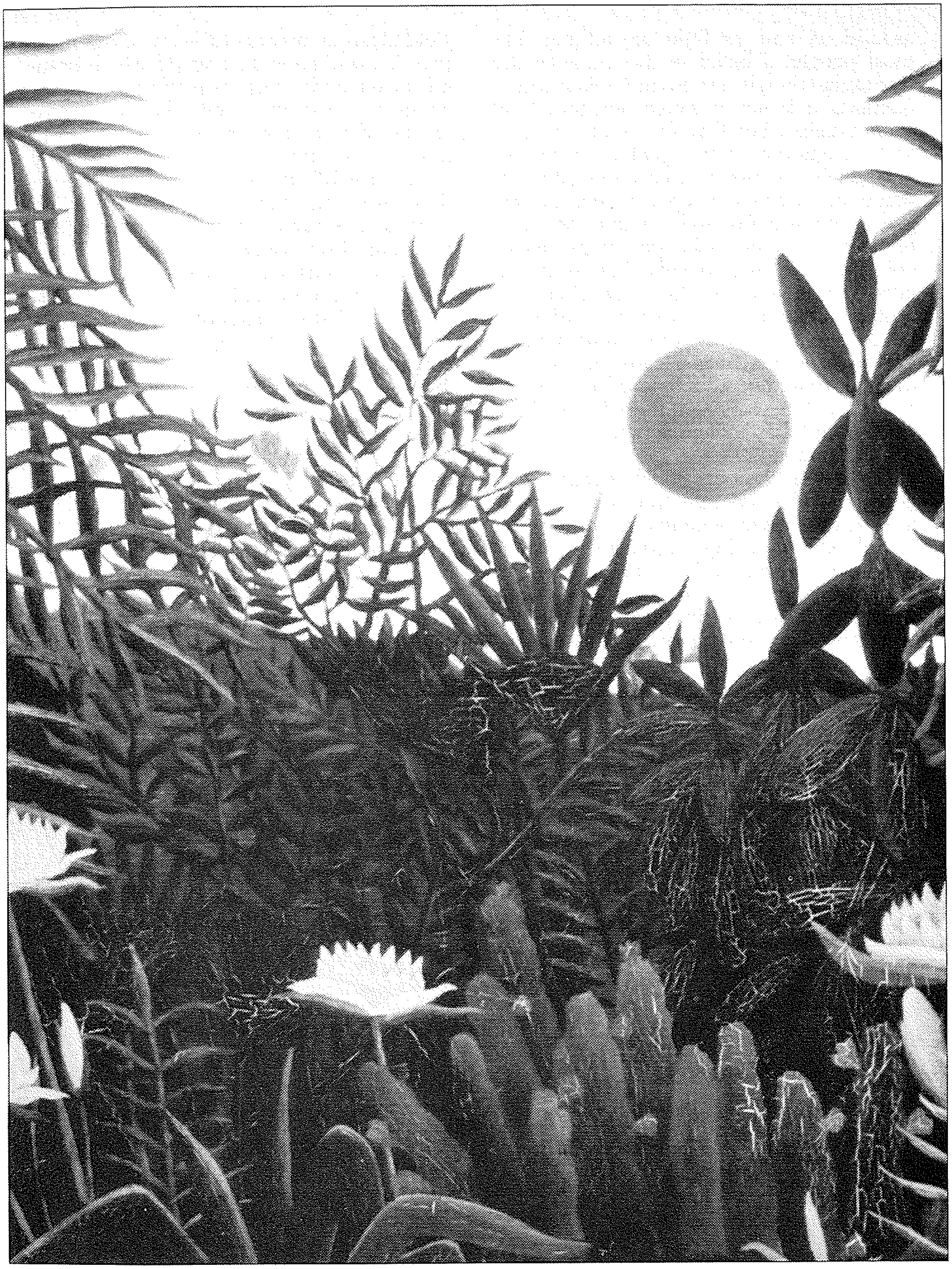

The state of nature: Scientists are now revising old notions of natural harmony and order.

Rethinking the Environment

The United States stands on the threshold of its third great era of environmentalism. The new age lacks heroes like the conservationists who put their stamp on the first, or a signal event like Earth Day 1970, which defined the second. It may be a pivotal moment in history. Today's opportunity to forge a genuine environmental ethic could well be wasted, for Americans are as confused about the environment as they are eager to protect it. As Stephen Klaidman writes here, they are alarmed by exaggerated crises such as Love Canal and distracted by minor environmental threats, even as larger ones go unattended. At a deeper level, biologist Daniel Botkin says, they hold ancient and sentimental misconceptions of nature, and of man's place in it, that could stifle the emerging new environmentalism.

A New Balance of Nature

by Daniel B. Botkin

Last June, California voters tried to strike a blow for the state's endangered mountain lions when they passed Proposition 117, protecting all but the most aggressive cats from human beings. Anybody caught killing, trapping, or transporting a mountain lion in the state now faces one year in jail and a $10,000 fine. The Wilderness Society, Defenders of Wildlife, and the Sierra Club all lined up behind the measure, and there was nothing in the debate (such as it was) to suggest that Proposition 117 was anything but the epitome of the "good cause." State Attorney General John Van de Kamp invoked an emotional roll call of vanished species in support of the proposition, writing, "Although our state symbol, the grizzly bear, no longer roams the wild lands of California and the condor no longer soars over our mountains, we still have areas where one remaining symbol of our wilderness heritage, the mountain lion, is free to live .... Mountain lion hunting is cruel and unnecessary."

Americans at the end of the 20th century seem to believe that they have finally learned to confront environmental problems such as the threat to the mountain lion rationally, that only a lack of information and political consensus limits their ability to solve problems. The logic of Proposition 117 seems self-evident: Mountain lions will do best if left completely alone. Their population will grow to an optimum size, then stabilize, threatening neither their own existence nor that of other species. But the general view on Proposition 117, like much of our thinking about the environment today, is based on a myth, the myth that nature left to itself will find a perfect balance, that "nature knows best." It is a myth that has led to unfortunate, sometimes even disastrous, results.

A classic example of the failure of the balance-of-nature myth is Kenya's Tsavo National Park. Landsat satellite images taken over Kenya in the late 1970s show a curious geometric feature—two straight lines stretching 50 miles or more and converging at an obtuse angle. To the east, inside the 5,000 square miles of the park, a dull brown signifies vegetation so thin that most of the light detected by Landsat is reflecting off bare soil. Outside the park, a garish red signifies dense vegetation. A visitor at Tsavo would have seen that the park was indeed desert-like, a thin scattering of live and dead shrubs and trees surrounded by dense thickets of vegetation beyond its borders. Tsavo was a photographic negative of one's expectation of a park: barren inside, green outside.

After Tsavo became a park in 1948, its first warden, David Sheldrick, spent years building roads, providing year-round water for wildlife, and eradicating poaching. Sheldrick apparently was convinced that he was only giving nature a benign helping hand. Indeed, the elephants flourished. So much so that they began consuming leaves, fruits, and twigs so quickly that the trees and shrubs started to die off. By 1959, much of the park began to resemble a "lunar landscape," Sheldrick's wife Daphne later wrote in *The Tsavo Story* (1973).

In the mid-1960s, a Ford Foundation study concluded that some 3,000 elephants should be shot to keep the population within limits of its food supply. Sheldrick at first agreed, but then reversed himself. He decided, as his wife put it, that "the conservation policy for Tsavo should be directed towards the attainment of a natural ecological climax, and that our participation towards this aim should be restricted to such measures as the control of fires, poaching, and other forms of human interference." To conservationists, the phrase "natural ecological climax" meant nature in a mature condition, which, once attained, persists indefinitely without change. Sheldrick and other specialists regarded the "climax" condition as the truly natural and most desirable state of wilderness. It is much the same idea that underlies California's Proposition 117: Left to itself, nature will achieve a balance.

But Tsavo was struck by a severe drought in 1969 and '70, and as some 6,000 elephants starved to death, they destroyed many of the park's remaining trees and shrubs, producing the devastation still painfully visible from space many years later. (Lately, the park has enjoyed the beginnings of a recovery.) Elephants and human beings together had drafted the lines on the Landsat image.

The elephants at Tsavo, like California's mountain lions and virtually all wildlife today, live in a fragment of what used to be large, often continuous habitats. In today's "ecological islands," a species can easily increase rapidly, exhaust its food supply, starve, and suffer a rapid decline, meanwhile causing many kinds of harm, sometimes even endangering the survival of other species.

