Preserves: Federally Protected Natural Areas

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Status

- Represent and protect the best of the Nation's natural heritage.
- Repository for the Nation's rarest species and for conserving biodiversity.
- Threatened by human activity.

The Climate Change Problem

- A shifting climate ''map' over protected areas with fixed boundaries.

What Is Most Vulnerable?

- **Areas that are small,** isolated, fragmented, under other stress.
- Areas containing climate-sensitive species or ecosystems.
- Some biodiversity loss likely.

Impediments

- Many levels of institutional and landscape fragmentation.
- Lack of knowledge.

Types of Responses

- Ideal responses (if we had the information): 1) maintain species and/or ecosystems "in place"; 2) help them move.
- Realistic responses (given gaps in our knowledge): 1) acquire needed information (basic research, inventorying, monitoring); 2) manage the areas to minimize impediments to adaptation and to increase resiliency of natural areas (through direct Federal action, indirect Federal action, partnerships).

OVERVIEW

Setting aside large areas of land to protect their natural qualities and processes has become a central strategy in preserving the American heritage. As long ago as the early 1800s, prominent American writers and artists envisioned the preservation of parts of the wild, undeveloped frontier and voiced their concern about the destructive effects of western expansion. The establishment of Yellowstone National Park in 1872 marked the beginning of putting these ideals into practice (157). Since then, the Federal Government has established several systems of reserved lands (e.g., the National Parks, the National Wilderness Preservation System, and National Wildlife Refuges) and special management agencies (e.g., the National Park Service and the Fish and Wildlife Service) to administer and protect valued resources (see box 5-A).[1] Federally protected natural areas have become a repository for the Nation's rarest species and for conserving biological diversity. Over 240 million acres (97 million hectares)[2] are now held by the Federal Government specifically to ensure the protection of wildlife, aesthetic beauty, or other natural attributes for the enjoyment of future generations. Nearly $3 billion is spent annually to manage, maintain, restore, and protect these lands. Climate change may threaten this substantial national investment in protecting natural areas.

Projected rates of climate change are faster than any that have occurred on a global scale over the past 10,000 years-since the last ice age (57). Climate regimes could shift dramatically.[3] Whether plants and animals accustomed to a particular climate regime will be able to adjust to climate change is uncertain (see ch. 2). The opportunities for species to respond by migrating or adapting may be limited; species in small, isolated, fragmented areas may be particularly at risk. The climate "map" that has helped shape the distinctive vegetation and wildlife of many reserves will shift, while the boundaries of the protected areas remain freed. Some reserves may be ''left behind," incapable of providing the benefits or serving the functions for which they were originally established, such as providing protection for rare species or supporting wildlife-related recreation (see fig. 5-l). It may become too costly or impossible to protect certain species. To protect other plant and animal species, land-management agencies might find it necessary to undertake increasingly aggressive approaches to management (see box 5-B).

To compound the problems, many natural areas have already become threatened by forces within and outside their boundaries. Population growth has led to development pressures, growing visitor use, and increased geographic fragmentation of natural areas. Institutional fragmentation, with the management structure governing Federal lands dispersed across several agencies and having no unifying goal, has in some cases also compromised preservation efforts. Boundaries of protected areas are somewhat artificially fixed, with many surrounded by actively managed or developed lands. With growing fragmentation, it will be increasingly difficult for natural areas to adapt to the stresses of climate change.

Given the vast amount of uncertainty surrounding climate change and natural area responses, the most sensible ways to prepare for climate change in federally protected natural areas today are to: 1) improve information gathering, and 2) enhance protection of federally protected areas and their resources.

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[1] The National Wilderness Preservation System is administered by four Federal agencies: the U.S. Department of Agriculture's Forest Service and the Department of the Interior's Bureau of Land Management, National Park Service, and Fish and Wildlife Service.

[2] To convert acres to hectares, multiply by 0.405.

[3] A warming of 5.4 "F (3 "C) over the next century would shift climatic regimes perhaps 200 to 300 miles (300 to 500 kilometers) northward or 1,600 feet (500 meters) in elevation (58, 96, 172).

Box 5A-Climate Change and Management Philosophies for Natural Area Management

National Park System-Recent National Park Service (NPS) policies state that managers should seek to "maintain all the components and processes of natural evolving ecosystems, including the natural abundance, diversity, and ecological integrity of the plants and animals" (151). Although "change is recognized as an integral component of the functioning of natural ecosystems," NPS policies regarding wildlife and plant protection are based on the assumption that climate is relatively static or at least slow to change. The changes currently protected under NPS policies imply "natural," including evolutionary, changes--not necessarily the rapid changes predicted for human-induced climate change. Stated policies may encourage resisting migration and other adaptive responses and maintaining only the existing species that now occur inside National Park boundaries. This goal may be difficult to attain under climate change as wildlife and plants attempt to migrate. On the other hand, if human-induced climate change is seen as a natural phenomenon, management of National Parks may tend to accommodate species shifts.

National Wildlife Refuge System--Climate change may pose a problem for refuge management because efforts to protect waterfowl and other species may require even more intensive and costly management than they do today. The ability to protect species maybe greater for National Wildlife Refuges than for National Parks because more intensive manipulation of habitat is allowed. Most refuges were established to protect waterfowl habitat, flyways, and breeding grounds (6, 125), which explains why roughly one-third of wildlife refuges are wetlands. Furthermore, refuge habitat and wildlife are often manipulated to meet production targets, such as waterfowl population quotas (6, 144). Over 30 refuges were established to protect threatened and endangered species, and their management is designed to protect those species--not necessarily to maintain the naturalness of the area (144). Recent additions to the system, such as those added under the Alaska National Interest Lands Conservation Act (P.L. 96-467), seek to "conserve fish and wildlife populations and habitats in their natural diversity," signaling a more hands-off approach to management (6). In addition, the Fish and Wildlife Service is currently reviewing the management philosophy for the entire System, and is advocating more emphasis on multispecies and ecosystem-level management (1 51).[1]

National Wilderness Preservation System-For most wilderness areas today, changes that occur as a result of human-induced climate change maybe consistent with maintaining the "wilderness character" of the area if climate change is perceived as a natural phenomenon. However, allowing those changes may prevent wilderness areas from offering high quality habitat or protection for rare or endangered species. Under the Wilderness Act (P.L. 66-577), all agencies that administer Wilderness Areas are directed to "preserve the wilderness character" of the area for future generations. Generally, a "hands-off" approach to management is followed when possible, and natural processes are allowed to govern with minimal human interference. Extreme threats of fire, insects, or disease can be controlled by using the "minimum tool necessary" to accomplish the task-as defined by the courts-so that wilderness values are minimally damaged (129, 139). If climate change is perceived as a human-caused disruption of natural processes, it is not dear how management would change. Changes in wilderness areas caused by human-induced climate change maybe interpreted as changes in the wilderness character of the area. If so, more active management to minimize these changes might be justified.

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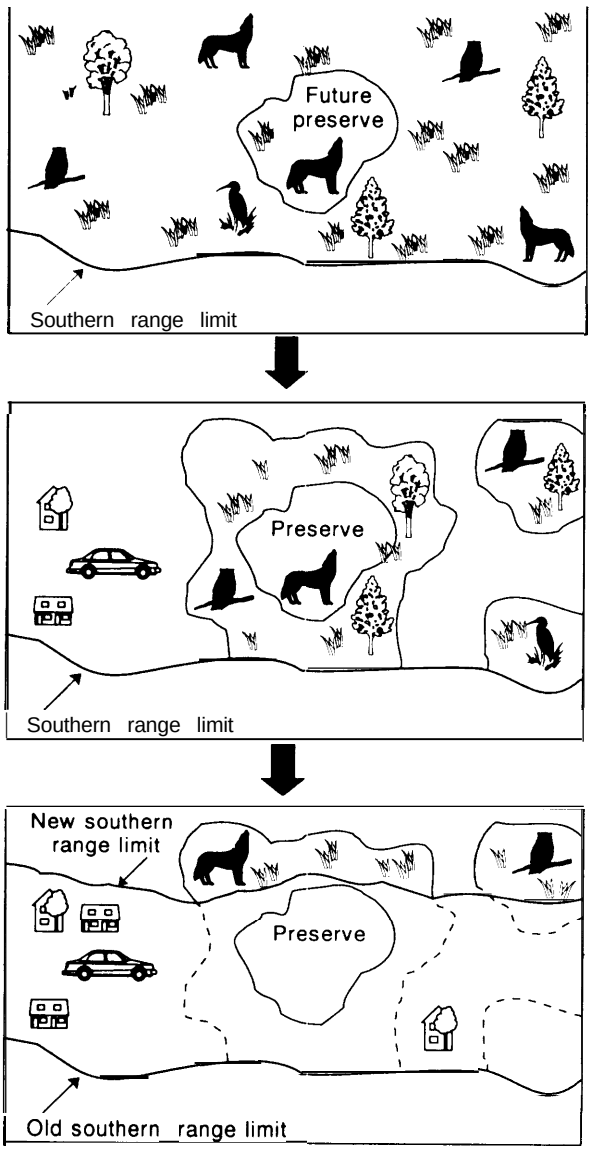
1 **Because** no law mandates an overarching direction for the Refuge System, this new management philosophy may conflict with the legislatlve objectivesforwhich an individual refuge was established and, if so, would become subordinate to those objectives.

SOURCE: Office of Technology Assessment, 1993.

Figure 5-l-Preserves and Climate Change



NOTE: As climate regimes change, species may migrate, decline, or become extinct, leaving preserves dramatically changed. Migrating species may find it difficult to find new habitat and may no longer be protected.

SOURCE: Office of Technology Assessment, 1993,

Additional research and monitoring are essential for informed decisionmaking about natural areas in a changing climate. Information is needed to help direct efforts in the acquisition of natural areas, to determine the sensitivity of species to climate, to restore damaged natural areas to ecological productivity, and to anticipate and respond to environmental hazards (85). To even identify the effects of a changing climate, baseline data on current ecosystem structure and functions are needed.

Enhancing the protection of federally protected areas that makes them more resilient to climate change and more able to confront existing stresses can be achieved in numerous ways. Direct Federal mechanisms, such as acquisition programs and agency management could be tailored to better protect natural areas by enlarging or joining existing areas, for example. Indirect Federal actions, including the suite of incentive and cost-sharing programs for private land management, could also be tailored to help buffer and protect natural areas. Partnerships among Federal, State, local, and tribal governments as well as private organizations and interest groups could be more aggressively pursued as a way to augment Federal natural area protection efforts.

Increasingly, land managers and scientists are calling for a more holistic approach to land management that is based on ecosystem, topographic, or watershed boundaries. For example, in 1992, the Forest Service and the Bureau of Land Management (BLM) announced policies that would place greater emphasis on total ecosystem management. Although this new approach is not yet well-defined, it is generally understood to include planning that transcends ownership boundaries and that requires active cooperation between multiple agencies, governments, and interest groups. Some see this new approach as the beginning of a fundamental change in the way the Nation protects its resources and, to the extent that landscape and institutional fragmentation are reduced, an effective approach to helping some protected areas adapt to climate change (13, 75, 96).

Box 5-B-The Strategic Dilemma for Protecting Natural Areas Under Climate Change

To minimize loss of the investment in natural areas and their resources, Federal agendas may ultimately need to change their management approach to one that runs counter to currently prevailing approaches. Because climate change may tend to change the composition of animals and vegetation in natural areas, management policies that seek to protect the status quo at any cost as well as those that allow unlimited change will be called into question. The "moving map" imposed by climate change will make each type of management scheme more difficult to implement- Current philosophies are based on a relatively constant mean climate. Climate change will shift this mean climate with year-to-year weather variations. Climate change will shift this mean. Subsequent changes in natural resources and processes might not be easily addressed under management strategies that are based on the assumption of a relatively static climate.

Areas valued for their ecological processes may require more manipulation and intensive management to save valued resources. Agencies may have to develop contingency plans to facilitate change in management direction when necessary. Three very general approaches to natural area protection are possible under climate change: 1) maintain existing species composition, 2) maintain some species in place and allow change for others, and 3) allow climate change impacts to occur.

Strategy 1: Maximize efforts to preserve current species composition-No management scheme governing Federal protected natural areas fully embraces this philosophy, although management of the National Park System in the 1960s advocated this approach. NPS policies were influenced by the 1963 Leopold Report, which suggested that the overriding goal for National Park management should be to preserve "pre-settlement" pristine conditions (88, 172). Hence, management policies favored protection of species historically living in the park and directed active restoration of areas damnaged by''post-settlement" activities. Although emphasis is still on maintaining the historical mix of species in National Parks, most recent National Park Service (NPS) policies also seek to protect evolutionary change and shifting natural processes. The overall goal is to maintain a healthy ecosystem.

Maintaining the status quo may be important for protecting rare species and communities and for maintaining biodiversity now. However, climate changes of the rate and magnitude predicted by scientists could cause changes in vegetation and species mixes that would make maintaining historical communities increasingly difficult and costly. Such preservation efforts may run counter to natural processes that are pushing for ecosystem change. Because of new developments in the scientific understanding of ecological communities, this strategy is currently being questioned even without considerations of climate change (88, 104).

To implement this strategy under climate change, more hands-on, intensive management will be required to stave off nonnative or opportunistic species invasions, fight unnatural pests and disease, and possibly prevent fires. Given the Nation's experience with protecting endangered species, the costs of preserving entire ecosystems by similar "brute force" will likely become prohibitive. Thresholds might have to be set to determine when to terminate preservation efforts for some areas. To best manage resources under this strategy, research efforts should focus on understanding how communities interact with-each other, respond to stress, and adapt to change.

Strategy 2: Preserve some species in place and allow change for others--Although this is not an official management strategy for any Federal land-management agency today, it is by default the primary method of management in National Wildlife Refuges. A National Midlife Refuge is generally managed to preserve a specific community or species so management may allow change in other resources as long as the primary refuge objective is not adversely affected. In addition, areas that contain endangered species are required by the Endangered Species Act {P.L 93-205) to provide protection for these species despite other management objectives. Still, the costs of protection for even a single species can be extremely high (see box 5-Don the expenditures of endangered species recovery programs).

