Potential Impacts of Climate Change and Adaptive Strategies for Natural Areas

William P. Gregg, Jr.
National Park Service

Abstract. Natural area managers have traditionally relied upon minimal intervention in managing natural forest ecosystems. The potential impacts of climate change are likely to require unprecedented intervention to conserve natural ecosystem processes and biological diversity. Integrated interdisciplinary research, involving natural and social sciences, and improved coordination mechanisms will be required to develop and demonstrate adaptive management response strategies. Natural areas will serve as benchmarks for assessing the condition of natural ecosystems and the effectiveness of adaptive management to maintain biological diversity under changing climate. Biogeographic areas are recommended for organizing integrated cooperative programs to develop the knowledge, skills, and attitudes to facilitate adaptive management. The role of national parks and biosphere reserves in adaptive management is emphasized.

Introduction.

During the hot summer of 1988, the greater Yellowstone area burned with an intensity probably not seen for 150 years or more. In a few weeks, an ecosystem was transformed. The effects of the fires on the Yellowstone landscape will be studied for decades and longer as the ecosystem establishes a new dynamic. No prudently cautious scientist would assert that global warming caused the Yellowstone disturbance. Yet most would agree that this is the kind of event that would be expected under global warming. Regardless of whether global change may have been involved, the Yellowstone fires helped focus world attention on global warming as a major scientific and policy issue (Greater Yellowstone Coordination Committee. 1991). The fires caused scientists and managers to think more seriously about how to prepare for managing reserved areas under the multiple stresses of rapidly changing climate.

In a recent review of the state of knowledge for responding to the

Paper presented at Conference on Forests and Global Change, convened by the American Forestry Association, Arlington, Virginia, 11-12 June 1991. (American Forestry Association, in press)

potential effects of global warming, the National Academy of Sciences concluded that adaptive management of the effects of global change on natural ecosystems and their biological diversity is problematic (National Academy of Sciences 1991). Predictions of how natural systems and individual species will respond to rapid climate change are highly speculative. The needed interdisciplinary approaches, involving the creative integration of the natural and social sciences, are beginning to receive serious attention. However, holistic models that reliably predict global change-related effects on complex natural ecosystems under different scenarios of global change are yet to be developed. Adaptive management of species, communities, and landscapes based on these models may represent humanity's most difficult challenge in responding to global warming.

Managers of national parks and most other natural area systems have traditionally relied on minimal intervention to maintain natural systems. Although this philosophy still prevails, policy and practice have responded to the need for active management to repair damage to natural systems from a growing variety of past and ongoing human influences. Fire is routinely used as a management tool to offset the adverse effects of past fire suppression on ecosystem processes and help restore the natural ecological role of fire. Aggressive exotic species, introduced by humans, are routinely controlled to reduce stress on native species. The management policies and practices relating to such types of

interventions recognize the inevitability of ecological change due to natural and anthropopogenic causes (National Park Service 1988). However, they implicitly assume that the patterns of natural variation that regulate natural systems will remain largely unchanged, at least within a human timeframe. Their goal is to restore conditions where such natural forces can operate as free as possible from human intervention. They do not take into account the possibility of rapid, significant, and directional change in such overriding ecological controls as atmospheric composition and global climate. Adaptive management of reserved areas to mitigate the pervasive effects of climate change on natural ecosystems and biota would thus require major expansions and innovations in policy and practice.

The managers of natural areas lack relevant experience for dealing with the complexity and fast pace of actions that may be needed. Limited interventions focused on such specific factors as fire and exotic species provide an insufficient basis for the complex manipulations that will be needed to address the effects of changes in climate and greenhouse gases themselves. Because natural systems are so complex, their managers face challenges that will almost certainly be greater than in intensively managed agriculture, water resources, and other systems that already incorporate climatological factors routinely in management.

The following discussion briefly reviews the reasons for concern

and factors determining the sensitivity of biological resources. The review provides a backdrop for identifying potential adaptive management responses, including the biogeographic area approach the National Park Service has undertaken to facilitate cooperation in global change research and eventual development of integrated approaches to adaptive management.

