Science and the Future of Mankind
Pontifical Academy of Sciences, *Scripta Varia* 99, Vatican City 2001
www.pas.va/content/dam/accademia/pdf/sv99/sv99-raven.pdf

SUSTAINABILITY: PROSPECTS FOR A NEW MILLENNIUM

PETER H. RAVEN

Humanity stands at a defining moment in history. We are confronted with a perpetuation of disparities between and within nations, a worsening of poverty, hunger, ill health and illiteracy, and the continuing deterioration of the ecosystems on which we depend for our well-being. However, integration of environment and development concerns and greater attention to them will lead to the fulfillment of basic needs, improved living standards for all, better protected and managed ecosystems and a safer, more prosperous future. No nation can achieve this on its own; but together we can – in a global partnership for sustainable development. (Agenda 21, Earth Summit; Sitarz, 1993).

The noted scientists and technologists who gathered for the Congress of Arts and Sciences in St. Louis in 1904 would not have understood the meaning of those ringing words. Instead of worrying about global inequities or the destruction of the environment, they were delighted with the prospects for a world in which the possibilities for progress seemed virtually unlimited. More than a century after the introduction of the steam engine, the fruits of the Industrial Revolution had become evident on every front, and the United States was looking forward to a future of international leadership. Taking my cue from the St. Louis Congress, I shall focus many of the following remarks on the role of the United States, but shall eventually broaden that view to encompass the world, a world in which the influence of the United States and other industrialized nations is pervasive.

When the delegates assembled in 1904, they would have been mindful of the death of Queen Victoria, who had given her name to an era that had witnessed the most extraordinary scientific, technical, and industrial advances that the world had known to that point. The St. Louis World's Fair

itself was celebrating not only the growing outreach and power of the United States, but also the broad vision of a diverse world that seemed to hold so much promise for the future. Theodore Roosevelt, the youngest American president, was in the White House, later to win the Nobel Peace Prize for his role in bringing about the end of the Russo-Japanese War; about to become the first American President to travel outside of the country, when he visited the construction site for the Panama Canal (completed in 1914); and poised, in defiance of Congress, to send the American Navy around the world as a show of national strength (1908).

At the same time as Americans were so excited about the prospects for the development of the airplane, of the automobile, of new modes of communication, and all of the other inventions that promised so much for the future, a few of them had also begun to realize that the world was not as unbounded and limitless as it once had seemed. Explorers had reached the far comers of the Earth, and knowledge was pouring in about its lands and its peoples: we increasingly knew what was there. Fredrick Jackson Turner, later to become America's preeminent historian, had announced the closing of the frontier, an idea that was to have great influence on collective visions of the world in the early years of the century. What were the turn-of-the-century antecedents of ecology, of sustainability, and of biodiversity – concepts that are now intellectual landmarks on the topography of the twenty-first century, but virtually unknown a hundred years ago?

The World Then and Now

At the turn of the century, after more than a hundred years of the Industrial Revolution, the global population stood at approximately 1.65 billion, with about 74 million people in the United States. In about four months, an event to be officially "celebrated" on October 12, 1999, there will 6 billion of us, including a billion added within the past 12 years, and the billion before that in 13 years. There are at present just over 270 million people in the United States. Human expectations have risen continuously over the course of the century, while the global population has more than tripled; consequently, the level of consumption in the industrialized world has risen to heights undreamed of just a few decades ago. Changes in the biosphere also have been unprecedented, with a major proportion of them having occurred during the past 50 years (Turner, 1990). Over this period, and for the past few hundred years, technologies have been invented and deployed, and the world has in what is geologically an instant of time been

converted from a wild one to one in which human beings, one of an estimated 10 million species of organisms, are consuming, wasting, or diverting an estimated 45 percent of the total net biological productivity on land and using more than half of the available fresh water, locally at rates that clearly cannot be sustained for long. The properties of the atmosphere have been and are being substantially changed by human activities, almost all major fisheries are under severe pressure, and habitats throughout the world have been decimated, with populations of alien plants and animals exploding and causing enormous damage throughout the world, while species extinctions have reached levels unprecedented for tens of millions of years. Despite the optimistic tone set by the Earth Summit declaration quoted above, with perhaps 3 billion additional people joining our numbers over the next half century, we will clearly have an increasingly difficult time in maintaining our current levels of affluence or in achieving the lofty goals which our historical progress seems to have made available to us. The scales and kinds of changes in the Earth's life support systems are so differenent from what they have ever been before that we cannot base our predictions of the future, much less chart our future courses of action, on the basis of what has happened in the past (Vitousek *et al.*, 1997).

As Bill McKibben has outlined in his book "The End of Nature" (1989), we have arrived at a time when human beings are effectively managing the whole planet, for better or worse. The end of nature as he understands it is the end of nature functioning independently of human beings. This is the vision that was explicitly explored in the outstanding collection of essays, "Uncommon Ground" (Cronon, 1995). Specifically, in the field of conservation, those organisms that survive will do so because human beings manage the Earth's resources in such a way that this is possible; those that are lost will be lost for the same reason. The pressures we exert on global ecosystems are so extensive that their future is up to us. For these reasons, it has become clear that we clearly are living in the most difficult and challenging times that humanity has experienced. How did we get to this point, and what have been some of the warning signs along the way?

A mere 10,000 years ago, when crop agriculture was first developed at several widely scattered centers both in the Old World and the New, several million human beings, far fewer than the number of people who visit the museums of the Smithsonian Institution annually, populated the world, at about the density of Aboriginal peoples in Australia before European contact. The availability of larger quantities of food, on a more dependable basis that had existed before that time, created conditions for the rapid

growth of the human population to an estimated 300 million at the time of Christ, a number that held more or less steady for a thousand years, grew to 1 billion around 1800, reached 2.5 billion by 1950 and will, as I mentioned above, reach 6 billion in the present year, 1999. As human numbers have grown, their impact on the environment increased also, regional evidences of overgrazing or deforestation having been regarded with dismay by some people ever since Classical times. It has been during the period of the Industrial Revolution, from the mid-eighteenth century onward, however, that the evidence of widespread human domination of the natural environment has grown so rapidly and become so obvious as to affect the world view of every person concerned with the future.

