Humans and Other Catastrophes: Perspectives on Extinction

Prepared by the **Center for Biodiversity and Conservation** at the

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Summary

Extinction is an inherent feature of life on earth. We tend to regard extinction as a destructive process, due largely to the unprecedented impact that human activities are now having on life's diversity, but this diversity in fact reflects an evolutionary history in which extinction is an essential ingredient. Extinction, however, is no longer solely a function of forces outside our control. In recent millennia, human beings have come to play a role that previously was reserved for asteroids, climate changes, and other global-scale phenomena. We humans are now the primary causal factor behind extinctions.

In April 1997, 28 scientists gathered at the American Museum of Natural History for a special two-day symposium on the theme of extinction. The goal of the meeting, sponsored by the Museum's Center for Biodiversity and Conservation, was to explore the causes of past extinctions; review the current status of the earth's biological diversity; and examine ways to prevent human-caused extinctions and preserve biodiversity. This report reviews the symposium's presentations and discussions. (The boxed quotations scattered throughout this volume are taken from symposium presentations.)

On the first day, participants discussed past extinctions in a session entitled "Humans and Other Catastrophes: Explaining Past Extinctions and the Extinction Process." In "deep time" — the immense stretches of time before human beings evolved — the earth experienced at least five major and many lesser extinction episodes. One of these, which occurred at the end of the Cretaceous period some 65 million years ago, saw the demise of non-avian dinosaurs, and the flourishing of other species, including our own mammalian forebears. Various causes have been adduced for these episodes. In recent years, research has suggested that this extinction event, and very likely, others before it, may have been initiated by cometary fragments, asteroids, or other extraterrestrial bodies colliding with the earth.

By contrast, extinctions in "near time" — the 120,000-year period since anatomically modern human beings arose — appear to have closely followed, both temporally and geographically, the spread of humans out from Africa and Eurasia. As human settlers arrived, shock waves of extinction spread into Australia, later into the Americas, then into the major island groups of the Mediterranean, the West Indies, Madagascar, Polynesia, Hawaii, and New Zealand. Curiously, and in contrast to prior extinction events, near-time losses appear to have affected predominantly large mammals, birds, and some other vertebrates. Anthropologists, biologists, and paleontologists continue to consider various explanations for these extinctions — overhunting, habitat transformation, climate change, introduced species, disease — but the evidence points toward an important linkage between the spread of humans and the incidence of extinctions.

It is . . . well established that the earth is currently undergoing yet another mass extinction event — sometimes called the "Sixth Extinction." And it is clear that the major agent for this current event is *Homo sapiens* — primarily through direct habitat destruction and degradation, overutilization of "natural resources," and the direct and inadvertent introduction of exotic species.

Niles Eldredge, "Cretaceous Meteor Showers, the Human Ecological 'Niche,' and the Sixth Extinction."

As scientists have helped clarify the causes and consequences of past extinctions, concern about the loss of the earth's present biological diversity has grown significantly. On the second day, symposium speakers focused on the theme, "Preventing Extinctions: Advances in Biodiversity Conservation." Using information on deep- and near-time extinction rates, some scientists have speculated that the coming decades will witness a loss of species at least 1,000 times (and perhaps many times more) above the normal or "background" rate of extinction. According to one estimate, species in tropical forests are currently being lost at a rate of approximately 27,000 a year[1]. (Tropical forests contain at least half the planet's biodiversity.) Other estimates range anywhere from 17,000 to 100,000 species lost each year[2] worldwide. For this reason, many conservation biologists warn that we may now be experiencing a sixth great mass extinction event. Unlike the major extinction events of the past, however, this one is due primarily to the activities of a single species — our own.

There may still be time to slow down this escalation of the extinction rate, but a wide range of actions will be required to do so. These include efforts to gather and organize information on the status of biodiversity (a task in which systematics will play a crucial role), to maintain the health of whole landscapes and ecosystems, to conserve particular populations and species, to reduce the impact we as individuals have on the environment, and to address basic causal factors, including unprecedented human population growth, consumption, and economic inequality.

We have a choice to make, one that no other species has ever been able or required to make. We now know that our actions can and will influence the fate of life on earth. We can either contribute to the growing list of vanished species, or we can take steps to sustain earth's precious biological diversity. The choice is ours; the consequences, however, will be shared with (or visited on) our fellow creatures.

Thinking about Extinction

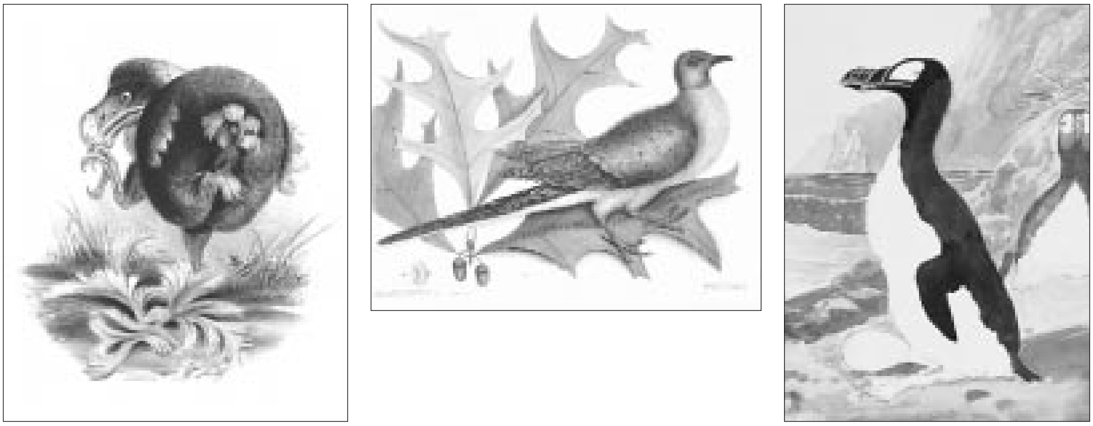
Few aspects of life on earth are as compelling to think about as extinction. Mention the word and a complex, sometimes conflicting blend of thoughts and emotions arises. We are fascinated by the signs of long-gone life forms, sea creatures turned to stone, imprints of ferns in shale, ants embedded in amber, the dinosaur fossils that fire our imaginations. We hear news of the current, human-caused "extinction crisis" and wonder what can be done. Beneath it all, perhaps, is a hint of apprehension: we recognize that the existence of our own species is finite; we ponder the possibility of our own eventual extinction.

Extinction is indeed a key fact of life on earth, and has been throughout life's 3.8-billion-year history. Yet only in the last two centuries have the natural sciences begun to illuminate that history, and only in the last few decades have we come to understand in any detail how and why extinction happens.

To avoid the predicted spate of extinctions, we will have to redefine the human role within the natural world. As our understanding of past extinctions expands, so does our awareness that human values and behaviors can affect the future of other life forms. "For one species to mourn the death of another is a new thing under the sun," wrote naturalist and conservationist Aldo Leopold, in contemplating the extinction of the once abundant passenger pigeon.[3] As a species, we are now struggling with this "new thing" — this awareness of our own impact on the rest of nature. The life forms with which we share our world provide us with foods, medicines, material goods and ecological services. They also provide our context; they make us who we are. With every loss, the fabric of life on the planet is weakened, and our own position becomes less secure.

Science has had a fundamental role in helping us to understand how our actions affect the continued existence of other life forms. But to think about extinction we need not only science, but ethics as well, underlain by a sense of humility before processes which we may influence, but can never control. Naturalist William Beebe noted this when he wrote:

> The beauty and genius of a work of art may be reconceived, though its first material expression be destroyed; a vanished harmony may yet again inspire the composer; but when the last individual of a race of living things breathes no more, another heaven and another earth must pass before such a one can be again.[4]



Famous for being gone (from left to right): The dodo, the passenger pigeon, and the great auk; three well-known recent extinctions that owed their disappearance to the activities of human beings.

Past Extinctions and the Extinction Process

Our view of the development of life on earth has changed dramatically as new theories and discoveries in the natural sciences have opened windows to the past. Ever since Charles Darwin and Alfred Russel Wallace laid the foundations of modern evolutionary biology in the mid-1800s, our understanding of the origins and diversification of earth's life forms has become more complete. We have come to see extinction and evolution as intertwined processes, their patterns determining the diversity and character of life.

