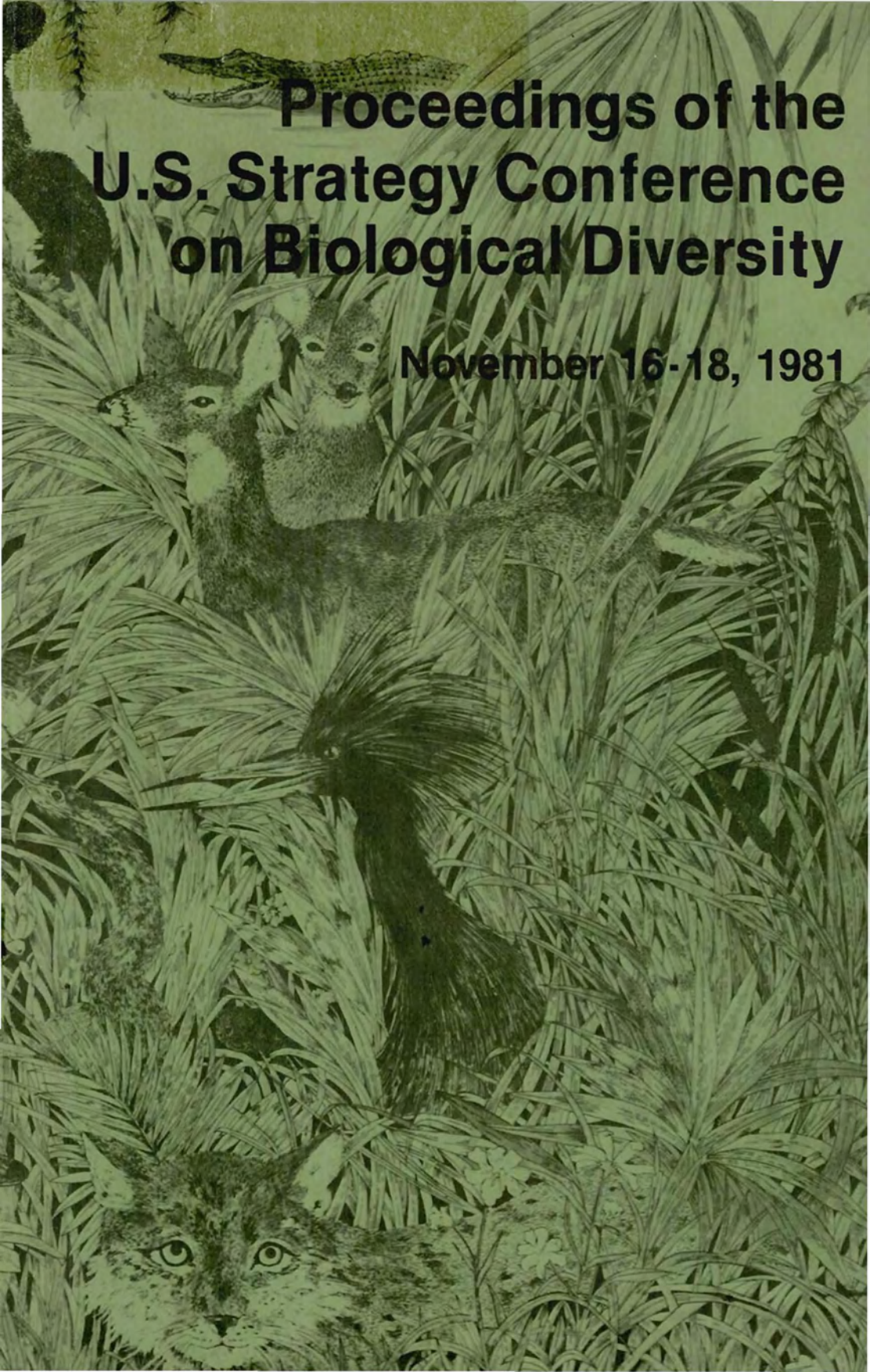
Proceedings of the U.S. Strategy Conference on Biological Diversity

November 16-18, 1981



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SPONSORED BY:

Agency for International Development, Department of State, Department of Agriculture, Department of Commerce, Department of the Interior, Council on Environmental Quality, Smithsonian Institution, National Science Foundation, and the U.S. Man and the Biosphere Program.

DEPARTMENT OF STATE PUBLICATION 9262
International Organization and Conference Series 300
Bureau of International Organization Affairs

Released April 1982

PREFACE

The long-term maintenance of the Earth's biological resource base has received growing attention in recent years. This has included concern about the survival of many plant, animal, and microbial species and the implications of a diminishing biological resource base for worldwide agriculture, public health, economic growth, and social development.

The World Conservation Strategy and various technical studies, such as those carried out by the U.S. National Academy of Sciences, have highlighted the pressures which modern civilization imposes on life-forms and have called for accelerated international efforts to counter what they project to be increasingly rapid loss of genetic resources. As worldwide awareness and concern have heightened, new policies and programs to protect and maintain biological diversity have been proposed in numerous international forums. As a participant in these forums, and as a major supporter and financier of international and bilateral resource management programs, the U.S. Government must continue to take positions on various proposals and resolutions and also to assess direct requests for assistance from other governments.

Early in 1981, officials in the Department of State and the U.S. Agency for International Development met to discuss a number of issues related to U.S. involvement in this area:

- What is the proper role for the U.S. Government vis-a-vis protection of species, their habitats, and variability within species, i.e., the protection of biological diversity?
- What vital U.S. interests are involved—economic, environmental, political, and strategic?
- How, during a period of shrinking budgets, can U.S. resources be applied most efficiently and effectively to this problem?
- What are the logical priorities? Are certain challenges, e.g., the preservation of most extant species, so large that U.S. investments would be wasted?
- How can the United States mobilize the support of other countries to deal with priority issues, and where does the United States fit within the larger international framework of countries and institutions working in this area?

It was agreed that as a first step a conference on biological diversity should be convened to promote public awareness of the linkages that exist among diversity issues; to engage Federal agencies in a dialogue with business, academic and scientific sectors, and congressional representatives; and to develop specific recommendations for domestic and international responses.

Support was provided by the Departments of Agriculture, Commerce, and the Interior; the Council on Environmental Quality; the Smithsonian Institution; the National Science Foundation; and the U.S. Man and the Biosphere Program. The resulting Strategy Conference on Biological Diversity was held at the Pan American Health Organization

and at the Department of State in Washington, D.C. on November 16–18, 1981.

These *Proceedings* contain the formal presentations, the major conclusions and recommendations which emerged from the conference, and a selection of informal reactions and comments from the participants. It is being distributed widely within and outside the United States to focus attention on the subject. It is intended to stimulate and guide follow-on activities that will be necessary if the governmental and scientific communities worldwide are to make substantial progress in addressing the problems discussed at the conference.

The conference organizers in the U.S. Department of State and the U.S. Agency for International Development bear sole responsibility for the selection and mode of presentation of these *Proceedings*. This is particularly true with respect to Chapter II, Principal Conclusions and Recommendations, since time did not permit the conferees to seek unanimous agreement on every point.

Special thanks go to all of the conference participants (listed in Chapter VI) who contributed their time and talent and particularly to the first-day speakers, the panel cochairmen, and the rapporteurs.

Appreciation is also extended to David McClintock (State), Molly Kux (AID), Jim Corson (MAB), Evy Sahli (State), Evelyne Todd (State), and Doris V. Ryan (State).

Finally, special recognition is due Susan Braatz, who served as deputy conference coordinator and who has been largely responsible for the production of these *Proceedings*, and to Anne Wickham, the conference coordinator, who has been responsible for the overall effort.

Full texts of the papers presented on the first day of the conference, the panel reports, or other information may be obtained from:

Office of Food and Natural Resources
OES/ENR, Room 7819
U.S. Department of State
Washington, D.C. 20520

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I. Introduction

The 3-day Strategy Conference on Biological Diversity was attended by approximately 300 individuals with relevant policy and managerial and/or technical responsibilities representing U.S. Government agencies, the Congress, university and business communities, nongovernment environmental organizations, private foundations, international organizations, and other countries.

Conference objectives were to:

- Review the nature and effectiveness of U.S. Government domestic and international policies and programs;
- Recommend initiatives the United States might undertake to assist an expanded worldwide effort in this area; and
- Promote public awareness of biological diversity issues.

The agenda addressed five areas of concern: *terrestrial plant species* (crop and noncrop); *terrestrial animal species* (domesticated and wild); *aquatic species; microbial resources;* and *ecosystem maintenance.*

Chapter II presents an overview of the principal conclusions and recommendations of the Conference.

During the first day (November 16), perspectives on needs, trends, state-of-knowledge, and key issues were presented by representatives of various interest groups in a series of invited papers. Edited versions of these presentations and comments from the floor are contained in Chapter III.

On the second day, 150 of the participants met in five panels, each focusing on one of the separate areas of concern. Their task was to attempt to reach a consensus on the most important issues and to recommend policy and program responses to perceived needs. The reports of these groups are presented in Chapter IV.

At the closing plenary session (November 18), short summaries of the working groups' conclusions and recommendations were presented, and those were followed by "reactions" from three congressional committee staff members. The congressional perspectives plus subsequent comments from the floor are contained in Chapter V.

Prior to the conference, all invitees were sent a list of "critical issues" related to the worldwide status of biological diversity and the

nature of U.S. interests and responsibilities. These issues (reproduced below) were provided as a framework for discussion in the plenary and working group sessions.

- What is the status of biological diversity worldwide and what are the principal factors of change?

- What are the economic, ecological, social, political, and strategic implications of the loss of biological diversity for the United States and other countries?

- What is the state of U.S. and global efforts to inventory, catalogue, and exchange germplasm? What institutions are involved? What are the problems?

- What is the quality of scientific knowledge, technologies, and institutions available to meet future needs, and what are needed modifications?

- What is the nature and quality of the world's institutional capability to maintain plant, animal, and microbial diversity? What gaps need to be filled, and what networks should be created? What international conventions and agreements deserve priority?

- What is the United States doing domestically and in cooperation with other nations and international organizations to protect germplasm, both *in-situ* and *ex-situ?*

- What should U.S. policy and program priorities be at the domestic and international levels?

- What policies and programs might the U.S. public and private sectors pursue? In what areas should the government and private sectors collaborate?

- What initiatives should the U.S. Government undertake unilaterally or in cooperation with other nations and international organizations to stimulate and assist an expanded effort in this area? Through which multilateral organizations should we focus our efforts (e.g., FAO, UNEP, OECD, ECE), or in what areas would bilateral cooperation be most effective?

- What is the potential of genetic engineering in maintaining diversity and what are its problems? What requirements of germplasm availability will have to be met? Will loss of germplasm have a significant impact on genetic engineering?

- What are the prospects for maintaining diversity, given the growing pressures on wild species and the difficulty in controlling habitat degradation, institutional problems, lack of management capabilities, lack of knowledge, and information and funding con-

straints? What are the best opportunities over the short and longer terms?

- What steps are needed to protect plant, animal, and microbial resources with unknown or unevaluated economic potential?

- Are different strategies needed for different ecosystems (e.g., tropical rain forests, grasslands, coral reefs, coastal wetlands, croplands)? What are the most threatened and/or vulnerable ecosystems? Can priorities for protection be set among ecosystems?

- What are the costs and benefits of *in-situ* and *ex-situ* approaches to conservation?

- How effective are parks, biosphere reserves, and other protected areas? Can we realistically expect the poorer nations to designate and maintain protected ecosystems? The developing world is now saying that the United States and others will have to absorb the cost of protecting and maintaining the wilderness. What are donor nations and international bodies doing in this regard now?

II. Principal Conclusions and Recommendations

This section presents the principal conclusions and recommendations which emerged from the Strategy Conference on Biological Diversity, as determined by its organizers and the editors of this *Proceedings*. General conclusions and recommendations are presented first, followed by specific ones from each of the five panels. The order in which these points appear does not imply that specific priorities have been assigned; rather, each represents part of a universe of issues that in the view of the majority of conferees must be recognized. Complete listings of the conclusions and recommendations of each panel can be found in Chapter IV.

PRINCIPAL CONCLUSIONS

1. As stated in the World Conservation Strategy, the preservation of genetic diversity is both a matter of insurance and investment, necessary to sustain and improve agricultural, forestry, and fisheries production; to keep open future options as a buffer against environmental change; and as the raw material for much scientific and industrial innovation. And it is a matter of moral principle as well.

2. The maintenance of genetic diversity is a challenge of global importance that affects developed and developing nations alike and the public and private sectors within each.

3. Protecting biological diversity and realizing its potential applications for human benefit can be entirely compatible goals.

4. The need for maintaining genetic diversity is not universally recognized; therefore, an important initial challenge is to increase awareness and understanding at both the public and governmental decisionmaking levels.

5. A particular problem exists in tropical areas which are rich in species diversity but which are the loci for human overpopulation and poverty. The governments of lesser developed nations in the Tropics thus have a tendency to give high priority to immediate economic growth and to discount less visible, long-term problems such as genetic diversity.

6. About 3 million species, or two-thirds of all species, are to be found

in the Tropics; of these, only about 500,000 have been named, meaning that about 2.5 million species are unnamed, uncatalogued, and uncharted. At present, in the entire world there are only about 1,500 taxonomists capable of dealing with this task.

7. Preservation on a broad front requires viable national and international institutional mechanisms for the multiple purposes of public information, assessment, collection and storage of specimens, and information dissemination. The existing international network is a patchwork of underlapping and overlapping institutions, vertically clustered around each of three macrosectors (animal, plant, and microbial) with only minimal lateral communication across these sectors.

8. One of the most urgent problems facing conservation activities today is the alarming *rate* of the loss of living species and the modification of the ecosystems in which they live. An equally alarming lack of knowledge of how to conserve them requires that education and training be given higher priorioty.

Given the inputs of human resources required to maintain genetic diversity on a global scale, training automatically becomes an area of priority concern.

9. The increasing dependence of the biotechnology industry on germplasm resources presents an opportunity to focus private resources in a cooperative effort to manage biological diversity; however, the success of such cooperation will depend on a considerable effort on the part of the public sector.

10. It is totally unrealistic in today's global economic environment to consider creating a single international institution for the purpose of developing cryogenic methods for the storage of *all* germplasm material, i.e., seeds, spores, semen and ova, and bacteria.

11. It is apparent that it will be impossible to save all genetic resources at risk. Realistically speaking, it may be possible to preserve a relatively small portion, so considerable attention must be given to prioritization and to achieving the greatest marginal return from scarce preservation resources invested.

12. A substantial effort is required in developing the gene pools that we have now and not simply preserving them.

13. All countries should maintain the maximum genetic diversity by means of both *in-situ* and *ex-situ* conservation measures; national inventories should be made of genetic resources whether under public or private control, in gene banks and protected areas, and in traditional cultivation. All such resources should be available to potential users, provided their use will not permanently impair or destroy the gene resource; and states using the genetic resources of another country should

contribute to their inventory and conservation. (Points adopted by the triannual meeting of the International Union for the Conservation of Nature, New Zealand, 1981 and reintroduced at this conference.)

RECOMMENDATIONS

1. An Interagency Task Force on the Conservation of Biological Diversity should be established to review current programs, develop comprehensive, long-term U.S. goals and strategies to maintain biological diversity, and recommend integrated national and international programs to carry out the strategies. By late 1983 the Task Force should report its findings to the President.

2. The United States should support efforts to identify, establish, and manage a worldwide system of conservation areas representing the major ecosystem types, particularly those which are unique, fragile, and/or highly diverse.

3. The policies of all Federal and State agencies with land stewardship responsibilities should be reviewed to insure that biological diversity is an explicit objective of planning and management.

4. Federal, State, and private cooperative programs should consider financing and supporting the study and realignment of existing areas and the establishment of additional areas in the United States, where necessary, to safeguard the national biological heritage.

5. Diversity can be maintained only by incorporating conservation planning into development planning. Protected areas should be a component of development plans. In addition, methods and techniques for sustainable agricultural, forestry, and fisheries production, which also provide for maintenance of biological diversity, should be developed. Demonstration projects using these methods should be encouraged.

6. A coordinated international program to analyze the current status of the Earth's ecosystems and the rates of conversion from a wild to an altered state should be developed.

7. Information and education campaigns should be expanded in the United States and elsewhere to familiarize the public and policymakers with the importance of maintaining biological diversity.

8. The United States should support research in tropical ecology and conservation biology. Development assistance projects should incorporate greater support for training developing country scien-

tists and resource managers to improve national capacity to manage biological resources for diversity.

9. Greater emphasis should be given to education and training in organismal and population biology, systematics, comparative taxonomy, and organization/management of germplasm collections. Continued support should be given to institutions which hold these collections.

10. International efforts to inventory the world's wild and domesticated plant, animal, and microbial resources and to maintain collections should be evaluated. The United States should contribute to these efforts. Standard references to species nomenclature should be developed in parallel with such inventories.

11. Open exchange of genetic material and information related to these resources should be encouraged worldwide. Data bases should be compatible for maximum accessibility to information.

12. A national network of culture collections should be created and a national data base on microbial genetic resources developed. A National Microbial Collections Resource Board should be established to inventory and assess culture collections, operate the national data base on microbial genetic resources, recommend procedures for culture preservation, and provide policy advice to appropriate agencies/institutions for development and support of resource collections.

13. Monitoring of the ecology of populations and morphology, physiology, and genetics of germplasm of economically important populations should be undertaken before long-term strategies for fisheries, livestock, and crop management are formulated.

14. Information on traditional local uses of plant and animal resources by indigenous peoples should be gathered so that we may identify species or varieties of potential economic significance. Application of this knowledge may lead to improved cropping systems, game ranching programs, or other sustainable production systems.

15. Research on the effects of industrial waste, persistent pesticides and herbicides, atmospheric pollutants, chronic low-level pollutants, and the introduction of exotic species on biological diversity should be supported and expanded.

16. The avoidance of further species loss wherever possible should be a global priority. To this end, the United States should maintain the conservation authority currently provided in the Endangered Species Act for the protection of all endangered or threatened animals and plants. The listing process should be

efficient and should be based solely on the conservation status of the species; importance of a species should not be based on whether it is considered to be "higher" or "lower."

17. The International Board for Plant Genetic Resources (IBPGR) of the Consultative Group on International Agricultural Research (CGIAR) should be continued and expanded. CGIAR should establish a similar International Board for Animal Genetic Resources (IBAGR).

18. The Secretary of Agriculture should establish a National Animal Genetic Resources Board with a structure similar to that of the National Plant Genetic Resources Board.

19. The United States should cooperate more fully with the existing international organizations which are concerned with the maintenance of biological diversity (e.g., United Nations Environment Program, Food and Agriculture Organization, UNESCO's Man and the Biosphere Program, and the International Union for the Conservation of Nature and Natural Resources).

III. Presentations

WELCOME AND INTRODUCTION

James L. Buckley
Under Secretary of State for Security Assistance, Science and Technology
Department of State, Washington, D.C.

On behalf of the State Department and the other Federal sponsors listed on your program, I would like to welcome you to this Strategy Conference on Biological Diversity.

It is hard to think of a task of more fundamental importance than the one to which you will be devoting your knowledge, intelligence, and judgment during the course of the next 3 days, because you will be dealing with the stuff of life itself.

Although the 1970's saw an extraordinary expansion of the American public's consciousness of the degree to which we depend on a sound environment, we have yet to see an equivalent understanding of the tremendous stake that future generations will have in the ability of this generation to stem the accelerating impoverishment of the globe's biological diversity.

We are still too ignorant of ultimate consequences to understand in full the urgent need to protect even the most inconspicuous forms of life so that we do not diminish the rich variety of biological resources that continue to exist.

Nevertheless, the urgency is there, and we need to impress upon the public consciousness that extinction is an act of awesome finality. Extinction is one of the few processes that man cannot reverse. But if man cannot restore species, he is nevertheless fully capable of destroying them, which he is presently doing at an astonishing rate. This century has witnessed over half the extinctions of animal species known to have occurred in recorded history; and, largely because of the vast scale on which tropical rain forests are being cut around the world, it is estimated that by the year 2000 upwards of a million additional species—about 20 percent of those now in existence—may become extinct. Yet on this threatened biological diversity depends, in significant degree, the fundamental support system for man and other living things.

As living creatures, the more we understand of biological processes, the more wisely we will be able to manage ourselves. Thus, the needless extermination of a single species can be an act of recklessness. By permitting high rates of extinction to continue, we are limiting the potential growth of biological knowledge. In essence, the process is tantamount to book burning; but it is even worse in that it involves books yet to be deciphered and read.

Unfortunately, this is a fact that is not as yet sufficiently understood. Therefore, if we are to generate the necessary support for the task ahead, we will need to remind the public that fully 40 percent of all modern drugs have been derived from nature, that most of the food man eats comes from only about 20 of the thousands of plants known to be edible, and that even those currently being cultivated require the preservation of large pools of genetic material on which plant scientists can draw in order to produce more useful strains or restore the vigor of the highly inbred varieties that have revolutionized agriculture in our times.

Recent well-publicized breakthroughs in genetic engineering may be what is required to focus public attention on the explicit interest each one of us has in seeing that the global stock of irreplaceable genetic material isn't squandered. This may help us focus attention on the practical need to conserve our biological resources. But we must also impress upon the public that this is inherently an international problem requiring an international approach.

A significant portion of the biological resources that today require the most urgent protection are located in underdeveloped nations that do not have the resources to do the job alone. Demands generated in the industrialized world can add to the pressures with which such nations must cope; witness the impact of the Japanese appetite for lumber on Indonesian forests. Also, migratory birds and marine life can only be protected through international cooperation.

There are other areas where our knowledge of ecological cause and effect is still too uncertain to enable us to reach firm conclusions as to the extent of our own self-interest in what happens to plant and animal life half a world away. What, for example, is the modulating role, if any, that is played by the world's biota on global weather patterns, which is another way of saying, what might be the impact of the destruction of Brazilian rain forests on the production of wheat in Kansas some 50 or 100 years from now? We don't know. But because the possibility of such an impact is not entirely implausible, it causes this conservative, at least, to urge caution—it being a conservative's and a conservationist's instinct to be careful about disturbing systems which seem to have been working reasonably well for an aeon or two.

In any event, as a long-time champion of the snail darter and furbish lousewort and other equally obscure but endangered species, I am espe-

cially pleased that this conference has attracted so distinguished a group of participants.

You more than most understand the special meaning for our times of Edmund Burke's reminder that the men and women of any generation are but "temporary possessors and life-rentors" who "should not think it among their rights to cut off the entail, or commit waste on the inheritance," lest they "leave to those who come after them a ruin instead of a habitation."

We need your insights and your guidance, not only as to the nature of the problems we face, but as to the practical, achievable measures we must be prepared to take both at the national and international levels to preserve our biological diversity—measures by which we can best protect our natural inheritance against the waste that this generation of "temporary possessors" has proven itself so capable of committing.

Dr. Nyle C. Brady
Senior Assistant Administrator for Science and Technology
Agency for International Development
Washington, D.C.

On behalf of AID, I am pleased to join Mr. Buckley in welcoming you to the Conference on Biological Diversity.

Maintaining genetic diversity is one area of international concern in which the developed and developing nations, as well as the private and public sectors within each nation, have a special interest. The collective long-term benefits provide the basis for continued human well-being. Some of the more tangible economic and scientific benefits to be gained by individual nations, wherever they rank on the development spectrum, include:

— The continuation of agricultural progress based on the ability to keep one step ahead of pests, pathogens, and climatic change;
— The utilization of still unknown species for industry and medicine;
— The development of new products for international markets, creating jobs and income in the process, and sometimes substituting natural products for costly, energy-intensive synthetics.

It is up to human beings to preserve the Earth's genetic inheritance not simply as a matter of principle, but also so that this priceless resource can serve legitimate human needs. Fortunately, protecting biological diversity and at the same time making use of its rich potential are not necessarily incompatible goals. Using need not mean using up.

All too often governments, individuals, and businesses have capitalized on nature's assets for the sake of short-term material gains, turning their backs on future environmental costs. Disregarding the importance of

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those things with no immediate economic utility to man, they have jeopardized long-term economic benefits.

The real challenge, if biological diversity is to be conserved for succeeding generations, is to work out an acceptable balance between long- and short-term needs, costs, and benefits and to devise some means of equitably distributing the costs among the beneficiaries. This challenge has innumerable variations that are specific to particular geographic locales. For the most part, however, these are variations on a single theme.

This theme is the pressure of powerful social and economic forces upon the natural habitat. The problem is particularly severe in the humid Tropics, where major losses of species are anticipated as populations and economic needs relentlessly expand. Large numbers of poor people, lacking land and job opportunities elsewhere, are forced to wrest their subsistence from marginal farmland or virgin tropical territories. Similar survival instincts motivate national governments whose biological wealth contrasts with their budgetary shortfalls. Hence, they are willing to let their resources be exploited by the highest commercial bidders who, in turn, are responding to the growing demands of affluent nations.

Many species have fallen prey to mindless development and the reckless pursuit of profit. But the driving force behind the disappearance of many more is the lack of alternative means of survival within prevailing economic and political systems. The prognosis for large numbers of threatened plants and animals is closely tied to the fate of millions of impoverished people whose own existence is threatened—threatened by lack of opportunity, wretched living conditions, high birth rates, and unemployment.

Seen in this light, the need to preserve biological diversity is a crucial dimension of the struggle for equitable economic development. The scientific and technical aspects of the problem cannot be isolated from these underlying social and economic considerations if enduring solutions are to be achieved.

By the year 2020, the additional food that must be produced just to maintain today's inadequate consumption levels will be equal to the total amount of food that is now being grown. At the same time, there will be accelerating demands for firewood, charcoal, agricultural plots, grazing lands, construction materials, and paper products. These are not frivolous or trivial needs. On the contrary, most of them are such basic survival needs that they will overwhelm even the most stringent conservation efforts, unless such plans are themselves carefully harmonized with regional development programs.

I hope that during the course of this conference you will consider some of the ways in which this might be accomplished. Clearly, one prerequisite is to sensitize political leaders, national planning

officials, and the international development community to the importance of biological diversity. A keen awareness of the need to safeguard genetic resources must become an integral part of development policies and programs—rather than an afterthought.

In the broadest sense, preserving the genetic diversity that still prevails within the biosphere can enable the human species to keep its options open and to maintain a range of possible responses to changing economic, technical, and environmental circumstances. In the eternal process of accommodating to change, biological diversity is as much a resource to be used as is the diversity of human talents and interests.

Continuing tensions are inevitable between compelling short-term social needs on the one hand and longer term environmental imperatives on the other. The ways in which specific conflicts are resolved will in turn condition the ability of future generations to meet their own immediate survival needs.

Policymaking in this area can be particularly hazardous because decisions must often be reached in the absence of adequate information. Hence, this conference has an especially important role and responsibility. By illuminating the public policy issues pertaining to biological diversity and in proposing guidelines for policymakers, you will be performing an enormous service to all of us.

WORLDWIDE NEEDS AND OPPORTUNITIES

Genetic Diversity: Serious Business for Crop Protection and Maintenance

Dr. William L. Brown
Chairman, Board of Directors, Pioneer Hi-Bred International
Des Moines, Iowa

My comments today will deal solely with biological diversity of cultivated plants—those used for the production of food, feed, and fiber, both domestically and abroad. It has been estimated that worldwide, about 15 species of cultivated plants literally stand between man and starvation. Should any of these cultivars disappear, or should the productivity of any of the more important ones be significantly reduced, the world's food supply could become seriously threatened.

The availability and the use of genetic variability are essential elements in plant improvement. While there are techniques for artificially inducing genetic variability into otherwise nonvariable

populations, experience has shown that these are seldom satisfactory substitutes for naturally occurring variation.

What are some of the more obvious worldwide needs as they relate to this important group of plants? Despite the great amount of plant exploration that has occurred in the past, for some species there are still some critical gaps that must be filled as rapidly as possible because of the continuous replacement of indigenous varieties with improved cultivars. For example, the primitive and semiwild progenitors of bread wheat in parts of Turkey and adjacent areas are disappearing and must be salvaged soon if they are to be salvaged at all. The soybeans of China, including many ancestral forms of this important species, have yet to be collected in a systematic way. Conversely, maize, sorghum, and rice have been extensively collected during the past 25 years, and as a result, the collection gaps within these species are relatively few. For these and certain other species there are other needs relative to germplasm which far outweigh the need for additional collecting.

A second and perhaps even more important problem worldwide is that of satisfactorily maintaining the integrity and viability of the existing collections, some of which are irreplaceable. To allow such sources of biological diversity to disappear through neglect, indifference, or inadequate funding seems almost inexcusable. Yet, this is precisely what is happening to some of the stored germplasm of some of the world's more important cultivated plants. Such losses are occurring, usually not because of a lack of interest of those directly responsible for the collections, but rather because of the failure to recognize the complexity of proper germplasm maintenance and the reluctance to fund adequate maintenance and regeneration of accessions. Certainly it is unrealistic to expect to preserve and maintain every accession that has been or will be collected, yet there seems to be no justification in allowing the loss of any collection if it can be avoided. When dealing with biological diversity, we are dealing with national and international natural resources of unknown value. Proper maintenance of these resources should be of sufficient interest to merit consideration of establishing an international body of experts to periodically review and report on the status of germplasm maintenance at the major gene banks around the world.

