INTERFACE BETWEEN ECOLOGY AND LAND DEVELOPMENT IN CALIFORNIA

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Southern California Academy of Sciences
1993

Published in 1993 by
The Southern California Academy of Sciences, Los Angeles, California

Printed by
The International Association of Wildland Fire
PO Box 328
Fairfield, Washington 99012

ISBN 0-9626305-3-5

To my daughter Kathryn
and the future generation of Californians

PREFACE

The interface between ecology and land development is a battleground of opposing interests and values, with factions fighting to ensure their own version of quality of life. Historically, land development has had broad-based support, and land developers have traditionally viewed themselves as pioneers, helping to shape the future through conquest of the wilderness frontier. In the last decade of the 20th century, such a view is rapidly becoming an indefensible position. By most measures we have won the battle and gained domination over wilderness. Unfortunately our world view has not kept pace with the ramifications of our victories and Californians are in need of a new world view. The adjustment to be made is not unlike the behavioral adjustments required for normal human development. As psychologists know, behavioral rules worked out during childhood are often unsuccessfully carried over into adulthood. Similarly, the exploitive role of land development in California's infancy is not a proper one for today.

What is emerging in California and elsewhere is a growing realization that we have won the war against nature. However, as is often true, such victories threaten a sustainable peace. To guarantee quality of life we must come to grips with how to ensure that necessary exploitation of our natural resources does not result in over-exploitation.

To this end, the symposium "The Interface Between Ecology and Land Development" was convened 1-2 May 1992, at Occidental College in Los Angeles. The goal of this conference was to bridge gaps that are not commonly filled between disciplines, and to provide a forum that would bring together consultants, academic researchers, government servants responsible for policy implementation, and citizens concerned with conservation of our natural resources. What emerged was a successful meeting of the participants' minds — their views, approaches, concerns and limitations. As is evident from these proceedings, each group has much to learn from the others. While there is much practical information contained herein, the collective message of these papers is a call for a "new world view" for California, one that requires a more disciplined approach to our environment if we are to maintain the quality of life we currently enjoy.

With each new development we tip the balance of nature in a direction that is often undesirable and irreversible. While it is clear that new approaches and policies will help safeguard our natural resources, we need a citizenry with a new aesthetic view of our surroundings. An unfortunate feature of modern life is that many Californians have lost touch with our environment and believe that technology can solve our problems and convert this "desert into a green oasis." An example is the often-heard lament that California "lacks seasons," which, of course, is only true in the urban landscape dominated by a non-native flora artificially maintained through copious irrigation. The natural environment is an important part of California's heritage, and a citizenry with a broader aesthetic appreciation of the riches of that natural environment is badly needed if we are to live in harmony with the remnants of what is left. Now we are at a crossroads where we have the momentum to change the world view of future Californians, making it one in which we minimize our imprint on the landscape in order to preserve our heritage.

J.E. Keeley, Editor
Occidental College

ACKNOWLEDGMENTS

Thanks are due Melanie Baer Keeley for inspiration and assistance in organizing this conference, Amy Gonzalez for her excellent organizational skills, May Huddleston for her keen editorial eye, and Maria and Jason Greenlee of The International Association of Wildland Fire (Fairfield, Washington) for their printing expertise, which has contributed to a high quality Proceedings.

Financial support for this publication was generously provided by the following organizations:

THE SOUTHERN CALIFORNIA ACADEMY OF SCIENCES
OCCIDENTAL COLLEGE
JOHN RANDOLPH HAYNES AND DORA HAYNES FOUNDATION
THE NATURE CONSERVANCY
U.S. FISH AND WILDLIFE SERVICE
CALIFORNIA FISH AND GAME, NATURAL HERITAGE DIVISION
HEALTH AND HABITAT
U.S.D.I., CHANNEL ISLANDS NATIONAL PARK
TREE OF LIFE NURSERY
IMPACT SCIENCES, INC.
WETLANDS RESEARCH ASSOCIATES, INC.
ZOOLOGICAL SOCIETY OF SAN DIEGO, CENTER FOR REPRODUCTION
OF ENDANGERED SPECIES
MICHAEL BRANDMAN ASSOCIATES
JONES AND STOKES ASSOCIATES
URBAN VISION
OGDEN ENVIRONMENTAL AND ENERGY SERVICES

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Interface Between Ecology and Land Development in California
Edited by J.E. Keeley. 1993. Southern California Academy of Sciences, Los Angeles.

