Macalester International

Volume 6 *Nature, People, and Globalization* Article 7

Spring 5-31-1998

The Global Environment: Opportunities or Constraints?

Thomas E. Lovejoy

THE GLOBAL ENVIRONMENT: Opportunities or Constraints?[1]

Thomas E. Lovejoy

In 1996, the National Medal of Science was awarded to a remarkable woman, Ruth Patrick, for her pioneering work on the ecology of rivers. Patrick showed that the numbers and kinds of species in a river (species in general, but in particular of diatoms, little algae which build gorgeous silica boxes) directly reflect the state of a river. If the species are present at something approximating normal diversity and abundance, the river is in pretty much a natural or "healthy" state. If not, the river ecosystem is stressed and the actual species present are very precise indicators of the kind or kinds of stress involved.

What Ruth Patrick established, and what almost all environmental science and management is based upon, is that there is an incontrovertible link between the "brown" (pollution) issues and the "green" (biodiversity and conservation) issues. Stated another way, environmental problems are generally considered problems *because* they affect biological systems.

The preceding is by way of stating that a biologist's-eye view of the human-environment dilemma is a highly appropriate one. That is basically what I will be presenting in this essay. No organism can exist without affecting its environment, so the question before us is not whether people should affect the environment or not, but rather in what ways and to what degree. So the issue of society and environment is complex from the very outset.

Biological diversity is a term dating from 1980 and is meant to encompass the variety of life on earth. Most easily thought of as the variety of species, plants, animals, and microorganisms, it is also intended to encompass variety at the genetic level as well as at the ecosystem and the landscape levels. As an environmental problem, loss of biological diversity is not only a problem in itself—i.e., the extinction of species and loss of variety at other levels—but it also essentially integrates all other problems, as Ruth Patrick's principle defines. What this means is that loss of biological diversity is the most sensitive measure of environmental change and deterioration. It also means that addressing biological diversity loss is enormously complex and challenging because resolving all the other kinds of problems has to be part of the solution.

I. What Is Happening to Biodiversity?

Current causes of biodiversity (the shorthand term for biological diversity) loss include overexploitation, habitat destruction, and habitat fragmentation. Overexploitation includes overhunting, overfishing, and overharvesting. Examples include the tree for which Brazil is named and which was highly prized for its purple dye—so much so that by the end of the colonial era, it was essentially commercially extinct. Another is the passenger pigeon, which once had populations in the billions and flocks that darkened eastern North American skies for hours on end. Part of its survival strategy was the unpredictability of its roosts from year to year. That worked fine until it had a predator in the form of humans, who had the telegraph and railroad. When Britain built its great natural history museum in South Kensington in the last decades of the nineteenth century, each of its gateposts was ornamented with a species typical of a different biogeographic region, with the passenger pigeon representing North America. In 1914, the last passenger pigeon died in the Cincinnati Zoo. "Martha," as she was named, is permanently on exhibit at the National Museum of Natural History at the Smithsonian.

Just as biodiversity is most easily understood in terms of loss of species, so is the full impact of environmental change most easily understood with the extinction of a species; it is therefore worthy of a brief digression. Qualitatively, it is apart from other forms of change because of its finality. It is the end of 3.5 billion years of evolution. Each and every organism—redwood, bison, or person—is a biological blueblood descended from microbes. Personally, I believe we should really hesitate every time we are about to put an end to a species and a 3.5-billion-year history. Often, however, we aren't even aware that species are becoming extinct — and that we are responsible for that extinction.

In the late seventeenth century, the dodo — a large, clumsy, flightless bird — became extinct. In *The Song of the Dodo*, David Quammen imagined what it might have been like for the last member of that species:

> Imagine a single survivor, a lonely fugitive at large on mainland Mauritius… Imagine this fugitive as female. She would have been bulky and flightless and befuddled—but resourceful to have escaped and endured when the other birds didn't. Or else she was lucky.
>
> Maybe she had spent all her years in the Bambous Mountains along the southeastern coast where the various forms of human-brought menace were slow to penetrate. Or she might have lurked in a creek drainage of the Black River Gorges. Time and trouble had finally caught up with her. Imagine that her last hatchling had been snarfed by a feral pig. That her last fertile egg had been eaten by a monkey. That her mate was dead, clubbed by a hungry Dutch sailor, and that she had no hope of finding another. During the past half-dozen years, longer than a bird could remember, she had not even set eyes on a member of her own species.
>
> *Raphus cucullatus* had become rare unto death. But this one flesh-and-blood individual still lived. Imagine that she was thirty years old, or thirty-five, an ancient age for most sorts of bird but not impossible for a member of such a large-bodied species. She no longer ran, she waddled. Lately she was going blind. Her digestive system was balky. In the dark of an early morning in 1667, say, during a rainstorm, she took cover beneath a cold stone ledge at the base of one of the Black River cliffs. She drew her head down against her body, fluffed her feathers for warmth, squinted in patient misery. She waited. She didn't know it, nor did anyone else, but she was the only dodo on Earth. When the storm passed, she never opened her eyes. This is extinction.[2]

