialized countries and is actually expected to decline slightly in the 1990's.

Water Supply Problems

The vagaries of rainfall make the distribution of water uneven related to human need. Water is chronically short in many areas of sub-Saharan Africa, threatening the ability of agriculture to keep up with population. Supplies of water are beginning to fall behind demand in northern China, and the World Resources Institute says shortages could reach crisis proportions in the Middle East before this decade is out. Shortages have become a familiar and serious problem in the southwestern United States, particularly in California.

In their thirst, humans have greatly altered the distribution and quality of fresh water on the planet, most of which is found in river basins. They have submerged an area the size of France in reservoirs, disrupting the flow of rivers and transforming their ecosystems. They have polluted more than enough river water to fill Lake Superior. And typically, they have caused the amount of choking sediments to triple in large rivers and to increase eightfold in smaller ones in crowded regions.

The World Resources Institute says that in general, river water quality as measured by the biological demand for oxygen has improved in industrialized countries over the last 20 years because of better sewage treatment.

In the developing world, water quality is difficult to determine with precision because of a lack of information. But there appears little doubt that it is deteriorating there, especially around urban areas. Industrial discharges are usually poorly controlled, according to the World Resources Institute, and few cities in the developing countries treat their sewage.

Both pollution and development have had a heavy impact on many river ecosystems, and the rivers also carry pollution to coastal areas, where they affect coral reefs and the breeding grounds of marine life.

Atmosphere

Potential Disaster

GLOBAL warming is the most far-reaching transformation wrought by humans because it could catastrophically magnify other changes as well — if it develops as many scientists fear.

Atmospheric levels of some gases that trap heat in the atmosphere, mainly carbon dioxide and methane, are rising steadily as a result of human activity like the burning of fossil fuels. But scientists agree on little else beyond that.

They have not yet fully understood the myriad atmospheric interactions that are touched off when these "greenhouse" gases trap heat. The ultimate heating depends on the degree to which these interactions cancel each other out. But with that caveat, an international group of scientists convened by the United Nations predicts that if humans continue to pour greenhouse gases into the air at the present rate, the average surface temperature of the globe will rise by 3 to 8 degrees Fahrenheit some time in the next century. In comparison, the average temperature of the earth has

risen by 9 degrees since the depths of the last ice age.

Whether a human-induced warming has already begun is unclear. The 1980's were an unusually warm decade, and 1990 and 1991 were the warmest years recorded, globally, since surface-temperature records have been kept. As provocative as this change is, it falls well within the natural swings of climate variability.

Warming, at least in the lower range of the prediction, could well benefit some people, scientists say. Higher concentrations of carbon dioxide, for example, stimulate crop growth. Some areas of the world would probably receive increased rainfall, making them more fertile. Some would enjoy longer growing seasons in regions where it is now too cold for maximum farm production. The cities of the industrialized North would experience a more salubrious winter climate, while still able to insulate themselves from summer's heat.

But there is also a long list of possible catastrophes, especially if warming develops in the high end of the predicted range. As glaciers and ice caps partially melt, according to the United Nations forecast, the level of the oceans would rise by about two feet by the end of the next century. This would place many coastal cities in jeopardy, inundate many low-lying, populous areas in countries like Egypt and Bangladesh and devastate coastal wetlands.

Redistribution of Water

Warming would pour more energy into the climate system, and some studies show that the result would be more frequent and more disastrous storms.

While some areas would receive increased rainfall, others, particularly in the interior of continents, would probably get less. This global redistribution of water would subject some areas to disastrous flooding. In others, drought would devastate agriculture, and some studies show that drought generally would become more frequent.

One recent study suggests that agricultural yields would increase in the lower ranges of the predicted warming but decline in the higher ranges, and that farming in industrialized countries would fare better than in the developing world.

Developing countries, according to a U.N. study, would generally be the most vulnerable to climate change because they depend more on agriculture, forests and other natural resources. People in many developing countries already live on the margins of existence, and their plight would be intensified.

Even if humans were able to adapt, many scientists say, natural ecosystems would not easily be able to do so. While nature has adapted to climate change many times in the past, the rate of change was much slower then, taking place over hundreds or thousands of years. Global warming would take place over mere decades, and ecologists say that many ecosystems would be torn asunder as temperate-zone trees, for example, would be unable to migrate to friendly climates fast enough. Many climate-sensitive habitats could be destroyed, hastening the extinction of species. One study suggests that as much as 40 to 60 percent of the planet's vegetation could be disrupted, and the web of life with it.

How all of this might actually play out remains to be seen. But one conclusion seems inescapable:

By altering the chemistry of the atmosphere, humans have launched out into unexplored territory.