I. The Winners of the Blue Planet Prize

1997

1997

Blue Planet Prize

Dr. James E. Lovelock (U.K.)

Honorary Visiting Fellow of Green College, Oxford University

Conservation International (CI) (Headquartered in U.S.A.)

At the 1997 Blue Planet Prize Awards Ceremony, the opening slides conveyed a message to children to remind us of our responsibilities to future generations and raise the question of what each one of us can do to leave our beautiful planet intact and habitable.

His Imperial Highness Prince Akishino congratulates the laureates.

Their Imperial Highnesses Prince and Princess Akishino at the Congratulatory Party.

Dr. James E. Lovelock accepts the 1997 Blue Planet Prize.

Sir David John Wright, Ambassador of the United Kingdom to Japan (left), and Christopher J. LaFleur, Chargé d'Affaires ad interim of the United States to Japan (right), congratulate the laureates.

Dr. Russell A. Mittermeier, representing CI, accepts the 1997 Blue Planet Prize.

The Blue Planet Prize Commemorative Lectures.

Prior to the awards ceremony, the award recipients meet the press. From right: Dr. Mittermeier; Dr. Lovelock; Chairman Jiro Furumoto; and Osamu Shiragami, senior executive director of the Foundation.

Profile

Dr. James E. Lovelock

Honorary Visiting Fellow of Green College, Oxford University

Education and Academic and Professional Activities

1919	Born in July in the United Kingdom.
1941	B.Sc., Chemistry, University of Manchester.
1941-1961	Medical Research Council, National Institute for Medical Research, London.
1948	Ph.D., Medicine, London School of Hygiene and Tropical Medicine.
1954-1955	Visiting Scientist, Harvard University Medical School, U.S.A.
1955	CIBA Foundation Award for Research in Aging.
1958-1959	Visiting Scientist, Yale University Medical School, U.S.A.
1959	D.Sc., Biophysics, University of London.
1961-1964	Professor of Chemistry, Baylor College of Medicine, University of Houston, U.S.A.
1964-1974	Visiting Professor, Department of Chemistry, University of Houston, U.S.A.
1964-1989	Visiting Professor, Department of Cybernetics, University of Reading, U.K.
1974	Fellow, Royal Society of London.
1975	M.S. Tswett Award for Chromatography.
1980	Award for Chromatography, American Chemical Society.
1986	Silver Medal and Prize, Plymouth Marine Laboratory.
1988	Norbert Gerbier Prize, World Meteorological Association.
1990	Commander, Order of the British Empire; Amsterdam Prize for the Environment, Royal Netherlands Academy of Arts & Sciences.
1993—	Honorary Visiting Fellow, Green College, Oxford University, U.K.
1996	Volvo Environment Prize.

In 1957, Dr. James E. Lovelock invented the electron capture detector (ECD), a device for use in gas chromatography that can detect tiny amounts of chemical compounds in the atmosphere and elsewhere on Earth. This device made it possible to detect halogenated compounds and nitrous oxide, even at levels of only one part per trillion (ppt), thus revolutionizing our understanding of the atmosphere and pollutants.

Dr. Lovelock used his own invention in 1970 to detect chlorofluorocarbons (CFCs) in air masses over Ireland. In 1973, the ECD was used to discover the existence of CFCs in the oceans and atmosphere throughout the Atlantic region from the Antarctic to the English Channel. The CFCs were particularly abundant in areas surrounding industrialized countries. These discoveries eventually led to the theory that CFCs destroy stratospheric ozone.

In the 1960s, Dr. Lovelock was invited by the U.S. National Aeronautics and Space Administration (NASA) to join one of their research teams. He became involved with the NASA program studying Mars and, while making comparisons between the atmospheres of Mars and of Earth, became interested in the special properties of the Earth's atmosphere. Dr. Lovelock, building on his broad background in chemistry and medicine, then formulated the Gaia Hypothesis, now the Gaia Theory. This hypothesis was first stated in 1972 and was later developed through an ongoing collaboration with the eminent American biologist Lynn Margulis.

The Gaia Hypothesis sought to describe the Earth from a comprehensive point of view, not in specialized, fragmented terms. Gaia could be understood as a control system for the Earth and offered a new way of looking at our planetary biosphere. It developed a new way of viewing our entire world and helped raise interest in the environment all around the globe.

Essay

The Evolution of the Earth

Dr. James E. Lovelock

June 2001

The American scientist Alfred Lotka published a small book, *Physical Biology*, in 1925. In it he wrote.

> It is not so much the organism or the species that evolves, but the entire system, species and environment. The two are inseparable.

As a follower of Alfred Lotka, I want to take his suggestion further and consider evolution as a science that is as much about the rocks and oceans as about the living things that inhabit them. In this view, what evolves is an Earth system that can move gradually for long periods under an ever-warming sun. But as it evolves, sudden changes punctuate its gradual evolution; such as the appearance of oxygen, or a glaciation, or a species like humans. Evolution is also punctuated by external events, such as the impact of planetesimals or the appearance of a species like photosynthesisers, or humans, that change the global environment. Whether internally or externally driven, these events change the whole system—material environment and organisms—neither of them separately.

Lotka's view of evolution passed almost unnoticed in his time and it was not until NASA in the 1960s began exploring our planetary neighbourhood that this broader, transdisciplinary view of the Earth was revisited. As part of NASA's exploration team, it led me to propose in a paper in *Nature* in 1965 that life and its environment are so closely coupled that the presence of life on a planet could be detected merely by analysing chemically the composition of its atmosphere. This proposal is now part of NASA's astrobiology program and they aim to use it in the search for life on extra-solar planets.

When we look at the Earth using one of these life detectors, we see an atmosphere that, apart from the noble gases, has a composition almost wholly determined by the organisms at the surface. So tightly coupled is life with the atmosphere, that if some catastrophe removed all life from the Earth without changing anything else, the atmosphere and surface chemistry would rapidly—in geological terms—move to a state similar to Mars or Venus. These are dry planets with atmospheres that are dominated by carbon dioxide and close to the chemical equilibrium state. By contrast, we have a cool wet planet with an unstable atmosphere that somehow stays constant and always fit for life. The odds against such stability are close to infinity. Science is about probabilities, so we are forced to consider the difficult but more probable alternative: something regulates the atmosphere. What is it? It has to be something connected with life at the surface because we know that the atmospheric gases—oxygen, methane and nitrous oxide—are almost wholly biological products, while others, nitrogen and carbon dioxide, have been massively changed in abundance by organisms. Moreover, the climate depends on atmospheric composition and there is evidence that the Earth has kept a fairly comfortable climate ever since life began in spite of a 30% increase in solar luminosity. Together these facts led me to propose in a 1969 paper in the *Journal of the American Astronautical Society* that the biosphere was regulating the atmosphere in its own interests. Two years later, I started collaborating with the American biologist, Lynn Margulis, and we published a paper in *Tellus* in which we stated:

> The Gaia hypothesis views the biosphere as an active adaptive control system able to maintain the Earth in homeostasis.

This idea was so contradictory to the views of evolutionary biologists that it was not long before the Canadian and British biologists, Ford Doolittle and Richard Dawkins, challenged it. They pointed out that global regulation by the organisms could never have evolved because the organism itself was the unit of selection, not the Earth. In time, I found myself agreeing with them. They were right; there was no way for organisms by themselves to evolve so that they could regulate the global environment. But I wondered could the whole system—organisms and environment together—evolve self-regulation? In 1981, I redrafted the hypothesis as an evolutionary model, Daisyworld, that was intended to do no more than show that self-regulation can take place on a planet where organisms evolve by natural selection in a responsive environment. The model was one that Alfred Lotka might have made had computers been available in his time. Following the model, the Gaia hypothesis was restated as follows:

> The evolution of organisms and their material environment proceeds as a single tight-coupled process from which self-regulation of the environment at a habitable state, appears as an emergent phenomenon.

At about the same time, Andrew Watson, Mike Whitfield and I suggested a mechanism for climate control by the Earth system, namely the biologically assisted reaction between atmospheric carbon dioxide and calcium silicate in soil and on rocks. This process could regulate both climate and CO_2 at a level comfortable for plants. Soon other putative regulation mechanisms were discovered, such as the connection between ocean algae, dimethyl sulphide gas, clouds and climate. By the end of the 1980s, there was sufficient evidence and models of the hypothetical system to justify calling it the Gaia Theory.

The name Gaia was not popular with scientists and, as a consequence, the theory has developed under the pseudonyms, geophysiology and Earth System Science. Because most Earth System scientists are geologists or geochemists, the science has lacked biological wisdom. Earth System scientists included the biota in their models, but did so as if ecosystems were passive reservoirs, like the sediments or the ocean, something unable to respond actively to change, still less able to evolve by natural selection or include biodiversity. In the biological community, the Gaia Theory was almost wholly rejected, and Earth System Science was ignored so far as evolution was concerned. Then, in the mid–1990s the eminent scientist William Hamilton became interested in the Gaia Theory. He accepted what was by then the strong evidence that the environment was regulated at a state comfortable for the biota. He saw it as a challenge to explain how this could happen as a consequence of evolution through natural selection. He published with Tim Lenton one paper on the cloud algal system. Sadly, he died shortly afterward, but his colleague, Peter Henderson, continues to model systems of biological evolution that include the material environment.

What Bearing Does This New View of Evolution Have On Current Environmental Concerns and What Practical Use Is It?

1) It draws our attention to the biological infrastructure of the Earth, namely microorganisms. Lynn Margulis first pointed out their significance and that they still play an important, if not major part, in planetary regulation. Bacteria were the whole biosphere for three-billion years before multicellular organisms like us and trees came on the scene.

2) In the real world, organisms grow in a material environment where growth is strongly constrained by the laws of physics and chemistry. When these constraints are included in evolutionary biology models, it becomes possible to build a wide range of stable model systems. Tim Lenton and Stephan Harding have separately explored imaginary ecosystems with different environmental or species properties. Their models offer insight into the nature of the Earth system and into the need for biodiversity. Biodiversity is usually valued for its aesthetic or human medicinal qualities; we think that biodiversity is an important part of planetary self-regulation.

3) We see the interglacial period that we are now in as a pathological state of the Earth System and see the ice ages as the normal state of the Earth system. In the present interglacial, all of the regulation systems so far proposed appear to be in positive feedback towards climate change. In other words, any change, either to hotter or colder, is amplified not resisted. This applies to the mechanisms for pumping down CO_2 from the atmosphere, for cloud production by algae and for the Daisyworld-like behaviour of the boreal and tropical forests. In addition, geophysical feedbacks, such as the effect of ice cover, are also in positive feedback. An interglacial like now can be seen as a period when regulation has temporarily failed and certainly no time to add more greenhouse gases or deplete biodiversity.

Many biologists, including E.O. Wilson, Norman Myers and Peter Raven, consider that we are in the midst of a great extinction as a consequence of the denial of land for natural habitats by its use for agriculture. In debates on this topic, the great diversity of organisms, especially in equatorial regions, is sometimes regarded as if it were a stable natural state. I wonder if instead we should regard the diversity of natural ecosystems as an indication that the Earth itself is continuously but gently, perturbed. Even the single environmental variable, temperature, is perturbed on the short time-scale of diurnal change, and through the yearly march of the seasons, to the alternation of glaciations with warm periods like now. Our models suggest that biodiversity is a symptom of perturbation during a state of comparative health. What seems important for sustenance is not so much biodiversity as such, but potential biodiversity, the capacity of a healthy system to respond through diversification when the need arises. In tropical forest and other regions under threat, destroying diversity will reduce the numbers of rare species. Among them may be those able to flourish and sustain the ecosystem when the next large environmental change takes place. The loss of biodiversity seldom occurs alone. It is part of the destructive process of converting natural ecosystems to farmland. It is the whole process, the loss of diversity and the loss of the potential of the region to sustain biodiversity, that makes the large-scale replacement of natural ecosystems with farmland so dubious an act.

The Gaia Theory is not contrary to Darwin's great vision; it is like neoDarwinism, a new look at Darwin's evolutionary theory. I suspect it will be some time before biologists and geologists collaborate closely enough for us to see the emergence of a truly unified Earth System science. William Hamilton, in a television interview, referred to the Gaian view of evolution as Copernican, but, he added, we await a Newton to explain how it works.