Extinction has shaped the world's biota (including us, of course) in essential ways. Repeatedly, past extinctions have altered the conditions and opportunities under which older life forms have (or have not) endured and new species have evolved. The character of the living world around us reflects the history of the planet — cataclysmic events that have fundamentally redirected the course of life, as well as slow and steady environmental changes to which species have (or have not) adapted.

Over the last 30 years, our understanding of the rate, timing, causes, and processes of past extinctions has itself undergone enormous change. Through the careful gathering and assembling of evidence from a wide variety of disciplines — astronomy, geology, geomorphology, paleontology, climatology, oceanography, evolutionary biology, ecology — the story of life on earth has been revised and updated, with revolutionary implications for our own times.

In studying the past, scientists distinguish between those extinction events that occurred in the more distant, or "deep," past (up to many millions of years before the present, or "y.b.p.") and those that have occurred since the advent of anatomically modern humans (beginning about 120,000 y.b.p.). Appreciating the differences between these eras is crucial to gaining perspective on the era some think is beginning now — the human-caused Sixth Extinction.

Extinctions in Deep Time

It has been estimated that of all the species that have ever existed on earth, more than 99.9 percent have gone extinct.[5] In other words, our extant species of plants, animals, fungi, and microbes represent only 0.1 percent of all those that have ever inhabited the planet. These are the survivors, or the descendants of the survivors, of past changes in the earth's biosphere.

A general tendency toward a greater diversity of life forms has been dramatically interrupted from time to time in earth's evolutionary history. Most species loss has taken place during periodic "minor" extinction episodes,[6] but more severe, global-scale mass extinction events have occurred five times over the last 535 million years. These "Big Five" mass extinctions have been identified by examining evidence of changes in the diversity of fossil plants and animals. ("Mass extinction" has no neat dictionary definition, but, as used by scientists, usually refers to an extinction event that affects organisms in many different environments, and that causes losses of great magnitude in a number of taxa.) Some of these changes have been extensive. For example, during the Permo-Triassic extinction event, occurring about 245 million y.b.p., it has been estimated that from 70 to 95 percent of all the species on earth became extinct.[7]

The best known — and perhaps best understood — of these previous extinctions took place 65 million years ago, between the Cretaceous and Tertiary periods (this is often called the "K/T boundary," from the initials of the German terms for these periods). This extinction resulted in the widespread loss of marine animal genera, radical change in terrestrial ecosystems, and the demise of the dinosaurs (with the exception of the progenitors of the birds). As the dinosaurs disappeared and ecosystem structures changed, mammals found new opportunities, and eventually increased in body size and diversified their forms. Among the evolutionary innovations were primates and, some 4 to 5 million y.b.p., hominids, the lineage that would produce *Homo sapiens*.

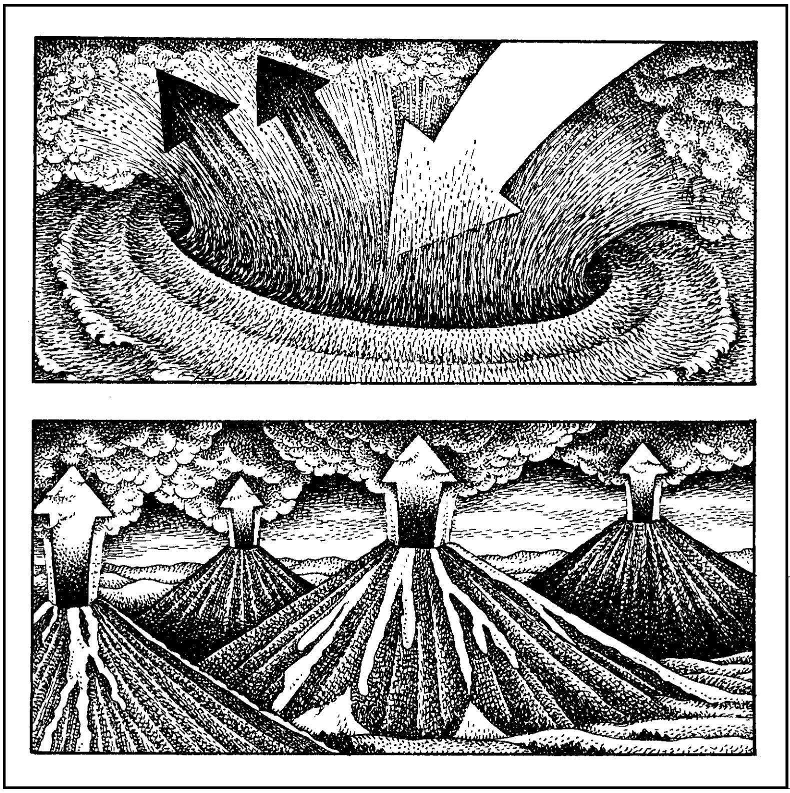
THE MAJOR EXTINCTION EVENTS				
Era	**Period**	**Epoch**	**Approximate duration of Era, Period, or Epoch (millions of years before present)**	**Major extinction events***
CENOZOIC	Quaternary	Holocene	present-0.01	←6th major extinction ?
		Pleistocene	0.01-1.6	
	Tertiary	Pliocene	1.6-5.3	
		Miocene	5.3-24	
		Oligocene	24-37	
		Eocene	37-58	
		Paleocene	58-65	
MESOZOIC	Cretaceous		65-144	←5th major extinction (end of Cretaceous; K-T boundary)
	Jurassic		144-208	
	Triassic		208-245	←4th major extinction (end of Triassic)
PALEOZOIC	Permian		245-286	←3rd major extinction (end of Permian)
	(Carboniferous) Pennsylvanian		286-325	
	(Carboniferous) Mississippian		325-360	
	Devonian		360-408	←2nd major extinction (late Devonian)
	Silurian		408-440	
	Ordovician		440-505	←1st major extinction (end of Ordovician)
	Cambrian		505-570	
PRECAMBRIAN			570-4500	

In the last 535 million years there have been five global mass extinction events. The current "Sixth Extinction" differs from its predecessors in its rapidity and its cause: human activity

* Many smaller extinction events are not indicated; see Raup (1991: fig. 4-1 for examples)

Since the early 1980s, investigations into the K/T extinction event have helped revise our explanations of mass extinctions. Scientists have long debated various explanations for these extinctions, including cyclical patterns in the earth's path in space, volcanism, shifts in the position of the continental land masses, and changes in sea level, global climate, and atmospheric chemistry. In 1980 the hypothesis that the K/T extinction event might be attributable to the impact of a large asteroid was proposed. Studies have identified the likely area of impact in the Caribbean basin.[8] Such collisions appear to have occurred at regular intervals, and this pattern correlates not only with the major extinction events, but the "minor" ones as well. [9]

Since its formulation, the "bolide collision hypothesis" has itself been subject to the constant bombardment of competing theories and corroborating evidence. It remains subject to intense scrutiny. Some researchers think that bolide impact may be just one factor among many in causing mass extinctions. Consensus on the cause of deep-time extinctions has not yet been achieved, and much work remains to be done in establishing the full sequence of events.Whatever the eventual outcome of this debate, the bolide-collision hypothesis has stimulated the formation of more integrated views of the earth's past, and of the changes that have shaped the destiny of life on the planet.



The impact of a large asteroid or cometary fragment (above) and intense volcanic activity (below) have each been proposed as the cause of the K/T extinction in which the dinosaurs vanished.

EXTINCTIONS IN NEAR TIME

"Near time," coinciding with the Late Quaternary (the most recent of the great geological periods), has been distinguished by extreme fluctuations in global climate (most apparent in the dramatic advance and retreat of the continental glaciers), rising and falling sea levels in connection with the amount of water locked up in the ice caps, latitudinal and elevational shifts in ecological communities and species ranges, and the gradual spread of human beings out of Africa and Eurasia to much of the inhabitable surface of the earth. Tracking these changes and the associated incidence of extinction has been one of the great scientific undertakings of recent decades.

Most of the losses that occurred in near time for which we have detailed knowledge — ones that we can detect paleontologically, for example — seem to have affected only a few groups. Also, these extinctions appear to have occurred regionally, rather than globally. The most important characteristic of extinctions in near time is their apparent correlation with the spread of *Homo sapiens* around the world.

Prior to the arrival of humans in the Hawaiian Islands, more than 125 species of birds thrived there. Today, less than 10 percent survive.

Stuart Pimm, "Extinctions, Geographic Ranges, and Patterns of Loss."