To implement this strategy in the future, research will be needed to identify what species should or can be protected in an evolving habitat and which species could migrate. For migrating species, corridor theory and design

(Continued on next page)

Box 5-B–The Strategic Dilemma for Protecting Natural Areas-(Continued)

techniques will need to be developed further, as will techniques for translocation of species. The current understanding of ecosystem structure and function will have to be greatly expanded Again, thresholds for when to intensify or abandon preservation efforts might have to be established to facilitate future management decisions.

Strategy 3: Allow climate change impacts to occur—This strategy represents a completely "hands-off' policy. Although it is not an official policy for natural area management, minimal human intervention with natural processes is an ideal goal advocated by the Wilderness Act (P.L. 66-577) and by some NPS policies. In practice, however, managers must intervene with natural processes to minimize damage from human activities (e.g., pollution and visitor use) and to simulate other processes (e.g., the natural fire regime).

Under this strategy, climate impacts would be seen as simply changing the composition of the landscape in a natural way. Extinctions and changing species composition would bean adaptation in and of itself. This may bean appropriate approach for areas that are not valued for a specific species or community mix and that are large enough to accommodate a wide range of natural processes. Because so little is known about how ecosystems work, this approach is favored by some experts as the best adaptive strategy for many species under climate change (13, 51, 69, 98).

However, if climate change accelerates weed, disease, and pathogen spread, a "hands-off" approach could result in serious conflicts with adjacent landowners. In addition, t his strategy offers the least active protection for rare and endangered species. Public and political pressure may lead to intervention with natural processes. To maintain the maximum amount of existing species and biodiversity while embracing this approach, new natural areas with diverse species compositions may need to be established. Given the level of fragmentation and development, especially in the East, there are few opportunities to establish new natural areas of sufficient size to sustain large ecosystems. Much more information about reserve design, size, and connectivity will be needed to effectively establish new natural areas,

SOURCE: Office of Technology Assessment, 1993.

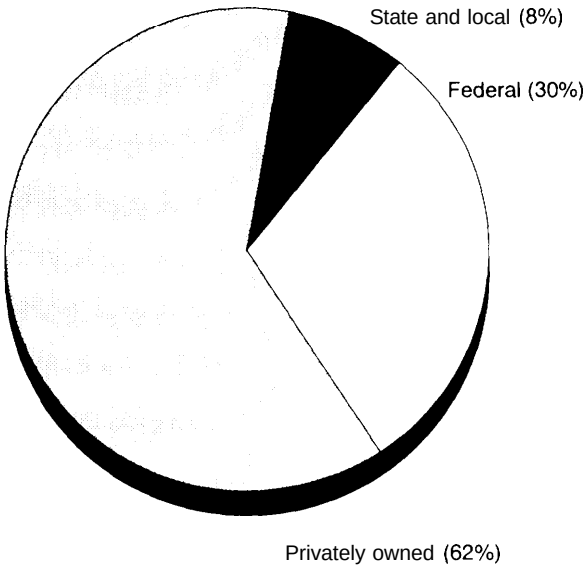
FEDERALLY PROTECTED NATURAL AREAS TODAY

• What Are Federally Protected Natural Areas?

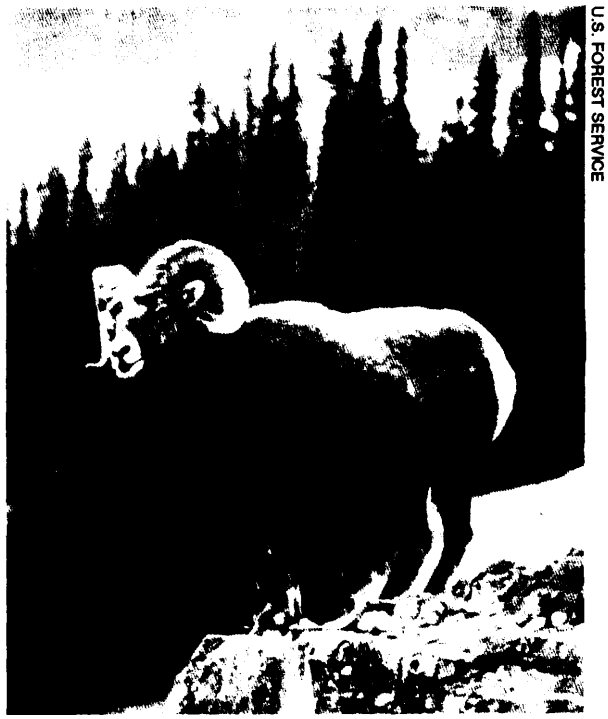
Many lands under various Federal management designations as well as substantial amounts of private- and State-owned land are more or less in a "natural' state (primarily governed by nature). In addition to conserving natural processes, these areas can provide: protection for fish and wildlife species and their habitat, a haven for endangered and threatened plant and animal species, and unique opportunities for certain kinds of recreation including wildlife watching, nature study, photography, hiking, and camping. In this sense, millions of acres of U.S. lands (including Federal, State, tribal, and private lands), some of which are as pristine as some designated Wilderness Areas, can be considered *natural areas.*

About one-third of the Nation's land base is held by the Federal Government and administered by several different agencies (see fig. 5-2). Although much of this land is essentially "natural,' its management varies. Some lands are managed explicitly to retain relatively pristine conditions by limiting human use and development and focusing on preserving the natural processes that have shaped the landscape. Examples of the lands under Federal ownership include National Parks, administered by the Department of the Interior's (DOI'S) National Park Service (NPS), and units of the National Wilderness Preservation System, administered by the U.S. Department of Agriculture's (USDA's) Forest Service, BLM, the National Park Service, and

Figure 5-2-Landownership of the U.S. Land Base



SOURCE: Congressional Research Service, 1990.


U.S. FOREST SERVICE

Bighorn sheep require large expanses of alpine habitat for survival. Wilderness areas provide sources of food and cover that they and other wide-ranging species-such as bear, caribou, and coyote--rely on.

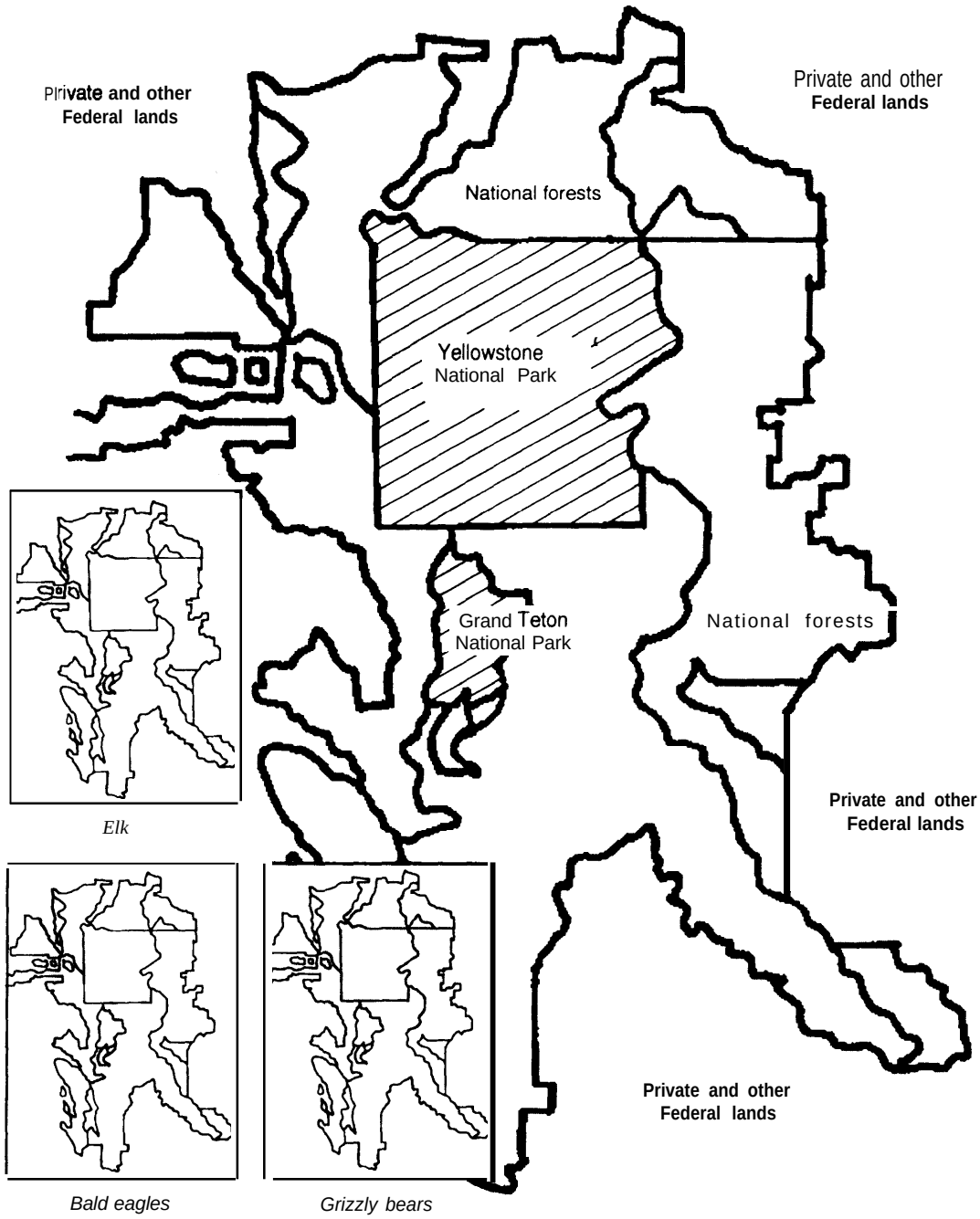
DOI's Fish and Wildlife Service (FWS). Some lands axe managed to provide for a variety of uses (multiple-use lands), including some resource use and development that may alter natural processes, and conservation of natural qualities and processes such as wildlife habitat and watershed protection. Examples of federally held lands managed for multiple uses include 151 million acres of the National Forest System[4] administered by the Forest Service and 236 million acres administered by BLM.[5] Other lands are managed primarily to provide for a single purpose, such as the protection of a specific species or ecosystem. Many National Wildlife Refuges (NWRS), administered by the Fish and Wildlife Service, are in this category. Lands managed to protect a single species, such as some National Wildlife Refuges, are often so intensively managed for that purpose that they may not strictly be considered natural areas.

Many species require large areas of suitable habitat-often much larger than contained in any one management area—to sustain a healthy population over the long term. Most natural areas with special Federal protection are too small to sustain whole ecosystems for larger species such as grizzly bears, grey wolves, and the Florida panther (29). Habitat for some species, such as migratory birds and salmon, may span several States. Thus, multiple, connected land parcels under various management regimes and ownerships may be critical habitat for certain species. Figure 5-3 illustrates the importance of surrounding lands for elk, eagles, and grizzly bears in

[4] The National Forest System includes 191 million acres, 40 million of which are set aside for Wilderness Areas, Wild and Scenic River areas, primitive areas, scenic research areas, recreation areas, game refuges, wildlife preserves, and monument areas and are therefore not included in the multiple-use management plans (2).

[5] BLM administers 269 million acres, 33 million of which are set aside for areas of critical environmental concern, research natural areas, outstanding natural areas, national natural landmarks, wilderness study areas, and wilderness lands.

Figure 5-3—Habitat Needs of Elk, Eagles, and Grizzly Bears in the Greater Yellowstone Ecosystem



SOURCES: Office of Technology Assessment, 1993; Greater Yellowstone Coordinating Committee, *The Greater Yellowstone Area: An Aggregation of National Park and National Forest Management Plans* (Washington, DC: U.S. Department of the Interior, National Park Service, and the U.S. Department of Agriculture, Forest Service, 1987).

Yellowstone National Park. Increased recognition of the importance of large land areas in maintaining natural processes and the species that depend on them has led to the development of a new management concept called *ecosystem management.* Although no one clear definition of this new kind of management has emerged, it generally refers to an attempt to view and manage natural processes on a larger scale. The Forest Service defines ecosystem management as promoting "diversity, productivity, habitat for wildlife, and longterm sustainability" (135).

Although all natural areas (public and private) are important for protecting the Nation's natural heritage, this chapter will focus primarily on federally protected natural areas —lands set aside by the Federal Government specifically for protecting unique natural characteristics or processes.[6] National Parks, National Wildlife Refuges, and Wilderness Areas compose the bulk of Federal lands under special Federal protection. Table 5-1 lists the numerous Federal designations for protected natural areas in the United States. And box 5-C broadly outlines the 'policy space''—the existing institutions, legislation, and regulations-for Federal natural areas.

Table 5-l—National Parks, Wildlife Refuges, and Wilderness Areas in the United States

Official designation	Number of sites	Area in acres[a]
National Parks[b]	49	47,240,000
National Wildlife Refuges	424	89,900,000
National Wilderness Areas	457	87,480,000
U.S. Forest Service	332	31,000,000
Bureau of Land Management	22	370,000
National Park Service	38	36,780,000
Fish and Wildlife Service	65	19,330,000

a To convert acres to hectares, multiply by 0.405.
b National Park acreage does not include all lands administered by NPS (e.g., National Monuments). See box 5-C for further explanation.

SOURCE: Keystone Center, *Biological Diversity on Federal Lands,* report of a Keystone Policy Dialogue (Keystone, CO: Keystone Center, April 1991); U.S. Congress, Office of Technology Assessment, *Technologies to Maintain Biological Diversity,* OTA-F-30, (Washington, DC: U.S. Government Printing Office, March 1987).

Current Distribution

The Federal Government has set aside about 71 million acres as protected natural areas (National Parks, Wildlife Refuges, and Wilderness Areas) in the lower 49 States, not including multiple-use lands such as National Forests, and an additional 180 million acres of protected lands in Alaska (see table 5-2).[7] These Federal holdings represent a range of land types that includes tundra, wetlands, forests, alpine areas, deserts, grasslands, and seashores. In the continental United States, the largest federally protected areas are located in the Western States, on the coasts, and in Alaska. There are also numerous, small protected natural areas in the East. Wilderness Areas comprise the largest single system of protected natural areas in the continental United States, with over 80 percent of their 35 million acres located in the 11 Western States. Most of the 23 million acres of the National Park System in the continental United States is also located in the West. The 13.4 million acres of National Wildlife Refuges in the continental United States are generally located along the major flyways of migratory birds: eastern coasts and waterways, the Great Plains, and desert areas of the West. Figure 5-4 shows the geographical distribution of federally designated natural areas and agency jurisdiction.