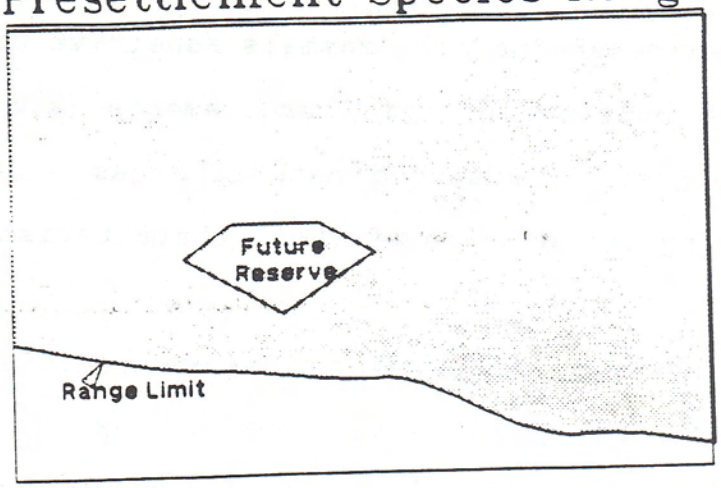
Reasons for Concern

The reasons for concern over the potential effects of climate change are well documented. Current models suggest that mean surface air temperatures have increased 0.3 to 0.6 °C during the past century and that, with no changes in present policy or rates of emissions of greenhouse gases, mean surface temperatures will increase by an additional 1 °C by the year 2025, and 3 °C by the end of the next century, with significant regional differences (Intergovernmental Panel on Climate Change 1990). By then, most natural ecosystems would be experiencing a warmer climate than at any time during at least the past 100,000 years. More significantly, the warming would occur 15 to 40 times faster than any documented recent natural changes in climate (IPCC 1991). The combined magnitude and rate of change may severely stress many natural ecosystems. Species unable to adapt or migrate to more favorable areas may become extinct, while others able to take advantage of changed conditions may experience population explosions.

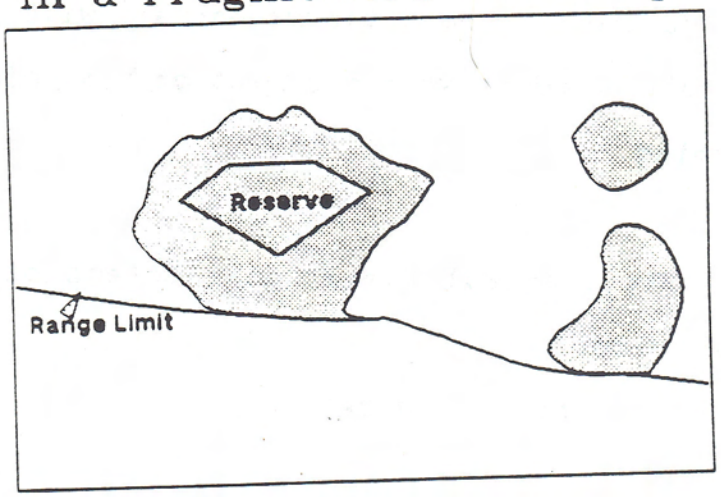
There is abundant paleoecological evidence of natural adjustments in the species distributions over many centuries in response to past climatic changes as great or greater than those currently projected. However, there is no meaningful precedent for assessing the effects of such climate change occurring rapidly over a period of just decades. Reliable estimates of climatic factors for individual regions of concern to resource managers are not yet available. Understanding and predicting the sensitivity of particular species and ecosystems to climatic variables and their interactions requires major research. Methodologies to predict lag times between the development of a given climate and changes in natural systems and species populations are needed. Additional methods are needed to predict multiple-factor effects involving climate change, carbon dioxide enrichment, increases in ultraviolet radiation, pollution, sea level rise and other components of regional and global change. Research is particularly needed to improve our understanding of the effectiveness of landscape features and regional land use patterns in enabling or preventing species migration in response to climate change. Finally, much work needs to be done to understand and assess the relationship between changes in biological, social, and economic systems that together influence the nature, magnitude, and timing of changes in the natural ecosystems and biota of particular regions (Commmittee on Earth and Environmental Sciences 1991).

The interaction of climate change and habitat fragmentation makes

Presettlement Species Range

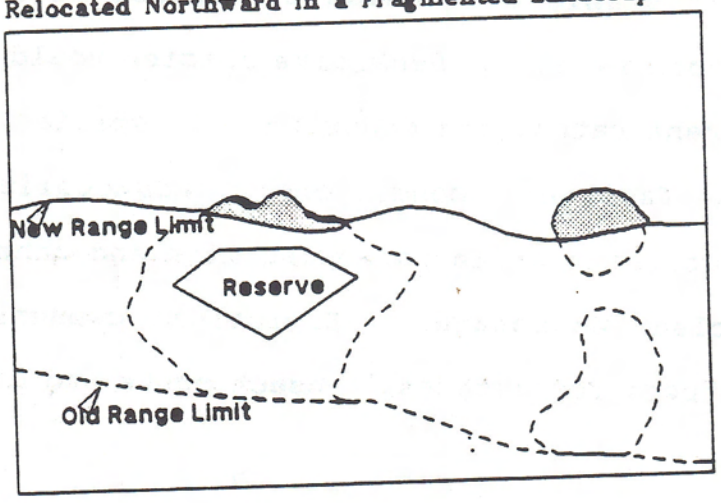


Existing Species Range In a Fragmented Landscape



Post-warming Species Range

Relocated Northward in a Fragmented Landscape



physiological requirements (e.g., reptiles with temperature-dependent sex determination, mammals sensitive to heat loads); and animals with multiple habitat requirements (e.g., amphibians and migratory birds). Reserved natural areas usually support many species having one or more of these characteristics.