A third and critical requirement has to do with the screening and evaluation of germplasm now in the major gene banks. While collections of gene resources will not long survive unless properly maintained and regenerated, they unfortunately will be little used by the breeder until the individual accessions have undergone some preliminary evaluation and proper documentation. The breeder has a full-time breeding program and does not have the time or facilities to carry out systematic evaluation or testing of the acquisitions when a new trait, such as resistance to a particular pathogen, is needed.

Although this need for further evaluation of the vast amount of stored genetic material is not limited to a few countries, but rather seems to be almost universal, I am not aware of any emerging programs designed to alleviate the problem. One fact is clear: Until more evaluation data are accumulated and disseminated, inadequate use will be made of the available resources. From a practical viewpoint, it makes little sense to continue to fill our germplasm banks if the new accessions do not become a part of the breeding pools of the user community. If these materials are not used, they simply become museum collections.

A fourth need is a global documentation and communication system linking institutions and organizations involved in germplasm resource conservation and use. Such a system would not only provide greater flow of information but should also encourage increased exchange of germplasm between users. Attempts to provide this service are being made by the International Board for Plant Genetic Resources (IBPGR) of the Food and Agricultural Organization of the United Nations. These efforts are to be commended. They provide an excellent base for expanded activities in this area. Moreover, the Board could probably furnish some of the professional guidance required for the implementation of an expanded international system. It is unlikely, however, that the Board could fund an expanded international network which would meet current and future needs.

Let me now turn to the second part of the broad topic, Worldwide Needs and Opportunities. Undoubtedly, the opportunities are many, but with respect to cultivated plants, I will deal with only one—the opportunity to increase diversity (i.e., usable genetic variability) within the breeding populations used by the plant breeder. We need to broaden the genetic base of most of the important cultivars upon which the world depends for its food, feed, and fiber, and to do so is an opportunity that in my opinion is not receiving the attention it deserves.

To give you some insight into how breeders function, it should be noted that most new cultivars emerging from breeding programs today are generated from the progeny of existing elite lines, varieties, etc. This system is highly efficient and has resulted in a continuous flow of new varieties and hybrids, which have contributed significantly to improved agricultural productivity. Despite its success, this approach to plant breeding has one major fault. It tends to continually narrow the germplasm base of those crops in which it is used, since it provides minimal provision for the introduction of new alleles into breeding populations. Breeders, working with highly select, high-performing genotypes, are currently using only a small percentage of the total germplasm available to them. Consequently, there is a tremendous opportunity to broaden the genetic

base by utilizing new and different sources of variability. However, to do this effectively and efficiently requires additional theoretical and experimental work on how to best incorporate exotic germplasm into elite, adapted breeding materials. The availability of information of this nature would, undoubtedly, stimulate efforts to increase biological diversity in many of the world's important food crops.

Among plant breeders in the developing world, the opportunity to use the highly productive cultivars from the developed world as new sources of increased diversity seems not to have been generally recognized. These high-producing cultivars, in contrast to native indigenous varieties, are excellent sources of desirable alleles, some of which can be rather quickly incorporated into adapted varieties for local use.

Finally, I should like to take this opportunity to correct a number of prevalent misconceptions relative to genetic vulnerability, biological diversity, and the alleged concentration of agricultural production in fewer and fewer varieties.

Critics allege that modern high-yield varieties are especially adapted to ideal growing conditions but are less stable and more susceptible to year-to-year variation than the older sorts they replaced. However, as has long been the experience of breeders, more and more experimental data is verifying that the newer high-yield varieties perform better than old ones and are more rather than less stable under the stresses of drought, heat, and low soil fertility. Moreover, in the United States, at least, the replacement of older varieties by new ones does not mean the old varieties are lost. These, for the most part, are preserved either in the germplasm collection of the breeder or in one of the regional gene banks.

The term "genetic vulnerability" has come into popular use since the southern corn leaf blight epidemic in the United States in 1969–70. That epidemic occurred as a result of the widespread use of one cytoplasm in maize. It prompted a study by a committee of the National Academy of Sciences (NAS) which concluded that several major U.S. crops did rest on a relatively narrow genetic base and were, indeed, genetically vulnerable. It is of interest to note the changes that have occurred in the genetic base of these crops in the decade following the NAS report. The results of a recent survey by Duvick indicated clearly that in 1981 the breeding base in the United States for all five species examined (cotton, soybeans, wheat, sorghum, and maize), was significantly broader than in 1970. It is encouraging to note that although a continued effort is needed to further reduce the potential hazards of genetic vulnerability, considerable progress has apparently been made in the past decade in expanding the genetic base of many of the economic species.

Relative to the widespread use of a few cultivars—a practice for

which the breeder is frequently criticized—one should recognize that it is the user (farmer) who makes the final determination as to what variety or varieties he uses on his farm. He attempts to use those varieties which, on the basis of experience, are the most productive and generate the maximum income per unit area of land. Fortunately or unfortunately, this does frequently result in a high concentration of a few varieties within a particular maturity zone. Such a practice may result in economic loss from increased disease and insect pests. One needs to keep in mind, however, that these potential problems have been anticipated by the breeder who usually has in hand other genetically different varieties which are almost as productive as those in use and which can quickly be made available as replacements if the need arises.

Conservation of Biological Diversity: The Indian Experience

Dr. T. N. Khoshoo
Director, National Botanical Research Institute
Lucknow, India

May I offer greetings from the Government of India and my own organization, the Council of Scientific and Industrial Research. India has an abiding interest in the environment and in conservation. At the same time, it has serious problems common to the developing world. I will try to briefly review the situation in my country.

The two processes—natural extinction and origin—have been an integral part of the evolutionary process. The present wave of extinction, however, is man made and is apparently unaccompanied by a comparable degree of species origin. The cause—and the dilemma of the developing world—is that development has become synonymous with deforestation and desertification; progress has become synonymous with pollution. We now have to encourage the process of development without destruction and protect the foundations of the life support system, including the habitats of plants, animals, and microbes. Gene erosion is very dangerous because genetic diversity is the backbone of evolution.

Let's now review our assets and our liabilities.

Assets

As for the Earth's assets, a total of 400,000 plant species has been identified. Of the 286,000 flowering plants, 170,000, or 70 percent, grow in the Tropics. And Professor Peter Raven [Missouri Botanical

Gardens] is of the opinion that 1 million plant species in the tropical Americas are still to be collected and named. This is the enormity of diversity in the Tropics, the cradle of evolution.

The world's flora has been divided into 37 floristic zones by Good (1953). Within these zones, there are small pockets of diversity where premature man domesticated plants. During the last 10,000 years, domestication has generated enormous variability in both plants and animals through mutation, recombination, and subconscious and conscious selection. The result is a complex pattern of variation. This variation was first studied by the distinguished Russian agrobotanist Vavilov, who identified 12 centers of origin. These include China, India, Indo-Malaysia, Near East, Mediterranean, southern Mexico and Central America, Peru, Ecuador and Bolivia, Paraguay and Chile, and Brazil.

I would like to identify three important points about these centers of diversity:

(1) Most if not all these centers are located in the developing world in the Tropics and sub-Tropics;

(2) These regions, which have given the world its present-day crop plants, are now ironically the regions of least productivity; and

(3) Most of these regions are populated by tribes whose socio-economic advancement will bring changes in crops and agricultural techniques, resulting in the loss of thousands of years of selection and adaptation of the traditional crop plants.

Take, for example, the situation in India. In the northeast region, southwest peninsula, and central India, we have large tribal populations. The tribal cultures, particularly in northeastern India, have perpetuated local land races of a variety of crop plants which have undergone thousands of years of natural and human selection. These plants contain treasures of resistance to pests and disease and adaptation to stress conditions. Good land is a finite resource, and if we have to increase agricultural production, perhaps it will be by expansion onto marginal land where these varieties will be suited.

Parallel to this enormous diversity in plants, there is diversity in domesticated animals such as buffalo, goat, sheep, pig, poultry, horses, ponies, camels, and yak. The productivity of these animals by American standards is very, very poor, but having undergone periods of rigorous selection, races are hardy, adaptable to heat and parasitic stresses, and can survive on very poor roughage. These are very important genes, now in great demand in Australia, the United States, and Latin America.

India also has a very rich diversity of wild plants. With changing environmental conditions and changing needs for food, fiber, fuel, fodder, shelter, and medicines, one cannot foretell what species will

be needed when. In India we have an old story. There was a physician living 3,000 years ago who was asked by his teacher to find a plant which was useless. He returned after 10 years, saying that there was no such plant. There is a great moral in this story. Look at the United States, a country which is agriculturally advanced and self-sufficient. About 1,000 economic species grow here, and few, if any, are indigenous. Most were introduced by Amerindians, explorers, and colonists. Given that there is a continuing need worldwide for new germplasm, a country's indigenous plants cannot be ignored.

Another asset of India is its infrastructure. The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), one of the 12 international institutes that have been created in the regions of diversity, is located in India. As for national programs, we have agencies of the Council of Agriculture, a beautiful center for agriculture, universities, and institutes. In addition, the following five national entities associated with the Council deal with conservation, biological diversity, and the environment: the Indian Bureau of Wildlife Management, the National Committee on Environmental Planning and Coordination, the Department of Environment, the Man and Biosphere Program (MAB—affiliated with the international MAB program), and the World Wildlife Fund (WWF—affiliated with the international WWF).

Liabilities

Large areas of our country have been stripped of trees as a result of overpopulation, expanding agriculture, and social needs. Other factors which have contributed to loss of vegetative cover are:

— The local population, particularly in the northeastern sector, which has historical rights to forest and forest products, resulting in depletion of many high-value plants and animals;

— Intensive grazing and shifting cultivation;

— Professional botanical and zoological collectors who gather plants and animals for purposes of teaching and trade;

— The large influx of tourists and pilgrims in the Himalayas; and

— Increased pollution from industrialization, use of agricultural chemicals leading to contamination of groundwater, and excessive use of pesticides killing a lot of pollinators.

In our eagerness to provide food for our teeming millions, we have chosen high-input agriculture with tremendous and immediate gains, not only for the food crops, but for industrial and even medicinal crops. In many cases, large-scale production is based on little genetic variability. Unfortunately, this concept of uniformity is

also entering the forestry sector. This is especially dangerous because of the long generation time and the generally high degree of heterozygosity in natural forest stands. Homozygous forest stands can be dangerously susceptible to pests and disease.

The erosion in wild plant wealth is of equal concern. It may appear that when one species goes extinct, we are losing only one species, but as Dr. Peter Ravin [Missouri Botanical Gardens] has said, 10 to 30 other species may be extinguished at the same time. Plant, animal, and microbe relationships are very close, so that when one is affected, a whole chain is affected.

Preservation Techniques

We have two approaches to conservation of genetic diversity: *in-situ* and *ex-situ* conservation. In India, we have practiced several methods of *in-situ* conservation, including gene sanctuaries, biosphere reserves, and sacred groves. We have established two gene sanctuaries, one for citrus and one for the pitcher plant, and we are planning to establish sanctuaries for rhododendron, orchids, and musa. It is not possible, however, to establish gene sanctuaries for every economic or threatened species. Biosphere reserves, often covering large areas, protect representative ecosystems. We have plans to have 12 biosphere reserves. Sacred groves, which have existed in India from time immemorial, are densely wooded areas on religious grounds. There is a religious belief in the local population that any damage to these grounds will invoke the wrath of a supernatural force. The philosophy of nonviolence, which is ingrained in the Indian culture, is an all-embracing conservation concept, in which no harm should be unnecessarily inflicted on any creature, whether it be human, animal, or plant. Another method of *in-situ* conservation is the reintroduction of critical plant species or groups to comparable habitats after careful population biology studies are made.

There are five techniques of *ex-situ* conservation: seed banks, botanic gardens, pollen banks, tissue culture, and genetic engineering. If and when genetic engineering is successful, it would definitely widen the gene pool. However, I must stress that this technique should not be followed at the expense of more traditional, time-tested, and surer methods. The devil we know is better than the devil we do not know.

One disadvantage in all *ex-situ* preservations is that only a small number of lines which may represent a small fraction of the total genetic variability can be preserved. One way to mitigate this is by appropriate sampling techniques based on enough information on life-form, breeding, and pollination systems. Therefore, it is necessary to do biosystematical and population biology studies.

Needs

Conservation efforts have been biased toward flowering plants and crop species. We need to consider all the plants (including lower plants), microorganisms, and marine resources.

Protection of the environment and life support systems is interwoven with conservation. Conservation has to be integrated into rural development, particularly in the Tropics, because if the Tropics, the cradle of evolution, turn to wasteland, the human future is in jeopardy.

There is a need for properly trained personnel. Unfortunately, the present-day biologists suffer from what is called a high-technology fix: everyone wants to be a molecular biologist. Perhaps a carefully chosen system of awards and incentives may encourage people to work in systematics, population biology, and species preservation. In India, we have a national award for doing such work in remote tribal areas. The first award went to an agricultural scientist who organized a sanctuary for citrus in the remote northeastern region.

There is also a social aspect of this work. We know that conservation is most needed in the Tropics and sub-Tropics in the tribal belt. The person who is in a commanding position to help is a tribe member or villager living inside or in the vicinity of the center of diversity. Perhaps for long-term success, it may be worthwhile to make him aware that he has an important role and that he can help humankind by preserving species diversity. I will give you an example from our own country. In the central Himalayas, there is a villager who started a movement, "Hug the Trees." He and his men do not allow contractors to fell the trees. This movement has produced miraculous results which colossal amounts of money and the Indian Forest Department could not accomplish in 30 years.

Lastly, for doing all this, funds are needed. I bring to you what one of the celebrated botanists of your country wrote in 1976:

> Billions of dollars have been spent on exploration of the moon. We know far more about the moon than we do about the rain forests of say, western Colombia. The moon will be there for longer than these forests, and perhaps longer than the human race. In the forests are found the most complex interacting systems on Earth, systems which might even hold the key to our survival and about which we know practically nothing. Would it not be prudent during the Bicentennial Year to consider allocating more funds for the study of tropical plants and animals?

As a student of life sciences, I fully agree with this statement. It is a queston of priorities. We must aim at development without environmental degradation or destruction; conservation of genetic diversity cannot be disassociated from development and a healthy environment.

Biological Diversity: The Global Challenge

Dr. Noel J. Brown
Director of United Nations Environment Program
New York, New York

Dr. Reuben Olembo, the Director of the Divison of Environmental Management of United Nations Environment Program (UNEP) in Nairobi, was invited to speak but unfortunately cannot be here today. He has asked me to extend his regrets and to read a statement he has prepared. I shall read it faithfully, resisting my natural inclination to digress and offer my own remarks.

Dr. Mostafa K. Tolba, the Executive Director of the United Nations Environment Program, sends his greetings and extends his best wishes for a successful conference. He wishes to commend your initiative in bringing into focus an issue which demands more systematic attention and concerted action both at the national and international level.

While we recognize that the subject of biological diversity does not lend itself to easy solutions or quick fixes, we are concerned that for much too long it has remained the "sleeper" among priority environmental issues. We hope that your efforts will help heighten public consciousness to the urgency of the problem.

This urgency was perhaps most recently underscored at the 15th session of the International Union for the Conservation of Nature and Natural Resources (IUCN) General Assembly held last month at Christchurch, New Zealand, which urged all governments to "maintain maximum genetic diversity by means of the most appropriate conservation measures." It was also a major concern of the last meeting of the International Coordinating Council of the Man and the Biosphere Program held in Paris last month, which concluded that "the most urgent problem facing conservation activities today is the alarming rate of the loss of living species and the modifications of the ecosystems in which they live, coupled with an equally alarming lack of knowledge on how to conserve them."

We have what has been termed by Frankel and others an "evolutionary responsibility." That responsibility is to do what we can to preserve the evolutionary continuum, limited though we are by the needs of our own species in the regions where the richest ecosystems remain. This was the challenge of the Stockholm Conference on the Human Environment, which 10 years ago placed the issue of biological diversity high on the list of global environmental priorities, concluding that "the natural resources of the earth and especially representative samples of natural ecosystems must be safeguarded

for the benefit of present and future generations through careful planning and management."

These principles were subsequently reaffirmed in the Plan of Action adopted at Stockholm and form part of the goals of the Man and the Biosphere Program and the proposed UNEP Charter for Nature. More recently, they were reflected in the World Conservation Strategy. Together these elements form the core of UNEP's efforts which are aimed at encouraging:

- Establishment of global registers of genetic resources collections;
- Conservation of habitats and of genetic resources;
- Establishment of regional genetic resources centers;
- Development of appropriate technologies for use of genetic resources; and
- Access to available genetic resources.

As we approach the Tenth Anniversary of the Stockholm Conference, it would seem timely for us to assess just how far humanity has discharged its responsibility in this regard and what governments and concerned publics must now do if we are to secure the genetic basis of our survival and assure our continuing evolution.

Even the most cursory look at the record reveals some very disturbing trends. For example, experts now tell us that the Earth's genetic resources are reported to include anywhere from 5 to 10 million species of animals and plants, but by the end of this century, many might be lost if the extinction rate of 1 a day is maintained. This was the conclusion reached by the World Conservation Strategy, a conclusion shared in even more dramatic detail by Edward O. Wilson, a Harvard entomologist. In his words:

> What event likely to occur in the 1980's will our descendants most regret, even a thousand years from now? The worst thing that can happen—will happen—is not energy depletion, economic collapse, limited nuclear war, or conquest by a totalitarian government. The one process that will take millions of years to correct is the loss of genetic and species diversity by the destruction of natural habitats. No one is sure of the number of living species . . . but estimates range between 5 and 10 million. A conservative estimate of the current extinction rate is 1,000 species a year. By the late 1980's the figure could easily rise to 10,000 species a year (1 species an hour) and it is expected to accelerate further through the 1990's. During the next 30 years, fully 1 million species could be erased.

As the Strategy reminds us, preservation of biological diversity is both a matter of investment and insurance necessary to sustain and improve agricultural, forestry, and fisheries production and to keep open future options as a buffer against harmful environmental change and as raw material for scientific and industrial innovation.

In spite of innumerable examples which conclusively demonstrate that plant and animal species—once thought insignificant—can suddenly become useful and important, the genetic base continues to

shrink, often under pressure for the creation of super strains or genetic uniformity. This is most advanced in the seed industry, and this should be a matter of concern to the Third World since the genetic strength of most of the world's crops is drawn from the regions of Africa, Asia, and Latin America.

The risks of food production inherent in the narrowing of the genetic base is amply documented in the Strategy which notes, for example, that:

— Only four varieties of wheat produce 75 percent of the crops grown on the Canadian prairies, and more than half of the prairie wheat lands are devoted to a single variety;

— Seventy-two percent of U.S. potato production depends on only four varieties, and just two varieties supply U.S. pea production;

— Most of Brazil's coffee production derives from a single plant;

— The U.S. soybean industry is entirely derived from six plants from Asia; and

— At present, the world depends on less than 20 crops for 90 percent of the world's food crops.

It is clear that developments such as these place a number of the world's food crops in a position of extreme vulnerability to outbreaks of pests and diseases and changes in growing conditions, as evidenced by the U.S. corn blight in 1970, which destroyed half the crops in the South and 15 percent of the world's resources. Compounding the problem, however, is the fact that corrective possibilities are themselves being undermined as the diversity of crop populations is being destroyed. Many wild and domesticated varieties of crop plants such as wheat, rice, millet, beans, yams, tomatoes, potatoes, bananas, limes, and oranges are already extinct, and many more are in danger.

We must examine our achievements to date.

In the field of plant genetics, coordination of international efforts is carried out mainly through the International Board for Plant Genetic Resources (IBPGR) in which FAO, UNDP, UNEP, and several national governments participate. The main approach is to (a) establish priorities for plant germplasm conservation; (b) support establishment of a worldwide network of plant genetic resources centers maintaining world base and working collections; and (c) maintain registers of available genetic resources. Assistance has been given to several centers in collecting threatened crop genetic resources which are stored in world base collections—often with IARC's[1]—as well as in the countries of origin. Priority has been given to the Vavilov Centres of crop genetic diversity and to those crops which provide the main staples of various peoples, and close coordination is maintained with breeding institutions for evaluation and

utilization of stored material. An emphasis on tree species especially useful for environmental application in marginal ecosystems has recently emerged.

The Threatened Plants Committee of IUCN monitors threats to plant species and periodically publishes data sheets on their conservation status in the Red Data Books[2]. The International Union of Forestry Research Organizations monitors and compiles data on genetic erosion within tree species. The Food and Agriculture Organization (FAO) carries out many activities relating to conservation of tree genetic resources within its forest management and reforestation programs, establishing stands for selected tree provenances. While both FAO and IBPGR aim at *in-situ* conservation of specific plant varieties, progress has been extremely limited due in part to lack of scientific knowledge on intraspecific diversity, higher conservation costs, and the pressure of other land-use demands. A consensus has developed that *in-situ* conservation could best be implemented through habitat protection such as in genetic reserves.

Documentation of gene bank information through genetic resources registers is essentially noncentralized, the early efforts of the IBPGR at establishing a global register of plant genetic resources having met with administrative and technical constraints. This has undoubtedly had a negative impact on accessibility of plant genetic resources. Efforts are mounted, however, by the IBPGR to formulate universally accepted descriptor lists, of varying levels of detail, to be used in documenting plant genetic resources by individual gene banks.

On the question of animal genetics, while there is no international structure similar to the IBPGR, an Expert Panel on Animal Genetic Resources recently has been established by FAO to carry out advisory functions similar to those of the IBPGR. FAO has carried out several surveys of specially adapted but marginally exploited breeds of livestock in all continents. As a result, efforts are now being initiated to establish pilot conservation schemes, regional data banks, and continental gene banks for selected breeds. The artificial insemination programs of FAO, while enriching diversity within certain breeds, has also encouraged threats to more traditional breeds which appear less productive in intensive systems.

The IUCN pays considerable attention to threats to wild species, specially large mammals, monitoring their status, encouraging protection, and compiling information for the Red Data Books. Attention has also been focused on semidomesticated wild species, which play a significant socioeconomic role in marginal environments and on relatives of domesticates.

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[1]International Agricultural Research Centres (established and coordinated by the Consultative Group on International Agricultural Research).

[2]For this purpose, the Conservation Monitoring Unit (CMU) has been established at Cambridge, England with support from UNEP and IUCN.

Conservation of fish genetic resources has not been as systematically approached internationally as the terrestrial species, sometimes because of technical constraints in defining acceptable criteria for genetic erosion in such species. FAO, however, regularly monitors fish introduction in aquaculture and compiles data on the genetic impact of such introductions, and UNESCO compiles information on the biological characteristics of various fish species.

As far as microorganisms are concerned, UNESCO established an international register of available microbial genetic resources and developed the appropriate descriptor lists for microbial gene banks. While the system is not comprehensively global—the North American gene banks being a notable absence—it approximates a global register of one category of genetic resources. UNESCO also monitors emerging biotechnologies with potential application in developing countries and conducts extensive training programs for scientists from developing countries. The concept of genetic resources centers as repositories of genetic resources and developers of deployment technologies has been implemented on a pilot scale with five Microbial Resource Centers(MIRCEN) in Africa, Asia, and Latin America, which are now in desperate need of sustained and increased financial and technical support.

Following an initial exploratory survey by UNEP and FAO, FAO has initiated an ambitious program for deployment of microbial genetic resources in provision of nitrogen fertilizers to small farms, while UNDP has been supporting an extensive research program—mainly at the IARC's—to adapt the technology to the needs of tropical and subtropical agriculture. United Nations Industrial Development Organization (UNIDO) has been quite active in stimulating efforts of developing countries to produce fuel by microbial conversion. FAO and UNIDO encourage the use of biotechnologies which use various residues, and both FAO and UNDP have supported training relating to biogas technology.

In terms of ecosystem management, assistance is provided by IUCN, FAO, and UNESCO to developing countries in designation and management of various types of protected ecosystems, with conservation as a major aim. While all protected ecosystems serve the goal of conservation of biological diversity, they serve as specific genetic reserves only when biological monitoring and documentation are regularly performed with the explicit purpose of finding and protecting gene-ecotypes of plants, animals, or microorganisms. In this respect, UNESCO's Biosphere Reserves program could double as an *in-situ* genetic reserves program with scientific and administrative inputs and as a link with utilization efforts, particularly breeding programs. Since biosphere reserves are national institutions, the degree of sensitivity to such needs, particularly to the documentation of intraspecific biological diversity, is rather uneven and is generally quite limited.

The international experience shows the following issues deserving the

most immediate attention:

(1) Establishment of global registers of available genetic resources is an effective means of monitoring threat and a prerequisite to making information on available resources accessible.

(2) Most of the remaining resources are in developing countries and are under immediate threats of changing patterns in bioproductive systems. While these resources are essential for future development of genetic material, the countries which have jurisdiction are ill prepared both financially and technically to conserve them. This argues for considering international costsharing for conservation of genetic resources and of regulating international accessibility to available genetic resources.

(3) Development is likely to exert continuing land-use pressure which leaves fewer and fewer habitats available for protection. This is the greatest threat to both known and unknown biological diversity. It is realistic to aim—as much as practical—at multipurpose protected areas. This also places presently protected areas in a central position with respect to conservation efforts. There will undoubtedly remain areas where monitoring and documentation, particularly below the species level, are difficult. But this should be the exception rather than the rule. This places large demands on taxonomists and highlights the need for training.

(4) Emerging biotechnologies will undoubtedly have significant impact on development, environment, and on microbial genetic diversity. This will highlight the need for broader application of the MIRCEN concepts, especially in developing countries, and the need for global documentation of microbial genetic resources.

U.S. GOVERNMENT'S ROLE AND CAPABILITIES

A. Alan Hill[1]
Chairman, Council on Environmental Quality
Washington, D.C.

As one of the cosponsors of the Strategy Conference on Biological Diversity, it gives me great pleasure to send you this word of welcome.

As the participants in this meeting are well aware, the preservation of both species and genetic diversity is one of the fundamental and most important challenges before this country and the world as we seek to develop new approaches to sustainable global development.

The World Conservation Strategy has correctly identified the preservation of genetic diversity as "both a matter of insurance and invest-

[1]Message read at conference by moderator.

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ment—necessary to sustain and improve agricultural, forestry and fisheries production, to keep open future options, as a buffer against harmful environmental change, and as the raw material for much scientific and industrial innovation—and a matter of moral principle."

The Global 2000 Report and other studies have indicated the potential for the extinction of plant and animal species on a scale without precedent in history, if present trends continue.

Within the Federal Government, we are beginning a process of examining a whole range of issues relating to global resources and the environment, seeking to improve our information base and our ability to forecast trends and to make more informed policy decisions.

Your deliberations will be a valuable contribution to this effort. And you are to be commended for your positive and practical approach to the challenge before you. I offer you my congratulations and every wish for success in your important work.

Biological Diversity: Basic for Agricultural Success

Dr. Anson Bertrand
Director of Science and Education, U.S. Department of Agriculture
Washington, D.C.

In an earlier communication to the State Department about this conference, I stated, "...we share your concern for the deterioration of our biological resource base and firmly believe that we must pool our collective talents and exert the effort necessary to stem the erosion of genetic diversity ... thus the conference is both appropriate and timely."

We are keenly aware of the need for biological diversity. Without access to and use of these resources, we would never have been able to reach our current food and fiber production levels. Genetic diversity has provided not only a variety of foods, but also the basis for increased productivity, increased nutritional value, greater disease resistance, ability to withstand various stresses, and other production, marketing, and consumer factors.

Despite these accomplishments, the demand for genetic diversity in agriculture has increased. This can be attributed to a number of factors, including:

— Vulnerability to biological and physical stresses from wide use of uniform varieties and monocultures over large land areas;

— Temperature and moisture extremes, poor soil, and low water quality;

— Consumer demands for appearance, flavor, color, and leaner meat; and

— Changing technologies, including no-till farming, multiple cropping, and biological farming.

Currently, certain land use patterns, some farm production practices, population pressure, and environmental pollution are actually reducing biological diversity. Around the world, many habitats are being destroyed. For example, some rain forests are being literally bulldozed down, clearing out areas very rich in plant and animal species in the process. Trees are being removed rapidly from savanna and semiarid areas all over the world. Since there has been little study of these sensitive habitats, we're not even sure what has been destroyed. In addition, urbanization and resettlement are encroaching on wild areas rich in genetic resources. We must encourage accelerated efforts to preserve these valuable resources, or the opportunity will pass us by forever.

With all of the recent publicity about genetic engineering, gene splicing, and recombinant DNA technology, there has been some tendency to look to this exciting area as *the* answer to major problems facing agriculture. As in other fields, genetic engineering places agriculture on the brink of new directions and exciting developments. In fact, during this past summer, the U.S. Department of Agriculture (USDA) announced two breakthroughs based on genetic engineering—development of a safe, effective, relatively cheap vaccine for foot and mouth disease and a technology for moving genes from one kind of plant to another, which may open the way for creating genetic variations not possible now because of sterility barriers between species and genera.