The final act of the tragedy at Tsavo was being played out even as the first Earth Day in 1970 was bolstering the comforting illusion that there are only two sides to any environmental issue, pitting environmentalists against their pro-development foes. But the disagreement at Tsavo was among conservationists who shared basic goals.

Sheldrick's views were consistent with contemporary theories about population growth and the development of forests and

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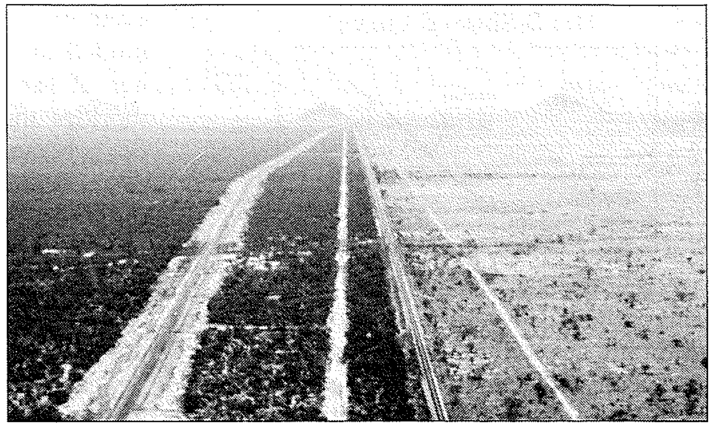
other communities of organisms. From these theories come such concepts as "carrying capacity" and "maximum sustainable yield," terms that are now regularly bruited about in newspapers and popular magazines. The theories have their origins in the mid-19th century, when the new science of ecology was born amid—and influenced by—the flowering of the machine age. Until recently, population theory relied almost exclusively on two formal models that were heavily influenced by machine-age thinking. One, called "the logistic," which was first proposed in 1849 by a Belgian scientist named Pierre-Francois Verhulst, described the growth of a single population; the other, called the Lotka-Volterra equations, cast predator-prey relationships in terms of predictable oscillations of population.



A photographic negative of our expectations: A view from the air in 1977 of Kenya's Tsavo National Park (at right), a virtual desert after nearly 30 years of careful conservation efforts.

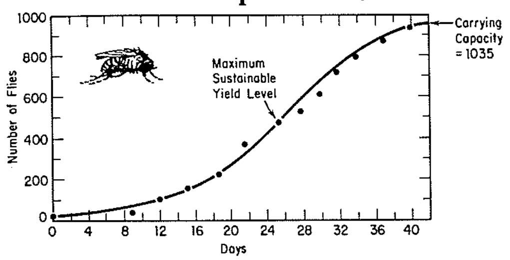
The logistic was explained by Alfred Lotka in his 1925 book, *Elements of Physical Biology*: Keep a population of flies in a cage with a constant food supply, he said, and a predictable pattern will be followed. When there are few flies, food is not a limiting factor and the flies will reproduce rapidly. But eventually they begin to exceed their food supply; deaths gradually rise to equal births and the population arrives at a steady size, its "carrying capacity." These ideas can be expressed with a simple equation in calculus that produces an elegant, S-shaped growth curve.

The logistic had another elegant quality: If a population at carrying capacity strayed from that balance, it would smoothly return to it. In short, the logistic seemed to show once again that there is a balance of nature.

It also relied upon assumptions that have proved to be false. The logistic assumes that all flies or elephants or mountain lions are identical, each contributing equally to reproduction, mortality, growth, and reduction in available resources. And although the logistic is supposed to be an ecological formula, it does not explicitly take account of changes in environment, such as variations in the availability of food and water. According to the logistic, the elephant population at Tsavo should have grown smoothly to an equilibrium.

It is one thing to err in the management of African elephants or California mountain lions. But the logic of the S-shaped curve has also been taken literally by, among others, the specialists who manage the world's fisheries directly, such as those at the U.S. National Marine Fisheries Service, and through international treaties. From the logistic comes the concept that wildlife biologists call the "maximum sustainable yield population," which says that a population grows fastest when it is at exactly one-half of its carrying capacity. So fisheries managers the world over have made it their goal to allow just a large enough catch every year to maintain this ideal population.

The S-Shaped Curve



Then, they believe, the fish population will grow at its maximum rate every year, like a jet engine at "best power" cruising speed.

A classic example of the failure of this idea is the Peruvian anchovy fishery, once the world's largest commercial fishery. In 1970, fishermen caught eight million tons of anchovies off Peru, but two years later the catch plummeted to only two million tons, and it continued to shrink. Yet this fishery was actively managed according to international agreement for a maximum sustainable yield. This failure has been repeated over and over again.* When Congress enacted a forward-looking piece of legislation to "save the whales" in 1972, the Marine Mammal Protection Act, the effort fell victim to the same faulty concepts during international negotiations to determine the permissible whale catch. Gradually, however, administrators have since remedied that mistake.

I have searched the scientific literature for 10 years and found no cases where a population outside a laboratory followed the S-shaped curve. Only microbes or flies or bees grown in a laboratory do that. And the regular oscillations predicted for predator and prey by the companion Lotka-Volterra model have *never* been sustained, even in the laboratory. Yet these flawed models are still used by a surprising number of fish and wildlife conservation authorities throughout the world. They are not products simply of flawed mathematics or incorrect calculations but of a fundamentally mistaken view of how nature works, a view that, as we shall see, is increasingly being undercut by new findings.

Forestry is a very different field, but the underlying mythology is the same. George Perkins Marsh (1801–82), the intellectual father of conservation in America, was struck while serving as U.S. Ambassador to Egypt and Italy by the impact of man on the environment in these ancient countries. "Nature, left undisturbed," he wrote in *Man and Nature* (1864), perhaps with his native Vermont in mind, "so fashions her territory as to give it almost unchanging permanence of form, outline, and proportion, except when shattered by geologic convulsions; and in these comparatively rare cases of derangement, she sets herself at once to repair the superficial damage, and to restore, as nearly as practicable, the former aspect of her dominion."

From Marsh and others came the idea of "ecological succession": A clearing in a forest would grow back through a series of regular and predictable stages to a final, constant, stable "climax" forest. The climax forest was believed to have the greatest amount of organic matter, the greatest diversity of species. Although forest biologists have rarely relied upon mathematical formulas, the climax forest had the elegant qualities of a logistic population: undisturbed it was constant, and when disturbed it grew back to its prior constant condition. The climax forest represented the balance of nature.

It was, in a sense, a walk in the woods as a graduate student during the 1960s that led me to question this idea of a climax forest and all that it implied. The woods was

*Likewise, Pacific sardines, once a major species off the California coast, suffered a catastrophic decline in the 1950s that continued through the 1970s. The Atlantic menhaden catch peaked at 785,000 tons in 1956, and dropped to 178,000 tons in 1969. Atlantic herring and Norwegian cod experienced the same kind of decline. The North Atlantic haddock catch, which had averaged 50,000 tons for many years, increased to 155,000 tons in 1965 but then crashed, reaching a mere 12,000 tons by the early 1970s.

New Jersey's Hutcheson Memorial Forest, established as a natural preserve in 1954 when Rutgers University was given a 65-acre tract of woodland known to have been intact—not clearcut or burned—since 1701. The creation of the preserve became a minor media event. Sinclair Oil, which had helped purchase it for Rutgers, placed a major national magazine advertisement that made much of the conventional wisdom, referring to the woods as a place where "nature has been working for thousands of years to perfect this 'climax' community in which trees, plants, animals, and all the creatures of the forest have reached a state of harmonious balance with their environment. Left undisturbed, this stabilized society will continue to perpetuate itself century after century." *Life* and *Audubon* also took note of the remarkable "climax forest."

But like the Peruvian anchovy fishery and Tsavo National Park, Hutcheson Memorial Forest did not remain constant. Originally filled with oaks, hickories, and chestnuts, it was by the 1970s becoming a forest of sugar and Norway maples in the mature stands, with Japanese honeysuckles and Asian trees of heaven in the gaps. It now appears that the sugar maple was artificially suppressed in the climax forest prior to 1701 by frequent fires, which were probably started by Indians. Two hundred years after these outbreaks of fire ceased, the woodlands began to change. Modern human influences, of course, contributed: The Norway maple, for example, was introduced into North America by Europeans.

Hutcheson Forest is not unique. Written histories, fire scars in trees, and fossil pollen deposited in lakes provided evidence in the 1960s and '70s to show that all forests are continually changing, and have done so since the ice ages. But ecologists and conservationists continued—and, to a surprising extent, still continue—to use the old theories to write laws, set policies, and manage natural resources.