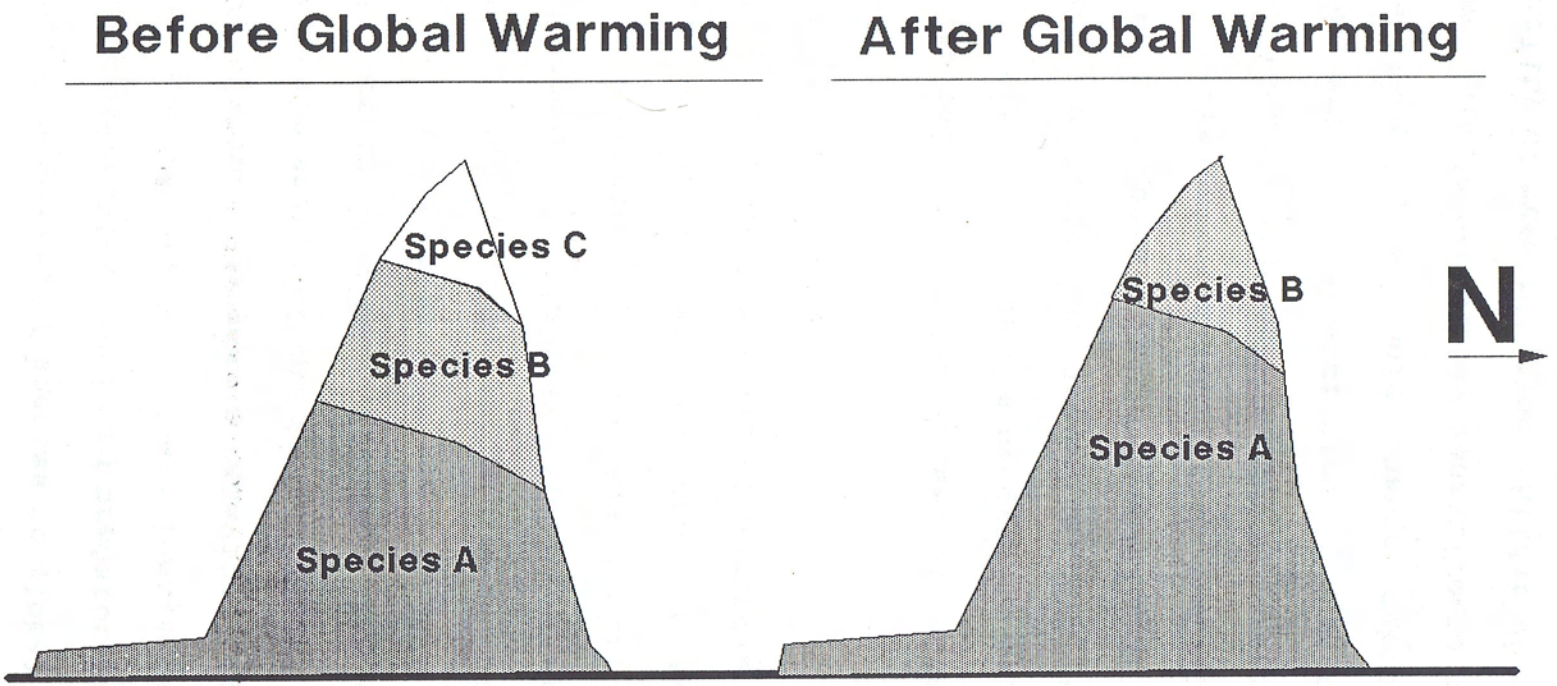
Species in mountaintop habitats may be especially at risk. If upslope migration possibilities do not exist, such species are likely to disappear (Figure 2). On the other hand, migration will be much easier to accomplish altitudinally than latitudinally. The many reserved areas in mountainous terrain will play a particularly important role in adaptive management of biological diversity under global warming.

Figure 2. Hypothetical Elevational Effect of Global Warming on Species Distributions.

(insert figure)

It is generally believed that ecological communities that have been relatively stable over human timeframes would dissociate rapidly under global warming. Sensitive species would disappear or migrate at different rates, and opportunistic species would take advantage of newly favorable conditions. Cosmopolitan species able to rapidly colonize areas following fire and other disturbances would have a clear advantage. Ecological communities would be under severe stress for decades. Insect pests and diseases, with obvious

HYPOTHETICAL ELEVATIONAL EFFECT OF GLOBAL WARMING ON SPECIES DISTRIBUTIONS



advantages in both migration and reproductive potential, could become more significant controls of ecosystem dynamics than they are today. The differential responses of species to global warming would affect ecological relationships involving predator and prey, host and parasite, plant and pollinator. These imbalances would ramify throughout the ecosystem. Changes in behavioral responses of animals would influence the status of the species themselves and their relationships with other species. For many species, the establishment of new ecological relationships would be problematic. In the absence of human intervention, extinction of the most sensitive species would appear to be an unavoidable consequence of global warming. Although individual natural areas might support more species after global warming due to invasions of cosmopolitan and opportunistic species, the total biological heritage would be impoverished.