Lecture

Travels with an Electron Capture Detector

Dr. James E. Lovelock

This afternoon I will tell you about the invention of the Electron Capture Detector, how this simple device helped to start the environmental movement and how, later, some of its measurements led me to the idea of the Earth as the self-regulating system, Gaia.

The Electron Capture Detector, which henceforward I will call the ECD, was invented almost exactly 41 years ago in October 1956. In those days, it was usual for scientists to make, or at least design, their own instruments. Most laboratories then had a workshop with metal working tools, lathes and milling machines, and scientists were expected to be able to use them. Electronic devices were made by hand using thermionic vacuum tubes manufactured for use in radio and sound equipment. Because we made our own equipment, we understood its limitations and capabilities. Such insight is denied most scientists today that use commercial instruments without understanding what goes on inside the decorous case of their chromatograph, spectrometer or other device. The greatest advantage to come from making one's own apparatus is that sometimes it is an invention whose novelty makes it years in advance of anything available in the marketplace.

In 1956, I was trying to discover the cause of the damage suffered by living cells when they were frozen. We had successfully frozen and reanimated small animals—hamsters—and we were now moving on to see if animals as large as a rabbit could be reanimated after freezing. I had found that most of the damage by freezing was to cell membranes. These are made of lipid protein complexes and sensitivity to cold seemed to depend in part on the fatty acid composition of the lipids.

To quantify my work, I needed accurate analyses of these fatty acids. It so happened that Archer Martin and Tony James, inventors of gas chromatography, were working in the same institute just one floor above me. I knew that their instrument had first been used to analyse fatty acids so I asked them if they could analyse those of my membrane lipids. They were enthusiastic to try until I showed them the quantity I had for analysis. It was a few micrograms. Martin said "Sorry, but we cannot do it for you. We need milligrams not micrograms. Go back and prepare a much larger sample." Then, as an afterthought one of them said, "Alternatively you could invent a more sensitive detector than our gas density balance."

At the National Institute, it was the tradition never to read the literature, especially not textbooks, before doing an experiment. Senior scientists warned that our job was to make the literature not read it. It was a recipe that worked well for me. Had I read the literature of ionisation phenomena in gases before doing my experiments, I would have been hopelessly discouraged and confused. Instead, I did some experiments. Fortunately, we were not hampered, like now, by a well-intentioned but hindering health and safety bureaucracy. Scientists who used dangerous chemicals or radioactive materials were expected to be personally responsible.

There was some risk, but I doubt if under the stifling restrictions of today I would have had the persistence to carry on with so uncertain a project as the infant Electron Capture Detector.

I first invented the Argon Detector—a device that used excited argon atoms to ionise the vapours of organic compounds. This was the sensitive detector that I had been seeking for fatty acid analysis. Until the even better flame ionisation detector displaced it, it served me and many other biochemists around the world for the analysis of minute traces of fatty acids and other lipids. Serendipitously, during the work leading to the argon detector, I discovered the ECD. Like the argon detector, it was a simple diode ion chamber. But with the ECD, nitrogen was the carrier gas and the chamber was polarised by only a few volts instead of the kilovolt needed by the argon detector.

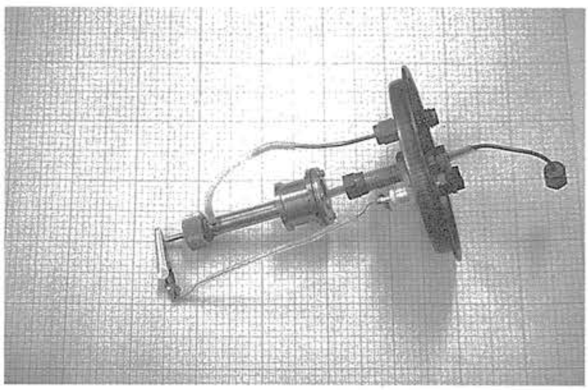

Figure 1. The electron capture detector.

I was fascinated by the strange behaviour of the ECD, but a full investigation of its scientific basis was far from that of the freezing problem I was expected to work on. It says much about the management of the Institute that I was allowed to spend any time on it at all. The physics of thermal energy electrons was hardly what the physicians running the Medical Research Council expected of me. I recall asking the director, Sir Charles Harington, " Can I spend some of my time finding out how the ECD works?" I added, "There is no certainty that it will be of practical use, but to me it is fascinating science." He replied "I am happy to leave it entirely to your own judgement. This is a scientific institute, and so long as what you do is good science, I am not much concerned about its immediate medical value."

My curiosity about the strange and anomalous behaviour of the ECD made me return to work with it whenever there was a spare moment. In 1958, I was invited to spend a year at Yale University by Dr. Lipsky. Here, I had the opportunity to work full-time on detectors, and by the end of 1959, was able to reduce the ECD to practice as a detector little different from those now in use. The ECD gives no response whatever to over 99.9 per cent of all organic compounds. Those few it does detect are often of biological and medical interest. Among them were compounds important in oxidative metabolism, such as the acids of the Krebs cycle, steroid and thyroid hormones, and coenzymes. It also detects substances that are poisons of this system, such as the nitro- and halo-phenols, and it was uniquely sensitive to chemical carcinogens. It is this selective response to poisons that makes it so useful in environmental studies. The detector was then, and still is, the most sensitive, easily portable and inexpensive analytical device in existence. So exquisitely sensitive that if a few litres of a rare perfluorocarbon were allowed to evaporate somewhere in England, we could with a little effort detect it in a 3-cubic-metre sample of the air here in Japan a week or so later, and within two years it would be detectable anywhere in the world. This extraordinary sensitivity to perfluorocarbons, which otherwise are wholly inert and harmless, has been put to use in methods for tracing the movement of air masses across whole continents and also for mass transfer experiments in the oceans.

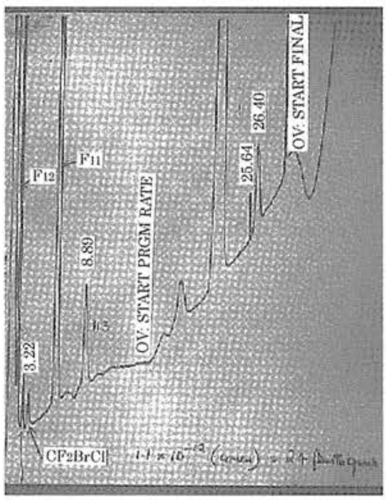

Figure 2. Chromatogram showing the detection of 1 part per trillion of the halon BCF.

What Makes it Work?

It was easy enough to understand the detector qualitatively, but a quantitative theoretical understanding of its operation eluded me until I worked with Drs. Wentworth and Chen at the University of Houston. We found that the electron attachment to molecules was sometimes reversible, but also could be irreversible and followed by the dissociation of the molecule. In the 1960s when we did this work, computers were not generally available and, because of this, the numerical solution of the detector equations was beyond us. By 1970, simple computers became available, and I was able to solve the detector equations and understand the theory of its operation. This analysis led to the invention of the constant current method for its operation, which is now used in almost all commercial equipment.

I find it helpful to think of the detector as a small reaction vessel holding a dilute suspension of the reagent chemical gaseous free electrons. We often forget that the free electron is a simple chemical and as much a fundamental particle of chemistry as it is of physics.

While I was improving and trying to understand the mechanism of detection by electron capture, serious scientists were applying the detector to the practical analysis of pesticide residues in foodstuffs. It was already known from conventional chemical analysis that DDT was present, at levels down to the detection limit of one part per million, in foodstuffs and in the fat of animals and humans. Conventional wet chemistry was not well suited to the comprehensive study of pesticide distribution. A more rapid, sensitive and discriminatory method was needed. In the United States, Watts and Klein of the FDA, and in the United Kingdom Goulden and his colleagues at Shell, pioneered the use of the ECD. They were soon joined by analysts worldwide, who used gas chromatographs equipped with ECDs to establish a global database of the distribution of halogenated pesticides, and soon this data were the hard facts of the environmental movement. When it was realised that pesticides like DDT and Dieldrin were distributed throughout the global environment and when it was shown that they were in the fat of Antarctic penguins and in the milk of nursing mothers in Finland, there was a recognition that pollution was no longer just a local problem; we humans were affecting the environment on a global scale. The data about the distribution of pesticides and their poisonous effect on birds of prey led Rachel Carson to write her seminal book, *Silent Spring*. A book that warned the world of the ultimate consequences if these chemicals continued to be used by farmers in their unceasing battle against all forms of life that are not livestock or crops. It was a book that was bound to affect the course of politics, and in many parts of the world, her gloomy forecast of a silent spring has come true. Not as she predicted by pesticide poisoning alone, but simply by habitat destruction.

When I first heard that the electron capture detector was being used this way, I was delighted. I shared with Rachel Carson her concern over damage to natural ecosystems. Some parts of the chemical industry reacted in a shameful and foolish way by trying to discredit her as a person. It did not work; in fact it made Rachel Carson the first saint and martyr for the infant and innocent green movement. All seemed set for the green movement to lead us into a seemly and sensible way of living with the natural world. As you know, it did not happen like this. Sadly, the environmental agenda has had to proceed at the normal slow pace of human politics.

Independent Science

In April 1961, I received a letter from Dr. Silberstein, Director of Space Flight Operations for NASA. It was an invitation to join with them in their exploration of the moon. We have to remember that in 1961, space flight was barely a few years old. Many scientists still looked on it as fanciful and a waste of time and money. To me, who had grown up on science fiction, the invitation was like a dream come true. This invitation was the spur that led me to leave a safe, tenured, well-paid job at the National Institute for Medical Research for the uncertainties of independence and working from home.

Soon, lunar exploration became commonplace, and the new interest was in planning an automated laboratory to send to Mars to look for life. In the early 1960s, not much was known about Mars. Its surface was poorly visible through telescopes, and it was easy to imagine that the seasonal wave of darkening that moved across the planet was due to the growth of vegetation. My colleagues at the JPL were busy designing instruments to test for life or life-like chemicals on the Martian surface. They were trying to put into practice in an automated form the very procedures that they were familiar with in their own laboratories here on Earth. Some of these experiments involved applying Martian soil to culture media to see if organisms would grow. Others looked for metabolism to see if oxygen was produced in sunlight or CO_2 in the dark. I found this detailed reductionist approach to life detection for Mars unconvincing. It could fail to detect the presence of life for many reasons. It might not be bacterial, the experiment might land at a barren site—or Martian biochemistry might be different. I suggested that they try a more general experiment, such as a top-down view of the whole planet instead of a local search at the site of landing. The experiment I proposed was simply to analyse the chemical composition of the Martian atmosphere. If the planet were lifeless, then it would be expected to have an atmosphere determined by physics and chemistry alone and be close to the chemical equilibrium state. But if the planet bore life, organisms at the surface would be obliged to use the atmosphere as a source of raw materials and as a depository for wastes. Such a use of the atmosphere would change its chemical composition. It would depart from equilibrium in a way that would show the presence of life. Dian Hitchcock joined me then, and together we examined atmospheric evidence from the infra-red astronomy of Mars. We compared this evidence with that available about the sources and sinks of the gases in the atmosphere of the one planet we knew bore life, Earth. We found an astonishing difference between the two atmospheres. Mars was close to chemical equilibrium and dominated by carbon dioxide, but the Earth was in a state of deep chemical disequilibrium. In our atmosphere, carbon dioxide is a mere trace gas. The coexistence of abundant oxygen with methane and other reactive gases are conditions that would be impossible on a lifeless planet. Even the abundant nitrogen and water are difficult to explain by geochemistry. No such anomalies are present in the atmospheres of Mars or Venus. Their existence in the Earth's atmosphere signals the presence of living organisms at the surface. Sadly, we concluded, Mars was probably lifeless.