One reason for our reluctance to part with these theories is that they grow out of very deeply rooted notions about nature. "Everything in the world is marvelously ordered by divine providence and wisdom for the safety and protection of us all.... Who cannot wonder at this harmony of things, at this symphony of nature which seems to will the well-being of the world?" wrote Cicero in *The Nature of the Gods* (44 B.C.). The idea is repeated throughout Western history. Nature was perceived as perfectly ordered and stable, constant unless disturbed, and tending to recover from disturbance by returning to its former condition. This perfect order was also a primary argument for the existence of God, for only a Supreme Being could create a perfectly ordered nature.

How, then, could one explain the occasional absence of order? Western culture traditionally has given two answers, both pointing at human beings. The first blames human beings for what they have done; the second blames them for what they have *not* done. Although casting humans as the despoilers of nature may have seemed like a new idea to the environmentalists of the 1960s, who were prone to see in the West only a tradition of exploitation of the environment, it is actually quite ancient. Pliny the Elder (A.D. 23–79) long ago contrasted the beauty and bountifulness of the Earth without human interference with the imperfections of people who abused the Earth. He speculated that there was a divine purpose for beasts of the wilderness: They guarded the Earth, protecting it from human actions.

The second explanation for the absence of order—blaming humans for what they have not done—emphasizes human stewardship of nature. God put us here to com-

THE FIRST ENVIRONMENTALISTS

Most historians see early environmentalism as a reaction to Western industrialization. Britain's Richard Grove, in an essay adapted from Nature *(May 3, 1990), proposes a new view.*

Anxieties about soil erosion and deforestation are to be found in the literature of classical Greece, imperial Rome, and Mauryan India, and in a sporadic fashion in the annals of the early Spanish and Portuguese empires. But it was not until the mid-17th century that awareness of the ecological price of capitalism started to grow into a fully fledged theory about the limits of the natural resources of the Earth.

Some historians have argued that European colonialism was not only highly destructive in environmental terms but that its very destructiveness stemmed from "imperialist" attitudes toward nature. But that hypothesis does not stand up. Ironically, a new sensitivity to the environment developed as a product of the specific, and ecologically destructive, conditions of the commercial expansion of the Dutch and English East India Companies and, a little later, of the Compagnie des Indes.

Colonial expansion also promoted the rapid diffusion of new scientific ideas by a coterie of committed professional scientists and environmental commentators. In India, for example, in 1838, there were over 800 surgeons. During the early 18th century the need to understand unfamiliar floras, faunas, and geologies, both for commercial purposes and to counter environmental and health risks, propelled many erstwhile physicians and surgeons into consulting positions and employment with the trading companies as fully fledged professional and state scientists long before such a phenomenon existed in Europe. By the end of the 18th century their new environmental theories, along with an ever-growing flood of information about the natural history and ethnology of the colonies, quickly diffused through the meetings and publications of a whole set of academies and scientific societies throughout the colonial world.

The first of these societies appeared in the island colonies. This was no accident. In many respects, the isolated oceanic islands stimulated a detached self-consciousness and a critical view of European origins and behavior, of the kind dramatically prefigured by Daniel Defoe in *Robinson Crusoe* (1719). Such islands became, in practical as well as mental terms, an allegory of a whole world, and observations of their ecological demise were easily converted into premonitions of environmental destruction on a wider scale.

It was on the French island colony of Mauritius that the early environmental debate came to a head. Between 1768 and 1810, the island was the location for some of the earliest experiments in systematic forest conservation, pollution control, and fisheries protection. These initiatives were carried out by scientists who, characteristically, were both followers of Jean-Jacques Rousseau and adherents of the kind of rigorous empiricism associated with mid-18th-century French Enlightenment botany. Their conservation measures stemmed from an awareness of the potentially global impact of modern economic activity, from a fear of the climatic consequences of deforestation and, not least, from concern over species extinctions. The "Romantic" scientists of Mauritius, and above all Pierre Poivre, Philibert Comerson, and Bernardin de St. Pierre can, in hindsight, be seen as the pioneers of modern environmentalism.

After the British annexed Mauritius in 1810, these environmental prescriptions were transferred to St. Helena and eventually to India itself. From 1820, they were strongly reinforced by the writings of Alexander von Humboldt, who strove in successive books to promulgate a new view of the relations between man and the natural world which was drawn almost entirely from the holist and unitary thinking of Hindu philosophers. His subordination of man to other forces in the cosmos formed the basis for a wide-ranging and scientifically reasoned interpretation of the ecological threat posed by the unrestrained activities of man.

This interpretation became especially influential among the Scottish scientists employed by the East India Company. Several of them, in particular Alexander Gibson, Edward Balfour, and Hugh Cleghorn, became enthusiastic proselytizers of a conservationist message which provided the basis for the pioneering of a forest conservancy system in India. For example, in 1847 the directors of the East India Company indicated their conversion to the need for conservation with a remarkable circular on the dangers of artificially induced climate change. The subject, they said, "is one having strong practical bearing on the welfare of mankind, and we are anxious to obtain extensive and accurate information in regard to it."

Time and again, from the mid-18th century onward, scientists discovered that the threat of artificially induced climatic change, with all it implied, was one of the few really effective instruments that could be employed in persuading governments of the seriousness of environmental change. The argument that rapid deforestation might cause rainfall decline and, eventually, famine, was one that was quickly grasped by the East India Company, fearful as it always was of agrarian economic failure and social unrest. Unfortunately, the argument often required an initial famine to lend credibility to scientists. In India, for example, serious droughts in 1835–39, the early 1860s, and 1877–78 were all followed by the renewal of state programs designed to strengthen forest protection.

The question of climatic change had thus become international in scope by the mid-1860s. It was reinforced by more detailed research that raised the possibility that the very constitution of the atmosphere might be changing. Such views found an early supporter in J. Spotswood Wilson, who presented a paper in 1858 to the British Association for the Advancement of Science on "The General and Gradual Desiccation of the Earth and Atmosphere." Wilson stated that upheaval of the land, "destruction of forests and waste by irrigation" were not sufficient to explain the available facts on climate change, and that the cause lay in the changing proportions of oxygen and carbonic acid in the atmosphere. Their respective ratios, he believed, were connected to the relative rates of their production and absorption by the "animal and vegetable kingdom." The author of this precocious paper concluded with a dismal set of remarks. "As inferior races preceded man and enjoyed existence before the earth had arrived at a state suitable to his constitution," he warned, "it is more probable that others will succeed him when the conditions necessary for his existence have passed away."

The raising, as early as 1858, of the specter of human extinction as a consequence of climatic change was clearly a shocking psychological development. But it was consistent with fears that had been growing within the scientific community. Awareness of species rarity and the possibility of extinction had existed since the mid-17th century as Western biological knowledge started to embrace the whole tropical world. The extinction of the auroch in 1627 in Poland and the dodo by 1670 in Mauritius had attracted considerable attention.

The appearance in 1859 of Darwin's *Origin of Species*, with its emphasis on the place of extinction in the dynamics of natural selection, helped make species protection a

New Guinea, 1776.

more valid concept in the eyes of government, and the period 1860–70 produced a flurry of attempts to legislate for the protection of threatened species. Once more, the initial locale was an island colony, Tasmania, where a comprehensive body of laws, designed mainly to protect the indigenous birds, was introduced in 1860.

So, by the early 1860s, anxieties about artificially induced climatic change and species extinctions had reached a climax. The subsequent evolution of the awareness of a global environmental threat has, to date, consisted almost entirely of a reiteration of a set of ideas that had reached full maturity over a century ago. The pity is that it has taken so long for them to be taken seriously.

plete the perfect harmony of nature. If there was disharmony, we had failed to carry out God's work. "For whom then shall we say the world was made?" asked Cicero. Why would the gods labor for trees or plants, which are "devoid of sense or feeling," or for animals, "dumb creatures who have no understanding"? Stewardship is the main idea that animates such older mainstream conservation groups as the National Wildlife Federation (founded in 1936) and the Conservation Foundation (founded in 1948, and since merged with the World Wildlife Fund).

