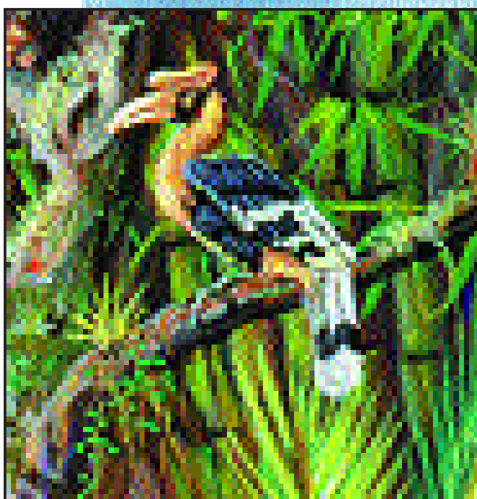
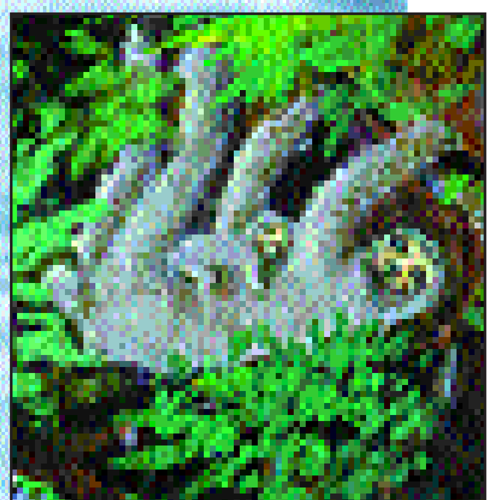
Biodiversity, Science, and the Human Prospect



Prepared by the
Center for Biodiversity and Conservation
American Museum of Natural History

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Contents

I. Summary

At the threshold of the 21st century, we face an unparalleled crisis: the accelerating loss of the plant and animal life on this planet. It has been conservatively estimated that as many as 27,000 species are being driven to extinction annually through the loss of tropical forests alone. As pressures on natural habitats around the world intensify, nature's endowment of biological diversity is contracting—along with the actual and potential benefits which humankind gleans from an abundant and diverse biosphere.

In 1995, a group of leading biodiversity experts gathered at the American Museum of Natural History (AMNH) to assess the status of global biodiversity and discuss how scientists and policymakers can work together on conservation solutions. This conference, "The Living Planet in Crisis: Biodiversity, Science, and Policy," was the first to be sponsored by the AMNH Center for Biodiversity and Conservation. The Center was established in 1993 to provide a focus for the Museum's conservation-related activities, and its inaugural conference attracted forty leading international experts and nearly 600 attendees. Several themes emerged from conference presentations, position papers, and extended panel discussions: that biodiversity is more extensive than we had calculated in the past; it sustains the ecological services upon which human life depends; it is eroding at a rate and scale unprecedented in human history; and, despite gaps in our scientific understanding, we must move forward with conservation measures or place at risk the very foundation of human health, agricultural productivity, economic prosperity, and political and social stability. This report summarizes the information and ideas generated at the conference and reflects subsequent discussions at the AMNH.

> *The American Museum of Natural History established the Center for Biodiversity and Conservation in 1993 to mobilize the Museum's extensive resources in the development of an interdisciplinary approach to conservation, one which will move us from current crisis management toward viable long-range planning. The establishment of the Center is testimony to the Museum's ongoing devotion to the understanding, appreciation, and protection of biological diversity.*

As unprecedented as the biodiversity crisis is in human history, so too are the collaborative efforts that people must—and are—undertaking in response. We are certainly confronted by a formidable array of difficulties: an incomplete knowledge of biodiversity, lack of integration among the relevant sciences, the failure to devise an adequate formula for figuring resource-loss into the economic and development equation, and poor communication between policymakers and scientists.

Science must remain the central reference and guide in meeting these challenges and in shaping sound conservation actions; however, a *new* kind of science will need to evolve—one that is interdisciplinary, issue-driven, and willing to communicate effectively with policymakers and populace. The crisis we are facing demands that science exceed the boundaries which it previously defined for itself and turn a new page.

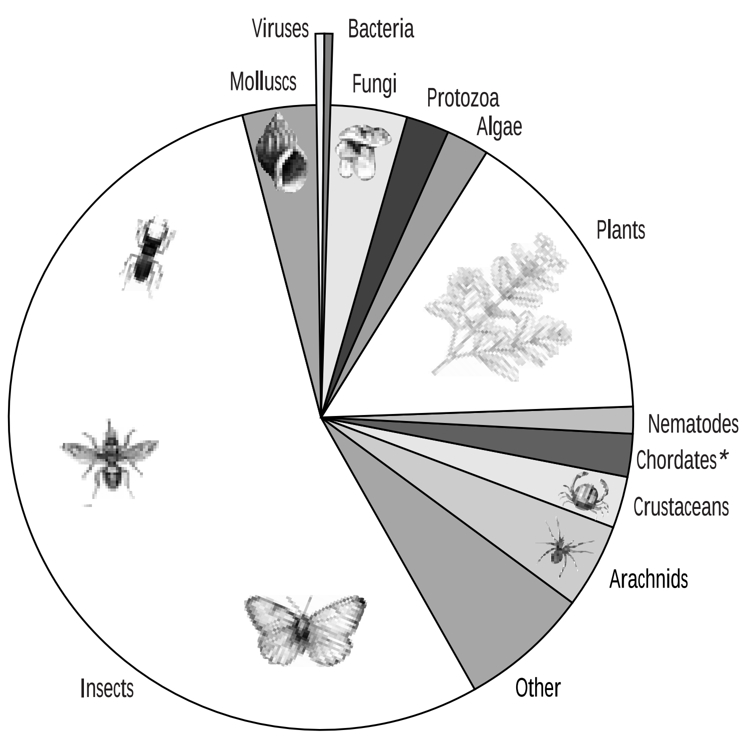
II. The Living Planet in Crisis

Introduction

Of all the characteristics of life on earth, none is so extraordinary as its sheer diversity: the seemingly limitless array of lifeforms, the vast genetic variety they contain, the rich ecological associations they form, and the complex behaviors they adopt in meeting the challenge of survival. This diversity reflects life's capacity to occupy the ever-changing spectrum of environments on the planet, from arctic ice cap to dense tropical rainforest, from sun-bleached desert to sunless subterranean cavern, from mountain summit to ocean depth.

Every day earth's biological diversity provides goods and services used by all people: the air we breathe, the water we drink, the foods and medicines that sustain our lives, the materials that support our economies, the sights and sounds and smells that enrich our quality of life—all draw upon nature's rich endowment of genes, species, habitats, and ecosystems.

Biodiversity refers to the variety of genetic materials within species, the variety of species in all taxonomic groups, and the variety of communities, ecosystems, and landscapes within which species evolve and coexist. Conservation seeks to sustain this variety, as well as the evolutionary and ecological processes that support it, by guiding human activities within nature. Fundamental to effective biodiversity conservation is the precept that it must take into account the multiple levels of biological organization, as well as the multiple scales of space and time over which the processes that sustain, perpetuate, and alter lifeforms operate.



Proportion of the approximately 1.75 million described species in the major groups of organisms. (Chordates include mammals, birds, reptiles, fish, and amphibians.)*

Biodiversity, our life-support system, is today increasingly threatened by human activity: unabated human population growth, overexploitation of resources, pollution, and global climate change.[1] Two sets of data point to an ongoing extinction event of devastating proportions: 1) the large body of observations that document human-induced extinctions, and 2) extrapolations based on available knowledge of diversity patterns in the landscape and the rate at which habitats are being lost due to human activities. If current trends continue, an alarming percentage of the world's species are likely to go extinct within the next several decades. Biologist E.O. Wilson calculates that 20% of the world's species will be extinct within the next 30 years and at least 50% in the decades that follow.[2]

This crisis has many faces: the desperate movement of subsistence farmers to forest frontiers and the resulting loss of tropical habitat to slash-and-burn agricultural practices; the moratoria placed on fisheries that were formerly the world's richest and most productive; the widespread loss of traditional crops and livestock breeds from rural landscapes; the bitter reaction of loggers whose livelihoods are undermined by the epic success of their industry in depleting North America's old-growth forests. These are all facets of a world-wide ecological catastrophe, the urgency of which we are just beginning to comprehend. Unlike most human-caused environmental perils, however, anthropogenic extinction—the most conspicuous form of biodiversity loss—is irreversible. A species lost is lost forever, as is its genetic legacy and its place in the larger community and longer story of life on earth.