6 This is a distinction made by political ownership systems-not by the quality of the land under them.

7 To avoid "double counting" of areas with more than one designation these figures include acreage of all lands managed by the National Park Service and the Fish and Wildlife Service (although a small amount of NPS lands is protected as historic sites and battlefields), plus acreage designated as Wilderness administered by *other* agencies (the Forest Service and the Bureau of Land Management). These figures may differ from those in table 5-2 because the protected areas listed there may occur under more than one designation. For example, acreage for the National Wilderness Preservation System cited in the table includes wilderness acreage located in the National Park System and the National Wildlife Refuge System.

Box 5-C-Federally Protected Natural Areas: The Legislative Framework

The National Park System–The National Park System is administered by the National Park Service (NPS) in the Department of the Interior (DOI). It comprises several units[1] totaling 76 million acres (31 million hectares).[2] Twenty-two official designations are used to group these units, and each designation reflects the primary purpose for which the unit was created. Designations include National Parks, National Monuments, National Preserves, National Lakeshore, National Seashores, and National Battlefields. The laws establishing some NPS units explicitly encourage economic development near the park and allow heavy resource use, such as off-road-vehicle use and oil development, while other NPS units possess legislative mandates t hat are more strict than those for Wilderness Areas. Over half of the acreage of the National Park System is contained in National Parks, and over 80 percent of total NPS acreage is under designations designed to protect the naturalness of the area.

To achieve some management consistency, the National Park Service has grouped all units, regardless of designation, into one of four management categories: *natural zones, cultural zones, park development zones,* and special use zones.[3] Natural zones are managed to conserve natural resources and ecological processes while allowing visitor use.

All NPS units are joined by the National Park Service Organic Act of 1916 (16 U.S. Code (U.S. C.) Sec. 1-4,22,43), which spells out the mission of the National Park Service: to "conserve the scenery and the natural and historic objects and the wildlife therein and to provide for the enjoyment of t he same in such manner and by such means that will leave them unimpaired for future generations." This directive sets up a dual and sometimes conflicting mission for NPS-to conserve and preserve park resources and to provide for public enjoyment.

The National Wildlife Refuge System (NWRS)-The 91 million-acre NWRS is administered by the Fish and Wildlife Service (FWS) in DOI to "provide, preserve, restore and manage a national network of lands and waters sufficient in size, diversity, and location to meet society's needs for areas where the widest possible spectrum of benefits associated with widlife and wiidlands is enhanced and made available" (147). Although the refuges are administered by the Fish and Wilddlife Service, management of each one is largely guided by the legislation that established it; thus, management varies widely among refuges. Early refuges were created as inviolate sanctuaries to protect waterfowl and migratory birds under the Migratory Bird Treaty Act (16 U.S.C. Sec. 703-708,709a,710,711) and the Migratory Bird Conservation Act (16 U.S.C. Sec. 715-715r). Although waterfowl protection is still the major thrust of NWRS management, later refuges were created specifically to protect endangered species, and the most recent additions aim to protect multiple species and ecosystems (148). Because management of most refuges is aimed at protecting specific species, the habitat is often intensively managed and manipulated. in addition, under the Refuge Recreation Act of 1962 (P.L. 87-714 et seq.) and the National Wildlife Refuge System Administration Act of 1966 (P.L. 91-135 et suppl.), economic and recreational uses such as oil and gas leasing, logging, grazing, haying, hunting, and fishing maybe permitted and encouraged if such activities are deemed "compatible" with the purposes of the refuge.

To commemorate the IOOth anniversary of the first wildlife refuge (Pelican Island, FL, in 1903), the Fish and Wildlife Service began preparing Refuges 2003, *A Plan for the* Future to address management issues facing the system. This planning process has identified seven possible management directions from strict protection to more emphasis on multiple use. In the most recent draft, the Fish and Wildilfe Service is advocating a "balanced" option, which would put greater emphasis on ecosystem management and wildlife-oriented uses for the system (151).

1 A "unit' refers to any area or parcel of land in the National Park System. For example, any given National Park National Seashore, or National Monument is a unit of the National Park System.

2 To convert acres to hectares, multiply by 0.405.

3 Cultural zones are managed for the "preservation, protection, and interpretation of cultural resources and their settings" while providing for pubilc use and enjoyment. Park development zones are lands that contain facilities for park managers and visitors. Special-use zones include lands and waters where activities can occur that are not appropriate for other zones (e.g., mining and cattle grazing) (153).

The National Wilderness Preservation System (NWPS)-This system is somewhat different from the National Park System and the National Wildlife Refuge System because no single agency administers it The 92 million-acre NWPS is a collection of areas under special management from each of the four major land-management agencies (the U.S. Department of Agriculture's Forest Service and DOI'S Bureau of Land Management (BLM), NPS, and FWS). The Wilderness Act of 1964 (P.L. 68-577), which established the NWPS, mandates stricter protection of resources in their natural state than any other Federal land designation. Its mandate is "to secure for the American people of present and future generations the benefits of an enduring resource of wilderness . . . in such a manner as will leave them unimpaired for future use and enjoyment and so as to provide for the protection of these areas, the preservation of their wilderness character." Any road building, construction, or use of motorized equipment is generally prohibited by the act, but some mining, grazing, and prospecting may be allowed in certain areas. Although "each agency administering any areas designated as wilderness shall be responsible for preserving the wilderness character," management of individual Wilderness Areas is the responsibility of the land-management agency that managed the lands before they were designated, and interpretation of that mandate may not be uniform across the system.

The National Wild and Scenic River System (NWSRS)-Like the NWPS, the NWSRS is largely a special management designation for rivers under various Federal ownerships. The Wild and Scenic Rivers Act of 1966 (WSRA) (P.L. 90-542) established the Wild and Scenic Rivers System, now covering 9,260 miles (15,000 kilometers)[4]0n 119rivers, so that rivers possessing "outstandingly remarkable scenic, recreational, geologic, fish and wildlife, historic, cultural, or other similar values, shall be preserved in free-flowing condition, and that they and their immediate environments shall be protected for the benefit and enjoyment of present and future generations." Management may vary among rivers in the system.

Other Federally Protected Natural Areas--Several other Federal designations are aimed at preserving land and wildlife in their natural state. The loosely coordinated Federal system of Research *Natural Areas* (RNAs), originally established for research and education purposes, are areas where natural ecological processes are allowed to govern. The system currently includes over 400 units covering more than 4 million acres. Like Wilderness Areas, RNAs are special management designations in various Federal land-rnanagement systems such as the National Forest System or the National Park System. BLM is directed to identify Areas of Critical Environmental Concern (ACECS) in its land-use planning. These are areas "where special management attention is required . . . to protect . . . important . . . historic, cultural, or scenic values, fish and wildlife resources or other natural processes" (P.L. 94-579). This designation accounts for over 6 million acres of BLM land (some RNAs are also ACECS). The system of ***National Natural Landmarks,*** administered by NPS to "identify and encourage the preservation of the full range of ecological and geological features that are nationally significant examples of the Nation's natural heritage" is useful for identifying important natural areas-especially those on private land. However, this designation relies on the stewardship of the landowner to voluntarily protect the land(7). The U.S. Man and the Biosphere Program (USMAB) is part of an international program administered by the United Nations Educational, Scientific, and Cultural Organization (Unesco) designed to foster cooperative protection of the biosphere, This objective is realized through the establishment of an international network of ***Biosphere Reserve*** areas with rnultiple ownership that represent the wide range of the Earth's ecosystems. Although designation of an area as a Biosphere Reserve is purely honorary, cooperative management, research, and education are strongly encouraged on the reserves and are seen as integral components of fulfilling USMAB'S mission. Many National Parks in the United States are also core areas of these Biosphere Reserves.

Other Natural Areas-Although preservation of wildlife and Biodiverslty has not been the top priority in managing National Forests or Federal public lands, many National Forests and public lands are not frequently

4 To convert from miles to kilometers, multiply by 1.607.

(Continued on next page)

Box 5-C-Federally Protected Natural Areas: The Legislative Framework-(Continued)

harvested, mined, or grazed and play a critical role in providing habitat and continuous landscapes for wildlifeand fish species. National Forests and public lands near natural areas can also be important for providing supplemental habitat, for buffering natural areas from certain threats, and for minimizing fragmentation and development. Because they fill the same role as some natural areas in protecting species and ecosystems, they are de facto natural areas.

Likewise, all States have some system of protected lands: State parks, State forests, or State preserves. The contribution of these lands to preservation efforts is significant. In addition to receiving matching-grant funds from the Land and Water Conservation Fund (LWCF) and other Federal programs, most States have passed laws designed to promote natural area conservation on private lands (62).[5] One important State effort that helps guide and focus State conservation efforts is The Nature Conservancy's National Natural Heritage Program. This voluntary program is operated in cooperation with various State agencies to collect, manage, and use biological, ecological, and related information.[6] This information is then used to prioritize State and Nature Conservancy conservation efforts. Heritage programs have been established in all 50 States.

5 Although LWCF funds provided to the States are often used to develop recreational sites and facilities, many of these projects also protect open space and natural vegetation and may have significant benefits for wildlife (6).

6 Typically, The Nature Conservancy provides methods, training, and technical support and coordinates data exchange and interstate collaboration while State agency personnel actually conduct the inventories (86).

SOURCE: Office of Technology Assessment, 1993.

Table 5-2—Management Goals for Some Federally Protected Natural Areas

System title, managing agency	Acres in millions[a] (in Alaska only)	Goals	Degree of protection from human intervention
Wilderness Preservation System, multiple agency	94 (57)	To preserve "wilderness character . . . unimpaired for future generations" (P.L. 88-577).	High
National Park System, National Park Service	73 (53)	To conserve the scenery, natural and historic objects, and wildlife so that they will be left unimpaired for future generations (16 U.S. Code 1).	High
Biosphere Reserves, multiple agency	32 (17)	To solve problems associated with the effects of human impacts, over time, on natural ecosystems through a categorization that includes a core protected area, buffer zones, and transition areas (73).	Depends on zone
Wild and Scenic Rivers, multiple agency	10,500[b] (3,210)[b]	To preserve rivers (and their immediate environments) with outstanding scenic, recreational, geologic, fish and wildlife, historic, cultural, or other similar values in their free-flowing condition for the benefit and enjoyment of present and future generations (P.L. 90-542).	High-medium

System title, managing agency	Acres In millions[a] (In Alaska only)	Goals	Degree of protection from human Intervention
National Wildlife Refuges, Fish and Wildlife Service	(76)	"TO preserve, restore, and enhance threatened and endangered species In their habitats; to perpetuate the migratory bird resource; to preserve a natural diversity and abundance of flora and fauna; to provide education and recreation to the extend that these activities are compatible with *refuge* purposes" (148).	Medium
Marine Sanctuaries, National Oceanic and Atmospheric Administration (NOAA)	0.02	"To protect marine and Great Lakes areas with conservation, educational, aesthetic, recreational, historic, and/or educational value of national significance" (OOCRM)[c].	High-medium
Research Natural Areas, multiple agency	5	"To provide for studies of naturally functioning ecosystems that can serve as ecological reference points for baseline monitoring and oontrols for experimental research" (57).	Medium
Natural Estuarine Research Reserves, National Ocean and Atmospheric Administration and State agencies	0.4	"TO protect representative examples of the United States' diverse estuarine biogeography and typology" (OOCRM)[c].	Medium-low
National Forest System, Forest Service	191 (22)	"The National Forests are established and shall be administered for outdoor recreation, range, timber, watershed and wildlife and fish purposes" (P.L 86-517).	Medium-fow
Public lands, Bureau of Land Management	269 (90)	To "protect the quality of scientific, scenic, historical, ecological, environmental, air and atmospheric, water resources, and archaeological values" based on the principles of multiple-use and sustained yield (P.L. 94-579(a)).	Medium-low
Other (includes Experimental Ecological Reserves, Experimental Forests, Ranges and Watersheds, Outstanding Natural Areas Management, Areas of Critical Environmental Concern, National Rivers, and National Environmental Research Parks), rnultiple agency	5	Varies	Varies

a Except for Wild and Scenic Rivers. To convert acres to hectares, multiply by 0.405.
b In miles (I 7,000 and 5,200 kilometers, respectively).
c Office of Ocean and Coastal Resources Management, NOAA, personal communication, Sept. 8, 1993.

SOURCES: Man and Biosphere Program, *Practical Guide to MAB* (Park, France: Unesco, Division of Ecological Sciences, June 1987); U.S. Congress, Congressional Research service (CRS), *The Major Federal Land Management Agencies of Our Nation's Land and Resources*, prepared by A. Bachiel, Environmental and Natural Resources Policy Division (Washington, DC: CRS, Feb. 8, 1993); U.S. Congress, Office of Technology Assessment, *Technologies to Maintain Biological Diversity*, OTA-F-30 (Washington, DC: US. Government Printing office, March 1987); U.S. Department of the Interior, Fish and Wildlife Service, *Application Manual for the Land Acquisition Priority System*, Version 5.0, July 1992.

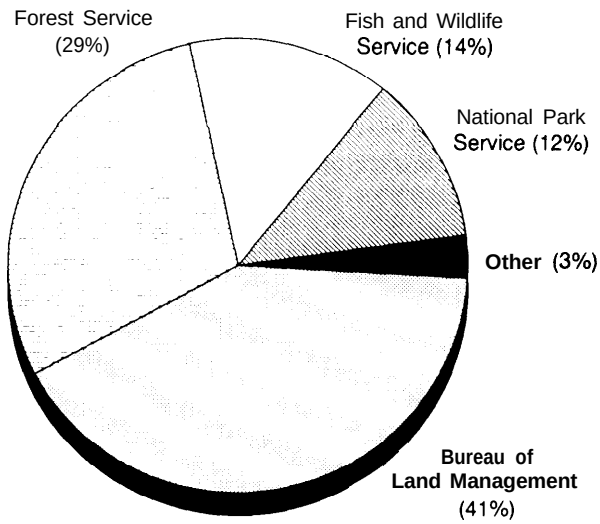
Why Are Natural Areas Valued?