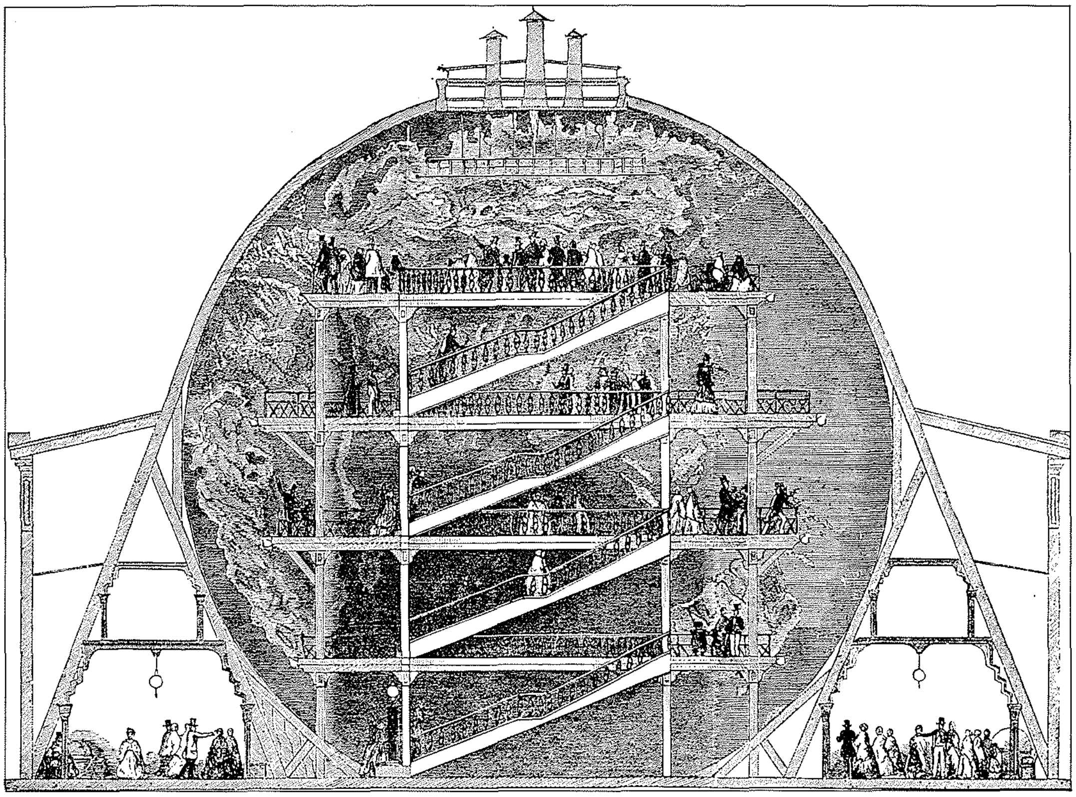
Before the rise of modern science in the 17th century, people explained the structure of nature in terms of divine order, but they had only organic metaphors, derived from plants and animals and especially the human body, to describe its workings. The first person to descend into an active volcano and return to write about it, a 17th-century Jesuit priest named Athanasius Kircher, began his analysis by citing Virgil, who believed that the "belching rocks" of volcanoes were the torn entrails of the mountains. Water mixed with ashes, Kircher wrote in *Mundus Subterraneus* (1638), produced a continual "conception and birth" of fires in Vesuvius and Aetna. The fires grew and matured until, becoming ripe, they erupted. To Kircher, a volcano was like a rose growing into flower.

The organic view suggested that the imperfections of the environment were manifestations of the aging of Mother Earth. Mountains were her warts, infertile farmland her wasted skin. Christians tended to believe that these organic processes, the chaos of nature itself, had been set in motion by the expulsion of man from the Garden of Eden and the Flood. One of Kircher's contemporaries, a theologian named Thomas Burnet, wrote that the Flood created "the ruins of a broken world" where before had existed perfect order and harmony, a world "smooth, regular and uniform; without Mountains and without a Sea."

Beginning in the 17th century, the rise of Newtonian mechanics and the work of scientists such as Johannes Kepler (1571–1630), along with the invention of such marvelous devices as the steam engine, created a new understanding of the universe. They also bred new metaphors, fostering the idea that the Earth and the solar system operate like clockwork, like a machine. Scientific discoveries, such as the recognition that the planets do not orbit in perfect circles around the sun, overwhelmed arguments that there was a perfect order in the observable architecture of the universe. No longer was the existence of God proved by the perfect and fixed structure of the world. Now, the *dynamism* of nature came to be seen as a demonstration of God's power. The visible physical order of old was replaced by a new conceptual order. A perfectly working, idealized machine could be seen as the product of a perfect God. "These Motions of Generations and Corruptions," wrote Sir Anthony Hale in 1677, "are so wisely and admirably ordered and contempered, and so continually managed and ordered by the wise Providence of the Rector of all things," that "things are kept in a certain due stay and equability."

The idea of order survived but the organic view of nature did not fare as well. True, in all of the arts, scientific discoveries bred a new aesthetic appreciation of the irregular and the asymmetric. English essayist Joseph Addison (1672–1719), for example, now found an "agreeable horror" in ocean storms. Later, William Wordsworth and the other 19th-century romanticists took custody of the organic metaphor.

But it was the mechanistic view that prevailed after the 17th century. A mecha-



The public's fascination with the natural world during the machine age made Mr. Wyld's Giant Globe, or Model of the Earth, a noted London tourist attraction from 1851–61.

nistic nature—except in our own age, an oxymoron—would have the attributes of a well-oiled machine, including the capacity to keep operating, replaceable parts, and the ability to maintain a steady state, and thus to be in balance. Births and deaths, immigration and emigration, the input of sunlight and the loss of energy as heat, the intake and loss of nutrients, would always maintain life in a constant state of abundance and activity. This is the view reflected in the writings of George Perkins Marsh, in the elegance of the S-shaped population curve, and in the management of Tsavo National Park.

But if nature is a machine, then the flipside is that human beings ought to be able to re-engineer nature and improve it. This is the side that has dominated much of our management of natural resources and the environment during the 20th century. It is reflected in the approach of the lumber company that clearcuts a diverse tropical forest and replants it with a single species of tree, and in a U.S. Army Corps of Engineers project that makes a meandering river into a straight canal. The ultimate irony is that the mechanistic view unites the most extreme preservationists, who believe that the machinery of nature functions perfectly without human intervention, and nature's most extreme exploiters.

I believe that we are living through a time of change, a transition from the mechanical age to a new era that appears to us as the space and computer age. We are gradually moving away from the mechanical view of nature, toward a different set of perceptions and assumptions that will blend the organic and the inorganic. But we have not yet settled on the right metaphors, images, and symbols.

The scientific basis of this new understanding was prepared almost a century ago by a Harvard biological chemist named Lawrence Henderson in *The Fitness of the Environment* (1913). Henderson was struck by the unique set of circumstances that made life on Earth possible. The planet is endowed with water, for example, which "possesses certain nearly unique qualifications which are largely responsible for making the earth habitable." Its high specific heat means that oceans, lakes, and streams tend to maintain a constant temperature; such bodies of water also moderate summer and winter temperatures on land.

During the last two decades, scientists such as James Lovelock and Lynn Margulis have begun to appreciate that the environment is "fit" for life in part because life has evolved to take advantage of the environment and has also altered the environment. Lovelock and Margulis have taken this insight to an extreme, reviving organic thinking about nature. Lovelock argues in *Gaia: A New Look at Life on Earth* (1979) that "the biosphere is a self-regulating entity with the capacity to keep our planet healthy by controlling the chemical and physical environment." The Gaia hypothesis—named after the Greek goddess of the Earth—suggests that nature is akin to a sentient being. One problem with this view—as with the mechanistic view of old—is that nature never achieves the self-regulating "steady state" of perfection that Gaia's advocates imagine.

But the notion that life and environment interact is important. The traditional view in science is that the Earth changes slowly and evenly, and is very little affected by the life—plants, animals, fungi, bacteria, and protists—that it hosts. After all, the total mass of all living things on Earth is a tiny fraction—two-tenths of one part in one billion—of the mass of the planet. But now even geologists, who study the least changeable face of the planet, are seeing connections. The theory of plate tectonics shows that the gradual shifting of plates has redistributed life around the globe, and that some forms of life have evolved to capture the benefits of geologic change. The Earth's major iron ore deposits are, in turn, the result of global environmental changes caused by bacteria on the early Earth. Likewise, atmospheric scientists have found that the evolution of plant life has greatly influenced the composition of the atmosphere.

From these and other findings a new view of nature is gradually emerging. No longer is it possible to see nature as a stately clock-like mechanism, slow, deliberate, static. Nature as we are coming to know it is a patchwork of complex systems with many things happening at once and with each system undergoing changes at many scales of time and space. Human beings, far from being alien interlopers who disturb the timeless rhythms of nature, are intrinsic elements of the natural order. Chance events seem to play an important role.