KEYNOTE ADDRESS

Ecology and Species Extinction: A Global Perspective

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I think the reason that we're all so interested in the subject of this remarkable conference is that there is evidence all around us that the world is changing in ways that are deeply troubling. Even those of us that have the good fortune to live in California, in very great prosperity, are beginning to understand that unless we address these problems effectively, the kind of world that our children and grandchildren will inhabit will resemble very vaguely the kind of world that we're enjoying at the present time.

The present rate of loss of species and the reduction of genetic diversity in plants, animals, fungi, and microorganisms constitutes an unprecedented environmental problem of global dimensions. These species are being lost forever as a result of pressures generated by the growth and behavior of the human population. The consequences of this extensive loss for human beings now and in the future will be severe, whether these consequences are viewed from a moral, aesthetic, scientific, or economic perspective.

Notwithstanding the central importance of this problem, it has not yet received the level of attention that is accorded other ecological concerns, such as oceanic pollution, the thinning of the stratospheric ozone layer, or global warming. Biological extinction has usually been thought of in terms of such matters as the loss of elephants or rhinos in Africa, of pandas in China, or whooping cranes in North America. It has been viewed as a local problem, and not seen properly as a matter of concern for every one of us. In fact, of all the global problems that confront us, this is the one that is moving the most rapidly, and the one that will have the most serious consequences; in addition, and unlike other global ecological problems, it is completely irreversible.

Biological diversity is the only basis of sustainable productivity, both for the earth as a whole, and for human beings locally. For that reason, its loss has very serious consequences with respect to that productivity, and the potential for improving it. The whole set of species of plants, animals, fungi, and microorganisms that occur together at a particular place make possible the functioning of an ecosystem at that place. Undisturbed ecosystems regulate the flow of energy, ultimately derived from the sun, and the cycling of nutrients on which all life depends. When natural ecosystems are undisturbed, they build and protect soils, control hydrological cycles, and regulate characteristics of the atmosphere, thereby playing a major role in determining climate throughout the world. Ecosystems are the basis for the overall functioning of our planet; the effectiveness of our sustainable utilization of these ecosystems will determine our quality of life now and in the future.

The complex ecosystems of the tropics and subtropics — rain forests and coral reefs are two of the best-known examples — have evolved in their localities, and they function under the prevailing conditions there, just as do the species-poor ecosystems found at high latitudes, on poor soils, or in the nutrient-starved middle of the ocean. It is not true that simplified ecosystems, like wheat or corn fields, can be substituted successfully over the whole world; in many areas, they simply are not productive. Natural ecosystems function well in their localities, where they have evolved over very long periods of time; in order to modify them for our benefit, or to replace them with others that produce more of particular products that we want, we have to understand the properties of the undisturbed ones.

In addition to the services that organisms provide as members of ecosystems, they are of fundamental importance to us individually. Indeed, we obtain our food, medicine, chemicals, fiber, clothing, structural materials, and energy (bombast), often almost exclusively from organisms — and we have just begun to understand how to use a very small fraction of those that are available. It is only 38 years since DNA was postulated to be the genetic material, and we simply do not understand the uses of biology yet, even though our lives ultimately are based on the functioning of biological systems.

Relative to food, approximately 103 species of plants contribute 90 percent of national per capita supplies of food plants at present, with perhaps a few hundred others being important locally. Most of these have been in cultivation for hundreds or even thousands of years, and none have been selected because they are particularly appropriate for the overcrowded world of today. It is, however, of great importance to maintain the genetic diversity of these plants, and to attempt to develop additional sources of food from among the tens of thousands of other plants that may be suitable for this purpose. Important tropical cultivated plants, frequently trees and shrubs, are not amenable to the standard methods for cultivating annual and perennial herbs that have been developed in temperate regions, and thus tend to be undervalued. Furthermore, subsidies to temperate-zone crops, grown for various purposes, and the lack of adequate supplies of capital in many tropical countries, retard the development of their native plants, even those with excellent promise. Overconcentration on the 20 or so best-known food plants tends to lead us to neglect the others, as well as the indigenous systems of cultivation that support their use. Relevant knowledge is being lost rapidly all over the world.