Projected climate changes could affect human uses of natural areas and the adjacent land uses that provide the geographic context for conservation. Impaired aesthetics or biological impoverishment resulting from global warming could impair the quality of reserved areas for meditation, nature-oriented recreation and educational uses. Such changes could also affect subsistence and cultural uses of protected areas by small-scale societies. The types and seasonality of recreational uses could change substantially. Water-based recreation could be especially sensitive to changes in the amounts and seasonality of precipitation. Milder winters could

adversely affect skiing and related winter recreation; longer and warmer summers could make important tourist destinations of northern reserves that presently have low visitation. Changes in recreational demand could affect scores of tourism-based economies, and would be one of many economic factors in potentially rapid land use changes in areas surrounding reserved areas. These conversions could either reduce or increase the effective area available for conservation. Climate change could also increase public pressure for conversion of reserved areas themselves to alternative uses, especially where the resources and values for which the reserved areas were established become compromised or no longer exist.

In many regions, national parks and other reserved areas now include the last remaining examples of natural ecosystems suitable for long-term studies to detect and assess climate change effects at a variety of temporal and spatial scales (Baron 1991). The ongoing trend toward increasing scientific use of reserved areas is likely to continue.

The National Park Service's Strategy to Prepare for Global Change: a Biogeographic Area Approach

In developing a strategy for responding to global change, the National Park Service is utilizing a biogeographic area approach for detecting, understanding, predicting, and eventually addressing the effects of climate change. Our rationale involves several

considerations:

- The opportunity for coordinated studies of abiotic and biotic factors at a subregional management-relevant scale.
- The opportunity to use site-specific studies in NPS areas to improve the accuracy of local and regional models of climate change.
- Possibilities for integrating conservation biology and landscape ecology in global change research.
- The opportunity to enlist outside expertise and involve reserved areas in cooperative research on the effects of global change (Parsons 1991). Research linkages between NPS units and long-term ecological research sites, experimental forests, and similar areas in a biogeographic context can be especially encouraged.
- The opportunity to help pool interdisciplinary capabilities from many agencies and institutions in developing integrated assessments of potential effects and eventually adaptive management strategies for biological and socioeconomic systems. In particular, we foresee opportunities to integrate research on climate change with research on other natural and human influences affecting parks and surrounding areas.
- Possibilities for developing public education activities that foster awareness of global change effects and build understanding needed for implementing adaptive responses.
- Possibilities for innovative cooperation among conservation, research, and economic development interests, and local communities

in developing sustainable ecosystem uses that facilitate biological conservation under global warming.

The NPS has initiated global change research in 6 biogeographical areas (BGA): the Olympic Peninsula, the Central and Southern Sierras, the Glacier National Park Area, the Colorado Rockies, the Ozark Highlands, and the Western Lake Forest Area (greater Lake Superior region). All of the initial BGAs encompass primarily forest ecosystems. All involve one or more existing or potential NPS units of the International Network of Biosphere Reserves.

Each BGA contains at least one unit of the National Park System as a core research area, where most of the research will be conducted, and may contain one or more contributing units containing complementary resources and research capabilities for conducting particular research projects. Each BGA has a designated research coordinator and base funding for operational support of a long-term research program. The BGA program goal is to help provide predictive understanding of the effects of global change on species populations, ecological communities, watershed processes, and landscape dynamics through the coordinated use of parks as benchmark research sites within larger BGAs. Paleostudies, experimental research and modeling, and long-term monitoring are important components of the overall effort. The initial research projects emphasize particular areas of disciplinary study. However, the long-term objective is to link these studies with

future NPS and outside research to provide interdisciplinary assessments for the larger areas. The NPS plans to expand the program over several years until 20 BGA programs are operational. At maturity, these programs will include most of the nation's major ecological regions, and will facilitate development of adaptive response strategies applicable to most areas of the National Park System.

Potential Adaptive Response Strategies

Most of the recently identified options for research and adaptive management of natural ecosystems and native species (IPCC 1990, 1991; Smith and Tirpak 1989; Peters 1990) could be implemented on a BGA basis. Most rely partly or entirely on the availability of reserved areas. Most are justifiable on grounds other than climate change. Most could facilitate addressing a variety of regionally significant resource issues if combined and coordinated effectively through broadly based mechanisms involving conservation, research, and economic development sectors.

Options involving reserved areas that have significant tie-in benefits in addressing other issues include:

o Increased scientific use of reserved areas, specifically for baseline inventories and integrated biological, physical, and climatological monitoring to detect climate change effects, and for experimental research to determine the sensitivity of species and ecosystems.

o Development of integrated regional risk assessments to assess impacts and help develop regional response strategies.

o Coordination of planning for biological diversity conservation strategies and management responses to climate change.

o Development of education and information programs to assist managers and decisionmakers in assessing the risks of intervention to address the effects of climate change.

o Local community participation in global change adaptation activities that integrate the conservation of reserved areas with appropriate regional social and economic development.

o Implementation of measures to reduce encroachment of adjacent development on existing reserved areas in order to improve ecosystem resiliency to the effects of global change.

o Demonstration of improved methods for managing stressed ecosystems, including relocation of biota from increasingly unfavorable areas to areas that become newly favorable.

o Strengthening ties between reserved areas and zoos, botanical gardens, seed banks, nurseries, and other ex situ facilities to help maintain sensitive genetic resources and provide genetic material for in situ adaptive management programs.

o Anticipatory cooperative planning involving reserved areas and surrounding regions, including possibilities for boundary adjustments and relocation of protected areas, establishment of conservation corridors, and creative use of zoning, regulation, and cooperative management approaches to achieve conservation goals under potential global change scenerios.