Background: The Role of Extinction and the Geological Record

Extinction, of course, is not a recent phenomenon; it is, in fact, a natural process inherent in evolution. At least five mass extinction episodes are recorded in the planet's geological record. Paleontologists differentiate between the high extinction rates that marked these mass extinctions and the normal "background extinction rate" recorded in other periods. According to conservative assessments, the current rate of human-exacerbated extinction is at least 1,000 times greater than what would have occurred naturally.[3] In fact, we are now experiencing a rate of extinction that rivals the mass extinctions of pre-history. When *Homo sapiens* evolved 100,000 years ago, the number of species on earth was at its peak; if the current rate of extinction continues, we will approach the lowest levels of extant species since the end of the Age of Dinosaurs, 65 million years ago.[4]

For thousands of years, human beings significantly modified earth's ecosystems, favoring some species while driving others to extinction. During the late Pleistocene (less than 2 million years ago), some 70% of North America's large mammals went extinct soon after human beings arrived over the Bering land bridge.[5] Although overhunting has been widely accepted as the cause of these extinctions, introduction of virulent diseases by humans and their commensals and global climate change may also have played significant roles. Human populations in the Pacific Islands eradicated as many as one-fifth of all birds—perhaps 2,000 species—over the last 1,100 years through overhunting and habitat alteration.[6] (At present, about 10% of the world's extant bird species—almost 1,000—are listed as threatened.[7])

Although the phenomenon of human-induced extinction is thousands of years old, the scope and intensity of the current crisis is unprecedented. Human destruction of species and habitats is no longer confined to particular localities or regions; it is now global in scale, affecting a much broader range of organisms. In the past, large and conspicuous species (especially birds and mammals) were at greatest risk; now, invertebrates, other small animals, marine and other aquatic organisms, and, significantly, plants are also threatened. In other words, entire species clusters and the habitats they occupy are now under assault.

First sighted on the island of Mauritius around 1600, the Dodo was extinct less than eighty years later. The disappearance of the Dodo represented above by a model, is attributed primarily to human activities–destruction of forests and introduction of non-native animals.

It has been suggested that, since as much as 99% of all species that ever lived are now extinct, today's losses are not significant. Furthermore, since the earth rebounded so magnificently from the greater biodiversity catastrophes of pre-history, it can fare no worse from those that belong to human history. Though this may be possible, it is important to remember that recovery from the five previous mass extinctions took anywhere from five to ten million years.[8] As the average lifespan for terrestrial species lies in the low millions (usually less than five), the recovery from the next mass extinction will require a span of time far in excess of the probable remaining lifespan for our species. Altering our behavior to prevent the needless loss of plant and animal life will depend on the full recognition of the consequences of that loss, at all levels, in our lives.

The Value of Biodiversity

Biodiversity generates a wide array of direct benefits for people in the form of food, energy, fiber, medicines and other goods. These biological resources provide sustenance and are the basis of local and national economies. Biodiversity also serves us in more indirect ways by maintaining the ecological and biophysical processes upon which environmental quality depends, which, in turn, is an indispensable anchor to social and political stability. Beyond such tangible assets, there are cultural, recreational, aesthetic, and spiritual benefits that derive from exploration of and contact with life's variety. Our hopes for a sustainable future lie in an acknowledgment and understanding that all of these benefits derive from the abundance of life around us.

Biological diversity maintains essential ecological services.

The indispensable ecological services that keep the earth a habitable place are performed by myriad plants, animals, fungi, and microorganisms. The earth's organisms are not merely "bystanders," but essential participants in the workings of the planet's atmospheric, climatic, hydrologic, and biogeochemical cycles.

- Through photosynthesis, green plants remove carbon dioxide from the atmosphere and replenish the supply of oxygen.
- A diverse group of microbes, the Rhizobia, convert atmospheric nitrogen into a form that plants can utilize.
- Phytoplankton in the oceans provide the foundation for marine food chains and help regulate global atmospheric cycles.
- Organic materials in dead and decaying organisms are decomposed and recycled by fungi, bacteria, saprophytes, and scavengers.
- Hydrological functions within watersheds are regulated by the biodiversity within the area's soils, watercourses, and upland and wetland biotic communities.

Only in the last several decades has science begun to comprehend these cycles (at various scales) and to reveal the functional role that biodiversity plays within them. As human pressures

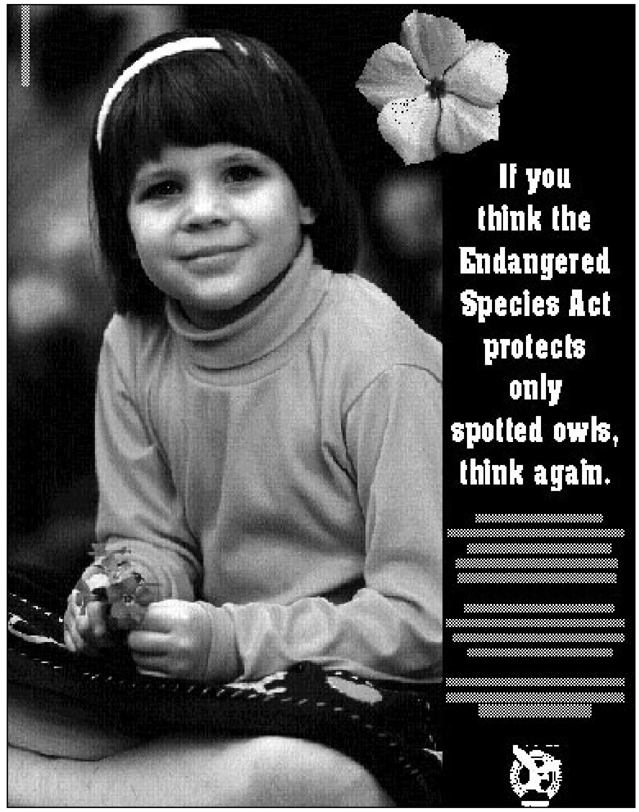
"The Life of the Forest Floor" diorama at the American Museum of Natural History represents a cross-section of forest soil, enlarged to 24 times its actual size. The diorama illustrates the amazing array of organisms which decompose and recycle organic materials.

on landscapes, aquatic systems, and ecological processes continue to rise, the need for sustainable management of resources will require even deeper understanding of the structure and function of ecosystems, the role that biological diversity plays within them, and the impact of human activity upon them.

Biological diversity provides the basis for human health.

Biodiversity contributes to our well-being by providing medicinal compounds, inhibiting pathogens, and maintaining environmental quality. Conversely, human-caused changes in the distribution and magnitude of biodiversity affect human health by increasing the risk of disease and decreasing our options for finding cures. Many of the links between human health and biodiversity are direct and obvious; others are more subtle.[9]

- Traditional plant- and animal-derived medicines remain the primary sources of health care for some 80% of the world's population — nearly 4.5 billion people.[10]
- Fifty-seven percent of the 150 most prescribed drugs have their origins in biodiversity.[11] In addition to these are less often used drugs such as Vincristine, derived from the Madagascar periwinkle (*Catharanthus roseus*) and the preferred treatment of childhood leukemia, and Taxol, first derived from the bark of the Pacific yew (*Taxus brevifolia*) and an effective treatment for ovarian and breast cancer.
- The biological adaptations of a wide range of terrestrial and aquatic organisms provide us with medical models that enable us to understand human physiology and disease; for instance, understanding why bears do not lose bone mass during their long hibernation could lead to treatments for osteoporosis, which costs the U.S. economy $10 billion in direct health care costs and productivity losses each year. Many species of bear are endangered today.[12]



A poster in support of the Endangered Species Act illustrates how a drug derived from the Madagascar periwinkle is an important treatment for childhood leukemia.

- Disruption of ecosystems may cause changes in food supply and water quality, which in turn affect nutrition and sanitary conditions. Such changes reduce resistance to disease even as they increase exposure to pathogens and disease vectors. In Ghana, for instance, where the tropical forest has been reduced to 25% of its original size, approximately 75% of Ghanaians depend on wild game to supplement their diet. Forest depletion has resulted in a sharp increase in malnutrition and disease.[13]
- As ecosystems are disrupted, changes occur in the numbers, kinds, and relationships of species within the system, including those

that cause and spread human disease. Increasing disturbance of tropical forests in Africa, for example, is believed to be a contributing factor in the emergence of the Ebola virus and other contagious disease agents in recent years.

"The wild beasts of this century and the next are microbial, not carnivorous."[14]

- Biodiversity also contributes to our emotional and psychological well-being. Recently, psychologists have begun to study how mental health and social conditions are affected by life in a human-dominated world increasingly devoid of the beauty, tranquillity, and stimulation afforded by contact with other lifeforms.[15]

As biodiversity is lost, humankind's storehouse of potential cures and treatments shrinks. At the same time, ancestral knowledge of medicinal substances is rapidly eroding. This is occurring even as new diseases are emerging and human pathogens are growing resistant to antibiotics. These examples demonstrate that we are often unable to fully understand complex interconnections within nature, to comprehend how human health is affected by those interconnections, or to predict the consequences of biodiversity loss.