The facts in this history are still emerging. Since the 1960s, evidence of various kinds has come from locales around the globe: fossil remains of prehistoric elephants, rhinoceroses, camels, kangaroos, birds, and a wide range of other creatures; age estimates of bones using radiocarbon dating; geochronological age estimates using pollen, charcoal, sediments, and other materials; spear points and other signs of human predation; and, for the most recent centuries, written records and other cultural artifacts. Those who study these pieces of the puzzle continue to engage in intense debates over the sequence of cause-and-effect. In just the last few years, however, as the evidence has accumulated, a more finely detailed pattern of the timing and extent of near-time extinctions has begun to emerge. They appear to follow a general sequence:

- Within those areas of longest human occupancy — Africa and Eurasia — relatively few known extinctions occur after the emergence of modern humans. Those that do occur are spread out over a long period of time.[10]

• Beginning approximately 50,000 y.b.p., modern human beings move into what is now Indonesia, which then loses about 50 percent of its large mammals.

• Between 60,000 and 40,000 y.b.p., human beings begin to spread into Melanesia, New Guinea, and Australia. Beginning soon after, large mammals and other vertebrates disappear from these regions. In Australia, 55 vertebrate species (including large mammalian carnivores and herbivores, large reptiles, and many marsupials and flightless birds) go extinct by about 15,000 y.b.p.[11]

• In the period lasting from about 12,500 to 10,000 y.b.p., North and South America lose some 135 mammal species from 85 genera (somewhat more dying out in South America than in North America). Approximately 70 percent of North America's large mammals vanish. The losses come at the tail end of the last period of continental glaciation and happen very quickly, over a period of just 400 to 1,000 years. They are coincident with the migration of human beings from Asia to the Americas, either across the Bering land bridge or by other routes.[12]

Humans have a very poor record of conserving biodiversity on islands. As we convert more and more land — either for industry or agriculture, or simply for human settlement — the biodiversity that we have on continents is being restricted to reserves of habitat which are essentially islands within continents . . . If we don't thoroughly investigate and try to learn from the island record, perhaps we will wind up to be just as poor managers of habitat archipelagos on continents as our predecessors were on islands.

Helen James, "Prehistoric Extinctions in Hawaii: The Search for Causes."

Over the past 10,000 years, the pattern of extinction shifts away from the continental land masses and toward the world's large temperate/tropical island groups. These are among the last lands to be settled by human beings.

• Human beings settle Crete, Sicily, Malta, and the other major islands of the Mediterranean Sea beginning approximately 10,000 y.b.p. Significant extinctions occur over the next 6,000 years — large land tortoises, dwarf elephants and hippos, and species of island deer, rodents, and insectivores.[13]

• In the West Indies, settlement begins about 7,000 y.b.p. Extinctions occur frequently thereafter, extending into historic times.[14] Losses include many endemic species of sloths, monkeys, rodents, and insectivores. Some islands, like Puerto Rico, lose their entire complement of native land mammals — in this case, five species.

• Madagascar is settled 2,000 y.b.p. Over the next 1,500 years, extinctions occur at an accelerated rate, claiming some two dozen species of mammals, birds, and tortoises, including virtually all of the large endemic land animals.[15]

• Hawaii's first human settlers arrive from Polynesia some 1,600-1,400 y.b.p. Subsequent waves of settlers arrive until 800 y.b.p. During this period, an estimated two-thirds of Hawaii's native vertebrates, including 90 percent of the bird species, disappear. Twenty more bird species are lost following the arrival of Europeans.[16]

• New Zealand is the last large land mass in the temperate zones to be settled (about 1,200 - 800 y.b.p.). In an extinction episode that extends until about 300 years ago, large and small animal species — birds, frogs, lizards — are lost, especially from the main islands. The 30 or so bird extinctions include the islands' 11 endemic species of moa, two species of large raptor, five species of rail, and six species of waterfowl.[17]

Taken together, these near-time extinction events display characteristics that are important in determining their causes and their relevance to the present. Large-bodied animals were strongly affected. In fact, all terrestrial species outside of Africa and tropical Asia that weighed more than 1,000 kg went extinct. Deep-time extinction events, by contrast, generally affected animal species across the spectrum of body sizes. The near-time extinctions occurred asynchronously and sequentially, affecting one region after another, whereas deep-time extinctions occurred globally and within the same time span. Finally, because these extinctions have happened relatively recently, and the ecosystems have been changed so dramatically, the species that were lost have not been replaced by others.

The pattern of loss in near time is still unclear in many respects, but two key attributes are supported by the growing mass of data. First, the extinctions happened quickly. Second, they appear to track the pattern of human expansion and migration, with losses following closely upon human arrival. This sequence has been called the "first contact pattern." Noting what has been described as the "dreadful syncopation" of the first contact pattern, Ross MacPhee of the American Museum of Natural History has succinctly stated the case: "When humans arrive on the landscape, the animals go."[18]

There is as yet no definitive scientific consensus on how these losses occurred so rapidly, over such extensive areas, and in the patterns that they did. By correlating information on environmental conditions, the timing, location, and extent of extinctions, the species affected, and the evidence (or lack of evidence) of human presence, several competing hypotheses and scenarios have been advanced.

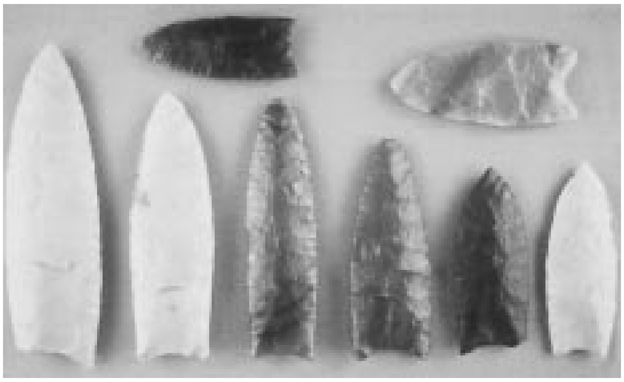
New Zealand was the last major land mass on the planet to be permanently settled by humans. Following human arrival, one-third of the more than 120 species of breeding birds there became extinct.

Richard Holdaway,"Differential Vulnerability in the New Zealand Vertebrate Fauna."

The overkill hypothesis

In the 1960s, Paul Martin first proposed that a wave of intense human hunting pressure led to the demise of mammoths and other large North American mammals after the last glaciation. Following Martin's original thesis, this school of thought holds that hunting by human beings has been the major cause of most near-time extinctions. In some cases, this is believed to have followed the arrival of skilled hunters in areas where the native fauna was "naive" and hence vulnerable to rapid and complete predation (this has been termed the "blitzkrieg" theory). Alternatively, species may also have disappeared through gradual overharvesting (as in the case of many of the bird species lost from Hawaii).

How could a relatively small number of hunting humans have had such rapid and extensive impacts on so many large species? Critics argue that there are very few examples even today of species being hunted to extinction; that the overkill hypothesis does not explain the lack of extinctions in much of Africa and Eurasia, where human beings did not arrive suddenly; that the thesis makes untenable assumptions about the number and behavior of prehistoric hunters; that the population of hunting groups could not have been sustained through such hunting practices; and that archaeological evidence for such an explanation is scant. The hypothesis, however, is supported by the strong correlation between patterns of human dispersal and species extinctions, and by the fact that large vertebrates were disproportionately affected. In addition, direct evidence of human hunting of mammoths and other species has been found at some early archaeological sites.



Clovis-period spear points found in Naco, Arizona in the ribcage of a mammoth skeleton. Overharvesting by human hunters has been proposed as the cause of mammoth extinction. Other scientists question whether this was the sole cause.

Climate change

Other scientists theorize that changes in the earth's climate, especially toward the end of the Pleistocene era, were responsible for profound alterations in habitats, with corresponding impacts on species in many regions. In response to this "climate forcing" argument, however, critics note that prior episodes of dramatic climatic change (especially glacial/interglacial transitions) had no such extensive impacts. Moreover, the disappearance of the large vertebrates occurred at different times in different places, with little apparent connection to changes in the global climate.

Disease

A recently proposed explanation suggests that, in certain times and places, introduced infectious disease may have been a leading cause of extinctions. Carried not necessarily by human beings, but by their commensals and other associated creatures (such as rats and birds), these diseases could have spread rapidly through susceptible populations in newly settled regions.[19] According to this line of thought, the African and Asian fauna were not affected by human-associated diseases because of their long period of co-adaptation with *Homo sapiens*. Species in other parts of the planet, however, had no such history of co-adaptation, and succumbed in large numbers when these diseases were first introduced.