"The finality of extinction is awesome, and not unrelated to the finality of eternity," said Aldo Leopold. Of the extinction of the passenger pigeon, he wrote,

> We grieve because no living man will see again the onrushing phalanx of victorious birds, sweeping a path for spring across the March skies, chasing the defeated winter from all the woods and prairies of Wisconsin…. There will always be [passenger] pigeons in books and in museums, but these are effigies and images, dead to all hardships and all delights. Book-pigeons cannot dive out of a cloud to make the deer run

> for cover, or clap their wings in thunderous applause of mast-laden woods. Book-pigeons cannot breakfast on new-mown wheat in Minnesota, and dine on blueberries in Canada. They know no urge of seasons; they feel no kiss of sun, no lash of wind and weather . . . . Our grandfathers were less well-housed, well-fed, well-clothed than we are. The strivings by which they bettered their lot are also those which deprived us of pigeons. Perhaps we now grieve because we are not sure, in our hearts, that we have gained by exchange. The gadgets of industry bring us more comforts than the pigeons did, but do they add as much as to the glory of spring?[3]

Habitat destruction, such as deforestation or elimination of wetlands, is probably the greatest threat to biodiversity. In this country, the great prairies are mostly eliminated and are the most threatened habitat type. Continuing habitat destruction eventually leads to endangered species and to extinction. The California coastal sage scrub, found mostly in the five southern counties of that state, has been so destroyed by urban/suburban sprawl that one of its characteristic species, the California gnatcatcher, is close to endangered status. Had not certain steps been taken (about which more later), it certainly would have had to be listed under the Endangered Species Act. Its status is essentially an indication of incipient endangered status for the entire biological community and the species that constitute it.

More subtle but with profound implications is habitat fragmentation. This also causes loss of biological diversity, especially in forests. Once a tract is no longer part of *continuous* forest, many of the species in it are unable to survive. The forest then becomes simplified and may also change and diminish in processes like pollination and decomposition. In a classic early study, Barro Colorado Island in Gatun Lake (created to provide fresh water for the Panama Canal) lost forty-five breeding bird species between the 1920s and 1970, of which, it was thought at the time, eighteen were lost because that island was not big enough. Although in essence that was the problem, we now know the reason is a bit more complicated than that.

Most U.S. National Parks have lost species since their creation because of isolation (the parks essentially being substantial fragments but not big enough). In the long-term research work I initiated on this subject in the Brazilian Amazon, one surprise result is loss of biomass—"biomass collapse"—about 30 percent with no apparent regrowth.[4] This means that there are fewer trees to store carbon, which is a problem as we struggle to reduce emissions of carbon as carbon dioxide into the atmosphere.

Introduced (“exotic” or “alien”) species are also a major threat to diversity because although they may in some instances increase the number of species in a particular place (Hawaii’s current flora has as many alien species as native ones), more often than not they displace native species and may drive them to extinction. One example is the brown tree snake. It has driven a number of bird species on Guam to extinction. And if it were to get to Hawaii, the islands’ avifauna would be extremely vulnerable. A few individual snakes have, in fact, made it to Hawaii, but they were caught before they could escape. Another example is the comb-jelly (ctenophore), which made its way in ballast water to the Black Sea. There, its population exploded, it short-circuited the food chain of the native anchovy, and destroyed what was once a $250 million-a-year anchovy-fishing industry.

Various kinds of pollution take their toll on biological diversity as well. Sometimes the problem is very localized and easily dealt with by “end of the pipe” solutions. In other instances, it is regional. Agricultural runoff, human waste, and airborne pollutants have contaminated the entire Chesapeake Bay. The ever larger dead zone in the Gulf of Mexico is essentially the product of human and agricultural metabolism of the Mississippi drainage. Acid rain is often a regional pollution problem. We now know that in the case of at least one forest — Hubbard Brook in New Hampshire — acid rain has leached the cation content of the soil to the point where the forest has stopped growing. A relatively new category of pollutants is the endocrine disrupters, which are thought to affect the reproductive systems of some wildlife and possibly humans as well.

Last but not least is climate change caused by our disrupting the natural metabolism of the planet. Carbon dioxide levels are 30 percent higher than in preindustrial times and rising rapidly. The exact climatic consequences are difficult to predict, but a global rise in temperature has already occurred (1°F in this century) and current projections of the Intergovernmental Panel on Climate Change (IPCC) are that if greenhouse gases continue to accumulate, the global temperature could rise another 3.5°F by the year 2100. Sea level rise, increasing frequency of severe weather, and changes in precipitation and temperature are all expected outcomes.