The first sight of the Earth from space as a dappled white and blue sphere filled our minds with wonder and delight. We saw, for the first time, how beautiful was the Earth and began to regard it as an icon like those of the great religions. In a similar way, the top-down view of atmospheric chemistry gathered at JPL was for me, in scientific terms, a revelation of the Earth. The analysis revealed the atmosphere as a gas mixture like that of the intake manifold of an internal combustion engine: oxygen and combustible gases mixed. Different from the exhausted, carbon dioxide dominated atmospheres of Mars and Venus. Much more than this, I knew that the chemical composition of the atmosphere was stable for long periods compared with the residence times of its gases. One afternoon in 1965 at the JPL in California, when thinking about these facts, the thought came to me in a flash that such constancy required the existence of an active control system.

Then, I lacked any idea of the nature of the control system, except that the organisms on the Earth's surface were part of it. I learnt from astrophysicists that stars increase their heat output as they age and that our Sun has grown in luminosity by 25% since life began. I realised that, in the long term, climate also might be actively regulated. The notion of a control system involving the whole planet and the life upon it was now firmly established in my mind. Sometime near the end of the 1960s I discussed this idea with my near neighbour, the novelist William Golding. He suggested the name Gaia as the only one appropriate for so powerful an entity.

I first stated the Gaia Hypothesis in 1972 in the journal, *Atmospheric Environment.* My proposal was "the biosphere interacts actively with the environment so as to hold it at an optimum of its own choosing." The proposal was based on arguments drawn from the atmospheric chemistry of the Earth and Mars. Soon after I began a collaboration and friendship with the biologist Lynn Margulis that has continued to this day. Lynn, from her wide knowledge and deep understanding of organisms—especially microorganisms—put flesh on the bare bones of my physical chemistry.

I now realise that the early statements of the Gaia Hypothesis were misleading. Worse, enthusiasts of the idea began to speak of the Earth as a living organism—not as we said "the Earth behaves like a living organism." These misunderstandings led to heavy criticism from biologists that still persists 25 years later. Sharpened by these criticisms, the Gaia Hypothesis evolved. Now, we see Gaia as a system made from the living organisms of the Earth, and from their material environment, the two parts tightly coupled and indivisible. Gaia theory views the self-regulation of the Earth's climate and chemical composition as emergent properties of the system.

My colleague, Andrew Watson, succinctly expressed the step that distinguishes Gaia theory from previous evolutionary theories. It lies in the tightness of the coupling between the organisms and their physical environment. Almost everyone, he said, now accepts that life profoundly influences the environment. This is now the conventional wisdom among geochemists, and a considerable change from their view pre-Gaia. It is equally obvious, he continued, that life is influenced by and adapts to the environment. This is the older wisdom that has prevailed throughout this century. Therefore, life and the environment are a coupled feedback system, where changes in one element will affect the other, and this may in turn feed back on the original change. The real debate is, then, how important and how tight is the coupling? Does it, as we believe, confer new properties on the system, such as enhanced stability or behaviour like a living organism? I see this coupling strong enough that we will not properly understand Earth history until we think of the system as just that, a whole system, and stop trying to understand its parts in isolation from one another. Gaia theory is testable and is developing normally in the Earth sciences, and in time will either be accepted or rejected on the evidence.

Among the insights that come from a Gaian approach is the idea that planetary life can never be sparse. A planet with sparse life could never self-regulate. We should keep this in mind as we destroy the natural ecosystems of the Earth to provide farmland for ourselves. The geophysical and geochemical evolution of the terrestrial planets is progressive and towards states like those of Mars and Venus now.

Thinking about Gaia led me to explore the natural world. I was curious to know how elements like sulphur and iodine that are scarce on the land surface, but plentiful in the oceans, are transferred back from the sea to the land in sufficient quantities to keep the land fertile.

The opportunity to start exploring came in 1968 when we purchased a holiday cottage in far Western Ireland on the shores of Bantry Bay. It was sited on the slopes of Hungry Hill, a small mountain of warm sandstone slabs, which looked out over the broad Atlantic. Here, during walks along the beach, I collected the different species of macroalgae—seaweed. I put the specimens into empty jars and later examined their volatile emissions, using a simple gas chromatograph. Summer holidays at Adrigole led serendipitously to another discovery about the atmosphere. On days when the air drifted from the East, from Europe, it became hazy and the visibility range fell from over 50 kilometers to less than one kilometer. I wondered if we were seeing a polluted air mass that had travelled intact more than 1,000 kilometers to western Ireland.

Figure 3. The cottage laboratory in Ireland.

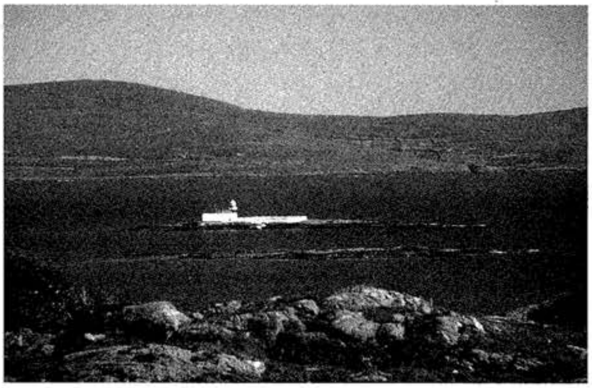

Figure 4. Clear air seen from the Adrigole cottage.

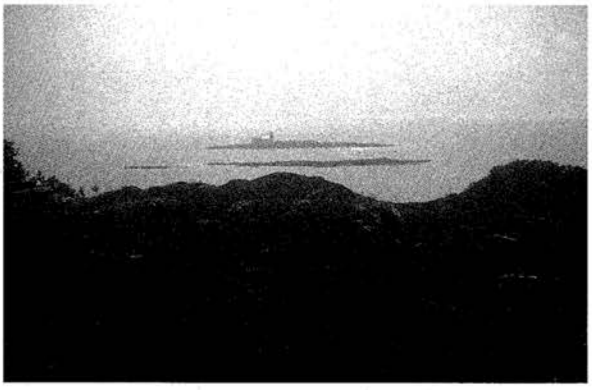

Figure 5. Smog seen from the Adrigole cottage.

I had the idea that it should be possible to decide if the haze was a natural phenomenon, or was man-made, by measuring the level of CFCs, the aerosol propellant gases in it. The CFCs are unique among chemicals in the atmosphere in being unequivocally of industrial origin. Other chemicals have both natural as well as man-made sources. My idea was that if the haze was pollution, it would come from an urban industrial area and in it there would be more of these CFCs than in clean Atlantic air. On the first few days of our holiday the air was sparkling clear, and I was surprised to find a small but easily measurable quantity, 50 parts per trillion of F11, in the air. A few days later, the wind shifted and an easterly drift of air blew from Europe. With it came the haze and the confirmation of my idea about the origin of the smog. For in the hazy air, there were 150 parts per trillion of F11, three times as much as in the clear air. So the haze was man-made. Later investigations showed it to be photochemical smog, rich in ozone, and to have come from Southern France and Italy, having drifted in the wind nearly 1,000 miles carrying the exhaust fumes of the millions of cars of European holiday makers.

There, this small investigation might have ended, but being curious and having no employer to tell me what I should be doing, I wondered about the 50 parts per trillion of CFC in the clean Atlantic air. Had it drifted across the Atlantic from America, or more important, were the CFCs accumulating in the Earth's atmosphere without any means for their removal? To find out, the only thing to do would be to travel by ship to the Southern Hemisphere and back and measure the CFCs as the ship travelled across the world. I had another reason to make the voyage. I wanted to know if there were molecular species of the elements sulphur and iodine released from the oceans in sufficient quantities to account for the rate of mass transfer of these elemental cycles. I tried for grant support to make these investigations, but without success. Being an independent, the lack of support was not a deterrent, and my wife agreed to support the expedition from our housekeeping budget.

The apparatus I used was so simple I was able to make it in a few days. It ran without failure throughout the six-month voyage. The total cost of the research, including the apparatus, was about 40,000 Yen. But the discoveries of the voyage required three *Nature* papers for their publication.

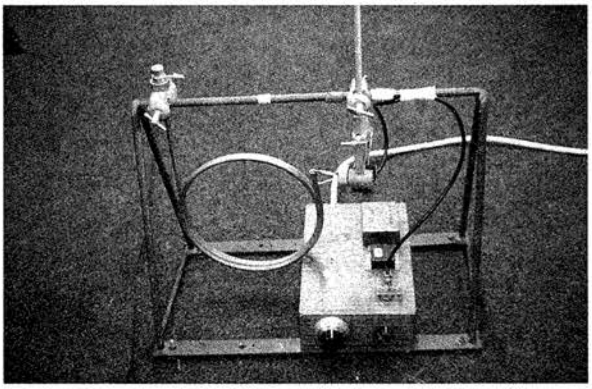

Figure 6. Gas chromatograph used on the Shackleton to analyse the CFCs.

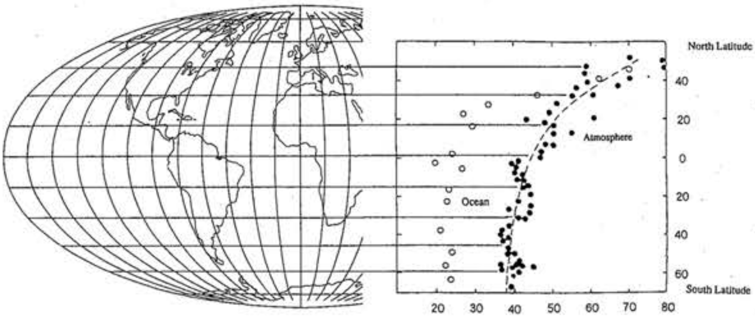

Figure 7. The abundance of F11 in the air and in the sea of the Atlantic Ocean.

This journey of research revealed the global presence of the chlorofluorocarbons, carbon tetrachloride and methyl chloroform. In addition, I found the unexpected presence of methyl iodide, dimethyl sulphide and carbon disulphide. It now seems that the environmental significance of these sulphur emissions may be as important as is that of the CFCs.

Sherry Rowland and Mario Molina used my data in their historic *Nature* paper. They made public their concern about the potential of the CFCs to deplete stratospheric ozone. At first, I was sceptical. I did not doubt the excellence of the science. Indeed, in 1974, I took samples of stratospheric air and was able to confirm the Rowland Molina hypothesis that the stratosphere was a sink for the CFCs. What I did doubt was that the 50 ppt of F11, and the 80 ppt of F12, in the air in the mid-1970s were, at that time, a significant threat. It is normal in science for new hypotheses to have a hard time—as I well knew from the opposition to the Gaia Hypothesis, and some of my scepticism came from this cause. At the time, it seemed that monitoring, not a ban, was needed. Looking back, I realise I was wrong to oppose an early ban on the release of CFCs to the atmosphere. I underestimated the time needed for the international understanding that led to the Montreal agreement on the CFCs.

As the years went by, the need grew for comprehensive global monitoring of the CFCs. Prinn and his colleagues suggested in 1977 that the accurate global monitoring of CFCs would provide data from which their residence times in the atmosphere could be calculated. In 1978, our holiday cottage at Adrigole became the site of the first station of what was to become the GAGE global monitoring network. The success of this trial run led to the establishment of a network of five monitoring stations in Barbados, Oregon, Samoa, Tasmania and Adrigole. These have successfully monitored the atmosphere ever since. From the results, the probable atmospheric lifetimes of the CFCs have been calculated.

The monitoring of the CFCs made accurate measurements essential. But the calibration of our detectors with a gas at a concentration of a few parts per trillion is easier said than done. My personal solution to this problem was twofold. First, I calculated from first principles the number of electrons that had reacted with fluorocarbon in the detector. This provided an absolute analysis and calibration was not needed. I was fairly sure that this method would not be in error by more than 20%. It turned out later to be only 5% in error. My second step was to move my home and laboratory to a remote country region close to the Atlantic Ocean. Here, I converted a barn into a 50-cubic-meter exponential dilution chamber. This chamber verified the standards used in the first years of global monitoring.

Liss and Slater, 1974, used the Shackleton data to estimate the flux of DMS and halocarbons from the sea to the air and vice versa. Later in the 1970s, the German scientist, Andi Andreae, made a series of careful and accurate measurements of the DMS abundance in both the air and the sea water over many parts of the world, and, indeed, most of our knowledge of the distribution of this gas now is due to this careful research.