Other scenarios

Other factors have been considered in explaining near-time extinctions: increased interspecific competition; extensive habitat destruction due to human settlement; and intensified predation by exotic and introduced animals. In some cases, the elimination of very large mammals (such as mammoths) may have had significant cascading effects within their ecosystems, transforming habitat conditions and leading to the demise of associated species. Under such circumstances, various factors would need to be considered together.[20]

The very large mammals, the so-called "megaherbivores," the elephants, rhinos…function as ecosystem managers and change woodland conditions, change grasslands, in a way that may actually have been beneficial to other species in creating a mosaic diversity of habitats. These ecosystem engineers…don't simply respond to habitats as they find them, they actively transform those habitats. (Norman Owen-Smith, "The Interactions of Humans, Megaherbivores, and Habitats in the late Pleistocene Extinction Event.")

The quest for explanations continues. In this dynamic field of research and speculation, new ideas, data, and hypotheses are presented regularly. There are plainly many possible and plausible causal factors, and none alone seems to provide an explanation for the full range of observed phenomena from around the world. Most agree that humans have played a significant role, and the "first contact pattern" seems well established. There is also an emerging consensus that anthropogenic extinctions have been more extensive and more important than previously appreciated. Generic explanations, however, remain tentative. It seems likely that the future will instead offer explanations more finely tuned to different times and places, involving specific causes or combinations of causes.

Lessons from the Past

The story of life's past is obviously still incomplete and will necessarily remain so. Our view of the past is skewed by the nature of the only evidence we have for much of it — the fossil record. Not all creatures fossilize well, or live in environments conducive to the formation of fossils. So creatures with bony, chitonous, or other hard parts that make good fossils are well represented, as are creatures that left their remains in the right kind of soil for fossil formation. We can't know how many organisms never appeared in the fossil record; our picture of past biodiversity will always remain partial. However, even with this limited view of past extinctions, we can find lessons relevant to the present threats to biodiversity and to the way we must live in today's world if we are to lessen them.

Background extinction rates

Studies of the fossil record allow us to estimate the rate at which extinctions occurred in the past. This is usually referred to as the "normal" or "background" rate of extinction. Although estimates vary, a useful rule of thumb is that one species in a million species goes extinct per year.[21] This figure, approximate as it is, is essential in understanding the magnitude of today's accelerated rates of species loss.

Not all extinction events are equal. The earliest recorded mass extinctions affected mainly marine species, as terrestrial life was still in its early stages of development. At the K/T boundary, a notable change involved the disappearance of the long-successful dinosaurs. In near time, we know that large mammals and other vertebrates were vulnerable, because they have left a fossil record in the form of their bones. For most other groups the scale of loss can only be indirectly and imperfectly estimated.

Recovery times

Life rebounded even from the extreme extinction events of deep time. But recovery was a long-term process. Evolution required up to 10 million years or more to attain prior levels of species diversity (and, of course, many new life forms emerged in the process).[22] The near-time extinctions of prehistory are so recent that we are still in fact living amid the effects — difficult though they may be to perceive. But just as human actions appear to have had unprecedented impacts on extinction rates, so are they liable to present unprecedented impediments to recovery.

The world we live in is not a complete, fully functioning one. Places like Australia and North America are full of ecological ghosts . . . The time since the megafaunal extinctions is so short, no new species have evolved to fill their niches. We're living . . . in a crippled world.

Tim Flannery, "The Timing, Nature, and Aftershock of Pleistocene Extinctions in Australia."

Island species

The particular vulnerability of island-dwelling species can be seen in the quantity of the losses that have followed human settlement of island groups over the last 10,000 years. The evidence is strong that whenever people, their technologies, and their associated plants and animals arrived in new lands, the extinction of native species followed. On islands, the process is accentuated. The same effect can be seen in the "islands" of habitat created when ecosystems are fragmented by widespread land exploitation and development.[23]

Differential human impacts

The extinctions of the last 40,000 years show that human beings — even if not the sole cause in all cases — are nonetheless unique agents of change in the history of life. Even when their numbers have been limited and their technologies modest, people have been able to effect large changes in the landscape and in the resident flora and fauna. These changes may be both direct and indirect, the result of conscious pursuit as well as unforeseen consequences.

The Contemporary Biodiversity Crisis

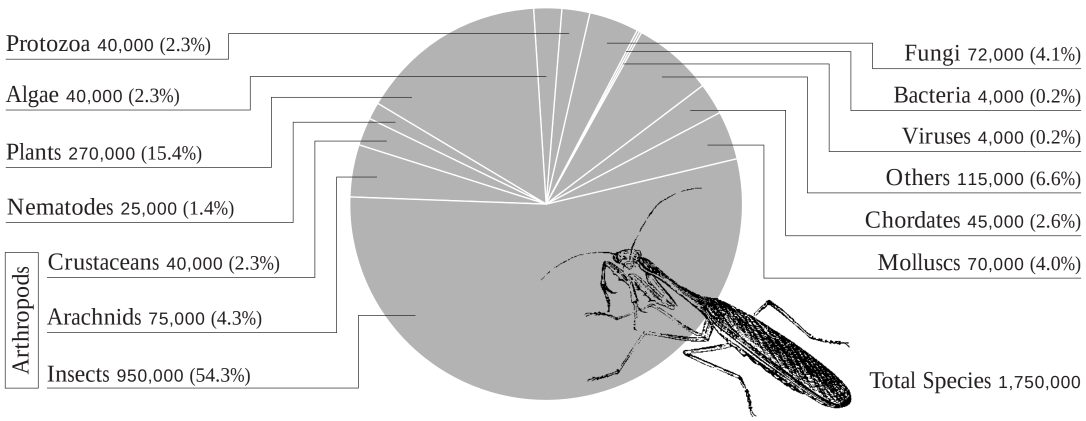
Against the background of geologic history, we can begin to understand the character and full magnitude of the crisis of extinction we are currently experiencing. We can recognize the impact that our activities are having on other life forms and their habitats, and on the processes that maintain them. We can appreciate the degree to which this also affects our own quality of life, and how it will affect posterity.

Human activity, especially over the last several centuries, has led to the loss of biological diversity from the local scale to the global, and from the genetic level to the biome. As human technology has developed, so has its capacity for eliminating species. Between 1600 and 1900 A.D., 75 species are known to have disappeared as the result of human activities. From 1900 to 1975, another 75 species were driven out of existence. If the increase in human-caused species extinctions observed over the last quarter-century continues, losses will accelerate dramatically in the near future.[24]

The Magnitude of the Biodiversity Crisis

Biodiversity refers to the diversity of species, the genetic variability within species, and the variety of communities and ecosystems to which species belong. At the genetic level, interest in recent years has focused on the impact of dwindling genetic diversity on rare and threatened species; the influence of human land use on the exchange of genetic material in the wild; the potential of some wild plants and animals for food, medicine, and other human benefits; and the loss of local crop varieties and animal breeds. At higher levels of biological organization, losses are more difficult to quantify. Only recently have scientists attempted to focus on declining populations and to assess the loss and degradation of ecosystems. Attention has focused on areas that are particularly rich in species and vulnerable to habitat destruction, including tropical forests, coral reefs, wetlands, lakes and streams. However, the extent of the biodiversity crisis has prompted scientists and conservationists to look anew at all terrestrial and aquatic systems.[25]

No one knows exactly how many species there are on earth. Biologists have described approximately 1.5 - 1.75 million species, but estimates of the total number run from a conservative 10 million to as high as 50 million or more.[26] Some groups of organisms — birds, mammals, reptiles, plants — are relatively well studied. However, only a small fraction of the more species-rich groups — insects, other invertebrates, fungi, microorganisms — have been described and classified. The wide disparity in the estimates of total species diversity reflects not only the limited amount of field research on these groups, but the limited number of qualified people and the lack of funding devoted to such research.



Number of species currently named and described.

How many species are dying out, and at what speed? Although scientists have grappled with these issues in several ways, there is an overriding problem that affects all efforts at estimation: since we don't know even within an order of magnitude how many species there are on earth, how can we determine how many have gone missing?