The Growth of Environmental Consciousness: Before 1900

Following Columbus' landfall in the New World five centuries ago, at a time when the global population was less than a tenth of what it is now (about 500 million), waves of people from the Old World colonized the newfound lands and grew to great numbers and great power. The same *phenomenon occurred* throughout the world, as colonial expansion and the extension of often unsustainable forms of land use rapidly changed the face of the continents (Grove, 1995). As Andrews (1999, p. 18), put it, "Colonization... was among other things an environmental policy". The ways in which relatively unspoiled lands were rapidly changed by the practices associated with colonization, and the ideal visions of such lands that persisted in the minds of Europeans far longer than they did on the ground, had a great deal to do with our collective understanding of the limited nature of local and ultimately global resources (McCormick, 1989). By the 1850s the problem of tropical deforestation was already being viewed as a problem on a global scale, and one that urgently demanded correction. Although less emphasized in the latter decades of the nineteenth century and the first half of the current one, the powerful metaphor of the destruction of Eden proved an enduring and influential one.

In Colonial America, the collective vision was one of an endless cornucopia of forests and meadows, rich in natural resources to be exploited – the destruction of the wilderness and the taming of nature were widely-accepted as desirable goals. The image of nature in all of its wonder and abundance, and the deep and abiding love of the land that Americans generally share, however, also. have their roots in this early history: the land seems inexhaustible, rich, and nurturing beyond our wildest dreams. As

Wallace Stegner (1980) put it, “While we were demonstrating ourselves the most efficient and ruthless environnient-busters in history, and slashing and burning and cuffing our way through a wilderness continent, the wilderness was working on us. It remains in us as surely as Indian names remain on the land. If the abstract dream of human liberty and human dignity became, in America, something more than an abstract dream, mark it down at least partially to the fact that we were in subtle ways subdued by what we conquered”. In these words, Stegner has captured the essence of the ethical, moral, and religious overtones to environmentalism, which are fundamentally important to our perceptions of the field, and underlie our hope of progress in the future. Although much of what we say and do is materialistic and operational, the reasons that we do it lie within ourselves.

Even in colonial times, some began to take seriously the evidence of threats to the bounty of the land, and to view the profligate use of natural resources as a problem (Nash, 1982; Shabecoff, 1993; Andrews, 1999). However, it was not until the advent of industrialization, roughly from the 1830s onward in America, that massive changes in the landscape began to become evident on many different fronts. In a relatively few decades, from the mid-nineteenth century onward, most of the prairies were cleared, the remaining great forests were cut, and farms and, increasingly, cities were established everywhere in the land – the activities noted so poetically by Stegner were carried on apace. In addition, it has gradually become clear that “nature” is a profoundly human construction: it can never be separated fully from our own values and assumptions (Cronon, 1995, p. 25).

Increasingly alarmed by these trends and their perceived effects on the future productivity of the land, influential writers and public figures, mostly living in the cities of the East, began to call for the preservation of some of our national wildlands, especially in the West: the sense of passing of the wilderness ultimately had a powerful effect on the national imagination. Ralph Waldo Emerson and Henry David Thoreau re-defined our relationship with nature, laying the foundation for modem environmentalism and the concept of sustainability. At the same time, Charles Darwin, by placing the human race clearly in the biological context of its evolutionary history, helped substantially to break down the dichotomy that had been so generally accepted earlier between people and nature. Subsequently, George Perkins Marsh, America's first true environmentalist, understood well the concept of the balance of nature and brought it to the attention of a wide public, basing his appreciation on his knowledge of his native state of Vermont, as well as on his wide travels in the Mediterranean basin and else-

where; his 1864 book, *Man and Nature; or, Physical Geography as Modified by Human Action* is a classic both of environmentalism and of ecology. Marsh saw clearly that the destruction of nature could not be sustained, and pointed out the need for care in the management of our resources for the sake of future generations. America's first national park, Yellowstone, was established the same year that Marsh's book was published. Another notable and far-sighted early experiment in re-defining the relationship between man and nature was the establishment of the Adirondack Forest Preserve, later the Adirondack Park, by New York State, in 1885.

At the same time that concern about nature, and especially about the fate of the Western lands, was growing, another important trend was greatly influencing the development of environmentalism. The explosive growth of cities and the increasing urbanization of the population brought widespread urban pollution, along with the development of a new way of life that differed remarkably from that of the countryside: the same trend that had accompanied the advances of the Industrial Revolution earlier in England and elsewhere in Europe. The new urban-centered life, and the development of the many remarkable institutions that it made possibe, provided an abundance that led to a growing equality and equity, but also gave rise to many new problems concerning the conditions under which people actually lived in those growing cities, swollen by the ranks of immigrants seeking a new life in America. Thus nearly 13 million immigrants came to the United States between 1890 and 1910, the great majority of them living in cities, where they were joined by large numbers of people moving from the farms. Coal dust, smoke, and toxic chemicals, open sewers, uncertain and often polluted water supplies, crowded and unsanitary toilets – these were the commonplace experience of urban dwellers at the turn of the century. The collective realization of what the awful crowding in cities, the squalid living conditions and urban pollution meant to the lives of people became, along with the protection of natural resources, a second element of fundamental importance in the formation of American environmentalism (Andrews, 1999, chapter 7), one that ultimately contributed enormously to the strength of the modem environmental movement (Gottlieb, 1993).

The Science of Ecology

The essays that were presented by Oscar Drude and Benjamin Robinson in St. Louis in 1904 revealed an ecology that was in its earliest stages of development. Their papers were mainly concerned with plant dis-

tribution and the organization of plant communities around the world, with no reference to any of the dynamic concepts that have come to be associated with the modem synthetic science of ecology a century later. The term “ecology” had first been proposed by the German biologist Ernest Haeckel in 1866, but Haeckel had no particularly novel insights about the field. In developing the concept, he was referring to the web that linked organisms with their environment, an idea directly related to the notion of “natural history” as it had been understood earlier. Essentially, the science of ecology is one that has developed entirely in the twentieth century.