This is a very different nature from the simple, one-thing-at-a-time, nothing-left-to-chance, everything-calculable-exactly nature of the machine age. Complexity, chance, simultaneity of events, history, and change are the qualities of nature.

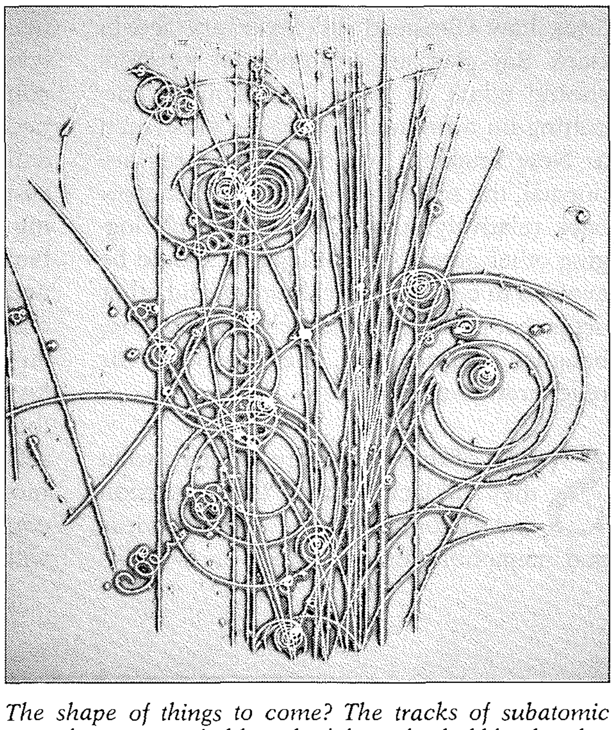
Perhaps the hardest of these ideas for us to accept is that of natural change. Do we open a Pandora's Box by admitting some kinds of change? How do we manage something that is always changing? If we concede that some kinds of change are good, how can we decide which kinds are not?

We are learning, however, that we have no choice but to accept change and to distinguish the good from the bad. Nature itself must be our guide. Changes that we impose on the landscape that are natural in quality and speed are likely to be benign. Rapid changes, or those that are novel in the history of biological evolution—such as the introduction of many new chemicals into the environment—are likely to cause problems. Global warming, for example, poses a challenge to us not so much because of the size of the change that is in the offing but because of the unprecedented speed with which it may occur.

On a practical level, this new view of nature leads to several possibilities for the management of natural resources. Consider the Kirtland's warbler, a small songbird that nests only in young jack pine woodlands in the coarse, sandy soils of Central Michigan. A friendly, pretty animal once proposed as the state bird, the warbler was the first songbird subject, in 1951, to a complete census. By the early 1960s, the population had fallen by half, leaving only about 200 males. Conservationists and scientists realized that the warbler was in trouble because its habitat, the jack pine forest, was disappearing. The reason, ironically, was that well-intentioned authorities were suppressing forest fires in Central Michigan. But jack pines require such blazes to reproduce; their cones release seeds only after they have been heated by fires, and the seeds germinate only in the sunny clearings created by fires.

It was not easy for scientists to persuade government conservation authorities that they would have to start controlled forest fires to save the warbler. That flatly contradicted cherished beliefs about the pristine balance of nature. Learning to manage the environment is in many cases like learning the lesson Alice did in trying to reach a looking-glass house in the Lewis Carroll classic: Sometimes the only way to reach a thing is to walk away from it.

Conservationists in Michigan learned that lesson. Today, the warbler survives in a preserve of 38,000 acres where since 1976 it has been government policy to set controlled fires periodically. This small episode may mark a turning point in the modern understanding and management of nature. The warbler population is not managed to obtain some magical number—a carrying capacity or maximum sustainable yield—but merely to be sizeable enough to minimize the chance of extinction. The idea is to move beyond constancy and static stability—to manage for the recurrence of desir-



The shape of things to come? The tracks of subatomic particles, as revealed here by false-color bubble chamber photography, suggest the randomness and irregularity that scientists are now discovering in nature.

able conditions.

Another goal can be the persistence over time within some desirable range. We could manage elephants at Tsavo so that they are reasonably visible to tourists yet allow their number to vary with changes in climate and other conditions. Gone are the stringent goals of a single carrying capacity, a perfectly constant climax ecosystem, a maximum sustainable production.

This emerging perspective can be applied to a variety of environmental problems. For example, it suggests that on the nation's farms, integrated pest management, with its mix of biological controls and some benign artificial chemicals, should be preferred over intense use of chemical pesticides. Flood control projects should no longer include the straight-line canals of machine-age surveying; designers should try to maintain the mixture of habitats that a natural flood plain has (as Frederick Law Olmstead did a century ago in Back Bay Boston). Commercial foresters should adapt to local conditions, clear-cutting on a limited scale in regions (such as New England) where disturbances are normal, the soil is fertile, and forests grow back relatively quickly, but selectively logging other areas. And all logging should be avoided in certain tropical forests and other areas that have been untouched and where, because of poor soil, the prospects for regeneration are bad.

Some of these ideas are familiar; what they still lack is a truly unifying vision and rationale. At the level of ideas and metaphors, our culture is in a transition, and where we will come out cannot easily be foreseen. The science of ecology lacks the equivalent of a Newtonian physics—a coherent set of laws that explain the *dynamics* of nature rather than its structure. It awaits a genius on the order of Newton or Einstein to create a new "mathematics of complex systems" that renders nature in all of its complexity, capturing the play of chance, randomness, and variability. And ecologists are hardly alone in appreciating the need to come to terms with such factors. Some physicists, astronomers, paleobiologists, climatologists, and others recognize that the natural processes they study are not simple, regular, or certain, that what some now call "chaos" is ever present.

As we search for new ways to understand nature, we need not throw out the machine and organic metaphors completely. From the machine metaphor we need the notion that systems can be analyzed, cause and effect understood, and repairs made. From the organic metaphor we need the idea of history, and of a beginning and end, of individuality. Computers suggest one avenue toward a new understanding. Computer games children play make familiar complexity, surprises, randomness, and the simultaneity of events in a rapidly changing situation. Our children will have an easier time conceiving of the nature we know from scientific observations than those of us who grew up building erector-set towers and cranes driven by electric motors—simple machines with a single equilibrium. Perhaps one of these children will become the Einstein of ecology.

MUDDLING THROUGH

by Stephen Klaidman

Two weeks into the Middle East War a distraught *Atlanta Constitution* editorial writer declared on a television news broadcast that the Iraqi oil spill in the Persian Gulf had thrown her into "despair." The same day, the *New York Times* and the *Washington Post* published equivocal news stories about a U.S. Environmental Protection Agency (EPA) decision to require an Arizona utility company to spend $2.3 billion at one power plant to try to eradicate a seasonal blue haze that sometimes obscures views of the Grand Canyon. A week earlier the *Times* and the *Post* carried lengthy reports under sharply conflicting headlines on the cancer risk posed by dioxin. "High Dioxin Levels Linked to Cancer" said the *Times*; "Extensive Study Finds Reduced Dioxin Danger" said the *Post.*

These are the actions of an environmentally conscious but confused nation. Environmentalists are responsible for most of the consciousness and much of the confusion (although there is plenty of blame to pass around). Because it takes a real cancer scare to make Americans buy less-than-perfect-looking apples, and because it will take an imminent threat of floods and parched earth to make them take the greenhouse effect seriously (not to mention the fact that taking such challenges seriously means spending a lot of money), environmentalists have always felt forced to manufacture crises and exaggerate risks to provoke political action. The news media leap on the story in its most dramatic form, rarely clarifying the issues. And so a crisis is born.

It is hardly surprising, therefore, that puzzled Americans have a hard time sorting out serious environmental threats from trivial ones. As EPA surveys regularly demonstrate, Americans misjudge these risks. "The remaining and emerging environmental risks considered most serious by the general public today," an EPA panel reported last year, "are different from those considered most serious by the technical professionals charged with reducing environmental risk." The regulators and scientists stress global warming and the depletion of the ozone layer, the public worries about hazardous waste dumps and groundwater pollution. And in general it is the public's concerns that shape policy.