However, we must continue to rely upon traditional genetics and breeding programs to bring about further improvements in yields, nutritional quality, pest resistance, and tolerance to environmental stresses. Standard breeding techniques will continue to give us superior strains of animals, cereal grains, forages, legumes, and many new fruits and vegetables. Therefore, despite the untold promise of genetic engineering, and indeed because of its demands, the need to collect, preserve, and study diverse populations is greater than ever.

USDA has a clear responsibility to provide leadership and coordination in scientific efforts to preserve biological diversity for agricultural needs. In such efforts, the Federal agricultural science and education agencies operate as partners in a much broader national system. This unique network includes universities, state agricultural experiment stations, private foundations, state departments of agriculture, industry, and others.

Through our cooperative National Plant Germplasm System, a network of public and private workers and facilities around the United States, over 450,000 collections of either seed or live vegetative plant material are currently being preserved. More than 200,000 samples from these collections are distributed to breeders and other scientists each year. The collection is expanding at the annual rate of 7,500 new introduc-

tions. This work is conducted at 26 sites in the United States, 6 of which are integrated Federal-State locations.

In addition, 50 States are contributing to eight regional germplasm projects organized by the State Agricultural Experiment Stations with some funding from USDA. Scientists involved with the regional projects work closely with USDA in guiding and setting policy for the entire germplasm system.

Special USDA grants now support research on problems such as genetic vulnerability. In addition to the national repository system, individual scientists have maintained valuable collections of basic germplasm for genetic studies, such as chromosome stocks of wheat and genetic stocks of barley and tomatoes.

The national system encompasses a continuum which begins with the acquisition of diverse germplasm and proceeds through maintenance, evaluation, development of improved germplasm, research on conservation of genetic diversity, and monitoring genetic vulnerability. Together, these efforts lead to increased productivity and decreased genetic vulnerability of crops grown on farmers' fields. If any segment of this continuum is weak or ineffective, the whole system is adversely affected, with serious implications for the scientific community, agricultural producers, processors, and consumers.

We've recently opened the first in a new series of clonal repositories for fruit and nut crops. Genetic material maintained in these repositories will help researchers develop a wider base of crops that will be able to withstand diseases, pests, and drought. The clonal germplasm repository system will, when completed, consist of 12 facilities. Germplasm will be made available to researchers and plant breeders of USDA, State Agricultural Experiment Stations, and industry throughout the country, and to the extent possible, to researchers and plant breeders in other countries.

The availability of diverse plant strains has been essential for research to develop cold-hardy citrus varieties, plants with enhanced nitrogen-fixing capabilities, budworn resistant cotton varieties, plants biochemically able to degrade herbicides, plants with increased photosynthetic efficiency, and those that produce food with higher nutritional value. Soil, land, and water shortages with which agriculture will be increasingly faced in coming years underscore how critical the success of such research efforts will be to the world food supply.

Livestock germplasm and breeding programs are also dedicated to increasing the efficiency of food production. Advances in animal breeding and genetics, such as improved genetic evaluation of breeding stock, embryo transfer, improved estrus detection and conception rates in cows, and synchronized farrowing in hogs, will help boost meat, milk, and egg production.

In other areas, particularly in disease prevention and control, exciting

research breakthroughs may soon produce tremendous benefits. Selection for genetic resistance to disease is already being practiced and is expected to eliminate the need for many drugs and vaccines. New techniques for determining specific genetic resistance to disease may soon make it possible to test and select fertilized eggs for transplanting to produce disease-resistant animals.

Preservation of breeds that have unique genetic and physiological traits is needed to assure a reservoir of genetic variability. For example, breeds with high production efficiency which are adapted to special environments in other parts of the world might well be valuable in U.S. regions with similar environments. Gains from crossbreeding may be enhanced by using exotic, highly productive breeds that differ genetically from our own.

Considerable research is needed for more adequate preservation of livestock germplasm, and there is a need to establish national and international systems to preserve valuable livestock germplasm similar to those that already exist for plant germplasm.

Genetic diversity is also critical to the success of the fledgling U.S. aquaculture industry. While some species such as trout have considerable diversity—most attained through research for desirable growth, disease-resistance, and hardiness—many strains still need to be tested and put into production, and we need a large gene pool to be able to develop new strains. The catfish, now edging its way into consumer markets, is essentially a wild creature which has had little genetic manipulation. Therefore, USDA has recently provided funds to Auburn University, Alabama, to investigate the potential and to develop techniques for improving catfish species through genetics and breeding. Related work is being supported at Mississippi State University for catfish and at Louisiana State University for crayfish.

In the United States we are just beginning to tap freshwater species as important food sources. We have learned valuable lessons from our neighbors around the world and are now successfully exploiting the potential of aquaculture. Difficult research questions abound, and it will take years to further improve all the species which hold the greatest promise for food production.

Genetic diversity is the foundation of biological pest control efforts which offer potential for saving precious resources. Our scientists are working throughout the world—through cooperative agreements, scientific exchanges, and in USDA labs in other countries—to collect potential control agents for pests attacking crops and animals in the United States. We need natural enemies capable of attacking pests under a variety of conditions and a variety of natural enemies to achieve a reliable rate of effectiveness. Biological diversity is essential because the scientist in the field can never be sure of exactly which organism will be a successful control agent.

Microbial germplasm, in an extensive network of working collections in this country and abroad, is an increasingly important resource. The collections are essential to studies of plant and animal resistance to pests, biological variation, host-parasite interactions, and development of resistant varieties. Collections of microorganisms are also extremely valuable resources in research on fermentation processes, production of organic compounds, and in such areas as nitrogen fixation, energy conversions, and methane production.

Collecting germplasm is just one step in the systematic preservation of materials for use today and in the future. Maintenance of the collections is time consuming and costly but essential to the viability of the collections. We need to strive not only to maintain our existing collection and preservation systems, but also to further improve and expand them.

We must continue to try to foster and improve cooperative research efforts involving USDA, universities, States, industry, private curators, international centers and foundations, and to expand all of our international activities. In view of the constraints on our resources, we must vigorously pursue the difficult task of determining which efforts will have the greatest payoff in terms of preserving germplasm while providing an adequate and safe food supply and improving production efficiency. In tandem with these thrusts, we must step up our technology transfer efforts so that we can get the maximum returns from our germplasm resources and research findings.

Agriculture does have valuable genetic resources to build on, but funds are limited. In the last 10 years, considerable progress has been made, especially with plants. Even so, the total worldwide effort, including that of the United States, is unacceptably low in relation to the magnitude of the job and the very short time for doing it. To assure that genetic diversity is available, we must act now in concerted efforts with countries around the world and with international organizations. The International Board of Plant Genetic Resources is working to collect and conserve crop germplasm worldwide, but this group too needs additional funds to expand collection, evaluation, maintenance, and use of resources.

People of the world today and in future generations will thrive or fail because of our efforts now. It is our responsibility as scientists, administrators, and resource managers to lend active support to meeting world needs for genetic diversity. We must reach out beyond our own numbers to explain the needs and challenges, scientific realities, and potential payoffs to the decisionmakers within our political systems who can provide the support necessary for these endeavors.

Even though genetic engineering has opened the prospect of a

dramatic new approach to improving crop and animal productivity, the Earth's lost genetic diversity is irreplaceable. A report of the Congressional Office of Technology Assessment provides dramatic examples: a wild melon collected in India was the source of resistance to powdery mildew and prevented the destruction of California melons; a seemingly useless wheat strain from Turkey was the source of genetic resistance to stripe rust when it became a problem in the Pacific Northwest; similarly, a Peruvian species contributed "ripe rot" resistance to American pepper plants, while a Korean cucumber strain provided high-yield production of hybrid cucumber seed for U.S farmers. Even genetic engineering is not ready to match the natural wealth of biological diversity and to meet such challenges.

By providing the needed genetic material for breeding programs, enviable strides have been made in agriculture and the world food supply. But the task is by no means complete. Challenges and opportunities abound. International cooperation and exchange programs are absolutely essential in moving forward.

Biological Diversity—Perspective of the National Science Foundation

Dr. Eloise E. Clark
Assistant Director, Biological, Behavioral and Social Sciences
National Science Foundation
Washington, D.C.

Homo sapiens, like no other species, has the ability to influence its environment far more than any animal of comparable size and reproductive capacity. In support of ever-increasing numbers of people and continued development and advancement of societies, humans are rushing toward an inevitable conflict between life as we now experience it and the continuing stability of the biosphere. It is timely to delineate choices for the wisest management of the natural resources of biological diversity.

My task this morning is to review for you the role, capabilities, and limitations of the National Science Foundation (NSF) in the area of biological diversity.

The Role of NSF

The mission of the National Science Foundation is to promote and advance scientific progress in the United States by sponsoring scientific research, carried out primarily by scientists at colleges and universities.

NSF Programs—Current Abilities and Limitations

The programs most relevant to the topic of biological diversity are those in our Division of Environmental Biology. These programs support the research that seeks to advance our knowledge of the attributes and interrelations of organisms in their natural environments. An oft-cited CEQ report treats biological diversity in terms of two related concepts—genetic diversity and ecological diversity. As used, genetic diversity refers to the genetic variability *within* a species, and ecological diversity refers to species richness in a community. Our Systematic Biology, Population Biology, Ecology, and Ecosystem Studies Programs support research that fully spans these concepts. The Biological Research Resources Program provides assistance for research facilities that are considered essential at the national level.

To illustrate more concretely the scope of our research in environmental biology, I will use two examples that cut across disciplinary program lines: tropical biology and resources for biological research. We see a significant and growing interest in research on tropical biology. About 20 percent of our funds available for environmental biology support projects in tropical biology. Some of the projects supported by NSF are large international efforts such as the Projecto Flora Amazonia involving U.S. and Brazilian scientists or the Flora of Meso-America, a joint undertaking between Mexico, England, and the United States. Other projects seek to understand the structure and function of terrestrial and aquatic ecosystem types, including a comparison of tropical agro-ecosystem structure and function with natural ecosystems. NSF awards about 50 percent of the funding by Federal agencies for tropical biology research.

Biological research requires support for field and marine facilities, stock centers, special purpose laboratories, and maintenance of major specimen collections. The Biological Research Resources Program was established to help meet these needs. We provide support for field stations operated by universities around the country and also the research site of the Organization of Tropical Studies at La Selva, Costa Rica. These grants are primarily for capital improvements and specialized equipment. Our resources in this regard are limited and in no way meet the legitimate needs that currently exist. Marine labs in the United States are particularly in dire need of some assistance. It is our intent this year to initiate a special grant competition to meet these needs for renovation and improvement. But we will only begin the process; participation by other agencies and the private sector will be required.

I can report that a second inventory of U.S. research sites which are suitable as experimental ecological reserves is nearly completed. This inventory emphasizes freshwater aquatic and coastal sites, as well as

additional terrestrial sites not reviewed in the earlier effort. This group of some 100 sites is under the stewardship of private, State, and Federal ownership. The United States is fortunate to have such a resource. Our challenge now is to use it more effectively to further our basic understanding of, and ability to manage, biological diversity.

The Biological Research Resources Program also supports living organism stock centers. Despite their very specific purpose of conducting basic research on genetic mechanisms, such centers are of direct and immediate use to the agriculture and pharmaceutical industries. Some 20 such centers now receive support from NSF and range from stocks of microorganism cell lines, to *Drosophila*, mutant mice, and maize.

As we proceed with the business of germplasm preservation, we expect sharply increased needs, especially for tropical plants and invertebrates important to agriculture and pharmaceuticals. The Federal Germplasm Planning Group, to which NSF and many U.S. agencies represented here today belong, is presently inventorying germplasm and living stock centers. How we meet this imminent need for germplasm remains unclear, but inventory and subsequent analysis, planning, and recommendations merit attention at the highest levels.

What can be done? Clearly no one agency, industry, or country can do the job alone. Judging from our experience with living organism stock centers, there are some excellent models of the type of cooperation that is required. The Tomato Genetic Stock Center, at the University of California, Davis, successfully meets the national and international needs of agriculture and basic research and effectively melds support from Federal and private sources to accomplish its tasks. A second example of successful collaboration in germplasm research is the American Type Culture Collection, a nonprofit organization located in Rockville, Maryland that deals exclusively with microorganisms. It serves and is served by NSF, National Institutes of Health (NIH), and numerous pharmaceutical companies. And there are international organizations as well that illustrate my point. The task of preservation, where this is the appropriate strategy, can be done when we decide it can be done.

International Activities

A second important role of NSF is to encourage and support U.S. scientific participation in international scientific activities. The Foundation is charged with fostering the interchange of information among scientists in the United States and foreign countries, initiating and supporting scientific activities as an element of international cooperation, and giving U.S. scientists opportunities to participate in cooperative activities involving developing country counterparts.

NSF support for cooperative science projects is provided through individual project grants to U.S. institutions. Support is contingent on the

demonstration that foreign counterpart scientists are appropriately involved in the planning, performing, and publication of research results.

NSF encourages cooperative activities through participation in some formal bilateral science agreements. Informal regional programs are in place in Latin America, South Asia, and Southeast Asia. In addition, an open program enables some U.S. scientists to work with counterparts in many low- and middle-income countries of Africa, Asia, and Latin America on problems of local priority interest.

Much concern has been raised about the funding cuts to science, especially international programs. NSF's Division of International Programs will search for ways to maintain its support for as many scientists as possible. Certainly with reduced resources, implementing these programs will require careful planning and creative approaches on the part of NSF and the scientific community.

Many of the problems that face humankind now and in the future transcend national boundaries. International cooperation is essential. Just as there are keystone species in biological systems, cooperation is a keystone component of efforts to understand, preserve, and manage biological diversity.

Conclusion

The issue of preserving and managing biological diversity faces us at a particularly difficult time. Meeting demands in these areas will push the limits of our fiscal resources, technical and management personnel, and time. This is not the time to make the plea for more money, but rather, to examine how to most effectively bring existing resources to bear on this need. There is a strong base of scientific expertise; there are programs to build upon to preserve germplasm and manage biological diversity; and there are activities associated with development and modification of the biosphere which carry with them the requirement to evaluate and mitigate adverse consequences. Despite good intentions, our collective efforts are not well coordinated. I don't mean to imply that we are proceeding in chaos—there certainly are examples to the contrary. I do feel, however, that in terms of communication, cooperation, and collaboration among the sectors represented at this conference, there is much more that can be done. I would urge the panels to approach these matters as creatively as possible. I would then urge those of us in a position to make some changes to listen and act on your recommendations.

VIEWS FROM THE COMMUNITY

Genetic Diversity: Strategic Significance and U.S. Opportunity

Dr. Jean Mayer
President, Tufts University
Medford, Massachusetts

Earlier this year, the State Department's Advisory Committee on Oceans and International Environmental and Scientific Affairs, of which I am a member, decided that the potential developments in genetic engineering over the next two decades and their implications for U.S. foreign policy loom so large that they warrant attention from a special ad hoc subcommittee. At the request of the Advisory Committee, a panel of internationally recognized experts was assembled and convened for the Department of State by the American Association for the Advancement of Science.

The panel, of which I am chairman, addressed the areas of application, such as agriculture, patents, and health. We consider that the coming developments in genetic engineering will be among the most significant scientific and technological breakthroughs of this century, on a par with unlocking the atom, escaping the Earth's gravity, and the computer revolution. Genetic engineering holds the promise of revolutionizing agriculture, health, and industry. It offers the United States the opportunity for commercial and scientific leadership, provided we take the appropriate steps now. In 10 years it will be too late.

The panel made a number of recommendations that address the broad implications of genetic engineering. The top priority, and the reason for this conference, is protecting the genetic resources we have now. Our report stated, "We must preserve germplasm on an international scale to protect against crop pathogens and loss of genetic diversity. The Department of State and other concerned agencies should give immediate attention to the development of an appropriate germplasm preservation system." We must move quickly. While people in the field have been aware for more than a decade of the increasingly rapid disappearance of species, the message has not spread widely enough to have much effect. Some efforts are already underway, but they are inadequate, especially in the Tropics, where many of the species and varieties originated, and where the bulk of agricultural increase must come if we are to feed the growing world population. If we do not move soon, there will be much, much less left to work with. It is critical that we conserve and inventory what we have on a worldwide basis.

Ten thousand years ago, when the world's human population num-

bered about 5 million and we were hunter-gatherers, there were about 25 square kilometers per person, and worldwide, man existed on some 5,000 wild food plants. Today, with over 4 billion people on Earth, there is an overall density of 25 persons per square kilometer, and fewer than 150 food plants enter world commerce. Just 10 plant species provide about 80 percent of the world's calories.

This increase in the Earth's ability to support man has been made possible by the development of agriculture, which in turn has been dependent on the domestication of plants. Our ability to feed the world as well as it is fed—in some cases, very, very poorly—rests largely on the genetic breakthroughs of the Green Revolution and the development of high-yielding varieties, particularly of cereals, wheat, and rice. But the achievement of these yields has been at the further sacrifice of crop diversity. Such an enormous concentration on a few species makes us extremely vulnerable to catastrophic disruptions in the food supply through natural or engineered disasters.

Many people here, and certainly every farmer, will remember the southern corn blight of 1970, a vivid illustration of the dangers of American genetic uniformity. About one-fifth of the U.S. corn crop was destroyed. The problem was able to be corrected the next year, so for consumers, the blight meant only higher food prices. But, if the crop failure had occurred, say in Guatemala or Kenya, where corn provides about half of the daily calorie intake, it would have been a major national disaster.

And such disasters *have* occurred. One has only to think of the Irish famine in the 1830's when a previously unknown disease infested the potato crop. In 10 years, 2 million people had died; 2 million had emigrated; and 4 million—half the number at the beginning of the decade—remained in Ireland, most living in absolute poverty. The genetic base of the Irish potato crop had been narrowed to the point where there was little resistance to the fungus. Subsequently, genes for resistance were bred back in by using potatoes from the Andes in South America.

There is a local joke in Pakistan that the new miracle wheat has given rise to a new miracle locust. In terms of feeding the world, it is black humor. There is always an uncertain truce between food plants and their pathogens. Like wild plants, pathogens are constantly changing genetically, and if one grows or preys suddenly on a previously resistant plant host, it may spread across the entire population if the plants are genetically uniform. In many parts of the world, such a population might still be limited to one field, or one village, or one district. But, by the year 2000, world population is expected to increase to slightly over 6 billion. At this point, and for the next 20 years, the only way we have to feed those new people is by extending the techniques of the Green Revolution, and as monocultural agriculture spreads, the dangers of genetic uniformity increase.

After the 1970 corn blight, the National Academy of Sciences did a study of the genetic vulnerability of major crops. It found that 40 percent of our acreage of hard red winter wheat was planted with just two varieties and their derivatives. The genetic base of soybeans was limited to just six seed collections. Some changes have been made in the last few years, but our basic crops are still highly vulnerable.

A narrow genetic base is necessary if we are to obtain the most uniformly high-yielding seed over a short period of time. But at the same time, it is absolutely essential to preserve and maintain the reserves of genetic diversity that still exist in native agriculture and in the world. Until very recently, geneticists have been able to return to these areas, usually in the Third World countries, to collect germplasm for new breeding programs. Today, more and more we are seeing Mexican farmers planting hybrid corn from the American midwest, Tibetan farmers planting barley from Sweden, and Turkish farmers planting wheat from the Mexican wheat program. Unless we act, when the Indian farmers in Bolivia and Peru adopt the newer, more productive potato varieties, the older varieties will die out, and nowhere will we have the diversity that restored the Irish potato crop.

There is another consideration. We should be looking not only at protecting and improving the domesticated plants and animals that have been the basis of agriculture for the last 10,000 years, but also at increasing the number of basic foods available to man. This means not just inventorying but protecting the diversity of wild things. Among their great variety, there may be some that will prove to be very important. For example, the School of Nutrition at Tufts is studying a species of palm from the Amazon valley whose oil is similar to olive oil and whose protein value is equivalent to the best animal proteins and 40 percent higher than that of soybeans. There are primitive cereals, some of them grains, that are known to grow well in saline soils or brackish water. Considering the cost of desalinization of water, these should certainly be looked at.

We have been talking just about foods, but there may be many other wild plants that could make very important contributions to the health and welfare of mankind. For example, some of the plants that secrete latex or oils may be a potential source of fuel. Even more important, perhaps, is the wealth of medicinal plants, used so extensively by native peoples, yet largely ignored thus far by the medical sciences. It is important to remember that many of our most potent and useful drugs came originally from plant medicines developed by primitive peoples. It may well be that there are some equally efficacious medicines waiting to be developed, if they do not disappear before we realize they exist.

Biological Diversity and Genetic Engineering

Dr. Jim R. Murray
President, Policy Research Corporation
Chicago, Illinois

The Revolution in Genetics

The revolution which has occurred in genetics in the last quarter of a century has made possible the development of a powerful new technology. This technology is genetic engineering, and it promises to have an impact on the order of computers or atomic power before this century is through. Any revolution of this magnitude inevitably turns many disciplines on their heads and forces a reassessment of old assumptions and traditions. Such is the case with genetic engineering.

What is Genetic Engineering?

In general, any manipulation of the genetic makeup of an organism aimed at increasing its usefulness to people is genetic engineering, including traditional forms of plant and animal breeding which have been practiced for thousands of years. However, the term is usually used in reference to new technologies of genetic manipulation which have been made possible by recent advances in genetics, cell biology, and molecular biology. Perhaps the most dramatic of these techniques is recombinant DNA technology, in which foreign genetic material is introduced directly into a cell's genes in the laboratory, resulting in a new organism with unique properties. Other techniques of the new biotechnology include gene splicing, cell culture, cell regeneration, and protoplast fusion. The techniques represent a wide variety of approaches to genetic and cellular manipulation, but they have one outstanding attribute in common: they are making it possible to cross taxonomic boundaries in the manipulation of genetic material.

Some of the early successes of genetic engineering include the development of modified bacteria which produce human interferon, human growth hormone, and human insulin economically. Most of the first successes of genetic engineering will be with microorganisms because techniques for working with them are the most advanced to date. However, applications of genetic engineering to other organisms are becoming increasingly practical, and within the next 5 to 10 years there will be a wide variety of successes with crop plants and even livestock. For example, it is now possible to use genetic engineering to combine the desirable traits of several of the economically significant species of coffee trees to develop greatly improved varieties. In a recent study,[1] the Policy Research Corporation and the Chicago Group, Inc. concluded that the

market potential from genetic engineering in the agribusiness sector alone would be in the $50-$100 billion dollar range by the end of this decade.

The new biotechnologies are making possible solutions to problems facing agriculture and will play a central role in meeting the increasing food demands occasioned by rapidly increasing populations in many developing countries. Biotechnology will also play a major role in developing alternatives to the use of fossil fuel and in developing renewable energy sources throughout the world. Genetic engineering will also make possible the development of many new vaccines for serious human and animal diseases.

Germplasm and Genetic Engineering

The importance of biological diversity to the future of genetic engineering cannot be overemphasized. Germplasm is the fundamental resource of the new biotechnologies, and it is conceivable that it could become a limiting resource preventing full realization of genetic engineering's tremendous positive potential.

Because genetic engineering makes it possible to use genetic material from almost any species in the improvement of commercially important species, it is necessary to reexamine the basic priorities of current efforts to maintain biological diversity. Most of the germplasm which is actively collected, described, and preserved today is from varieties of economically useful organisms. However, the scope of future germplasm needs will be far greater. Germplasm from many organisms considered to be of no current economic importance may be used in genetic engineering. Although it is difficult to do, the many ways in which germplasm resources will be used by genetic engineering must be anticipated if a realistic approach to biological diversity is to be formulated. A number of current activities do provide some examples of a new approach to germplasm utilization.

One example concerns a variety of microbes capable of surviving in polluted environments and those which use pollutants as energy sources, degrading the pollutants in the process. Recent estimates indicate that $36 billion is spent annually by the public and private sectors in efforts to control pollution, thus the development of microbes which can be used for pollution control is considered to be of tremendous importance. Companies in the pollution control and monitoring field have found unique strains of certain microbes at polluted sites and have preserved these for further genetic engineering and refinement. But there is no coordinated effort to identify and collect microorganisms with specific adaptations to polluted environments, and preservation of such germplasm is largely dependent upon the activities and foresight of a small number of corporations.

[1]*An Assessment of the Global Potential of Genetic Engineering in the Agribusiness Sector.*

Another potential contribution of genetic engineering, which will depend in the long run on access to a wide variety of currently unavailable germplasm resources, is the engineering of stress resistance in crops. Recent research indicates that a number of plants have similar genetic responses to stressful conditions such as high temperature or nutrient deficiency. As the function and genetic regulation of stress response is decoded, it should become possible to use this information in the development of crop varieties which are better suited to marginal environments. Such varieties would be of considerable significance to agricultural development in many Third World countries.

Developing Priorities

Existing approaches to the development of priorities for germplasm preservation and management are not realistic because they do not reflect the many new possibilities for germplasm use in genetic engineering. A better approach might be to determine for each group of organisms, such as microbes or plants, what traits, rather than species, will be of economic importance, and then attempt to preserve species with these traits.

The identification of new priorities for management of biological diversity is an issue of importance to the future of genetic engineering and the success of any further efforts to preserve germplasm. Before further action is taken, priorities should be developed with the advice of the public sector; the private sector, the major supplier of genetic engineering; and developing countries, the major source of biological diversity and possibly the primary beneficiaries in the coming years.

Private Sector Involvement

Genetic engineering is unusually dependent on commercial interests. There are over 130 corporations in the United States alone which have made substantial investments in genetic engineering in the past 10 years, and private sector support is far greater than public support of the new technologies in almost all industrialized countries. In addition, commercial applications of the technology will become a primary source of research problems and priorities, and further research will be primarily motivated by the needs and problems of the private sector and consumers of products it produces.

Some companies treat their germplasm as a proprietary resource. In addition, secrecy has become a dominant characteristic of private sector genetic engineering efforts, and this secrecy is already being extended to private germplasm collections. Therefore, private sector competition for germplasm resources is an important issue. The increasing dependence of the private sector on germplasm resources presents an opportunity to

focus private resources in a cooperative effort to manage biological diversity as wisely as possible. But without considerable effort on the part of the public sector, especially public organizations already working to preserve biological diversity, the private sector is more likely to be a hindrance than a help.

National Interests

As germplasm is perceived as more important to agricultural and industrial development, and as its central role in genetic engineering becomes clear, it may become an important issue to most countries. The United States is presently the largest supplier of biotechnology equipment and expertise. Other technology suppliers are Japan, a number of European countries, Israel, and Canada.

Developing countries must continue to depend upon the United States and other sources of biotechnology for a number of years. However, many developing countries will have an advantage in that they are the sources of a large percentage of the germplasm resources of the world. In many cases countries will recognize the significance of this natural resource and will begin to make stronger efforts to limit outside access to it. A context must be developed in which a strategy of cooperation is appealing for both developing and industrialized countries if the full potential of genetic engineering is to be realized.

Important Issues

A number of issues become of primary importance for the management of biological diversity when the new context created by genetic engineering is considered. These issues are central to the development of a coherent policy toward germplasm and must be resolved before further efforts are made to formulate a strategy toward germplasm management on either a national or international level.

The most basic issue is the germplasm needs of genetic engineering. First, it is necessary to set some priorities for application of genetic engineering. Priorities for germplasm collection and description must then be established, as consistent with the needs to which genetic engineering will be applied.

An issue which is also relevant to germplasm management is the development of methods for germplasm analysis and description on a large scale. It is necessary to develop a better understanding of the biochemistry and genetics of many of the organisms already preserved in germplasm collections and to obtain more detailed information about many other organisms as they are identified or

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collected. Germplasm collections should not only reflect the needs of genetic engineering, but should also maintain germplasm such that it is of practical value to genetic engineering.

The dominant role of the private sector in the development and support of genetic engineering creates another issue: the need for involvement of the private sector in efforts to manage biological diversity. Both sides of this issue must be considered. On the one hand, the greater interest of the private sector in germplasm resources will present obstacles to widespread collection, management, or sharing of germplasm. On the other hand, the economic dependence of the private sector on germplasm resources may make it possible to utilize private sector capital and technology for more successful management of germplasm.

A final issue is the economic, political, and related interests of various countries in their technical expertise or natural resources necessary for genetic engineering. Germplasm has the potential to become an issue in the national policy of many countries, but hopefully national interests can also be used to facilitate better germplasm management and to increase access to greater resources.

Biological Diversity and Environmental Quality

Dr. David Pimentel
Professor, Cornell University
Ithaca, New York

Maintenance of a quality environment depends upon a myriad of complex natural systems composed of hundreds of thousands of plant, animal, and microbial species. We rely not only on our crop and livestock species, but also on natural biota, which perform many essential functions for agriculture, forestry, and other segments of human society. These functions include preventing the accumulation of wastes; cleaning the water and soil of pollutants; recycling vital chemical elements within the ecosystem; buffering air pollutants and moderating climatic change; conserving soil and water; serving as sources of certain medicines, pigments, and spices; preserving genetic material for agriculture; and supplying food via the harvest of fish and other wildlife. In addition to these important ecosystem functions, the natural biota are of great aesthetic value to society.