At first, it was the study of plant ecology, and the relationships within plant communities that dominated ecology; but oceanography, linmology, and other disciplinary approaches now part of the field were developed during the same years. Efforts to chart the limits of plant distribution and to understand those limits in a historical sense were pursued actively, with terrestrial animal ecology coming along later (McIntosh, 1985). F.E. Clements, who had served as secretary for the ecology section of the 1904 St. Louis meeting, became an important pioneer and leader in the development of more dynamic concepts, and helped to lead ecology away from its roots as a purely descriptive discipline. During the same years, H.C. Cowles, at the University of Chicago, played a seminal role in the development of the science by adding his valuable insights to the concept of plant succession. Eventually, the British ecologist C. Elton in his book “Animal Ecology” (1927) laid the foundations for terrestrial animal ecology. There followed rapidly in the ensuing decades the development of quantitative community ecology as a field, and an appreciation of the dynamics of populations and of the relationships between populations in communities, the flow of energy and the movement of materials in communities (in the second half of the century), and finally the emergence of a science of systems ecology, in the development of which the American ecologists Eugene P. and Howard T. Odum played major roles.

Like all branches of science, ecology has become increasingly quantitative and theoretical, with an emphasis on mathematical modeling, population ecology, and feedback loops; scientists such as G. Evelyn Hutchinson and his student Robert MacArthur were important contributors in this area.

It needs to be emphasized at this point that ecology and environmentalism are by no means synonymous concepts: ecology is in fact a scientific discipline that deals with the relationships between organisms and with their environment and develops logical ways examining and making pre-

dictions concerning them. A concept such as “sustainable development” is necessarily based on the principles of ecology, as those principles operate in a social and economic context. Notwithstanding this fundamental distinction, the development of the field of ecology into a strong scientific discipline during the course of the twentieth century is one of the factors of fundamental importance allowing us to evaluate the dilemma that faces us as we enter the new millennium. The whole set of biological relationships that it comprises provide the basis for understanding the reactions of different sets of populations, whether of humans or of other kinds of organisms, to their changing environment. Ecology likewise, especially through the synthetic field of conservation biology, illuminates the fundamental principles on which our biological heritage can potentially be conserved for our future welfare.

Environmentalism in Twentieth-Century America

Environmentalism in the United Stateswas marked in the early years of the twentieth century by the emergence of the remarkable leadership of Gifford Pinchot, John Muir, and Theodore Roosevelt. These inspirational men considered in their individual ways that our natural resources should be managed so as to serve the needs of the future as well as those of the present: their influence was enormous, and persists to the present. They built particularly on the concept of parks and reserves, and that of safeguarding natural resources for all people. Among the events that marked the growth of environmentalism prior to World War II were the establishment of the National Audubon Society (1905), the controversy over Hetch Hetchy Valley in the Sierra Nevada of California (the valley was granted to San Francisco in 1913), the Migratory Bird Treaty Act established with Canada (1918), the establishment of the Civilian Conservation Corps (1933), and the passage of much Federal legislation to regulate forests, water, and soil erosion during the 1930s. The influence of cartoonist Ding Darling (1876-1962; Lendt, 1979), who published widely syndicated and much-appreciated environmental cartoons from 1916 onward, cannot be overestimated. As chief of the Biological Survey (later the Fish and Wildlife Service) in the 1930s, and because of his wide networking, he contributed a great deal to making Americans aware of their environment and what they were doing to it, and to the world – he clearly has an international vision of the environment, and projected that vision in many ways. And these are just a few samples of what was going on during those years.

During World War II, environmental concerns were largely sidetracked by the urgent ones associated with the war effort. Following the war, there occurred a period characterized by what Shabecoff (1993) called “careless optimism and materialism.”. Environmental concern gradually returned, however, as people were confronted on all sides with widespread evidence of severe problems. During these years, events such as the severe air pollution that occurred in Donora, Pennsylvania, in 1948, in which 20 people died and 14,000 became ill; the London “Killer Smog” that left 4,000 people dead in 1952; and concern over soil loss, water pollution, and the destruction of natural resources drew widespread attention and lead to the enactment of new laws protecting people and natural lands.

One of the first books to call attention to these problems forcefully to a general audience was Fairfield Osborn’s “Our Plundered Planet” (1948), which by its title as well as by its substance helped to stimulate serious and widespread debate. Osborn considered “the grand and ultimate illusion [to be] that man could provide a substitute for the elemental workings of nature”. The concerns expressed by Osborn gradually moved to center stage in the public mind, his book having played a major role in stimulating concern about the environment and the directions in which we were heading.

Aldo Leopold, a great conservationist and philosopher, wrote some of the most stirring essays in the history of the field; his posthumously-published “A Sand County Almanac” (1949) has inspired generations of environmentalists. This book immediately became a landmark of the movement towards what we would now call sustainability, and is surely one of America’s finest gifts to the world conservation movement, and thus to future generations. Leopold’s “land ethic” speaks of a complex world dominated by human beings, who thus have either the power of good, nurturing care of their land, or the ability to degrade and destroy it. In his words, it “changes the role of *Homo sapiens* from conqueror of the land-community to plain member and citizen of it” (1943, p. 216).

Partly as a result of the writings of leaders such as Osborn and Leopold, and partly because of the increasing evidence of environmental degradation seen ever more widely, public concern over environmental matters reached new heights in the 1960s. The publication of “This is the American Earth,” an exhibit-format book featuring the photographs of Ansel Adams and the poems of Nancy Newhall, by the Sierra Club in 1960, made a significant contribution to environmentalism and a new way of thinking about the Earth at a spiritual level at the start of the decade. Over the following years, many influential writers and speakers began to warn of the dangers of excessive

human domination of the Earth, generalizing from when had earlier been seen as individual, unconnected problems. They did so during a half century in which a world population that had grown by 850 million people during the preceding 50 years to a record level of 2.5 billion continued to increase at accelerated rates to its present level of 6 billion people. Such growth, coupled with industrial expansion from 1945 onward and increasing expectations on the part of consumers, greatly increased the strains on all ecological systems in ways that had become widely evident by the 1950s and 1960s.