Bees, important pollinators, are threatened by exposure to pesticides and changes in their environment. This is Callonychium, *a pollinator in Argentina.*

Biological diversity is the source of agricultural productivity and sustainability.

Agriculture arose as a result of humankind's conscious alteration and refinement, over thousands of years, of wild plants and animals. The long-term productivity of agroecosystems still depends on the diverse organisms found within them. Agroecosystems include not only the plants and animals we use directly, but other living components which allow the system to remain productive and healthy.

- Rhizobial bacteria make nitrogen available for use by crops, pastures, forests, and natural vegetation. The economic value of this activity has been estimated at $50 billion annually.[16]

- More than 40 crops produced in the United States, valued at approximately $30 billion, depend on insect pollination.[17] Of these, only 15% are serviced by domestic honeybees; the rest are pollinated by wild bees and other wildlife. Bees and other insects, butterflies, birds, bats, and various small mammals pollinate 75% of the world's staple crops and 90% of all flowering plants.[18] Populations of both wild and managed pollinators are, in many instances, in sharp decline due to exposure to pesticides, habitat fragmentation, and climatic fluctuations.

- Farmers around the world spend about $25 billion annually on pesticides. Yet, natural parasites and predators in the world's ecosystems provide an estimated five to ten times this amount of free "pest control." Without wild species, losses due to pest damage would be catastrophic, and the costs resulting from increased use of chemical controls would be economically and environmentally prohibitive.[19]

"Bats, hummingbirds, moths, and butterflies are among the pollinators that seasonally migrate, long and short distances. Their migratory routes are often well-defined 'nectar corridors' where the sequence of flowering offers the pollinators sufficient energy to sustain their journey. Many of these corridors are no longer fully intact, however: land conversion has eliminated some floral resources over twenty-to - sixty-mile segments, in some cases longer than the distance energy-depleted pollinators can fly in one day." [20]

- At the larger landscape scale, natural plant and animal communities—forests, savannahs, grasslands, wetlands—play a critical role in the functioning of hydrological cycles and systems. When these natural habitats are destroyed through unsustainable agricultural and forestry practices, or urban encroachment, the result is often a serious decline in the fertility of arable land due to increased erosion, compacting, salinization, and acidification. It is estimated that 2 to 3 million hectares of cropland are lost annually to erosion and that as much as one-fifth of the world's cropland is suffering from some degree of desertification.[21]
- Animal, fungal, and bacterial agents are essential to the breakdown and recycling of organic matter, maintaining the fertility of cultivated soils by allowing nutrients to be reincorporated into the production cycle.

These functions, and many others integral to the performance of agroecosystems, reflect the action of biological agents within the system. Although artificial methods have been developed to imitate these functions, they invariably cost more, pollute more, and require more off-farm inputs. By contrast, development of more sustainable agricultural systems often involves reintroducing biodiversity into the management plans and practices of farmers.

A special category of biodiversity includes the genetic lines and species that are cultivated and/or harvested through the operations of crop and livestock agriculture, forestry, and fisheries. Over the millennia, people have domesticated some 12,000 wild plant species and twenty to thirty animal species, primarily for agricultural uses. Agriculture, aquaculture, and forestry still depend upon wild relatives of domesticated species for genetic materials that provide disease resistance, enhance productivity, and improve adaptability to environmental conditions. A wild species of perennial corn, for example, proved to be resistant to seven main types of viral disease and may hold the key to the future security of the world's $60 billion corn crop. This species, *Zea diploperennis*, was found in an area of Mexico experiencing high rates of deforestation.[22]

In recent decades, the introduction of high-yielding varieties and the adoption of intensive agricultural production practices world-wide has dramatically reduced the number of species of crops and livestock, as well as genetic diversity (i.e., breeds, varieties, and landraces) within species. Today, some 90% of the world's food needs are supplied by just twenty crops.[23] Due to this loss of diversity, breeders find it increasingly difficult and expensive to maintain and increase yields in the face of stresses imposed by pests, pathogens, and large-scale environmental changes.

Biological diversity underlies economic stability and prosperity.

Our economic well-being ultimately depends on biodiversity. As already discussed, biodiversity is the basis for the maintenance of ecological services, human health, and agricultural productivity. A severe erosion in the overall quality of any of those vectors could have serious consequences in the economic sphere.

- As biodiversity is lost and ecological services deteriorate, the cost in declining human and livestock health over time could exceed all other economic gains. The resurgent spread of malaria is a good example. Throughout the tropical reaches of Africa, where deforestation has led to erosion and flooding, mosquitoes proliferate and with them the incidence of malaria. The cost of widespread disease lies not only in health-care dollars, but in lost productivity. Therefore, while the World Bank has urged developing countries to spend more on primary health care, the loss of productivity among a debilitated populace weighs in against the chances for increasing GNP and gaining the means for better disease prevention.[24]
- Sacrifice of important non-renewable resources for short-term gain may have a negative impact on long-range productivity. We have yet to develop a way to adequately figure resource-loss into the economic equation; generally, we are not weighing short-term gains against long-term losses. Robert Repetto, a resource analyst, has used the degradation of agricultural lands in Java as an example. He estimated the total cost of one year of erosion to be about $481 million, or the sacrifice of approximately 40 cents of future agricultural income for every dollar of current income.[25]
- Along with population stresses, environmental deterioration and resource shortages could lead to massive migrations of people, not only from rural to urban centers, but across national borders. Both scenarios, already being experienced in many developing countries, have the potential to disrupt labor markets, weaken the tax base, and undermine financial and political institutions.[26]

Beyond the systemic economic impacts which could occur due to environmental deterioration caused or exacerbated by biodiversity loss, we also must consider our dependency on the thousands of species which we use for food, shelter, clothing, fuel, medicines, and other commercial goods. Discoveries of raw materials or functions within those materials also give us models for approaching problems; these have led to some of the latest advances in biotechnology and medical science. A heat-resistant bacterium found in the hot springs of Yellowstone National Park, for instance, provides an enzyme essential to the development of the polymerase chain reaction (PCR) technique. This breakthrough, which allows large quantities of identical DNA to be produced from small samples, makes possible research in biomedical science and biotechnology.[27] With the loss of biodiversity, therefore, humankind loses both raw materials and inspiration for new technologies.

Biological diversity helps to ensure the stability of social and political systems.

Human rights do not arise or thrive in an environmental vacuum. True societal security involves interconnected social and environmental components, and among these is the status of biodiversity. In many regions of the world, the accelerating loss of habitats and the long-term decline in biodiversity contribute to social inequity and instability.

- People need access to food, clean water, medicines, and the other resources that healthy ecosystems provide. In some areas, especially in the developing world, loss of biodiversity threatens the availability of such resources. This can be an acute threat to indigenous peoples who rely on such resources for their survival and livelihood.
- Biodiversity loss is often linked to systems of land tenure that encourage unsustainable patterns of resource use. As a result, the rural poor are often forced to migrate to remote, ecologically fragile areas or into cities, which in turn exacerbates existing environmental problems in those areas.
- The loss of environmental integrity undermines the security of nations by increasing

the actual and potential incidence of poverty, famine, displacement, migration, and even armed conflict. The global community has spent billions of dollars in emergency aid responding to crises ranging from the Philippines to Haiti to Rwanda.

Global-scale environmental threats—including deforestation, climate change, and rapid population growth—are associated in complex ways with biodiversity loss. Although the long-term social impacts of such massive changes are difficult to quantify and impossible to predict with accuracy, they are real and inevitable.

"The linkages between environmental change and conflict are complex, involving numerous intervening variables…The Filipino population growth rate of 2.5% is among the highest in Southeast Asia. To help pay their massive foreign debt, the Philippine government encouraged the expansion of low-scale lowland agriculture. Both factors have swelled the number of landless agricultural laborers. Many migrated to the Philippine's steep and ecologically vulnerable uplands where they cleared land or established plots on previously logged land. This set in motion a cycle of erosion, failing food production, and further clearing of land. Even marginally fertile land is becoming hard to find, and economic conditions are often dire. Civil dissent is rampant in these peripheral areas, which are largely beyond the control of the central government." [28]

Biological diversity enriches the quality of our lives.

Biodiversity is essential to our humanity, serving as the medium through which unique educational, cultural, aesthetic, and spiritual values are expressed. Although these elude measurement, they are pervasive.