Beyond food, there are many other useful products that plants, which are natural biochemical factories, can provide. Plants are traditional sources of medicine, and still provide the major source of medicine for most people in the world. Most pharmaceuticals, in turn, have either been derived from plants, fungi, or bacteria, or are based on molecules first observed in these organisms. To give just a few examples, vinblastine and vincristine, derived from the rosy periwinkle (*Catharanthus annuus*), a native of Madagascar, are effective against certain forms of childhood leukemia, raising the chances of survival past the age of 5 from about 10 percent to about 90 percent; they reached the market in 1971. The alkaloid artemisin, derived from an annual wormwood (*Artemisia annua*), is now being investigated actively as an alternative to quinine, the usual prophylactic against the *Plasmodium* organisms that cause malaria, a disease that afflicts about 250 million people at any one time. The two molecules are entirely different in structure, and neither the existence of artemisin nor its effectiveness against malaria could have been predicted from the existence of quinine, except for the fact that the Chinese people, who employ some 6,000 of the estimated 30,000 species of plants in their country for medicinal purposes, have been using extracts of the wormwood against malaria for more than 2000 years. A particularly relevant example to Californians is the Pacific yew tree, indigenous to coniferous forests of the Pacific Northwest. Once considered a weed by the timber industry, today it is a highly prized species by the pharmaceutical industry, for its bark contains taxol, which is the most promising new drug for the treatment of certain cancers. Such examples could be multiplied indefinitely.

Given the possibility of genetic engineering, which provides the opportunity of transferring genes from one organism to another and thus enhancing the qualities of the recipient, the potential usefulness of individual organisms — even though they may have no economic value themselves — is obvious. These principles must be applied fully to the improvement of sustainable, productive systems in developing countries, which in turn will require a massive augmentation of the human and institutional capabilities of these countries, a subject to which I shall return later.

Aside from the obvious economic importance of the biological diversity that we are losing because of our inattention to the problem, many have considered that there is a serious moral question whether a single species, ours, has the right to drive into extinction hundreds of thousands, and ultimately millions, of other organisms that share this world with us. Life on earth originated at least 3.5 billion years ago, in a world that was richly populated with other kinds of animals, plants, fungi, and microorganisms. What should our appropriate place in the world be, quite apart from the question of our ultimate survival, which obviously depends on our skillfully managing the ecological systems that surround us?

Why Is There a Problem?

Although human beings are biologically only one of the millions of species that exist on earth, we control a highly disproportionate share of the world's resources. The major changes that are taking place in the constitution of the atmosphere illustrate this point clearly, and the resulting trends toward climatic warming and increased ultraviolet radiation threaten to alter fundamentally the nature of the planet. Even from space, our impact on the character of the earth we inhabit is clear, and this impact is becoming more intense with every passing year.

One way of measuring the magnitude of our collective impact on the earth is to consider the proportion of net primary production on land that human beings appropriate. Net primary productivity is the amount of energy left after subtracting the respiration of primary producers (plants, algae, and a few kinds of bacteria) from the total amount of energy, almost all of which is derived from the sun, that they fix biologically. These organisms capture the energy through the process of photosynthesis. In turn, the materials that they incorporate into their bodies provide the total food resource for

all other organisms on earth: for animals, fungi, and all other organisms that do not have the ability to photosynthesize. How much of this total resource do human beings use directly, coopt, or forego at present, and how much is left to support all of the millions of other species on earth?

Currently, organic material equivalent to about 40% of the present net primary production on land is being consumed or diverted by people. The material is being used by human beings and organisms associated with them in such a way as to deny it to most of the other millions of species that occur on land. An equivalent concentration of the earth's productive resources by a single species clearly has not occurred for at least hundreds of millions of years; and if such a concentration ever did occur in the past, it would have done so at a time when only a tiny fraction of the numbers of species that exist today would have been present.

Why is the human pressure on the biosphere so enormous, and what does it tell us about our prospects for the future? Starting with the discovery of agriculture, which seems to have occurred independently in several areas about 10,000 years ago, the human population has grown rapidly. There seem to have been about two million individuals in the entire world at that time; by the time of Christ, their numbers had grown to some 200 million, still less than the current population of the United States. The world population first reached the level of one billion people in the middle of the last century, and then took some 80 years to reach two billion, in about 1930. Some 57 years later our population reached five billion and it is now growing at a rate estimated at 1.7 per year; if the current rate were sustained, our numbers would double to the staggering level of 10 billion people in just 40 years — by the year 2027! In fact, the rate of increase is slowing down throughout most of the world, and most demographers estimate that the global population will stabilize at a level of perhaps 10 billion people at some point in the second half of the next century.