In 1962, the first excepts of Rachael Carson's "Silent Spring" appeared in The New Yorker, and our common vision of our relationships with our planet were permanently altered. Clearly the most important environmental book written in America, "Silent Spring" focuses on chemical pesticides, but with clear vision charts the destruction that technology can bring if carelessly applied. Carson presents a vision of a future world in which intelligent people can create a sustainable world. By doing so in such a convincing way, she moved environmentalism permanently to the center of the American agenda. Another landmark work was published near the end of the decade, when Paul Ehrlich's best-seller "The Population Bomb" (1968) dramatized and made available for a wide public for the first time the problems associated with rapid growth in human population, in effect adding a new dimension to the environmental debates.

The gathering momentum of the environmental movement culminated on Earth Day, April 22, 1970, when some 20 million Americans, one of every ten people in the nation, massed to demonstrate their concern over the state of the environment. Environmentalism had emerged as a mass social movement, resonating with civil rights and the other major social movements of the day. Many new environmental groups had been organized, and they were growing rapidly along with others that had been in existence earlier. Starting with the National Environmental Policy Act, signed into law on January 1, 1970, the concerns of those who were attempting to lay the foundations for a sustainable future were embodied in our laws, followed by the passage of the Clean Air Act. The Environmental Protection Agency was created at the end of the same year; the Clean Water Act in 1972. Of particular significance was the establishment of the Endangered Species Act in 1973: the world's most comprehensive legislation dealing with the conservation of biological diversity.

Earth Day in 1990 was even more significant in demonstrating the degree to which environmentalism had pervaded every aspect of American society, from corporations to consumer life styles, and become a force that

could not again be disregarded in the formation of public policy. What it called into focus, however, was that even though the environmentalism that was so strongly expressed in the 1960s had resulted in the establishment of outstanding environmental legislation, these accomplishments were not enough. Human nature combined with a failure to appreciate the global environmental situation, based partly on wishful thinking – the desire to continue on with "business as usual" – has resulted in bizarre and distorted conclusions like those of Easterbrook (1995), or the ones found daily in much of the economic press. Taken at face value, the assertions presented in such works would lead one to believe either that world economics functions in a vacuum, or that the natural productivity of the Earth and its maintenance and healthy functioning is of no interest in calculating human futures. Evidently, relatively few people in positions of authority are willing to deal with the shock that comes when the global scale of these problems is recognized. Yet it is patently true that economic growth can be sustained over the long run only in the context of care for the environment.

Global Environmentalism

On a world scale, the formation of the United Nations in 1946 and the subsequent development of the organization gradually led to an increasing emphasis on problems associated with the environment. In 1968, the International Conference of Experts for Rational Use and Conservation of the Biosphere met in Paris under the auspices of UNESCO, and became the first major international meeting to examine human impacts on the environment. From this conference came the Man in the Biosphere (MAB) program, which specifically called for new ways of considering this relationship, and implementing improvements in it.

Four years later, in response to environmental problems in the Baltic region, the 1972 United Nations Conference on the Human Environment was convened in Stockholm. Here, the Canadian Maurice Strong began his brilliant international environmental career, and, when acting as the head of the secretariat, brought about a strong examination of the relationship between the environment and development that has dominated international considerations of this area ever since. Building in part on the concepts expressed by the microbiologist and conservationist Rene Dubos, the conference examined the conditions under which human beings could exist in harmony with the rest of nature. Dubos' famous admonition, "think globally, act locally," has greatly influenced environmentalists, and his role

in developing the concepts examined at Stockholm was of seminal importance., At the conference itself, a memorable role was played by Indian Prime Minister Indira Gandhi, who stated, "The inherent conflict is not between conservation and development but between environment and the reckless exploitation of man and the earth in the name of efficiency".

Among the products of the Stockholm conference was the formation of the Governing Council for Environmental Programs, a body that changed the following year (1973) into the United Nations Environment Program (UNEP), with its headquarters in Nairobi, Kenya. Its global orientation has served the world well during the 26 years of its existence, with many solid accomplishments to its credit. Nonetheless, its status as an agency supported by voluntary contributions has tended to marginalize some of its themes and the conclusions of its deliberations, and many believe that a more central role for the environment within the U.N. General Assembly would be an appropriate response to the world environmental situation as we prepare to enter the new millennium. The scope of the world's problems does indeed seem to cry out for such a solution.

Another, and very different, event of key significance in the elaboration of the concept of sustainability was the publication by the Club of Rome of "The Limits to Growth" (Meadows *et al.*, 1972). The study this book reports uses comprehensive mathematical models to develop its conclusion that if present trends in world population continued, that the limits to growth on the planet would be reached within a hundred years; that the underlying conditions could be changed to establish a condition of ecological and economic stability that would last for the indefinite future; but that if the world's people decided to change these conditions, that the sooner they began, the more effective their actions would be. The remarkable feature of this book was its presentation of a comprehensive global model in which the various environmental, social, and economic factors that affect the human future could be considered in context for the first time. Although the study was widely reviled, particularly in economic circles, for the details of its projections, the majesty of its vision is as impressive today as when it first appeared, and the kind of reasoning it made possible remains fundamentally important. No enduring vision of the world's future can fail to take into account the effects of population growth, of affluence (consumption per person), or of the use of inappropriate technology, all of which need to be addressed in achieving global sustainability.

In practice, however, the appearance of the book set off a strong debate between the "cornucopians," who believed that environmental threats are

grossly exaggerated, and that we should continue on with business as usual, and those who hold that catastrophes of various kinds are either upon us or just around the comer. What is certain in this debate is that early and intelligent actions will be required if some of the directions we are pursuing are to be changed; and change them we certainly must.

In the preceding remarks, I have deliberately not emphasized the growth of the global environmental movement, which parallels in different ways and with various regional and national characteristics that of the American environmental movement. McCormick (1989) and others have done a good job of charting the growth of what has become the largest social movement in history. One need only consider words such as Chernobyl, Times Beach, Brent Spar, and the Rainbow Warrior to understand how the concepts of global environmentalism have pervaded our collective consciousness, and why. Certainly this movement, from the grassroots up through organizations, will have a major role to play in the organization of our responses to the problems that we so evidently confront as we enter the new millennium.