- Biodiversity is inextricably woven into our cultural expressions. A wide range of arts and artifacts derive their materials and inspiration from nature's diversity. These derivations express local and regional character and, in this sense, underlie the cultural diversity through which we explore and communicate our hopes and traditions. Plants and animals are woven into our songs, stories, dances, poetry, and myths; used in our crafts and cuisines; reproduced and symbolized in our decorative arts; and celebrated in our rituals, festivals, and holidays.
- Biodiversity enriches our experience of the outdoors. The pleasures to be found through contact with nature depend on biodiversity. The emotional fulfillment that comes through contact with other living organisms expresses itself in a wide array of popular activities: hunting, fishing, hiking, camping, birdwatching, gardening, diving, whale-watching, collecting, painting, photography, and even indoor activities such as aquarium-keeping and flower-arranging.

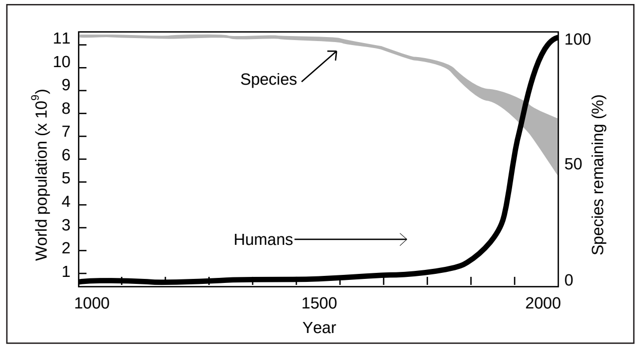
Central Park provides valuable habitat for both resident and migrant birds as well as hours of enjoyment for New York City birdwatchers.

- Humankind's intellectual curiosity developed within a diverse world, and we return to the natural world to seek understanding and insight. Genes, species, and ecosystems are repositories of information about the ways life has adapted to past environmental change. Evolutionary biology, genetics, ethnology, anthropology, psychology, engineering, and philosophy seek to understand the nature of the world and our place within it in order to gain inspiration for human invention.
- In addition, traditions of faith around the world have drawn upon biodiversity in their imagery, giving voice to the mystery, beauty, and responsibility to be found in the observation and contemplation of nature.

In short, we depend on biodiversity not only for our physical sustenance, but for the vitality of our creative and spiritual lives.

Biological diversity is intrinsically valuable.

Many conservationists hold that biodiversity, apart from the benefits that people derive from it, also has inherent worth; that life's varied expressions, including species and biotic communities, deserve respect by the very fact of their existence.[29] Although these values and the instrumental values described above are not mutually exclusive, the recognition of intrinsic significance places additional responsibility upon our own species. Intrinsic value also lends special importance to efforts to protect species and ecosystems that have become endangered as a result of human activities. By expanding our appreciation of the community of life, recognition of intrinsic value has helped to clarify how, where, and when such human activities become threats to biodiversity.



World population growth and species decline over time

Earth's population is expected to stabilize at the end of the 21st century, and the United Nations' mid-range estimate of the global population at that time is 10.2 to 11 billion people —twice the size of the planet's current population. While the industrial nations will contribute only about 5% to the increase, our per capita consumption rate is expected to remain at 10 to 100 times that of most developing countries. It is predicted, therefore, that the environmental stresses caused by a slight population increase in the United States could exceed those of India and China combined. In other words, one new American child will consume as much as 10 children born in India, Africa, or China.[30]

THREATS TO BIOLOGICAL DIVERSITY

How is biodiversity being lost? Although many factors interact in any given place to diminish biodiversity, the main threats fall into several categories.

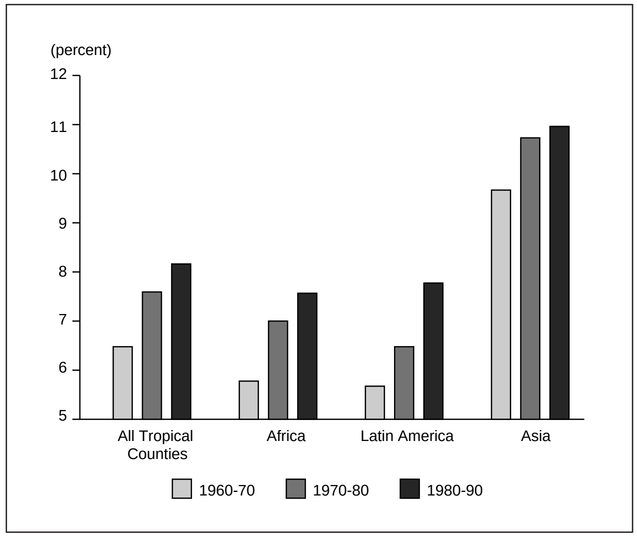
Habitat loss and degradation

Habitat loss and degradation is the most significant threat to biodiversity. Although human beings always modified to varying degrees the ecosystems they inhabited, the rate and scale of modification is intensifying and escalating as a result of human population growth, heightened economic pressures, and the development of new technologies. Throughout the world, habitats are being destroyed or altered by intensified agricultural conversion, soil erosion and sedimentation, deforestation, urbanization, and industrial development.

- Over half of the earth's vegetated lands have experienced medium to high levels of disturbance.[31]
- Agricultural expansion drives most wildland conversion. Over the last century, the area of cultivated land worldwide increased 74%, the area of grazing land 113%.[32] In this same period, the area of forest and woodland decreased 21%.[33]
- An estimated 4.6 million hectares of humid tropical forest are cleared annually.[34]
- Other forest types within the tropics are being decimated by human activities. Every year, 6.1 million hectares of moist deciduous forest, 2.5 million hectares of montane forest, and 1.8 million hectares of dry deciduous forest are subtracted from the global inventory of forestland.[35]

Of the world's many habitat types, the forests of the tropics harbor the largest number of species and experience the greatest degree of biodiversity loss. Tropical forests are home to millions of species, most of which have not yet been identified or described. Although calculations of species loss necessarily vary, it has been conservatively estimated that as many as 27,000 species are being driven to extinction annually through the loss of tropical forests.[36]

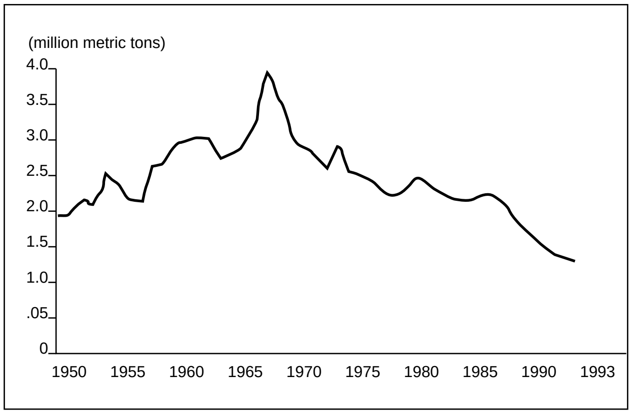
Tropical forests are of special concern due to their high degree of species diversity, but many other habitats are similarly threatened. It has recently been estimated, for example, that over the last 200 years the United States has lost more than 50% of its wetlands, 99% of its tallgrass prairies, and virtually all of its native oak savannahs.[37] Similarly discouraging losses have occurred among the world's savannahs, grasslands, river basins, wetlands, coastal zones, estuaries, coral reefs, and other habitats. Even the living systems of the open oceans have not escaped degradation and disruption as a result of human activities.



Estimated rate of loss of natural tropical forest cover, 1960-1990

"Humanity, in the desperate attempt to fit 8 billion or more people on the planet and give them a higher standard of living, is at risk of pushing the rest of life off the globe. And that's really what it comes down to. Pushing the remaining natural environment and much of the rest of life off the globe. That's the damage that's going to be felt as far into the future as can be conceived." (E.O. Wilson interview in Audubon, *January 1996)*

Habitat loss is especially severe in areas where population pressures, poverty, and inequitable land tenure systems leave people with little choice but to adopt overly intensive resource use practices. In much of the world, for instance, people must use traditional fuels—firewood, charcoal, crop residues, manures—for cooking and other energy needs. Such practices deplete soil, water, and biological resources, further con-



Decline in Atlantic cod catches from 1950 to 1993. Such declines in the stocks of groundfish which have sustained fisheries in the northern Atlantic for centuries, pose a threat to the future of the fishing industry in the region.

straining future options for sustainable development. Finding a balance between addressing desperate immediate needs while conserving resources and environmental stability for future growth is the dilemma facing many of the world's developing countries and most biologically rich habitats.

Overexploitation

Overexploitation of economically important species and of terrestrial and aquatic habitats was an important factor behind biodiversity loss historically and remains the leading threat in many regions of the world.