Natural areas are valued for the distinctive character offered by a mix of physical and biological factors. Many of the most notable federally protected natural areas are famous for their spectacular scenery (e.g., gorges and canyons), vegetation (e.g., alpine wildflowers, fall foliage, and giant sequoias), and abundance of unusual wildlife (e.g., grizzly bears, alligators, and certain birds). The particular composition of the landscape, vegetation, and animal species makes natural areas valuable for certain kinds of outdoor recreation such as camping, hiking, sightseeing, wildlife watching, fishing, and, in some places, hunting and trapping. The rare species and biological diversity that natural areas harbor and protect also contribute to the areas' recreational value and unique character.

Over 75 percent of land-based outdoor recreation occurs on Federal land, and recreational use of Federal natural areas is increasing (131). In 1992, people made over 274 million visits to units of the National Park System—representing an increase of over 76 million annual visits since 198@ (see fig. 5-5). According to a 1991 survey of fishing-, hunting-, and wildlife-associated recreation, over 108 million U.S. residents participated in viewing, photographing, and studying wildlife that year (152). Wildlife-associated recreation can also contribute significant.ly to local economies. Over $18 billion was spent on activities and equipment related to viewing, photographing, or studying wildlife in 1991 (152).

Demand for recreation that requires remote areas, such as hiking, camping, and wildlife watching, is expected to increase faster than any other outdoor recreation (13 1). However, because of development pressure, opportunities for this kind of recreation are projected to decrease in the future (131). Because of these trends, Federal natural areas may eventually become even more valued for remote outdoor recreation.

Figure 5-4A-Federally Owned Lands: Agency Jurisdiction

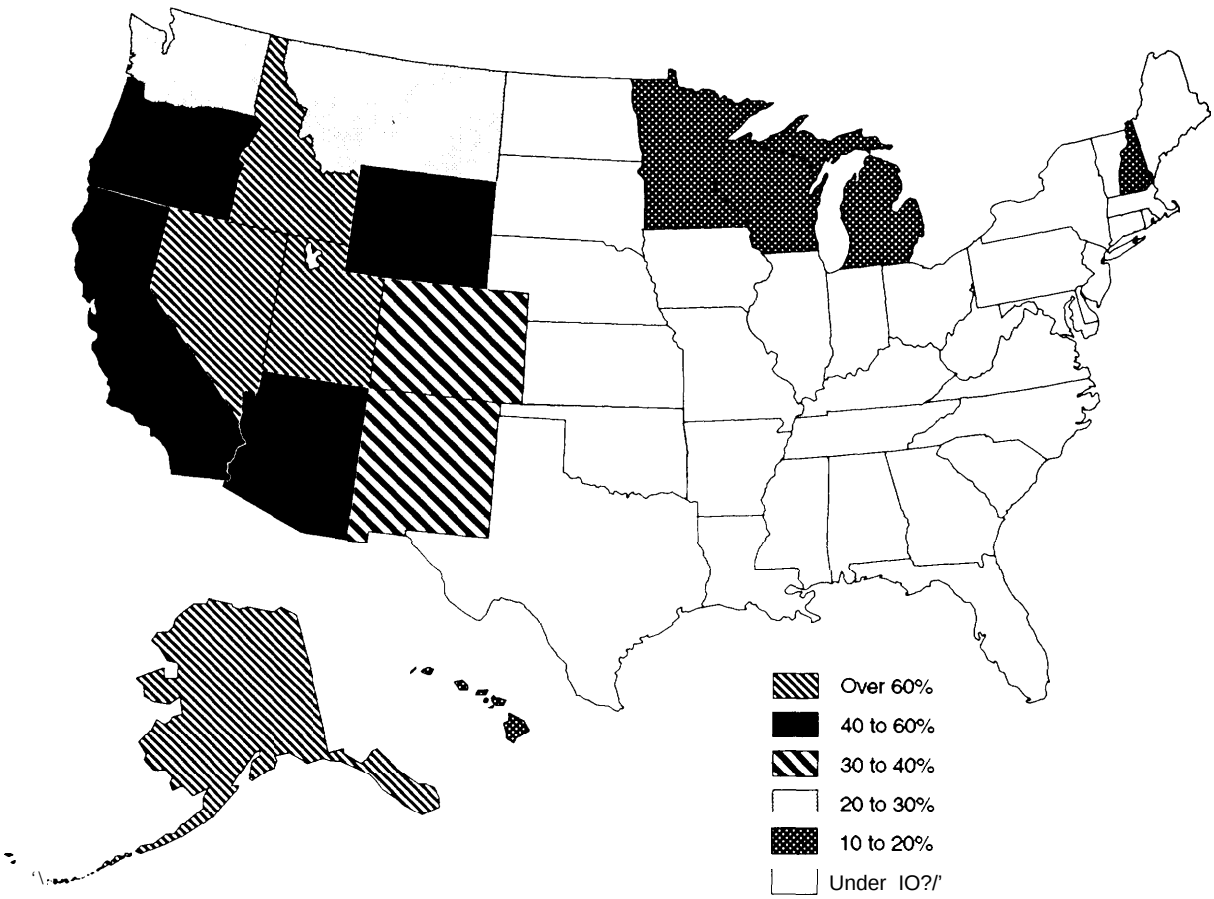


Federally protected natural areas are playing a larger role in conserving rare species and biological diversity than they have in the past (13, 35,66, 100). In 1993, the list of species considered endangered or threatened in the United States surpassed 800,[9] with thousands of additional species officially awaiting consideration for threatened or endangered status (146). Because destruction of habitat remains the main cause of species extinctions, preservation of adequate natural habitat is a key factor for most recovery efforts (126, 146, 176). As a result, many federally protected natural areas with suitable habitat for endangered species are an increasingly important component of endangered species recovery programs. If climate change accelerates the rate at which species are threatened with extinction, Federal natural areas may become even more valuable for species-protection efforts. Box 5-D illustrates the

[8] K. Hornback, U.S. Department of' the Interior, National Park Service, personal communication, August 1993.

[9] U.S. Fish and Wildlife Service, Endangered Species Office, personal communication, August 1993.

Figure 5-4 B-Federally Owned Lands: Percentage of State Area



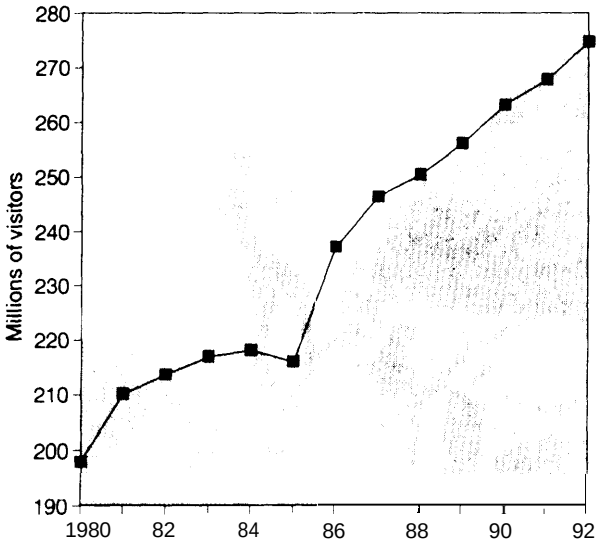
SOURCES: Congressional Research Service, 1993; U.S. Geological Survey, 1993.

kinds of problems climate change could pose for species protected under the Endangered Species Act (P.L. 93-205).

The loss of species, communities, and ecosystem types means a loss of biodiversity. Society benefits in many ways from biodiversity—medically, socially, culturally, and spiritually (see table 5-3)-but one of the most compelling reasons for conserving it may lie in the fact that species are irreplaceable. Maintaining biological diversity *may be* especially important if the natural world is to be able to adapt to environmental stresses such as changing climate (13, 96, 98).

Although the debate continues over how best to conserve biodiversity, management policies of some Federal natural areas increasingly recognize the importance of conserving ecosystem and species diversity. For example, the National Park Service's policy is to conserve the diversity of native plant and animal species in units of the National Parks System. Conservation of biodiversity is an explicit consideration for future additions to the National Park System (153). Federal natural areas may become the focal point for the protection of biological diversity, as they are now for the protection of endangered species

Figure 5-5-Recreational Visits to National Parks



NOTE: Numbers cited for recreational visits do not include travel to and from private homes, through traffic, or visits for business purposes.
SOURCE: National Park service, 1993.

-especially if trends in existing stresses continue.

Federal natural areas systems are defined by legislative requirements that provide the basis for their management. These legislative requirements and management directives are what make each system slightly different. Table 5-2 summarizes the management goals for various types of Federal natural areas.

The Organic Act of 1916 (16 U.S. Code (U.S.C.) Sec. 14,22,43) established the Park Service to administer the National Park System "to conserve the scenery and the natural and historic objects and the wildlife therein and to provide for the enjoyment of the same in such management and such means that will leave them unimpaired for future generations." In addition, each National Park unit possesses its own goals and management philosophy. Over 20 different designations are used to classify management of some *340* units of the National Park System. Each designation reflects the values for which the area was protected. Some National Park System units, such as National Battlefields or National Memorials, are protected for political or historical purposes. National Park System units valued primarily for their natural qualities include National Parks, National Monuments, National Preserves, National Seashores, National Lakeshores, and National Rivers. Because nearly half of the National Park System acreage is held as National

M. CUTLER

River narrows, such as this one in Utah's Zion National Park, lure countless hikers each year. Public use of the Nation's parks and wilderness areas is becoming increasingly popular and is expected to continue to rise in the future.

Box 5-O-Implications for Endangered Species Conservation Under a Changing Climate

Climate change is likely to alter the environment and habitat for all organisms. Many rare or endangered spades require specialized environmental conditions and are extremely sensitive to changes in their habitat. In many cases, these species are already threatened by habitat loss. Climate change could accelerate their decline and push them to the brink of extinction (see box 2-E for details on how species may respond to climate change). The United States has one major mechanism for protecting species in danger of extinction: the Endangered Species Act (ESA) of 1973 (P.L. 93-205). Despite this law, species are still declining at increasing rates, the backlog of species awaiting protection under ESA is growing, and conflicts between protection of species habitat and human development are intensifying. The 1982 amendments to ESA provide an avenue that may help resolve the potentially bitter conflicts between species protection and economic development: habitat conservation plans (HCPS). These are voluntary agreements among the Federal Government, developers, and other stakeholders that provide species protection while allowing some small amount of habitat destruction. Although HCPS are not a substitute for species protection, they do offer a creative solution to some conflicts and backlog problems.

Natural areas, rare species, and climate change-Most species depend on suitable natural habitat for survival. The rapid conversion of natural habitat to agriculture and settlements over the past century has led to the decline of a diverse array of species that depend on them. Because there is little opportunity to regulate the use of private lands, protected natural areas on public lands have become the focus of habitat protection for declining species. Nearly 200 species of threatened and endangered amphibians, birds, clams, crustaceans, fish; insects, mammals, reptiles, snails, and plants live on National Wildlife Refuges. Many refuges contain several endangered species, and over 30 National Wildlife Refuges have been established specifically to protect endangered species. Also, lands of the National Park System provide protection for one-third to one-half of the rare and endangered species in the United States (1 77). Wilderness Areas on Bureau of Land Management and Forest Service lands also contain numerous rare species.

Climate change could accelerate the rate of species decline, thereby adding substantially to the list of species threatened with extinction. Habitats for rare or declining species are often already isolated or fragmented and are extremely sensitive to any environment! changes (see box 5-E). Many endangered species require specialized environmental conditions. Climate change is likely to substantially change the conditions of many habitats within and outside natural areas and perhaps make them unsuitable to sustain certain species (see ch. 2). Some species may not be able to adapt.

The implications for natural areas are numerous. Natural areas may become like large-scale zoos, requiring intensive management to protect species from extinction. Widespread species decline coupled with continued habitat destruction and modification could make natural areas more valued for species protection. Because natural areas may offer the only option for survival other than captivit y in zoos or botanical gardens, public pressures may build to use increasingly intensive management to sustain species mixes and concentrations that might no longer otherwise be self-sustaining. On the other hand, the impacts of climate change on natural areas may make them less able to provide choice habitat for species, and thus less able to protect species from decline or extinction. If species are no longer adequately protected in natural areas, fulfilling the mandate of ESA may increasingly require the cooperation of private landowners.

The Endangered Species Act—The Endangered Species Act of 1973 was enacted to stem loss of species. It represents a commitment to preventing extinction even if that means tempering economic gain and development (8, 50). Under the act, which is administered primarily by the Fish and Wildlife Service (FWS),I a scientific assessment determines whether a species is threatened with extinction by habitat destruction or overuse, disease,

1 Future administration of the **Endangered Species Act,** or parts of it, may become the responsibility of the new National Biological Survey in the Department of the Interior.

(Continued next page)

Box !W-implications for Endangered Species Conservation Under a Changing Climate--Continued)

or other factors. If such a determination is made, the species is "listed" and awarded Federal protection. To protect a listed species, the act directs all Federal agencies to "use all methods and procedures necessary" to help the listed species recover. Specifically, all Federal agencies (through consultation with the Fish and WildlifeService) are to ensure that their actions do not jeopardize the existence of the species.

Since its enactment, several important lessons and issues have emerged that were not foreseen in the act's early years. First it is now clear that the threat of extinction is much more far-reaching in the United States than was recognized 20 years ago(8). Over 800 species are currentl`y listed as endangered, and thousands more are *candidate* species, awaiting consideration for listing. Second, programs focused on recovery and protection efforts require far more resources than have been made available (8). The Fish and Wildlife Service's Endangered Species Program has grown from about $4.5 million in 1974 to over $30 million in 1988, and still the status (improving or declining) of about 20 percent of listed species is unknown, and backlogs for listing candidate species continue to grow (103, 145). By the time the winged maple leaf mussel was listed as endangered in 1990, 99 percent of its habitat had been lost and only one population remained (71). Similarly, the polo de jasmine plant was listed in 1991 with only one individual remaining (71). Many candidate species maybe completely extinct before they are listed (103). Habitat destruction caused by human development is the main cause of continuing species decline, and conflicts over development and destruction of habitat are becoming more frequent and more intense.