Role of Biosphere Reserves

Effective adaptation to climate change will benefit from coordinating mechanisms that enable integration of complementary research, educational, and demonstration activities on a BGA basis. The cooperative organizations being developed through the U.S. Man and the Biosphere Program (USMAB) to facilitate the development of regional biosphere reserves appear to provide a potentially suitable framework for achieving this integration in particular biogeographic areas.

There are presently 300 biosphere reserves in 75 countries, including 47 in the United States, which collectively include 91 administrative areas. Biosphere reserves include many of the world's outstanding conservation and experimental ecological research areas, and, more recently, multiple use areas. These areas are designated internationally as biosphere reserve units, either as core areas for conservation and baseline studies, or as zones of managed use for experimental research and demonstration of sustainable types and patterns of ecosystem uses. The designated areas are increasingly serving as the hubs for organizing regional biosphere reserve programs involving conservation, research, and development interests in both government and the private sector. These programs address resource issues of regional concern cooperatively and holistically within a large open-ended zone of cooperation that typically surrounds the

designated areas (Figure 3).

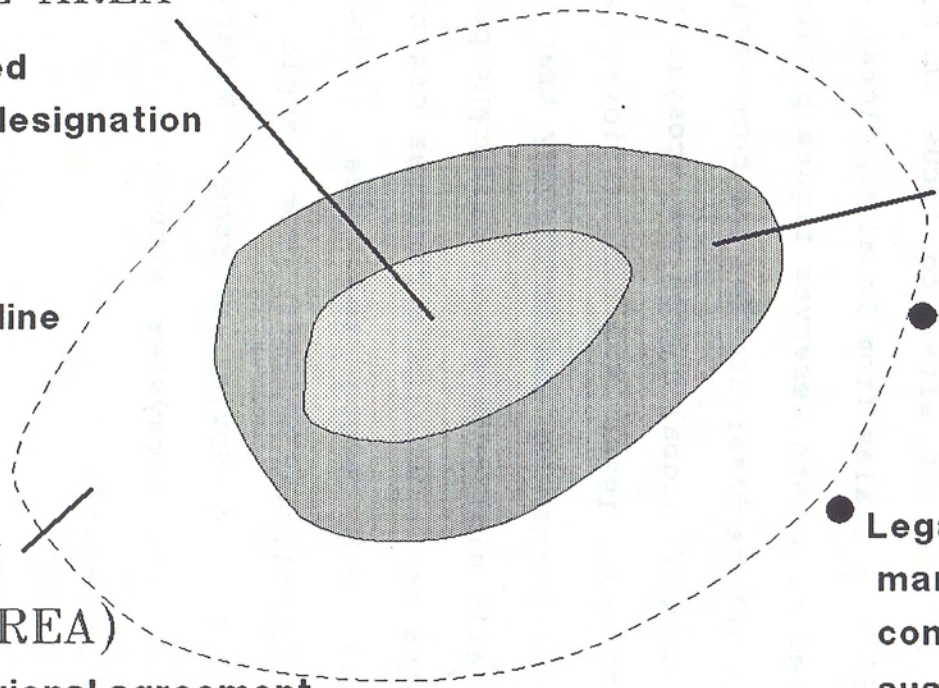
Figure 3. Conceptual Biosphere Reserve Zonation

(insert figure)

Biosphere reserves provide important possibilities for developing an integrated network of sites to focus on a broad range of scientific issues at scales from local to global (Dyer and Holland 1991). Selected biosphere reserves figure prominently in efforts to establish biosphere observatories for comparative studies of the relationships between global change and ecosystem processes (Dyer, DiCastri, and Hansen. 1988). The international network provides a framework for data sharing and technology transfer, particularly among ecologically similar areas in different parts of the world. Comparative studies in biosphere reserves can help detect global change signals and reduce the time needed for detecting statistically significant effects. For example, ongoing long-term research in U.S. and Soviet Biosphere Reserves is providing comparative data on ecosystem structure and functions using standard methodologies.