In 1986, I was invited to spend a month at the University of Washington in Seattle. While there, I spent some time with Robert Charlson, who was interested in the significance of cloud condensation nuclei (CCN) in the atmosphere. These are, for the most part, especially over the open oceans, tiny droplets of sulphuric acid and its ammonium salts. I asked him why he was so interested in them, and his reply astonished me. Without the CCN, he said, there could be no clouds. Of course, I knew that small droplets of pure water will always have a higher equilibrium vapour pressure than larger droplets, but never had I put together in my mind the obvious fact that natural selection among cloud droplets would leave only the larger ones, which would rapidly fall out from the air as rain. In other words, without the nuclei, there could be no clouds as we now know them. At first I protested, saying, surely there are always enough sea salt and other water-soluble particles floating in the atmosphere to act as nuclei. Dr. Charlson explained to me that for the greater part of the Earth's surface, that is to say over the open oceans, the numbers of sea-salt particles are too small to account for the abundance of CCNs. There were sufficient droplets of sulphuric acid and ammonium sulphate, but there was no way that these could have come from either industrial or volcanic sources. Where did they come from? Such particles cannot travel far over the ocean, which means that they must be produced locally. It was one of those happy moments in science when truth suddenly dawns. The atmospheric oxidation of DMS could be the answer. We moved on to discuss these ideas with Andi Andreae who knew much more about the abundance of DMS in the atmosphere than we did. Our conclusions were published in a paper in *Nature* in 1987. My interest in Gaia led me to seek mechanisms for climate control. Together with Whitfield and Watson in 1983, I had proposed the pump-down of carbon dioxide from the atmosphere by biologically accelerated rock weathering as one possible mechanism. I wondered if the association between algae in the ocean, clouds and climate could provide another. At first, it did not look like a promising candidate, but there is now strong evidence for the link between algae, clouds and climate. Kump and I showed in 1995 that this is most evident in the cooler parts of the world where the sea temperature is less than 12 degrees Celsius. So complex is the connection between cloudiness and climate that it will take time to resolve. The vigour of the debate and the worldwide research interest in DMS seems to me to indicate the value of Gaia as a different way to view the world. Whether or not it is a fact seems less important.

I hope that I have shown that science can still be a vocation, not just a career. Something even that can be done at home, in the way an artist or novelist works. Doing environmental science this way and walks through the countryside and on the seashore have kept me in touch with the natural world. I have tried to show how the ECD influenced the development of the environmental movement and how this simple detector has taken me literally around the world in search of new information. Similar journeys in the mind, especially those using the opportunities provided by the NASA space program, enabled me to see the world of Gaia from outside. I am blessed to have two able successors who will carry on my work, Tim Lenton and Stephan Harding. It is a joyful fulfillment to have your tangible recognition through the Blue Planet Prize.

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Dr. James E. Lovelock

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Profile

Conservation International (CI)

History

1987	CI established by Peter A. Seligmann, the current chairman and CEO.
1989	Dr. Russell A. Mittermeier joined CI as president.
1990	First hotspot map published. First RAP expedition conducted. Tagua Initiative launched. Debt-for-nature agreement signed with Madagascar (US$5 million). First Regional Priority Setting Workshop held in Amazonia.
1991	Dept-for-nature agreement signed with Mexico (US$4 million). CI's Geographic Information System (CISIG) released. This system is available in four languages and used in more than 350 institutions in 27 countries.
1992	CI participated in Rio de Janeiro Earth Summit. CI held its first Asia-Pacific region Conservation Priority-Setting Workshop in Papua New Guinea.
1994	RAP expedition to Peru recorded six new species of butterflies, eight orchids, two beetles and other important new findings. First Marine RAP Expedition conducted to the Indispensable Reefs region of the Solomon Islands.
1995	Formal RAP course launched to train local field biologists.
1996	Bolivia created the 1.9-million-hectare Madidi National Park, largely as a result of attention focused on the region through CI's RAP expeditions. Internet network created to link 25 international biosphere reserves. CI's RAP expeditions and long-term Peru Program led to establishment of 325,000-hectare Bahuaja-Sonene National Park.
1997	Owing to major efforts by CI and Brazilian partner-organization IESB, the Government of the State of Bahia created the 7,000-hectare Serra do Conduru State Park, doubling the area protected in this critically endangered hotspot region. CI published *Reinventing the Well*, a volume highlighting the importance of "best practices" in the oil and gas industry.

Conservation International (CI) is a private, nonprofit organization that was established in 1987 with the goals of conserving global diversity and demonstrating that human beings are able to live harmoniously with nature. CI was founded by Peter A. Seligmann, the organization's current chairman and chief executive officer. The organization's president is Dr. Russell A. Mittermeier. Headquartered in Washington, D.C., CI is active in 24 countries with an international staff of nearly 400 experts in biology, forestry, conservation planning, marketing and product development, economics, law and other areas. CI carries out many of its conservation programs through partnerships with international organizations that include the United Nations and World Bank, as well as with governments, research institutes, local nongovernmental organizations (NGOs), and major corporations. CI's activities include the identification of conservation priorities, areas of the world that are particularly rich in biodiversity and under imminent threat of destruction. CI uses the term "hotspots" to describe these areas. Through the use of cutting-edge biological research and its Rapid Assessment Program (RAP), CI quickly collects and analyzes data on potentially important sites.

Since its establishment, CI has set out to develop positive examples of people coexisting with natural habitats. The organization's activities, which are based on world-class scholarship and research, help developing countries pursue economic development while maintaining biological diversity through multifaceted efforts solidly grounded in economic theory, advanced scientific methods and respect for cultural differences.

Essay

Setting Priorities for Saving Life on Earth: Megadiversity Countries, Hotspots, and Wilderness Areas

Dr. Russell A. Mittermeier
Cristina G. Mittermeier
Cyril F. Kormos

July 2001

At the outset of the new millennium, our planet unfortunately faces a wide range of increasingly pressing environmental problems: from global warming and ozone layer depletion, to toxic waste disposal, persistent pesticides, acid rain and a host of other pollution issues impacting our air, water and soils. However, as critical as it is to address these problems, Conservation International believes that one environmental issue surpasses all others in terms of magnitude, urgency and long-term significance. That is the loss of our planet's biological diversity. Biological diversity is the sum total of life on Earth, the wealth of species, ecosystems, and ecological processes that, after all is said and done, makes our living planet what it is—the only place in the universe where we know with certainty that life exists. This diversity is not only essential as our living natural resource—our biological capital in the global bank—but doubly important because its loss is an irreversible process. We have, or can develop, technological solutions to combat most other environmental ills, especially the so-called "brown" issues mentioned above. In many cases, we simply lack the political will or the economic incentives to put them into place. However, once a species of plant or animal goes extinct, it is gone forever and will never be seen again. We now face not only the loss of individual species, but the loss of entire communities and ecosystems on which we, as living creatures, ultimately depend for our own survival.

With so many issues to confront, in so many different scenarios, and with so little time remaining in which to act, the challenge of conserving biodiversity may at times seem overwhelming. Given the seriousness of the threats to natural environments from expanding populations, development and other pressures, the question even emerges as to whether we can still have a significant impact on biodiversity losses, especially in the tropical regions of the world. Indeed, we have already lost well over half of the world's tropical forests, and we are potentially at the beginning of an extinction episode unlike anything seen since the loss of the dinosaurs some 65-million years ago. The only difference between this and the previous five major extinctions being that this one would be driven not by cosmic events, but by the actions of a single species—our own.

Conservation International believes strongly that it is not too late to save biological diversity, and that we can in fact have a major impact. To be successful in this task, however, we must be very strategic. We must first recognize that biological diversity is by no means evenly distributed over the surface of our planet, and that much of it is concentrated in a relatively few biologically rich regions that are often under severe threat. We must, therefore, set clear priorities for conservation action in these regions. To be successful, we must also establish strong partnerships within the conservation community, and with other key actors, such as local communities and the private sector. In addition, we must bring to bear a level of funding and global support at least two orders of magnitude beyond what has been invested thus far.

The essential task of priority setting can be carried out in a variety of ways, but to Conservation International it has always been essential that biodiversity conservation be based first and foremost on biological data. Thus, we first seek to determine where the greatest species and ecosystem diversity is to be found, and then to focus on those areas with the highest levels of endemic species. Species that are found only in a particular place and nowhere else. Endemic species tend to be restricted in range and specialized in terms of habitat requirements. A growing body of research indicates that they are the most heavily impacted by human-induced changes to the environment, and therefore the first to be lost.

We have used three different kinds of priority setting: the *megadiversity country* concept, *threatened biodiversity hotspots* and *major tropical wilderness areas*. The megadiversity country concept recognizes that, of all the countries on Earth, only a small handful account for a major portion of life on Earth, including terrestrial, freshwater and marine life. Dr. Russell Mittermeier first developed this concept in 1988, based on a preliminary analysis of primate conservation priorities. In looking at where the majority of the world's primates were to be found, Dr. Mittermeier discovered that only four countries in the world, Brazil, Madagascar, Indonesia and the Democratic Republic of Congo (formerly Zaire), accounted for two thirds of all primate species. These countries also had the highest levels of endemism, with 100% of Madagascar's 55 different kinds of lemurs being endemic, and levels of endemism in Brazil and Indonesia being on the order of 100%. Subsequent analysis of other mammals, birds, reptiles, amphibians, plants and selected groups of insects led to the conclusion that 17 countries qualified for megadiversity status, with Brazil, Indonesia and Colombia topping the list, followed by Australia, Peru, Mexico, Madagascar, China and nine others. This study resulted in a book, entitled *Megadiversity: Earth's Biologically Richest Nations*, published in 1997 by the Mexican cement company, CEMEX, and Agrupación Sierra Madre, a Mexican non-governmental organization. The findings in this book indicated that these 17 countries by themselves accounted for more than two-thirds of all life forms and for the vast majority of tropical rainforests, coral reefs and other priority systems. The conclusion is obvious: we must focus most of our attention on the richest and most diverse countries roughly in proportion to the diversity they contain, and we cannot leave them out of any strategy, regardless of how difficult it may be to include some of them.

The second and most important of our priority-setting approaches is that of the *threatened biodiversity hotspots*. This concept was first developed in 1988 by British ecologist Dr.

Norman Myers, and was adopted and has been used by Conservation International and the MacArthur Foundation since 1989. In 1996, Conservation International carried out a detailed reanalysis of the concept to bring it up-to-date and to determine its validity and usefulness for the new millennium. This process reaffirmed the value of the hotspots concept and validated Myers's earlier list, but also substantially expanded upon it.

Among the most important new additions were quantitative criteria for hotspot countries. Endemism was considered the most important criterion, and plants, in this case *vascular plants*, which make up the vast majority of the Plant Kingdom, were chosen as the main group of organisms to determine whether or not an area qualified as a hotspot, primarily because most other terrestrial life forms depend on them to some degree. Data on plant endemism were combined with data on total plant diversity (all species found in a particular area, including both endemics and non-endemics) and complemented with data on diversity and endemism for four vertebrate groups (birds, mammals, reptiles and amphibians). Data on these groups were then used to refine our understanding of the importance of the hotspots, to set priorities and to provide rankings among the hotspots themselves. Thus, to qualify as a hotspot, an area must contain 0.5% of the global total of vascular plants (estimated at 300,000 species), or 1,500 species, as endemics.

The second major criterion for hotspot status, applied as a second layer of analysis after an area had qualified on the basis of plant endemism, was *degree of threat*. In order to be included on the list on the basis of this criterion, an area must have lost 70% or more of its original natural vegetation, leaving 30% or less in intact condition. The threat criterion enabled us to distinguish between areas with high diversity and endemism under severe threat (Madagascar and the Philippines) and those with equal or higher diversity and endemism but still largely intact, the so-called *major tropical wilderness areas* (Amazonia, the Congo forests of Central Africa and New Guinea) that are the focus of the third of our major priority-setting approaches.