Concern for preserving the natural environment is reflected in recent passage of numerous State and Federal laws, including the National Environmental Policy Act (NEPA) of 1969, the Marine

Mammal Protection Act of 1972, the Endangered Species Act of 1973, and the Fishery Conservation and Management Act of 1976. NEPA mandates that national government agencies be concerned with any "major Federal actions significantly affecting the quality of the human environment . . . " This interest manifests itself in the activities of the U.S. Environmental Protection Agency and the preparation of environmental impact statements (EIS). Attention has been directed at such aspects as the social, economic, physical, and biological impacts that proposed environmental manipulations might have. Biological impacts have included possible effects on fish and wildlife, plant conservation, and endangered species. No mention is made of microorganisms, pollinators, and many other small species, although the general nature of the guidance does not exclude their consideration.

If environmental policy is to include all "significant impacts" of an action, then it should consider the potential impacts on all organisms vital to the total ecosystem. We must, therefore, assess and understand the ecological role of major species groups, so that we can identify those that are essential for a viable ecosystem. To make this assessment, we will need all the available, though limited, data concerning the abundance, distribution, and roles of all natural biota.

Here I will attempt to point out the relative importance of major species groups in the ecosystem, examine some of the vital processes these biota carry out, and identify potential human impacts on the biota.

Although humans dominate the U.S. ecosystem, they make up only a small percentage of the biomass of the system. Specifically, the average biomass of humans per acre in the nation is about 16 pounds; insects and earthworms average about 1,000 pounds; protozoa and algae about 134 pounds; bacteria about 1,500 pounds; fungi about 2,500 pounds; and plants about 49,000 pounds per acre.

One vital role of biota is degrading and recycling the tremendous quantities of organic waste produced by plants and animals. Each year, the human population in the United States produces about 130 million tons (1,200 pounds per capita) of excreta, and the livestock population produces about 2 billion tons of manure. On the whole, over 12 billion tons of organic wastes, half of which are produced by human activities, are generated in the United States annually. Less than 1 percent of the total is burned; the rest is degraded by earthworms, nematodes, protozoa, bacteria, algae, and fungi. Without microorganisms and invertebrates, we literally would be buried in wastes.

Large quantities of about 50,000 different chemical compounds are produced annually for use by U.S. agriculture, industry, and

homes. These include more than 500,000 tons of pesticides, 4 million tons of soaps and detergents, 18 million tons of ammonia, 12 million tons of alkalies, and 4 million tons of acids. A large proportion of these chemicals eventually finds its way into the environment as pollutants. For example, of the 500,000 tons of pesticides applied to crops in the United States, less than 1 percent reaches the target pests. Pesticides and other chemicals released into the environment are degraded both by biotic mechanisms (particularly microorganisms) and physical mechanisms. Microorganisms also facilitate degradation of organic chemical wastes, such as the 8 million tons of phenols and 7 million barrels of oil spilled into the environment annually.

Each year billions of tons of air pollutants are produced through the combustion of fossil fuels. Four of these—sulfur dioxide (SO_2), carbon monoxide (CO), nitrogen dioxide (NO_2), and carbon dioxide (CO_2)—total 5 billion tons. Natural biota act as sinks for some of these air pollutants. For example, macroscopic plants remove SO_2 from the atmosphere; soil fungi and bacteria reduce and oxidize almost all the carbon monoxide produced; and most of the NO_2 produced by fossil fuel combustion is easily incorporated into the biological nitrogen cycle. Although carbon dioxide is essential for plant growth and development, vegetation in the United States removes only about 15 percent of the 4.7 billion tons of CO_2 produced by the combustion of fuels. Worldwide, the combination of fossil fuel combustion and the destruction and burning of many forests may be increasing the CO_2 content of the atmosphere, which may in turn cause global warming and climatic changes.

Nitrogen is an essential element for plant growth and production of high-protein food. It may be supplied either through the application of nitrogen fertilizers or by biological nitrogen fixation carried out by microorganisms which transform elemental nitrogen from the atmosphere into a form that plants can use. Annually in the United States, an estimated 15 million tons of nitrogen is biologically fixed, with a calculated value of about $3.5 billion, and about 11 million tons of nitrogen fertilizer are applied. As domestic natural gas supplies decline and other fossil energy supplies become much more expensive, agriculture will become increasingly more reliant on biological nitrogen fixation.

Cross-pollination is essential to the reproduction of many plants. A total of 90 U.S. crops, valued at nearly $4 billion, are dependent upon insect pollination, and 9 additional crops, valued at $4.5 billion, are significantly benefited by insect pollination. In addition to the cultured plants, large numbers of wild plants—an estimated 20,000 species of U.S. native flowering plants—are dependent upon biotic

cross-pollination mechanisms. Despite man's many technological advances, substitutes for insect pollination of plants do not exist. Clearly, insect pollination is essential to U.S. food production and the perpetuation of many wild plant species.

Naturally occurring predators and parasites play important roles both in controlling actual "pest" insect populations and preventing outbreaks of potential pest species. It has been estimated that these organisms save several billion dollars by controlling insect pests of agricultural and forestry crops. Field tests demonstrated that certain insects were about one-tenth as abundant in diversified crop plantings as in simplified monocultures. In host plants, genetic diversity tends to prevent plant pathogens and insect pests from evolving and overcoming resistance bred into these host plants. A greater understanding of the importance of genetic diversity and stability in parasite-host systems will result from thorough investigations of wild parasite-host populations. This basic scientific information will aid man in controlling deleterious plant pathogens and insects that devastate agriculture.

Annually in the United States, about 5 million tons of fresh food is harvested from the natural biota, with a value of over $2.8 billion. The commercial and sports fisheries represent the largest proportion of the harvested natural biota, with about 4 million tons valued at more than $2.4 billion. The remaining products harvested from the natural biota include big and small game mammals, game birds, maple syrup, tree nuts, blueberries, and algae. The estimated food value of the harvested products from the natural biota totals about 4 pounds of protein per capita per year, representing about 6 percent of our total animal protein.

Clearly, the various species of the natural biota play many roles in maintaining a quality environment in this country. To what extent does man interfere with these essential ecological processes? Available data suggest that many are being seriously affected by human activities, such as extensive highway construction, great expansion of urban areas, and generation of wastes from industrial production. Atmospheric emission of sulfur dioxide during coal combustion is a major cause of "acid rain"—a phenomenon which may poison soils and water and reduce forest and fish yields. Harvests of commercial fish have been reduced by pesticides, oils, and other pollutants. These losses have increased substantially since 1969. In the last 5 years an estimated 450 million fish have been killed by pollutants.

Thus, several human activities are affecting the functioning of many of the major ecological processes carried out by natural biota. In particular, the processes of pollination, waste degradation, and fish harvests are under increasing stress. Most environmental concerns, however, center upon endangered species, large species such

as mammals and birds, and vegetated areas legislated for consideration by numerous environmental statutes. Although some attention is given to the status of small organisms such as microorganisms and invertebrates, the evaluation of these species groups has generally been limited. If the stated objective of the National Environmental Policy Act is to include all "significant impacts," then potential effects on all organisms vital to maintaining a quality environment should be considered.

Clearly, a need exists for more complete data on the relative importance and functions of the major species groups that dominate the essential processes of the natural ecosystem. This basic information is required for the development of sound policies for environmental assessments by all government agencies. Priorities and policy decisions can be only as reliable as the data are sound. Therefore, assessments of environmental hazards must include all major species groups that are vital to the nation's ecosystems.

Biological Diversity and Society

Dr. Thomas E. Lovejoy
Vice President for Science, World Wildlife Fund
Washington, D.C.

Ultimately what we are addressing at this conference is the value of our diverse biological resources and what might be done to safeguard this fundamental cornucopia. The values are based on the very nature of life itself, the magnificent exception to the second law of thermodynamics. Only life has the capacity to take energy and create greater order by converting it into living matter. Only in this form is it consumable by other forms of life, including ourselves.

Although it is not beyond the realm of possibility, we do not know of life elsewhere in the universe. Even were life to be found elsewhere, there is no guarantee that it would be compatible with our life forms and useful to us, and it certainly would not be accessible to us in any practical sense. We are really restricted to the life we have on Earth and, as robust as it may seem, this magnificent exception of which we are part is, in the last analysis, very fragile unless handled with care.

It is important to remember that life on Earth is never at a status quo, that it is constantly adapting to new conditions. Although there have always been extinctions, the great reductions in biological diversity which are so imminent are on a scale never before experienced in the history of our species.

Throughout our existence, we have drawn upon the cornucopia of biological diversity to sustain and improve our welfare. Two major

drawing periods for agriculture were during the neolithic, when agriculture was born, and during the later period, when European society first had access to the New World's resources such as the turkey, potato, corn, and tobacco. The search for new biological resources has been a major driving force in our cultural history. The first cultural and commercial links between China and the Western world were derived from a lust for the exotic flavors of oriental spices and for the secretions emanating from the nether end of silkmoth caterpillars. Quests for similar resources were major inspirations for the voyages of many of the great explorers. Today there is continuing search and discovery of ways in which species in the wild can improve human welfare.

The example of the recently discovered species of wild perennial corn on a hillside in Mexico is much cited. Even if its potential to transform corn agriculture from an annual to a perennial crop, or to transfer to domestic corn its resistance to a number of important critical virus diseases is never realized, the lesson to be derived from this example is critical. Society is indeed likely to be better off because that hillside had not been transformed, as so many in Mexico, into an ordinary cornfield. The future welfare of society can best be served by a landscape both domestic and wild.

The recent discovery of a small group of compounds with marked antiviral and antitumor properties is another example of how esoteric forms of life, with no apparent redeeming social importance, are being found to be significant. These compounds were isolated from one of the lowliest of our relatives in the phylum Chordata, a tunicate or sea-squirt, a species new to science and yet unnamed. If the potential medical value is realized, it may not prove as revolutionary for human welfare as vaccinations, which are derived from the properties of a virus, or antibiotics, which are derived from the properties of a mold, but it would, nonetheless, be of real value.

Many of what in the popular mind are considered endangered species, namely vertebrates—particularly birds and mammals—are perhaps less likely to provide such direct use benefits. But as highly advanced forms of life, they have the potential to tell us a lot about our own biology, and they play important roles in their ecological communities, which include species more likely to be of value.

One of the critical values of the variety of plants and animals is the basis they provide for growth of knowledge. It is very useful to know the various conditions under which life can exist and the solutions arrived at in the course of evolution under particular sets of conditions. Indeed, the almost melodramatic habit of salmon to die soon after spawning means that the greatest contribution of that species to society is likely to be a better understanding of the aging process rather than being served as a canape.

In considering biological diversity, it is immediately apparent that the great majority of species are invertebrates (most of them insects), which we, as vertebrates, tend to look down upon, as if afflicted with a sort of vertebrate chauvinism. In their role as pollinators, insects are vital to the functioning of natural ecosystems. It is no small matter for New Zealand that it lacks suitable pollinators for its alfalfa crop and must import North American leaf cutting bees, and similarly will soon face a pollinator problem with the rapid increase of kiwi fruit agriculture because it, too, is not a native species. Australia still has a major problem from lack of native insects capable of encouraging decomposition of the large amounts of livestock excreta.

In the overwhelming majority of cases it is not possible to speak of the direct use benefits of species, either because they cannot be divined with our present state of knowledge or because there simply may never be any. Our inability to predict which species may be useful gives us cause not to write off, with impunity, any species.

All species, however, take part in ecosystem functions and contribute to the valuable services of ecosystems. The watershed service of forests is a traditional example, and one of sufficient importance to inspire an Agency for International Development (AID) project to reforest the watershed of the Panama Canal. In those forests tens of thousands of species are literally making a contribution to the part of world commerce dependent on the canal.

Least appreciated and perhaps not very well understood is the role the biota collectively play in the stability of global chemistry and climate. The composition of the Earth's atmosphere is remarkably different because of past life, and it appears to be kept stable because of current life. The current disruptions of global cycles of carbon, nitrogen, and sulfur are worrisome in this context because they are partly generated by disruption of the biota and because of the potential for further biotic disruption.

An interesting example of an ecosystem function is the relationship between the floodplain forests of the Amazon and its tributaries and the major fishery they contain. The food chains of many of the important food species can be traced back to these forests where seeds and fruit falling into the water are eaten by fish. Despite recognition of the critical function of nutrient transfer from land to freshwater by the floodplain forest ecosystem, there are thoughts to cut these forests in favor of growing rice or water buffalo on the alluvial soils. It will be very difficult to argue in favor of fish over rice when it is so hard to quantify the productivity of a hectare of floodplain in fish as opposed to rice. In any trade-off analysis, rice is likely to come out ahead. Yet trade-offs are deceptive. In this case the productivity and diversity of the river and its fishery would be

reduced forever. This should not be an acceptable trade-off; rather, ways should be sought to increase productivity of portions of the floodplain in ways immediately useful to people without any major effect on the fishery. One of the tragedies of the Aswan Dam is that such a trade-off was probably accepted, forever reducing the capacity of the eastern Mediterranean fishery.

The relationship between conservation and development has been a matter of considerable attention of late, particularly as highlighted by the World Conservation Strategy. No one would argue that good conservation is not basic to sound development, or that it is not easier to achieve sound natural resource practices once a reasonable standard of living is achieved. In some instances, however, the resource base is already too overburdened. Then standards of living can increase, but only temporarily, by further overdrafts on natural resources. There will be strong pressure to do so, however unwise it would be in the long view. Indeed, in some instances, humane considerations or political reality may not permit any other choice, but the planet's capacity to support people may well, in the process, be irrevocably diminished. It is important to be ever alert to such situations, for frequently what may under the circumstances seem reasonable as an incremental decision may be incorrect when such decisions are viewed in the aggregate.

A lot is heard these days of the potential of genetic engineering, and indeed, there are important gains to be made in production of certain kinds of biological products. Production, if handled wisely, can help protect biological diversity by meeting certain pressures. It would be the ultimate irony, however, if through developing new strains of crop plants better adapted to presently marginal lands, it were to lead to insouciant encroachment on the remaining strongholds of biological diversity. Biological engineering depends on biological diversity for the very stuff with which it works and can only reach its full potential if diversity is maintained. Should high-volume biological production of the tunicate antiviral compounds prove desirable, it will only have been possible because those tunicates still existed. Indeed, the ultimate genetic engineering is what goes on daily in nature, conducted by millions of species. What a tragedy if genetic engineering's seeming ability to promise anything were to lead to it undercutting itself.

There are, then, a variety of important and urgent practical arguments for the maintenance of biological diversity, but persuasion will nonetheless not be easy. Fortunately, of those disinclined to listen, at least some will be convinced because so much of the natural world is beautiful, and because if one permits oneself a glimpse, it is found to be intricate, interesting, and exciting in its constructs and workings.

It is to be hoped that the diversity crisis will lead to an increase in biological literacy among people everywhere. Utopian it may be, but perhaps rather than nations scrapping with one another over dwindling biological resources, the ultimate gift of the biota will, in the moment of their peril, be to lead to a degree of collaboration among nations never realized heretofore. If this happens, it could well turn out to be the best of what Barbara Tuchman terms "mankind's better moments."

International Programs With Special Reference to Genetic Conservation and the Role of the United States

Dr. J. Trevor Williams
Executive Secretary, International Board for Plant Genetic Resources
Rome, Italy

For years, we have been receiving reports[1] predicting that in the immediate future the world will be more densely populated and more unstable ecologically and that any development has to take account of the conservation of living resources.[2] Pliny, who wrote nearly 2000 years ago, said, "It is not unusual for us to poison rivers and the very elements of which the world is made; even the air itself in which all things live, we corrupt til it injures and destroys."

In the last decades, concern for maintaining biological diversity has grown out of the understanding that living resources are renewable if conserved, but destroyed if not. Scientifically, our concepts have also developed. We now accept that to maintain diversity, gene pools, rather than several individual representative specimens, require preservation.

My task is to outline the international aspects of such work. At the outset I have to stress that:

(1) Maintenance of gene pools may be done in a number of ways and is not necessarily synonymous with conservation.

(2) We have an overriding need to preserve genetic diversity and to genetically improve cultivated plants, forest trees, fish, and animals. Today we have a responsibility to consider the billions of additional poor who will populate the earth by the turn of the century. The international communities' policies, strategies, and programs must weigh carefully the resources and the approach to conservation. We must realize that it is not practicable to preserve the total array of genetic diversity. Limits have to be defined for action on species of direct concern to society's "present and future health and welfare"[3] and on those which should be protected for possible future uses.

(3) The World Conservation Strategy of the International Union for the Conservation of Nature, the U.N. Environment Programme, and the World Wildlife Fund states that "national and international capacities to conserve are ill-organized and fragmented amongst many sectors such as agriculture, forestry, fisheries, and wildlife."

For a number of years, the Food and Agriculture Organization (FAO) of the United Nations has been concerned about conservation of the genetic resources of crops, animals, forests, and fish and has held a number of important consultations and conferences in association with other international agencies or organizations. The main goals are to stimulate awareness of the needs for conservation, to insure that living resources are freely shared, and to promote international action that stimulates and supports national action. In 1974 the FAO Panel of Experts on Forest Gene Resources endorsed a global program for Improved Use of Forest Genetic Resources, and in December 1980, FAO/UNEP held an expert consultation on *In Situ Conservation of Forest Genetic Resources.* In June 1980, FAO and UNEP considered Animal Genetic Resources Conservation and Management. The Fisheries Department of FAO held a consultation in 1980 on fish genetic resources.

In relation to crops, concern by FAO in the 1960's led to a proposal to establish an international program. As a result, in 1974 the International Board for Plant Genetic Resources (IBPGR) was founded as an institution of the Consultative Group on International Agricultural Research (CGIAR). The IBPGR is the only organization which operates a truly international action program on genetic resources of a particular category of living material. It mobilizes funds from an informal group of donors and has developed a worldwide network of activities. In the process, the following lessons, which are salient to this conference, have been learned:

(1) Global and regional crop priorities have to be *well defined* and then carefully *refined,* based on detailed knowledge of experts on individual species.

(2) Priorities amongst regions are necessary because of *operational* considerations.

(3) Action on genetic resources is an international responsibility. In many cases, nations possess resources which are endangered, but collection and conservation of these resources are not high national priorities because of the urgent development tasks which face the

[1]For example, the Global 2000 Report.
[2]See *World Conservation Strategy.*
[3]*National Research Council, 1978. Committee on Germplasm Resources.*

nations. Also, a well-developed strategy for conservation of seeds in gene banks or planting materials in plantations, orchards, or botanic gardens does not necessarily require that every country develop an individual national conservation program.

(4) The IBPGR has operated effectively without any formal legal convention and thus has maintained flexibility and generated goodwill and cooperation.

(5) The IBPGR has identified a gray area between the interests of agencies dealing with *in-situ* conservation and its own work, which is largely geared toward *ex-situ* conservation. Through a study it commissioned from IUCN, it has made others aware that there is a need for inventories in areas which may be designated for ecosystem conservation and has expressed its willingness to collaborate with such agencies and organizations. However, the further along the line a species is in the process of domestication, the less chance an *in-situ* method will be able to be used for conservation, and *ex-situ* methods, such as gene banks, must be used.

(6) There are numerous constraints to our work, namely, financial constraints, a critical shortage of trained technicians, the lack of interest of many governments in maintaining national programs and actively participating in a global network, and major scientific limitations.

Since there is a range of species used in agriculture, we need a range of conservation techniques. The methodology of seed storage in low temperatures is now fairly well worked out. However, an expert committee of the IBPGR has emphasized that good training in seed physiology as it relates to storage is a major gap, and many seed technologists working in our genebanks do not insure that material is correctly treated in the various procedures.

Both the seed-propagated species, which cannot be stored by drying and low temperatures because of sensitivity to dessication or cooling, and the clonally propagated species need to be kept in plantations. Such collections are vulnerable to diseases and have high maintenance costs. Preservation through tissue culture would be ideal, but even where suitable culture techniques are available, genetic integrity cannot be maintained. This is a large field for research and development.

Although collections of crop germplasm are now much safer than they were 10 years ago, they need to be organized with greater efficiency to encourage description of samples, a better spread of variability, and better documentation.

Finally, I turn to organizational aspects. First, international efforts will be supported by any strong national programs. For example, the U.S. crop germplasm program is a most important part of the world network. It should be strengthened and adequate

funds mobilized. It goes beyond the initial work of the IBPGR in the sense that it is concerned with evaluation and utilization, with parallels to the excellent work carried out by the International Rice Research Institute of CGIAR. Since the IBPGR's main task is to assemble and conserve the material before it is lost, less emphasis is placed on use, although this must be the ultimate goal.

With hindsight, we accept that many aspects of genetic conservation, whether of crops, trees, or animals, relate to aspects of low temperature biology. Surely scientific work in this field should be accelerated and coordinated.

Since biological diversity is unevenly distributed around the world, efforts of agriculturists, foresters, zoologists, and others frequently are directed at the same regions, so problems of duplication of effort and competition for funds and influence arise. We should use what we have learned from U.N. agencies, nongovernmental organizations, and bilateral donor organizations about coordinating activities most effectively and efficiently.

I am proud to represent the IBPGR, which is unique in germplasm conservation. Maybe 20 years ago someone should have promulgated the idea of one international institute to cover *all* aspects of biological genetic conservation to solve problems of cryogenic storage whether of seed, semen, or ova. But in times of economic recession, such an idea is tantamount to madness. Although IBPGR covers only plants, it is a program that is in place and carries out important work which must continue. The IBPGR has established a world network which is sustained and developed at an annual cost of a little over $3 million. It would be insidious of me to draw comparisons with expenditures of any other program whether for overseas aid, television advertising, or wildlife conservation. This small amount of money needed to support this program's work *has* to be forthcoming. We cannot afford to lose the race against time.

COMMENTS

Dr. Peter Raven
Missouri Botanical Gardens

First I'd like to say something about recognition and utilization of wild species in the Tropics. Several speakers have mentioned that about 3 million species, or two-thirds of all species, live in the Tropics. Of these, about 500,000 have been named, meaning that there are about 2.5 million unnamed, uncatalogued, and uncharted species in the Tropics. There are at present in the entire world only about 1,500 systematic biologists-taxonomists capable of dealing with these 3 million species. The rate of forest destruction leads most

of us to conclude that virtually all of them will be gone in 30–40 years. Many of us have concluded that one-quarter to one-third of this diversity might be gone in the next 30–40 years. This means that if we want to learn anything about or from these unknown plants or press any of them into service, we are going to have to set some very definite priorities about how to deal with them.

Last year the National Research Council published a report called *Research Priorities in Tropical Biology.* It identifies priority fields in tropical biology and ecology for the very small number of people who are available to work in these fields. It also suggests ways to direct our priorities in systematics and inventories, specifically addressing certain taxonomic groups and geographical areas. In view of the great rapidity with which we as a human race are losing our options of doing anything at all about this diversity, I want to call attention to this report and the fact that there have been some careful priority judgments made by an international committee about how we might approach the problem.

Dr. Norman Myers
Nairobi, Kenya

We've heard a lot today about the possible difficulties of selling this issue to the other Federal agencies and to the public at large in this country. We've heard some talk about economic grounds for selling this message, but I suggest a further ground—political rationale. This country, as well as countries of Europe, Japan, and Australia, are quite heavily dependent on supplies of genetic resources from beyond its national boundaries, primarily from the Tropics or the developing Third World. I recall a speech given about 18 months ago by a former Secretary of State, Mr. Edmund Muskie, in which he termed this kind of issue to be almost a strategic interest of the United States. I've heard that term seldom used since. I do not suggest that this government perceive the issue in quite such critical terms as strategic interest, but might I suggest that the countries of the Third World are beginning to see this matter as of strategic interest with political leverage. That is why I suggest you may want to sell the issue on political grounds.

A second point. We've heard today the word "priority" used on a number of occasions. It is plain that we can't help all species or all genetic resources at risk. We may find that we will help only a fairly small proportion of them, so there is going to be a premium on getting the best possible return for each scarce conservation dollar invested. Supposing we can help only half of all species at risk on Earth and that we will really lose 1 million by the end of the century, leaving 2 or 3 million species. What categories do we feel should come

at the top of our shopping list—the vertebrates, the invertebrates, the tropical forests—those that appear to have most potential for medicines? How do we set our priorites? How do we arrive at some sort of hierarchical ranking of priorities, given the scarcity of Federal dollars?

Dr. Carlton Ray
University of Virginia

I'm not quite certain how the subject of biological diversity has become translated into what we've heard most about today, namely preservation of genetic material and species. Protecting the stability of systems is not synonomous with preserving species diversity. In order to maintain biological diversity, one has to pay a lot of attention, particularly in aquatic systems, to sustainable use of systems and to preservation of ecological processes. Now, there seems to be two ways of preserving species, *in-situ* and *ex-situ*. In the ocean, we don't deal with creating new whales or sea turtles; we have to depend on *ex-situ* preservation. And what it comes down to is not the individual species at all, but to the preservation of ecological processes. The *World Conservation Strategy* speaks of this very strongly. Therefore, I would like to call the attention of all the panels to the fact that resources cannot always be protected according to terrestrial models, nor will a narrow focus on species entirely suffice. We have to think in our recommendations on how these species might be preserved *in-situ*, with maintenance of ecological processes.

Dr. Gene Namkoong
U.S. Forest Service

An essential issue related to genetic engineering is that preservation or gene conservation is not enough, because diversity can either be decreased or increased by appropriate gene pool management. Current molecular/genetic information indicates that we hardly know what we are doing when we are breeding, that we are doing very complicated things to the molecular organization of the cells, and that the organism is not simply a mixture of traits that can be pasted together by putting genes together in the same cell. We have seen that at the organism level; in *Drosophila* spp. we cannot pick apart single gene functions. We cannot do that in maize-breeding programs either. What we need is a focus on genome and gene pool management, given the view that preserving genes and engineering the organism somehow may never be realizable dreams. A substantial effort is required to develop the gene pools that we have now and not simply to preserve them.

Dr. Paul Opler
U.S. Department of the Interior

The conference should think about some of the problems that are underlying the reduction in biological diversity worldwide. The world human population problem should certainly be addressed, at least as a matter of principle, as should the rapid use of fossil fuels, which is contributing both directly and indirectly to the reduction in biological diversity.

Various people speaking of the numbers of species on the Earth have mentioned figures of 2 million, 3 million, and 4 million. I might add that some entomologists gauge the number of species at between 8 and 12 million, which I feel is probably more accurate.

Professor H. K. Jain
International Board for Plant Genetic Resources

A number of comments are generally made about the impact of the "Green Revolution" on the evolution of genetic variability. There is a need to clarify one or two points. First of all, what we now call the Green Revolution is not entirely new; in fact, it is nothing more than an extension of the generation of the high-yield agriculture which started in countries such as the United States about 30 years ago. This process of change simply is being accelerated because of population pressures worldwide. The contention that something new in the last 15 years is threatening genetic resources is to my mind untrue; it has been going on for a much longer period.

Secondly, we should all realize that high-yield agriculture is absolutely inevitable because of population pressure, especially in developing countries, and because of the plant/animal/human food chain which has come to be accepted in the Western countries. We all know that it is rather a wasteful chain; Western man consumes on an average five times more food grains than people in the developing countries. It has come to be accepted, and I believe it is here to stay. Now, if we need all these food grains because of this food chain, we've got to produce more, and some amount of genetic erosion resulting from development of high-yielding varieties is inevitable.

But there is something we can do. One question that we should be asking is can we plan our plant breeding strategy in such a manner as to decrease the present rate of loss of genetic variability? For example, is it really necessary to evolve such uniform varieties in terms of genetic structure? Also, is it really necessary to limit the number of improved varieties, as we seem to be doing?

Here we have an example of something which is avoidable, narrows genetic variability, and is nevertheless being pursued with

great speed. Because scientifically, genetically, it is not really needed, it is, I would say, indefensible. Any plant breeder will tell you that you really need some residual genetic variability, even in the highly self-pollinated crop. But we are making them more uniform than is really necessary and then spreading a single variety over a very large area.

One of the speakers this afternoon said that much of the research in genetic engineering, even in this affluent country, is being supported by private corporations. This came as a big shock to me, because I would have expected the U.S. Government to provide leadership in the development of this technology and to provide a model for the rest of the world. By leaving genetic engineering only under private auspices, the free flow of manmade genetic variability will be limited.

Dr. Archie Carr, III
New York Zoological Society

The record as we have created it thus far today may be incomplete. We are trying to define why it is important to save species, something those of us at the New York Zoological Society have discussed for many, many years. I would like to submit that one important reason for preserving species is because people like them. There is an aesthetic side to all of this, a side that is admittedly difficult to work with, but one that is important not to ignore, because in the longrun it is perhaps the greatest motivation for public support. People look at species as irreplaceable art forms created by nature. We feel a mysticism about them, and therefore, seem determined not to lose them. It is very important to be able to show other practical reasons for the need to preserve species, but we should not ignore the aesthetic reasons.