There are two responses to this conundrum. One is to use a "proxy" measure of the rate of loss. (A proxy is "a stand-in;" scientists often utilize proxy variables that they can measure in order to achieve an understanding of the behavior of variables that they cannot measure directly.) The "species-area" relationship is one such proxy: if you can estimate, for example, how many species should be living in a particular environment like a Brazilian rain forest, then if the forest disappears (through clear-cutting, or fire, and so forth), that should have an effect on the number of species that can survive. Using this approach, E. O. Wilson and others have estimated that the loss rate of species in moist tropical forest alone is approximately 27,000 species per year, given 1992 rates of forest clearance.[27]

Another approach is to realize that we can, within reason, count the species that were described by scientists in the past, but subsequently became extinct. We can also count species that were never scientifically described, but which — thanks to their bony remains — can be proven to have recently existed (and possibly even dated as to their actual time of loss, using radiometric techniques). Obviously, for many groups (e.g., most arthropods) such an empirical count will be pointless, since their taxonomy is woefully incomplete and there are no remains to be recovered of recently extinct forms.

For other groups, however, there is actually a high chance that very accurate lists of recent losses can be compiled. This is not the same as being able to count all the losses that might have occurred within a specific period. To be sure, many species will be missed by empirical counting techniques because the taxa were never described, or because their remains have not been found, or because the remains that are available are not diagnostic.

Approximately 11,000 years ago, in North, Central and South America, a rapid extinction event wiped out 85 genera of large-bodied land mammals — arguably shortly after the arrival of the continents' first humans.

Ross MacPhee and Preston Marx, "Lightning Strikes Twice: Blitzkrieg, Hyperdisease, and Global Explanations of Late Quaternary Catastrophic Losses."

Having verifiable lists of the disappeared, however, has real importance. For some groups that have been very well studied systematically, like birds and mammals, thanks to empirical counts it is now possible to make several generalizations about extinctions that have occurred in the past 500 years. First, it is now beyond reasonable doubt that the vast majority of mammal and bird extinctions have occurred on islands (at least 70 percent in the case of mammals, perhaps over 99 percent in the case of birds). By contrast, continental locales have lost relatively few species. Secondly, some groups have been much more severely affected than others. In the case of mammals, for example, rodents, insectivores, bats, and several groups of marsupials have had the highest losses. Ungulates, carnivores, and primates have lost relatively few species, and whales none. Notice that these statements describe complete losses at the species level; they do not refer to threat status or endangerment. Thus no one can seriously doubt that many of the world's species of great whales are in extreme danger. However, it is surely important that — fortunately — none of them has yet been driven to complete extinction. This should inspire the hope that, for whales at least, conservation measures still have time to be effective.

But what should be done with such information? Should it not be collected in some organized, rational manner so that it is broadly available to everyone concerned with the biological health of the planet? In August, 1998, scientists at the American Museum of Natural History formed the Committee on Recently Extinct Organisms (CREO), which in turn has recruited an international group of more than 70 scientists to define a series of common procedures that can be utilized to assess biotic losses empirically, and to oversee the collection, organization, and dissemination of their results. CREO's Advisory Panels are now collecting information on several different groups of related organisms, from mollusks to arthropods to vertebrates. As already noted, for some groups the collection of good-quality, verifiable data will be very difficult. However, even in these cases, it is important to have a realistic basis for assessing loss, even if it is quite imperfect to begin with.

Among the products that this organization is in the process of creating is a preliminary guide to the world's recently extinct species, under the aegis of DIVERSITAS, an international partnership of governmental and non-governmental organizations concerned with documenting world biodiversity. This volume should be ready for publication in 2001. The object of this new survey is to analyze extinctions by more rigorous criteria, to make more complete assessments of sampling evidence, and to increase the comprehensiveness of extinction lists by determining losses at the level of the smallest identifiable difference. This level includes species, but (depending on the group and the state of its systematics) may also include entities sometimes called "subspecies," "distinct populations," "varieties," and so forth. The overall intention is that, with better documentation and improving methodology, CREO will eventually be able to provide "extinction maps" for many groups in many parts of the world, so that the scope and impact of biological losses can be accurately gauged by scientists, conservationists, policy makers, politicians, and the interested public. A better picture of the patterns of species extinction in space and time will help us predict future extinctions, and perhaps allow us to modify those human activities that contribute to them.[28]

Comparing Past and Present Extinctions

Those who study life's evolutionary past and those who work to understand and safeguard biodiversity in the present have begun to share knowledge across their professional and disciplinary boundaries. This expanded conversation has allowed for valuable comparisons of past extinctions with the "Sixth Extinction" that many scientists believe is taking place today. Although we can now see current and expected losses as part of a larger historical pattern, we can also see what distinguishes the contemporary situation.

Causes

The most basic difference between past extinctions and the current crisis is that many extinctions are no longer the result of forces beyond our control (or, in the case of some near-time extinctions, beyond our awareness of the consequences of our actions). The present extinction crisis is due not to cataclysmic events like widespread volcanism or asteroid collision, but to the immoderate impact of our own activities. We now know that the decisions and choices we make can result in the extinction of other creatures.

Extinction rates

The estimated rate of species extinction would translate into a loss of some one-fourth to one-third of the world's species within the next 50 years — approximately 2.5 to 9.0 million species, depending on the calculations of total species diversity. Species would thus be lost at a rate at least 100 to 1,000 times the background rate of one extinction per million years. Some scientists predict future rates as high as 10,000 times the background rate.[29] The rates vary among taxonomic groups: The current rate of loss for birds has been calculated at 100 times the background rate; for mollusks, 1,000 times.[30] It also varies by region and ecosystem. Much attention has recently been devoted to the tropical rainforests, but other, lesser-known communities are also being significantly affected. For example, South Africa's unique *fynbos*, renowned for its exquisite diversity of plants and its high rate of species endemism, may have lost plant species at a rate 100 times the background rate.[31]

Breadth of taxonomic groups affected

Extinction episodes in deep time affected a broad range of species around the globe. In near time, extinctions have tended to affect only certain regions, such as islands, and a relatively limited range of taxa, such as large mammals and birds. The extinctions we are beginning to see in the current crisis are, as in deep time, occurring across a broad range of taxonomic groups simultaneously, including mammals, birds, reptiles, and freshwater fish; the vast realm of invertebrates (especially those in the tropical forests); and, importantly, plants. In the past, most plants have survived extinction episodes relatively successfully. Now plants are being lost at an accelerated rate, with far-reaching consequences for all the members of the food chains they support, and the fungi, pollinators, dispersers, and other organisms with which they coexist.

Endemic species, especially those on islands, have always been particularly vulnerable to extinction, and the rate at which these species are affected has indeed been increasing. Now, however, more widely distributed, generalist species are also increasingly threatened. The disappearance of the once-abundant passenger pigeon and the near loss of the American bison — due in both cases to over-hunting and habitat destruction — were especially troubling warning signs.

Spatial distribution

Mass extinctions of the distant past were global in scope, suggesting global-scale causal factors (including bolide collisions and shifts in climate). Over the last 100,000 years, the extinctions associated with the spread of human beings affected successive regions and, notably, islands. Now, as human beings and their technologies have become agents of global change, those effects are being felt in all major ecosystem types, both terrestrial and marine. (While there is no evidence of global-scale marine extinctions, there have been pervasive regional and local environmental effects.) The impact of our species on the biodiversity of the planet may be as devastating as any ancient asteroid collision.

Adaptive capacity

Mass extinctions have been relatively rare events in the earth's past. Surviving life forms were able to repopulate and rebuild ecosystems, evolving in response to new opportunities as well as persistent environmental stresses. Now the impact of human activities is being superimposed over these "normal" evolutionary processes. Many species may be unable to adapt, given the speed and scale at which human-caused environmental changes are taking place.

Recovery potential

Life has proven to be capable of rebounding even from profound levels of depletion, and will rebound again in the wake of the current period of human-caused extinctions. In the process, however, many unique expressions of life will have been unnecessarily lost. And based on the past record of average species longevity, human beings themselves are likely to have passed from the scene long before a recovery occurs.

Unique expression of life: This Brazilian rainforest frog is one of the countless species whose existence is threatened by habitat destruction.

Current Threats to Biodiversity

Only rarely can the loss of biodiversity be traced to a single, discrete cause. Rather, many factors interact in complex ways to place species and habitats at risk. The leading direct threats to the world's biological diversity fall into several main categories.[32]

Habitat loss and degradation: (Left) Illegal logging in French Guiana. Tropical forests around the world are threatened by overexploitation. (Right) The vast grasslands of the tampoketsy, *which occupy most of central Madagascar, are burned off every year during the dry season.*

Habitat loss and degradation

Destruction and loss of habitat is the most important threat to biodiversity. Throughout the world, ecosystems are being extensively modified by people. Habitats of all sorts, from forests to deserts, rivers to coral reefs, high mountains to the open ocean, are being altered, degraded, or destroyed. The forces behind habitat loss include intensified exploitation of natural resources, agricultural conversion, and urban and industrial development. The fragmentation of large habitats into smaller patches is an especially significant form of habitat degradation. The species within such "islands" of habitat face increased extinction risks.