- Overexploitation is the leading factor behind the decline of fisheries around the world. As Elliot Norse noted during the conference, "Most of the world's commercial fisheries are overexploited, and some, [such as] the once-bounteous cod, haddock, and flounder fisheries of Georges Bank in the North Atlantic verge on commercial extinction." [38] The United Nations Food and Agriculture Organization now believes that all of the world's major fishing areas have either reached or exceeded their natural limits and that nine are in serious decline.[39] The decline in fisheries around the world is not only a concern in terms of the loss of a valuable food resource, but in terms of lost livelihoods. In New England alone, 22,000 fisherman, or 47% of the current fishing workforce, are expected to be out of work in the next few years.[40]
- In North America during the post-European settlement period, overexploitation contributed to the extermination of the passenger pigeon and the near extermination of the bison — once two of this continent's more numerous species.[41] In 1832, a single flock of passenger pigeons was estimated to contain at least 2,230,270,000 birds; 75 years later, President Theodore Roosevelt spotted a flock of twelve birds and that was the last recorded, confirmed sighting.
- The harvesting of wild species to satisfy the desire of the affluent for non-essential commodities like black coral, tortoise-shell, ivory, or rhino-horn continues to decimate populations of previously abundant species. Between 1970 and 1987, an estimated 85% of the world's remaining rhinos were lost. The population of black rhinos in Africa, once estimated in the hundreds of thousands, was estimated at 3,800 in 1987 [42], but

Glen H. Spain, Northwest regional director of the Pacific Coast Federation of Fisherman's Associations: "We're no bunch of environmentalists, but we have 106 salmon runs already extinct in the Northwest, and at least 214 runs at risk of extinction in the near future. Unless land use policies that are driving salmon to the brink of extinction are changed, nine out of ten salmon species of the Northwest will be extinct. We will go to the mat to protect this resource because it's our lives, our jobs, our homes." (Quoted in the National Journal, *July 6, 1996)*

A victim of an exotic pathogen, the American chestnut has disapppeared from much of its former habitat range.

current figures suggest it may be much lower. The remaining population is scattered in groups that rarely number more than 50 animals, making them extremely vulnerable to poaching—the number one threat to their survival. Rhino horn daggers sell for thousands of dollars in East Asia and powdered rhino horn has also garnered a high price.

In many cases, overexploitation affects entire ecosystems through intensified agriculture, forestry, range management, and other applied resource management fields. As demands on resources increase, the pressure to improve efficiency and productivity results in the adoption of economies of scale and production systems that reduce diversity. In typical forest plantations, for example, the diversity of tree species and the genetic variation within species are often minimal. Genetic and species diversity are similarly narrowed in hatchery-dependent fisheries, input-intensive cropping systems, and other monocultural production systems. [43]

Exotic species

The intentional and accidental introduction of alien species into terrestrial, freshwater, and marine ecosystems poses a significant long-term threat to global biodiversity. Over time, alien species can come to dominate their adopted habitats, driving out more specialized endemic species and disrupting the ecological processes within the system. Approximately 40% of the recorded extinctions of aquatic organisms were caused by the impacts of introduced species.[44]

- In one particularly striking example, two-thirds of the cichlid fish species in Africa's Lake Victoria—about 200 species—have gone extinct since the Nile perch *(Lates niloticus)* was introduced to the system in the 1950s.[45]
- In the United States, the American chestnut *(Castanea dentata)*, once an important component of the eastern deciduous forest, was almost driven to extinction in the early 1900s by an introduced fungal disease, the chestnut blight. In turn, seven species of moths and butterflies that fed exclusively on chestnuts may now be extinct as well.[46]
- In Guam, the arrival of the brown tree snake (*Boiga irregularis*) by air transport after World War II has apparently led to extinction of six of the island's ten native species of forest birds and endangerment of the remaining four.[47]

Island ecosystems are especially vulnerable to invasive species. Plants and animals on islands have often evolved in the absence of large mammalian herbivores or predators. Human introduction of these animals, often in tandem with disruption of the native vegetation, has altered island ecosystems around the world.

Global change

Global change encompasses a variety of interrelated environmental phenomena, including: global warming due to the greenhouse effect; depletion of the earth's ozone layer; tropical deforestation and other large-scale forms of habitat conversion; acid precipitation and other types of pollution-related environmental degradation; and the combination of human population growth, poverty, and unsustainable patterns of consumption. These global-scale forces, separately and in combination, will have unpredictable impacts on the abundance and distribution of biodiversity. In turn, the impacts of biodiversity loss feed back into these global-scale concerns. As Norman Myers has noted, "We have reached a point where we can save biodiversity only by saving the biosphere."[48]

- Global climate change could result in major alterations of ocean currents from sea warming and changes in salinity. This, in turn, poses the threat of changed weather patterns; for instance, India, which receives 70% of its precipitation from the monsoon cycle, could experience severe and unremitting drought.
- CO_2 concentrations have risen from the pre-industrial level of 280 ppm to current levels of 350 ppm; this may threaten ecosystems by altering carbon and nitrogen cycles fundamental to the interactions among plants, the atmosphere, and the soil.[49]
- Warming seas off the coast of San Diego have been linked to an 80% reduction in zooplankton and to similar declines in seabirds and fish; the area is now considered a "biological wasteland." [50]
- Under the ozone hole, phytoplankton output has been reduced by 6–12%, and the Antarctic krill are also exhibiting significant reductions. Phytoplankton and krill in the Antarctic are one of the largest biomasses in the ocean and are a critical support to the entire ocean ecosystem.[51]

Forest on the border between the Czech Republic and Germany shows evidence of damage caused by acid rain.

Pollution and contamination

Pollution has an acute impact on organisms and habitats, as well as a long-term impact on the genetic characteristics of populations and the physical, chemical, and biological cycles that sustain diversity. The effects of pollution may be less visible or direct than those associated with habitat loss, but they are no less pervasive or lasting. Much of the increase in concern about biodiversity over the last few decades stems from recognition of the impact of pollutants and contaminants on wild species and systems.

- The U.S. now applies twice the amount of pesticides that it used when Rachel Carson published *Silent Spring*, in 1962. DDT has been largely replaced with organophosphate pesticides that are proving harmful to wild insect pollinators and domestic honeybees. It has been estimated that the cost to agriculture of honey bee poisoning is $13.3 million per year.[52]

- Pesticides that are illegal in the United States are exported to developing countries with devastating consequences for North American avian species. It is estimated that 20,000 Swainson's hawks, 5% of the world's remaining population, were killed in Argentina after exposure to monocrotophos, an organophosphate withdrawn from the U.S. market, but exported to South America. The Foundation for Advancements in Science and Education estimates that at least 344 million pounds of hazardous pesticides (of which number, 28 million pounds were DDT, silvex, heptachlor, and chlordane) were shipped out of U.S. ports from 1992 to 1994.[53]
- Endocrine disrupters (a chemical pollutant) are among the factors, along with stratospheric ozone depletion and habitat destruction, in the marked decline in frogs, toads, and salamanders. It is believed that endocrine disrupters mimic normal hormone activity in these animals, thus disrupting their reproductive cycles. Amphibians have existed for over 100 million years, having survived the mass extinctions of pre-history; they are pivotal species as they function both as predators (ridding humankind of many insects, especially disease carrying mosquitoes) and as a food source for many birds and mammals.[54]
- Contamination of wetlands due to high levels of pesticide residues in runoff from agricultural lands has been a contributing factor in the loss of over 50% of the original 220 million acres of wetlands in the United States during the last 200 years.
- Acid rain has led to the depletion of aquatic life in "remote" water bodies due to its effects on water chemistry, and it is leading to the destruction of forests around the world.

The effects of pollution may be cumulative and synergistic and, thus, difficult to identify, analyze, and predict in the field. Because human health is often affected by the same pollutants, however, scientific research and environmental policy in this area are more advanced relative to other biodiversity threats.

Dimensions of the Challenge

Biodiversity loss is outpacing our current ability to understand the causes and nature of the crisis, to determine effective and timely conservation interventions, and to mobilize policymakers, public opinion, and resources to staunch the damage. The crisis is pushing us to mobilize on a number of fronts simultaneously, exceed the parameters of our previously defined disciplines, and to develop systems of study and response that mirror and embrace the complexity of the problem before us.

Scientific understanding of biodiversity is limited.