There is a growing consensus that those administering the Endangered Species Act are overburdened. Yet it is likely that climate change will accelerate species decline. Adding more species to the list may dilute efforts to protect other listed species so that none are protected adequately. On the other hand, earlier listing may help recovery prospects. By the time species are listed, their habitats are usually destroyed or badly degraded, their populations are dangerously low, and their genetic diversity is seriously reduced (19, 175). To date, less than 10 percent of all listed species are considered to be improving (145), 2 percent (1 1 species) are extinct, and despite some herculean efforts, species loss continues. Only 15 species in the history of the act have recovered (103). Protection for imperiled species may simply come too late. In 1992, the Fish and Wildlife service announced measures to expedite the listing process, which are expected to help improve the chances for survival for many species currently awaiting listing (106).

One partial solution to this problem maybe to begin protecting species before they become endangered-by preserving habitats at a broad, ecosystem level (109). This "preventive care" approach may help augment the "emergency room" efforts under the Endangered Species Act. Conservationists have long called for a broadbased, multispecies protection effort and the current administration is beginning to embrace this concept for Federal conservation efforts (5).

Habitat conservation plans: Hope for species under climate change?—The Endangered Species Act requires the designation of critical habitat (areas that are "essential to the conservation of the species") when a species is listed, as well as development of a recovery plan, detailing actions to aid species recovery. Recovery plans for listed species must identify specific recovery actions (which mayor may not include protection and management of critical habitat), estimate a time frame and costs for recovery, and establish criteria by which to measure recovery status. Economic impacts can be considered in both the designation of critical habitat and the development of a recovery plan. However, because of the lack of personnel, resources, and adequate scientific information, many species do not have designated critical habitat and over 40 percent of listed species do not have a recovery plan.

Because Federal agencies are explicitly directed under ESA to conserve endangered species and are forbidden to jeopardize the existence of endangered species, conservation rnechanisms such as the designation

of critical habitat and development of recovery plans have focused on regulating Federal activities. However, the increasing decline of species and continued habitat destruction have required more aggressive extension of ESA provisions to private landowners and local governments. Conflicts have increased in the past decade over the application of Section 9, which prohibits any "taking" of spa-es, to private property. The 1982 amendments to ESA established a mechanism to address this issue.

The 1982 ESA amendments allow the fish and Wildlife Service to issue incidental "take" permits (e.g., permits to destroy a certain amount of species) in cases where developers and landowners have an approved HCP that would provide for long-term protection for the species elsewhere.[2] This approach explicitly makes a compromise between economic development and endangered species protection. Typically, an HCP establishes a Federal natural area and employs other land-management techniques such as zoning, habitat restoration, and management agreements to provide habitat protection (1 O). This approach to species conservation may become a favored mechanism in the future because it approaches long-term conservation at a larger, ecosystem level, it could provide an alternative to large direct acquisitions, and it provides a forum for bringing together many landowners and interest groups. However, it is too early to tell whether the HCPS that have been prepared will provide the long-term protection of the species t hey are designed to protect.

One notable example is the Coachella Valley Fringe-Toed Lizard. HCP, designed to protect an endangered lizard that is uniquely adapted to its sandy desert habitat in California. Fringed toes, wedged snout, double-sealed eyelids, and ear flaps are all features unique to this species and serve some function for its survival in the desert. In 1983, conflicts overdevelopment of 400 acres (162 hectares)[3] of the lizard's habitat resulted in an agreement among conservation groups, developers, local governments, State governments, and Federal agencies to develop an HCP for the area (1 O). Biological assessments are required under ESA to help design the protection plan that would maximize chances for long-term survival. The final plan included the establishment of three habitat reserves, each with its own sand source, and an agreement t hat adjacent Bureau of Land Management (BLM) lands were to be managed to protect about 15 percent of the lizard's potential habitat (about 370,000 acres) (1 O). Acquisition funds were provided by the Federal Land and Water Conservation Fund, a BLM land exchange, The Nature Conservancy, and mitigation fees paid by developers.

Although HCPS are an attractive model for resolving conflicts over endangered species preservation on private lands, they are not without problems. It is not clear that HCPS themselves ensure long-term habitat protection. Some criticize that an HCP essentially amounts to a license to destroy critical habitat in exchange for establishing a "zoo" requiring intensive management (10). If HCPS allow development just outside the preserved habitat, the effects of fragmentation and habitat isolation could degrade the protected habitat (e.g., development could leave only the 15 percent of protected fringe-toed lizard habitat intact). In addition, most conflict that results in the development of HCPS are near urban areas. Close proximity to urban development may indirectly degrade habitat despite protection under the plan. On the other hand, HCPS may be the only alternative for habitat protection in densely populated areas.

To effectively protect the national interest in these plans and perhaps to address some of these concerns, FWS personnel who are involved in these negotiations and responsible for implementing the act should have the skills necessary for negotiating with developers, economists, and politicians. Many negotiators from FWS are

2 The development of habitat conservation plans is different from the designation of critical habitat or the development of recovery plans. HCPs are voluntary agreements pursuant to the "taking" prohibition of Section 9, whereas designation of critical habitat and development of recovery plans are mandated. However, the development of an HCP mayor may not Include the formal protection of a designated critical habitat, and some recovery plans may overtap with portions of the HCP. Nevertheless, because an HCP is a localized plan, It is not a substitute for the development of an overall recovery plan for a species or for the designation of Its critical habitat.

3 To convert acres to hectares, multiply by 0.405.

(Continued on next page)

Box 5-D-implications for Endangered Species Conservation Under a Changing Climate-(Continued)

wildlife biologists with expertise infield biology and perhaps few skills in negotiation involving multiple interests and disciplines.[4] In addition, the scientific knowledge required to maximize species survival under a localized plan is often not available (scientific information is also lacking for the mandated recovery plans and for designation of critical habitat), and HCP preparation and implementation are not cheap (1 O). Because most sensitive habitat is near urban areas, market values are high and acquisitions are expensive. Moreover, most funding for HCPS to date has come from Federal sources.

HCPS also do not consider the larger issues of biodiversity because they are targeted to a single species under the Endangered Species Act. A multispecies approach to conservation is frequently cited as the most effective, but a few plans, such as the Balcones Canyonlands HCP, are beginning to take a broader approach (10). The Balcones Canyonlands HCP seeks to provide protection for three endangered species as well as several rare plants and invertebrates by preserving large habitat areas pursuant to an overall biological assessment of habitat requirements for several species. Even so, HCPS are only pursued when a species is on the brink of extinction. There is no mechanism for instituting conservation efforts when populations are still healthy. As conflicts between human development and species survival become more frequent and intense, and as more and more species are threatened with extinction from climate change and other stresses, new approaches to conservation will be needed. HCPS, if properly developed and implemented, could be expanded from focusing on endangered and threatened species to addressing a broader set of conservation efforts, including conservation of biodiversity (120).

[4] M. Bean, Environmental Defense Fund, personal communication, May 1993.

SOURCE: Office of Technology Assessment, 1993.

Parks, and the other types, such as National Monuments, make up a relatively small proportion of the units valued for natural qualities, this chapter focuses primarily on National Parks.[10]

The "crown jewels" of the National Park System (the oldest and largest National Parks such as Yellowstone, Yosemite, Grand Canyon, and Glacier) were originally preserved for recreation opportunities, outstanding scenery, and unique geologic features (177). Current management policies reflect an expansion of National Park Service emphasis to include the preservation of ecosystems and biological diversity. Today, areas are designated as new National Parks only if they contain rare remnant or disappearing landscapes or biotic types, exceptional biological diversity or geological features, rare or unique species or communities, or outstanding scenic qualities (153).[11]

Most National Wildlife Refuges were established to protect and manage populations of a single species or species group such as migratory waterfowl (6, 125). The Fish and Wildlife Service is beginning to take a broader approach to managing the refuges. More and more refuges are using the "ecosystem management" approach, and a biodiversity target has been developed for new acquisitions. Its current mission is to "provide, preserve, restore, and manage a national network of lands and waters sufficient in size, diversity, and location to meet society's needs for areas where the widest possible spectrum of

10 However, because many of the other designated units (e.g., National Preserves) are designed to protect natural qualities and because the management of these areas is similar to that of National Parks, much of this chapter applies to these units as well.

11 The National Park Service uses these criteria to rank proposed additions to the National Park System, but Congress ultimately designates through legislation which land will be acquired for use as National Parks.

Table 5-3-Examples of Benefits from Ecosystem, Species, and Genetic Diversity

Ecological processes	Research	Cultural heritage	Recreation and tourism	Agriculture and harvested resources
Ecosystem diversity Maintenance of productivity; buffering environmental changes, protection of watershed and coastal protection.	Natural research areas; sites for baseline monitoring.	Sacred mountains and groves; historic landmarks and landscapes (e g , Voyageurs Park, MN)	275 million visitors per year to U.S. National Parks	Rangelands for livestock production (e.g., 34 in the U.S.); habitats for wild pollinators and pest enemies (e.g , saving $40 to $60 per acre, or per 0.4 hectare, for grape growers).
Species diversity Protection of the role of plants and animals in forest regeneration, grassland production, and marine nutrient cycling	Models for research on human diseases and drug synthesis (e.g., bristlecone pine, desert pupfish, medicinal leeches)	National symbols (bald eagles); totems; objects of civic pride (e.g., bowhead whale, *Ficus religiosa),*	In **1991, 76 million people in the United States observed, photographed, and/or fed wildlife; 36 million fished; 14 million hunted**	Commercial logging, fishing, and other harvesting industries ($27 billion/year in United States); new crops (e.g., kiwi fruit, red deer, catfish, and loblolly pine).
Genetic diversity **Protection of the raw materials of evolution required for survival and adaptation of species and populations,**	Fruit flies in genetics, corn in inheritance, and Nicotiana in virus studies	**Bread and cultivars of ceremonial, historic, aesthetic, or culinary value (e.g , Texas longhorn cattle),**		Required to avoid negative selection and for enhancement programs; pest and disease resistance alleles.

SOURCE: U S. Congress, Office of Technology Assessment, *Technologies to* **Maintain** *Biological Diversity,* **OTA-F-30 (Washington, DC: U.S. Government Printing Office, March 1987); 1987; U.S. Department of the Interior, Fish and Wildlife Service, and U.S. Department of Commerce, Bureau of the Census, 1991 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation, (Washington, DC: U.S. Government Printing Office, 1993).**

benefits associated with wildlife and wildlands is enhanced and made available" (147). Waterfowl hunting and other "compatible" recreation uses are also valued services provided by this system.

Wilderness Areas are protected and preserved for their "wilderness character," where "earth and community of life are untrammeled by man, where man himself is a visitor who does not remain, . . . which generally appears to have been affected primarily by forces of nature,. . . [which] has outstanding opportunities for solitude or a primitive and unconfined type of recreation; . . . [and also contains] ecological, geological, and other features of scientific, educational, scenic or historical value" (P.L. 88-577). Simply, Wilderness Areas are valued because they have remained relatively untouched by human activity .12

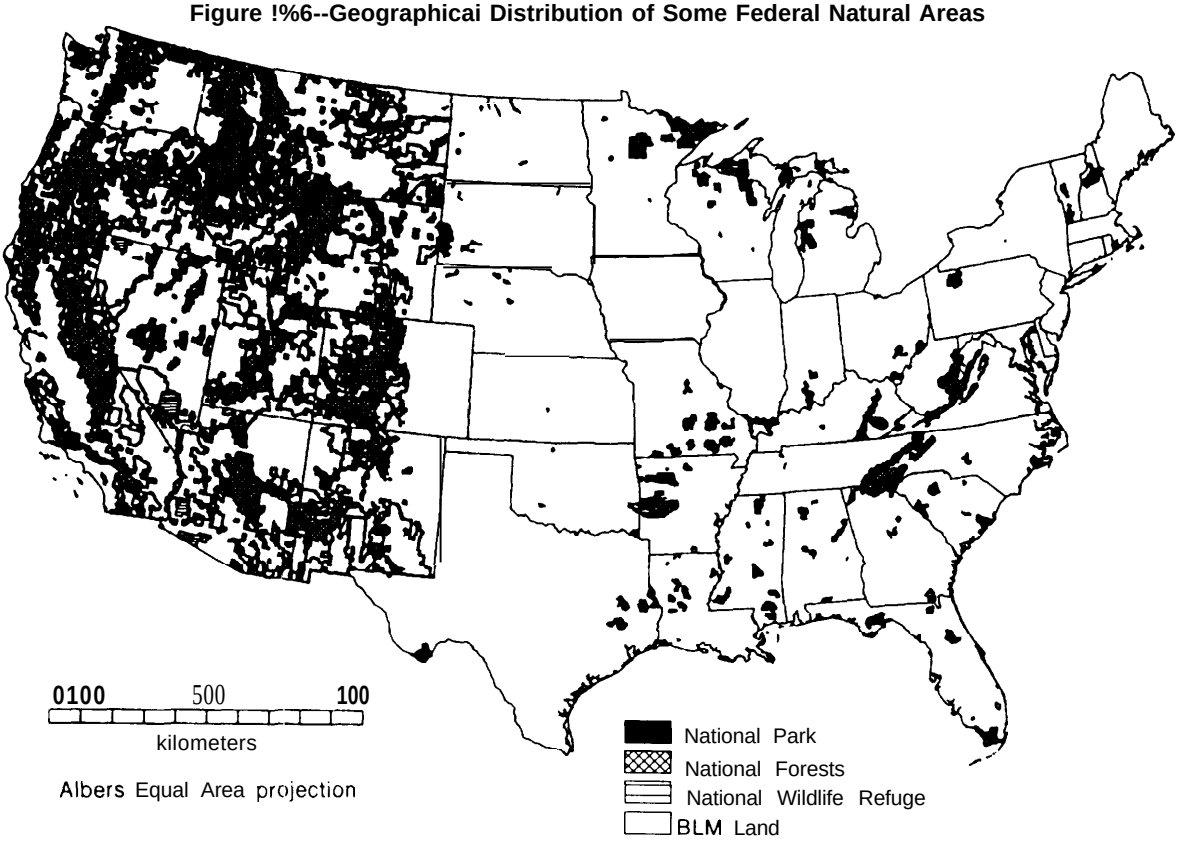
Existing Stresses on Protected Natural Areas

Landscape Fragmentatlon

The complete list of existing threats to natural areas includes nearly every type of human activity within and near designated natural areas, ranging from poaching to visitor use to air pollution to industrial development (52, 154, 159), but perhaps the most pervasive threat to all natural areas is the *landscape fragmentation* that results from development and the encroachment of human

12 In the eastern United States, some areas have been designated as Wilderness even though they were once heavily farmed because they have grown wild and seem pristine to an untrained eye. This practice is most common where more-pristine areas do not exist.