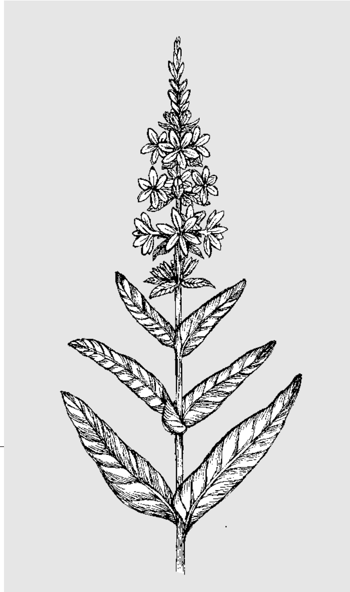
Overexploitation

Exploitation of economically important species (such as the passenger pigeon and the great auk) and of both aquatic and terrestrial habitats (such as Chesapeake Bay or tropical forests in the Amazon basin or in southeast Asia) has been a leading factor behind the loss of biological diversity. Overexploitation remains a threat throughout the world, affecting whales, rhinos, large cats, and various groups of species. Extensive ecosystems can be affected as well as species, as witness the impact of driftnets and other destructive fishing methods on certain fisheries, or clearcut logging in old-growth forests.

Overexploitation: Modern fishing techniques can devastate marine ecosystems. The fish in this photograph are what is called bycatch, killed incidentally in the pursuit of another species.

Exotic species

The spread of intentionally and accidentally introduced species is a critical long-term threat to global biodiversity. As the number of exotic species introduced into an ecosystem increases, they can disrupt ecosystem functions and drive out more specialized endemic species. In disturbed systems, some native plants and animals can also proliferate to the point where they become problem species. In island systems, species are often part of a fairly restricted fauna in terms of diversity, and are especially vulnerable to competition from invasive exotics.



(Above) The cane toad, Bufo marinus, *an exotic species introduced into Australia to control agricultural pests, has become a pest itself.*
(Right) An escapee from North American gardens, purple loosestrife (Lythrum salicaria) *has become a troublesome invader of disturbed ecosystems, especially wetlands.*

Since the mid-19th century, there have been 1,354 documented cases of introduction of exotic species into virgin fresh waters . . . involving 140 countries and 237 species . . . nearly always to the detriment of native populations and native ecosystems.

Melanie Stiassny and Ian Harrison, "Vanished from Fresh Water: Species Decline and the Machinery of Extinction."

Pollution and contamination

Pollutants can have both acute and chronic impacts on species and their genetic structure, altering the physical, chemical, and biological character of their habitats and compromising plant and animal communities. The toxic effects of pesticides, industrial by-products, heavy metals, and other contaminants are often cumulative, synergistic, and difficult to monitor and analyze. For this reason, it is difficult to predict the ultimate effects of the increasing amount and variety of polluting substances that we are introducing into the environment.

Global climate change

Our reliance on fossil fuels has altered the character of the earth itself. Global warming is almost certainly due, at least in part, to increasing concentrations of greenhouse gases such as carbon dioxide in the atmosphere; this change in climate may in turn cause changes in weather patterns and ocean current dynamics. Acid precipitation is a direct consequence of large-scale coal-burning; northern forests around the globe are being damaged by it. Chlorofluorcarbons released into the atmosphere have led to the depletion of the earth's stratospheric ozone layer, with uncertain implications for living things.

Habitat conversion, especially tropical deforestation, has an obvious negative effect on biodiversity. In cases where tropical forests are burned, the damage is triple: the burning releases long-stored carbon into the atmosphere, adding to the problem of global warming. The burned-over forest is no longer available to pull carbon from the atmosphere and store it. And habitat for forest species has been destroyed.

The trees in this forest, in New York State's Adirondack Mountains, have been damaged by acid rain.

Overpopulation

Although conservation programs can respond to these threats to biodiversity, they alone cannot address the unprecedented rate of human population growth and contemporary patterns of resource use and consumption.

- As we approach the millennium, the world's human population is nearing 6 billion, and at current growth rates will double in just over 40 years.
- Even if growth rates ease, the total human population is likely to reach at least 10 billion by the middle of the 21st century, with much of the growth occurring in tropical countries where species diversity is especially high.
- At the same time, high rates of per-capita consumption in the world's developed countries are contributing disproportionately to the pressures on global resources.

These combined forces are only further driven by unequal distribution of the world's wealth, inequitable systems of land tenure, and short-sighted economic incentives that drive resource development.

Preventing Extinctions: Advances in Biodiversity Conservation

Conservation biologists are working with people in fields from public policy and health care to sustainable agriculture, transportation, and education to confront the causes of present-day extinctions and to preserve biodiversity. We now know, as no previous generation has, that extinction has always been a part of the evolutionary process, and that human beings have had significant impacts on biodiversity. We know, too, that the wave of extinctions we are witnessing follows previous waves, and is in some ways comparable to them. But this wave represents an order-of-magnitude escalation of extinction processes. It threatens many other species, of course, but its human causes and consequences make it a vital issue for our own future.

> **...ancient extinctions have patterned the world that we live in today.... We've had our big hit at the megafauna, we've exploited plants and forests...now what's under threat are soil and water.... Once you start attacking the ecosystem at those very fundamental levels, you're...actually precipitating extinction events on the scale of the Cretaceous extinctions.**
>
> *Tim Flannery, "Emerging Patterns in Australasian Quaternary Extinctions."*

Principles for Survival

Conservation has long been split between sustaining the use of particular resources and protecting wild nature's scenic, recreational, and spiritual values. As our understanding of the human impact on biodiversity has grown, however, a fresh synthesis has begun to emerge. This new understanding is changing our approaches to forestry, agriculture, fisheries and wildlife management, and other traditional conservation fields, and is stimulating new applications in fields from restoration ecology to urban design and planning.

Contemporary conservation actions are increasingly based on a set of emerging fundamental principles:[33]

• *Diversity itself should be the primary focus.* Conservation has traditionally focused on a few species of obvious economic, recreational, and aesthetic value. Increasingly, though, conservationists are beginning to recognize the need to conserve genetic, species, and habitat diversity.

• *Natural systems function on multiple levels.* Living things exist within a hierarchy of biological systems, from genes to populations to species to communities to landscapes. Conservationists should try to understand how these systems interact, and attempt to predict the effect of any actions on the whole.

• *Natural systems are dynamic.* Nature is in a constant state of flux. Conservationists should try to ensure that natural processes are functioning, rather than focus on any particular natural state thought to be "ideal." These processes include such "normal" functions as herbivory and nutrient exchange and periodic ecosystem disturbances such as fire, flooding, and storms.

• *Natural systems work across multiple scales of time and space.* Nature's processes work across many spatial and temporal scales, from the micro to the global, from the ephemeral to the geological.

• *Natural systems and human communities interconnect*. Few places on earth remain free of human influence. At the same time, human communities are a part of the larger natural world. Increasingly, conservationists try to find solutions to conservation dilemmas that include an understanding of the connections between local people and the places they inhabit.

• *Conservation involves ecological (not merely economic) considerations.* Traditional conservation sought to sustain the productivity of resources through efficient management. While economic functions remain critical, the science of ecology has expanded our understanding of how our economic activities depend upon the healthy functioning of natural systems.

CONSERVING GENES, POPULATIONS, AND SPECIES

Many of conservation's most visible campaigns have focused on wild plants and animals threatened by human exploitation or encroachment — redwood trees and Arabian oryx, whooping cranes and Siberian tigers, African cichlids and baleen whales. While initial *in situ* actions — those that seek to perpetuate species in their wild habitats — may also protect other organisms sharing the same ecosystems, often the risks to the threatened species are so great that more narrowly focused and intensive *ex situ* efforts — those that take place "off site" — are also required. For example, many conservation efforts combine a mix of legal safeguards against hunting organisms or altering their important habitats, along with species recovery and management plans to reestablish self-sustaining or "viable" populations in the wild. *Ex situ* methods, such as captive breeding, reintroductions, and translocations, can be important tools to help reestablish wild populations. Conservation genetics, including analyses of individual relatedness, genetic diversity within populations, and the relatedness among populations, can help guide the conservation decision-making involved in these efforts.