Stephen Lintner
Near East Bureau, Agency for International Development

Today we have mainly focused on more technical and research-oriented aspects of preserving biological diversity. At the Agency for International Development (AID), we are very much interested in ideas which could help us improve our programmatic planning. One of the obvious problems which has not been sufficiently highlighted today is explosive population growth, principally in the Tropics and in other developing regions, which is placing incredible stress on resources and requiring large development efforts. As we are aware, there are tremendous land-use conflicts in the Tropics. These pressures are the result of interventions by agencies like AID and the

World Bank, international corporations, and in many cases by the host governments themselves in attempting to improve the livelihood of their citizens, perhaps in a short-sighted sense, but certainly in a dramatic sense in terms of land transformation and reduction of critical biological habitats. The members of the panels tomorrow might seriously consider practical recommendations which would assist AID and other development agencies in formulating projects which are more responsive to the concurrent need of preserving biological diversity and forwarding development.

Dr. Kenneth Dahlberg
Western Michigan University

Throughout the day, I have found a somewhat interesting contrast between the concern about conserving biological diversity and the underlying organizational model which I sense most people are operating on—a centralized, bureaucratic organization model which tends to use high technology approaches. It seems to me that in a sense this is equivalent to an organizational monoculture, and it has the same sort of risks as biological monoculture. In thinking about promoting biological diversity, we also have to think about the infrastructural and the organizational patterns which will be consistent with that goal.

Dr. George Rabb
Chicago Zoological Society

I would like to draw attention to the following resolution passed at the recent triannual meeting of the International Union for the Conservation of Nature and Natural Resources in Christchurch, New Zealand, because it deals with genetic resources and has some implications for the work of the panels tomorrow:

Recognizing that genetic material forms part of the natural heritage of mankind and should therefore remain available to all nations;

Recognizing that the conservation of this genetic material is essential for the maintenance and development of animal and plant resources for a large number of present and future beneficial uses;

Considering that states have a duty of stewardship toward the conservation of genetic resources;

Considering that states using these resources should contribute to their conservation;

Recalling recommendation number 39 of the 1972 Stockholm Conference and the work of FAO, UNEP, and UNESCO on the conservation and utlization of genetic resources;

The General Assembly of the IUCN recommends that all countries maintain maximum genetic diversity by means of both *in-situ* and *ex-situ* conservation measures, further recommends that natural inventories be made of genetic resources whether under public or private control, in gene banks and protected areas and in traditional cultivation, and that all such resources should in principle be available to potential users, provided that their use will not permanently impair or destroy the genetic resource, calls upon states using the genetic resources of another country to contribute to their inventory and conservation and instructs the IUCN Secretariat to undertake an analysis of the technical, legal, economic, and financial matters relating to the conservation, accessibility, and use of these resources with a view to providing the basis for an international arrangement and for rules to implement it.

Dr. Michael Soulé
Institute for Transcultural Studies

Seconding what Archie Carr said, it is regrettable that we must all pretend to be concerned exclusively with man and his welfare and put nearly all of our arguments for conservation of biological diversity in terms of benefit for man. I think we will have reached cultural adolescence when we can admit in public that conservation is not only for people, something most of us admit already in private.

In a more concrete vein, I would like the panels tomorrow to consider how best to fund research in conservation biology. Conservation biology suffers from the image of being an applied science. Cancer research escapes this stain because approximately one out of three Senators or their wives will die of cancer. Unfortunately, politicians don't die of genetic erosion. Strategies and programs are not implemented in the absence of hard data, but because only a minuscule amount of resources goes into basic research on the problems that we are discussing, very little hard data is available. At the moment, there is very little glory and very little money to do conservation biology research.

IV. Panel Reports With Recommendations

Biological diversity issues as seen from different points of experience were examined in five separate concurrent conference sessions. Five panels of 20–30 people each were convened on November 17: Terrestrial Plant Species, Terrestrial Animal Species, Aquatic Species, Microbial Resources, and Ecosystems Maintenance. *Panel deliberations were limited to one full day during which the panel members were asked to prepare recommendations for presentation to the final session of the conference on November 18.*

A common concern, repeatedly expressed by the panel members, was that the time allowed for panel discussions was insufficient for the task at hand. This lack of time precluded discussion of many relevant issues.

The conference organizers wish to thank the talented people who contributed their time to the panel discussions and the co-chairmen and rapporteurs for their work in preparing the following panel reports. The reports provide an excellent "first cut" at outlining the issues and opportunities which confront the United States in the area of biological diversity.

Terrestrial Plant Species Panel

Chairmen

Dr. William L. Brown
Dr. Quentin Jones

Rapporteurs

Dr. Gilbert Hersh
Dr. Gene Namkoong

Panel Members

Dr. Peter Ashton
Dr. John Bouwkamp
Dr. Stephen Brush
Dr. Bees Butler
Dr. John Creech
Dr. Byrd Curtis
Dr. Kenneth Dahlberg
Dr. Carl Gallegos
Dr. William Gregg
Dr. Clarence Grogan
Dr. James Hester
Ms. Maureen Hinkle
Dr. Clive James
Dr. David Kafton
Dr. T. N. Khoshoo
Dr. Harold Loden
Mr. Grenville Lucas
Dr. Judith M. Lyman
Dr. David McClintock
Mr. Roger McManus
Ms. Kathleen McNamara
Dr. James Murray
Dr. Gordon Snow
Dr. Garrison Wilkes

The Panel on Terrestrial Plant Species recognized that to deal effectively with the diversity encompassed in its assigned subject matter and the diversity of knowledge represented in the panel, it must organize and classify the range of plant resources and then identify the activities essential for preserving and using plant genetic diversity.

To accomplish this, the panel devised a two-dimensional matrix with plant groups arrayed on the horizontal axis and the activities dealing with them arrayed on the vertical axis (Table 1). The plant groups were classified into four categories according to man's information about them—ranging from those species not yet botanically classified at the binomial level to the major crops of the world, information on which fills many libraries. This permitted the panel to address the status of biological diversity across this spectrum and to identify and give some value judgments to activities dealing with them.

The plant categories were described in the following manner:

Category I Species for which we have essentially no information.

Category II Those species which have been taxonomically classified and their geographic and ecological distributions are known in general terms.

Activities \ Plant Group	Unclassified Species	Named Species	Distribution Known	Synecology Known	Usefulness (Primitive)	Composition Known	Exploited From Wild	Progenitors of Cult. Spp.	Minor Crop (Local)	Minor Crop (Extensive)	Major Crop
A. Identification	H		H			H			NA		
B. Acquisition (incl. exchange)	NA		NA			M			H		
C. Maintenance ex-situ	L		L			H			H		
C. Maintenance in-situ	H		H			H			L		
D. Evaluation	H		H			H			H		
E. Enhancement	NA		NA			L-M			H		
F. Monitor Genetic Vuln.	NA		M			H			H		
G. Info. Mgt. & Communication	H		H			H			H		
H. Training	H		H			H			H		
Categories	I		II			III			IV		

Table 1

Category III Noncultivated species known to have some present or potential usefulness to man. This is the group which will be the most immediate source of new crops and other products.

Category IV Cultivated species and their wild progenitors, the products of which presently have local, regional, or international economic importance. This group includes the crops which now provide, and which for the foreseeable future will continue to provide, food and fiber and other products for an expanding world population.

The activities that the panel considered essential to dealing effectively with the preservation and use of plant genetic diversity are:

1. **Identification.** Research is needed on the geographic distribution of biological diversity to determine what diversity is available and where.

2. **Acquisition.** This involves bringing diversity into *in-situ* and *ex-situ* systems of control (e.g., protected areas, experimental plantings, laboratories, and gene banks). Changing land-use patterns are destroying habitats of noncrop plants and of primitive crop varieties and their wild relatives, principal sources of genetic diversity. Once lost, this genetic diversity can never be replaced. Expanded collection and conservation efforts are required now.

3. **Maintenance.** Minimizing loss of biological diversity requires carefully planned and operated maintenance systems in *in-situ* and *ex-situ* environments. Natural habitats, including the biota they support, will have to be conserved to assure species survival.

4. **Evaluation.** Plant germplasm cannot be used unless traits which could be used for crop improvement or other purposes (e.g., fuel, pharmaceuticals, etc.) are identified and made available to the user community. Therefore, germplasm must be evaluated morphologically, physiologically, and genetically and the resultant data disseminated through an information network. Greater knowledge of a species' characteristics and environmental requirements will also increase the effectiveness of maintenance systems. The panel rated this function as a top priority for increased attention.

5. **Germplasm Improvement.** This is the process of incorporating exotic germplasm into agriculturally or otherwise useful genotypes. The degree to which diversity is used in plant-breeding programs is positively correlated with activity in germplasm improvement.

6. **Monitoring Biological Diversity.** Throughout the continuum which begins with identification of availability of diversity in natural populations and primitive cultivars and results in eventual use for cultivation or other activities, it is necessary to assess the status of biological diversity. A result of not doing this could be genetic vulnerability and the loss of essential ecological services, leading to economic and social setbacks.

7. **Information Management.** Information on germplasm resources and germplasm itself must be readily accessible to all having a *bona fide* need for it. An open information and exchange network is truly the "central nervous sytem" of any effective program of germplasm conservation and use.

8. **Training.** Scientists and technicians working in plant genetic resources in this country and elsewhere require special training in field collecting, curating germplasm collections (*in-situ* and *ex-situ*), designing and managing experimental plantings, data collecting and management, and communication skills.

The panel concluded that biological diversity in terrestrial plants requires serious attention in all plant categories and in most functional areas. It gave highest priority to Category IV (Major Crops) and to the activity of evaluating useful traits.

Observations and Recommendations

1. **Observation.** Feeding the world's population is today's single most pressing global issue; plant biological resources are a heritage which belong to all people; plant genetic resources are necessary to improve yields of food crops and to provide a host of other products to maintain and enhance human well being.

Recommendation. Access to maximum plant biological diversity should be assured through identification, acquisition, maintenance, and evaluation. Open exchange of genetic material and information related to these resources should be encouraged worldwide.

2. **Observation.** The International Board for Plant Genetic Resources (IBPGR) has played an effective and commendable role in initiating and coordinating germplasm resources activities throughout the world.

Recommendation. The United States should continue and strengthen its support of the IBPGR through the Consultative Group for International Agricultural Research (CGIAR) and through direct cooperation in pursuing common goals in plant germplasm activities.

3. **Observation.** The United States does not have native sources of germplasm for its principal crops and depends on other countries for

the genetic resources required to maintain a productive, healthy crop agriculture. In turn, other countries depend on the United States for improved hybrid seed varieties.

Recommendation. High priority should be given to increasing support for the U.S. National Plant Germplasm System and for international efforts to conserve useful or potentially useful plant germplasm.

4. **Observation.** Only an estimated 10 percent of the Earth's plant species have been evaluated in any way for potential usefulness to man. The greatest diversity of the world's plant species is found in the Tropics. Many of these are yet to be cataloged and given scientific names. Due to the rapid conversion of tropical forests, it is estimated that as many as one-third of the species found there may become extinct during the next 30–40 years. There is, therefore, an urgent need to conserve natural tropical communities and to catalogue and evaluate the plants of arid, humid, and saline tropical habitats.

Recommendation. Studies should be undertaken to identify natural communities in tropical areas that are threatened by serious environmental change with the objective of identifying and providing a basis for conservation of their species composition, community structure, and species interactions. Such communities should be conserved *in-situ* to the greatest extent possible and also used as field laboratories.

The recommendations of the National Research Council report, *Research Priorities in Tropical Biology*, should be implemented, especially those pertaining to the need for accelerated training and provision of jobs for taxonomists; selective taxonomic inventories of groups of plants of particular economic importance or scientific interest; special attention to identified tropical areas in which the plants are poorly known and the natural vegetation is undergoing rapid conversion; and finally, support for the institutions in developing and developed countries that are addressing these problems.

5. **Observation.** *In-situ* conservation of species can be accomplished in concert with regional or local development. National parks, national forests, wilderness areas, biosphere reserves, and multiple-use lands can provide relatively natural areas where plant species may be conserved. There are also international, national, and local laws, such as the U.S. Endangered Species Act, which are designed to protect biological resources.

Recommendation. Existing legal and administrative mechanisms for conserving plant species and their habitats should be maintained and improved.

6. **Observation.** There are regional differences in traditional crops and cultural practices which have developed from generations of trial

and error, observation, and evaluation. This local knowledge of crop/environment interactions is a valuable resource.

Recommendation. The United States and other national governments should insure that due account be taken of regional differences in crops, cultural methods, and cropping systems and that full use be made of local human and institutional resources in development programs.

7. **Observation.** The study of the cultural traditions of indigenous human populations have enabled the identification of native plants having properties of significant benefit to the well being of technological societies. The cultural assimilation of these peoples is foreclosing many opportunities to obtain valuable information on the traditional uses of plants.

Recommendation. We support expansion of academic curricula and training opportunities in ethnobotany and cultural anthropology and increased support of research in these areas leading to the identification of plants of potential cultural significance.

8. **Observation.** Data bases on the molecular biology of important animal and bacterial cells now exist. A similar data base is needed for important plant cells.

Recommendation. An on-line data base system should be developed containing published sequence data on plant genetic material.

9. **Observation.** There are many underexploited plants, including timber trees, that can be properly used only when technical solutions are found to such biological problems as erratic flowering, recalcitrant seed, specific pollinators, or other propagation constraints.

Recommendation. Research should be undertaken to solve technical problems that are restricting the usefulness of many plant species.

10. **Observation.** Particular attention needs to be given to the risks of overexploitation of plant species when their harvest from natural environments is nonsustainable and destructive to their environments.

Recommendation. Legal and administrative regulatory mechanisms should be implemented and improved. Steps should be taken to reestablish vegetation and restore the environments.

11. **Observation.** While recognizing the great potential value of genetic engineering to agriculture, medicine, and industry, we are convinced that it will not replace the continuing need for naturally occurring genes.

Recommendation. Access to the broadest range of biological diversity should be assured through assessment, acquisition, main-

tenance, evaluation, information management, and other related activities, as necessary.

12. **Observation.** Bilateral, regional, and international cooperation in the collection and interchange of plant germplasm is growing, but some issues have yet to be resolved. For example, should the principal repositories be in developed nations where scientific and automated data-processing resources are readily available, or should storage be widely disbursed among the many countries where specimens are obtained but where this infrastructure is lacking? While an international convention could address these issues, it might take many years to conclude, fail to achieve support from key countries, and possibly slow the development of alternative cooperative mechanisms.

Recommendation. We recommend that the U.S. Department of State continue to encourage simultaneous bilateral and multilateral *ad hoc* cooperative efforts. No action should be taken at this time to promote an international convention on plant germplasm.

Terrestrial Animal Species Panel

Chairmen	Rapporteurs
Dr. Roger Gerrits*	Dr. Estel Cobb*
Dr. George Rabb	Dr. Gary Wetterberg

Panel Members

Dr. Gardner Brown, Jr.	Dr. Keith Gregory*
Dr. William Y. Brown	Mr. James Hester
Dr. Peter Brussard	Ms. Cathy Kennard
Mr. F. William Burley	Dr. Charles Kiddy*
Mr. John Bushman	Ms. Fran Lipscomb
Dr. Archie Carr, III	Dr. Malcolm McPherson*
Mr. John Crawford	Dr. David Meissinger*
Dr. Herbert Dessauer	Dr. Russell Mittermeier
Mr. William Durfey*	Dr. Norman Myers
Dr. Stephen Edwards	Mr. Richard Parsons
Dr. Alfred Gardner	Dr. Christine Schonewald-Cox
Dr. George Gee	Mr. Robert Smith

SUBPANEL ON DOMESTICATED ANIMALS

Animal products provide U.S. consumers with two-thirds of their protein, one-third of their energy, four-fifths of their calcium, two-thirds of their phosphorus, more than one-third of their iron, and nearly all of their vitamin B12. Increasing affluence in developed and developing countries historically has resulted in increased demand for foods of animal origin. The intensification of animal production systems to meet this increased demand has consistently resulted in major changes in affected ecosystems and in some reduction of domesticated animal germplasm.

The production resource base for domesticated animals is highly dynamic on a global basis. It is usually not practical to modify the animals' production environment (nutrition, climate, diseases, parasites, etc.) in such a way as to achieve maximum production of animal products. Thus, it is common practice to match the animal to the environment. Continuing changes in the animals' environment will require that appropriate genetic diversity is available to adjust the animals' genetic composition to fit the new conditions.

Genetic diversity in important and potentially important draft, food, and fiber-producing animals must be maintained. This has

*Domesticated Animals Subgroup.

been recognized by national and international symposia. The Agricultural Section of the American Association for the Advancement of Science (AAAS) sponsored a symposium in 1959 on Germplasm Resources. The Food and Agriculture Organization (FAO) of the United Nations sponsored or cosponsored at least five meetings relating to conservation, evaluation, and use of animal germplasm resources (livestock in general (1966, 1980); cattle (1968); pigs (1971); and poultry (1973)). The First World Congress on Genetics Applied to Livestock Production, held in Madrid in 1974, featured a symposium on "The Conservation of Animal Genetic Resources." The collective recommendation that evolved from these meetings can be summarized as follows: "Appropriate national and international organizations should develop an international program that will provide the leadership and coordination necessary to conserve and utilize genetic diversity in all currently important and potentially important species that contribute to draft, food, and fiber needs of the Earth's human population."

Considerations relating to maintenance of animal health in different countries and constraints imposed by animal germplasm storage technologies favor strong national programs. These would be the basis for creating a strong international program to provide for maintenance of genetic diversity.

Preservation of genetic diversity is essential to maximize potential gains from the new technology of genetic engineering. With respect to genetic improvement of food and fiber-producing animals, the potential usefulness of genetic engineering by recombinant DNA techniques cannot be assessed until basic research has identified the molecular basis of genetic variability. There is a real potential in the short term for increasing the role of genetic improvement through development of practical procedures for preserving and manipulating embryos. Research is needed to perfect embryo preservation techniques in all the species involved. Sexing and cloning of embryos will likely be possible within a decade if the needed research is done. The capability of preserving semen, ova, and/or embryos will greatly facilitate the preservation of germplasm resources.

There are no organized programs at the international level with the objective of maintaining genetic diversity in domestic animals at the level required to adjust to a highly dynamic resource base. There are some national efforts in both developed and developing countries to maintain genetic diversity in some currently important food and/or fiber-producing animal species. However, the lack of an appropriate international organization to provide coordination and leadership limits the potential usefulness of these efforts in the international context.

International leadership and coordination for conserving and

using plant genetic resources is now provided by the International Board for Plant Genetic Resources (IBPGR), headquartered at FAO in Rome. The IBPGR was established by the Consultative Group on International Agriculture Research (CGIAR) in 1974. The U.S. leadership and coordination for conserving plant germplasm resources is provided by the U.S. National Plant Genetic Resources Board (NPGRB) that reports to the Secretary of Agriculture. There is a close and effective liaison between NPGRB and IBPGR.

The International Board for Plant Genetic Resources (IBPGR) and the National Plant Genetic Resources Board (NPGRB) are appropriate models of organizational entities for conservation and use of animal germplasm resources at the international and national levels. Because of considerations relating to communicable animal diseases, differences in storage technologies, reproduction, etc., different tactical approaches are required for the maintenance of genetic diversity of animal germplasm as compared to plant germplasm resources.

Recommendations

1. The Consultative Group on International Agricultural Research (CGIAR), sponsored by the FAO, the World Bank, and the U.N. Development Program and comprising 45 countries, international and regional organizations, and private foundations, should establish an International Board for Animal Genetic Resources (IBAGR). The IBAGR would be funded and staffed to provide technical assistance for the coordination of national programs into a network of international programs to conserve and use animal germplasm resources.

2. We recommend that similar to the IBPGR, the IBAGR primarily should perform a service rather than a research function. The specific procedures and tactical approaches the IBAGR staff would use to accomplish its mission should be identified by the CGIAR and IBAGR. However, the IBAGR staff should provide technical assistance for effective national and international programs that:

- Identify and catalog breeds and/or populations from all species that contribute to draft, food, and fiber;
- Assess trends expected in resource bases for animal production as well as other relevant changes in the production environment for all species that contribute to draft, food, and fiber needs of the Earth's population;
- Identify the breeds and/or populations that should be preserved to maintain genetic diversity in each species as appropriate to meet anticipated changes in the animal production environment in each major ecological zone;

- Identify information needed to estimate potential future usefulness of breeds or populations and organize regional programs of characterization and evaluation to provide an information base for making informed decisions on conservation and use of specific breeds and populations;
- Encourage studies aimed at reducing hazards of communicable diseases to provide for the safe exchange of animal germplasm resources at the international level;
- Encourage the use of breeds and/or populations on a national and regional basis that have the potential to increase the production resource conversion rate;
- Encourage the maintenance of appropriate stocks by national programs that are identified to have potential for making future contributions to the production of animal products if such stocks would not otherwise be maintained.

3. FAO should collaborate closely with CGIAR in establishing the IBAGR and work closely with IBAGR in operating the global conservation programs which attempt to maintain optimum genetic diversity in draft, food, and fiber animal germplasm resources.

4. It is recommended that USDA, AID, and the U.S. Department of State work with all sponsoring organizations and countries involved in CGIAR with the objective of establishing and funding a viable IBAGR that will serve a role for the conservation and use of animal genetic resources similar to that served by the IBPGR for plants.

5. It is recommended that the Secretary of Agriculture establish a National Animal Genetic Resources Board (NAGRB) which has a structure similar to that of the National Plant Genetic Resources Board (NPGRB). The NAGRB should collaborate closely with IBAGR. The overall goal should be to achieve the optimum level of conservation and use animal genetic resources at the national and international level.

SUBPANEL ON WILD ANIMAL SPECIES

The panel recognizes that the Earth's species and their genetic resources are agents of critical biological processes and represent a valuable potential stock of new materials that are undergoing accelerating depletion. The disappearance of these resources has major economic, strategic, and political implications for the United States and the world.

The panel discussed the existing knowledge about the status of ecological and genetic diversity, causes for loss of diversity, and

existing domestic and international institutional structures concerned with studying or managing biological diversity of wild fauna.

Observations

— Loss of biological diversity of wild animals is accelerating worldwide. This loss is caused principally by increased population and accompanying land-use pressures that alter habitat, local and regional pollution (e.g., acid rain) that degrades the environment, and overharvesting of selected species for food and other products for local use and export.

— Fundamental knowledge about the status of existing animal resources is lacking, as are the funds and personnel to gain this knowledge. Furthermore, existing data should be stored in compatible computer systems to facilitate use.

— There is a shortage of technical expertise in systematics and the management of wildlife and wildlands. Serious even in the United States, these deficiencies are more severe elsewhere. Thus, global efforts to integrate systematics and wildlands management into educational systems is particularly important.

— *In-situ* conservation is a priority because it not only conserves the material of biological diversity but also maintains ecological processes. Preservation of ecosystems rather than targeted species has the advantage of saving many species, including inconspicuous species with important functions in the ecosystem and those with potential economic uses. Particular attention should be given to unique, highly diverse, and/or fragile ecosystems, such as tropical rain forests, coral reefs, arid lands, and polar regions.

— *In-situ* conservation should be used in concert with *ex-situ* species conservation methods. These methods include zoos, game ranches, germplasm banks (for embryos, eggs, sperm, etc.), and captive breeding programs.

— A number of governmental and nongovernmental organizations, both domestic and international, are working to protect species and habitats in order to maintain genetic diversity; others are concerned with protection of natural areas or particular species for different reasons. Maintenance of biological diversity should become a fundamental management objective of national parks, forests, refuges, and sanctuaries.

Recommendations

1. As a fundamental response to the specter of biological improvement, the United States should support and fund efforts to identify,

establish, and manage a worldwide system of national parks and other conservation areas to insure the perpetuation of all major ecosystem types and the diversity of organisms and processes they contain. This should be done within the framework of the World Conservation Strategy in a way which promotes local economic development compatible with long-term ecosystem integrity and the sustained use of natural resources.

2. National and international agencies must recognize sustainable use of natural resources and conservation of biological diversity as goals of development planning. These agencies should assist countries in the development of alternate land-use plans which combine local development with sound conservation practices. Reserves should be a critical component of development plans. Such plans should also provide for maintenance of biological diversity in areas not held in reserves.

3. The United States should maintain the conservation authority currently provided in the Endangered Species Act. Among other policies which should be continued are:

—Protection for all endangered or threatened animals and plants;
—The requirement that Federal agencies insure that any actions which they authorize, fund, or carry out will not jeopardize the continued existence or any endangered or threatened species, wherever located;
—Authorization for the acquisition of habitat for endangered and threatened species; and
—Provision for international cooperation in the conservation of endangered and threatened species.

The listing process should be maintained and improved and should be based solely on the conservation status of the species; listing should not be ranked according to whether a life form is considered "higher" or "lower."

4. A National Task Force on the Conservation of Biological Diversity, chaired by the Department of State, should be established. By 1983 it should develop comprehensive, long-term U.S. goals and strategies to maintain biological diversity and should review current programs and recommend strong, integrated national and international programs to carry out the strategy. The Task Force should include representatives of appropriate Federal and State agencies as well as the private sector.

5. The President should designate tropical forests, prime croplands, and coastal wetland-estuarine and reef ecosystems as natural or ecological resources of global importance under Executive order

12114. In addition, the National Task Force on Conservation of Biological Diversity should identify resources in other ecosystems which should be designated because of their global importance to biological diversity.

6. The President should issue an Executive order that appropriately identifies the importance of managing the Federal lands for biological diversity and establishes mechanisms for achieving effective results.

7. The U.S. Government should assist IUCN in implementation of the World Conservation Strategy (WCS), and the United States should develop a National Conservation Strategy in line with the principles set forth in the WCS. The U.S. Government should recognize the IUCN as an international organization, and appropriate Federal agencies should broaden or initiate support of IUCN and its Commissions.

8. The National Task Force on the Conservation of Biological Diversity should evaluate international efforts to inventory the world's plant and animal species and should recommend an effective U.S. contribution to these efforts. Standard references to species nomenclature should be developed in parallel with such inventories. Academic institutions and Federal agencies concerned with the conservation of biological diversity should give greater support to training systematists and to systematic research.

9. The government should develop new research programs and strengthen existing programs to acquire basic knowledge by providing more substantial funding to appropriate institutions and organizations concerned with biological diversity questions.

10. National and multinational business, conservation organizations, and appropriate U.S. Government agencies should work together toward the maintenance of ecological stability and current levels of biological diversity and take the lead in conservation programs both within the United States and abroad. Programs which educate business executives in ecology and in environmental management should be developed. Appropriate government agencies should investigate tax incentives to promote ecological considerations in business and development programs.

11. Fiscal mechanisms, including excise taxes on selected items related to nongame wildlife conservation activities, should be established by Congress. Revenues should accrue to an independent fund for the U.S. Fish and Wildlife Service to administer for the purpose of providing grants to state wildlife agencies to increase nongame wildlife conservation activities.

12. The National Task Force should explore means to increase public awareness worldwide on the need to maintain biological diversity.

13. The United States should evaluate and recommend a comprehensive program for training wildlife management and conservation professionals of developing countries. These efforts should be coordinated with those of other nations and international organizations and be aimed at the development of indigenous capability abroad to sustain maintenance of biological resources.

14. Increased research on traditional local uses of wildlife resources by indigenous peoples should be carried out. Application of such knowledge may be made in game ranching programs or other sustainable production systems.

15. The national management and scientific authorities implemented under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) are often the core of wildlife and plant conservation in their respective countries. USAID should assist in training developing country personnel for these organizations.

16. USAID, along with other governmental agencies and the private sector, should cooperate with regional programs for conservation of threatened and endangered species such as elephants and rhinos in Africa.

17. Both domestically and internationally, the United States should pursue means of conserving viable populations of wild animal species, especially avian, which are the ancestors or close relatives of domesticated species. Other animals deserving particular attention are wild populations of nonhuman primates. The United States should take steps to increase the number of these primates through captive breeding colonies in the United States and elsewhere.

18. The National Task Force on the Conservation of Biological Diversity should recognize the potential of zoos, aquaria, botanical gardens, arboreta, and universities for the conservation of rare, threatened, and endangered species and should encourage research on conservation genetics and reproductive biology. The capabilities of existing institutions to serve as centers for these activities should be evaluated. A global network of cooperating institutions should be established, especially in tropical areas.

A registry of biological collections (systematics, germplasm, genetic stock, etc.) should be developed to provide such information as the taxonomic and geographic representation in the collection. This registry should be compatible with the International Species

Inventory System (ISIS) that has been established for the zoo community.

19. Appropriate U.S. agencies should maintain depositories which preserve animal germplasm and tissue samples of a wide variety of organisms, as well as biological reagents, such as antisera. Government agencies should promote the international interchange of such material for use in research and commercial enterprise. Appropriate U.S. agencies should encourage and support research on cryogenic preservation of animal tissues and their use in studies of genetic diversity.