Biodiversity has been able to respond to past natural climatic change fairly successfully it appears. Species sought out the climate they needed by moving up or down slope, up or down latitude. They did so at different rates, so ecosystems disassembled and reassembled in new configurations. Projected rates of climatic change appear to be much faster (10×) than species have been known to cope with in the past. What is particularly difficult is that biodiversity is increasingly locked up in isolated reserves and parks surrounded by human-dominated landscapes, which are essentially obstacle courses. The combination of current land-use patterns and climate change will be disastrous for biodiversity.

The preceding catalogue of ways in which we are affecting biological diversity is a set of proximate causes. Driving them is a complex set of socioeconomic vectors involving human population, consumption patterns, and social factors. In the end, the solutions require dealing with these forces as well as finding ways to achieve desired ends in less destructive ways.

II. What Does/Will Biodiversity Do for Us?

It is important to understand what biodiversity does for society and, equally important, what its potential is. Fisheries and forestry depend in large degree on wild ecosystems, although fish farming and plantation forestry play significant roles. Both the latter as well as agriculture depend in the end on a continuing infusion of new genes from the wild. Wild species are also of great value in pest management. An ichneumon wasp species from Paraguay, for example, was used to battle the mealy bug that was menacing West African cassava, saving the crop and preventing famine. Savings of this sort for U.S. agriculture are measured in billions of dollars annually. An astonishing array of species are harvested from the wild, ranging from truffles to ginseng.

Nature has long been a source of medicines. Indeed, aspirin, probably the best-selling medicine of all time, is derived from the bark of the European willow tree (genus *Salix*) and the actual compound — now produced synthetically but inspired by the wild template — is named, accordingly, salicylic acid. Hippocrates prescribed infusions of willow bark as a painkiller.

Plants with medicinal qualities (either harvested in the wild, grown as a crop, or used as a template for synthetic drugs) continue to be of great significance. Of the top 150 prescribed drugs in the United States in 1993, 57 percent contained at least one compound derived from or patterned after natural compounds. Natural compounds still are a significant source despite the new approaches of combinatorial chemistry (where known active elements are combined in a random mix) and computer-designed molecules. The Pfizer research labs essentially divide the search for new medicines 50–50, with half coming from natural product screening. The discovery, or "hit," rate is about equal between natural and combinatorial chemistry, until an ecological screen is applied to natural products. Ecological screening is a method of discovering plants with beneficial properties. For example, if no animals or insects are eating a particular seed, it probably has some biologically active compound. Or, say, if leaf-cutting ants that use leaves for mulch avoid a certain tree, its leaves may contain a natural fungicide. Such ecological screening can significantly improve discovery rates.

Very often a plant may have the capacity to produce a particular compound, but because it is metabolically "expensive" to produce, will do so only on demand. A compound produced to deter insect herbivory, for example, may be produced only once the insect grazing pressure has passed a particular threshold — something that can be experimentally reproduced in some instances using a paper punch to make holes in leaves. This means that initial screening can miss an important compound and that it is critical to be able to return to the exact individual from which the successful sample was taken. Costa Rica's Instituto Nacional de Biodiversidad (INBio) is doing organized inventory with just such precision and, consequently, has attracted contracts with a number of corporations like Merck.

Biological diversity, also quite logically, serves as the most sensitive set of indicators of environmental change. The disappearance of the peregrine falcon from Mississippi in the 1960s was the first indicator of the hazards of chlorinated hydrocarbon pesticides, DDT in particular. At the moment, declining and vanishing amphibians — populations and species—in many parts of the world are signaling one, and probably more than one, set of environmental threats.

One of the most important ways in which biodiversity contributes to human welfare is through the provision of ecosystem services. This includes pollination (e.g., of 3 trillion commercial fruit tree blossoms annually in New York State); generation of soil fertility; cycling of nutrients; cleansing of water and air; and, at least in the Amazon Basin, climate stability (where the forest generates about half of the annual rainfall). One species alone, the American oyster, filters a volume of water equal to the entire Chesapeake Bay about once a year. Prior to the deterioration of the bay's ecosystem, the oyster filtered an equivalent volume every week. It contributed so significantly to water quality that oysters are now being reintroduced into the bay specifically to perform this filtration function.