In situ*: Humpback whale in Antongil Bay, Madagascar. Scientists and conservationists hope to establish a marine reserve in the bay to help protect these whales and other marine mammals.*

Zoos, aquariums, botanical gardens and arboretums are becoming more involved in saving both species and habitats through breeding programs, educational campaigns, and fundraising for field programs. Natural history museums and herbariums also provide essential information on biodiversity through their collections, while seed banks serve as repositories of plant germplasm diversity. While these activities provide critical help in preserving genetic and species diversity, other direct interventions at the habitat and ecosystem levels are fundamentally important for conserving biodiversity.

CONSERVING HABITATS AND ECOSYSTEMS

The world contains unknown millions of species, and conservation cannot succeed if it operates solely on a species-by-species basis. Ultimately, biodiversity can be preserved only in sufficiently protected, well-functioning habitats of all types — tundra, forests, savannahs, grasslands, deserts, wetlands, streams, lakes, estuaries, coral reefs, kelp forests, mangrove forests, and sea-grass beds. Areas of limited human impact are especially important, but the need to protect habitat encompasses places from the wild to the urban.

Protected areas

Establishing protected areas — reserves, parks, refuges, sanctuaries, wilderness areas, and so forth — is one of the most important means of maintaining biological diversity. Because protected areas can contain many of the species native to a given region, their creation provides a "coarse-filter" approach to biodiversity conservation. The World Conservation Union, an umbrella organization of the world's biodiversity conservationists, has recommended that each country strive to retain 10 percent of its land base in protected areas.

As we move into the next millennium, our nation must strive for a state of harmony. We can no longer be satisfied with slowing erosion, water pollution and other forms of land degradation. Harmony will demand that we set our sights higher, to improve the land upon which our destiny rests, by restoring those places whose condition is merely adequate; and by protecting those areas that remain pristine.... Only then will we have a true geography of hope.

Paul Johnson, "America's Private Land: A Geography of Hope."

Many protected areas, however, no longer function in a fully natural manner, and require some degree of human intervention. Often protected areas are too small or isolated to sustain the processes that maintain biodiversity, such as migration, predation, flooding, and fire. Reserves are also vulnerable to such pressures as air and water pollution and urban development. For these reasons, core reserve areas often need "buffer zones" — areas of restricted development — around them, and habitat corridors connecting them to other reserves. Finally, protected areas exist within a cultural as well as a natural context, and should be integrated into the lives of local people.

In most parts of the world, however, much of the natural diversity in any given region is likely to be found outside formally protected areas or their buffer zones. Conservation biologists call such areas the "matrix" — the more intensively cultivated, settled, and developed landscape within which reserves are situated. One important, evolving approach to preserving diversity both within and outside formally protected areas is community-based conservation, which involves local people in the protection and sustainable management of their own landscapes. In the long run, the ways these lands and waters are protected and used will determine how diverse the regional biota remains.

Landscape and ecosystem approaches

In recent years, conservation scientists and land managers have sought to analyze biological diversity and natural resources at larger landscape scales. For some single species, these analyses focus on what are called "metapopulations" — networks of potentially connected populations. Such systems are characterized by populations that periodically experience low levels or even local extinctions before being reinforced or recolonized by rare migrants from other populations. In other words, metapopulations contain populations that continually go in and out of existence at the landscape level. While local extinctions seem to be natural and even necessary events in the dynamics of metapopulations, these systems are subject to total collapse and extinction when too many populations disappear at once. The recognition of metapopulation dynamics can have important consequences for the design and management of reserves, wildlife corridors, and "matrix" areas around protected land.

Community-based conservation: The Comarca de Kuna Yala, Panama. In 1983, the Kuna created the world's first nature reserve controlled by an indigenous group. They continue to manage their own territory, regulating tourism and patrolling to prevent illegal poaching and settlement. Parts of the rainforest are preserved as sacred sites.

Analyzing biodiversity on a landscape scale has been greatly aided by the increased availability of Geographical Information Systems (GIS) — computer programs that combine and manipulate different types of geo-referenced data with aerial and satellite imagery to produce multiple-layered maps. Using GIS to analyze a landscape, scientists and managers can more rigorously define and even predict a threatened species habitat range, using such information as human land use, vegetation cover, temperature, and rainfall patterns. Scientists can also analyze a landscape for the greatest concentrations of unique species as an aid to planning protected areas. Since analyzing a landscape with GIS requires significantly more data and is consequently more expensive and difficult to complete than qualitative, or "rule-of-thumb" methods, GIS analysis is often used as a complement to other, more traditional analytical approaches that continue to be used in conservation decision-making and management.

Ecosystem management has also become an increasingly popular approach to conserving natural resources while managing economic activities. Proponents argue that since natural systems are large, highly interconnected, and dynamic, we need to shift management away from static and piecemeal attention to individual species and places, and toward management of the whole, fluctuating system. Unfortunately, there is still little agreement over what rigorous, scientifically based ecosystem management is and how it should be conducted. Critics of this approach worry that it is vague enough to justify almost any management practice, and that important levels of biodiversity (such as specific patterns of genetic and species diversity) may be lost in the process. Balanced hybrid approaches that combine detailed understanding of ecosystem functions and knowledge of selected species dynamics may provide one solution.

Sustainable resource management

As a species we rely on the natural world to meet our basic biological needs for food, shelter, clothing, and other goods. Beyond these material benefits, we also depend on natural systems and processes for clean land, air, and water, and for intangible psychological, aesthetic, and spiritual nurturance. Biological diversity provides these human goods and services, directly and indirectly. However, it cannot do so on an unlimited basis. We see now, as we could not a century ago, that human economic activities take place within an ecological context, and that systems modified to meet human needs must still adhere to basic ecological principles.

Restoration ecology

Rather than abandoning lands and waters that have been destroyed or radically changed through human use, the intent of restoration is to rejuvenate habitats by reestablishing lost species and ecological functions — to the extent possible — such as the pioneering efforts beginning in the 1930s and 1940s to restore tallgrass prairies in the midwestern United States. Projects are being undertaken in widely different ecosystems, from very small local restorations to such landscape-scale efforts as the rehabilitation of Florida's Everglades or the replanting of dry tropical forest in Costa Rica's Guancaste National Park.

Volunteers working to restore native landscape near Chicago.

If we are to conserve the world's biodiversity, all of these approaches, from establishing reserves to revitalizing degraded lands, will be required, and they will need to work together. Success in restoring an ecosystem in one place does not remove the need to protect it in another, or to work for more sustainable uses elsewhere. Aldo Leopold defined conservation as "a state of harmony" between people and land. A recent publication of the U.S. Natural Resources Conservation Service put it this way: "Harmony will demand that we set our sights higher, to improve the land upon which our destiny rests by restoring those places that are damaged, by enhancing those places that are merely adequate, and by protecting those areas that remain pristine."[34]

Improving Our Knowledge of Biodiversity

The biodiversity of the earth is so complex that we will never know all there is to know about it. But the more we learn, the better informed our decisions will be. Expanding our knowledge is one of the most important conservation actions we can take.

We need to bridge the gap between what scientists know and what the public knows, and to educate students and teachers so that our future citizens are committed to environmental education — more outdoor exploration and community investigations, more interactions between scientists and social scientists and educators, more emphasis on careers and conservation and more citizenship education.

Judy Braus, "Windows on the Wild: A National Biodiversity Education Program."

All of the life sciences are relevant to conservation, from zoology and botany to agriculture and medicine. In biology, taxonomists and systematists working in the field provide fundamental contributions to our understanding of biological diversity. Contributions from the social sciences and the humanities are needed as well, including the study of political and economic systems and analyses of the cultural significance of natural resources and biological diversity to humans.

The job of building a biodiversity knowledge base is not restricted to specialists. Many of the most significant contributions are being made by volunteers equipped with little more than basic field skills, simple equipment, and a lively interest in nature:

- In Chicago, students in schools along the Chicago River monitor its health by studying its chemistry and organisms.
- In Wisconsin, hundreds of people visit marshes around the state every summer to record the presence or absence of frog species; these surveys provide critical information about the state of wetlands and water bodies.
- Across North America, bird enthusiasts have conducted annual bird counts around Christmas Day every year since 1900.
- Thousands of children throughout the hemisphere track the seasonal progress of birds, whales, caribou, and other migratory animals through the Minnesota-based Journey North project.