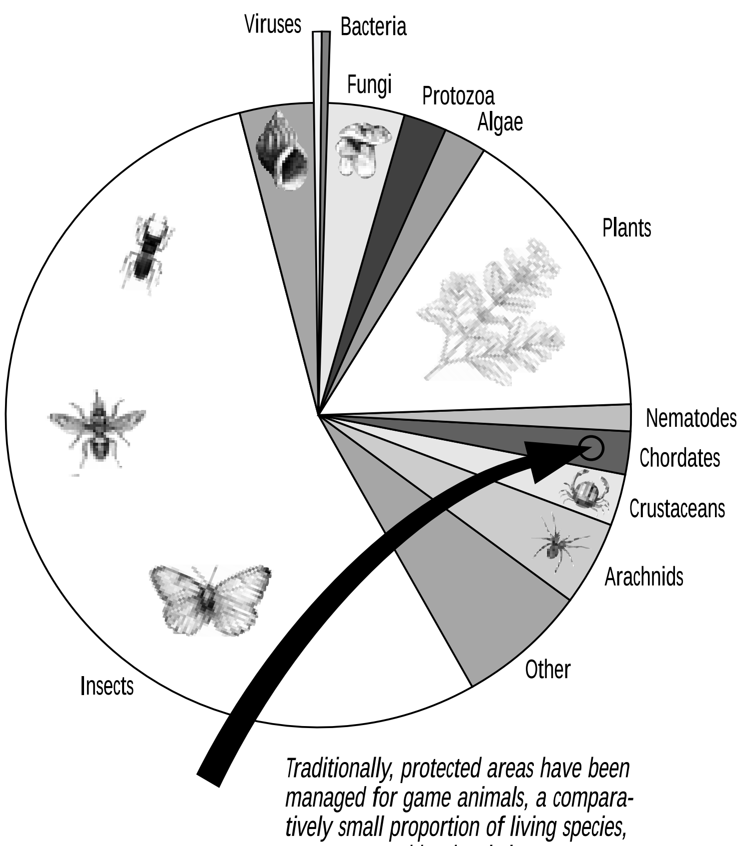
While estimates of the total number of species vary widely, all experts agree that millions more remain to be discovered, primarily insects, other small invertebrates, and microorganisms. Of the estimated 7 to 20 million species on earth, biologists have discovered and described about 1.75 million species. This means that 80% of the earth's species remain unknown, their roles unrecognized, their potential benefits for humanity untapped. And if our knowledge of species is limited, our understanding of their genetic characteristics, population dynamics, and evolutionary and ecological relationships is necessarily even poorer.

Scientific expertise needs to be expanded.

Although the role of science is changing in response to the biodiversity crisis, the number of people trained to provide scientific expertise remains inadequate. Biogeography, taxonomy, plant and animal ecology, and other disciplines that provide us with our basic understanding of the distribution, identification, classification, evolutionary history, and ecological relationships of organisms are poorly funded relative to other branches of biology. Institutional and government commitment to these basic fields has been slipping. Expertise in these areas is especially limited in the biologically-rich developing countries, where it is most needed.[55]

The sciences underlying conservation are inadequately integrated.

Solutions to conservation problems invariably require integration of knowledge and experience from a wide range of biological and social sciences, as well as other fields. Conservation problems often arise because resource managers have been taught to concentrate on particular components of ecosystems—soils, water, trees, forage grasses, game animals, threatened species, and so forth—rather than the interaction of all the biotic and abiotic components within the system.



Traditionally, protected areas have been managed for game animals, a comparatively small proportion of living species, as represented by the circle.

The scientific and political aspects of biodiversity conservation mesh poorly.

As Jeffrey McNeely observed, "Science and policy provide two rather different approaches to reality… Ideally suited to carry out research, scientists are seldom suitably placed to understand the pressures under which policymakers work… But policymakers are seldom scientists and do not have the time to digest detailed information that would enable them to make full use of scientific advice."[57] This inherent limitation is exacerbated by the lack of facility in communication between scientists and policymakers. Thus, it is important to create a dialogue that builds on a shared understanding of both scientific and political realities. Receptivity to the need for such a dialogue would be greatly enhanced by building a broader base of public support for biodiversity conservation policies.

"But market failure is not just a local phenomenon. Many environmental assets have global economic value. This is most pronounced and least understood for biological diversity, but extends to global climate change. All forests, for example, store carbon so that, if cleared for agriculture, there will be a release of carbon dioxide that will contribute to the accelerated greenhouse effect and hence global warming… Global "missing markets" do a lot to explain the skewed development paths of resource rich countries, and hence the loss of so much of the world's environmental assets." [56]

Our economic systems do not fully account for biodiversity's value.

Only recently have economists begun to devote greater attention to the full array of values that biological diversity serves. Many of biodiversity's benefits are poorly reflected by traditional market values. Conversely, the loss of biodiversity imposes costs that are real, but difficult to quantify. In addition, many existing incentives contribute to a policy environment in which biodi-

Forest cleared for industry makes way for economic gain, but often does not fully account for costs resulting from resource depletion, environmental degradation, and biodiversity loss. Pictured is a sisal plantation which has replaced spiny forest in

versity loss is encouraged and rewarded. Such market distortions place natural diversity and habitats at a disadvantage relative to those forms of economic development that have easily identifiable returns. As Robert Repetto writes: " A nation could exhaust its mineral reserves, cut down its forests, erode its soils, pollute its aquifers, and hunt its wildlife to extinction—all without affecting measured income."[58]

Our institutions are poorly prepared to respond to the biodiversity crisis.

Societies must now assume responsibility for charting a new course of action before the cumulative loss of biological diversity robs us of the opportunity to secure a sustainable world for future generations. The social institutions that we depend upon to provide leadership within society—governmental bodies (at all levels), schools and universities, the law, the media, businesses and corporations, religious institutions—must assume civic and scientific leadership in the conservation of biodiversity.

Our educational system prepares us inadequately to meet these challenges.

The biodiversity crisis is also an educational crisis; that is, it reflects faults in the way we teach ourselves to think about and respond to the natural world. Educator David Orr writes: "We have fragmented the world into bits and pieces called disciplines and subdisciplines, hermetically sealed from other such disciplines. As a result, after twelve or sixteen or twenty years of education, most students graduate without any broad, integrated sense of the unity of things."[59] Without such a sense, we are prone to the distortions, biases, and blind spots inherent in our own professional training and experience. While disciplinary competence remains indispensable, it must be complemented by the interdisciplinary skills that lead to solutions.

III. Integrated Approaches to Biodiversity Conservation

Science and Policy

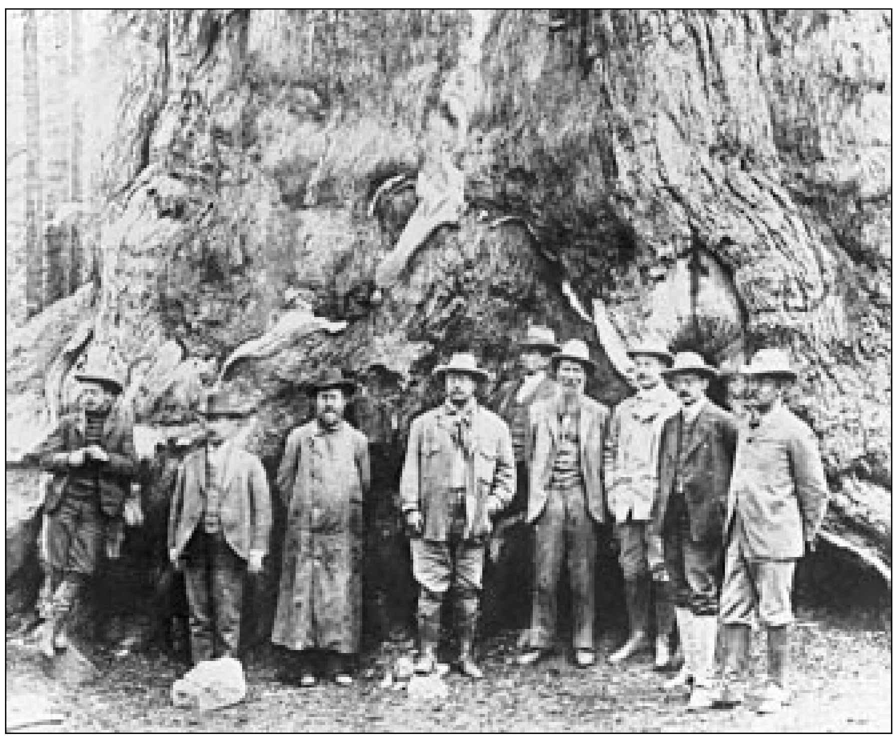
Perhaps the greatest challenge facing conservation scientists is the acknowledgment that science itself cannot ensure that biodiversity will be conserved. Progress toward effective biodiversity conservation requires the skillful infusion of science into the policy making process. Even the best scientific information remains inert unless it is effectively channeled and applied to conservation issues. Scientists are reluctant, however, to enter the policy arena because they are uncomfortable with the often inconsistent use of scientific data.