Aquatic Species Panel

Chairmen	Rapporteurs
Dr. Ruth Patrick	Dr. Jerry Downhower
Dr. Carl Sindermann	Dr. Harold Kincaid

Panel Members

Dr. William Anderson	Mr. Stephen Lintner
Dr. John Brooks	Dr. Elliott Norse
Dr. Daniel Cohen	Dr. Francisco Palacio
Dr. Nicole Duplaix	Dr. G. Carlton Ray
Mr. Thomas Garrett	Dr. Aaron Rosenfield
Dr. Clarence Idyll	Dr. Michael Soulé
Dr. William Klesch	Mr. James Talbot
Mr. Ron Kuhlman	Dr. Fred Utter

Dr. Robert Vrijenhoek

The Panel on Aquatic Species was concerned with the preservation of biological diversity in aquatic habitats, both freshwater and saltwater (e.g., streams, rivers, lakes, freshwater and coastal wetlands, and deep oceans). Although freshwater and marine ecosystems have many characteristics in common, they support distinctly different plant and animal species.

At the outset, the panel recognized the close relationship between land-based activities and the quality of freshwater and marine environments. An examination of biological diversity in an aquatic habitat must consider the use of the watershed of that area.

Some freshwater ecosystems—rivers, streams, lakes, potholes, and wetlands—support the most diverse assemblages of genetically distinct taxa in the aquatic world. These ecosystems furnish food (e.g., fish and crayfish) and recreation, help in pollution control (assimilation, degradation, and recycling of organic substances), provide sources of drugs (e.g., *Penicillium* sp., a freshwater mold), and have been and continue to be a major source of energy (e.g., hydroelectric, peat, and methane).

Observations

Increased consumption of natural resources by a growing population is placing greater demand on freshwater resources. It is therefore important that activities in watersheds be planned and managed to minimize adverse affects, which include the influx of

sediments, organic debris, and chemical and organic pollutants into aquatic environments. Successful management depends on research on the effects of such materials on aquatic ecosystems and on effective control and monitoring of pollutants.

Sensitive indicator species or species groups can be used to monitor environmental change or degradation. Data from indicator species should be gathered, interpreted, and used as a basis for management decisions.

Changes in abundance of certain species and local extinction of others may result from human activities. The problem of adverse man-induced changes is most acute in tropical and subtropical freshwater ecosystems, where population and development pressures are altering habitats dramatically. Harmful activities include the overcutting of watersheds, draining of wetlands, and diversion and channelization of rivers.

It is important to protect freshwater and marine ecosystems, particularly those that are fragile, highly diverse, or highly productive. Regional species assessments, surveys, and nutrient cycling studies should be undertaken to identify and evaluate endangered ecosystems. Efforts should be initiated to preserve and manage these selected areas.

Little is known of the genetic diversity of the vast number of freshwater animals and plants. Species for which we have adequate information have been more effectively managed and maintained. Therefore, conservation of and research on the genetic diversity in native freshwater species is necessary to provide for future use of the organisms, such as in aquaculture stocks.

The introduction of exotic species (e.g., water hyacinth and some tropical ornamental fish) can be a problem. Actual and potential competition and predation on native species and other disturbances caused by exotics can lead to the disappearance of indigenous freshwater flora and fauna.

Maintenance of fish species diversity is an acute problem in fresh water, especially in the Tropics, but is less of a problem in the sea, where change in abundance is a much more serious problem. Knowledge about marine fish stocks has advanced steadily in recent decades, largely in response to an obvious need to manage fisheries for optimum yields. Because of sampling difficulties and insufficient commitment to research, there are still serious shortcomings in the data base and in assessments of stocks. Despite these inadequacies, some advances in management have occurred. Certain commercial stocks are being better managed because of increased scientific information on the ecology and population structure of these species. The Fishery Conservation and Management Act of 1976 has resulted in some progress in managing coastal stocks.

While maintenance of fish species diversity is less of a problem in the sea than in freshwater, there is little information on changes in the diversity of marine populations. The best information on fish populations concerns commercially exploited stocks. Intensive selective fishing has reduced standing stocks of a number of fish species in various parts of the world, but not to the point that there is danger of extinction. Reliable information on the degradation of aquatic plant communities, coral reef ecosystems, and mangroves is minimal.

Available information on marine mammals and turtles suggests that a few species have been reduced to the point that extinction is a distinct possibility. Where remedial steps have been taken, recovery of several species is evident. However, lack of uniform worldwide surveys and protective measures have delayed or impeded the recovery process.

Pollution is a significant threat to aquatic ecosystems. Metal accumulation and the presence of radionuclides resulting from man's activities have been identified in fish. There is also abundant documentation of habitat alteration and disappearance of localized stocks. We have experimental information on the detrimental effects of pollution on spawning and on egg and larval survival. However, there is little information on low-level, chronic pollution effects and their interrelations with natural environmental variables (e.g., predation, disease, physical factors) that influence the relative abundance of species.

From the foregoing, it is clear that biological diversity in aquatic ecosystems is adversely affected by many human activities. Knowledge of the structure and function of these systems is rudimentary, yet such knowledge is necessary to successfully manage and maintain these systems over the long term. The following recommendations address some of the problems that are related to aquatic ecosystems.

Recommendations

1. A Task Force on Conservation of Biological Diversity, consisting of appropriate Federal agencies, State governments, industries, conservation organizations, and the academic community, should be convened. By 1983 the Task Force should develop strategies to maintain biological diversity, review current programs, and recommend integrated national and international programs.

2. Existing information and education campaigns by conservation groups, industry, the scientific community, and governments should be expanded to familiarize the public with the importance of biological diversity.

3. In order to protect the range of biological diversity that currently exists in aquatic ecosystems, it is recommended that the United States accelerate efforts to identify and protect areas that represent unique ecosystems and that have high species diversity and monitor those ecosystems by examining environmental conditions and indicator species. This work should be done by appropriate State, Federal, and private organizations. The United States should cooperate in establishing education programs and international exchange projects that demonstrate the benefits of establishing and carefully managing protected areas of adequate size to maintain biological diversity.

4. Tropical forests and aquatic habitats are being rapidly degraded or destroyed. The protection of these habitats will have long-term social and economic benefits because a large portion of the planet's biological diversity is stored in these systems. However, there is a lack of scientific information and local scientists to assess the impacts and risks of alternative development programs in these habitats. Therefore, U.S. and international support for research in tropical biology and conservation biology and the training of local scientists should be continued and expanded.

5. Diversity can be maintained in aquatic systems only by incorporating conservation planning into the early stages of development planning. First, areas of special biological importance should be identified by evaluating available data. Then criteria such as economic importance, biological diversity, productivity, representativeness, and uniqueness should be used to select areas and problems of highest priority for immediate action. During this process, serious gaps in knowledge will become apparent and will have to be addressed. Based on this increased knowledge, development activities must be planned so as to minimize negative impacts, such as loss of diversity and ecosystem disruption.

6. Every effort should be made to augment domestic and international programs to expand the system of protected marine environments. These efforts should place special emphasis on protecting diverse and unique areas or those with threatened or endangered species, protecting the integrity of highly productive ecosystems and promulgating the sustainable use of living resources. For these programs to be successful, it is essential that governments, foundations, international organizations, and private industry—especially the fishing industry—collaborate so that protected areas contribute to maintenance of aquatic productivity and ecosystem function.

7. In order to maintain biological diversity within freshwater and marine communities containing species whose economic uses

may be in conflict (e.g., recreational versus commercial exploitation), all U.S. Government agencies should examine, coordinate, and establish policies to minimize conflict and to protect and maintain the structure and composition of those communities.

8. The United States should continue and expand its domestic commitment to wetland conservation, particularly the restrictions on draining, dredging, and filling of wetlands such as bottomlands, prairie potholes, arctic tundra, and coastal marshlands. Commitments should be made to protect watershed systems from agricultural, residential, and industrial pressures.

9. Prevention of further species loss should be a global priority. Therefore, the United States should maintain the conservation authority currently provided in the Endangered Species Act for the protection of all endangered or threatened animals and their habitats. We recommend that: (a) protection should continue to be available for all endangered or threatened animals and plants; (b) the listing process should be efficient and should be based solely on the conservation status of the species, e.g., listing should not be prioritized on whether a life form is considered to be "higher" or "lower"; (c) the Act should continue to require Federal agencies to insure that any actions which they authorize, fund, or carry out will not jeopardize the continued existence of any endangered or threatened species, wherever located; (d) the Act should continue to authorize acquisition of habitat for endangered and threatened species; and (e) the Act should continue to provide for international cooperation in the conservation of endangered and threatened species.

10. Many concerned and responsible groups are willing to assume part of the burden of mitigating the harmful effects of development on aquatic ecosystems. We recommend that in addition to support from Federal and State funds, industry and interested private and corporate funding agencies be encouraged to contribute money derived from profits, sales of assets, assignment of stocks, donations, and self-imposed excise taxes to an independent fund. This fund should be administered by appropriate State, Federal, or other agencies and used to conduct environmental assessments and investigations on the impacts of man-induced changes on biological diversity and to plan and implement necessary rehabilitation and conservation programs. These actions should in no way eliminate the responsibilities of governments for insuring preservation of biotic resources through enforcement of appropriate laws such as the U.S. Endangered Species Act, the Clean Air Act, and various other statutes affecting clean water.

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11. Research and education in freshwater and marine animal and plant systematics and taxonomy should be a continuing and robust part of the biological sciences in the United States. Knowledge of the diversity of organisms that inhabit aquatic ecosystems is rudimentary. Continued attention should be paid to the training of systematists, support for systematic institutions, and the systematic identification of biological diversity in marine and freshwater ecosystems. In particular, it is urged that the administration reconsider the proposed closure of the National Oceanic and Atmospheric Agency (NOAA) Systematics Laboratory. Training and research on disease organisms, competitors, predators, and forage organisms of commercially important species must also be encouraged.

12. Continued monitoring of the ecology and genetics of economically important populations is essential for formulating long-term strategies for fisheries management. Attention should be paid to maintaining genetic diversity of hatchery strains and to avoiding inbreeding and genetic drift. Programs to preserve genetic diversity through germplasm maintenance and dissemination should be encouraged. Cooperative programs with other nations to express the urgency for acquiring this information and to coordinate the scientific expertise necessary to implement these programs should be initiated. Existing laboratory facilities are adequate to undertake these programs. Programs already existing within several government programs should be pursued and encouraged.

13. Local, regional, and global effects of long-term, low level pollution on the biological diversity and ecosystem integrity of the seas should be given high priority by the responsible local and Federal agencies, including the Environmental Protection Agency (EPA) and NOAA. Particular attention should be given to research on effects of industrial wastes, persistent pesticides and herbicides entering the wetlands, estuaries and seas, and operational discharges from offshore oil and gas operations.

14. Materials released into the atmosphere also affect aquatic ecosystems and can have global impacts since they do not recognize geopolitical barriers (e.g., the acid rain of the northeastern United States and southeastern Canada). Fragile, unique ecosystems, such as those in Antarctica, are especially susceptible. Implementation and enforcement of the Clean Air Act should be effective enough to limit such violations.

15. The introduction of exotic aquatic species has caused damage to the diversity of native aquatic communities. Once imported, there is a high probability that the introduced aquatic species will move into other areas. It is recommended that U.S. Federal laws be enacted to strengthen Executive Order 11987, to regulate the

introduction of aquatic plants or animals into the United States, and to provide substantial penalties for deliberate or accidental unauthorized introduction of exotic organisms. Authorization to introduce a species should be given only after potential economic, biological, and ecological risks and benefits have been evaluated. If this judgment cannot be made because of insufficient information, permission for the introduction should be withheld until adequate investigation has been performed.

The States should be encouraged to institute controls on exotic species introductions which are compatible with the proposed Federal laws.

16. The Departments of Commerce and Interior should complete inventories of coastal ecosystems and should, in coordination with other interested agencies, implement a program for their protection. The United States should adhere to the Convention on Wetlands of International Importance, also known as the "Ramsar Convention."

17. Estuaries, freshwater wetlands, sea grass and algal beds, coral reefs, and mangroves are areas of high biological diversity and are of enormous economic importance to the United States and the world. The Federal Government should seek through both its agencies and international channels to retard and mitigate the impact of traditional development practices on these fragile ecosystems. Although this problem is global in nature, it is particularly severe in tropical countries.

18. Species diversity, nutrient cycling in arctic ecosystems, and the potential contribution of the unique arctic flora and fauna to man's well-being are not well understood. Steps should be taken immediately to increase their support of arctic programs addressing these topics.

19. Data now being collected indicates that the deep sea is a unique environment. It is ecologically diverse and inhabited by an irreplaceable biota which is poorly understood. The marine environment should not be considered as a convenient dumping ground for wastes. Areas supporting living populations should be protected by State and local governments and by international agreements. Research and monitoring should be expanded.

Microbial Resources Panel

Chairmen	Rapporteurs
Dr. Robert Stevenson	Dr. Lloyd Frederick
Dr. Deane Weber	Dr. Harold Keyser

Panel Members

Mr. Irwin Asher	Dr. Peter Joseph
Dr. Barbara Bachmann	Dr. Micah Krichevsky
Dr. Jean Brenchley	Dr. Asger Langlykke
Dr. Rita R. Colwell	Dr. Roger Lawson
Dr. John Corliss	Dr. Peter Mazur
Dr. William Dowler	Dr. Brinton Miller
Dr. Robert Gherna	Dr. Larry Moore
Dr. Phillip Harriman	Dr. Theodore Sudia
Dr. Robert Hodson	Dr. Marjorie Tingle
Dr. Riley Housewright	Dr. James Tyler

Observations

While man has recognized, collected, and domesticated many forms of plant and animal life for millenia, it has only been in the past century that bacterial forms of life have been studied and their importance appreciated. Discovery of the indispensability of microorganisms in food, energy, chemical transformations, and mineralization chains demonstrates the interrelatedness of all life forms in the world's ecosystems. Paradoxically, the contributions of microorganisms in ecological systems are so fundamental to the existence of higher life forms that they are often taken for granted and ignored in policy considerations.

Included in the category of microbes are algae, bacteria, fungi, protozoa, chlamydiae, and viruses. Some of these are thought to be the most primitive forms of life and have their hereditary code in a single naked strand of DNA. Others have their DNA enclosed in a separate compartment and are thought to be precursors of higher multicellular life forms. The viruses and chlamydiae are special cases thought to represent retrograde evolution.

The microbial world is almost completely invisible to the naked eye. Because of its dimensions,it is useful to think of micro-niches and molecular sizes rather than the square miles or hectares employed by botanists and zoologists in establishing the ecology of their specimens.

Diversity in the microbial world is enormous. Hundreds of

thousands of species are estimated; at present some 40,000 of them are collected and exchanged. Emphasis has been placed on disease-causing strains and those important in human enterprises (e.g., food production and industrial fermentation). Major advances in understanding cellular processes and molecular biology have been made. However, rapid progress in biomedical applications, and now genetic engineering, have siphoned off the trained investigators to these exciting fields, slowing extension of knowledge on ecological aspects of microbial life. Facts are known about microbes, but mankind is far from completing an inventory or assessment of their diversity or significance.

Without microbes, food, energy, and chemical transformations would be impossible. For example, the productivity and food value of 15-odd major plant species upon which man depends for food are, in turn, dependent upon nitrogen-fixing microorganisms.

All plants and animals have an associated flora of numerous microorganisms. Loss of higher species may therefore eliminate adopted microbial species as well. It is chastening to realize that 90 percent of the cells contained within the human body represent associated microflora.

Just as loss of higher species that are endangered may eliminate microbial species adapted to them, threats to microbial diversity may endanger plant and animal diversity. The cutting of tropical rain forests with ensuing soil infertility can be linked to the ability of rhizosphere microbial populations to provide nutrient compounds not stockpiled in tropical soils. In some places, reestablishment of vegetation not having the associated microbes has depleted soil fertility and ultimately resulted in serious damage to the ecosystem. If the knowledge of rhizosphere associations had been used in the decisionmaking process, these activities might have been adjusted to minimize the effect of forestry operations on soil fertility.

It is believed that no ecosystem has yet been fully described, especially with respect to the microorganisms. Requisite methods for isolation, identification, and characterization of microbial components are available and should be incorporated into ecosystem studies. Benefits which can be expected from such efforts include information for ecosystem management, useful byproducts of microbial activity, and increased understanding of natural processes.

Increased research on microorganisms, especially on microbial processes, will provide greater understanding of their potential as suppliers of alternate food and energy sources, their role in preservation or sustaining biological diversity in natural ecosystems, and their capacity to modify or control harmful effects of disease, food spoilage, and acid mine-waste drainage into pristine streams, etc. These benefits provide a rationale for spending tax dollars or

investing scientific effort in studying, collecting, and preserving microbes.

The current status of industrial microbiology and its promises for the future have been described in a very informative series of articles appearing in *Scientific American*, September 1981. Application of molecular biology, gene and protein mapping, DNA sequencing and synthesis, and genetic engineering have great potential to improve the quality of human life.

The U.N. Environment Program promotes the concept of "domestication" of microbes and portrays the spectrum of expected benefits (UNEP Report 5, 1980). It is a technically feasible but ambitious program requiring many years of effort and huge resources.

Knowledge of microorganisms is derived from the processes of discovery, description, and definition. Many years of research may be required to determine the structure and function of a single microbial cell. Sharing information about organisms representing the same species but isolated in differing locales thus would facilitate accumulation of knowledge and avoid unnecessary duplication of work. Type specimens and associated data on their properties form the base of knowledge that is used for comparison and recognition of new or novel properties that are of use or significance to mankind. Availability and dissemination of the collected information is fundamental to the organized study of microbial populations and to prevent endless reisolation and characterization of ubiquitous species.

Current data bases, including information on collection holdings and strain data, as well as availability for exchange, are limited. A survey conducted by the Culture Collection Committee of the American Society for Microbiology revealed that there are an estimated 1,200 culture collections of various sizes in the United States. Of these, however, only 133 collections catalog their holdings, and only 24 offer a catalog for general distribution.

During the first plenary session of the International Association of Microbiological Societies on July 25, 1930, in Paris, France, a resolution of the Nomenclature Commission was passed:

> Among the most important agencies working toward satisfactory nomenclature and classification of bacteria are the several type culture collections. These constitute invaluable repositories and much of the future development of bacteriology will depend upon their adequate growth, support, and utilization. In some cases ...they should develop into research institutes of high grade. It is urged that the coordination and cooperation existing among these institutions be expanded, the better to serve the interests of bacteriology in its theoretical, medical, and other economic aspects. It is further urged that all bacteriologists publishing descriptions of new species or important strains of bacteria deposit pure cultures ...with a culture collection, so they may be made available to others. Particularly it is urged that the adequate financial support of these culture collections by official agencies, by educational and research

institutions, and by foundations constitutes an important and immediate need.

Fifty-one years later, only Japan has supported development of a comprehensive national data bank listing algae, bacteria, fungi, protozoa, viruses, and animal cell lines. In the United States, support for similar activities has been fragmented and rather parochial. Funds are made available according to the interests and missions of the funding agency, as well as its philosophy and continuity of commitment to long-term support. Attempts have been made to establish worldwide data bases, but such efforts always have been underfunded and have lacked international cooperation and support.

A "collection" is an assembly of things for purposes of comparison or exhibition. Collection as an activity occurs at many different levels of research, including that of the field microbiologist who may accumulate hundreds of specimens, the clinical microbiologist who deals with thousands of patient isolates, individual reference collections, genetic stock centers, industrial stock collections, and regional and national collections, etc. Each has its own needs and justifications and represents significant potential for use and application, with proper cataloging of information.

At the level of the individual investigator who may be supported by research grants, collection activities and exchange of material with peers are most frequently accomplished without requiring approval or recognition by any funding agency or study section. However, in most cases, funds or institutional commitment are not made to preserve the results of the research, other than through publication in peer-reviewed journals.

Occasionally, agencies embark upon programs of research resource development, especially when fast-developing research areas open and produce a constituency that is vocal about its needs. As a field matures and new areas become "trendy," older areas of speciality are abandoned, and any collections of microorganisms that have been amassed are either abandoned or left to lie fallow. Preservation of such materials usually places an impossible burden on already impoverished institutions and results in loss of expensively gathered and potentially useful material. In particular, the panel noted the anomaly of national institutions being assigned the tasks of physical and chemical standardization, without comparable assignment or support for biological standardization.

There is a growing awareness of the need to employ well-characterized, standardized biological material in experimentation. This may be more costly, since a lot of work is required for full characterization of a given microbial species; however, the expense is justifiable if it can prevent the loss of many years' work through contamination or misidentification of starting material.

The major actions which the panel recommends are:

(1) Coordinate collection activity;

(2) Establish a clear definition of collection activity as a component of the laboratory experiment, i.e., in providing suitable reference material;

(3) Make available properly characterized materials for research and teaching;

(4) Guide Federal agencies towards policies that are consistent with the support and operation of culture collections; and

(5) Involve professional societies and scientific journal editors in promoting biological standardization.

A number of detailed reports on microbial genetic resources, conservation of germplasm, and significant microbial processes exist and may be consulted for more specific information on these points (see Bibliography). These and other reports contain significant recommendations, but few of them have been implemented. The panel wishes to recognize these prior contributions and acknowledge them as sources of information used in formulating the following recommendations which, if implemented, can result in an improved infrastructure for development of available resources, manpower, and knowledge.

Recommendations

1. A national network of culture collections should be created, comprised of the three major types of collections: (1) specialized research (working collections); (2) major reference; and (3) national resources. A national data base on microbial genetic resources should be developed, perhaps modeled after Japan's. Such a data base would be an ongoing responsibility of a National Microbial Collections Resource Board with representatives from Federal, State, nonprofit, and private sectors. The charter of the Board would include the inventory and assessment of culture collections, maintenance and operation of a data base on collections, evaluation and recommendation of procedures for culture preservation, and policy advice to appropriate agencies/institutions for development and support of resource collections.

2. Microbial systematists should be part of any team carrying out broad ecological surveys. The end result will be only as useful as the talent involved in the data gathering and the quality of the data gathered.

3. Collaborative U.S. and international programs for exchanges of microbial cultures and resource data should be established and

supported as continuing activities with long-term commitments.

4. Departments, agencies, bureaus, institutes, and divisions of the Federal Government having responsibility for biological science research support should review and evaluate their programs and policies to encourage development of microbial collections and data bases.

5. Scientific societies, editors of scientific publications, educators, and peer review groups should establish adequate criteria for standardization of microorganisms used in research projects and cited in peer-reviewed research papers to avoid non-reproducibility of results and misleading information arising from contamination, incorrect identification, or incomplete characterization.

6. Scientific societies and/or government agencies should establish panels or committees of qualified members to make recommendations on the identification, collection, and preservation of microbial genetic resources. Such experts would serve as consultants to government or public institutions in the creation and maintenance of microbial collections and associated data bases. For example, the Committee on Microbial and Subcellular Particles has been authorized by the Secretary of Agriculture to provide a focus within USDA for activities related to living microbial culture collections of importance to agriculture. This committee is working to establish a cataloged national network of collections important to plant science, to prevent loss of valuable germplasm, and to cooperate with other organizations and societies relative to methods of authentication, maintenance, and analysis of collections.

7. Academic institutions should emphasize a broader training and education in organismal biology, systematics, ecology, comparative taxonomy, and organization and management of collections of research material on microorganisms.

8. Support should be given to the U.S. Federation for Culture Collections. All scientists who isolate, compare, maintain, and preserve collections of microbial genetic material should participate in the Federation. Such participation will lead to improved communication and exchange of material that in turn will result in higher quality material and better return on research investments.

9. Recognizing that man-induced changes in the environment may occur more quickly than ecosystem studies can be planned and executed, support should be given to:

- The concept of the "Biosphere Reserve" of the UNESCO Man and the Biosphere Program in establishing protected areas representative of the biotic provinces of the world;

- Establishment of a similar system for identification of the world's croplands and the study of unique microbial/crop associations; and
- Collection of information from environments upon which human impacts have had catastrophic effects.

10. The U.N. Environment Program should be commended for its establishment of Microbial Resource Centers (MIRCEN's) in developing countries and for training microbiologists to apply knowledge to practical problems.

11. Finally, the panel restates its conviction that interdisciplinary approaches to examination of biological diversity are essential and that to do otherwise is the essence of folly.

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Ecosystem Maintenance Panel

Chairmen

Dr. Edward Ayensu
Dr. Kenton Miller

Rapporteurs

Dr. Walter Parham
Mr. R. Michael Wright

Panel Members

Dr. Gerald Barney
Dr. John Belshé
Dr. Russell Burns
Dr. Faith Campbell
Mr. Vernon Gilbert, Jr.
Dr. Wm. Franklin Harris
Dr. Robert Hoage
Dr. Stanley Krugman
Dr. William Lawrence
Dr. Cyrus McKell
Mr. Rob Milne
Ms. Margery Oldfield
Dr. Paul Opler
Mr. Albert Printz
Dr. Peter Raven
Dr. Richard Saunier
Dr. Manuel Sirvent-Ramos
Dr. Joseph Tosi

The Panel on Ecosystem Maintenance dealt with the need for the careful management of natural protected and cultured (man-modified) ecosystems.

The *in-situ* maintenance of plant and animal species is the most comprehensive approach to the conservation of biological diversity. Most importantly, *in-situ* methods offer unique advantages over offsite alternatives: for example, natural selection, coevolution, and development of new varieties continue; both the known, conspicuous, and currently valued as well as the yet-unknown species are maintained; entire communities of species and their diverse habitats can be retained; and, intuitively, the cost per species conserved is lower than *ex-situ* conservation methods.

Two complementary strategies or plans of action stand out as ways to foster conservation of maximum biological diversity. These include: (1) establishment of a worldwide network of natural protected areas, and (2) development of broad regional planning mechanisms which provide for biological resource conservation in terrestrial and aquatic ecosystems and requirement of site-specific plans to manage the disruption of ecosystems caused by development projects.

Natural protected areas can provide for maintenance of wild species and ecosystems. This management objective generally can be combined with other activities, including research and monitoring, and to varying degrees with recreation, watershed management, wildlife protection, hunting and fishing, and carefully controlled harvesting of timber and other renewable resources. These protected

areas may represent a major storehouse of natural biological diversity.

Today, in some 110 nations there are about 333 million hectares in over 2,000 parks, forests, and other types of reserves. Even though the total value of this current "estate" in terms of the objective of maintaining biological diversity is unclear, it represents a considerable point of departure. However, new areas must be established to insure full coverage of biological resources. In selecting new areas, particular attention must be paid, perhaps for the first time, to addressing crop cultivars and materials important to industrial and medicinal processes.

Mechanisms for international cooperation in establishing, monitoring, managing, and legally protecting natural areas and conserving natural resources exist at regional and global levels. The United States is a member of the Convention on Nature Protection and Wildlife Preservation in the Western Hemisphere, Convention Concerning the Protection of the World's Cultural and Natural Heritage, the Man and the Biosphere Program, and the Convention on International Trade in Endangered Species of Wild Fauna and Flora.

The disruption of ecosystems caused by development projects can be destructive of biological diversity, especially the genetic diversity of subspecies, animal populations, and plant associations. Such disruption can be reduced by coordinating timing and land area disruptions (e.g., to allow ecological adjustment and providing buffer zones and access corridors for resident species) to insure maintenance of biological diversity.

The majority of most nations' lands consists of cultured landscapes. Agriculture, forestry, and near-shore fishing together provide fundamental human needs and, at the same time, should contribute to the maintenance of biological diversity. Such activities are important in reducing pressures for converting wild areas to cultured uses to meet growing human demands with the inadvertent loss of biological diversity from these areas. Maintenance of diversity, in contrast to excessive dependence upon monocultural production systems, provides for flexibility against pest infestations and extreme environmental conditions. Wild and semi-domesticated relatives of the major world food crops are still cultivated and multiple varieties maintained in annual plantings. Substantial amounts of outbreeding by the cultivated products with neighboring wild species occur, thereby enlarging the gene pool of the products being cultivated.

At the extreme end of the spectrum of land-use lie the so-called waste or marginal lands. Typically defined in terms of their lack of potential for modern agricultural production, these lands commonly

either are left uncultured or are used extensively for certain periods and subsequently abandoned to natural processes and plant succession. Such areas often harbor wild species and varieties that have been destroyed elsewhere. Through appropriate management practices, these areas, which often feature rocky soils, arid lands, bogs, steep slopes, or hedgerows, can be left in wild and semi-wild status to contribute to overall regional diversity or otherwise used productively, thereby relieving the pressure to convert still undisturbed areas.

The Panel on Ecosystem Maintenance agreed on the following:

(1) Protected areas should be considered fundamental elements of a coordinated and comprehensive strategy for the maintenance of biological diversity.

(2) The status and value accorded to the stewardship of natural protected areas is not commensurate with the critical importance of this enterprise for human welfare and sustainable development.

(3) The success of genetic engineering for sustaining and enhancing productivity in the future depends largely on the availability of basic plant and animal material and models from the wild.

(4) Highest priority should be given to the Tropics where the greatest biological diversity is found and where the most rapid land and water-use changes are occurring.

(5) The question of biological diversity should be addressed within a framework which explicitly recognizes the relationshp between biological impoverishment and poverty, unemployment, food and water scarcity, energy shortages, and population growth.