There is, of course, a vague awareness among the public that environmental choices mean trade-offs: A better view of the Grand Canyon, for example, will mean bigger utility bills for citizens of Arizona. But neither public opinion nor public policy is guided by a comprehensive vision that is consistent with the broader economic and social goals of American society. In a survey conducted by the *New York Times* in 1989, an astonishing 80 percent of those polled agreed with the proposition that "Protecting the environment is so important that requirements and standards cannot be too high, and continuing environmental improvements must be made regardless of cost." *All* environmental standards? *Regardless of cost*? Such sentiments, in a nation that already spends $90 billion annually on pollution control, cannot be the product of a rational approach to environmental problems.

Science cannot be relied upon to extricate us from our dilemma over what to do about environmental challenges. Advances in ecology, toxicology, and other fields have contributed to our relatively new-found solicitude toward the Earth. But despite the increasing sophistication of the environmental sciences—including the perfection of highly precise measurement technologies such as gas chromatography—there is much that we do not know. Scientists often alert us to potential risks long before they can quantify and assess them. Uncertainty plagues researchers over a whole range of phenomena: low-level radiation; oil and chemical spills; air pollution (indoor and outdoor); and water pollution (groundwater and drinking water). How does one assess the risks posed by doses of carcinogens measured in parts per billion, or of natural toxins and man-made toxins measured in parts per trillion?

Officials who favor doing nothing more than additional research usually have two imposing allies: inertia and powerful economic interest groups. Environmentalists, on the other hand, must create a sense of urgency to motivate the public and put pressure on policymakers. To do this they create crises, not out of whole cloth, but often based on evidence that is meager, at least by the standards of science. This process does not necessarily lead to bad policy. Indeed, in some cases—global warming comes to mind—it may be the only way to get action in time to make a difference. But this haphazard lurching from crisis to crisis frequently leads to costly errors, and always leaves us woefully ill-informed about the ecological and health issues that confront us. We have become environmentally aware without developing a true environmental ethic.

Modern environmentalism was born a mere three decades ago when Rachel Carson published *Silent Spring* (1962), an eloquent warning about the destruction wrought by synthetic chemicals such as DDT, Aldrin, Chlordane, and Heptachlor. Carson took aim not only at industry, but at much of the existing conservation movement in America, founded more than a century earlier by the lawyer-legislator-diplomat George Perkins Marsh. Marsh lamented man's destruction of the environment, but he was equally clear about humanity's right to use the Earth for its own purposes. Man, he reminded his readers, is "a power of a higher order than any of the other forms of animated life, which, like him, are nourished at the table of bounteous nature."

Carson attacked this notion head on. "The 'control of nature,'" she declared, "is a phrase conceived in arrogance, born of the Neanderthal Age of biology and philosophy, when it was supposed that nature exists for the convenience of man. The concepts and practices of applied entomology for the most part date from that Stone Age of science. It is our alarming misfortune that so primitive a science has armed itself with the most modern and terrible weapons, and that in turning them against the insects it has also turned them against the earth."

Carson's outrage was deeply felt, but Marsh, too, was motivated by a concern for the environment. The question of whether humankind should assume stewardship of nature, managing it prudently for human

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benefit, as implied by Marsh, or accommodate itself to the Earth's natural order, as Carson believes, is not laid to rest by invective. Marsh's perspective sees humans as paramount and is strongly grounded in scientific evidence and argument. It encourages reasoned debate on the most compelling of all grounds: human self-interest. Carson's argument is nature-centered and polarizing. Even James E. Lovelock, the British scientist who speaks of nature in near-mystical terms in *Gaia: A New Look at Life on Earth* (1979), notes, "When Rachel Carson made us aware of the dangers arising from the mass application of toxic chemicals, she presented her arguments in the manner of an advocate rather than that of a scientist. In other words, she selected the evidence to prove her case."

Earth Day 1970: Media event?

Lovelock notes that the chemical industry responded to Carson in kind, a response, he wrote, that may have set the pattern of self-serving environmental argument. Industry generally has been refractory, for the unsurprising reason that environmental protection cuts profit margins: Despite the public's professed concern for the environment (see box, p. 80), catalytic converters don't sell cars.

Undoubtedly, good things came out of *Silent Spring*. It awakened the environmental consciousness of the nation and led to controls on DDT and other pesticides and herbicides (some of which, however, turned out to be excessive). But the echoes of Carson's clarion call over these past three decades have drowned out cool discussion and helped prevent us, ironically, from arriving at a meaningful environmental ethic and sensible environmental policies that reflect it. Instead, we lurch from crisis to crisis.

How this happens, and what it costs us, can be appreciated by reviewing three recent "crises": one exaggerated, one virtually an illusion, and one likely all too real.

I

In 1953, when the Hooker Chemical Company turned over its Love Canal property to the Niagara Falls, N.Y., Board of Education for $1, the canal (by then covered over) held roughly 21,000 tons of chemical wastes, ranging from benzene to trichlorethylene.* The deep, clay-lined waste dump was considered adequate by the standards of the day, but because the board insisted upon building a school on the site, the deed specified that the board would accept all risk and liability. In 1957, despite warnings by Hooker officials, the board also traded land with developers, who built houses in the area.

Over the years, a few people near the

*Much of what follows is drawn from Martin Linsky's excellent account in *How the Press Affects Federal Policymaking* (1986), of which he was co-editor.

AN ENVIRONMENTAL PROGRESS REPORT, 1970–91

Since 1970, the United States has spent some $700 billion on the war against pollution and billions more in related fields, such as conservation. The results so far are mixed.

AIR Since the 1970 Clean Air Act, emissions of many pollutants have dropped: lead by 96 percent, sulfur dioxide by 28 percent, particulates by 61 percent. But increasing use of automobiles (there was one car for every 2.5 Americans in 1970; one for every 1.7 in 1990) has pushed up emissions of ozone, carbon monoxide, and nitrogen oxides. Some 150 million Americans breathe air considered unhealthy by the EPA, costing an estimated $40 billion annually in health-care outlays and lost productivity. New on the EPA's most wanted list: "greenhouse" gas carbon dioxide, emissions of which have grown by 1.4 percent annually since 1970, and airborne toxic chemicals.

WATER One of the rallying points for Earth Day 1970, then-dirty and dying Lake Erie has made a rally of its own. As a result of the 1972 Clean Water Act, 400,000 lake acres and 47,000 miles of rivers and streams are cleaner today. Some 8,400 miles of waterways have been added to the National Wild and Scenic Rivers System's "protected" list, a twelvefold increase. "Nonpoint" pollution (runoff from streets and farms) and groundwater contamination are a big concern; one study found 46 pesticides in the groundwater of 38 states, tainting the drinking water of half the populace.

TOXICS Cleanup work has begun on only 261 of the approximately 31,000 hazardous waste sites discovered by the EPA as part of the $8.5 billion Superfund program.

PESTICIDES More worrisome to the EPA than hazardous waste dumps or air pollution, pesticide residues on food have come to public attention, ironically, as a result of the false alarm over Alar. Another concern: Ninety percent of pesticides end up as runoff in waterways. Over four billion pounds of pesticides are sold worldwide each year.

SOLID WASTE Between 1970 and 1988, annual U.S. output of solid waste (i.e.

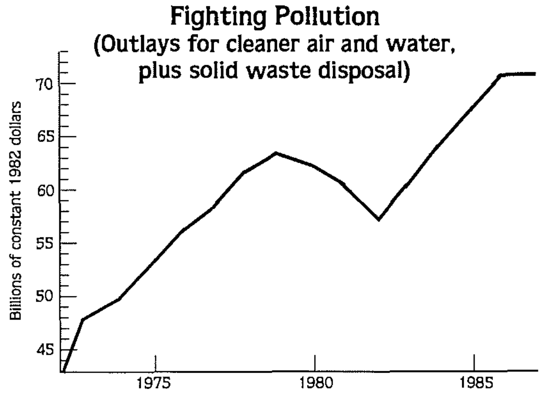
canal suffered burns, itchy skin, and blisters, and a number of trees mysteriously shrivelled up and died, but little was made of these incidents. Then, in 1976, the *Niagara Gazette* reported that the New York State Department of Environmental Conservation was investigating the canal as a source of a flame retardant called Mirex, which had been found in Lake Ontario fish. From that point, the crisis built rapidly. The *Gazette* jumped on the story (and reporter Michael Brown later helped make it national news with articles in the *Atlantic* and the *New York Times Magazine* in 1979); Representative John LaFalce, the district's congressman, also took up the cause. Both looked for links between Hooker, a suitable corporate villain, and the health complaints of the Love Canal residents. By August 1978, based on tests that revealed the presence of several chemicals in the Love Canal area, state Commissioner of Health Robert Whalen was announcing a "great and imminent peril" to Love Canal residents and recommending the evacuation of pregnant women and very young children from one part of the Love Canal site; President Jimmy Carter designated it an emergency area and Governor Hugh L. Carey announced that the state would buy the houses of 236 Love Canal families. There still were no studies demonstrating any threats to health.