In all, a total of 25 hotspots were identified for the terrestrial realm. These include five (20%) that are exclusively tropical rainforest; seven (28%) that include both tropical rainforest and tropical dry forest; another three (12%) with tropical rainforest, tropical dry forest and other non-forest elements (including desert scrubland or grassland formations); five (20%) that are Mediterranean-type ecosystems; three (12%) that consist of temperate forest and grasslands; one (4%) that is a mix of tropical dry forest, woodland savannas and open savannas; and one (4%) that is mainly an arid region. Of particular note is the emergence of the five Mediterranean-type systems as major priorities. These regions, which include the Cape Floristic Province of South Africa, Southwest Australia, Central Chile, the California Floristic Province, and by far the most diverse, the Mediterranean itself, are characterized by cool wet winters and hot, dry summers. They exhibit very high plant diversity and endemism. Indeed, what remains intact in these five areas accounts for only 0.2% of Earth's land surface, yet it is home to an astounding 26,743 endemic plants, 9% of the global total. Humans have also long impacted these Mediterranean-type systems, especially the Mediterranean basin, because they provide excellent climates for human habitation.

Together, the hotspots once occupied a land area of 17,541,969 km^2, or 11.8% of the planet's land surface—roughly an area the size of Russia. Cumulatively, they have lost 88% of this area, meaning that only 2,127,908 km^2, or 12% of the original extent, remains intact. This represents just 1.4 % of the land surface of the planet, a relatively small area that is equivalent to the American states of Alaska and Texas combined, or about four times the area of France.

Our study indicates that this small portion of Earth's land surface has within it, as endemics, an astounding 133,199 vascular plant species, or 44.4% of all the world's plants. Representation of vertebrates in the hotspots is comparably impressive. Our results indicate that there are 9,681 endemic non-fish vertebrates in the hotspots, representing 35.4% of the global total. Level of vertebrate endemism varies, from the birds, which have 2,746 endemic species (27.6%) found only in hotpots, to the amphibians, which have a staggering 2,572 species, or 53.8% of the global total. Mammals totaled 1,406 endemic species, or 29.2%, and reptiles somewhat higher at 2,957 endemic species, or 37.8% of the global total.

The overall conclusions of the hotspots analysis are simple and obvious. If we have 44.4% of all plants and 35% of all non-fish vertebrates endemic to just 1.4% of Earth's land surface, and if this same 1.4% is under the most severe threat, then it is only logical to focus a significant portion of our attention on these areas in the next few decades, and especially over the next two to five years. To put it even more strongly, the hotspots are fundamental to preventing a mass extinction crisis in the early part of this new millennium. If we fail to act in these areas and lose that 1.4% of the land surface of the planet, we will lose, at the very least, those plants and animals that are found nowhere else than in the hotspots—even if all of efforts in other parts of the world are successful. Without decisive action in the hotspots, major extinctions are inevitable.

Our final priority-setting approach is the *major tropical wilderness areas approach*, which seeks to complement the hotspots by looking at high-biodiversity areas (again mainly in the tropics) that are at the opposite end of the threat spectrum. Whereas the hotspots consist of heavily exploited and often highly fragmented ecosystems greatly reduced in original extent (usually between 4% and 25% remaining), the major tropical wilderness areas are still largely intact (over 75% of original vegetation cover remaining) and have very low human population density (less than 5 people/km^2). These wilderness areas have enormous importance as storehouses of biodiversity, as major watershed protection areas, and as controls against which we can measure the management of the more degraded hotspots. They are also often the last places where indigenous people have any hope of maintaining their traditional lifestyles. And they are likely to assume increasing recreational, aesthetic and spiritual value on an ever more overcrowded planet. Furthermore, since they are still under far less human pressure than the threatened hotspots (although the pressures on them are mounting rapidly), the "opportunity cost" of conservation is much lower in these areas. In other words, large-scale conservation set-asides can be achieved at far lower financial cost than in the areas where little remains and threats are high.

Few such wilderness areas have managed to persist in our rapidly changing world. The principal ones being in the Guayana Shield region encompassing Suriname, Guyana, French Guiana, Venezuela and adjacent parts of Brazil; in a large area of upper Amazonian Brazil, Colombia, Ecuador, Peru and Bolivia; in a substantial portion of the Congolese forest block/Congo River Basin in Central Africa; and on most of the island of New Guinea and adjacent, smaller Melanesian islands (Solomon Islands, New Britain, New Ireland and Vanuatu). The major tropical wilderness areas will be the subject of the third book in this CEMEX series to appear in 2001.

To the question of whether or not we can still have a significant impact on biodiversity losses, Conservation International answers that, despite the significant challenges, we are optimistic. Success will depend on maintaining a very strategic focus on priority regions and building the alliances necessary to pursue conservation in these areas. However, given the strong support accorded to the concept of *threatened biodiversity hotspots* by the scientific community, in particular at a conference entitled "Defying Nature's End" sponsored by Conservation International in Pasadena in 2000, there is every indication that this strategic focus and partnership approach will be maintained. Thus, we firmly believe that by concentrating most of our efforts on these priority areas, we can turn today's conservation dreams into tomorrow's conservation realities.

Lecture

Biodiversity Conservation: A Global Challenge, A Global Priority

Dr. Russell A. Mittermeier
President, Conservation International

As we take our first steps into a new millennium, our planet and our species face some of the most severe threats that we have ever encountered. Amazingly, these are not only geopolitical, like the risk of nuclear war, the spread of terrorism, or other issues that have been preoccupying us since the 20th century, but rather environmental. Our planet currently faces many different environmental stresses, such as overpopulation in the developing world, over-consumption in the developed countries (and increasingly in the richer developing countries as well), global warming, ozone layer depletion, toxic waste disposal, erosion, air, soil and water pollution, and a number of others. Although many of these so-called "brown" environmental issues are more evident and may appear more urgent to our increasingly urban global society, we believe that there is one environmental issue that surpasses all others in terms of long-term significance, and that is loss of our planet's biological diversity. This biodiversity, simply defined, is "the sum total of life on Earth," that wealth of species, ecosystems and ecological processes that makes our living planet what it is; it's our living resource base, our biological capital in the global "Bank," and most importantly, its loss is an irreversible process.

We already have, or can develop technological "fixes" to most of our "brown" environmental problems, and sometimes lack only the economic incentive or political will to put them into place, but biodiversity loss is a different story. Once a species of animal or plant goes extinct, it is gone forever and will never be seen again, and we now face not just the loss of individual species, but the degradation and eventual loss of entire communities and ecosystems upon which we ourselves ultimately depend for our own survival.

One example that indicates mass extinction episodes may already be in progress is provided by the "declining amphibian phenomenon," a global trend in which certain rare frogs and other amphibians with restricted ranges are going extinct, and more common species are becoming rare or appearing with a number of mutations and genetic defects. The golden toad (*Bufo periglens*) from a tiny area of cloud forest in Costa Rica is symbolic of this phenomenon, and has not been seen in the wild for the past decade. Regardless of all our other accomplishments, the one critical measure by which future generations will judge our success, or lack thereof, as a society as we start this new millennium will be whether or not we have the capacity to maintain the same healthy and diverse living planet that we were born into during the last century.

The mission of our organization, Conservation International, is *to conserve our planet's* *biological diversity, and demonstrate that people and Nature can live harmoniously*, and we have dedicated ourselves to achieving this complex objective. Some of the critical issues that we face in conserving biodiversity include the fundamental role of setting clear priorities, and the need for rapid action in the field in the remote areas where so much of our planet's biodiversity is still found.

How Much Do We Know about Life on Our Planet?

In terms of the most critical issues in biodiversity conservation, it is important to recognize that we are still amazingly ignorant as a culture about the rest of life on this planet. Scientists have thus far described only about 1.4- to 1.8-million species of plants, animals and microorganisms, yet estimates of total planetary diversity run as high as 10-million, 30-million or even one hundred million or even more species. If we look at the complex ecological interactions that exist between and among these different species, something that really is just in its infancy as a science, our ignorance is several orders of magnitude greater. We can send spaceships to the farthest reaches of our solar systems, and indeed spend more in the United States in a single space probe to Mars, with the rationale of seeking extraterrestrial life, than we have spent on the ground in the past decade doing biodiversity research. We put millions of bits of information on tiny computer chips, develop extremely sophisticated and complex information superhighways; and we have global institutions like the World Bank and the various United Nations agencies that invest hundreds of millions of dollars towards achieving the worthy, but poorly defined goal of sustainable development.

In spite of this, we still do not know, to within two orders of magnitude, how many other species of organisms share our planet with us. Trying to achieve sustainable development based on natural resources use in the face of such ignorance is rather like trying to construct one of those Martian space probes with nothing more than a few pieces of scrap metal, a hammer and a few rusty nails. Put another way, our wonderful technologically sophisticated 21st century society is in many ways still in the Dark Ages in terms of our understanding of the rest of life on Earth.

To give you an example of this ignorance from my personal perspective, we can look at nonhuman primates, whose study and survival have been cornerstones of my own quarter-century career in wildlife conservation. Although it's not that surprising, we still haven't catalogued all the tiny beetles of the tropical rainforest canopy, all the microorganisms living in our soil, or all the strange creatures far down in the deep ocean trenches, but one would think that we would at least know all our closest living relatives. Nonetheless, even with primates much remains to be learned. In 1992, I described a species of marmoset from the central Brazilian Amazon, and another just this year, again from the Amazon. Including these marmosets, 10 new monkeys have been discovered in Brazil since 1990, bringing the total number of primate species to 79. With 25 percent of all known species, Brazil has the greatest diversity of primates in the world. And my Brazilian colleagues have several more new forms that await scientific description.

Over the past decade in Madagascar, eight new species of lemur have been described, and several others have been rediscovered after not having been seen for more than a century.

So our ignorance of biodiversity is not limited to insects and microorganisms, but extends across the board to all forms of life.

We are similarly ignorant of the true values of biodiversity, the many goods and services that it already provides and that it has the potential to provide in the future, a nascent science that in some quarters is referred to as *valuation of biodiversity*. We talk vaguely about the future potential that the rainforests and the oceans have for new medicines and new agricultural products, we have some notion that the wild relatives of crop plants are important in maintaining genetic diversity and resistance to disease, and we can place economic value on a small number of forest products like timber, rubber, rattan and Brazil nuts that regularly enter into international commerce.

However, the vast majority of biodiversity use at regional, local and household levels throughout the tropics and the rest of the world remains largely unrecognized and unmeasured, and never enters into the national income accounts. The importance of forests in protecting watersheds and the enormous value of wetlands, though generally recognized, also remains largely unassessed in economic terms, although a recent study that placed a value of several trillion dollars per year on watersheds clearly indicated the magnitude of importance that living ecosystems represents to us.

The value that biodiversity and natural ecosystems provide us in terms of recreation is starting to be measured and recognized, especially in the enormous growth of ecotourism in recent years, but the subtle aesthetic and spiritual benefits they provide remain poorly understood. We are so far behind in capacity to value biodiversity that we do not even have in place the metrics by which this kind of analysis could be done. Clearly, much more is needed in the immediate future.

In trying to conserve global biodiversity and put a brake on spasms of extinction impending or already under way, two things concern us in particular. The first of these is the time frame under which we are operating and the other is the need to set priorities. Using tropical rainforests as an example, we have already lost on the order of 60% of all primary rainforest that existed at the beginning of this century; as if that were not bad enough, the situation in a number of countries is far more serious, with as much as 97% lost in certain parts of the world. At current rates of destruction in some of these areas, we have at best five to 10 years to halt these trends and save at least some representative remnants of what once existed.

Where to Begin? The Importance of Setting Priorities

Also of great importance is the need to set priorities. Biodiversity is by no means evenly distributed over the surface of the planet and certain regions and certain countries simply have far higher concentrations of life than others. Rather than trying to do everything, Conservation International decided early on in its history that it would focus its limited resources on those areas that are richest in biodiversity and also under the most severe threat.

Our principal priority-setting approach is based on a concept developed by British ecologist Norman Myers in two scientific papers published in 1988 and 1990. Myers recognized that a modest number of hotspot ecosystems covering a small total land area, most often in tropical forest areas, accounted for a high percentage of global biodiversity. CI scientists revised this concept with Myers in 1998 to update and confirm his earlier findings. The results were published in 1999 in a book sponsored by the Mexican company CEMEX and entitled "Hotspots, Earth's Biologically Richest and Most Endangered Terrestrial Ecoregions."