These incredible numbers, taken together with what was pointed out earlier, immediately call our attention to a very serious problem. If we are now consuming 40% of the world's total productivity on land, what steps are we taking to be able to use more of it in a sustainable way? Agricultural productivity has increased 2.5 times since 1950, but it has done so as a result of a 7-fold increase in the use of fossil fuels, a level of increase that cannot be supported in the future, and one that is contributing substantially to the increased level of carbon dioxide in the earth's atmosphere, with its attendant effects on the climate. The global human population is not well served at present levels of consumption; we may therefore legitimately ask how we might hope to improve our situation in the future, when our swelling numbers will place even higher demands on an earth that may well not be able to supply our needs in a sustainable fashion. It is clear that drastic action, going far beyond anything that we have contemplated yet, will be necessary if we are to be even approximately as well off in the decades to come as we are now. Despite these relationships, we seem to be able to continue to ignore this problem, even though we have already become a dominant ecological force without parallel in the history of our planet.

What about the future? At the present rate, the global human population would double in 39 years. This clearly will not occur, however, because too many of us will die along the way. Still, something approaching a billion people will be added to the total during the 1990's — as many people as populated the entire world less than 200 years ago, at the start of the Industrial Revolution. The addition of these people makes the prospects of alleviating the widespread poverty and starvation that afflict so many of us remote, even if we redouble our efforts to accomplish these aims.

It is a national disgrace for us who live in the United States that, having provided leadership in the worldwide family planning efforts that are underway throughout the less developed world now, we have turned our back on these efforts and refuse to provide funds to those very multilateral agencies that could best administer them.

It is a national disgrace that, although we indulge ourselves by consuming at a rate 20 to 30 times that characteristic of most of the less developed countries of the world, we have never even considered adopting a population policy for ourselves. The impossibility of putting in place an appropriate immigration policy without having a national population policy ought to be obvious to any biologist.

Sadly, the loss of biological diversity is not widely recognized as a global problem. That may sound strange to this audience, which is so aware of the problem, but the world's leaders, as you may have noticed, are not clamoring to put in place any initiative to deal with this issue. To some extent, I think that we biologists have been at fault. As "global change" has become a widely acceptable theme — the U.S. has proposed spending more than $1 billion in this area in the coming fiscal year — we have, I would suggest, tried too hard to link biological diversity with this movement, and thus to secure additional funds to support our efforts. The net effect has been to make the problem of the loss of biological diversity appear as a kind of minor component (one of unfortunate side consequences) of the atmospheric changes that "everybody" understands. The problem of the loss of biodiversity has also been linked conceptually with the loss of tropical forests, which does contribute substantially to the accumulation of carbon dioxide in

the atmosphere, and "the biological diversity problem" is often equated in the political mind with "the tropical forest problem," both then being relegated to a side category of a major effort to model global change.

It is a sad commentary on the selfishness of human nature that some economists will still argue that there isn't any real problem, so let's get on with business as usual. In this way, many business journals, for example, simply ignore these issues, even though the CEO of many major companies would be dismissed for incompetence if he or she were to take as simpleminded an approach to environmental problems as is presented as gospel on a daily basis in the major trade journals. As long as we regard 2.5% growth as barely acceptable, applaud rising populations in our cities, states, and nations and deplore declines, and fall back on the oxymoron "sustainable development" as the Holy Grail that we seek, we clearly shall continue to destroy the sustainability of the world as surely as if we had adopted a general plan to accomplish this aim.

How Rapidly Are Species Being Lost?