Sustainability

In the history of the environmental movement, "sustainability" is a recent concept that has proved powerful in describing the different factors that bear on our future. In 1987, the World Commission on Environment and Development published "Our Common Future," a report on the global environment in a human context. This report, which was adopted by the U.N. General Assembly calls for sustainable development as "development which meets the needs of the present without compromising the ability of future generations to meet their own needs". In other words, it combines the need to protect natural resources with the improvement of living standards: ecological systems and human systems working in harmony with one another. Pointing out that the problems of the environment in relation to human development are well known, the Commission called for urgent action to address these problems and to set the world on a sound course for the future. The Commission produced a brilliant and well-reasoned report, with strong recommendations in most fields affected by sustainable development. To some extent, its conclusions were built into the Declaration from the Rio de Janeiro meeting five years later, but the objectives it laid out so clearly are still to be fully met. Achieving economic growth while taking into sufficient account environmental and social realities is our com-

mon goal, but it is very difficult to achieve. Despite the strong emphasis given this area in the recommendations of the Earth Summit at Rio (Sitarz, 1993), relatively little progress has been made. Why has this been the case?

Twenty years after the Stockholm conference, it had become obvious that the state of the environment had deteriorated greatly from its 1972 condition. The authors of "Limits to Growth" (Meadows *et al.*, 1992, p. 2) wrote in their new analysis, "Beyond the Limits," "Human society has overshot its limits, for the same reasons that other overshoots occur. Changes are too fast. Signals are late, incomplete, distorted, ignored or denied. Momentum is great. Responses are slow... if a correction is not made, a collapse of some sort is not only possible but certain, and it could occur within the lifetimes of many who are alive today".

In that same year, 1992, and once again organized under the tireless and effective leadership of Maurice Strong, the 1992 World Conference on Environment and Development in Rio de Janeiro re-emphasized and expanded upon these themes, and led to the development of several important international treaties, including ones dealing with climate change and a second with the protection, sustainable use, and fair and equitable sharing of biological diversity. The Earth Summit was a success to some degree, with the vision articulated twenty years earlier at Stockholm now widely accepted, and the depth of the problems confronting humanity generally understood. In addition, the enhanced role of non-governmental organizations (NGOs) in the meeting was an important advance that suggests one of the fundamental ways in which change may occur in the future. In addition, the organization of the Business Council for Sustainable Development was another important theme of the meeting, and one that has grown subsequently. The replenishment of the Global Environment Facility (GEF; formed in 1991), a financial mechanism to help developing countries deal with global warming, biodiversity loss, the pollution of international waters, and depletion of the ozone layer, was one important step, and several groups established or given new mandates at the time of the Rio meeting are addressing problems of great importance. What the Earth Summit did bring into sharp focus, however, was the huge difference between the concerns of the governments of industrialized countries, a fifth of the world's population with a per capita income of more than $20,000 and a life expectancy of 75 years, with those of the developing countries, four-fifths of the world's people, with a per capita income of about $1,200 and a life expectancy of 63 years. Some 1.3 billion people live in acute poverty, with incomes of less than $1 per day, 840 mil-

lion of them receiving less than 80 percent of the U.N.-recommended minimum caloric intake, and thus literally starving.

When it became definite that India would attain independence, a British journalist interviewing Gandhi asked whether India would now follow the British pattern of development. Gandhi replied "It took Britain half the resources of the planet to achieve this prosperity. How many planets will a country like India require?" More recently, Wackernagel and Rees (1995) and others have emphasized again that if everyone lived at the standard of industrialized countries, it would take two additional planets comparable to Earth to support them, three more if the population should double; and that if worldwide standards of living should double over the next 40 years, twelve additional "Earths". Aspirations to such a standard of living are clearly unattainable, and yet advertising continually tells everyone that it is both appropriate and achievable. Even those who already live in rich countries continually strive to seek to improve their standards of living. The paradox presented by these relationships can be solved only by achieving a stable population, finding a sustainable level of consumption globally, accepting social justice as the norm for global development, and developing improved technologies and practices to make sustainable development possible.

We certainly understand better than ever the nature of the problems confronting us, but our willingness to deal with them, as we enter the new millennium, remains very limited, whether they be global warming, the destruction of forests, toxic pollution, the control of nuclear arms, or the destruction of the biological diversity on which we so confidently hope to base so much of our future prosperity. Seven years after the Earth Summit, industrialized nations have not funded the important recommendations of Agenda 21, the principal document that emerged from the meeting, and seem less interested in taking those recommendations seriously as time goes by. The lack of leadership by the United States, the world's wealthiest nation, has meant that the aspirations and plans developed in Rio de Janeiro in 1992 have mostly not been realized. How then can *we* and those who come after us expect to enjoy the benefits of a peaceful, healthy, and prosperous world in the twenty-first century and beyond?

Our collective inability, or perhaps unwillingness, to deal with conditions in the poorer parts of the world, on the one had, and the consumption patterns and lifestyles in more affluent parts of the world, on the other, pose serious obstacles to the attainment of global sustainability. With four-fifths of the world's people sharing the benefits of only 15 percent of the world's

economy and their countries home to less than a tenth of its scientists and engineers, it is clear that the global system will operate properly only if there are increasedfinancial contributions from the North. In most of the South, environments are deteriorating rapidly, and for large areas, the conditions in which people live are clearly unacceptable and unstable, often leading directly to. environmental degradation (Shabecoff, 1996). Perhaps, as Shabecoff outlined, *we* are on the verge of a new enlightenment about the environment, but there are *few* indications that this is in fact the case.

Even though future societies based on information seem to promise less environmental degradation, the world view that so many of us share seems an unsuitable one for building a sustainable world. As Kai Lee (1993, p. 200) puts it, "How much misery will it take to make a global norm of sustainability first visible, then credible, then feasible, then inevitable? We do not know. And we do not know if the lessons of environmental disaster can be learned in time to ward off still more suffering. However bleak that prospect, we in the rich nations must bear the certain knowledge that our societies are both historically responsible for many of the circumstances that imprison the poor and that we will on average fare much better than they. Against this background it is possible to see that sustainable development is not a goal, not a condition likely to be attained on earth, as we know it. Rather, it is more like freedom or justice, a direction in which we must strive, along which we search for a life good enough to warrant our comforts".