New York City's watershed, once responsible for some of the best-quality water of any city in the world, had, in recent years, deteriorated because of land-use changes to the point where the Environmental Protection Agency (EPA) would have required construction of $4 billion worth of water filtration plants to replace it. It was eventually realized that an investment of $600 million could restore the watershed ecosystems and protect them so they could do the job in perpetuity. This was ultimately done with a bond issue. Costa Rican economists estimate that the contribution of its protected forests through provision of water to its hydroelectric power is worth $104 million annually in fossil fuels that do not have to be imported. As most ecosystem services are treated as free goods, their value tends to be ignored in most decision making. Robert Costanza et al. produced the first estimate of ecosystem restoration and protection services for the entire planet: $33 trillion per year.[5]

Biodiversity contributes powerfully to human society as the basic library from which the life sciences are built. Not only do certain animals serve as useful surrogates in medical science, but also a great number of advances derive serendipitously from observation or research on species previously considered irrelevant. For example, the genetics of the Rh-negative baby problem was illuminated by studies of the wing pattern of a British butterfly. Ace-inhibitor compounds for control of hypertension stem from studies of the action of the venom of a South American pit viper. Antibiotics resulted from observation of a moldy melon, and vaccination from observation of the interaction of cowpox and British milkmaids. The biology of Antarctic fishes is helping improve organ transplants. The physiology of diving seals contributes to research on sudden infant death syndrome (SIDS).

At the dawn of the age of biotechnology, biological diversity presents a new panorama of opportunity, indeed some major elements of sustainable development. Probably the most dramatic example of this potential is the polymerase chain reaction (PCR), whose discoverer received the Nobel Prize in Chemistry in 1993. PCR is an extraordinary magnifying reaction that can multiply a tiny amount of genetic material millions of times in the space of hours. It has become central to diagnostic medicine and forensic medicine. It is basic to much of biotechnology and is key to the human genome project with all its incredible implications for human health and well-being. It generates economic activity probably in billions of dollars annually.

PCR proceeds in two steps. The first involves heat, which causes the two strands of DNA to separate. The second involves an enzyme that catalyzes each of the two separate strands to build a duplicate of the missing partner. When originally conceived, the only known enzymes to catalyze the second step were heat sensitive, so a chain reaction was not possible. Finally, someone realized that organisms living at high temperatures in nature might have a suitable enzyme, so a search was made of the American Type Culture Collection in Maryland (ATCC). ATCC had a bacterium from a Yellowstone hot spring, *Thermus aquaticus*, that has the enzyme now used for most PCR activity. It is literally a multibillion-dollar molecule.

Catalytic enzymes and organisms are now being used in industry. An example is the manufacture of acrylamides, the building blocks of plastics. This approach eliminates the need for toxic catalysts. There is an active search for promising new molecules and organisms that live in extreme environments, the so-called extremophiles. This approach is termed *bioindustry* and has the great advantage that when a better microbe is found, it is only necessary to change the microbe, not redesign the factory.

Microbes with strange appetites and strange metabolic pathways are now used to clean up environmental messes in a process called *bioremediation*. Ideally, bioremediation can be moved into factories to help enable the dream of industrial ecology where the waste stream of one industry becomes the feedstock of another. Essentially the same process, but termed *bioconcentration*, it recovers valuable resources that otherwise would be lost with wastewater and thereby helps improve both efficiency and environmental safety.

Genetic engineering, like any technology, is neutral and can be used beneficially or detrimentally. But for essentially the first time, genes and characteristics can be transferred between different species—even very distantly related ones: A gene from the winter flounder confers frost resistance upon the russet potato. Microbes can be designed to produce insulin and other useful molecules.

Of longer-term potential is *nanotechnology*, essentially the ultimate in miniaturization, which means technology that uses molecules and atoms. Biodiversity contains an essentially unfathomable wealth of molecules for nanotechnology.

All the above leads to the possibility that biologically based and more environmentally friendly development can play a major role in the quest for sustainable development. The wealth of nations can benefit to an increasing degree from the economic potential of biodiversity at the level of the molecule.

III. Progressing toward Sustainability

How can one create sustainable development? The answer, at least on an operational level, comes down to particular places and how people live and work in relationship to them. In my view, this would involve managing large units of landscapes in such a way that they maintain their characteristic biodiversity (i.e., that the species list for the region as a whole would remain essentially the same) and that ecological processes would remain intact. That would take into account every factor intrinsic to that region and every factor extrinsic to it—even climate change. A great deal of voluntary and collaborative decision-making would be necessary. This would be *sustainable ecosystem management*, and if it were done for the full set of the world's ecosystems/regions (however defined), the sum would be sustainable development.

The United States has embarked on some intensive experiments of the sort with the North-West Forest Plan, South Florida, and the coastal sage scrub region of California. South Florida — the southern two-thirds of the peninsula — has suffered the consequences of more than half a century of independent decisions about water control and supply. Each of the decisions presumably seemed reasonable in their context and time yet the net result is that not a drop of water flows naturally — someone has to turn a valve — and only one-quarter to one-half of normal freshwater flow reaches the Florida Bay. The bay is hypersaline, the sea grasses are gone, there are ugly algal blooms, the shrimp fishery has collapsed, and the super-salty water pours out between the Florida Keys onto the already stressed reef system.