In order to estimate global rates of extinction, we must first estimate how many species there are. About 1.4 million have been named, including about 250,000 plants, 44,000 vertebrate animals, and 750,000 insects. Plants and vertebrates as well as a few other groups, such as butterflies, are relatively well known, with probably 90 percent of the species named, although very little information is available about most of them. Comparing the number of species of these groups that are present in different parts of the world, and estimating our degree of knowledge of other, less well known groups, we can say only that the world total of number of species of organisms is likely to fall between 10 million and 100 million species. As E.O. Wilson of Harvard University has pointed out, we can not even estimate the number of species on earth to an order of magnitude! For the tropics and subtropics of the entire world, there are 400,000 to 500,000 named species of land dwelling organisms, out of a total estimated as between 8.5 million and 100 million. No wonder that we cannot understand how to manage most tropical ecosystems well! In the sea, there are perhaps a tenth as many kinds of organisms as exist on land, again mostly unknown at present except for relatively conspicuous forms and those that live on coastal shelves.

The impact of human beings on forests and other biologically rich communities around the world is so intense that we are losing species, most of them unknown, at a rate between 1,000 and 10,000 times greater than that which occurred before our ancestors first appeared on earth. Habitats such as tropical rain forests, which occupied about 7% of the world's surface at their maximum extent, and apparently are home to more than half of the world's species of organisms among the most poorly known organisms found anywhere, are being destroyed rapidly. Most tropical rain forests will be gone in less than 40 years, during which time the populations of most developing countries will more than double. The loss is resulting both from the conversion of these forests for economic benefit, and extensive forest farming being carried out by large and increasing numbers of poor people throughout the world.

With this background, it is possible to offer an estimate of the global rate of extinction. This estimate is based on our knowledge of relatively well-known groups of organisms and the degree of habitat loss in the areas where they occur. For plants, perhaps 20 to 50% of the total number of species, and a third or more of those in the tropics, are a risk during the next two or three decades. The projected loss of some 50,000 of the 250,000 species of plants by the year 2020 would have extremely serious consequences for human prospects in the future. By analogy, perhaps 8,000 of the 44,000 species of vertebrates might become extinct during the same period. If we accept the relatively low estimate for the total number of species of organisms in the world, 10 million, then perhaps 3 million of them are likely to be lost during this period of time, with fewer than 10 percent known to science. This would amount to the loss of nearly 300 species a day over the next 30 years, including about 5 species of plants and nearly 1 species of vertebrate each day. The rate will presumably accelerate as the years go by. As approximately 1 billion people are added to the populations of tropical countries during the 1990's and each of the subsequent two decades, even though world population growth is decelerating, it is difficult to see how consequences of this magnitude can be avoided.

A Plan of Action

How can we learn about the world's organisms, save as many as possible of them and thereby improve our prospects for the future? In the most general terms, biodiversity will be preserved best in a stable world, characterized by sustainable productivity. Actions to conserve biodiversity, therefore, must be organized around the achievement of this goal. At the onset, it must be stressed that since the conservation of biodiversity depends on the direct perception of the governments and people of individual countries of its value, strategies to save biodiversity globally must be designed so as to permit understanding and commitment from the participating nations. Specific actions designed to conserve the

world's remaining biodiversity must also be consistent with the present global dynamics and in particular with the developing world's strong economic dependence on natural resources, which is unlikely to change during the next century at least.

Given this level of participation by developing countries in the process, the first prerequisite of a sustainable world is the attainment of a stable human population. Considering that the present human population — 5.3 billion people — have inflicted such obvious and extensive damage on the sustainability of the earth, wasting over a fifth of the top soil, destroying more than half of the forests, polluting a major proportion of the fresh and onshore marine waters, and changing the characteristics of the atmosphere profoundly, it is a sobering thought that two to three times the present number of people may be present when stability is finally achieved. At that point, the wise use of organisms, individually and in combination, will make possible security for all people.

Reaching a stable human population will not in itself allow the attainment of a stable world. For such a condition to occur, the problem of poverty and social justice must be addressed much more effectively throughout the world. Overconsumption, involving the direct utilization of more than four-fifths of the world's resources by the rapidly shrinking fraction of the global population — now less than a quarter of the total — that lives in industrialized countries, must be brought under control. Plans to preserve, or even to utilize properly, biodiversity will fail as long as the global community continues to ignore this enormous problem. The annual net flow of tens of millions of dollars from poor, developing countries to rich, industrialized ones is a major factor in regional and worldwide instability.

Assuming that the twin problems of population and poverty in the developing world and overconsumption in the industrialized nations — the attainment of social justice on a global scale — could be addressed adequately, there are a number of strategies that could be employed for the management of biodiversity, including the conservation of a reasonable sample of the species that exist today, despite the major problems that have just been outlined.