Observations and Recommendations

The Panel on Ecosystem Management developed recommendations covering the following categories:

— General Recommendations
— Human Capacity To Manage Ecosystems
— Inventory and Information
— Natural Reserve Systems
— Cultured Lands/Waters—Agriculture, Forestry, and Fisheries
— Traditionally Managed Lands/Waters

GENERAL RECOMMENDATIONS

1. The United States should establish a U.S. Interagency Task Force on Biological Diversity to develop comprehensive, long-term goals and strategies to maintain biological diversity. This body

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should include representatives from the key Federal and State agencies and private organizations with natural resource stewardship responsibilities. Current programs should be reviewed and recommendations should be made for domestic and international action. The report should be presented to the President by late 1983.

2. The Task Force could establish and oversee a series of special working groups or commissions on such specific topics as:

- Inventory and Information on Biological Resources
- U.S. System of Ecological Reserves
- Regional Planning and Cultured Landscapes
- Traditional Land and Water Use
- Training and Institutional Development for Biological Diversity

3. The Task Force should consider establishment of a national policy to promote the maintenance of biological diversity domestically and internationally.

In addition to the aforementioned recommendations, several additional items of an important but of a more general nature warrant consideration. These recommendations can be obtained from the conference organizers.

HUMAN CAPACITY TO MANAGE ECOSYSTEMS

Observations

— There is little awareness of the lack of trained human capacity to design and implement programs, carry out research projects, screen materials, select and manage protected areas, and work effectively with local people in rural development to maintain biological diversity in ecosystems.

— The need for training is dramatic, yet the level of investment in training programs is extremely low in proportion to the importance of these efforts to human welfare.

— There is a fundamental image problem whereby field staff are generally thought to require only a minimal education and assume only a small amount of responsibility; yet, they are *de facto* stewards of the world's natural heritage.

Recommendations

1. Offer training to professionals from other countries; provide support to and help build up training institutions in foreign countries; and encourage communication among professionals involved in ecological reserves and biological diversity concerns in the developing world.

2. Incorporate into development assistance projects greater support for training of local personnel and the development of management capacity related to biological conservation.

3. Promote an awareness among development administrators of the importance of training and professional status for ecosystem managers.

4. Develop educational and training materials drawing on existing materials and focusing on methods and techniques for inventory of ecosystems, inventory and collection of wild plant and animal materials, and the planning and management of protected areas and agriculture, forestry, and fisheries for the maintenance of biological diversity.

5. Undertake and encourage applied research on the planning, management, and development of protected areas.

6. Expand the sharing of technical expertise between U.S. resource management agencies and international development organizations.

7. Expand cooperative activities between the U.S. and foreign national and international organizations in tropical forest ecosystem management.

INVENTORY AND INFORMATION

Observations

— There is a need to determine the current status of the Earth's ecosystems, including protected areas and cultured landscapes, monitor trends in their alteration, and assess their capacity to maintain biological diversity.

— The capacity to inventory and catalog wild species and varieties in the United States and worldwide is extremely limited.

— It is essential to increase our level of knowledge regarding ecological relationships.

— Long-term effects of pollution, alteration of climate, introduction of exotic species, and resource management practices can have significant impact on biological diversity.

Recommendations

1. Develop a coordinated international program to map and monitor land and water use to analyze the current status of the Earth's ecosystems and the rates of conversion from wild to altered states.

2. Evaluate current international and U.S. efforts to inventory wild species and varieties and to maintain germplasm collections.

3. Develop appropriate ecosystem classification system(s) to guide selection of areas to be managed for protection of biological diversity.

4. Determine priorities for designation of protected areas and components within cultured landscapes meriting special management.

5. Compile one national register of Federal, State, and private protected areas and components of cultured landscapes and assess their importance to the maintenance of biological diversity.

6. Support U.S. participation in global programs related to inventory and information on biological diversity. The IUCN Conservation Monitoring Center, UNEP Global Environmental Monitoring System, FAO's work on genetic resources, UNESCO's Man and Biosphere Program, and the World Heritage Convention provide key instruments for international collaboration.

7. Implement the National Academy of Science *Report on Research Priorities in Tropical Biology.*

8. Support high-priority cooperative research efforts, including those on CO_2 and climate, crop cover, acid precipitation, and analysis of coastal ecosystems. U.S. resource management agencies should improve and increase assistance to developing countries to conduct biological inventories as the basis for land-use planning, management, and conservation of biological diversity.

9. Increase research on *long-term* effects of climate change, pollution, and the effects of introduction of exotic species and resource management practices.

NATURAL RESERVE SYSTEMS

Observations

— Establishment and management of existing protected areas generally focuses on a variety of objectives which may not explicitly include the maintenance of biological diversity. Therefore, the contribution of these areas to conserving biological diversity needs additional clarification.

— Existing protected areas may require boundary realignments

and modified internal management practices to insure conservation of biological diversity. Some new areas may have to be established. Limited time remains for this action as adjacent lands, and wildlands in general, are being converted to cultured landscapes.

— The policies and legal frameworks for research, monitoring, and collection of biological resources in protected areas are at best inconsistent.

Recommendations

1. Establish a comprehensive U.S policy for a national network of protected areas representing the nation's ecosystems. Federal legislation should establish a National Ecological Reserve System. Particular attention should be given to developing protected areas in prairie ecosystems.

2. Revise and amend the policies of all Federal and State agencies with stewardship responsibilities to establish biological diversity as an explicit objective of planning and management. Conflicts in management for this objective and other objectives should be addressed.

3. Expand research activities in support of protected area management. Protected area selection and management must be based upon the best scientific knowledge and techniques available.

4. Determine the feasibility of Federal, State, and private cooperative programs to finance and support the study and realignment of existing areas in the United States and the establishment of additional areas, where necessary.

5. Revise and establish appropriate policies regarding the access to and use of genetic materials from protected areas. Access and collection of plant and animal materials for purposes of research and breeding are to be encouraged within a framework of overall protection and stewardship.

6. Expand U.S. participation in international conventions, treaties, and programs which focus on conservation of global biological diversity. Assess global need for additional protected areas in wetlands, freshwater and marine ecosystems, coastal zones, and cave systems. Provide assistance to developing countries to expand the network of protected areas to maintain biological diversity.

CULTURED LANDS AND WATERS

Observations

— The vast majority of the terrestrial landscape and most freshwater and marine areas are used to meet human needs through agriculture, forestry, and fishing and also should play a role in maintaining biological diversity.

— Many genetic resources may benefit from maintenance within these cultured or man-modified systems.

Recommendations

1. Encourage and support the development of methods, techniques, publications, and demonstration projects for sustainable agricultural, forestry, and fisheries production, which also provide for maintenance of biological diversity.

2. Assess the feasibility of providing incentives for restoration of degraded landscapes and waters.

3. Assess the feasibility of providing technical assistance and financial incentives to farm, forest, and coastal enterprises to maintain wild and semiwild or abandoned sectors of value to biological diversity.

4. Incorporate the objectives of maintaining biological diversity into technical and financial assistance projects at the international level. The recent progress in environmental management by AID is encouraging.

5. Support the development of methods of sustainable use of tropical forest resources for supplying goods and services which at the same time retain biological diversity.

TRADITIONALLY MANAGED LANDS AND WATERS

Observations

— Traditional cultures include knowledge regarding plant and animal resources which has not been fully incorporated into modern science. Traditional agro-ecosystems feature wild relatives to important crop cultivars. Similarly, native cultures have developed a pharmaecopoeia based upon wild plants and animals which has received incomplete attention by modern medical research.

— This knowledge is being supplanted by modern land and

water-use practices, movement of rural people into urban centers, and the general disintegration of cultures. Both the traditional knowledge and plant and animal varieties are being lost.

Recommendations

1. Compile information on traditional practices in the United States and abroad, with particular reference to food and medicinal plant and animal cultivation and uses in the tropical latitudes.

2. Promote general awareness regarding the value of traditional land and water-use systems.

3. Investigate the use of incentives to maintain traditional systems and develop modern applications of traditional practices.

4. Encourage assistance agencies to develop policy guidelines to review the impact of projects on native peoples and consider preservation of knowledge of biological value as an integral element of development projects.

V. Closing Remarks and Response to Panel Reports

James L. Malone
Assistant Secretary for Oceans and International Environmental and Scientific Affairs, Department of State
Washington, D.C.

I would like to extend to each of you a warm welcome to the Department of State. To those of you who are representing other governments and international organizations and to the members of the foreign diplomatic corps, we particularly appreciate your participation and your support for this conference.

I am certain that many who proceeded me over the last 2 days have referred to the importance of the issues that this conference is addressing. Regardless, it bears repeating. And possibly my repeating it, and in this building, may be especially significant.

Clearly, maintenance of the Earth's biological diversity has not been in the mainstream of traditional U.S. foreign policy concerns—and State Department interests—over the years. However, the fact that the State Department was one of the original proponents and organizers of this conference testifies to both changing conditions and changing perceptions.

In his welcoming remarks on Monday morning, Under Secretary of State Buckley emphasized that our ability to sustain economic growth and social development over the long term is critically dependent on our ability to maintain the productive capacity of the biological resource base. This recognition is certainly not a unique discovery by the State Department—or by the United States. Throughout the world over the last decade there has been a very visible and rapid emergence of concern about the sustainability of biological systems and their relevance to human societies. This is reflected in reports emanating from numerous international fora, in statements by public officials from other nations, and in our bilateral discussions with other governments.

Many reasons can be cited for this growing awareness. But to make the point, I need single out only the significant hardships many nations are now experiencing as the continuing loss of tropical

forests disrupts water systems, triggers erosion of agricultural land, and causes disasterous flooding of human settlements. Threats to our biological systems are clearly translating into threats to economic and social systems. As biological systems are degraded and undercut, so too are our development investments.

This, therefore, accounts for the importance that we in the State Department attach to this conference and why the issues you are addressing have become a dimension of U.S. foreign policy interest in today's world.

I know that many of you have devoted careers to the subject matter of this conference and have probably attended many meetings on these issues. I hope, and I trust, that this event will prove to be special—special in the sense that it will make a distinct difference in how we proceed in this area in the future.

In his written statement to the conference, A. Alan Hill, Chairman of the Council on Environmental Quality, referred to a new government-wide effort which the Council is spearheading to examine a range of "global issues" of importance to the United States, with a view toward defining appropriate policy and program responses by the United States in the years immediately ahead. The conclusions and recommendations produced by the Conference on Biological Diversity will become part of that analysis and evaluation. Further, we intend to work closely with the other sponsoring agencies to insure that any recommendations which call for specific Federal action receive early and careful consideration.

The best symbol of hope that I can offer in that regard is that this is the third in a series of interrelated resource management conferences that the State Department has sponsored with other agencies over the past 4 years. The others addressed the subjects of tropical deforestation and pesticide management. In both cases, these earlier conferences produced recommendations that were subsequently translated by the Federal agencies into new U.S. policy directions and program initiatives.

We began planning for this meeting some 8 months ago with this same vision of a meaningful, action-oriented outcome. Our approach was to attempt to obtain insights and ideas from the best people we could assemble so that future U.S. efforts in the biological diversity field can be more effective, more efficient, and more supportive of the needs and efforts of other nations.

If we are to be successful, however, it will require not just a response by the Federal Government, but also a collaborative undertaking which engages the U.S. business community, our universities, the environmental community, and the Congress. It also requires that we proceed with a clear vision of the problems, interests, and responsibilities of other nations.

Consequently, I am delighted that we have been able to assemble such an outstanding and representative group of participants, and I look forward with keen anticipation to your findings and recommendations.

Let me conclude by expressing my deep appreciation for the time and effort you have invested in this undertaking and by assuring you of my support for effective action by the State Department and by the Federal Government as a whole on those biological diversity issues of prime importance to the present and future well-being of the United States and other nations.

Several key staff members of House and Senate Committees were invited to provide their perspective on the issues before the conference and on the panels' analyses and recommendations. Congressional participation was considered essential in recognition of its legislative and oversight responsibilities and of the need for close coordination between Congress and the Executive Branch. Although action on two important pieces of legislation prevented Senate staff from participating, a broad range of congressional concerns is reflected in the following comments from House Committee staff.

The congressional responses are followed by comments from the floor and closing remarks by the conference moderator.

Congressional Perspectives

Skip Stiles
Representing the Subcommittee on Department Operations, Research and Foreign Agriculture, Committee on Agriculture
U.S. House of Representatives

The loss of genetic diversity is an issue that is terribly important but it would be an overstatement to say that it is of major importance to Congress. It is, however, one of those issues typical of any chronic problem that is not noticed until it blows up because we are busy dealing with day-to-day crises.

The Subcommittee on Department Operations, Research and Foreign Agriculture under the shared leadership of Representative George Brown (D-CA) and Representative William Wampler (R-VA) held a hearing earlier this year on the National Plant Germplasm

System, partly in response to a Government Accounting Office (GAO) study done on the subject. It was in the nature of an oversight hearing to see how some of the issues addressed in the GAO study were being dealt with. We would like to get more involved with some of the issues raised at this conference. I would like to think that we could have one or more hearings on biological diversity in the coming year.

Yesterday, I sat in on the plants panel. While we were creating various cells within a matrix constructed as a working tool, I was given to a flight of fantasy. I envisioned the problems about which we were talking to be one cell in a larger matrix which constitutes the concerns of this conference, which is but one cell in a still larger matrix of problems, up and up and up to the level at which Congress views problems. So ultimately, the problems of this conference are barely discernible. They form a small dot, and yet, they are tremendously important.

In the session this morning I kept hearing of the need to bring the message to the public and to Congress that this is a problem that demands our attention. In struggling with ways to deal with this, I took my matrix model, gave it a third dimension, and rotated it 90 degrees. I then had an upside-down pyramid standing on one point—genetic resources. A lot of what we are doing depends on that point. I am not so egotistical to believe that the events of the last couple of days constitute the sole resting point of all society, but when you consider that 20%–25% of our gross national product depends upon the resources that we have been discussing, it becomes apparent that with the erosion of these resources, we are in a fairly precarious position. If you have this upside-down pyramid trying to get its support from genetic resources—which are disappearing at an alarming rate—you see the necessity of devoting more attention to the issue. I think that through educating the public we can get its mind to rotate the matrix 90 degrees and see that this is a very important concern.

In looking at the National Plant Germplasm System in the hearing earlier this year, it became apparent to me how woefully inadequate the resources devoted to this problem are, given the magnitude of the task that faces us. And that was just with plant genetic resources.

I would hope that the energy I have seen at this conference will continue and not just dissipate. I hope that researchers will begin to make a little noise about the need to devote more attention to this issue. I hope that those from industry and others in the private sector will begin to thread some of these issues into their messages to Congress. It is essential that this not be just another in a series of conferences, to be followed in a year by another conference at which the same issues will be discussed and then everyone will go home.

At times it appears that postindustrial society is bent on shaping and controlling natural systems for society's benefit and that sometimes we believe ourselves to be above the effects of these natural forces. I do not know of any society or civilization that is so blessed. I have, however, read of many societies and civilizations that have failed because they have ignored natural systems. I hope this is not our fate. I would hope that those here today and others would take the message of this conference to policymakers in Congress and elsewhere in the government.

Carole A. Grunberg
Representing the Subcommittee on Human Rights and International Organizations, Committee on Foreign Affairs
U.S. House of Representatives

I would like to start off by telling you a little about the jurisdiction of our Committee and Subcommittee. The Foreign Affairs Committee has jurisdiction over general foreign policy, the State Department, and AID. The Subcommittee has specific jurisdiction over international bodies such as the United Nations Environment Program and the International Whaling Commission.

Some of the activities of the Subcommittee in the 2½ years of which Representative Don Bonker (D-WA) has been chairman are the yearly authorization of voluntary contributions to U.N. programs, like the U.N. Environment Program (UNEP), and money for the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). We have been involved in the Antarctic Convention, over which we have shared jurisdiction with the Committee on Merchant Marine and Fisheries. We have also done work on acid rain and the environmental aspects of the Law of the Sea treaty. Perhaps most relevant to the issue today is the Subcommittee's work on tropical deforestation.

Hearings held by the Subcommittee in response to the report of the Interagency Task Force on Tropical Forests led us to propose an amendment to the Foreign Assistance Act. This has not been enacted into law yet; the Senate has passed it, and the bill is awaiting House floor action, which should take place sometime in December.[1] I would like to read it to you to give you an idea of the Subcommittee's work on this issue.

The amendment reads:

In enacting section 103 of the Foreign Assistance Act (which deals with agriculture), the Congress recognized the importance of forests and tree

[1]The House passed the bill on December 16, and the President signed the FY 82-83 Foreign Assistance Authorization bill into law on December 29, 1981.

cover to the developing countries. The Congress is particularly concerned about the continuing and accelerating alteration, destruction and loss of tropical forests in developing countries. Tropical forests constitute a major world resource. Their destruction and loss pose a serious threat to development and the environment in developing countries. Tropical forest destruction and loss result in shortages of wood, especially wood for fuel, siltation of lakes, reservoirs and irrigation systems, floods, destruction of indigenous peoples, extinction of plant and animal species, reduced capacity for food production and loss of genetic resources. Properly managed tropical forests provide a sustained source of fiber and other commodities essential to the economic growth of developing countries.

The directive is that:

The concerns expressed in paragraph 1 and the recommendations of the U.S. Interagency Task Force on Tropical Forests shall be considered by the President in formulating and carrying out programs and policies with respect to developing countries, including those relating to bilateral and multilateral assistance and those relating to private sector activities, and in seeking opportunities to coordinate public and private development and investment activities which affect forests in developing countries. It is the sense of the Congress that the President should instruct the representatives of the United States to the United Nations and to other appropriate international organizations to urge that their organizations attach a higher priority to the problems of tropical forest alteration and loss and that there be improved coordination and cooperation among these organizations with respect to tropical forest activities.

Also, as a result of the hearings on tropical forestry, we requested that the full committee write to the Board of the Office of Technology Assessment (OTA) and request a technology assessment of tropical forestry management and the whole range of tropical forestry issues. This is now underway.

The other study that I want to bring to your attention is "Background Papers for Innnovative Biological Technology for Lesser Developed Countries," done under the leadership of Walter Parham at OTA. The study, requested by the Committee on Foreign Affairs, is based on panel discussions held in November 1980 and deals specifically with substitutes for fertilizers.

I would like to endorse Skip Stiles' statement about getting Congress more involved in international environmental questions, such as loss of biological diversity. There ought to be increased public pressure on the Congress, bringing these ideas and problems to the attention of the Members through letters and, more effectively, through visits to your Congressman and the appropriate people on the Committees. Echoing what Dr. George Rabb [Chicago Zoological Society] said, probably the most effective way to bring this issue to the attention of Congress is to present it in terms of the linkage between biological diversity and our day-to-day social and economic well-being.

I have some specific comments for some of the chairmen of the panels:

— Of the Terrestrial Plants Working Group, I would like to

endorse what Dr. Quentin Jones said about giving special attention to tropical plants. Our hearings have shown this to be of particular importance. It was also indicated that we should not now take action on drafting an international convention, that perhaps we ought to be looking at ways to strengthen the many international conventions already on the books rather than drafting an entirely new covention. A convention I have not heard mentioned is the UNESCO Convention for the Protection of the World Cultural and Natural Heritage. When a country signs the convention, it can submit a natural or cultural heritage site to be eligible for international protection and assistance. When the site has been placed on the list, the country becomes eligible for technical assistance from UNESCO.

— I think the idea of developing a National Conservation Strategy, along with the World Conservation Strategy, merits serious attention and that in our bilateral relations we ought to attach a priority to having other countries consider doing the same.

— I was interested in the recommendation of Dr. Rabb on recognizing the IUCN, and on that of Dr. Roger Gerrits that FAO coordinate activities in preserving domestic animal germplasm. As these are international organizations, these issues fall under our Subcommittee's jurisdiction, and we will consider them next year.

— Dr. Robert Stevenson of the Microbial Working Group commended UNEP for establishing microbial research centers in developing countries and for its work on training scientists and resource managers. UNEP has been given $10 million annually by the United States for the past several years, but this Administration initially wanted to cut this figure back to zero for Fiscal Year 1982 and beyond. We went to work with several of the people in the Department of State, and Secretary Buckley was effective in getting $2 million for UNEP in the budget. While we are saying that we ought to be attaching a higher priority to international organizations, the United States is at the same time drastically slashing contributions. We ought to be more consistent.

I think Chairman Bonker would be supportive of creating an interagency task force similar to the Interagency Task Force on Tropical Forests. I think he would also like to see this issue be given higher priority and more emphasis through our bilateral and multilateral foreign assistance programs.

One last thing: the Subcommittee next year will hold hearings to review the status of the world environment since the Stockholm Conference. It might be beneficial to devote one day of hearings to biological diversity so as to increase public and congressional awareness of the issue.

Stan Senner
Representing the Subcommittee on Fisheries, Wildlife Conservation and the Environment, Committee on Merchant Marine and Fisheries
U.S. House of Representatives

I am responding from the perspective of a staff member of the

Committee on Merchant Marine and Fisheries. Representative Thomas Evans (R–DE) regrets that he cannot be here but sends his support and encouragement in your endeavor. In addition to being a member of the Committee on Merchant Marine and Fisheries, he is the ranking Republican on the Subcommittee on International Development Institutions and Finance of the Committee on Banking, Finance and Urban Affairs which oversees the World Bank and the Inter-Asian Development Bank. He is interested in your concerns from both standpoints.

As Skip Stiles said, your concerns are a very small fraction of the overall agenda of Congress. There is, however, virtually nothing that our Committee or Subcommittee addresses that does not relate directly to the concerns you have about maintaining biological diversity.

Just to review. Our Subcommittee has jurisdiction over all matters pertaining to fisheries and wildlife conservation, which includes commercial fisheries, the Fisheries Conservation and Management Act, the establishment and protection of the National Wildlife Refuge System, and the non-game legislation which passed during the last Congress. In addition, it shares with the Subcommittee on Human Rights and International Organizations jurisdiction over matters such as the International Whaling Commission and the implementation of the proposed Convention on Antarctic Living Resources. So, we have a very broad range of matters, virtually all of them relating directly to your concerns.

I would like to touch on some of the items that were mentioned this morning and relate them to what the Committee has done or plans to do. First, the President has just signed the revision of the Lacey Act which came out of our Committee. For the first time, the Lacey Act extends the sanctions of the Federal law to violators of State laws as they relate to plants. Previously, the Lacey Act covered only violations of wildlife law. This is a highly significant change, one that we may build on in the coming years.

Earlier this fall, the Committee extended the life of the Marine Mammal Protection Act, at times a hotly contested matter in our committee, but one that has now been resolved.

The Endangered Species Act, mentioned several times this morning, is coming up for reauthorization later in this Congress, probably early in 1982. The occasion of reauthorizing an act is usually greeted with some trepidation by the supporters of the act; for, if Congress does not take conscious action to extend the life of that act, it lapses. It is like going to the doctor. You know you need a physical, but you keep putting it off. You finally decide to go, the doctor says that you will live for another 100 years, and you are happy that you went through the process. Of course, the doctor can give you bad news too,

and I think it behooves you to present your concern about the Endangered Species Act to the Committees in the coming months. The occasion of a reauthorization is a chance to renew old commitments in the Congress, find new friends, and build up the coalition that supported the act initially, because those same people in the public and the Congress are the ones on which you must depend to make new advances toward meeting your objectives.

On the matter of biological reserves, parks, and refuges, as I mentioned, our Committee has jurisdiction over the National Wildlife Refuge System. We were very much involved in the landmark Alaska lands legislation which passed in the last Congress. Establishing new reserves in this country is more difficult now because tax dollars needed to acquire private land are becoming more scarce. Several of you mentioned the need for more coordination in identifying priorities. I think this is precisely what our Committee will have to do. We have had any number of requests for new National Wildlife Refuges, and hard choices will simply have to be made. One might like to protect them all, but as a practical matter, it is not possible.

In the area of aquaculture and fisheries management, I will mention briefly that the Committee this year has engaged in a series of oversight hearings on the implementation of the Fisheries Conservation and Management Act, more commonly known as our 200-mile-limit law. One of the new or relatively new aspects that a couple of witnesses addressed this year was the interaction of sea birds with commercial fishing efforts. I will not predict whether or not changes in the law will result, but I think that recognizing the role and importance of the rest of the marine biota in considering commercial fishing programs is a step forward in our Committee and the Congress.

Loss of wetlands was mentioned in the Aquatic Resources Panel report. Our Subcommittee is holding a hearing this Friday on loss of wetlands. Although it focuses on the Mississippi Valley, it is applicable to the entire country.

Dr. Miller of the Ecosystems Maintenance Panel mentioned that the maintenance of ecosystem diversity is sometimes a byproduct of other actions that are taken. One example of that is the Coastal Barrier Resources Act in which Congressman Evans is deeply involved. It in essence would deny Federal subsidies and financial assistance to development on barrier islands on the Atlantic and Gulf of Mexico coasts. The fundamental rationale is economic. The government sinks a lot of money into these areas; they get blown away in a hurricane; then the government steps in and refinances the construction. It is an endless cycle in which we lose a lot of money. The act will provide a disincentive to the developers that rely on

getting Federal subsidies and thus it will indirectly serve to protect the wetlands and estuarine areas which are behind those barrier islands. So, good things can come in odd ways.

To close, I would like to echo a couple of the comments made by Carole and Skip. The first is simply to be very practical as you approach Congress. Dr. Stevenson of the microbial panel mentioned the need to justify the expenditure of tax dollars. The importance of that statement cannot be overstated. Competition now is exceedingly fierce; we are struggling to retain many good programs—much less start new ones. And you must remember that everything a Congressman does in Washington on your behalf to meet one of your objectives must ultimately be justified back home to those 500,000 constituents who sent him or her to Congress.

This leads me to the last point: You cannot overstate the importance of educating the public. It is not just a matter of going to a Congressman, offering your viewpoint, and being persuasive. Again, support must come from his/her constituents, and that requires your educational efforts.

COMMENTS

Dr. Peter Ashton
Harvard University, Arnold Arboretum

It is evident from the preliminary reports of the panels that recommendations which we made in the plants group were also made by other panels, and their spirit has been stressed by the congressional representatives here this morning. I would like to refer to these if only to underline their importance.

The particular point I wish to emphasize is the critical problem of the attrition of plant species diversity in the wild worldwide. The stress has been on the humid Tropics where most of the attrition is taking place and will almost certainly take place most rapidly over the next few years, but we should not forget the arid Tropics and the many useful plants there which increasingly are being threatened. Another concern we should have is the human aspect of the rapid disappearance of traditional, multi-species agricultural systems, again largely concentrated in the Tropics. These two reserves of germplasm resources—plant species in the wild and the traditional agricultural systems—represent the major reserves of species diversity whose continued preservation is essential if future options are to be kept open in the changing world of agriculture and forestry.

In this spirit, the plants panel recommends that current statutes and programs for conserving plants in the wild through reserves and

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also through such statutes as the Endangered Species Act be maintained and strengthened. Secondly, we recommend increased support for research into underexploited plants that are recognized as useful. A concentrated effort is needed to overcome the considerable structural and economic inertia to the introduction of new crops into the agriculture and forestry industries. Perhaps we have not stressed this sufficiently in the past. The 20 or so world crops which are the current major crops and undoubtedly the major crops for the future should not be developed to the exclusion of these other currently minor crops which we are convinced will also be major crops of the future.

Dr. Paul Opler
Fish and Wildlife Service

I certainly cannot speak officially for the Department of the Interior, but I might make a few comments regarding some of the panel recommendations that relate to the Endangered Species Act. Since the Act is coming up for reauthorization in 1982, the recommendations of the varous panels should be made available to the Congress, the officials of the Department of the Interior, and other groups. At the moment, Interior is trying to formulate its own positions on reauthorization and possible amendment of the act, and I think it would want to take these recommendations into consideration.

Dr. Norman Myers
Nairobi, Kenya

We have heard a lot during the last 3 days about how the great bulk of our species is to be found in the Tropics, which means in the developing Third World. We have also heard a good deal about how the capacity to exploit those genetic resources lies primarily in the developed North, especially in this nation. This leads us to a political dimension which I don't think has received as much attention in these 3 days as it might have. When news of this conference reaches some of the capitals and political leaders of the Third World, as it will very shortly, some of those folks might ask why all those people in Washington are getting so highly interested in these species and in the genetic resources that they represent. There is a growing risk that the Third Worlders, realizing that they sit on a stock of natural resources of growing significance, are going to start playing rather hard pool with the developed nations. They are even starting in one or two cases to deny access to their genetic reservoirs of materials for agriculture, medicine, industry, and genetic engineering. I believe it

would be a tragedy if there were to be a polarization of attitudes along those lines. The approach of the Third Worlders, as I understand it from my travels over the last 20 years, can be summed up in the remark of a Nigerian a few years ago. He said: "How come the conservationists in the North are so concerned about IUCN without equally being concerned about NIEO?" To translate the acronyms, IUCN stands for International Conservation of Nature and Natural Resources, and NIEO stands for the New International Economic Order. People in the developed world may not see the relationship in those terms, but that is the way the Third Worlder increasingly sees it. There is room here for political confrontation, but there is also a lot of room for political cooperation.