The process — of restoration, in this case — is long and messy because everyone (federal, state, and local government; private interests; and environmental groups) is involved. Yet the process seems to be working — in part because it takes decision-making back to where people live, and because an individual willing to cede some of her rights about how to manage her particular piece of the mosaic gains considerably more in the ability to influence how adjacent pieces that affect her piece are managed.

This operational definition of sustainable development does not obviate the need to pay attention to the social and economic elements of sustainable development. Indeed, if they are not tended to, it will not be possible to maintain the biodiversity and ecosystem process elements of the operational definition.

It also must be recognized that although we know enough about the broad outline of what needs to be done, we do not have sufficient experience and accumulated knowledge to know exactly how to plan and manage most ecosystems. There will inevitably be a lot of learning by doing and need for adjustment as we proceed. At the outset, for example, efforts to clean up Chesapeake Bay did not include the factor of airborne pollutants (30 percent of the nitrogen overload comes from air pollution, principally from transportation exhaust). Much of what society does is just simply done, without any real basis for comparing the actual effects of a development project, and often with a complex mix of vectors that makes it difficult to truly understand the real effect of any one.

The biosphere preserves of UNESCO's Man and Biosphere Program (MAB) are a refreshing initiative in this respect. The preserves always consist of a core area (often a national park or protected area) and a surrounding region that can be manipulated for various forms of economic and noneconomic benefit. This makes it possible to compare the effects of the manipulations with essentially natural habitat so that these development experiments can be truly scientific in their approach. It is unfortunate that at the moment, the biosphere preserve designation (through an entirely voluntary national self-nominating process) is misunderstood by some Americans as a mindless ceding of national authority to the United Nations.

A similar commonsense approach is that of adaptive management, in which an agency or industry designs a land-use management exercise in such a way that it approximates a scientific experiment. This means that success or failure can be evaluated on a scientific basis and that the conclusions can be integrated into a revised management scheme. The real power of adaptive management will come if it is integrated with the ecosystem management approach outlined previously.

There are many who believe that economic growth and environment, or economic growth and sustainable development, are by definition antithetical. That would be true if all 5.4 billion people on this planet were to live an American lifestyle. I find it instructive that there are two kinds of growth in biological systems. In one, the organism simply gets larger (by consuming resources). In the other, the organism does not get larger but rather becomes more complicated in structure and function. At least to some extent, there are analogous economic growth patterns—one in which industry grows by consuming more resources (e.g., more aluminum produced uses more bauxite and more energy), and the other in which relatively little is consumed in the way of resources in activities like service industries and the information industry. Biologically based industries can fit into either category depending on how resources are used. The timber industry certainly has been highly consumptive of resources and still is in some places, particularly the tropics. Biotechnology and some of the industries previously cited provide economic product with relatively little consumption. The value of biologically based industries is that they can be prime examples of sustainable resource use with biodegradable wastes.

The most dramatic example of the gap between the dream of sustainability and the reality of human destruction of the environment is the buildup of greenhouse gases and climate change. That carbon dioxide concentrations are now 30 percent higher than in preindustrial times and increasing at about 3.5 billion tons per year is a very tangible measure of the effect of human activity on global metabolism. In a sense, this is just the first problem of distortion of the global nutrient cycle—nitrogen is likely to be the next—and it involves methane and other gases. CO_2 by itself, however, and its relationship to energy primarily but also in significant degree to land use (through deforestation and biomass burning), is perhaps the best example to examine for its international implications, in part because of the negotiations leading up to climate convention meetings in Kyoto in December 1997.

At the moment, it is a roiling negotiating mess. Targets and timetables on CO_2 emissions have yet to be agreed upon. The United States has not fulfilled the original commitments it made in 1992 in Rio de Janeiro. The automobile and fossil fuel industries are mounting a massive publicity campaign to slow down and possibly even postpone significant commitments. A great deal is being said about negative economic consequences, but actually that is not so clear. Twenty-five hundred economists have signed a letter saying many needed steps make sense on their own, and Robert Repetto has shown that modest changes in assumptions could make the results positive not negative.[6]

China's aggressive economic growth requires a huge number of new power plants, most of which are likely to be fueled by coal—the highest emitter of CO_2 per unit of energy production. China currently uses so much coal that 70 percent of their railroad rolling stock is tied up with coal delivery. By and large, the developing world — with the exception of the island nations, which have very real concerns about sea level rise—is quite concerned about the energy implications and also that whatever is agreed upon not preclude opportunities for development. Those countries point out that most of the problem to date has been the consequence of the economic success of northern nations. As a result, developing nations are quite vocal about the need for technology and resource transfer.

What can science and technology contribute toward the solution? First, there is room for improvement in fossil fuel technology. Substitution of natural gas for coal reduces CO_2 output per unit of energy produced by a factor of four. There is also tremendous potential for savings in energy efficiency and energy conservation. Solar and wind power certainly have their place, and solar is particularly useful for remote areas where it becomes much cheaper than establishing a standard electric grid since every community or dwelling can have independent units. Geothermal units are possible for individual places like Washington, D.C., or New York City; despite a substantial upfront cost, there are definite savings in the long term. In special cases, nuclear energy may play a role, but it is very expensive and the nuclear waste problem is daunting.