Figure !%6--Geographicai Distribution of Some Federal Natural Areas



NOTE: Protected lands in the heavily populated East are already quite fragmented. Much more land Is protected In the West, but as this map shows, adjacent parcels are often managed by different agencies with different goals.

SOURCE: J. Jones, U.S. Geological Survey, 1993,

activity. These activities effectively dissect the landscape into smaller and smaller parcels. Natural areas become ''islands' of habitat surrounded by developed or altered landscapes and are vulnerable to a variety of stresses. Figure 5-6 shows the distribution of National Parks, National Forests, National Wildlife Refuges, and BLM lands in the continental IJnited States. Although most larger and older natural areas are protected, or "buffered," by adjacent undeveloped areas managed for multiple uses (e.g., National Forests) that effectively increase their size, many Federal natural areas are not large enough to withstand future stresses or to sustain ecosystems on their own (29, 51, 75). Geographic fragmentation is also a problem within natural areas as demands for roads and facilities to support recreational use increase. As natural areas become more fragmented, they become more vulnerable to stresses, including climate change, especially if the area is not large enough to absorb the impacts of numerous threats. Box 5-E describes the numerous threats to natural areas caused by landscape fragmentation.

Institutional Fragmentation

Institutional fragmentation also affects natural areas. The two Cabinet-level departments that manage the most land are the Department of the Interior and the Department of Agriculture. Under these departments are four major land-management agencies: the Forest Service in the Department of Agriculture and the Bureau of

Box 5-E-Landscape Fragmentation: Islands of Nature in a Sea of Human Activity

Since civilization began, humans have been shaping the landscape with tools ranging from hand-held axes and hoes to chainsaws and bulldozers. Throughout much of history, these activities carved out relatively small patches of land for uses including agriculture, timber harvesting, mining, and dwelling. The intensively used patches were still surrounded by vast natural areas where ecosystems continued to function more or less undisturbed. As the human population has grown and encroachments into the landscape have expanded, human actions have affected ever larger areas and have carved the landscape into ever smaller patches. In many areas, the landscape is now characterized by a predominance of land used for human activities surrounding small remnant patches of the original ecosystems-islands of nature in a sea of human activit y. Barriers such as roads, buildings, and vast stretches of cleared and chemically treated agricultural fields may separate the plants and animals that inhabit the remnants of formerly extensive ecosystems. These remnant wildlands contain much of the diversity of terrestrial species that remains in this country, and afford the last invaluable glimpses of the structure and function of ecosystems as they were once composed. Many remnant wildlands are already too small to sustain habitat for some species without active management (1 9).

Although fragmentation of the landscape is not necessarily bad, it becomes a problem when species cannot easily migrate from one area to another and when a habitat area is too small or poor in quality to sustain viable species populations. The effects are often not immediately obvious nor are they always noticeable in each location, but they accumulate over time and space. Fragmentation poses several distinct types of problems for plants and animals and the larger communities in which they interact.

Small size-Fragmented landscapes may simply be too small to supply the forage and habitat needed by individuals of various wide-ranging species. For example, the Florida panther routinely roams over a territory of 200 square miles (520 hectares)[1]. The highly developed Southern Florida landscape offers an obstacle course of roads and fields that limit the panther's possibilities for finding prey and leave the panther vulnerable to dangers such as cars. The endangered red cockaded woodpecker prefers to stay in wooded areas. When it must travel through open fields to find new forest dwellings, it is at a much higher risk of predation from owls and hawks. Pairs of northern spotted owls require a territory of several thousand acres to support food gathering, nesting, and reproduction. The owls scout out territory in more or less random directions from their former sites; if t hey do not find suitable nesting sites within several weeks, they may fail to reproduce or, in extreme cases, even die from hunger and exhaustion (16). Numerous other species such as bears, wolves, moose, and elk range over large territories but have rather specialized requirements for food and habitat (see fig. 5-3). If climate change alters vegetation patterns, such species may have to travel even farther to satisfy their nutritional requirements. For some species, an open space such as a field or road imposes an enormous behavioral barrier that will be crossed only with great reluctance. Such species may effectively become trapped in a small area even if other suitable habitats are relatively close by. When suitable habitat has been diminished to small and distantly separated parcels, populations of many of these species decline. Isolation can also interfere with effective pollination and seed dispersal.

Local extinctions-Another consequence of fragmentation is that the populations of plants and animals that remain on a patch may have less genetic variability than does the species as a whole. Limited variability offers fewer possibilities for adaptation to changes in the environment (see ch. 2). Small, isolated populations maybe more vunerable to extreme events, such as fires, storms, drought, and late spring or early fall frosts-many of which could become more common as the climate changes, and any of which could lead to local extinction. When enough local populations become extinct, the species as a whole is endangered.

1 To convert square **miles to hectares,** multiply by 2.590.

(Continued on next page)

Box 5-E—Landscape Fragmentation: Islands of Nature in a Sea of Human Activity-(Continued)

More edges-Fragmentation also creates many more edge areas compared with the amount of land in the interior of a habitat zone. As the landscape is divided up into more and smaller patches, the area that lies at the edge of a patch increases. Forest edges are often zones of high diversity because the varied light conditions offer a range of habitats and because they are areas where species from surrounding ecosystems may mix with forest species However, many of the species that inhabit the edges are invasive species that can displace forest flora and fauna For example, the cowbird, which rarely travels deeper into a forest than several hundred feet from a clearing, is an aggressive competitor with many songbirds. What many ecologists fear is that increasing the amount of edge may lead to a predominance of invasive and opportunistic species at the expense of an array of historic species. The drying effects of the wind are generally greater at the edges of forests and wetlands than in the interior, so as the ratio of edge to interior increases, so does the area susceptible to drought. In some areas, cutting back forests has been linked to changes in wind and precipitation patterns, and in extreme cases, it may lead to desertification.

Loss of transition zones-Fragmentation may obliterate the transition zones between different types of vegetation or leave them separated by a large distance. This poses a problem for species that rely on different types of habitat during different stages of their life cycles or during some seasons. For example, some species of butterflies spend their larval stages on cordgrass, which grows in coastal wetlands, but live their adult lives in habitats farther upland and inland. Land-use patterns that diminish or destroy the gradual transition between wetlands and upland areas disrupt the butterflies' reproductive cycles. The clapper rail, an endangered bird in Southern California, is a another example. Although dapper rails dwell within the tidal zone of coastal wetlands, they prefer to remain just above the reach of the water, past the high-tide line. However, in many areas (even those bordering protected natural areas), development has occurred right up to the high-tide line. To escape January and June high tides and numerous storm surges throughout the year, clapper rails often end up perched on cars in seaside parking lots or near the edges of roads, where t hey are vulnerable not only to cars but also to predation by domestic cats and dogs. Sea level rise due to climate change could further squeeze, if not eliminate, the transition zone between coastal wetlands and uplands.

Natural areas in the United States today often make up relatively small patches in a larger fragmented landscape. Although most large and older natural areas are buffered, or protected, by adjacent natural areas or by de facto natural areas (such as multiple-use lands managed by the Forest Service or Bureau of Land Management) that effectively increase their size, many ecologists claim that most Federal natural areas are not large enough to sustain ecosystems without suffering from some impacts of fragmentation (29). Combating those impacts is not easy. In general, the !arger the contiguous area of land maintained with minimal human disturbance, the less severe will be the consequences of fragmentation. However, even if the public wanted to set aside vast new natural areas to protect a range of ecosystems, large relatively undisturbed sites simply do not exist anymore in the East, and opportunities are quickly disappearing in the West. Many actions that humans may make in response to climate change could accelerate the process and damage of fragmentation; the movement of agriculture into new areas and increased water diversions could aggravate existing problems (see vol. 1, chs. 5 and 6).

Buffer zones around natural areas and corridors connecting different natural areas can help guard against some fragmentation effects and allow for greater movement by species. (Some innovative programs for establishing buffers around natural areas are described in box 5-F.) Although the concept of corridors is simple, establishing optimal corridors is a complex, controversial, and incompletely understood process. The size, shape, and location of corridors all affect their utility for any particular species. Furthermore, although corridors offer migration pathways for the native flora and fauna that are often the target of protection efforts, they can serve equally well as a conduit for the passage of invasive or opportunistic nonindigenous species Despite the potential problems and the considerable amount of research that remains to be done, corridors have already been

established and used in a few cases, and the concept of linking natural areas is receiving increasing attention from land-management agencies and private organizations. For example, there are new linkages between the Oceola National Forest and Okefenokee Swamp in Florida and Georgia and an expanded network of corridor connections across Florida is under consideration (90).

In sum, setting aside a given amount of land in natural areas within the modern fragmented landscape does not alone ensure that the biological features for which they are valued will be preserved. To best conserve species, natural areas should include an array of ecosystems and the transition zones between them, which will allow for the many complex interactions that rely on links between different parts of the landscape.

SOURCES: P.L. Fiedler and S.K. Jain (eds.), Conservation *Biology: The* Theory and *Practice of Nature* Conservation, *Preservation,* and Management (New York, NY: Routledge, Chapman, and Hall, 1992); W.E. Hudson, Landscape *Linkages and Biodiversity* (Washington, DC: Defenders of Wildlife and Island Press, 1992); PKarieva et al. (eds.), *Biotic Interactions and Global Change* (Sunderland, MA: Sinauer Associates, Inc., 1993); D.A. Saunders, R.J. Hobbs, and C.R. Margules, "Biological Consequences of Ecosystem Fragmentation: A Review," Conservation *Biology,* vol. 5, March 1991, pp. 18-32.

Land Management, the National Park Service, and the Fish and Wildlife Service in the Department of the Interior. Each manages its own system of natural areas under its own mission. The National Wilderness Preservation System is managed by these four separate agencies and subject to varying management policies depending on which agency administers a particular Wilderness Area. To speak of one Federal system of natural areas as a single entity is, therefore, misleading.

The Greater Yellowstone Ecosystem, for example, comprises two National Parks, one National Parkway, six National Forests in two different Forest Service regions (four of which have designated Wilderness Areas adjacent to park boundaries), three National Wildlife Refuges, BLM lands, State lands, Indian reservations, and private lands. The entire area encompasses about 19 million acres and is referred to as the "largest single, essentially intact, functional 'natural' ecosystem" in the lower 49 States (92). The ecosystem has been able to support an abundance and diversity of wildlife because the land has remained relatively unfragmented. Maintaining a "whole" ecosystem depends on the condition of its parts. In recent years, increased visitor use, tourism, recreation, resource development (e.g., dam building and mining), timber harvesting, and air pollution have been posing threats to the ecosystem. Each landowner manages these stresses differently according to his or her own mission and as a result, the landscape is managed in isolated fragments that may not lead to effective protection of the entire ecosystem.

Problems that cross agency and ownership boundaries may not be addressed uniformly. Timber harvesting, construction, and heavy visitor use brought about by different management regimes can pose a threat to the large habitats required by some species, such as threatened grizzly bears, bighorn sheep, endangered peregrine falcons, and trumpeter swans, by disrupting the behavior and habitat of these species. A 1986 congressional evaluation of the Greater Yellowstone Ecosystem concluded that 'regional boundaries fragment the area into three [parcels].. . Even within the regions, individual unit boundaries often have little relevance to the Ecosystem. . . In virtually all agency decision-making, the whole is subordinated to its fragments" (122). In addition, efforts that do aim to coordinate management over the entire ecosystem either exclude important parties or are aimed at certain species, reflecting a fragmentation of coordinating bodies (122).

To help minimize landscape and institutional fragmentation and its consequences, there have been movements toward practicing more coordinated management under the existing agency structure with the goal of ecosystem management (see box 5-F). However, reconciling differing missions of agencies and interests of landowners

Box 5-F-Some Innovative Management Models: Toward Ecosystem Management in Natural Areas

As climate change begins to affect the plants and animals that reside on natural areas in the United States, managers may seek to establish buffer zones and migration corridors to continue protecting the living resources that these areas were designated to protect. Indeed, entire landscapes maybe required to accommodate range shifts. However, differing ownerships, management structures, agency missions, and jurisdictions often preclude management of areas larger than each individual management unit. Conserving biological resources is already becoming increasingly difficult because problems like pollution, development, and landscape fragmentation transcend management and ownership boundaries. Climate change is likely to compound these problems as yet another global-scale threat to some natural resources.

Within the past few years, land managers have recognized these problems and the need to address land and resource conservation on a larger scale. This relatively new concept for conservation has many names: ecosystem management, landscape management, cooperative management, integrated management, regional management, watershed management, or river basin management. Although no specific definition of this large-scale management concept has emerged, some generalizations can be made. Ecosystem, or landscape, management generally refers to the management of natural resources on a scale that crosses management boundaries and seeks to protect a variety of species and natural processes over the long term. Currently, no mechanism that effectively facilitates this kind of cooperative management on a large scale is in place. However, some programs are beginning to help bring some practical definition to the "ecosystem management" concept.

Many natural areas are located in regions where land is highly valued for economic uses, and attempts to expand protection around a natural area often conflicts directly with pressures for economic development. In many cases, especially in the eastern United States, land is simply no longer available. Thus, managers throughout the country have begun to explore new and innovative management strategies other than acquisition for balancing the needs of people who live and work near natural areas with t he needs of the ecosystems those natural areas aim to protect. In some cases, these strategies involve greater coordination among various Federal agencies that manage public lands; in other cases, they establish interactions between Federal land managers and local and private interests. In all cases, these strategies seek to bring together a diverse set of interested parties and harmonize conflicting needs before controversy erupts and complicates further action.