In this analysis, we found 25 areas around the world of critical importance to biodiversity conservation, based on the number of species present, the number of those species found exclusively in an ecosystem and the degree of threat they face. Their remaining natural habitats occupy only about 2% of the land surface of the planet, and yet have within them more than 50% of all terrestrial biodiversity and more than three-quarters of biodiversity at greatest risk. These hotpots, which include the Atlantic Forest region of Brazil, the Philippines, Madagascar and the Indian Ocean islands, and the Polynesia/Micronesia archipelago, among others, are the most endangered species-rich ecosystems with less than 25% of their original vegetation remaining.

CI's hotspots analysis is a powerful tool to help chart the course for biodiversity conservation because it makes a sometimes overwhelming issue become much more manageable. If a major portion of the world's plant and animal species are found in only 2% of the planet's land surface, then clearly a strong focus on targeted regions will maximize results. The hotspot approach can help guide investments through this critical era for life on Earth. By demonstrating that something can actually be accomplished, further investment can be stimulated and greater involvement encouraged by the private sector, international aid agencies and development banks.

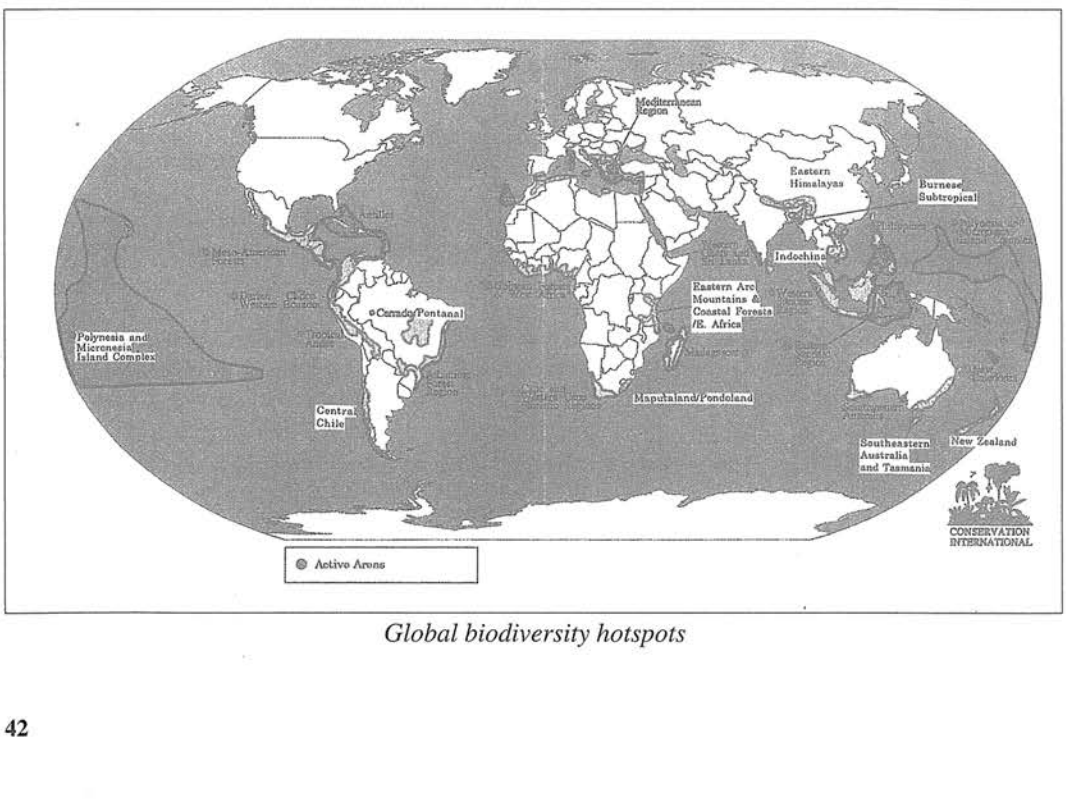
Indeed, a new $150-million fund designed to better safeguard the world's threatened biological hotspots in developing countries was recently launched as a joint initiative of Conservation International (CI), the World Bank and the Global Environment Facility (GEF), and has subsequently been joined by the MacArthur Foundation. The Critical Ecosystem Partnership Fund (CEPF) focuses primarily on the biodiversity hotspots, where it will try to advance the global conservation agenda on several fronts, resulting in improved management of protected areas and coordination in biodiversity corridors. Investments will support projects such as training, trans-national planning, local dialogue with extractive industries, conflict resolution, priority setting and consensus building, strengthening indigenous organizations and facilitation of partnerships between the private sector and protected areas.

At the other end of the threat spectrum, we have the last remaining major tropical wilderness areas. Like the hotspots, these are also rich in biodiversity, but they differ in that they still have more than 75% of their original natural vegetation and they have low human population densities of 5 people/km^2 or less. These areas are few and far between, but they are of great global importance for variety of reasons, among which is the fact that they are the last places where indigenous tribal societies are likely to be able to maintain any semblance of their traditional lifestyle. These include the upper Amazon region of South America; the southern Guianas and southern Venezuela, also in South America; the Congo Basin in Africa; and much of the island of New Guinea. Unfortunately, even these largely intact regions are now under assault, and like Conservation International and the Government of Suriname did in the case of the Central Suriname Wilderness Nature Reserve, it is important to set a precedent in protecting large blocks of undisturbed tropical wilderness.

To meet this challenge, Conservation International has created the Global Conservation Fund (GCF) to help finance major conservation corridors in the Earth's few remaining major tropical wilderness areas. Implementing the GCF will require further refinement of conservation priorities through assessment of the scope of threat to these areas, incorporation of economic assessments that will highlight areas where conservation can best compete with more destructive land uses, estimates of carbon sequestration potential, appraisal of potential funding sources and current investment climates, further biological assessments of unknown areas, and institutional assessments of the feasibility of wilderness protection in certain key countries.

We have also placed emphasis on what I have called the Megadiversity countries; 17 nations out of a global total of more than 230 that by themselves account for more than two-thirds of all life on Earth—terrestrial, freshwater and marine. Countries like Brazil, Indonesia, Colombia, Mexico, Australia, Madagascar, China and the Philippines top this list, which also includes Peru, Ecuador, Venezuela, Papua New Guinea, Malaysia, India, the Democratic Republic of the Congo, South Africa and the United States.

To provide a better idea of the importance of these Megadiversity countries, just three of them, Brazil, Indonesia and the Democratic Republic of the Congo, by themselves account for almost 50% of the world's tropical rainforest. Using the primate example, once again, although populations of non-human primates occur in some 92 countries worldwide, just four of the Megadiversity countries, Brazil, Indonesia, Madagascar and the Democratic Republic of the Congo, account for at least two-thirds of living primate species, including some that are most endangered. The details of the biodiversity found within these 17 outstanding regions have also been published by CI and CEMEX in a book entitled "Megadiversity: Earth's Biologically Wealthiest Nations," which was coauthored by myself, my wife Cristina and the famed Mexican photographer and conservationist, Patricio Robles Gil.



Global biodiversity hotspots

To give you a few examples of these priority areas, I would like to provide a brief profile of the Atlantic Forest region of Brazil, one of the world's top-priority hotspots occurring within one of the two richest Megadiversity countries on Earth; the island of Madagascar, which is in its entirety both a threatened hotspot and a Megadiversity country; and the small South American country of Suriname and the island of New Guinea, which are perhaps the best examples of tropical wilderness areas.

Brazil's Atlantic Forest Region

Starting with the Atlantic Forest region of Brazil, this is a region that has been one of my two principal research interests over the past 25 years. Although we usually hear much more about the Amazon, the Atlantic Forest region is, without a doubt, the highest conservation priority in the country. It is a unique series of ecosystems that is quite distinct from the much more extensive Amazonian forests to the northwest, and once stretched almost continuously from the state of Rio Grande do Norte in northern Brazil, south as far as the Rio Grande do Sul, the southernmost Brazilian state, an area of about 1.2 million km^2, or about 3.2 times the size of Japan. When naturalists passed through this region in the beginning of the nineteenth century, they found some of the richest, tallest and most impressive forests on Earth, with an especially rich orchid and bromeliad flora and an abundant and diverse fauna.

However, this was the first part of Brazil to be colonized, and it developed into the agricultural and industrial center of the country. And this now has within its borders two of the three largest cities in all of South America and one of the two largest in the world, Sao Paulo and Rio de Janeiro. The results have been large-scale forest destruction, especially in the last three decades of rapid economic development, first for lumber and charcoal and then to make way for plantations, cattle, pasture and industry. These maps of the state of Sao Paulo show very well what has happened. Although development took place from the 16th century onward, the real pressure began in the 20th century and especially after 1950. Now, there is only about 3% left of what once was an expanse of forest in this important state.

Things are much the same in the rest of the region, and we estimate that at most 8% of the Atlantic Forest still stands. In some states, the remaining primary forest cover is 1% or less. Most of what has survived is in small, isolated, widely separate forest patches surrounded by developed and degraded land. Only in the mountains in Serra do Mar, especially along the Sao Paulo and Paraná coast and also some extents in Rio de Janeiro and Espirito Santo, do reasonably continuous stretches of forest remain, and even these are at risk.

As one might expect, the animals and plants native to the Atlantic Forest are not doing very well under such circumstances, and it is important to point out that the Atlantic Forest has one of the highest concentrations of terrestrial biodiversity on Earth. Indeed it has an estimated 20,000 higher plants, of which 6,000 are endemic; together with 261 mammals, 73 endemic; 620 birds, 160 endemic; and 260 amphibians, 128 endemic. These numbers make the Atlantic Forest one of the highest five hotspots on Earth, and if the region were a country, it would by itself rank among the top ten countries on Earth for biodiversity.

Unfortunately, much of this spectacular biodiversity is at great risk, and the primates are the species example. There are six genera and 24 different species and subspecies of monkeys found in the Atlantic Forests. Studies that we have been conducting since 1979 indicate that fully 79% of these are endemic. Two groups of monkeys stand out among the rest, they are the muriquis, genus *Brachyteles*, which are the largest of the South American monkeys, and the lion tamarins, genus *Leonthopithecus*, which includes the famous golden lion tamarin and its three spectacular relatives, the golden-headed lion tamarin, the black lion tamarin, and the black-headed lion tamarin, the last of which was not discovered by science until 1990. These animals are representatives of two of the most critically endangered primates genera in the world, and they are now found only in forest remnants in the region. Their numbers are shockingly low, with only several hundred to a thousand golden lion tamarins, black lion tamarins and black-headed lion tamarins, less than 300 of the northern species of muriqui and perhaps a thousand of the southern species of muriqui remaining; only the golden-headed lion tamarin is somewhat more abundant, with an estimated population of 6,000 to 15,000, but even it is considered endangered. These unique and attractive animals have been the flagship species for this entire region. The golden lion tamarin has been the subject of a successful reintroduction program and a major international research and education program. All of these species have been used in a variety of campaigns and study programs that have helped to conserve not only themselves, but their remaining forest habitats as well. As a result, the muriquis and tamarins which were virtually unknown to the Brazilian public at the beginning of the 1980s, are now so popular that they appear on the cover of phone books, on postage stamps, as themes of parades and in theater presentations, and they have even made it onto floats of Rio's famous Carnivale and into the local folklore.

Even more important, by using these species as symbols, we have managed to elevate this previously unknown and overlooked region to national and international attention, to the point that there are now many different conservation programs totaling tens of millions of dollars focusing on the work in the Atlantic Forest, the most recent of which is a 40-million-hectare corridors project that is being discussed by the World Bank and the European Union. As unbelievable as it may seem, much of this would not have happened had it not been for the great appeal and charisma of a handful of monkeys.