Biosphere reserves uniquely serve as "landscapes for learning" by facilitating coordination of conservation, long-term ecological research, education, and demonstration activities in particular biogeocultural regions. (U.S. MAB defines a biogeocultural region as "an area within a biogeographical province distinguishable on

CONCEPTUAL BIOSPHERE RESERVE ZONATION



CORE AREA

- Always recognized by international designation
- Strictly protected natural areas
- Emphasis on baseline monitoring

ZONE OF MANAGED USE

- Nearly always recognized by international designation
- Legally delineated areas managed for ecosystem conservation and sustainable resource uses
- Emphasis on monitoring, experimental research and demonstration in managed systems

ZONE OF COOPERATION (TRANSITION AREA)

- Recognized by regional agreement
- Supports regionally characteristic resource uses
- Emphasis on cooperative programs to address resource issues and achieve ecosystem sustainability in a biogeocultural area

the basis of some combination of physiography, climate, vegetation, characteristic species, natural processes, human populations and characteristic resource uses. [U.S. Man and the Biosphere Program 1989]). They can play key roles in developing predictive understanding and adaptive responses to climate change at biologically, managerially, and institutionally relevant scales.

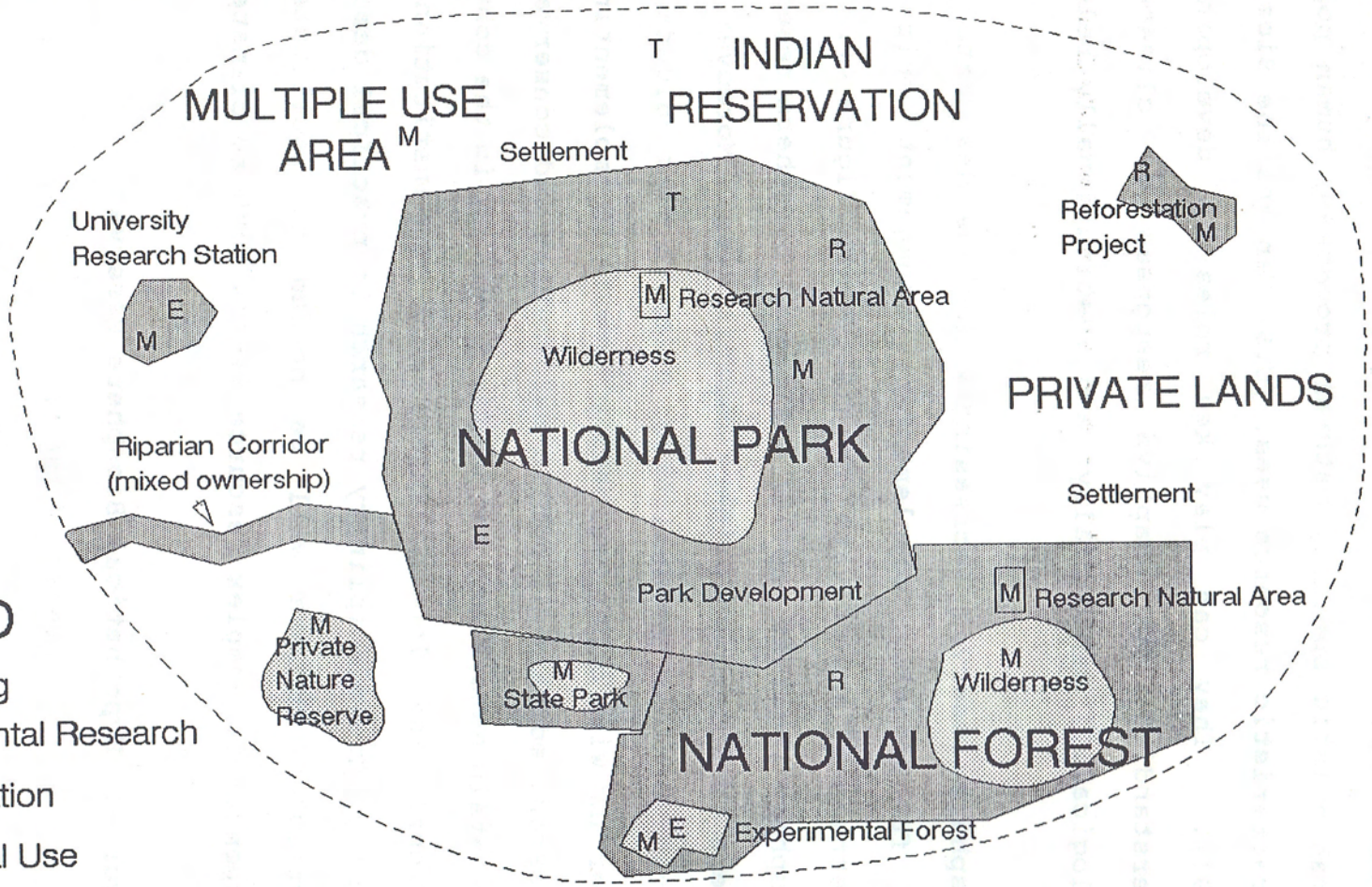
Biosphere reserves increasingly include designated ecologically and functionally complementary management units under both governmental and private administration (Figure 4). Such regional biosphere reserves provide designated biosphere reserve units with access to interdisciplinary capabilities. Moreover, they provide a framework for the designated units to work voluntarily with each other and with other regional interests in implementing cooperative research, education, public information and conservation programs to sustain ecosystems and biotic diversity in the context of local, regional, and global change. Such new institutional models for linking interdisciplinary research to practical demonstrations in particular regions will be needed to facilitate coordinated responses to complex resource issues such as climate change.