The Greater Yellowstone Ecosystem-As the first National Park (designated in 1872), Yellowstone has represented land-management leadership for the past century. Now, it is beginning to encompass a new management philosophy based on regional landscapes (64, 68). The Greater Yellowstone Ecosystem is a region under multiple ownership that scientists believe encompasses one of the largest and most important remaining ecosystems in the United States. Two-thirds of the 19 million-acre (7.7 million-hectare)[1] area is owned by the Federal Government: 2.5 million acres in Yellowstone and the Grand Teton National Parks, over 9 million acres in seven National Forests (nearly 4 million acres are designated as wilderness), and another million acres are managed by the U.S. Fish and Wildlife Service (FWS) and by the Bureau of Land Management (BLM). Over 6 million acres are State, private, and tribal lands. The region covers parts of t three States: Wyoming, Idaho, and Montana. Although each ownership and management scheme has its own philosophy and mission, regional issues such as wildfire and wildlife management are forcing these diverse groups together.

The Greater Yellowstone Coordinating Committee was created in the 1960s to address these issues. The committee includes regional and local representatives of the National Park Service (NPS) and the U.S. Department of Agriculture's (USDA's) Forest Service.[2] The historical distrust among the differing Federal agencies limited the

1 To convert from acres to hectares, multiply by 0.405.

2 Although the Fish and Wildlife Service and the Bureau of Land Management also hold land in the Greater Yellowstone region, they are not represented on the Greater Yellowstone Coordinating Committee. In addition, private landowners, Indian tribes, and State agencies holding land in the Greater Yellowstone Area are also not on the committee.

effectiveness of the committee and resulted in a Congressional report criticizing the committee-especially, the lack of coordination between the Forest Service andNPS(125). The committee was revitalized in the late 1980s after congressional threats of legislative reform and pressure from grass-roots organizations. The Committee then developed an integrated management plan (or "vision" document) for the Greater Yellowstone Ecosystem.

Proposals included using a "compatible management" approach in which the surrounding National Forests would essentially serve as buffers to the Park; however, diverse mandates of NPS and the Forest Service precluded any management plan that would make one agency's mission subservient to the other. Nevertheless, a report entitled Yellowstone Vision Statement was released in 1990 and outlined how interagency cooperation could lead to ecosystem management (48). Fierce opposition to the report by politicians, commodity groups, and private landowners was so intense that the 70-page report was re-released as an 1 l-page document that removed many of the original preservation and coordination themes (49, 114). Despite the failure to actually formulate an ecosystem-management strategy for the region, the fact that such an effort was undertaken is significant given the intense and almost war-like friction between environmentalists and members of the wide use movement (i.e., resource-development advocates) in this area. indeed, several obstacles to attaining cooperative management of the Greater Yellowstone Ecosystem remain. However, there is still hope that some consensus can be reached to protect the integrity of Nation's first National Park.

The New Jersey Pine Barrens-The New Jersey Pine Barrens is a unique region of habitat for rare and unusual plant and animal species that has remained largely undeveloped despite its proximity to New York City, Philadelphia, and Atlantic City. in the 1960s, proposals emerged to develop the area for retirement villages and jet ports (21). Forces aiming to preserve the area also grew (74). After several years of debate over how to best protect the resources and interests of the Pinelands, the Pinelands National Reserve was established in 1978. The 935,000-acre region is now managed by the Pinelands Commission, an intergovernmental (Federal, State, and local) authority with the responsibility to implement a regional plan "designed to guide development away from environmentally sensitive areas and into designated growth centers" (68). A variety of techniques is used to implement this plan, including imposing levels of restricted development according to a zoning system and using transferable development "credits" to help compensate landowners in restricted zones.

Early strategies for protecting the Pine Barrens recognized that acquisition by the Federal Government was not feasible because oft he high costs of direct purchase and because traditional uses such as agriculture, logging, and mining would have been disrupted. Early attempts by the State of New Jersey to form a conservation plan were perceived as pro-development and drew criticism from conservationists. Interest in a cooperative Federal-State effort grew. As a condition for Federal involvement, a Department of the Interior (DOI) task-force report challenged the State to increase its land and water conservation policies for the area (141). The State responded with a proposal for managing the area with a "graded" management scheme designed to protect the core of the Pinelands and also to provide an intermediate "buffer" area (1 00).

In 1978, the National Parks and Recreation Act (P.L. 95-625) became law and established the Pinelands National Reserve. However, the Federal Government had minimal authority to manage the reserve. A commission was established with representatives from county and State governments, private interest groups, and one DOI member to develop a Comprehensive Management Plan (CMP) for the area. Under the final protection and management plan, only 100,000 acres of key parcels were directly acquired by the State. Innovative incentives were employed to ensure flexibility in land use and equity among interests and to facilitate long-term protection. For example, a Pinelands Development Credit System was established to compensate landowners in areas with special zoning restrictions. Development credits can be sold to developers in designated growth areas, allowing them to build housing over the density limits specified in the CMP. In addition, local governments are compensated for lost tax opportunities through payments in lieu of taxes. Tax credits and special loan and grant assistance are also offered for management practices that promote land uses consistent with preservation of the reserve.

Because the Pinelands management scheme seeks to protect the region without placing excessive burdens

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Box 5-F-Some Innovative Management Models: Toward Ecosystem Management in Natural Areas--(Continued)

on any particular group, it has been called one of the most successful regional land-use-planning efforts in the United States and is to be regarded as a model for future protection efforts (99). Much of the success of this management scheme stems from the diverse methods used to protect the Preserve, the involvement and support of local residents, and the joint protection by the State and Federal Governments.

Unesco's Man and the Biosphere Program--The United Nations Educational, Scientific and Cultural Organization (Unesco) established the international Man and Biosphere (MAB) Program in 1970 to "develop a scientific basis linking the natural and social sciences for the rational use and conservation of the biosphere . . . and for the development of the relationship between humans and their environment" (73). This objective is realized through the establishment of an international network of Biosphere Reserves representing the wide range of the Earth's ecosystems. Although designation of an area as a Biosphere Reserve is purely honorary, cooperative management, research, and education are strongly encouraged and are seen as integral components of fulfilling MAB's mission. MAB Biosphere Reserves seek to correct fragmentation of the landscape by approaching research and management-training issues on a regional scale. Another purpose of the Biosphere Reserve program is to combat fragmentation of institutions and landownership by bringing diverse interests and disciplines together through education and research.

The Biosphere Reserves are generally composed of three regions in a Biogeographic *Area* (an area with distinctive biological, geological, and geographical characteristics).[3] These three regions are categorized as core areas, buffer zones, and transition areas. A *core area* is managed to preserve natural processes and genetic resources and is therefore usually under legal protection by the country (e.g., a National Park); a *bufferzone is* managed to minimize harm to the core area by human activity; and a *transition area is* where traditional land uses are found.

The U.S. component of the MAB program (U SMAB) was started in 1974, and 47 Biosphere Reserves have been designated thus far, covering 49 million acres (60, see figure). Five *directorafes* were formed to ensure interdisciplinary research in a variety of areas.[4] Most core areas are National Parks, Wilderness Areas, or areas under other legal protection (e.g., the Adirondack State Park in New York and the New Jersey Pinelands have been designated Biosphere Reserves). Although management of a region does not change once it has been designated a Biosphere Reserve, the various MAB committees facilitate integrated management through interdisciplinary, region-wide research and education projects. The intent is t hat these programs and projects will serve as catalysts for cooperative management. To help focus Biosphere Reserve activities, each USMAB directorate has a set of "interest areas" that include sustainable development, cooperative policy development, global change monitoring, and biodiversity protection (73).

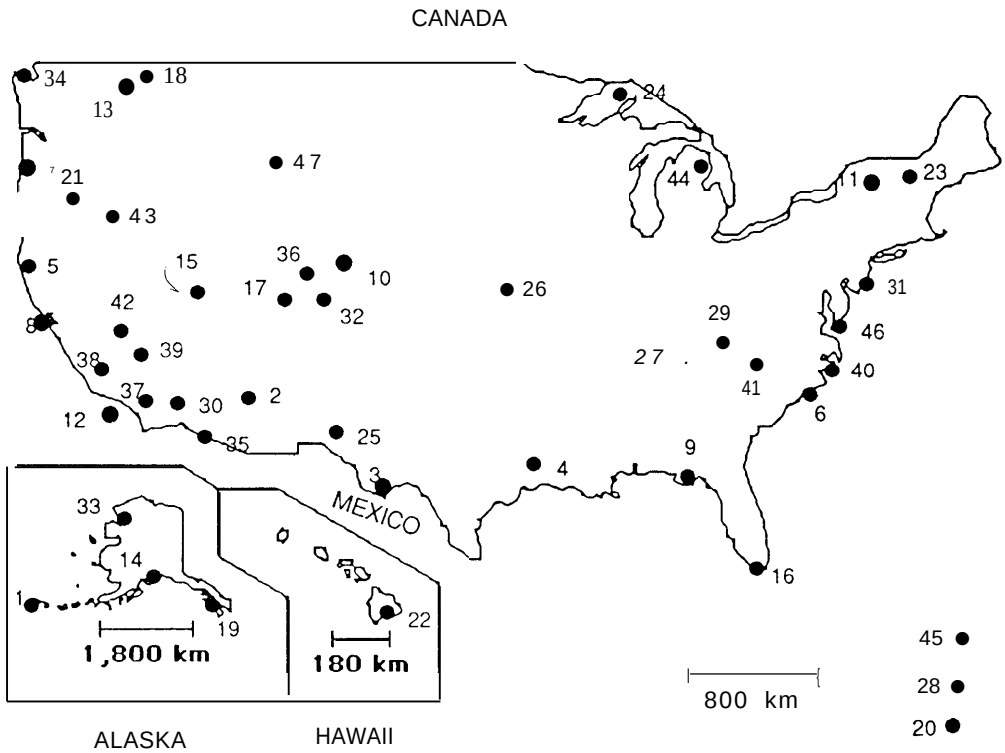
The Nature Conservancy's Last Great Places Initiative--The Nature Conservancy (TNC) is a private conservation organization, founded in 1951, with a mission to "preserve plants, animals, and natural communities that represent the diversity of life on Earth by protecting the lands and waters they need to survive" (118). In addition to owning and managing over 1,300 preserves covering over 1.3 million acres, TNC launched a new program, the Last Great Places Initiative, in May 1991, aimed at using a broader approach to protection efforts by protecting entire ecosystems-not just isolated species.

Twelve sites, ranging in size from 40,000 to 11 million acres and spread around the country, are currently included in the program, which has the potential of growing to 40 or more sites in the future. The sites are chosen

3 Biosphere Reserve is the term used in official MAB documents. The distinction between Biosphere Reserve and Biogeographic Area is that a Biosphere Reserve is a site that has been explicitly designated by Unesco whereas a Biogeographic Area is a more conceptual term referring to an area exhibiting a given set of biological and geological characteristics. However, the terms are sometimes used interchangeably.

4 The USMAB directorates are: **High Latitude Ecosystems, Human Dominated Ecosystems, Marine and Coastal Ecosystems, Temperate Ecosystems, and Tropical Ecosystems (73).**

Biosphere Reserve Sites In the United States



EuroMAB DIRECTORY

1. Aleutian Islands
2. Beaver Creek
3. Big Bend
4. Big Thicket
5. California Coast Ranges
6. Carolinian-South Atlantic
7. Cascade Head
8. Central California Coast
9. Central Gulf Coastal Plain
10. Central Plains
11. Champion-Adirondack
12. Channel Islands
13. Coram
14. Denali
15. Desert
16. Everglades
17. Fraser
18. Glacier
19. Glacier Bay-Admiralty Island
20. Guanica
21. H.J. Andrews
22. Hawaiian Islands
23. Hubbard Brook
24. Isle Royale
25. Jornada
26. Konza Prairie
27. Land Between the Lakes
28. Luquillo
29. Mammoth Cave Area
30. Mojave and Colorado Deserts
31. New Jersey Pinelands
32. Ntwot Ridge
33. Noatak
34. Olympic
35. Organ Pipe Cactus

UNITED STATES

36. Rocky Mountain
37. Sam Dimas
38. San J Canyon
40. South-Atlant Coastal Plain
41. Southern Appalachian
42. Stanislaus-Jolumne
43. Three Sisters
44. University of Michigan
45. Virgin Islands
46. Virgnia Coast
47. Yellowstone

SOURCE: National Park Service, 1993.

in part because they contain: 1) high-quality examples of terrestrial or aquatic communities that are endangered or inadequately protected, 2) concentrations of rare species, 3) a large, relatively undisturbed example of a natural community once characteristic of its ecoregion but now fragmented or degraded, or 4) a critical migratory stopover point or corridor (14). The management concept for these bioreserves is not unlike that of the MAB Biosphere Reserve concept: a core natural area is managed for preservation and is surrounded by a buffer zone with land uses managed to minimize harm to the core area. Like MAB Biosphere Reserves, core areas are generally under legal protection as a park or wilderness. However, TNC'S approach differs from MAB's in that inactively negotiates with local landowners to develop a plan to protect the core area while accommodating community growth.

TNC envisions using several protection measures including Habitat Conservation Plans, which have been used in other TNC efforts to protect endangered species. For example, the Balcones Canyonlands Conservation

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Box 5-F-Some Innovative Management Models: Toward Ecosystem Management in Natural Areas-(Continued)

Plan was developed by environmentalists, developers, local government officials, and Federal agency personnel to protect seven threatened and endangered species and other rare plants in the area and to fend off the threat of habitat fragmentation.[5] A 65,000-acre preserve was created near Austin, Texas, with about 30,000 acres to be managed by FWS as a National Wildlife Refuge and the rest acquired by and/or managed in cooperation with local industries. Acquisitions will be funded by a combination of Federal, State, and local grants as well as by private contributions. In addition, an impact fee imposed on new construction in designated areas will provide additional revenues.

The Nature Conservancy's Last Great Places Initiative seeks to coordinate and balance very diverse interests in order to preserve environmentally important regions that transcend ownership boundaries through various incentives and agreements. As a result, it represents yet another innovative approach to land management that does not require government ownership.

New York's Adirondack Park—This 6 million-acre State Park Consists of a 2.6 million-acre Forest Preserve established in 1885 and additional land under both State and private ownership added in 1892. The Park is protected indefinitely by Article XIV Section 1, of the New York State Constitution. It is the largest State Park in the continental United States and the largest single forested area east of the Mississippi, and it represents one of the most significant hardwood ecosystems in the world. Protection of the area was prompted by timber harvesting and other activities over a century ago and has been strongly supported until very recently (68).