The Island of Madagascar

Switching continents now, let's take a trip to one of the world's most exotic locales, the island of Madagascar. And in moving to Madagascar we are not just traveling to another part of the world, we are really traveling back millions of years in evolutionary time. Madagascar is a unique evolutionary experiment, a living laboratory unlike anywhere else on Earth. Although it is located only about 400 kilometers off the East coast of Africa, Madagascar has been separated from the African mainland for a very long time, perhaps as long as 160-million years, and most of the plants and animal species occurring there have evolved in isolation and are found nowhere else in the world. The very high levels of endemism that have resulted, not just at the species level, but at the generic and family levels as well, really set Madagascar apart, and have contributed to its being both on the top of the list of Earth's Megadiversity countries and, like the Atlantic Forest of Brazil, one of the most threatened hotspots as well.

Since it is situated largely within the tropics, Madagascar also has very high species diversity in certain groups of organisms, especially given its relatively small size; about 1.5 times the size of Japan. For instance, although it occupies only about 1.9% of the total land area of the African region, it has more orchid species than the whole of the African mainland, and indeed it is home to about 25% of all African plants. Its total vascular plant diversity is estimated at 11,000 to 12,000 species, of which an astounding 80% are endemic. Reptile and amphibian diversity is also quite high with some 300 species of reptiles, of which 274 are endemic; and 178 species of frogs, with 176 endemic and more species being discovered every year.

However, the most conspicuous and attractive group of organisms in Madagascar, and the one for which the country is best known, is the primates. But we are not talking about monkeys and apes, of which we usually think when we envision primates, but rather the lemurs. The living lemurs are a fantastic radiation of five families, 14 genera and 64 different species and subspecies, 100% of which are endemic to Madagascar, although two also occur on the nearby Comores, where they were almost certainly introduced by man. They include such animals as Madame Berthe's mouse lemur (*Microcebus berthae*), which, at 30 grams, is the smallest living primate, up to ones as large as the Indri (*Indri indri*), which is as big as a medium-sized dog, looks like a cross between a teddy bear and a giant panda, and moves by bounding from tree to tree like an arboreal kangaroo. And the lemur radiation includes some very strange species, most notably the mysterious Aye-aye (*Daubentonia madagascariensis*), which is surely one the strangest mammals on Earth and the only living representative of an entire primate family, the Daubentonidae.

To give some indication of the great responsibilities that Madagascar has, it alone is responsible for approximately 15% of all primate species, about 20% of all primate genera, and close to an incredible 30% of all primate families, making it the single highest priority area on Earth for conservation of these, our closest living relatives.

I should point out that we still know very little about Madagascar's great diversity and that a lot of basic biological inventories of the country's fauna and flora are still needed. This is especially true in the eastern rainforest region, which is the most diverse part of the country, but also the least known. Prior to my first trip to Madagascar in 1994, I had always wondered why little had been done there. It certainly couldn't be any more difficult to work there than, for instance, in remotes parts of the Amazon.

Now, a lot of people have a very romantic vision of what tropical forest research is like and how wonderful it is to be in the forest primeval. Well, it is wonderful in many ways, but I can assure you that it is not all coconut palms and white sand beaches. After a visit to the rainforest of eastern Madagascar, I discovered one of the reasons why so little had been done there: leeches. In all my experience in the tropical rainforest, including a number of other countries in Southeast Asia that have land leech populations, I had never before found them as abundant and as persistent as they are in the rainforest of Madagascar. Fortunately, there is a cure for them. A local plant called mangily is extremely effective in killing them and keeping them off your body as long as it is applied. But if there is no mangily around, the leeches can be a real problem.

Why are we so concerned about Madagascar? And why is it considered such as high priority? Well, although the human population is not that large, about 13-million people, or about 10% of the population of Japan in an area half as large again as Japan, there has been a long history of environmental degradation on the island. Our own species arrived there only about 1,500 to 2,000 years ago, with land-use practices from Southeast Asia and from Africa that were entirely inappropriate to the fragile Malagasy environment, and has had a major impact since that time. For example, a mosaic of forest and woodland savannah once covered the central plateau of Madagascar, but now there is little forest left. Erosion there is as serious as anywhere on the planet, and every year the rivers run red with eroded soil. A recent estimate by the World Bank indicates that Madagascar was losing more than 300-million dollars per year in future potential through erosion. Some 85% to 90% of Madagascar's natural habitats is already gone and the remainder is being chipped away for firewood and charcoal and converted for slash-and-burn agriculture.

Hunting is a problem as well. Although certain species are taboo to certain tribes, like the radiated tortoise among the Antandroy people of the far south and the Indri among the Betsimasaraka people of the eastern rainforest, others are subjected to serious hunting pressure. At risk are not only the lemurs, which are both trapped and hunted, but also other endemic species such as the coua, one of Madagascar's endemic birds.

Lest anyone believe that extinction spasms that we so often talk about are a figment of our imagination, he or she need only look at what has already been lost there over the past 2000 years in Madagascar. Among the species that disappeared are the elephant birds, which were the largest birds that ever lived and whose eggs weighed almost 10 kilograms; and fully nine genera and 16 species of giant lemurs, all of them the larger of the living species, representing almost 40% of known lemur genera. These include some spectacular creatures like *Megaladapis*, which resembled a large Australian Koala and grew to be the size of a calf, and *Archeoindris*, which was larger than an adult male gorilla and probably occupied a niche similar to that of the now-extinct North American ground sloth.

We have been very active in Madagascar, and have focused a lot of attention on key elements of the protected area network of the country, particularly on the Zahamena Reserve in the eastern rainforest region of the country and the Ankafarantsika Reserve in the western, dry deciduous forest. We have also been involved at a policy level. And our current program director, the honorable Leon Rajaobleina, was a former Ambassador to the United States and the former Minister of Finance. We have produced a protected area focused action plan for lemur conservation for Madagascar, a *Field Guide to the Lemurs of Madagascar*, to stimulate ecotourism, a much-needed source of foreign exchange and a great potential growth industry for this country. And in 1995, we held the first-ever biodiversity priority-setting workshop for the country, bringing together experts from Madagascar and all around the world.

Consequently, although we still have a very long way to go in Madagascar, and certainly cannot afford to be complacent, the fact is that there is much reason to be optimistic. We are now in an excellent position to change the course of conservation history in a unique country.

Suriname and Papua New Guinea

Finally, in terms of specific areas, I would like to focus your attention on two parts of the world, Suriname and Papua New Guinea, that really represent the opposite end of the spectrum to the threatened hotspots of the Brazilian Atlantic Forest and the Island of Madagascar. Unlike the hotspots, where so much has already been lost, these two countries fall within the category of major tropical wilderness areas, meaning that, like the hotspots, they are high in biodiversity, but unlike the hotspots, most of their natural vegetation is still intact. These are areas where we still have some hope of achieving natural resource based sustainable development and where there is also some chance that indigenous tribal people will be able to maintain some semblance of their traditional lifestyles.

The first of these, Suriname, is a former Dutch colony that was known as Dutch Guiana. It achieved its independence from the Netherlands in 1975 and is the second of the three Guianas in size and population. It had one of the lowest human population densities on Earth, with only 400,000 people in an area of about 166,000 km^2 (44% the size of Japan). On top of this, most of the people live along the coast, and especially around the capital city of Paramaribo, with only about 5% living in the vast interior. Suriname also has the distinction of having the highest remaining forest cover of any country, with some 90% of its forest still in primary condition, making it one of the best countries for conservation of large intact tracts in this globally important biome.

Suriname's culture is unique and very different from the rest of South America. The coastal region is inhabited by Creoles of African origin: 31% Hindustanis of East Indian origin, 37% Javanese, 15% both of which came over as indentured servants at the turn of the century; Chinese (less than 2%); and Dutch and a variety of other groups of European origin (2%), including one of the oldest Jewish communities in the New World. Several native Amerindian tribes, among them the Trio, the Wayana, the Akurios, and the Bushnegroes or Maroons, inhabit the interior. The Bushnegroes are especially interesting. Numbering some 50,000 and divided into six tribes, they are the last runaway slave cultures in the Americas still living what is in effect a West African lifestyle. They are a fiercely independent group that has lived for centuries with little contact and little interference from the outside world.

On the other side of the planet is Papua New Guinea, one of the biologically and culturally most interesting nations on Earth. Another of the Megadiversity countries, it is also megadiverse in human groups; indeed, in spite of its relatively small size (only a little larger than Japan), it has the highest human cultural diversity of any country, with some 875 different languages spoken over its land area of some 475,369 km^2. What is more, most of these cultures are still intact. Like Suriname, Papua New Guinea has most of its forest intact, and some 97% of it is in the hands of traditional owners. This is rather like the United States or Brazil still being in the hands of the Native American Indians, and is very unusual for a nation that was colonized by European powers.

Back in 1997, when I wrote the first version of this essay, both the integrity of human culture and the natural environment in both Suriname and Papua New Guinea were under severe pressure, to the point that they too were at risk of being propelled into the hotspots category over the next decade. Largely overlooked for centuries, both of these countries were targeted by international timber conglomerates and international mining companies. The threat of timber companies was being driven largely by Malaysia and to a lesser extent Indonesia, Taiwan and Korea, whereas mining interests were coming from a variety of different countries, especially Canada. These activities, which I have referred to as "the last great natural resource grab," have a strong neo-colonial flavor, and, like the European colonialism of past centuries, leave little or nothing for the countries in question.

The attack by timber companies is particularly disconcerting since there is little respect for local forestry legislation. Widespread bribery and corruption, and much under-reporting and cheating on actual revenues, on top of the fact that concessions have five- to 10-year tax holidays, mean that the country receives very little in up-front benefits other than employment for the low income manual labors.

Indeed, analyses of the economics of these operations, including one done for Suriname by the World Resource Institution and Conservation International, indicated that cash profits to the countries in question were very small and bordered on the insignificant. Furthermore, if real social and environmental costs were taken into the equation, these poor countries would have wound up in effect subsidizing the wealthy timber conglomerates by liquidating their only significant long-term assets, their natural resources. Needless to say, this form of predatory exploitation has no place at the beginning of the new millennium and should be resisted by the leadership of countries like the United States and Japan.

I am happy to report that, a year after I originally wrote this piece, the ecological tragedy that Suriname was about to agree to, turned into a conservation reality. Through a variety of efforts involving both high level contacts within the Suriname government and international media attention, we succeeded in convincing the Surinamers that there are better long-term alternatives for them, including ecotourism, bioprospecting, non-timber forest products and perhaps joint implementation of carbon-offset and low-impact timber harvesting. With this input, the Surinamers rejected requests from one Malaysian and two Indonesian companies for some 3-million hectares of timber concessions, representing more than 20% of their forest estate.

Indeed, in recognizing that Suriname's future economic well-being will in part be based on the appropriate use and conservation of its natural resources, together with CI, the country created the Central Suriname Nature Reserve. This conservation corridor links three existing protected areas, making it one of the largest nature reserves in South America, and quite possibly the single-most pristine, tropical forested protected area on Earth. The Central Suriname Nature Reserve forms a corridor linking the three most important protected areas in central Suriname—the Raleighvallen, Tafelberg and Eilerts de Haan Gebergte Nature Reserves—and protects the entire upper Coppename River watershed, one of Suriname's most important river systems.

The new reserve covers a diversity of rainforest ecosystems, and is home to all eight species of Suriname's primates, more than 400 bird species, and other impressive wildlife, such as the jaguar, giant armadillo and giant river otter.

The Central Suriname Nature Reserve is the critically important centerpiece of a long-term conservation and development strategy for Suriname. It is our belief that the creation of this Nature Reserve will generate significant economic benefits for the country and international recognition of Suriname as a global environmental leader. We hope that this major step by one visionary country will inspire other nations to make similar commitments to the protection of critical tropical wilderness areas around the world.

In Papua New Guinea, unfortunately, the situation is much more complex and the international companies much more deeply entrenched, sometimes resulting in political upheavals. The crisis in Bouganville, focusing on its copper mine, has been a major issue for the last decade, and the recent government of Sir Julius Chan was toppled earlier this year because of controversy over logging and mining concessions. At the same time, however, Malaysian companies are well established in many parts of Papua New Guinea and have converted large areas of forest.