Figure 4. Hypothetical Biosphere Reserve

(insert figure)

The first regional biosphere reserve institution in the United States was organized in 1989 in the Southern Appalachians (Figure

HYPOTHETICAL BIOSPHERE RESERVE



LEGEND

- M Monitoring
- E Experimental Research
- R Rehabilitation
- T Traditional Use

CORE AREA | ZONE OF MANAGED USE | ZONE OF COOPERATION

5), and presently consists of an eight agency Cooperative and a non-profit foundation that cooperate in implementing projects. A secretariat is cofunded by the participants to help plan and implement cooperative programs. Six interinstitutional committees are operational to coordinate projects in environmental education and training, research and monitoring, resource management, cultural resources, economic development, and public affairs. Improving regional coordination of global change programs is an important program emphasis. Regional biosphere reserve programs are being organized in the Adirondack-Champlain Region, the Central California Coast, the Mammoth Cave Area, The Land-Between-the-Lakes Area, and are being discussed in many other areas.

Figure 5. Organization of the Southern Appalachian Man and the Biosphere Cooperative.

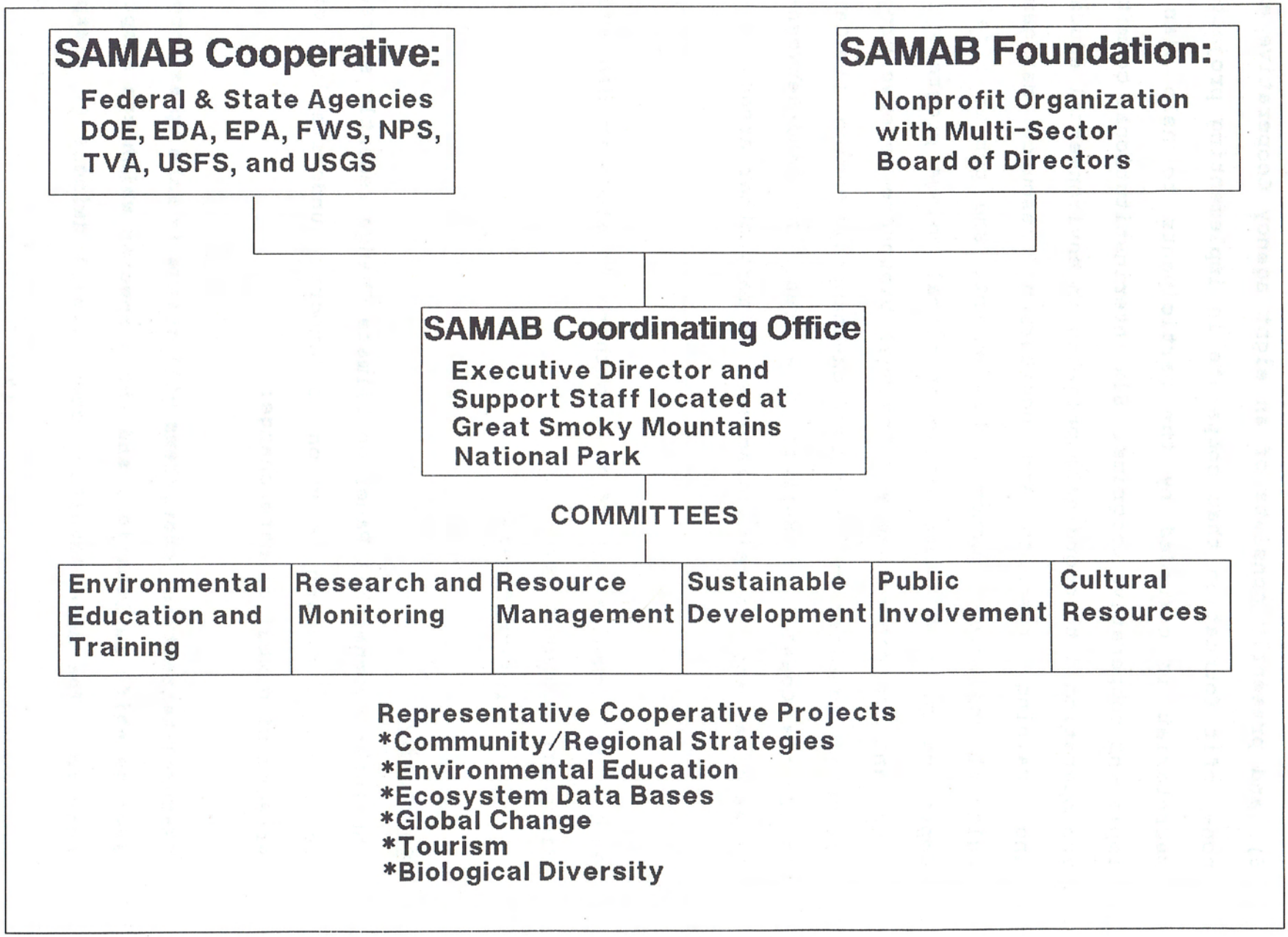
(insert figure)

Conclusion

The Intergovernmental Panel on Climate Change recently stated the following conclusion based on contemporary understanding of the effects of global climate change:

"Natural terrestrial ecosystems will change in make up as composite species shift in location, and those species which can adapt will survive. The more sensitive ones....will dwindle or disappear.