First, a worldwide system of protected areas, perhaps based on the UNESCO World Heritage program, ought to be established and maintained. These protected areas should be selected systematically so as to include the greatest possible proportion of the existing global biodiversity. They must be managed in a regional context, taking into account modified and partly natural ecosystems and human interactions of all kinds, since it will clearly not be possible to protect all of the world's biodiversity by preserving samples of pristine ecosystems in their original condition permanently. This will happen only with the full participation of the peoples of developing countries, who must be assisted strongly by the industrialized world in this effort.

Second, mechanisms must be established for the preservation of samples of selected organisms outside of these natural areas. Plants, for example, with 250,000 species, are a likely target for such efforts. Properly supported networks of botanical gardens and seed banks could play a major role in the attainment of these goals. Other groups of organisms, such as bacteria and fungi, lend themselves to preservation in culture centers, and are extremely important economically.

In pursuing these and related endeavors, the development of strong scientific communities in the developing countries themselves is of fundamental significance. When this has been accomplished, the people who live in these countries will come to appreciate the importance of the proper management, sustainable use, and conservation of biodiversity, and will carry out the necessary steps to accomplish these objectives. At present, only about 6 percent of the world's scientists and engineers live in developing countries, which have a rapidly growing 77 percent of the world's population. Consequently, the chances for most countries to improve the technological basis for sustainable productivity without outside assistance are therefore poor. Developing countries must be given the chance to explore the multiple paths, consistent with their own social values, for making biodiversity an indispensable ingredient of socioeconomic, cultural, and scientific development.

One attractive model for dealing with biological diversity in a developing country is that of the Instituto Nacional de Biodiversidad (INBio) in Costa Rica. Bringing together the nation's scientists, biological collections, libraries, and other sources of information, INBio is exploring the total set of organisms that occur in Costa Rica comprehensively, and putting the knowledge to work for the benefit of Costa Ricans. The information about biodiversity is organized in a major relational database, which can be used to identify gaps in the available information. Given that background, intelligent efforts can be made to fill those gaps.

National biological inventories are effective tools for national development, and can assist greatly in building national capabilities to deal with biological diversity. They can be used actively for identifying individual organisms for commercial use; groups of organisms for the construction of artificial communities to promote local ecological stability; as a source of information to assist in making decisions about appropriate of organisms; for scientific studies; and for conservation purposes, including both the management of reserves and their integration into their regions, and the preservation of individual organisms of interest in botanical gardens

and zoos, seed banks, and stock culture centers for microorganisms. Features of the organisms of direct economic importance and other information about the key features of organisms as functional units of natural communities should be collected aggressively, and the information gained be put to use for their management and commercialization.

In connection with their management of biological diversity, all nations should have access to the relevant biotechnology. Such technology can lead directly to reduced pressures on natural ecosystems, and at the same time to an enhanced perception of the value of biodiversity by society. Young scientists in the developing world in particular should be encouraged to learn about the principles of biotechnology and to apply them to indigenous organisms. By applying these principles, hundreds of additional tropical species could be used appropriately at a commercial level. Achieving this goal would ultimately involve the stimulation of relevant industries as for example by the provision of tax incentives, to return to the use of new sources of natural products to a substantial degree. Such developments should take into account the benefits to the owners of the forests from which the products are being derived — a strategy that would lead directly to the preservation of those forests. In addition, the knowledge possessed by indigenous peoples, or other rural peoples living in close contact with the relevant communities, must be viewed as a precious and rapidly vanishing field of information about which we must gain knowledge while there is still time.

For both scientific and economic reasons, steps ought to be undertaken to try to sample the diversity that exists now, because the next few decades, with their projected 50 percent increase in a human population that already consumes, diverts, or wastes some 40 percent of total net photosynthetic productivity on land, can only be a time of catastrophic extinction. In many ways, we have an opportunity now, comparable to that of living in the terminal decades of the Cretaceous period, 65 million years ago; the opportunities that exist to sample the full range of biodiversity with which we coexist will never occur again. The importance of managing biodiversity properly for human benefit, of understanding it, and of conserving it, cannot be overstated. Understanding the problem is the first step in dealing with the appropriate management of the biological resources of the planet earth, our common home, for our mutual benefit.