Local landowners, many of whom were duped into signing over their land, are showing signs of resistance throughout the country and in other parts of Melanesia as well. In some instances, especially in the neighboring Solomon Islands, contracts were signed with illiterate landowners unable to read the documents they were signing, and logging activities are sometimes carried out 24 hours a day, using floodlights at night, to ensure that the maximum amount of timber can be extracted before the landowners realize what is being done to them and begin to resist.

The role of conservation international in these wilderness area countries is to inform them of the alternatives that exist to such predatory forms of exploitation, and to demonstrate to them successes based on rational biodiversity use in other tropical countries. One particularly successful effort was to take two delegations of Suriname parliamentarians to Costa Rica to meet with then Costa Rican President Jose Maria Figueres, one of the leading proponents of biodiversity conservation, and to see firsthand what was being done in terms of ecotourism and bioprospecting in this enlightened country.

Ecosystem Conservation: CI's Comprehensive Approach

These are some of the problems we face in biodiversity conservation and some of the priority areas in which our organization works. What I would like to do in the remainder of this presentation is to tell you a bit more about the tools that we employ in our conservation programs and the specific kinds of activities in which we are engaged. The mission of Conservation International is "to conserve global biodiversity, and to demonstrate that people can live harmoniously with Nature." Our comprehensive approach is simply referred to as "ecosystem conservation" and includes a heavy emphasis on local capacity building and the need to fully involve local people in all conservation endeavors.

We are particularly proud of the fact that we have a truly international organization. Although our main office is in Washington, D.C., we have 24 offices in the countries in which we work, and most of these are staffed entirely by nationals of the countries in question. We have staff members from more than 25 countries, speaking more than 30 different languages. The field-based programs of the organization rest heavily on what we refer to as our cornerstones, especially science, economics, policy and communications, and all of our programs have a protected area of some kind as their focal point.

A Sound Scientific Basis

Perhaps the most fundamental of all CI cornerstones is *science*, since we firmly believe that neither conservation nor sustainable development can be achieved without the soundest scientific underpinnings. To address this goal, CI, with a generous donation from CI's Board Members and founders of the Moore Foundation, Gordon and Betty Moore, has created the Center for Applied Biodiversity Science (CABS), a knowledge-based early warning system designed to identify critical issues confronting the conservation of biological diversity. It both anticipates destructive situations and is a preemptive force. The Center's mission is to strengthen our ability to respond rapidly, wisely and effectively to emerging threats to the Earth's biological diversity. To accomplish this, the Center mobilizes science, acts strategically, leverages partnerships and broadens public outreach. The Center identifies the most serious threats through a managed network of experts in related fields, such as natural resource economics, conservation biology, biogeography, forestry, marine biology and others. Experts are drawn from governmental agencies, international organizations, development agencies, private corporations, universities, research centers, nongovernmental organizations and museums.

Each year, the Center funds 10 to 15 outstanding, senior-level scientists from a range of backgrounds as Biodiversity Research Fellows, enabling them to focus on developing field-based solutions. If appropriate, the fellows field-test new theories, building upon Conservation International's presence in the hotspot regions.

Our other signature science program, the Rapid Assessment program (RAP), which uses the talents of some of the world's best field biologists to provide quick assessments of poorly known tropical ecosystems is overseen by CABS. RAP methodologies have been perfected by a team of superstar scientists working mainly in the Tropical Andean region of South America, the Melanesia region, Madagascar and, more recently, in the Caura River basin of Venezuela, the Okavango Delta of Botswana and Irian Jaya in Indonesia. Upcoming RAP expeditions include the Cutucu Mountains of Ecuador and the Kanuku Mountains of Guyana.

CI also works closely with the World Conservation Union, especially through its Species Survival Commission. This commission is the world's largest volunteer network of biodiversity experts, and currently is composed of some 8,000 members divided into more than 100 specialist groups. I have chaired the Primate Specialist Group since 1977, and we produce a wide variety of newsletters and journals through the SSC. These include a primate conservation journal, four different primate newsletters (for Asia, Africa, Madagascar and the Neotropical region), a Neotropical bat newsletter, an edentate newsletter, and a journal of chelonian conservation and biology.

We have also just produced the latest version of the IUCN Red Data Books and Red Lists, the principal reference works on threatened species and a mainstay of the conservation community for some three decades. Finally, we are producing a Tropical Field Guide series aimed at providing ready-to-use information on a wide variety of tropical organisms, with a special goal of increasing interest in specialized ecotourism and "life-listing" and "watching" for everything from frogs and butterflies to turtles and monkeys.

Economics: Conservation through Enterprise Development

Also of great importance for Conservation International is *economics*. We recognize that it is essential to demonstrate that good biodiversity can also be good business, and that we can in fact come up with "win-win" solutions that conserve natural ecosystems and contribute to the national and local "bottom line" as well. To address these issues CI, with a generous donation from Ford Motor Company, has recently created the Center for Environmental Leadership and Business (CELB). Like CABS, CELB operates as a division of Conservation International and is headquartered in Washington, D.C. But it is governed by its own executive board of prestigious business and environment leaders.

The Center works in partnership with a wide range of companies and environmental organizations to promote business practices that reduce industry's environmental effects and contribute to conservation. These practices also benefit business by cutting the costs associated with environmental impact and by enhancing a company's reputation with communities, customers, employees, and shareholders. The result is what the Center calls a "net benefit" for both the global environment and for business. The Center concentrates on those industries with the greatest environmental effect on critical ecosystems and those with the potential to bring about positive environmental change, including agriculture and fisheries, forestry, energy and mining, travel and leisure, transportation, manufacturing and financial services. The Center provides an open forum where business leaders, environmentalists and academics can work together to create innovative solutions.

Another of Conservation International's tools is the Conservation Enterprise Fund (CEF). This was created in 1999 with a $1 million loan from the Small and Medium Enterprise (SME)—Global Environmental Facility program of the International Finance Corporation. CI acts as the financial intermediary to provide debt and equity financing of $25,000–$250,000 to small and medium-sized enterprises ($5 million or less in assets) that are strategically important to conservation. The CEF is an enterprise development tool that enables conservation enterprises to expand their operations through financial leverage. CEF funds are directed to businesses engaged in activities such as agroforestry, ecotourism and wild harvest products.

Multifaceted Policy Program

The third of our cornerstones is *policy*, and it recognizes that you can have the best possible science and the strongest economic incentives and still fail in your conservation efforts if perverse national and international policies militate against what you are trying to accomplish. Our policy program is multifaceted, and deals with a wide range of issues. Beginning with the first ever debt-for-nature swap carried out by Bolivia in 1987, we have always paid attention to creative financing mechanisms and have attempted to stretch each conservation dollar as far as possible. Subsequent to that first debt swap, we have also carried out swaps in Mexico, Costa Rica and Madagascar, and several of these are producing returns.

More recently, we have pushed the concept of trust funds designed to meet the recurrent costs of managing protected areas. CI has structured national and regional conservation funds to provide long-term, steady disbursements consistent with the needs of field programs. Conservation funds have contributed significantly to conservation for specific regions, and also to the building of leadership and institutions within communities.

The creation of a fund usually requires the creation of a board of directors drawn from local communities, from government agencies and from business groups. The process of administering the funds, making grants and dealing with regional and national institutions builds individual leadership and strengthens community interests. In essence, these funds act as catalysts in developing consensus between different interest groups such as local communities and donor agencies. Consequently, national and regional conservation funds have now become important actors in delivering resources to conservation projects.

CI's policy department is also building on our combined experiences in conservation biology, economics and policy to promote "best practices" in natural resource extraction with the goal of influencing the resource-extraction industries to become forces for biodiversity conservation, rather than threats to it.

Finally, we have worked on influencing a variety of legislative processes relating to biodiversity, from the United States to Brazil, to Madagascar, the International Finance Corporation (IFC), and the Global Environment Facility (GEF), among others.

International Communications Program

Finally, the *communications* cornerstone, which recognizes the fact that support for conservation must ultimately come from all sectors of society, from the highest-level decision makers to the poor villager living in the vicinity of a globally important protected area. Our International Communications department helps to develop regionally appropriate strategies for getting the word out and provides video and other materials ready for use in-country. Our Washington, D.C., Media department concentrates on getting press, television and Internet coverage for biodiversity, and on keeping the issue on the agenda of the national and international media at all times.

These different conservation "tools" are mixed together in a variety of ways to come up with the most effective and culturally sensitive conservation programs in each of the 23 countries in which we work, and we feel that our programs have had significant impact everywhere. Indeed, our basic philosophy is that we should not be involved in a particular area if our presence is not going to make a difference, and that we should work only where we have a real chance of "changing the course of conservation history."

Realizing the Dream of Biodiversity Conservation

After all is said and done, where do we really stand at this critical juncture in human history, as we take our first steps into this new millennium. Will the whole world wind up looking like a devastated central plateau region of Madagascar or is there a chance of developing solutions and achieving some level of harmony between Nature and the needs and aspirations of our own species?

Well, I am an optimist by nature, and I believe that we have made very significant progress, especially in the last 10 years. Ever since the Earth summit in Rio de Janeiro in June 1992, a much criticized and underrated event that I believe was the turning point in biodiversity conservation, we have seen some very important seed changes in attitude on the part of governments, multilateral banks, bilateral aid agencies, the different branches of the United Nations and other major players.

The World Bank and other major international lending agencies, which were considered to be the enemy by the environmental community as recently as the mid 1980s, have done a major turn around and they are slowly becoming a positive force for conservation (although to be sure much needs to be done and some components of the World Bank family, especially the International Finance Corporation (IFC) lag far behind).

I had the privilege of chairing the first ever World Bank task force on biodiversity in 1998, which was actually responsible for first introducing the term "biodiversity" into the Bank lexicon. Virtually nothing was being done on the issue at that time. Now, just 13 years later, the World Bank has become a major player in biodiversity conservation, and we expect it to advance even further under the able leadership of Bank President Jim Wolfensohn.

The Global Environment Facility, a joint program of the World Bank and the United Nations Development Programme (UNDP) and the United Nations Environment Program (UNEP), and housed at the Bank, has put several hundred million dollars into biodiversity conservation since 1993. Another product of the Earth Summit, the Biodiversity Convention, provides the international legal framework and a forum for discussing biodiversity issues on a legal basis.

However, the most encouraging new development is, without a doubt, the increasing interest demonstrated by the private sector. Over the past few years, and again especially since the Earth Summit in Rio, we have seen the emergence of a new generation of corporate executives who are truly interested in doing something positive for the global environment and also understand that being "green" is good for the "bottom-line."

Here in Japan, we at CI have had an excellent relationship with the Keidanren for just the past ten years, and they have established an important nature conservation fund to support worthy projects in tropical countries. In the United States, real leadership on biodiversity conservation is coming from corporations like INTEL, United Airlines, Mobil, McDonalds, Ford Motor Company, Disney, Starbucks and a number of others, and in the tropical countries we are seeing the same trend with major participation from companies like Pulsar and CEMEX in Mexico and the Unibanco and Banco Real in Brazil. Since so much of what happens in the world is driven by or at least heavily influenced by the corporate sector, we are particularly pleased by this encouraging new trend.

The role of Japan is especially critical. As one of the world's economic powers and a major trendsetter in the Asia-Pacific region, and indeed the entire world, Japan's example is followed very closely. Japan needs to take a leadership role in environmental issues in general and in biodiversity conservation in particular, and there are very encouraging signs that this is taking place. The creation ten years ago of the very important Blue Planet Prize, which I truly believe to be the environmental equivalent to the Nobel Prize, is one such sign, and we at CI feel honored and privileged to have received this prestigious award this year.

The final message I would like to leave you with is that we all have to be upbeat and optimistic about biodiversity conservation. In spite of all the gloom and doom and endless reports of destruction, species loss, and environmental disasters, there are real success stories out there. We have to learn from them, build on them and replicate them wherever possible. It is going to take ever increasing interest, financial support and technical support from developed countries like Japan and the United States, but I think that by working together with our colleagues from biodiversity-rich tropical countries, we can achieve solutions that will help us to maintain life on Earth for future generations and attend to real needs of people at the same time. We simply have to approach conservation as the art of the possible, and if we can do that, I see no reason why we can't turn today's conservation dreams into tomorrow's conservation realities.

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