The transportation sector is in the first stage of a revolution that will move from the internal combustion engine to one that runs on hydrogen, namely the hydrogen fuel cell. Hydrogen fuel produces energy and water. The source of the hydrogen can involve natural gas, but it can also be produced with CO_2-free energy such as is available during the low-demand ("off-peak") times of hydroelectric sources. Originally plagued by huge, bulky cells, the technology is rapidly improving, so much so that Daimler-Benz is now embarking on a $300-million joint venture with Ballard, the largest fuel cell manufacturer in North America. This technology is developing much more rapidly than envisioned. Imagine the impact on future CO_2 scenarios if China's railroads — as well as all the automobiles that country aspires to produce — were to run on fuel cells?

In the meantime, of course, American consumption of some of the cheapest gasoline in the world has been increasing, and fuel efficiency of the average new automobile has been falling as people buy sport utility vehicles like the Jeep Cherokee and Ford Explorer. The American public is known for its dislike of gasoline price increases, particularly in the form of gasoline taxes. What will it take for the American public to support a policy that is beneficial for the greater global environment? One hopes, of course, for greater U.S. commitment to global leadership and renewed realization that unless the wealthiest nation on earth gets fully engaged, not much will happen. One hopes for recognition that this is the moment in which the United States can influence energy development in countries like China and India, which will otherwise ultimately surpass us in CO_2 emissions. One also hopes that this will be recognized as an important opportunity for U.S. industry and technology to make money in the process of doing good.

A major difficulty, however, is that the days of massive development aid seem to be over despite a need for a global environmental equivalent of the Marshall Plan. Private capital investment vastly outweighs multilateral investment bank and public service sector flows to developing nations. Beyond the need to think of ways to influence private sector investment, however, a process known as joint implementation, provided for in the Climate Convention, holds promise. It is rather like the emissions trading for sulfur dioxide provided for by the Clean Air Act to deal with the acid rain problem. While derided by some initially as a permit to pollute, that process has led to SO_2 reductions and at dramatically less cost than originally envisioned. The scheme, which allows an industry to meet its goals by achieving them in whatever location, brought the power of market forces to bear so that SO_2 trades now occur at 5 percent of the original cost per ton.

In joint implementation, the process is taken international. To meet national goals in Norway, for example, a company that wants to build a new energy plant may find it cheaper to use coal but offset the CO_2 release by paying for energy efficiency or alternate energy in another nation. There is some suspicion that this is but another way to constrain Third World development, but in places like Costa Rica, it is being openly embraced. In fact, it brings investment capital and new technology to developing nations.

Another way joint implementation can be used recognizes the significant amount of carbon stored in forests that is released as CO_2 when forests are cut and burned. It has been estimated that as much as one billion tons of carbon as CO_2 are released annually by tropical forest burning. So, any effort to protect a pool of carbon, or to create one by reforestation, contributes to the solution. There is a view that this is just another way to prevent development, but since the process is entirely voluntary, that argument is specious.

When used with forests, joint implementation can provide an additional benefit of protection of the biodiversity in the forests. It is also possible to use the same tract of forest for non-carbon-releasing activities. These could include ecotourism, extraction of minor forest products (rubber, Brazil nuts, etc.), and bioprospecting. It could even be used for sustainable forestry, although with a lower carbon-storage value. The point is that it becomes possible to generate multiple income streams from the same forest, making it more profitable to leave it as forest than to clear it. Costa Rica has been so bold as to issue "certifiable carbon offsets" on the Chicago Board of Trade, counting on a market that anticipates a global trading scheme. In retrospect, it is interesting to recall how some tropical forest nations used to say that if the world wants to enjoy the oxygen from their forests—actually erroneous since they consume almost as much oxygen as they produce—the world should pay them. Joint implementation is essentially that—but for carbon storage rather than oxygen production.

This is but one of a number of innovative financial instruments that are likely to come into existence as we strive to address global environmental problems. Some, for example, might be tradable securities for ecosystem services, as in the New York watershed. One I am known for, the debt-for-nature swap, is alive and well, although it has prematurely been called dead more than once. The potential for debt-for-nature swap—which can be used for any purpose money can be used for—will exist as long as debt exists. It basically alleviates a government's foreign hard currency obligation by buying it at a discount in dollars or even for giving it, in some instances, in exchange for local currency or a local currency instrument used for environmental purposes. It has already taken on myriad forms. I believe there should be a basic principle that before debt is forgiven by a government, the question should always be asked, Should a portion of this be sequestered as an endowment for something—like the environment—that the particular government is otherwise unlikely to afford?