Direct experience of local landscape is more important than ever. Participants in such projects learn more about local species and ecosystems, and expand the circle of people who take an active and involved role in understanding and protecting biodiversity. As David Ehrenfeld put it in "Conservation Biology in the 21st Century," his symposium presentation, "How can a public that doesn't know nature be expected to support conservation biology?"

Biodiversity in Our Daily Lives

Even as individuals, we can help slow the rate of extinction. People everywhere are increasingly coming to understand the environmental impacts of their own lives, and are learning how to limit those impacts. The pressures on biodiversity reflect the demands we place on ecosystems. These demands in turn are the result of the choices and preferences we express every day. In the workplace, at school, at home, at the store and in the voting booth, the way we live and the choices we make affect our environment and the other species we live with. "The ultimate success of all conservation," says David Ehrenfeld, "will depend on a revision of the way we use the world in our everyday living when we are not thinking about conservation."[35]

- Non-governmental organizations (NGOs) around the world are taking an active role in shaping conservation programs, providing a forum for citizens concerned about environmental quality. Especially in less-developed countries, the impact of NGOs can be great even when their funds are limited.

- Increased citizen participation in local zoning and land-use planning reflects a growing concern with the impact of unchecked development on the environment and on local quality of life.

- More and more products are going through "green" labelling and certification procedures, providing consumers with more information about the impacts of production processes.

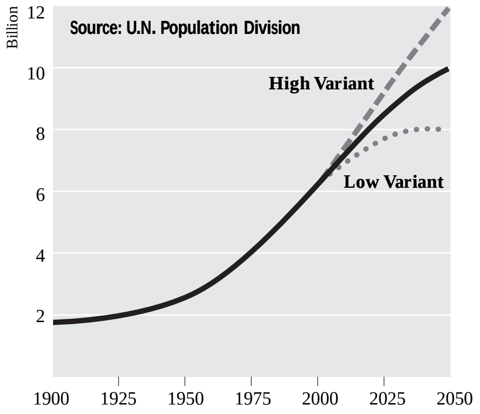
- Many consumers are becoming aware of the effects of their food choices on biodiversity, and choosing farmer's markets, community-supported agriculture, and other alternatives to the mass production and marketing of food.

BIODIVERSITY AND A SUSTAINABLE WORLD

Biodiversity conservation is often constrained by social and economic conditions such as population growth, poverty, environmental quality, public health, education and literacy levels, the status of women and children, and economic inequality. In the long run, biodiversity cannot be conserved if these issues are not addressed; conversely, progress in these areas is undermined if the biological foundations of human health and long-term prosperity are depleted.

Standard economic analyses ignore the important goods and services that biological diversity provides. Governmental policies also often contribute to habitat loss, overexploitation, and other threats to biodiversity by encouraging and rewarding non-conserving economic behavior. Public policies on transportation, land use, population, investment, and other issues all affect the ability to preserve biodiversity.

WORLD POPULATION GROWTH



Earth's current human population numbers almost 6 billion. Scientists predict that, early in the new millennium, that figure will reach 10 billion and could double again by the middle, reaching 40 billion by the start of the millennium that follows. (Stuart Pimm, "Extinctions, Geographic Ranges, and Patterns of Loss.")

Many of these issues need to be addressed at the international level. The nations of the world are increasingly interconnected politically and economically. Environmental problems, including the loss of biodiversity, have global causes and consequences, and require global solutions. This has been the aim behind international agreements such as the United Nations Convention on Biological Diversity.

The richer and poorer countries both have contributions to make, as well as responsibilities to accept, if a sustainable world is to be achieved. Conservation problems are exacerbated by the eversharper contrast between the lives of the wealthy few and the many poor. Life in the more developed countries typically involves high levels of resource consumption. As a consequence, a small fraction of the world's population utilizes the earth's resources disproportionately. The long-term economic and environmental costs of this imbalance must sooner or later be paid. There is little likelihood that we will solve conservation problems in a world characterized by a growing disparity between rich and poor.

Choosing to Conserve

We learn from the past that life has always been subject to extinctions. We learn too that life has the capacity to recover, even from large-scale extinction events, to persevere in the task of creation, to assume new and varied forms. Life is likely to survive whatever human beings may do to the earth. Other questions remain unanswered, however. Which forms of life will persist? With what potential for continuity? At what cost to ourselves and our descendants?

For the first time in evolutionary history, one species has the ability to choose how it will affect life's path and direction. The decisions we make and the actions we take will either contribute to an impoverishment of biodiversity, or to its conservation. In choosing to conserve, we grant other life forms the same opportunities to prosper and perpetuate their kind that we so value for ourselves.

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20 In summarizing this perspective for the AMNH symposium, Norman Owen-Smith noted that "even though humans may have been a major agent in the extinction of the very large animals — the so-called megaherbivores — perhaps people had not paid enough attention to the consequences of the elimination of those species on the habitat transformations that certainly occurred at around the same time.... Various factors might have interacted in those extinctions."

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28 For more information on the Committee on Recently Extinct Organisms, including details of their publication initiatives, see their website at *http://www.creo.org.*

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Symposium Participants and Presentations

John Alroy
Smithsonian Institution
"Reorganization of Late Quaternary Mammal Faunas and Causes of Extinction."

Judy Braus
World Wildlife Fund
"Windows on the Wild: A National Biodiversity Education Program."

David A. Burney
Fordham University
"Rates, Patterns, and Processes of Landscape Transformation and Extinction: Madagascar as an Experiment in Human Ecology."

Marianne Cramer
Central Park Conservancy
"Central Park's Woodlands: A Case Study in Restoring and Managing an Urban National Resource."

David Ehrenfeld
Rutgers University
"Conservation Biology in the 21st Century."

Niles Eldredge
American Museum of Natural History
"Cretaceous Meteor Showers, the Human Ecological 'Niche,' and the Sixth Extinction."

Carol J. Fialkowski
The Field Museum
"Chicago Wilderness: A Regional Biodiversity Initiative or an Oxymoron?"

Tim F. Flannery
Australian Museum
"Emerging Patterns in Australasian Quaternary Extinctions."

Russell W. Graham
Denver Museum of Natural History;
Thomas W. Stafford, Jr.
University of Colorado;
Holmes A. Semken, Jr.
University of Iowa
"Pleistocene Extinctions: Chronology, Non-analog Communities, and Environmental Changes."

Gary Hartshorn
Organization for Tropical Studies
"Integrating Sustainable Forestry and Biodiversity Conservation in Tropical Forests."

Gary Haynes
B. Sunday Eiselt
University of Nevada
"The Power of Pleistocene Hunter-gatherers: A Forward and Backward Search for the Evidence about Mammoth Extinction."

Richard N. Holdaway
University of Canterbury, New Zealand
"Differential Vulnerability in the New Zealand Vertebrate Fauna."

Helen F. James
Smithsonian Institution;
Douglas Siegel-Causey
National Sciences Foundation
"Prehistoric Extinctions in Hawaii: The Search for Causes."

Paul W. Johnson
Natural Resources Conservation Service
"America's Private Land: A Geography of Hope."

Ross D. E. MacPhee
American Museum of Natural History;
Preston A. Marx
Aaron Diamond AIDS Research Center
"Lightning Strikes Twice: Blitzkrieg, Hyperdisease, and Global Explanations of Late Quaternary Catastrophic Extinctions."

Paul S. Martin
University of Arizona
"Prehistoric Overkill: Four Decades of Discovery and Debate."

Michael J. Novacek
American Museum of Natural History
"Mapping the Ebb and Flow of Life."

Norman Owen-Smith
University of the Witwatersrand
"The Interaction of Humans, Megaherbivores, and Habitats in the Late Pleistocene Extinction Event."

Stuart L. Pimm
University of Tennessee
"Extinctions, Geographic Ranges, and Patterns of Loss."

Melanie L. J. Stiassny
Ian J. Harrison
American Museum of Natural History
"Vanishing from Fresh Water: Species Decline and the Machinery of Extinction."

A. J. Stuart
Norfolk Museum Services/Castle Museum
"The Role of Humans in Late Pleistocene Megafaunal Extinction, with Particular Reference to Northern Eurasia and North America."

Discussion Moderators

David Hurst Thomas
Joel L. Cracraft
American Museum of Natural History

Credits

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Page 23: Chart from United Nations Population Division, *World Population Prospects: The 1998 Revision*.

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