By December 1979, the federal government had filed a $124.5 million lawsuit against Hooker and local authorities. According to Jeffrey Miller, who headed an EPA hazardous waste task force, the agency launched the suit with two main goals in mind: to get Congress to pass hazardous waste legislation and to get the press off its back for inept handling of hazardous waste garbage) rose by nearly 25 percent, to 160 million tons, or 1,455 pounds per person. Castoff plastics, up by 14 percent annually since 1960, now account for 20 percent of U.S. waste by volume. Nearly 75 percent of American garbage still ends up in landfills, with half the remainder incinerated and half recycled. Ten U.S. states have mandatory recycling laws; more than 1,000 communities have started curbside pickup programs.

LAND CONSERVATION Since 1970, U.S. national parks have expanded by 50 million acres (up by 167 percent), national wildlife refuges by 60 million acres (up threefold), the national wilderness preservation system by 81 million acres (up ninefold), and national forests by 4 million acres (up 2.2 percent). But most growth occurred during the 1970s and early '80s. Meanwhile, some 300–400,000 acres of wetlands, irreplaceable habitats for many fish, birds, and plants, are lost annually to development.

ENDANGERED SPECIES During the 1980s, 28 American animal species were put on the threatened list, 32 on the endangered list. The number of plant species on the lists jumped from 58 in 1980 to 205 in 1989. Six species have become extinct in this period, among them Sampson's pearly mussel. Five species have recovered and been removed from the list since 1985, most recently the purple-spined hedgehog cactus.

OZONE DEPLETION In the 1987 Montreal Protocol, the major industrial nations agreed to a 50 percent cut in production of the chlorofluorocarbons (CFCs) that erode the Earth's protective ozone layer. In 1989, the U.S. and other countries vowed to halt all production by the year 2000. Yet CFCs already in the atmosphere will continue to do harm.



problems. The EPA still had no scientific evidence to establish Hooker's liability, so it commissioned a pilot study to look for chromosomal damage. The results seemed to show some deviations, but the study lacked a control population and was not conclusive. Nevertheless, the results wound up, through a leak, on page one of the *New York Times*.

The alarming story unleashed a media blitz—and a quite understandable panic among local residents. At one point, an angry crowd held two EPA officials hostage, demanding action from Washington. On May 21, 1980, the EPA ordered the emergency evacuation of 2,500 Love Canal residents from their homes, and the Carter administration later announced that the state and federal governments would foot the bill for the permanent relocation of more than 400 Love Canal families.

Ultimately, Love Canal cost the taxpayers some $50 million, not to mention untold anguish. And all, apparently, for naught. Indeed, within a year the *New York Times* ruefully concluded that "it may well turn out that the public suffered less from the chemicals there than from the hysteria generated by flimsy research irresponsibly handled." Later studies by the Centers for Disease Control (1983) and in the *Journal of the American Medical Association* (1984) have shown no elevated levels of chromosomal damage among Love Canal residents compared with other people in the Niagara Falls area. Since cancer has long latency periods, these results are not conclusive either. But to date, little or no scientific evidence has been produced to justify the Love Canal panic. Indeed, several hundred people have moved back to the area, since renamed Black Creek Village.

II

Before Christmas 1983, American farmers used about 20 million pounds of a chemical known as EDB annually to fumigate grain milling machinery and citrus and other crops. There was evidence that EDB was a potent carcinogen in laboratory animals, but none that it caused cancer in humans. Moreover, it was not believed to leave significant residues in fields and orchards that might leach into groundwater. When William Ruckelshaus took over as administrator of the EPA for the second time in 1983 (he had served as its first administrator in 1970–73), however, traces of EDB had been found in groundwater in Georgia and California. This discovery was noted in the appropriate offices at EPA, but did not rise to Ruckelshaus's attention; not, that is, until he went to Florida to spend Christmas with his mother.

The discovery of EDB in Florida groundwater, which Ruckelshaus learned about from local television and newspaper coverage, gave the story a whole new twist. Doyle Conner, the state commissioner of agriculture, was being accused by the *Orlando Sentinel*, the *St. Petersburg Times*, and other Florida newspapers of permitting the pesticide to be injected into the soil in amounts greater than federal standards allowed, raising the specter of groundwater contamination. A diversionary action was needed to get the heat off. So Conner had a few popular supermarket items tested for EDB residues, and lo and behold, they were found. Overnight, EDB was national news.

Between December 21 and December 23, 1983, all three television networks carried stories about EDB in food on their nightly newscasts. On the 21st, NBC anchor Tom Brokaw posed the portentous question: "How dangerous is it?" No one knew, but all three broadcasts showed packages of well-known foods such as Duncan Hines muffin mixes and Pillsbury cake mixes being removed from supermarket shelves. There was no mistaking the message: This stuff is really bad for you.

Ruckelshaus spent most of the winter dealing with the snowballing panic over EDB, and finally ordered a ban on its use. The ban hamstrung U.S. grain sales to the Soviet Union, which had agreed to buy 7.1 million tons of U.S. wheat and corn in fiscal year 1984; it also hurt several Caribbean nations whose sales of tropical fruits to the United States were compromised. The ban even wreaked havoc on the personal lives of a handful of EPA employees, one of whom suffered a nervous breakdown as a result of the pressure he was under during the storm over EDB. Yet the ban was unnecessary and Ruckelshaus, as he later said in an interview, knew it. There was little or no evidence that it was harmful to humans in the amounts at which they were being exposed to it. Indeed, the most likely replacement for EDB, methyl bromide, was possibly more dangerous than EDB. Why did Ruckelshaus do it? Never mind that no one had proved that trace amounts of EDB in food could cause cancer in humans; no one could prove that they didn't. News media misrepresentation of this uncertainty made enough people deeply fearful that political prudence left the EPA administrator no real choice.

III

This nation, along with the rest of the world, is deeply engaged in what could turn out to be the most important environmental debate in history. And then again, maybe it won't. The debate is over global warming and what, if anything, to do about it. It is not over the greenhouse effect, which is real: Greenhouse gases such as carbon dioxide, methane, and chlorofluorocarbons do trap heat in Earth's atmosphere and do increase the planet's air temperatures. There is also little doubt among qualified scientists that there will be some global warming eventually, probably in the next five to 10 years. But no one is sure how much temperatures will rise and what effect the increases will have. Predictions range from 1.5 to 4.5 degrees Centigrade. At the low end, effects would be minimal, but the high end leads to some frightening scenarios—flooding of coastal lands, crop-destroying droughts, and massive deforestation. With so much uncertainty about what might happen, and at least an equal amount of uncertainty about how much it will cost to contain the warming, what is a poor policymaker to do?

On June 23, 1988, a bright and socially conscious climatologist named James Hansen decided to lend a hand. Hansen, the director of the National Aeronautics and Space Administration's Goddard Institute for Space Studies, told a U.S. Senate committee chaired by Albert Gore (D.-Tenn.) that the mean global temperature had risen by one degree Fahrenheit during the previous century. Moreover, Hansen said that he could say with "a high degree of confidence" that there was "a cause and effect relationship between the greenhouse effect and the observed warming." This circumspect-sounding bit of jargon meant there was now something dramatic for the media to talk about (during what happened to be a particularly tropical summer). Global warming, Hansen had announced to the world, is here, right now. It is not coming in five or 10 years. It has arrived. Never mind that none of his colleagues agreed.

Hansen's judgment carried more weight because he was cloaked in the garb of the scientist and was speaking as an impartial government expert. According to Richard Kerr, a reporter at *Science* magazine with a Ph.D. in chemical oceanography, "had it not been for Hansen and his fame, few in public office, and certainly not the public itself, would have paid much attention to a problem that everyone . . . agrees threatens social and economic disruption around the globe." In this case a scientist with an environmentalist bent, James Hansen, was the crisis-maker. Time may prove that he was right. The public often responds radically to environmental threats that seem to pose a direct and dramatic threat to individuals—toxic waste dumps in the backyard, Alar on apples, and EDB on oranges—but it sleeps through warnings about threats that seem diffuse and indirect, even if they are ultimately much more serious. Hansen woke us up, and if the greenhouse effect assumes the dimensions many scientists believe it

"So what is it today, Mark?
The beginning of another ice age or catastrophic warming due to the Greenhouse Effect?"