Biodiversity

The word "biodiversity," which was coined by Walter G. Rosen at the U.S. National Research Council in 1986, in connection with the organization of a National Forum on "BioDiversity" sponsored by the U.S. National Academy of Sciences and the Smithsonian Institution (Wilson, 1988). Although it was a contraction of the familiar phrase "biological diversity," the new term took an expanded meaning, and as Takacs (1996) points out, has become the rallying cry currently used by biologists and others to draw attention to the global ecological crisis broadly. At the 1986 conference, we were still largely dealing with a concept of "biological diversity" that tended to connote the army of species in the world, our knowledge of theta, and the degree to which they were threatened by extinction. In contrast, "biodiversity," includes not only the genetic variation of those species but also all of the ways in which they interact with one another in communities and

ecosystems – the entire fabric of life on Earth. Viewed in this broader way, biodiversity becomes the stuff of sustainable development, our primary hope for sustainable management of the planet in the future, and, of course, the resource on which we hope to base the coming "age of biology" over the decades to come. In other words, a concept that started as "biological diversity," transformed into "biodiversity," has added to its original connotation of a set of individual organisms a much broader social meaning. In that sense, it approaches the meaning of earlier broad concepts such as "wildlife" or "nature".

It is notable that the formation of the Society of Conservation Biology occurred in – the same year (1986) as the original conference on biodiversity. Like the conference itself, the formation of the Society signaled the maturity of an interdisciplinary effort in which the strands had been coming together for a number of years. An increasing maturity, based to some extent on the concepts that had been presented so poetically and well by Aldo Leopold 40 years earlier (Takacs, 1996), had deepened and broadened the conservation movement and the ways in which we can aspire to nurture the land and its living creatures.

The immediate inspiration for the formation of the concept of biodiversity was the sense of loss presented so clearly by authors such as Paul and Anne Ehrlich and Norman Myers in the 1970s and 1980s. Arguments based on the economic value of individual species, which are unquestionable and need not be elaborated here; those based on the value of ecosystem services, which in turn depend on interactions between species; and fundamental moral and ethical values all play important roles in explaining the reasons for the loss of biodiversity, estimated to amount to two-thirds of the species on Earth by the end of the coming century (Pimm and Brooks, 1999). Without biodiversity, we cannot respond well to the challenges we face, including global climate change: how will we form the new productive and stable biological systems of the, future? A habitable planet requires the maintenance of the living systems that support all living things on Earth, including human beings.

Current extinction rates are several hundred times higher than those that have prevailed for tens of millions of years, and habitat destruction continues apace, so that extinction rates of 1,000 to 10,000 times those that existed in the past will wipe out species at a rate that has not prevailed since the end of the Cretaceous Period, some 65 million years ago – at just the time when humanity bases so much of its future hopes on its ability to use those species for human benefit. Furthermore, we have charted only a small frac-

tion of the Earth's biodiversity, perhaps 1.6 million eukaryotic species even given a name of an estimated total number of perhaps 10 million, with next to nothing on a global scale really known about such critically important groups as bacteria, fungi, and many groups of marine organisms. What we are losing, we do not even know: and perhaps never will.

A View of the Future

Over the course of the twentieth century, it has become overwhelmingly apparent that humanity cannot expect a healthy, peaceful, and productive future – in other words, a sustainable one – if we continue to live off the Earth's capital, rather than its interest: natural productivity. A world in which people are using or wasting nearly half of the total terrestrial photosynthetic productivity, one in which more than half of the available fresh water is already appropriated for human use, one in which the characteristics of the atmosphere are being altered rapidly, and one in which the species on which we hope to base the construction of sustainable and productive systems at the level of individual species and that of communities are disappearing in huge numbers – such a world will not be able to continue with its profligacy much longer without severe crashes of major ecological and economic systems (Meadows *et al.*, 1992). Global security likewise depends ultimately on environmental sustainability rather than on the expenditure of a huge proportion of the world's economic output to fund armies for rich, industrialized nations and poor ones alike (Myers, 1995). Food security, health, social justice – all are dependent on rising above our parochial and perhaps ingrained views of how to live, and learning together how to manage our planetary home for our common benefit. Empowering women throughout the world, seeking means to raise their status, and alleviating their poverty – microcredit has proved an effective strategy in this important effort – constitute among the most important actions to be taken to achieve sustainable development Science and technology need to be fully applied in our striving toward global sustainability (Lee, 1993), but they alone will clearly not be enough. The new Social Contract for Science called for so forcefully by Lubchenco (1998), one in which scientists will address the most urgent needs of society; communicate their knowledge and understanding widely in order to inform society's decisions; and exercise good judgment, wisdom, and humility, constitutes a powerful call to action in a world that needs such action badly.

As the century comes to its end, it seems clear that the regulation of eco-

nomic policy, with allowances for supporting the actions of the private sector, will have more impact on the environment than direct legislative initiatives. Conservative economists and radical environmentalists agree that the true value of the materials that we are using must become the basis of the sustainable commerce of the future, and that irrational taxes that drive unsustainable activities by mis-stating the value of their materials should be abandoned. Indeed, Myers and Kent (1998) have estimated that perverse subsidies leading to the destruction of natural resources worldwide amount to some $1.5 trillion annually, approximately twice as large as total global military spending, and larger than the economies of all nations on Earth except the five largest – recognizing the undesirable nature of these subsidies and eliminating them or changing them in ways that will contribute to the. sustainability of global ecosystems and resources would be one of the most important actions that humanity could take as we enter the new millennium. Perhaps the world's major corporations could in their own interest pursue an agenda in which the actual prices of resources were taken into account. In the many design and construction community, for example, architects and building scientists are just now starting to operate by the rules of such an agenda, conserving energy and using new life cycle analysis (LCA) software tools to evaluate the environmental costs, such as resource depletion, greenhous gas emissions, and energy consumption, of materials from “cradle to grave”. Green consumerism is growing rapidly, with more than 31 million certified acres supplying “green” wood products in 1999. In addition, and of great importance, national and global systems of green accounting to reflect the full environmental costs of economic activities would help.