Environment must now play an important role in foreign policy, a fact that can be seen by the restructuring of the U.S. Department of State to create an Undersecretary for Global Affairs, and in former Secretary of State Warren Christopher's 1996 directive to make the environment a major priority in U.S. foreign policy. A key approach will be to find ways to integrate environmental objectives with other foreign policy goals. It is not coincidental that the Carnegie Endowment for International Peace, an eminent foreign policy think tank, and the Ford Foundation have recognized this imperative and, therefore, have reorganized similarly.

A critical aspect of advancing the environmental agenda is broadening and deepening public awareness. It is important to understand that in industrial nations what is important to one segment of the population is not necessarily important to another. The environment is often a higher priority to poorer segments of society because the health threats of pollution hit closer to home. More affluent segments have the luxury and comfort to think of issues farther from home and of longer term. Issues like climate change and biodiversity sometimes seem so abstract as to be of no immediate concern. Of more serious concern is to what extent people are willing to change their high-consumption lifestyles for less environmentally damaging ways of living.

In contemplating differences between developed and developing nations, it is important to avoid stereotypes. Many developing nations have elements of society and areas that are as affluent as any on earth. They also have enormous poverty, largely concentrated in huge urban areas where environmental justice problems are overwhelmingly great. As important as climate change and biodiversity are, in themselves and in their implications for all people including the poor, the environmental movement needs to show its concern for people.

In this context, the apocalyptic negative approach has definite limits. It is, of course, important to recognize the environmental consequences of not addressing certain issues, to do so realistically, and to sense their enormous scale and urgency. Yet it is important to provide hope and inspiration, not just a sense of impending doom. Too often and too easily environmentalists can be portrayed (or portray themselves) as negative. "Don't." "Stop." "You can't do that." What we really are about is trying to conserve opportunity, and we should constantly remind ourselves and everyone that environmental challenges provide chances for human creativity to come up with better ways of living on earth.

The challenge, as so correctly defined in Rio, is about environment and development — about sustainable development. All nations are part of the process and the consequences, including even the poorest ones that suffer the most in some ways. The solution is not just about intellectual and financial resources between nations, it is about partnerships of a sort I don't believe we have seen before. One example might be jointly owned and operated research and development (R&D) efforts (binational or multinational) through which new energy technologies are developed and the financial return shared.

In small incremental ways, such partnerships have begun to spring up spontaneously in the field of bioprospecting—the search for important species and molecules from nature. Prior to the Convention on Biological Diversity, genetic resources were basically free game and much of the economic return benefited industrialized nations rather than the countries of origin, often developing nations.

The collapse of the rubber boom in the Amazon of Brazil and Peru is one of the most dramatic and classic examples. Those nations had the monopoly on this highly coveted resource, and the legends of rubber barons sending their laundry to Paris to be starched are entirely true. In the forest, rubber trees are naturally interspersed among other species, and diseases do not spread easily from one species of tree to another. They do spread easily in plantations, however, so plantation rubber, while potentially much cheaper, has always been difficult to produce in Amazonia. When Henry Wickham arranged for rubber tree seeds to be sent to the Royal Botanic Garden at Kew (which was a legal shipment despite allegations that they were smuggled), it set the stage for plantation rubber in southeast Asia (where there were no native diseases of rubber) and thus the collapse of the rubber industry in the Amazon.

The Convention on Biological Diversity essentially gives sovereign ownership of biodiversity to the countries where it occurs naturally, essentially recognizing genetic capital as national property. Companies like Merck that are interested in bioprospecting in the species-rich tropics, have initiated agreements (in Merck's case with Costa Rica's INBio) in which genetic capital is recognized as well as financial and intellectual capital. A prospecting fee is paid up front, and if a discovery comes to commercial production, a royalty is paid. If the natural molecule is then modified, a residual royalty is paid. The National Institutes of Health have similar arrangements with a number of nations. Such agreements are not confined to the search for medicines and apply to the potential of genetic resources across the board. As such interactions mature, they will probably include local manufacturers and joint R & D instead of just provision of raw material or relatively simply screening. In their more mature form, these interactions will become a serious conduit for technology transfer.

All of these emerging and potential partnerships are relatively small compared to the rapid globalization of the economy and the proliferation of the free trade zones. Some, like myself, are attracted by free trade because it strips away hidden subsidies and incentives that are negative for the environment. It does, however, make it difficult to put in special positive incentives for the environment or special environmentally related trade restrictions. It is not easy to argue with the World Trade Organization that the environment should be a special case. There are also concerns about the sheer power invested in global corporations with annual economic products greater than the GNP of most nations.