Some climatologists warned during the 1970s of an impending new Ice Age, which has not helped win great public credibility for their more recent predictions of global warming.

THEORY VERSUS PRACTICE

In opinion surveys, most Americans talk a good pro-environment game. Watch what they do, not what they say, caution editor Joe Schwartz and Thomas Miller, a vice president of the Roper Organization, in American Demographics *(Feb. 1991).*

Saving the environment is a high priority for most American citizens. But as consumers, most of us are not willing to act on our beliefs. Over three-quarters (78 percent) of adults say that our nation must "make a major effort to improve the quality of our environment," according to a recent study commissioned by S. C. Johnson and Son and conducted by the Roper Organization. But at the same time, most say that individuals can do little, if anything, to help improve the environment.

Public concern about the environment is growing faster than concerns about any other issue monitored by Roper—at least before the Persian Gulf crisis and the softening of the economy. Businesses are tuning into this trend by producing "green" products, services, and advertising campaigns. But banking on environmental awareness can backfire, because the majority of Americans are already convinced that businesses are not environmentally responsible . . . .

•

Americans tend to blame businesses for the environmental problems they see at global, national, and local levels. More than eight in 10 Americans say that industrial pollution is the main reason for our environmental problems, and nearly three-quarters of the public say that the products businesses use in manufacturing also harm the environment. Six in 10 Americans blame businesses for not developing environmentally sound consumer products, and an equal share believes that some technological advancements made by businesses eventually produce unanticipated environmental problems.

Americans blame themselves, too. Seventy percent say that consumers are more interested in convenience than they are in environmentally sound products, and 53 percent admit that consumers are not willing to pay more for safer products.

In theory, almost every American is pro-environment. But the ardent environmental attitudes that come out in opinion polls cool down significantly when you look at consumer behavior. Perhaps bad-mouthing businesses is easier than making important lifestyle changes and accepting some of the blame.

Consumer behavior usually affects the environment at two points. First, consumers can either buy or reject environmentally unsound products. After the purchase, they affect the environment by either recycling products or sending them to the dump.

At the moment, recycling appears to be the most rapidly growing pro-environmental behavior. Between March 1989 and February 1990, the share of Americans who say they regularly recycle bottles and cans rose from 41 percent to 46 percent, and the share who regularly recycle newspapers rose from 20 percent to 26 percent. Those who sort their trash on a regular basis rose from 14 percent to 24 percent of all adults.

Altruism isn't the only force behind the recycling boom. Many states and municipalities have passed "bottle bills" and other mandatory recycling laws. People may be complying with the new rules and may even be doing more than is required. But in many cases, legislation stimulated their behavioral changes.

More than half of all adults (52 percent) never recycle newspapers. Only 16 percent say they avoid products that come from environmentally irresponsible companies, and just seven percent regularly avoid restaurants that use foam containers. Only eight percent of Americans say they regularly cut down on their driving to protect the environment. More than three-quarters (76 percent) say they just motor on as usual, even though most acknowledge that emissions from private automobiles are a leading cause of air pollution.

Vast majorities of Americans are worried about our environmental future. So far, only a minority have adopted more environmentally responsible lifestyles. But attitudinal changes generally precede behavioral ones. The stage, it seems, is finally set for the "greening of America."

may, we will thank him for it. But time may also make Mr. Hansen a villain.

What makes these three cases typical is that scientists, politicians, and journalists used inconclusive scientific data to advance their own agendas. Our adversarial, interest-group-dominated politics lends itself to this kind of manipulation, as does our commercial news media, whose only consistent bias is for a dramatic, conflict-filled story. (It is this story bias, not any ideological bias, that drives the news media.)

The real failure of the environmental movement has been the extent to which it has contributed—along with industry, Congress, and the news media—to national confusion and misunderstanding about the comparative risks posed by different hazards. Environmentalists would have us believe that many deaths and much illness can be attributed to the nuclear accidents at Three Mile Island, Davis-Besse, and Brown's Ferry, to Love Canal and Times Beach, to living near high-tension power lines, to agricultural chemicals such as DDT, EDB, and Alar. But there is virtually no reliable evidence to support these charges. Environmentalists, along with journalists, portrayed the *Exxon Valdez* oil spill in Prince William Sound as a calamity on the order of a small war. Environmentalists know that there is nothing like 30 seconds of television network news footage of dying, oil-soaked sea gulls and seals to stir the nation's environmental conscience: It was just such disturbing images of an oil spill in Santa Barbara, California in 1969 that helped create the momentum behind the first Earth Day. But apart from the sad drama surrounding creatures in the area at the time, how much long-term damage to ecological systems is done by oil spills? Relatively little. In Prince William Sound, for example, spawning of some fish species may have been disturbed, but the salmon catch this year set a record.

Environmental advocacy, which is meant to serve the public interest, has gotten out of hand. It is arguable, indeed probably correct, that 20 years ago hyperbole was the only way to make industry and government begin protecting the nation's health and environmental patrimony. In many cases, however, the science has caught up with these exaggerations, resulting in a loss of credibility for environmentalists. Moreover, public interest in the environment today is high. In the 1990s, a more straightforward approach might yield better results. Environmentalists should learn the lessons of Alar and dioxin. They should stick to the facts. They should seek to educate rather than merely alarm the public.

Uncertainty remains the most difficult obstacle to public understanding. For example, a recent study by the Congressional Office of Technology Assessment found that it is possible to reduce carbon dioxide emissions by 35 percent over the next 25 years. Would that slow the onset of global warming? Perhaps. The study also says that the economic effect of this reduction might be anything from a net annual gain of $20 billion to a net annual expenditure of $150 billion. How can one respond to expert disagreement of this magnitude?

But where science fails to provide answers—and it often does—a prudent, common-sense calculation of the public interest can lead to a conclusion. It would pay, for example, to reduce carbon dioxide emissions produced by the burning of fossil fuels even if the global warming payoff is minimal because there are sufficient collateral benefits—such as reducing dependence on imported oil. On the other hand, research shows that dioxin, only recently billed as one of the great killers of the 20th century, poses no significant threat at the trace levels of exposure that exist outside the workplace.

Scientific uncertainty by itself need not paralyze policy. But we are still struggling to develop a real environmental ethic that allows us to confront those very serious problems that don't make good headlines and to confront others before they do become headlines. Certain basic questions must be faced. How much do we care about the environment? Who should pay the costs of addressing our concerns? How much? Take the blue haze over the Grand Canyon. It's not clear how much of it is caused by emissions from the Navajo Generating Station. But even if most of it is, is the removal of the haze worth the price? Should the operators of the plant bear the full $2.3 billion cost? Should a decision of this kind be made by administrative fiat? Should the utility be allowed to pass on to its customers any or all of the cost? Should the general public share the cost?

The fact that 80 percent of those answering the *New York Times* poll of 1989 said that no price is too great to pay in the name of environmental quality shows that we have yet to confront such questions. Our approach now recalls an old slogan with many painful associations: We are saying that we are willing to pay any price and to bear any burden for the environment. That is not a serious position at a time when, for example, $70 billion will be needed over the next 30 years simply to repair leaking underground storage tanks nationwide. Increasingly, we will need to put aside our anxieties over such high-profile but relatively trivial risks as Alar and EDB and begin to take cognizance of such submerged—not only literally but figuratively—threats as the storage tanks. This falls under the unexciting but essential category, "rational ordering of risks."

There is good reason to doubt, however, whether we are yet capable of such changes. Consider the Navajo Generating Station again. Environmentalists hailed the EPA decision; business decried it. The news media presented the claims and counter-claims of the utility, the government, and the environmentalists, but usually without adequate background to allow intelligent public participation. Traditionally, reporters and editors have maintained that they are not qualified to resolve scientific controversies; the most they say they can do is to give a balanced presentation of what the parties are saying. What is required, however, is not resolution but enough investigation to separate facts and reasonable beliefs from half-truths and misleading constructions, and enough information for a reader or viewer to make an informed judgment.

Biology, epidemiology, ecology, climatology, and other sciences will continue to offer mostly inconclusive answers to questions about environmental risks. And despite years of experience, dozens of mistakes, and a high level of concern, the public remains woefully ignorant about the environment. For better or worse, neither can one expect much change in politics as practiced in the United States. A politics based on compromises hammered out through a televised clash of interests does not encourage environmental statesmanship. For these reasons, despite whatever good intentions we might have, America is likely for the foreseeable future to continue lurching from crisis to crisis.