By pursuing strategies of the sort just reviewed, it might actually be possible to improve the potential condition of the world, and to counteract humanity's partly hard-wired tendency to behave as if we were still highly dispersed hunter-gatherers, rather than members of a rapidly growing human race comprising six billion people, some very rich, but many living in abject poverty. How could we build the political will to accomplish this? In view of the failure of the United States and other leading industrialized countries to address responsibly the agenda proposed at the Earth Summit in Rio de Janeiro in 1992, we cannot legitimately enter the new millennium with a sense of optimism. Despite this, we must be as effective as we can for the sake of those who will follow us, and we have significant choices to make that will clearly influence the shape of the world in the future, as analyzed effectively by Allen Hammond (1998).

Concretely, we could continue to strive to move sustainability closer to the center of the United Nations agenda, where it would be recognized as the most powerful factor in determining human futures. The United States could ratify the Convention on Biological Diversity, and all parties could refocus its activities on its three key objectives, which will help to conserve biodiversity and improve livelihoods, rather than allowing it to be consumed by questions of gene technology that have at best a marginal bearing on the survival of species around the world. The reform of the activities of the Convention, and their redirection towards appropriate objectives, would be a major step forward in the field of sustainable development. A global plan for the preservation of species, properly funded, would result in the greatest gift that, we could possibly give to our descendants.

On the other hand, it may be that the model of a world driven by nations and the kinds of international institutions that were established in the wake of World War 11 will not prove to be dominant in the future. On the one hand, there is growing evidence that enlightened corporations are increasingly realizing that understanding and working with the conditions of sustainable development is a necessary prerequisite for success in the corporate world of the future (Hawken, 1993). John Browne, CEO of BP, for example, has set the company on a course that will embrace alternative energy sources and energy conservation, reasoning that in the face of global warming, they must do this if they are to continue to be a profitable energy company in the future. How much more likely BP is to prosper than companies that ignore the conclusions about climate change that are so evident to the scientific community? Ray Anderson, chairman of Interface, an Atlanta-based carpet manufacturer, is likewise reorganizing his company's efforts around the conditions of the future, where sustainability will be a necessary condition of successful business, rather than those of the past. There are signs that the forestry and fisheries industries are starting to take sustainability seriously, and indications that consumers will increasingly demand appropriate certification for such products because of their concern for the environment. If corporations listen carefully to their stakeholders and take care to operate sustainably, they will affect the actions of governments and international agencies significantly and help to create conditions for their own prosperity, and for the world's sustainability. Frameworks such as that developed by The Natural Step, a Swedish organization that is having much influence throughout the industrialized world, will provide convenient blueprints to help guide us along the path of sustainability – but Kau Lee's

(1993) principle that sustainability can perhaps best be viewed as an ideal, like justice, should be kept carefully in mind as we travel in that direction.

The kinds of grassroots activities that are promoting sustainability on a local basis have become a powerful force throughout the world: perhaps they are fundamentally only a reemphasis of what has been traditional. Whether establishing local clinics and sustainable industries in the Biligiri Rangan Hills of south India, people-based ecotourism centers in native lands in Kenya, rebuilding a broken landscape at the Bookmark Biosphere Reserve in South Australia, learning how to ranch sustainable on the vast grasslands of the Malpai Borderlands of New Mexico and Arizona, or simply rooting out alien plants on Albany Hill in the San Francisco Bay Area, the people who are pursuing sustainability in a direct and personal way will hugely affect the shape of the world in the future. Outstanding books like those by Baskin (1997) and Daily (1997), explaining in detail how nature works and how we benefit from it in ways that most of us never consider will continue to play an important role in stimulating our desire to achieve sustainability. For example, watershed protection, the determination of local climates, and the protection of crops by birds and beneficial insects, including pollinators, that live in the ecosystems surrounding them are examples of ecosystem services – goods that nature provides without charge if we maintain sufficiently the integrity of the ecosystems that support them. In the light of this awareness, growing numbers of people will find ways to consume less energy, to recycle their materials, to participate in the political process, to promote the acceptance of international understanding as a prerequisite for sustainability, and to support others, individually or in organized groups, who are pursuing these objectives.

For the basic conditions of change must clearly come from within us. A small minority of Earth's residents cannot continue to consume such a large majority of Earth's potentially sustainable productivity. By doing so, they will untimely destabilize their own future, as well as the futures of all other people. Population, overconsumption (among others, Schor, 1998, offers a powerful analysis of overconsumption in America), and the use of appropriate technology must all be brought into the equation if our common objective is to achieve a sustainable world in the new millennium. As Paul Hawken (1993) has put it so well, we need completely new ways of thinking about our place on Earth and the ways in which we relate to the functioning of natural systems if we are to find a better way to live in har-

mony with nature. Nothing less than a new industrial revolution (Hawken, Lovins, and Lovins, 1999) and a new agriculture (Conway, 1997) are required to make possible the sustainable world of the future. The task is incredibly challenging, but it is nonetheless one that we much undertake if we responsibly understand the realities of our situation, and for the enduring good of those who come after us. It is also a fundamentally spiritual task. As Cronon (1955, p. 90) put it, "If wildness can stop being (just) out there and start being (also) in here, if it can start being as human as it is natural, then perhaps we can get on with the unending task of struggling to live rightly in the world – not just in, the garden, not just in the wilderness, but in the home that encompasses them both".

In the words of Gandhi, most appropriate as we chart our course for the new millennium, "The world provides enough to satisfy everyman's need, but not everyman's greed". These words illustrated why Wilson (1993) was able to conclude that humanity would be able to overcome its drive to environmental domination and self-propagation with reason – why, in short, we are not necessarily suicidal in our approach to the world. In the spirit of Gandhi, one of the greatest leaders of our century, let us take his thoughts to heart and find the new inspiration that we so badly need at this incredibly challenging time. Global arguments may have little impact on the behaviors of individuals unless they perceive the crisis as unbearably severe, something that impinges on people's lives in dramatic and frightening ways. By then it will be too late. Our ethics and our values must change, and they must change because we come to understand that by changing we will be happier people, guaranteeing a decent future for our children on a healthier planet in more vibrant democracy in better neighborhoods and communities.