Species and genetic resources in the Third World are allowed to jump down the tube at an accelerating rate because these genetic reservoirs do not have a marketplace price on them. Although they are very valuable in terms of their end products, wild species don't have any immediate value to the peasant who wishes to use the habitat of these species. Perhaps we should start thinking of putting a marketplace price on genetic resources. Hitherto, germplasm has been traded internationally virtually for free. If there were a marketplace price on genetic resources, conservation of genetic reservoirs might then become a competitive form of land use in the Third World. To give you one example, Eli Lily in this country has formulated a very powerful antileukemia drug called vencristine from the rosy periwinkle, a tropical plant. The commercial sales of that drug in the developed world now approach $100 million a year. To my knowledge, the countries in which the rosy periwinkle is found have not received 1 cent to reflect the benefits that they supplied by providing the rosy periwinkle materials in the first place. It is thought that in the tropical rain forest there may be another 10 superstar anticancer drugs, but at present the Third Worlder does not see very much incentive in conserving those plants. Perhaps we could mobilize the immense power of the marketplace to offer them greater incentive.

Dr. Carlton Ray
University of Virginia

I thoroughly agree with everything that is said about the Tropics, but we should not ignore other regions. For example, the polar regions are coming into their own, particularly the polar seas. The polar regions are areas of low diversity, but they contain the largest biological biomass on Earth, the largest flocks of sea birds, and the largest remaining food resources. The Chukchi-Bering Sea contains 40 percent of the outer continental shelf oil and gas of the United

States. Obviously, we are going to have some very severe conflicts there. As Norman Myers has just said, we have to find some way to address the problems of exploitation and try to apply some of the profits therefrom derived to addressing the problems of preserving diversity. It is exceedingly important that this be done not only in the Tropics.

Richard Krasnow, Science Fellow
Office of Representative George Brown

One point I want to raise is the tendency of many defenders of nature to be satisfied when certain gains are embodied in administrative law instead of statutory law. As we have seen in this administration, past gains can be lost through simple administrative fiat. I think this gathering ought to recommend that any of the consensuses that are arrived at should be embodied in statutory law and not be satisfied with administrative regulation.

Another issue I'll mention concerns the concept of the common heritage of mankind. This lofty sounding phrase, turned, I think, by the Prime Minister of Malta some years ago, has some diplomatic and legal implications. As many of you probably know, the Law of the Sea is in a sense bogged down in a dispute precisely over the meaning of common heritage of mankind. Mr. Malone, the Assistant Secretary of State for Oceans and International Environmental and Scientific Affairs, stated the other day that with respect to the Law of the Sea, the United States is holding to a position of freedom of the seas instead of a position of a common heritage of mankind. However, when it comes to genetic resources, we are now trying to foster, out of self-interest, the concept of common heritage for mankind. My suggestion is that if an interagency task force on biological diversity is convened, it might propose that the United States define the common heritage of mankind in the legal and diplomatic sense and not merely use it as a fine lofty set of words.

Dr. Kenneth Dahlberg
Western Michigan University

I think you could say that in this conference, with some notable exceptions, we have taken a curative approach to the problem, that is, gathering information, analyzing it, diagnosing it, and then prescribing some sort of cure focusing on a specific biota or specific ecosystems. I think we also have to look at the longer term preventative dimensions. One question we have to address is how to relate matters of biological diversity to the assessments and reduction

of major disruptive trends such as pollution, acid rain, climate and carbon dioxide changes, and so on. Hopefully, this in a sense will be considered when the results of this conference are fed into the soon-to-be-convened CEQ global issues task force or interagency task force on biological diversity.

A somewhat related issue partially emerging from Skip Stiles' comments is that we may need to redefine what is meant by national security and global security. I think we should argue that the preservation of biological diversity is just as important as a number of other national security issues that we are willing to spend much more money on. The prevailing tone here has been that we can't really expect many more resources, but that's partially because we haven't said that this is just as important as other national security issues.

Another dimension that we haven't discussed is how to reduce the demand structure for products in the industrial world. That is, how do we design more energy and mineral-efficient systems, and manage fiber, timber, and food usage so that we're not placing as much demand on global ecosystems? This implies looking not only at conservation but also at recycling approaches within the industrial world.

I certainly agree with Norman Myers that we have to think of the ways in which we encourage development in the Third World. What sort of organization and institutional patterns best assist us in moving in this direction? Much more work has to be done on finding ways of decentralizing much of our work. As I mentioned Monday, the organizational approach that is used is one which seems to rely upon large, centralized organizations and bureaucratic approaches. These approaches may be productive in one sense but in another tend to be very simple and subject to disruption if there is any sort of external disturbance, social or natural.

Dr. Walter Parham
Office of Technology Assessment, U.S. Congress

Most of the comments I have heard today have been positive. However, on the first and second days, some of the comments showed a note of pessimism. The kinds of comments that I heard were ones like: "With the new political realities in the U.S. today, our concerns for maintaining global biological diversity will be ignored"; "Decision-makers won't understand the importance of conserving biological diversity"; "All that we have heard here has been said before and there is little that we can add, therefore, why bother with such a conference?"; "What use will the document be that this conference turns out—who is going to read it?"; and, simply, "We don't need this

sort of study." So, in spite of the pessimism that showed up earlier, I think the feeling today has been rather positive.

Some of us in the audience, including myself, were involved in the beginnings of the Conference on Tropical Deforestation that was held by AID and State in 1978. At the time the deforestation conference was held, Congress probably neither knew very much about nor cared much about tropical deforestation. I don't think this is true today.

For example, this year the Office of Technology Assessment (OTA) has been asked to do a study on technologies for sustaining tropical forest resources. We are a nonpartisan analytical support unit of Congress. In order for us to undertake any study, we have to get a letter from a full Committee Chairman. In addition to the letter of request for the study, we had more support letters for the study from congressional committees than any I have seen in the 2½ years that I have been at OTA, with the possible exception of the MX missile.

This increase of support and awareness of the problem didn't happen by accident; it is an outgrowth of hearings on tropical deforestation organized last year by Congressman Bonker and his staff.

But that isn't where it began either. It began with the report of the Interagency Task Force on Tropical Deforestation, which was paralleled by a nongovernmental study that involved industry and business, a study by the National Academy of Sciences, the National Research Council, and other studies and popular books by people like Eric Eckholm.

But why was there an interagency task force? Because there was a recommendation that came out of our first tropical deforestation conference, similar to this one.

So, do we need the conference? For those who asked, I'd say yes. Rather than being pessimistic, there's reason to be more optimistic. I firmly believe that activities of this sort and the recommendations that emerge can be very beneficial and can influence the people that are making the decisions for funding and followup activities.

Dr. Faith Campbell
Natural Resources Defense Council, representing the Task Force on Biological Diversity of the Global Tomorrow Coalition

I'm very pleased with the results of the conference and I'm happy to feel the energy generated here. Much has come out of the preceeding Conference on Tropical Deforestation, with a lot of effort by many people. I'm hoping that we will see similar action on biological diversity issues by the administration, the Congress, and the nongovernmental community. I believe the environmental

organizations that I am representing will certainly wish to take an active part in all aspects of the work.

Dr. Bryan Norton
Center for Philosophy and Public Policy, University of Maryland

I'm working on a study on the preservation of species which will address the questions of why species and species diversity are important. Within that context, we will look at the question of defining priority species or taxonomic groups to be preserved. Much has been said about setting priorities, but in reading theoretical literature, I have noted that almost all of the arguments given for species protection could generate an argument that all species are basically of equal value or that since we don't know which ones will be important, we should protect them all. Given the magnitude of the problem and the shortage of resources, defining priorities may be very important.

I would also like to observe that from a philosophical perspective there seems to me a fairly common conflict underlying much of the discussion of the last few days. A number of people have referred to the intrinsic value of species other than our own, but at the same time, much of this conference has dealt with the economic value and utilitarian function of species. If one says on the one hand that species are of intrinsic value, that means that we may not treat them as if they have no end in themselves, as if they are merely of value to *us*.

Dr. Geza Teleki
George Washington University

I've spent 2 years in West Africa in the country of Sierra Leone trying to get a park started. In doing so I have had some singular problems, problems not really having to do with local people at all. We managed to convince a chiefdom in Sierra Leone to give up 400 square miles of land without compensation to set up the first park in the country. While I was doing this work, I became very frightened when I found out that a company in Denver was preparing to unload thousands of tons of toxic chemicals in Sierra Leone—and the place that it would have gone was the national park, because it was the only place without people. I'd like to ask the government representatives in this room whether there would be some possibility of arranging a clearing house in this country so that commercial interests do not run into direct conflict with preservation of species and natural environments overseas. I fail to understand why American companies, which must abide by laws in this country to keep the environment

clean, do not have to abide by the same laws overseas. These problems have a tremendous impact overseas.

One of the major difficulties that I have faced in the 2 years in Sierra Leone is that each set of resources is being torn out under maximum stress to the local environment. A forestry company comes in, clearcuts an area, and destroys all the wildlife. A pharmaceutical company comes along and through the government buys 300 chimpanzees which are taken out of natural areas—not the area where the forest company has cut all the trees down and where the chimps starve to death. What's the possibility of coordinating ourselves at home on these kinds of issues? These are political, economic issues, and yet I feel they would have tremendous impact on everything we have discussed in this conference. Perhaps we can't solve it, but I'd like the government representatives here today to take this home as a thought and perhaps ask some people higher up in their offices as to how we can go about coordinating our activities overseas so that we don't run into conflict with each other and create problems entirely aside from the problems that normally exist in the lesser developed countries.

* * * * * * *

In closing the conference, the moderator, Bill L. Long, reviewed the original objectives of the meeting, concluding that the major objectives had been achieved. He then thanked the participants for their hard work which contributed to a more complete understanding of the issues and problems.

The first step in the followup process would be publication of a conference Proceedings, *which would contain specific recommendations covering all general areas under discussion.*

Mr. Long noted that responsibility for reviewing the recommendations for possible implementation was now with the conference organizers (the Department of State and the Agency for International Development) and the other sponsoring agencies. He then expressed his hope that private sector participants will continue to advise the government on these important natural resource management issues.

VI. Conference Participants

Dr. William Anderson
National Park Service
1100 Ohio Dr. SW
Washington, D.C. 20240

Mr. Irvin Asher
Deputy Science Advisor to Administrator
Room 5758
Agency for International Development
Washington, D.C. 20523

Dr. Peter Ashton
Arnold Arboretum
125 Arborway
Jamaica Plain, MA 02130

Dr. Edward S. Ayensu
Office of Biological Conservation
National Museum of Natural History
Room W501—MRC 166
Smithsonian Institution
Washington, D.C. 20560

Dr. Barbara Bachmann
Department of Human Genetics
Yale University School of Medicine
New Haven, CT 06510

Dr. Gerald O. Barney
1730 North Lynn St., Suite 400
Arlington, VA 22209

Dr. John Belshé
Army Corps of Engineers
7113 Pulaski Bldg.
20 Massachusetts Avenue NW
Washington, D.C. 20314

Dr. Anson R. Bertrand
Director, Science and Education
Room 217W, Administration Bldg.
U.S. Department of Agriculture
Washington, D.C. 20250

Dr. John Bouwkamp
Department of Horticulture
University of Maryland
College Park, MD 20742

Ms. Susan M. Braatz
Bureau of Oceans and International Environmental and Scientific Affairs
OES/ENR, Room 7819
U.S. Department of State
Washington, D.C. 20520

Dr. Nyle C. Brady
Senior Assistant Administrator for Science and Technology
Agency for International Development
Washington, D.C. 20523

Dr. Jean Brenchley
Genex Laboratories
12300 Washington Avenue
Rockville, MD 20852

Dr. John Brooks
Division of Environmental Biology
National Science Foundation
1800 G Street, NW
Washington, D.C. 20550

Dr. Gardner M. Brown, Jr.
Director, Institute of Economic Research
Department of Economics
University of Washington
Seattle, WA 98195

Mr. Noel J. Brown
Director, New York Liaison Office
United Nations Environment Programme
United Nations, Room A3618
New York, NY 10017

Dr. William L. Brown
Pioneer Hi-Bred International
1206 Mulberry Street
DesMoines, IA 50308

Dr. William Y. Brown
Environmental Defense Fund
1525 18th Street NW
Washington, D.C. 20036

Dr. Stephen B. Brush
Anthropological and Linguistical Services
National Science Foundation
1800 G Street NW
Washington, D.C. 20550

Dr. Peter Brussard
Section of Ecology and Systematics
Langmuir Lab
Cornell University
Ithaca, NY 14853

Mr. James L. Buckley
Under Secretary for Security Assistance, Science and Technology
U.S. Department of State
Washington, D.C. 20520

Mr. F. William Burley
Director, Science and International Natural Heritage Program
The Nature Conservancy
4 East Loudoun Street
Leesburg, VA 22075

Dr. Russell Burns
Timber Management Research
U.S. Department of Agriculture
P.O. Box 2417
Washington, D.C. 20013

Mr. John Bushman
Environmental Resources Branch
Army Corps of Engineers
DAEN-CWP-V, 7133 Pulaski Bldg.
20 Massachusetts Ave. NW
Washington, D.C. 20314

Dr. Bees Butler
Department of Agricultural Economics
University of Wisconsin at Madison
905 University Ave.
Madison, WI 53706

Dr. Faith Campbell
Natural Resources Defense Council
1725 I St. NW
Washington, D.C. 20006

Dr. Archie Carr, III
Assistant Director of the Animal Research and Conservation Center
New York Zoological Society
185 St. and Southern Blvd.
Bronx, NY 10460

Dr. Eloise E. Clark
Assistant Director, Biological, Behavioral and Social Sciences
National Science Foundation
1800 G St., NW
Washington, D.C. 20550

Dr. Estel Cobb
U.S. Department of Agriculture
USDA/CSPS
Room 6437, South Bldg.
Washington, D.C. 20250

Dr. Daniel M. Cohen
Northwest and Alaska Fisheries Center
NMFS/NOAA
2725 Montlake Blvd. East
Seattle, WA 98112

Dr. Rita R. Colwell
Department of Microbiology
University of Maryland
College Park, MD 20742

Dr. John Corliss
Department of Zoology
University of Maryland
College Park, MD 20742

Mr. James W. Corson
Man and the Biosphere Program
U.S. Department of State
IO/UCS, SA-5, Room 410
Washington, D.C. 20520

Mr. John Crawford
Bureau of Land Management
Division of Wildlife, Room 2649
Department of the Interior
Washington, D.C. 20240

Dr. John L. Creech
14 Legendary Road
Hendersonville, NC 28739

Dr. Byrd Curtis
CIMMYT
Londres 40
Apartado Postal 6-641
Mexico 6 D.F., Mexico

Dr. Kenneth Dahlberg
Department of Political Science
Western Michigan University
Kalamazoo, MI 49008

Dr. Herbert Dessauer
Department of Biochemistry
Louisiana State University
14542 Tulane Avenue
New Orleans, LA 70112

Dr. William M. Dowler
Director, Plant Disease Research Lab
U.S. Department of Agriculture
P.O. Box 1209
Frederick, MD 21701

Dr. Jerry Downhower
Division of Environmental Biology
National Science Foundation
1800 G Street NW
Washington, D.C. 20550

Dr. Nicole Duplaix
TRAFFIC
1601 Connecticut Ave. NW
Washington, D.C. 20009

Mr. William Durfey
National Association of Animal Breeders
Box 1033
Columbia, MO 65201

Dr. Stephen Edwards
Executive Director, Association of Systematics Collections
ASC Museum of Natural History
University of Kansas
Lawrence, KS 66045

Dr. Lloyd Frederick
Agency for International Development
SA-18, Room 420
Washington, D.C. 20523

Mr. George Furness
Bureau of Oceans and International Environmental and Scientific Affairs
OES/ENR, Room 7819
U.S. Department of State
Washington, D.C. 20520

Dr. Carl Gallegos
International Paper
P.O. Box 2328
Mobile, AL 36652

Dr. Alfred Gardner
Wildlife Research Center
Fish and Wildlife Service
Department of the Interior
Washington, D.C. 20240

Mr. Thomas Garrett
Deputy U.S. Whaling Commissioner
616 C Street SE
Washington, D.C. 20003

Dr. George Gee
Patuxent Wildlife Research Center
Laurel, MD 20708

Dr. Roger J. Gerrits
U.S. Department of Agriculture
Division of Livestock and Veterinary Sciences
Bldg. 005, Room 209
BARC West
Beltsville, MD 20705

Dr. Robert L. Gherna
Head, Bacteriology Department
American Type Culture Collection
12301 Parklawn Drive
Rockville, MD 20852

Mr. Vernon C. Gilbert, Jr.
2017 Chadds Ford Dr.
Reston, VA 22091

Dr. William Gregg
Office of Science and Technology
National Park Service
Department of the Interior
Washington, D.C. 20240

Dr. Keith Gregory
Meat Animal Research Center
U.S. Department of Agriculture
Clay Center, NE 68933

Dr. Clarence Grogan
Office of Cooperative Research
SEA/CSRS, Room 6017 South Bldg.
U.S. Department of Agriculture
Washington, D.C. 20250

Ms. Carole A. Grunberg
Subcommittee on Human Rights
and International Organizations
Committee on Foreign Affairs
Room 703, House Annex 1
U.S. House of Representatives
Washington, D.C. 20515

Dr. Phillip Harriman
Office of Biological, Behavioral
and Social Sciences
National Science Foundation
1800 G Street NW
Washington, D.C. 20550

Dr. Wm. Franklin Harris
Deputy Director, Division of
Environmental Biology
National Science Foundation
1800 G Street NW
Washington, D.C. 20550

Dr. Gilbert Hersh
Laboratory for Information
Science in Agriculture
Colorado State University
Fort Collins, CO 80523

Dr. James Hester
President, New York Botanical
Gardens
Watson Bldg.
Bronx, NY 10458

Mr. James Hester
Bureau of African Affairs
AFR/DR/SDP, Room 2484 NS
Agency for International
Development
Washington, D.C. 20523

Mr. A. Alan Hill
Chairman, Council on
Environmental Quality
722 Jackson Place NW
Washington, D.C. 20006

Ms. Maureen Hinkle
National Audubon Society
645 Pennsylvania Ave. SE
Washington, D.C. 20003

Dr. Robert Hoage
Special Assistant to the
Director
Education Bldg.
National Zoological Park
Washington, D.C. 20008

Dr. Robert Hodson
Department of Microbiology
University of Georgia
Athens, GA 30602

Dr. Riley Housewright
Executive Director, American
Society for Microbiology
1913 I Street NW
Washington, D.C. 20006

Dr. Clarence Idyll
NACOA
3000 Whitehaven St. NW
Page Bldg. I, Room 438
Washington, D.C. 20235

Dr. Clive James
Deputy Director General for
Research
CIMMYT
Londres 40
Apartado Postal 6–641
Mexico 6 D.F., Mexico

Dr. Quentin Jones
National Program Staff
USDA/SEA
BARC West, Bldg. 005
U.S. Department of Agriculture
Beltsville, MD 20705

Dr. Peter L. Joseph
USDA-APHIS-VS
Biological Licensing Staff
U.S. Department of Agriculture
6505 Belcrest Rd.
Hyattsville, MD 20782

Dr. David Kafton
Director, National Council of Gene
Resources
2855 Telegraph Avenue, Suite 216
Berkeley, CA 94704

Ms. Cathy Kennard
Council on Environmental Quality
722 Jackson Place NW
Washington, D.C. 20006

Dr. Harold H. Keyser
Cell Culture and Nitrogen Fixation
Lab
U.S. Department of Agriculture
Beltsville, MD 20705

Dr. T. N. Khoshoo
Director, National Botanical
Research Institute
Lucknow–226001
India

Dr. Charles A. Kiddy
BARC West
Room 208, Bldg. 005
U.S. Department of Agriculture
Beltsville, MD 20705

Dr. Harold Kincaid
National Fisheries Center
Experimental Hatchery
Route 3, Box 4DF
Kearneysville, WV 25430

Dr. William Klesch
Environmental Group
U.S. Army Corps of Engineers
20 Massachusetts Ave. NW
Washington, D.C. 20314

Dr. Micah Krichevsky
ASM Committee on Culture
Collections
Building 31, Room 3B04, NIH
National Institute of Dental
Research
Bethesda, MD 20205

Dr. Stanley Krugman
U.S. Department of Agriculture
Timber Management Research
U.S. Forest Service
P.O. Box 2417
Washington, D.C. 20013

Mr. Ron Kuhlman
Chief, Resource Sciences Staff
Bureau of Land Management
Department of the Interior
Washington, D.C. 20240

Ms. Molly Kux
Agency for International
Development
ST/FNR, Room 203, SA-18
Washington, D.C. 20523

Dr. Asger F. Langlykke
Genex Corporation
16020 Industrial Drive
Gaithersburg, MD 20760

Dr. William H. Lawrence
School of Natural Resources
University of Michigan
Ann Arbor, MI 48109

Dr. Roger Lawson
Florist and Nursery Crops Lab
Northeastern Region, ARC
U.S. Department of Agriculture
Beltsville, MD 20705

Ms. Fran Lipscomb
Animal Welfare Institute
1686 34th Street NW
Washington, D.C. 20007

Mr. Stephen F. Lintner
NE/PD, Room 4709
Agency for International
Development
Washington, D.C. 20523

Dr. Harold Loden
American Seed Trade Association
1030 15th Street NW
Washington, D.C. 20005

Mr. Bill L. Long
Bureau of Oceans and
International Environmental
and Scientific Affairs
OES/ENR, Room 7819
U.S. Department of State
Washington, D.C. 20520

Dr. Thomas E. Lovejoy
Vice President, World Wildlife
Fund, Inc
1601 Connecticut Ave. NW, 8th
floor
Washington, D.C. 20009

Mr. Grenville Lucas
The Herbarium, Royal Botanical
Gardens
Kew, Richmond
Surrey TW9 3AE
England, U.K.

Dr. Judith M. Lyman
Conquest of Hunger Program
The Rockefeller Foundation
1133 Avenue of the Americas
New York, NY 10036

Mr. James Malone
Assistant Secretary for
Oceans and International
Environmental and Scientific
Affairs
Department of State
Washington, D.C. 20520

Dr. Jean Mayer
President, Tufts University
Medford, MA 02155

Dr. Peter Mazur
Biology Division
Oak Ridge National Laboratory
Oak Ridge, TN 37830

BEST AVAILABLE COPY

Dr. David McClintock
Bureau of Oceans and
International Environmental
and Scientific Affairs
OES/ENR, Room 7819
Department of State
Washington, D.C. 20520

Dr. Cyrus McKell
Vice President for Research
Native Plants Inc.
University Research Park
360 Wakara Way
Salt Lake City, UT 84108

Mr. Roger McManus
Center for Environmental
Education
1925 K St. NW
Washington, D.C. 20006

Ms. Kathleen McNamara
Asia/TR, SA-18, Room 703
Agency for International
Development
Washington, D.C. 20523

Dr. Malcolm F. McPherson
The Rockefeller Foundation
1133 Avenue of the Americas
New York, NY 10036

Dr. David Meissinger
National Pork Producers Council
P.O. Box 10383
Des Moines, IA 50306

Dr. Brinton Miller
Director, Animal Infections
Merck, Sharp and Dohme
Research Labs
P.O. Box 2000
Rahway, NJ 07065

Dr. Kenton R. Miller
School of Natural Resources
University of Michigan
Ann Arbor, MI 48109

Mr. Rob Milne
Chief, International Park Affairs
National Park Service
Washington, D.C. 20240

Dr. Russell Mittermeier
Department of Anatomical
Sciences
Health Sciences Center
State University of New York
Stonybrook, NY11794

Dr. Larry Moore
SEA/CR, USDA
Room 6440, South Bldg.
U.S. Department of Agriculture
Washington, D.C. 20250

Dr. James Murray
Policy Research Corporation
738 North Wells St.
Chicago, IL 60610

Dr. Norman Myers
P.O. Box 48197
Nairobi, Kenya

Dr. Gene Namkoong
Department of Genetics
North Carolina University
Raleigh, NC 27650

Dr. Elliott A. Norse
Center for Environmental
Education
624 9th St. NW
Washington, D.C. 20001

Ms. Margery Oldfield
Division of Biological Sciences
University of Texas at Austin
Austin, TX 78712

Dr. Paul Opler
Office of Endangered Species
U.S. Fish and Wildlife Service
Department of the Interior
Washington, D.C. 20240

Dr. Francisco J. Palacio
Director, Tinker Center
Rosenstiel School of Marine and
Atmospheric Science
University of Miami
Miami, FL 33149

Dr. Walter Parham
Food and Renewable Resources
Program
Office of Technology Assessment
U.S. Congress
Washington, D.C. 20510

Mr. Richard Parsons
Federal Wildlife Permit Office
Department of the Interior
1000 North Glebe Rd., Rm. 617
Arlington, VA 23219

Dr. Ruth Patrick
Academy of Natural Sciences
19th and the Parkway
Philadelphia, PA 19103

BEST AVAILABLE COPY

Dr. David Pimentel
Professor, Department of Entomology
Cornell University
Ithaca, NY 14850

Mr. Albert Printz
AA/PPC, Room 3245
Agency for International Development
Washington, D.C. 20523

Dr. George B. Rabb
Director, Chicago Zoological Park
3300 Golf Rd.
Brookfield, Il 60513

Dr. Peter Raven
Director, Missouri Botanical Gardens
2345 Tower Grove Avenue
St. Louis, MO 63110

Dr. G. Carlton Ray
Department of Environmental Sciences
Clark Hall
University of Virginia
Charlottesville, VA 22903

Dr. Aaron Rosenfield
Director, Oxford Laboratory
Northeast Fisheries Center
Oxford, MD 21654

Dr. Richard Saunier
Department of Regional Development, Energy and Natural Resources
Organization of American States
1889 F St. NW
Washington, D.C. 20006

Dr. Christine Schonewald-Cox
Natural Science Division
National Park Service
Washington, D.C. 20240

Mr. Stan Senner
Committee on Merchant Marine and Fisheries
Room 1334 LHOB
U.S. House of Representatives
Washington, D.C. 20515

Dr. Carl J. Sindermann
Director, Sandy Hook Laboratory
National Marine Fisheries Service
P.O. Box 428
Highlands, NJ 07732

Dr. Manual Sirvent-Ramos
Director General of Soil Protection and Improvement
Subsecretariat for Environmental Improvement
Secretariat of Health and Assistance
Government of Mexico

Mr. Robert Smith
African Wildlife Leadership Foundation
1717 Massachusetts Ave. NW
Washington, D.C. 20036

Dr. Gordon Snow
Council on Environmental Quality
722 Jackson Place NW
Washington, D.C. 20006

Dr. Michael Soulé
Director, Institute for Transcultural Studies
905 South Normandie
Los Angeles, CA 90006

Dr. Robert E. Stevenson
Director, American Type Culture Collection
12301 Parklawn Drive
Rockville, MD 20852

Mr. Skip Stiles
Office of Rep. George Brown
2342 RHOB
U.S. House of Representatives
Washington, D.C. 20515

Dr. Theodore W. Sudia
Office of Science and Technology
National Park Service, Room 3314
Department of the Interior
Washington, D.C. 20240

Mr. James Talbot
JRB Associates
8400 Westpark Dr.
McLean, VA 22102

BEST AVAILABLE COPY

Dr. Marjorie Tingle
Division of Research Resources
Building 31, Room 5B29
National Institutes of Health
Bethesda, MD 20205

Dr. Joseph Tosi
Centro Cientifico Tropical
Apartado 83870
San Jose, Costa Rica, C.A.

Dr. James C. Tyler
Program Director, Biological Research Resources Program
National Science Foundation
Washington, D.C. 20550

Dr. Fred M. Utter
NW Fisheries Center
NMFS/NOAA
2725 Montlake Blvd. E.
Seattle, WA 98112

Dr. Robert Vrijenhoek
Department of Zoology
Nelson Biological Labs
Rutgers College, Busch Campus
P.O. Box 1059
Piscataway, NJ 08854

Dr. Deane F. Weber
Cell Culture and Nitrogen Fixation Lab.
U.S. Department of Agriculture
Beltsville, MD 20705

Dr. Gary Wetterberg
Office of International Park Affairs
National Park Service
Washington, D.C. 20240

Ms. Anne Wickham
Bureau of Oceans and International Scientific and Environmental Affairs
OES/ENR, Room 7819
U.S. Department of State
Washington, D.C. 20520

Dr. Garrison Wilkes
University of Massachusetts
Harbor Campus
Boston, MA 02125

Dr. J. Trevor Williams
Executive Secretary
International Board for Plant Genetic Resources
FAO
Via delle Terme di Caracalla
00100 Rome, Italy

Mr. R. Michael Wright
Vice President, World Wildlife Fund, Inc.
1601 Connecticut Ave. NW, 8th floor
Washington, D.C. 20009

U.S. GOVERNMENT PRINTING OFFICE : 1982 O - 377-963

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