The early conservation movement was driven by varied, and sometimes conflicting, aims. One wing of the movement, led by forester Gifford Pinchot, stressed the need to provide for efficient management and equitable distribution of natural resources by producing sustained yields of particular commodities -- timber, forage, fish and game animals, water, and so forth. Another wing, led by naturalist John Muir, emphasized the importance of protecting special wild and scenic areas for human enjoyment and contemplation. Between these figures stood Theodore Roosevelt, who catalyzed conservation during the Progressive Era. The history of 20th-century conservation is in large part the story of conflict and accommodation between these utilitarian and preservationist factions, and of the gradual continuing emergence of a new vision that emphasizes the need to combine protection and sustainable management in a manner that reinforces the restorative capacity of the ecosystem itself.

As Jeffrey McNeely noted:

> *Legislators need scientific advice to translate their ideas into draft legislation; the various interest groups need science to help ensure that their concerns are built into the legislation and to support its passage through Congress; and science is needed to assess how policies, programs, and projects are affecting biodiversity. But how science is actually used in these various contexts depends very much on the users.*[60]

At the same time, those in the policy arena may be insensitive to the intellectual constraints under which scientists must work and the assumptions that delimit the appropriate use of data. These tensions reflect underlying differences in the methods and goals of scientists and policymakers.



Theodore Roosevelt (center) in Yosemite National Park with John Muir (on Roosevelt's right) in 1903.

Even within the scientific sector, scientists committed to biodiversity conservation operate under special constraints when attempting to inform policy debates.

- The threats to biodiversity, as well as the consequences of biodiversity loss, are often subtle, extensive, long-term, or invisible.
- The inherent complexity of biodiversity science makes it difficult to communicate organizing concepts to the non-scientific public and to translate findings into policy actions. Because of its complexity, there is also a high degree of uncertainty and unpredictability in biodiversity science, which could be misconstrued as a license to adopt policies and projects based on less complex analyses.
- As understanding of biodiversity expands and the implications of biodiversity loss become more widely communicated, the political stakes become greater—increasing the level to which scientific discourse is likely to be politicized.

The key question then becomes: how can scientists and non-scientists promote the responsible use of scientific information and concepts in the policy making process? While there is no simple answer, a growing body of experience suggests several critical principles that scientists and others involved in the policy process can follow to encourage such responsible use.

- Many stakeholders and disciplines must participate in the policy process in order to provide critical assessment of scientific information and the manner in which it is used.
- Scientists must organize and communicate their evidence in ways that will be useful not only to other scientists, but to others involved in the policy process.
- Scientists must recognize that research does not take place within a vacuum, but is embedded within geographical, cultural, and political contexts. Consequently, the policy implications of their research are likely to vary from place to place and from time to time.
- In order to provide useful advice, scientists must be sufficiently aware of the legal and policy aspects of biodiversity conservation.

Despite the daunting obstacles that we face, there are signs that the global biodiversity crisis is eliciting concern from a sufficiently broad and diverse sector of the populace to forge solutions. Scientists are expanding their efforts to survey, assess, and monitor biodiversity in ecosystems around the world. Policymakers are beginning to incorporate concerns about biodiversity loss into resource management policies. And, on a global scale, the world's governments came together during the 1992 United Nations Conference on Environment and Development to develop the Convention on Biological Diversity, a landmark in cooperative efforts to protect the world's biological heritage.[61]

"We need to bring nature back in. We have to stop separating politics from the physical world—the climate, public health, and the environment. For too long we've been prisoners of 'social-social' theory, which assumes there are only social causes for social and political changes, rather than natural causes, too. This social-social mentality emerged with the Industrial Revolution, which separated us from nature. But nature is coming back with a vengeance, tied to population growth. It will have incredible security implications." (Thomas Homer-Dixon interview with Robert Kaplan, quoted in Kaplan's article, "The Coming Anarchy," *Atlantic Monthly*, February 1994)

Conservation Science in the Future

While scientists are now charting the ways in which their work must respond to the urgency of this crisis, the essential work of science remains the same:

- to discover, identify, and classify species
- to understand the history of life
- to understand how species and other taxa are distributed geographically and how they have come to be distributed in that way
- to understand how species interact within ecosystems and how the behavior of organisms may affect and be affected by local biodiversity
- to understand how human cultures interact with biodiversity and to apply scientific principles in ways that promote conservation goals
- to work with other scientists and non-scientists to share knowledge of biodiversity

Various scientific organizations have published research agendas that describe priorities for biodiversity conservation. In 1991, for example, the Ecological Society of America produced "The sustainable biosphere initiative: An ecological research agenda," which defines priorities of broad importance to future conservation practice.[62] In 1994, the world's systematic biologists, who provide the foundation of knowledge upon which biodiversity conservation rests, published *Systematics Agenda 2000: Charting the Biosphere*, a comprehensive program of discovery and research to guide their scientific work on a global basis.[63]

Research in support of biodiversity conservation necessarily entails many disciplines, with varied approaches, tools, and techniques. The challenge of the future lies not only in redefining research priorities within the sciences, but in framing the methods for the studies we undertake. The issue at hand will largely determine the methodology required. The restoration of degraded pastures in the Amazon Basin, for instance, has different objectives and requires a different mix of talents than research to assess the long-term impacts of climate change on island ecosystems. As Meffe and Carroll observe, "Issue-driven research is different from discipline-driven research because it starts with real-world issues and then tries to determine what methods, knowledge, and information might be available or needed to help resolve the problem."[64]

In recent years, new organizing concepts (including the term *biodiversity* itself) and new fields of applied science have emerged to bridge interdisciplinary gaps.

- **Conservation biology** brings together scientists from various disciplines, as well as policymakers, economists, resource managers, and educators to develop practical models for conserving biodiversity.
- **Community-based conservation** places greater emphasis on the integration of biodiversity conservation and community

Ecological restoration is an integral part of the Central Park management plan in New York City. Volunteers help to remove exotic species in the Ramble area of the park.

development goals by enlisting a broader franchise of community involvement.

- **Restoration ecology** applies ecological principles to the rehabilitation of degraded habitats.
- **Sustainable resource management** is a unifying theme within agriculture, forestry, and other resource management professions.
- **Ecological economics** brings those fields together to explore new concepts that might promote the development of sustainable economies.
- **Environmental ethics** enlists philosophers, ethicists, and theologians in exploring the intellectual and moral foundations of conservation actions.
- **New urbanism** addresses environmental problems which stem from poor urban planning and architectural design.

These and other creative approaches to conservation problem-solving are still emerging. They are accompanied by important technical advances, including geographic information systems, electronic databases, and improved methods of biological survey and inventory. Through these new ideas and technologies, we are shaping solutions to the biodiversity crisis that involve all parts of the landscape and varied fields of human endeavor.

Finally, as Jeffrey McNeely also pointed out, science in the past was "an essential collaborator in much of the ecological destruction" to which we are heir.[65] Science, therefore, must now embrace a dimension which it heretofore eschewed, at least in any systematic way: We must evaluate the consequences of the work we do and the work we fail to do; we must consider the cost. In addressing this issue more than fifty years ago, wildlife ecologist Aldo Leopold stated:

> *Our job is to harmonize the increasing kit of scientific tools and the increasing recklessness in using them with the shrinking biotas to which they are applied. In the nature of things we are mediators and moderators, and unless we can help rewrite the objectives of science our job is predestined to failure.*[66]

IV. The Role of the Museum

Natural history museums serve as the principal institutions through which knowledge of the world's past and present diversity is preserved, interpreted, and presented to professional and general audiences. While this remains their essential function, museums are now being called upon to provide even greater leadership in bringing this knowledge to bear on all aspects of the biodiversity crisis.

AMNH artists making studies for the Klipspringer Group diorama, Lukenia Hills, Kenya; Eastman - Akeley - Pomeroy Expedition, 1926-1927. Once a pristine environment, farms and other signs of development are now encroaching on the valley in the distance.

The Evolving Mission of Natural History Collections

The museum's role in gathering, organizing, and maintaining information on biodiversity becomes even more critical as that diversity is lost from nature. (The same also holds for other types of natural history collections—herbaria, botanical gardens, arboreta, aquaria, seed banks, and zoological parks and gardens). Through decades (even, in some cases, centuries) of painstaking analysis and correlation of data from the museum's collections, paleontologists and evolutionary biologists are able to trace the course of life on earth and understand how past extinction events shaped the modern biota. Equally, the collections are playing an important role in understanding and responding to today's conservation problems.