In returning to the specific concerns I was asked to address in this essay, the principle environmental questions of our era are climate change, population, and biodiversity, with the latter essentially comprising the various kinds of pollution. Biodiversity originates, however, from a complex set of social and economic vectors, including consumption patterns. Science and technology are critical elements in solutions, and while I am not a total technological optimist, I believe technology will respond in wonderful and surprising ways to the environmental challenge. We will need every ounce of what technology will be able to provide. Developed nations need to reconsider their role as major consumers of resources at least to the extent of helping developing nations to achieve economic development and quality of life for all their citizens in less environmentally destructive ways.

When the full extent of environmental problems is reviewed, the various positive initiatives, including the important proliferation of nongovernmental organizations in most parts of the world, as remarkable as their numbers are as compared to just a few years ago, fall frighteningly short of really addressing the problem on the right scales of magnitude and time. Why not wait until 2020, as some would, before addressing climate change? By then there will be substantially more CO_2 and temperature increase with all the associated consequences. Far worse will be that all the new energy production from nations like China and India will be essentially current fossil fuel-style technology, making it even harder to change and take the right steps. We are dealing here not with some little backyard experiment that needn't be repeated if the outcome is undesirable, but rather with an experiment on a global scale, essentially betting the planet when in reality we have nowhere else to go.

What is needed in the end is a basic change in values, a move from thinking of the environment as a frontier to be exploited and subdued, to thinking of ourselves as living within the environment and depending on it. We need a new definition of the quality of life that does not equate it with raw, economic growth and unabated consumption, but includes beauty and a sense of community with other living things. We need to move toward forms of national accounting such as the one proposed by the World Bank in which environmental capital is recognized as an asset and environmental destruction as a cost that lowers net worth. We need to broaden our way of looking at things so we recognize—as urged by the University of Virginia's William McDonough—that a large part of what needs to be done is to broaden our definition of what are acceptable outcomes, to realize that the problems are often ones of design rather than particular desired outcomes or products.

The Pulitzer Prize-winning historian Daniel Boorstin once said critically that environmentalists are always talking about limits, but he didn't believe there were any limits (adding that, of course, he didn't believe in extinction). Upon reflection, I realize that what he meant was that he did not believe there were limits to human creativity. I responded that I believed very deeply in a close-to-infinite capacity of human creativity but that the environmentalists' concern is not to constrain that creativity by loss of environmental assets like biodiversity. That, in the end, is much of what the global environmental challenge is all about: changing values, recognizing new values, and being maximally creative and pragmatic at the same time. The environment continues to grow in importance on the global agenda, but not fast enough. While there are real differences in where various nations start from on different agenda items, the fundamental imperative is that almost all need to contribute to the solution in an unprecedented North-South, East-West partnership. The United States bears the greatest burden as the nation with the greatest leadership potential and responsibility. ◉

Notes

1. Keynote address, Macalester College International Roundtable, 2 October 1997.

2. David Quammen, *The Song of the Dodo: Island Biogeography in an Age of Extinctions* (New York: Scribner, 1966), 275.

3. Aldo Leopold, *A Sand County Almanac, and Sketches Here and There* (New York: Oxford University Press, 1987), 109–10.

4. William F. Laurance et al., "Biomass Collapse in Amazonian Forest Fragments," *Science*, Reprint Series 278 (7 November 1997): 1117–18.

5. Robert Costanza, et al., "The value of the world's ecosystem services and natural capital," *Nature* 387, no. 6230.

6. Robert RePetto and Duncan Austin, *The Costs of Climate Protection: A Guide for the Perplexed* (Baltimore: WRI Publications, 1997), i–viii, 1–51.

Bibliography

Colborn, Theo, Dianne Dumanowski, and John Peterson Myers. *Our Stolen Future: Are We Threatening Our Fertility, Intelligence, and Survival?: a scientific detective story*. New York: Dutton, 1996.

Daily, Gretchen C., ed. *Nature's Services: Societal Dependence on Natural Ecosystems*. Washington, D.C.: Island Press, 1997.

Ehrlich, Paul R., Anne H. Ehrlich, and Gretchen C. Daily. *The Stork and the Plow: The Equity Answer to the Human Dilemma*. New Haven and London: Yale University Press, 1997.

Grifo, Francesca, and Joshua Rosenthal, eds., with a foreword by Thomas E. Lovejoy. *Biodiversity and Human Health*. Washington, D.C., and Corvelo, Calif.: Island Press, 1997.

Gore, Albert. *Earth in the Balance: Ecology and the Human Spirit*. New York and London: Houghton Mifflin and Beston, 1992.

Peters, Robert, and Thomas E. Lovejoy, eds. *Global Warming and Biological Diversity*. New Haven and London: Yale University Press, 1992.

Reaka-Kudla, Marjorie L., Don E. Wilson, and Edward O. Wilson. *Biodiversity II: Understanding and Protecting Our Biological Resources*. Washington, D.C.: Joseph Henry Press, 1996.

Wilson, Edward O. *The Diversity of Life*. Cambridge, Mass.: Belknap Press of Harvard University Press, 1992.