Southern Appalachian Man and the Biosphere Program Organization



The best solutions to the ecological upheaval resulting from climate change are not yet clear. What is clear, however, is that these climatological changes would have tremendous impact on communities and species isolated by development and by the middle of the next century may dwarf any other consideration." (IPCC 1990)

The effective conservation of natural ecosystems and native species may well be the ultimate barometer of the success of efforts to develop integrated approaches to manage the risks associated with global change. Within the next few decades, commitments on use and management of most of the earth's remaining undeveloped terrestrial areas will be made. Actions taken during the next decade will largely determine whether, and where, holistic approaches for managing landscapes to conserve biological diversity will be possible if and when global change becomes a significant management concern.

Most reserved areas are at risk of becoming ecologically and genetically isolated from their surrounding areas by the time the effects of global warming require urgent management action. The trend toward habitat fragmentation and isolation of reserved areas will intensify as human communities struggle to deal with the environmental, social, and economic effects of climate change. Reserved areas could fare poorly under such pressures unless significant efforts are made now to involve these areas in developing predictive understanding of the effects of climate

change and practical approaches for managing dynamic landscapes for sustainable uses, including the conservation of biological diversity.

The expanding application of ecological principles in landscape management provides cause for optimism that the philosophy of integrated landscape management will be well established, and the practices sufficiently well developed soon enough to provide enough lead time for adaptive management of global change effects to be successfully implemented.

Biogeographic areas may provide the most suitable framework for improving the communication among conservation, research, educational and economic interests that will be required to address the interrelated effects of global change and other resource issues. They provide a basis for implementing long-term case studies to develop and demonstrate adaptive management strategies at ecologically, culturally, and managerially relevant scales. These applications can then be applied in the larger surrounding regions, and considered in similar regions in other parts of the world. Biosphere reserves uniquely recognize the conservation and scientific value of certain biogeographic (or, more specifically, biogeocultural) areas in developing and demonstrating these applications. They uniquely raise interdisciplinary cooperation to the level of international principle, while providing a practical framework for organizing and

implementing cooperative programs to demonstrate the benefits of cooperation in particular biogeocultural regions. Their potential value as standardbearers in efforts to develop adaptive management strategies for global change in landscapes containing outstanding natural areas deserves full consideration.

Literature Cited

Baron, J. 1991. Addressing global change from a global perspective. George Wright Forum 7(3):37-40.

Committee on Earth and Environmental Sciences. 1990. Our Changing Planet: The FY 1991 Research Plan. U.S. Government Printing Office, Washington, DC. 62-74p.

Dyer, M.I., F. diCastri, and A.J. Hansen -eds. 1988. Geosphere-biosphere observatories: their definition and design for studying global change. Biology International, Special Issue No.16. 39p.

Dyer, M.I., and M.M. Holland. 1991. The Biosphere reserve concept: needs for a network design. BioScience 41(5):319-325

Intergovernmental Panel on Climate Change. 1991. Climate change: the IPCC response strategies. Island Press, Washington, DC. 272p.

Intergovernmental Panel on Climate Change. 1990. Climate change: the IPCC impacts assessment. Australian Government Publishing Service, Canberra, Australia.

National Academy of Sciences. April 1991. Policy implications of greenhouse warming. National Academy Press, Washington, DC.

U.S. Department of Interior, National Park Service. 1988. Management Policies. U.S. Government Printing Office, Washington, DC. 4:5-14

Parsons, David J. 1991. Global change: an opportunity for the 1990s. George Wright Forum 7(3):40-42

Peters, R., ed. In press. Proceedings of the Conference on the Consequences of the Greeenhouse Effect for Biological Diversity. Yale University Press, New Haven.

Peters, R.L. and J.D.S. Darling. 1985. The greenhouse effect and nature reserves. BioScience 35:707-717

Smith, J. B., and D. Tirpak, eds. 1989. The Potential Effects of Global Climate Change on the United States: Report to Congress. U.S. Environmental Protection Agency; U.S. Government Printing Office, Washington, DC.

UNESCO. 1984. Action plan for biosphere reserves. Nature and Resources 20(4):1-12

U.S. Man and the Biosphere Program. 1989. Guidelines for the selection and coordination of biosphere reserves in the United States (draft). U.S.MAB, Project Directorate on Biosphere Reserves. 33p.

Greater Yellowstone Coordinating Committee. 1990. The Greater Yellowstone postfire assessment of research needs. Greater Yellowstone Coordinating Committee. National Park Service and USDA Forest Service. 103p.