- **Scientific collections provide the primary scientific evidence for the existence and identification of different species.** The magnitude of the earth's species diversity requires that information gained in the field be checked against existing collections. Scientists use collections to identify new species, clarify older classifications, substantiate previous evaluations of diversity, and determine future research priorities.
- **Scientific collections provide the most reliable documentation of past extinctions.** An obvious example is the passenger pigeon, once believed to be the most abundant bird species on earth, with estimates of the total population running into the billions. Its extinction, coinciding with European settlement of North America, is recorded in the collections that maintain the only remaining specimens.
- **Scientific collections record approximations of past abundance and distribution of extant species.** Museum records of highly endangered species contribute to our knowledge of the species' historic range, which in turn may contribute to recovery programs involving captive propagation and reintroduction.
- **Scientific collections document responses of organisms to environmental stress.** In the 1960s, for example, ornithologists were able to trace the detrimental impacts of DDT on birds of prey by com-

paring the thickness of egg shells in museum collections with specimens gathered from the wild.

- **Scientific collections provide researchers with an historical perspective on contemporary biological questions.** Scientists examining, for instance, museum specimens of ticks were able to verify that the spirochete that causes Lyme disease is not a newly evolved pathogen, but has been present (though not so prevalent) in the past.[67]

Natural history collections provide a timeline and an historical record whose utility for future generations is unpredictable. They hold answers to questions that have yet to be asked.

BEYOND COLLECTIONS

The modern museum is at once a scientific, educational, and social institution. Museums fulfill their scientific mission in many ways. Most directly, museums sponsor biological expeditions and surveys that document the world's ancient and extant diversity. They provide identification services for scientific colleagues as well as for the public at large. They organize and communicate information so that it is useful to scientists in other institutions. They host conferences and other meetings that allow scientists (as well as non-scientists) to share information and ideas.

As public institutions, museums play a leading role in providing the public with information about nature and human cultural responses to survival within it. Especially for urban dwellers with limited access to the larger natural world, museums may be the most significant single source of personal experience of that world. Even more sobering is the fact that many exhibits and dioramas in natural history museums have already become historical artifacts — the only point of perspective on species and habitats that have disappeared.

As social institutions, natural history museums serve a unique function by linking together research centers, schools, universities, government agencies, civic and professional groups, corporations, foundations, and other organizations. Museums thus have special opportunities to communicate the importance of science to decision-makers to develop and share databases, build support for research and conservation projects, stimulate local and regional interest in conservation, and work with other institutions in strengthening their conservation activities. The American Museum of Natural History in particular, through its international linkages and its research, training, and education programs, has unique opportunities to catalyze conservation activities globally. As the social aspects of biodiversity conservation become increasingly important, these Museum activities become even more central to its evolving mission.

Relief supplies for the Crocker Land expedition leaving the Museum in May, 1917. The last extensive dog sledge expedition to the polar regions, the four-year Crocker Land expedition undertook work in geology, botany, ornithology, and ethnography.

Doctoral student Diana Silva studying spiders in Manu National Park, Peru

ACTIVITIES OF THE AMERICAN MUSEUM OF NATURAL HISTORY

Since its founding in 1869, the American Museum of Natural History has been one of the world's leading institutions devoted to understanding the natural world. Throughout its history, the Museum has been devoted not only to the accumulation of knowledge about biodiversity, but to the application of that knowledge to conservation efforts. This tradition continues in the Museum's many activities: sponsorship of scientific expeditions; research in its own laboratories and at its active research stations in the United States, representing the ongoing endeavors of some 200 scientists; maintenance of the Museum's extensive biological collections; the world's most extensive systematics training program; education programs that reach some three million visitors annually; exhibits that make scientific knowledge of biological diversity accessible to a broad public; various professional and popular publications; maintenance of the Museum's natural history library, the largest in the western hemisphere; and support for professional meetings and conferences.

Conservation necessarily embraces an astonishing variety of human endeavors. Whether it involves field studies of endangered fish species in Madagascar, meticulous comparison of insect specimens in quiet collection rooms, or hands-on training of new generations of scientists, the human adventure of conservation is carried out on a daily basis under the auspices of the Museum.

THE AMERICAN MUSEUM OF NATURAL HISTORY CENTER FOR BIODIVERSITY AND CONSERVATION

While the Museum's conservation commitment continues to be woven into the work of all its departments and programs, the Center for Biodiversity and Conservation (CBC) strengthens these efforts by providing new opportunities for action. The CBC is dedicated to enhancing the use of rigorous scientific data to mitigate critical threats to global biodiversity. Drawing on the combined strengths of the Museum's scientific, education, and exhibition departments, as well as its extensive collections and library, the CBC strives to disseminate scientific information to a wide audience and to develop viable, science-based solutions to biodiversity conservation problems. The CBC sponsors programs in research, training, and outreach to scientists, students, and organizations worldwide, to ensure that current and subsequent generations of scientists will be equipped to apply their expertise to biodiversity problems.

Research Programs

The CBC seeks to build global collaborations that integrate the AMNH's resources with the diverse strengths of sister institutions, conservation organizations, environmental NGOs, and educators. A series of field-based projects is being developed to conduct multidisciplinary surveys of species distribution and density in regions of the world with high concentrations of biological diversity. A priority of these projects is to ensure that resulting data is disseminated efficiently, and in readily accessible terms, to resource managers, decision-makers, and the general public.

The CBC sponsors a research grants program to provide research support to AMNH curators whose work addresses questions of direct relevance to conservation. Recently funded projects include:

- An inventory of ants, bees, wasps, and termites in Brazil that will enable scientists to use these insects as bioindicators,
- An assessment of diversity and endemism patterns among Africa's birds and mammals.
- A study of the status of humpback whales and other marine mammals off northeastern Madagascar.
- The use of DNA sequence variation to determine the migration patterns, relationships, and interactions of populations of rare and threatened species.
- A project to determine the actual status of mammals thought to be recently extinct on Hispaniola.

Graduate Training Program

The Graduate Training Program offers course- and field work in systematics and biodiversity science to students from around the world. Currently, the program supports students from Ethiopia, Indonesia, Madagascar, Peru, and the U.S., conducting research on the diversity of often rare animals, including groups of: Asian Heliconid butterflies, Andean mice, neotropical high flying insectivorous bats, nocturnal predatory spiders, African algae eating carp, and several groups of birds.

Outreach

As noted earlier, biodiversity science necessarily entails the involvement of many disciplines that are called upon in response to particular issues.

In many cases, this represents a break from traditional discipline-oriented approaches. The Center provides expanded opportunities to integrate the biodiversity sciences around specific important issues.

The CBC is committed to integrating scientific research findings into education and communication about biodiversity conservation through training workshops for international environmental educators; conferences that convey important topics to both the scientific community and the general public; and the fostering of relationships with other institutions.

The biodiversity crisis is only one of many factors redefining the traditional role of the Museum. Natural history museums are faced with new opportunities,demands, and technologies (as well as new fiscal realities). But if they are to fulfill their responsibilities as scientific, educational, and social institutions, their commitment to conservation must continue to expand. The alternative—disengagement from the most profound environmental concern of our lifetimes—will serve neither science nor society.

Participants in an AMNH-Peace Corps Workshop on interpretive centers in Madagascar.

V. Conclusion

For the first time in human history, a generation of human beings is consciously facing the question of whether its actions will diminish or perpetuate the diversity and evolutionary potential of life on earth. A corollary question is whether the institutions that we have devised are flexible enough to anticipate and respond constructively to this unprecedented ecological crisis. The answers that we provide will have momentous consequences for ourselves, our society, future generations, and the living world around us.

Science, as an expression of the human capacity to reason, will play a central role in finding conservation solutions. But it will be a different kind of scientific endeavor in which we engage: reason will seek a partnership with other human traits—the capacity to remember, to anticipate, to moderate, to celebrate, to revere. Conservation of biodiversity implies conservation of the world in which we evolved and to which we belong.

NOTES

[1] For overviews of the status of and threats to biodiversity, see E.O.Wilson and Frances M. Peters, eds., *Biodiversity* (Washington, D. C.: National Academy Press, 1988); WRI, IUCN, UNEP, *Global Biodiversity Strategy* (Washington, D. C.: WRI, IUCN, UNEP, 1992); Paul R. Ehrlich and E. O. Wilson, "Biodiversity studies: science and policy," *Science* 253 (1991):758-762; E. O. Wilson, *The Diversity of Life* (Cambridge, MA: Harvard University Press and Norton, 1992); World Conservation and Monitoring Centre, *Global Biodiversity: Status of the Earth's Living Resources* (London: Chapman and Hall, 1992); Elliot Norse, *Global Marine Biological Diversity: A Strategy for Building Conservation into Decision Making* (Washington, D. C. and Covelo, CA: Island Press, 1993).

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