Many of the world's life-support systems are deteriorating rapidly and visibly, and it is clear that in the future our planet will be less diverse, less resilient, and less interesting than it is now; in the face of these trends, the most important truth is that the actual dimensions of that world will depend on what we do with our many institutions, and with the spiritual dimensions of our own dedication. Clearly, the opportunities that are available to us now are very much greater than those contemplated with such joy by those who gathered in St. Louis in 1904, and the stakes are much higher.

LITERATURE CITED

Adams, A. and N. Newhall. 1960. *This is the American Earth*. Sierra Club Books, San Francisco

Andrews, R.N.L. 1999. *Managing the Environment, Managing Ourselves. A History of American Environmental Policy*. Yale University Press, New Haven and London

Baskin, Y. 1997. *The Work of Nature. How the Diversity of Life Sustains Us*. Island Press, Washington, D.C.

Carson, R. 1962. *Silent Spring*. Houghton Mifflin Company, Boston

Conway, G. 1997. *The Doubly Green Revolution. Food for All in the 21st Century*. Penguin Books, London

Cronon, W. (ed.). 1995. *Uncommon Ground. Toward Reinventing Nature*. W.W. Norton & Company, New York

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

Easterbrook, G. 1995. *A Moment on the Earth: The Coming Age of Environmental Optimism*. Penguin Books USA, Inc., New York

Ehrlich, P.R. 1968. *The Population Bomb*. Ballantine, New York

Elton, C. 1927. *Animal Ecology*. Sidgwick and Jackson, London

Gottlieb, R. 1993. *Forcing the Spring. The Transformation of the American Environmental Movement*. Island Press, Washington, D.C.

Grove, R.H. 1995. *Green Imperialism. Colonial Expansion, Tropical Island Edens and the Origins of Environmentalism, 1600-1860*. Cambridge University Press, Cambridge

Hammond, A. 1998. *Which World? Scenarios for the 21st Century*. Global Destinies, Regional Choices. Island Press, Washington, D.C.

Hawken, P. 1993. *The Ecology of Commerce*. HarperCollins Publishers, New York

Hawken, P., A. Lovins, and H. Lovins. 1999. *Natural Capitalism. Creating the Next Industrial Revolution*. Little, Brown, New York

Lee, K.N. 1993. *Compass and Gyroscope. Integrating Science and Politics for the Environment*. Island Press, Washington, D.C.

Lendt, D.L. 1979. *Ding. The Life of Jay Norwood Darling*. Iowa State University Press, Ames

Leopold, A. 1949. *A Sand County Almanac*. Oxford University Press, New York

Lubchenco, J. 1998. "Entering the century of the environment: A new social contract for science", *Science* 279: 491-497

McCormick, J. 1989. *Reclaiming Paradise*. Indiana University Press, Bloomington and Indianapolis

McIntosh, R.P. 1985. *The Background of Ecology. Concept and Theory*. Cambridge University Press, Cambridge

McKibben, W. 1989. *The End of Nature*. Random House, New York

Meadows, D.H., D.L. Meadows, and J. Randers. 1992. *Beyond the Limits*. Chelsea Green, Post Mills, VT

Meadows, D.H., D.L. Meadows, J. Randers, and W.W. Behrens 111. 1972. *The Limits to Growth*. Universe Books, New York

Myers, N. 1995. *Ultimate Security. The Environmental Basis of Political Stability*. W.W. Norton and Company, New York and London

Myers, N. with J.V. Kent. 1998. *Perverse Subsidies: Tax $s Undercutting Our Economies and Environments Alike*. International Institute for Sustainable Development, Winnipeg, Manitoba, Canada

Nash, R. 1982. *Wilderness and the American Mind*. 3rd. edn. Yale University Press, New Haven and London

Osborn, F. 1948. *Our Plundered Planet*. Little Brown, Boston

Pimm, S.L. and T.M. Brooks. 1999. "The sixth extinction: how large, how soon, and where?" in Raven, P.H. and T. Williams (eds.), *BioDiversity*. National Academy Press, Washington, D.C.

Shabecoff, P. 1993. *A Fierce Green Fire. The American Environmental Movement*. Hill and Wang, New York

Shabecoff, P. 1996. *A New Name for Peace. International Environmentalism, Sustainable Development, and Democracy*. University Press of New England, Hanover and London

Schor, J.B. 1998. *The Overspent American. Why We Want What We Don't Need*. HarperCollins Publishers, New York

Sitarz, D. (ed.) 1993. Agenda 21. *The Earth Summit Strategy to Save Our Planet*. EarthPress, Boulder, CO

Stegner, W. 1980. "Coda: Wilderness Letter," in *The Sound of Mountain Water*, pp. 147-8. University of Nebraska Press, Lincoln

Takacs, D. 1996. *The Idea of Biodiversity. Philosophies of Paradise*. The Johns Hopkins University Press, Baltimore and London

Turner, B.L., II. (ed.). 1990. *The Earth as Transformed by Human Action. Global and Regional Changes in the Biosphere over the Past 300 years*. Cambridge University Press, Cambridge

Wackernagel, M. and W. Rees. 1995. *Our Ecological Footprint: Reducing Human Impact on the Earth*. New Society Publishers, Gabriola Island, BC, Canada

Wilson, E.O. (ed.). 1988. *BioDiversity*. National Academy Press, Washington, D.C.

Wilson, E.O. 1993. "Is humanity suicidal?" in *The New York Times Magazine*, May 30, 1993, pp. 24-28

World Commission on Environment and Development. 1987. *Our Common Future*

Acknowledgments:

I wish to thank for useful discussions in connection with the preparation of this paper Robert Archibald, Gretchen C. Daily, Anne H. Ehrlich, Paul R. Ehrlich, Paul Faber, Kate Fish, Chris Hammer, Paul Hawken, Peter Jutro, Robert W. Kates, Jonathan Lash, Jane Lubchenco, Harold Mooney, Warren Muir, Norman Myers, Kerry ten Kate, George M. Woodwell.