The Adirondack Park Agency (APA), created in 1971 by the State of New York manages the development pressures on public and private lands in the park. It set up a zoning system in its 1973 *Land Use and Development Plan* that resembles the core and buffer idea with designations and density limits ranging from "resource management areas" (with most protection of naturalness) to "hamlets" (population and commercial centers) (173). Although APA established the density limits in the six land-use areas, actual control, enforcement, and implementation of the plan lies with the local communities. As of 1990, only 11 of the 105 communities in the region had developed zoning plans because of resistance to restrictions that would limit private-property rights.

Now, a century after the park was established, development pressures are threatening park protection. Projected growth trends would fragment about 3 million acres of the park and increase the park's population fivefold (68). A commission was established by New York Governor Mario Cuomo in 1989 to study implications of these pressures on t he park. The commission recommended a new administration for the park that would have broad authority over land use and development with a focus on limiting fragmentation. The commission also advocated the use of corridors to link the Adirondack natural community with those of the northeastern United States and Canada and it recommended that "the processes which maintain habitats most likely to be affected or lost through climate change should be determined" and that mechanisms to ensure their perpetuation be investigated. However, it is estimated that implementing the plan would cost at least $15 million annually, with proposed funding from luxury-home taxes and user fees. Not surprisingly, many residents and local governments strongly oppose the commission's recommendations.

Although tension between diverse interests is growing over future management of the Adirondack Park are% the management ideas first suggested by APA incorporated some of the novel methods (e.g., graded protection through zoning) that seem successful in other areas, such as the New Jersey Pinelands. If the residents of the

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5 The Balcones Canyonlands Conservation Plan is a Habitat Conservation Plan required under the Endangered Species Act (see box 5-D). The threatened and endangered species that the plan seeks to protect Include two species of migratory songbird—the black-capped vireo and the golden-cheeked warbier, and five species of invertebrates that have adapted to the unique cave environment-one spider, two types of beetle, a "pseudo" scorpion, and a daddy longlegs (10).

Adirondack Park region and other interested parties can jointly support a conservation goal for the region, efforts for coordinated management may find greater success.

The Northern Forest Lands Study—As a result of rising land values and development pressures in New England's forests, the governors of New York, Vermont, New Hampshire, and Maine appointed a Governors' Task Force on Northern Forest Lands in 1966 to study the status and trends of roughly 26 million acres of their States' forests with the help of the USDA Forest Service. The resulting report proposed several strategies for maintaining undeveloped areas of private forest lands while keeping them open to the public (53). A variety of protection measures was evaluated, including zoning, conservation easements, acquisition, and tax incentives. In essence, the report challenges the States to find a common vision and to take the lead in developing a regional protection plan for the area by encouraging the States and the Governors' Task Force to evaluate the region's resources and to develop strategies for their protection in the future. It also includes a proposal for Federal assistance in these planning efforts and for purchasing key parcels of land.

In 1990, the Northern Forest Lands Council was established to continue the Northern Forest Lands Study for another four years. This council will further develop the themes and challenges raised in the report and present a set of specific recommendations to the New England States and to Congress by the fall of 1994.

Because the 1990 report favors a variety of protection measures and cooperation among differing ownerships, a "pinelands-like" management model may emerge from future negotiations. If successful, the coordinated-management effort will be among the largest because of the degree of interstate cooperation required in an area 25 times the size of the Pinelands National Reserve.

Glacier National Park Biogeographic Area, Crown of the Continent Project—This research and education project represents an attempt tore-integrate a fragmented landscape by "creat[ing] and implement[ing] a coordination process and the necessary facilities to achieve a quantitative understanding of the natural and human environment of the Crown of the Continent Ecosystem" (36). This idea is similar to the MAB approach in that integrated, regionwide research and education will ideally lead to better-coordinated management of the region. The "crown of the continent ecosystem" includes Glacier National Park, the Bob Marshall/Great Bear-Scapegoat National Wilderness complex, and surrounding Indian Reservations and private land. An Ecosystem Center, administered by an independent board of directors, would fill five specified roles: policy exploration, basic research, monitoring and database management, ecosystem interpretation, and education (36). The activities of the Ecosystem Center would generate an integrated and reliable source of information for various management decisions. In addition, various advisory councils (representing interest groups, tribal governments, Federal and State agendas, and local landowners) are envisioned to help facilitate communication and cooperation. There are already significant efforts under way to begin to synthesize information for decisionmaking. Both Glacier National Park and Flathead National Forest maintain well-developed Geologic Information Systems that could contribute to better cooperative management. Although this project has not yet been funded or implemented, the ideas embodied in its proposal illustrate yet another way to begin to consider landscapes as a whole without undermining the owners and management regimes of individual parcels.

Rio Grande Basin Consortium-Although not directly targeted at natural areas, the Rio Grande Basin Consortium (RGBC) is a recent attempt to engage disparate public agencies and private interests in a multidisciplinary effort to conduct research and share information aimed at improving planning for the river basin. The consortium was launched in 1990 after a well-attended and enthusiastic conference held in Albuquerque on global climate change scenarios for the basin, "The Rio Grande Basin: Global Climate Change Scenarios." RGBC'S goals are to serve as a clearinghouse of environmental, social, and economic information on the region, to match researchers with suitable projects and increase the effectiveness of those projects through greater coordination, to provide a forum for interaction through means such as conferences and newsletters, and to translate knowledge and guide planning in ways that will promote the sustainable development of the area's

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Box 5-F-Some Innovative Management Models: Toward Ecosystem Management in Natural Areas-(Continued)

resources (166). Members of RGBC'S steering committee include representatives from the Forest Service, the Bureau of Reclamation, NPS, the U.S. Army Corps of Engineers, and the U.S. Geological Survey, as well researchers from the University of New Mexico, New Mexico State University, and New Mexico Tech and officials from local agencies ranging from the City of Albuquerque to the Indian Health Service. The consortium is also exploring the possibility of working with the Houston Area Research Center to address Rio Grande issues on both sides of the U.S. border. Although not directly linked to land management, RGBC'S activities are designed to further protect the biological resources of the Rio Grande while at the same time meeting the needs of the diverse cultural groups that inhabit the basin area.

SOURCE: RJ. Lilieholm, *Preserves at Risk An Investigation of Resource Management Strategies, Implications and Opportunities,* contractor report prepared for the Office of Technology Assessment, January 1993.

is not easy and will require unprecedented leadership and vision. The Yellowstone area is not unique-institutional fragmentation threatens ecosystems throughout the United States. Some innovative first efforts are in place that aim to minimize both landscape and institutional fragmentation for ecosystems or habitat areas. Although the effectiveness of these cooperative management schemes is sometimes limited by competing interests, the schemes signify promising frost steps toward innovative solutions to fragmentation problems.

Human Impacts

In addition to the different types of fragmentation that impinge on natural areas, numerous other threats exist within and outside their boundaries. Within designated natural areas, damage from overuse and overcrowding by tourists and recreationists is often cited as a major concern, especially with respect to long-term impacts and future management (76). These activities may destroy vegetation and cause erosion that disturbs wildlife habitat. Increased exposure to human activity can disrupt breeding and modify animal behavior. Other activities in federally protected natural areas such as cattle grazing and boating can increase water pollution, facilitate the spread of exotic species, damage habitat (through erosion and agitation of water), and disrupt nesting. For example, power boating and water skiing allowed on Des Lacs National Wildlife Refuge in North Dakota during the 1980s has been found to directly disturb migratory bird nesting and broods of newly hatched chicks-the refuge's primary purpose (163). Grazing cows in the Browns Park NWR in Colorado disturb the habitat of geese and ducks by eating the vegetation necessary for bird habitat (163). The cumulative effect of these various threats can lead to the decline of sensitive species that the reserves aim to protect and increase the proportion of species that are tolerant of landscapes disturbed by humans (44, 56).

A survey of managers of the Fish and Wildlife Refuge System concerning the harmful effects of secondary uses on the primary mission of refuges found that at least one harmful use was occurring on 59 percent of the refuges. Harmful uses included public use (camping, hunting, boating, and off-road-vehicle use), economic use (grazing, logging, commercial fishing, and mining), and military use (air and ground exercises). For example, airboats were considered harmful on 69 percent of the refuges where airboat activity takes place, and beach use and swimming were considered harmful on 41 percent of the refuges where beach use and swimming occur. More than one

harmful use was occurring on several refuges (163).[13] These activities can disturb wildlife directly or indirectly by disturbing their habitat. Resource damage from recreational activities such as erosion caused by hiking and camping has led to diminished wilderness character in one of every four Wilderness Areas according to a 1988 Forest Service survey (93). Several reports on the state of National Park resources cited visitor use, consumptive uses, vehicle noise, soil erosion, and invasion of exotic species as among the most common internal threats to native vegetation, animal habitat, and other resources (17, 154). The larger National Parks, including Yosemite, Yellowstone, Glacier, Great Smoky Mountains, the Everglades, and those designated as Biosphere Reserves, endure over 30 different human-caused internal and external threats (17)--over twice as many as the NPS-wide norm (52).

Because internal stresses canto some extent be regulated by the designated agency, they are generally less threatening than external stresses, which cross agency and ownership boundaries and often fall out of the purview of agency influence. The primary external threats include encroaching development, air and water pollution, logging, encroaching exotic plant species, fire, poaching, livestock grazing, and military air exercises (93). These activities have the potential to alter the natural processes in protected areas, contribute to erosion, damage habitat and scare wildlife, and contribute to a decline in biodiversity in protected areas, especially for species sensitive to human disturbance (45, 87). For example, resources in the Everglades National Park have been severely affected by herbicides, pesticides, and fertilizers in the agricultural runoff water that feeds into the park. In Yosemite National Park, a buildup of Calthane (an agricultural pesticide) in the bodies of endangered peregrine falcons causes a weakening of their egg shells and makes them unable to breed in their third to fifth year (154). Also, Kesterson National Wildlife Refuge in California is threatened by selenium toxicity from agricultural runoff (see vol. 1, box 4-E). The sonic booms and low-elevation flybys associated with military air exercises over the Cabeza Prieta NWR in Arizona are believed to adversely affect the fawning and calving of Sonoran pronghorn antelope and desert bighorn sheep (163).

Water conflicts can also constitute a threat to natural areas, especially in the arid West, where water allocation is determined by the prior appropriation doctrine (see vol. 1, ch. 5). Under this doctrine, those who first put water to a certain use obtain a‘ ‘right’ to use the water. The conflict over water surrounding the Stillwater National Wildlife Management Area, described in box 5-G, shows the complexity of water-allocation issues. Unfortunately, water rights under State law for wildlife and fish and other environmental benefits are very junior (where they exist at all), making water supplies dependent on those who hold more senior rights. Securing adequate water for Federal natural areas by claiming Federal water rights (and overriding the State priority system) is a continuing point of debate (see box 5-H).

The cumulative effect of landscape fragmentation, institutional fragmentation, and other threats has taken its toll on federally protected natural areas. In a recent survey, only around one-third of all National Park units reported their resources in “good” condition (154). Although similar surveys have not been conducted for other Federal natural areas, there are indications that multiple stresses are degrading them (159, 163). Climate change may only intensify these existing threats to resources, especially in the arid West, where water is already a scarce resource.

[13] FWS has only partial authority over mineral-resource-development and military activities on some refuge lands because authority Over these resources often falls under the jurisdiction of other agencies (145, 163).

Box 5-G-Competition for Water: The Case of the Stillwater National Wildlife Management Area

Wildlife refuges occupy a precarious position in the arid West. Most refuges are centered around water bodies--rivers, lakes, or marshes-but competing human demands for water have significantly reduced the amount of water that actually remains in streams to flush through and replenish refuges. A study by the Bureau of Reclamation on refuge water supplies and needs in the central valley of California found that only one refuge[1] has a firm supply of water "in the amount considered necessary for proper management of existing wetlands and facilities within the refuge boundaries" (142). If, as most climate models predict, the interior Western States become hotter and drier due to climate change, Western refuges could themselves become threatened with extinction (see chs. 2, and 4 and vol. 1, ch. 5).

Water has long been a precious commodity in the arid West. Scarce water flows from rivers and streams are in high demand by farmers and urban residents, who seek to dam, divert, and pump water into *offstrearn uses,* such as irrigation and municipal water supplies. At the same time, the maintenance of fish and wildlife habitat, as well as traditional uses by Native Americans and recreational uses by Western residents and tourists, relies on protecting *instream* flows--that is, keeping a certain minimum volume of water flowing through streams year-round (the necessary volume depends on the type of habitat or use to be maintained). A complex legal structure has grown up over the past century to mediate hotly contested battles over who gets water, and how much each party gets. The legal doctrine for water allocation that has prevailed in the West is one of prior *appropriation,* which means that those who historically used the water first have the highest priority in claiming present water supplies for continuing use? Ironically, fish and wildlife habitat and traditional uses by native Americans were the initial uses of most Western rivers in their natural conditions, yet these uses have rarely been quantified or been allocated water; if water has been allocated to these uses, the rights are often considered junior to agricultural and municipal claims.

The case of the Stillwater National Wildlife Management Area (NWMA) and Pyramid Lake in the Truckee-Carson River basins illustrates the complex conflicts among competing human and natural area uses for water, and suggests that the situation for refuges may worsen if climate change intensifies the squeeze for Western water. The Truckee River originates in the Sierra Nevada Mountains. It is the only outlet of Lake Tahoe and flows northeast from the lake through California and Nevada to drain into Pyramid Lake in northwestern Nevada (see figure). The Carson River originates southeast of Lake Tahoe, near the California-Nevada State line, and flows roughly parallel to the Truckee River to empty into a marshy area known as the Carson Sink. The Stillwater NWMA was established in this area in 1948 and offers food and habitat to bald eagles, American white pelicans, and numerous species of waterfowl. A dam upstream of Carson Sink created the Lahontan Reservoir, which has diminished the flows to Stillwater Marsh and other wetlands in the Sink. A canal connecting the Truckee and Carson Rivers was constructed in 1905 as part of the Bureau of Reclamation's Newlands Project to supply water for irrigated agriculture.

Four major users compete for water from the Truckee and Carson rivers: l) farmers served by the Newlands Project, 2) Native American tribes, 3) Reno-area residents, and 4) the wetland ecosystem. The Newlands Project which includes the Truckee Canal, is used by farmers to irrigate some 63,100 acres (25,600 hectares)[3] down-

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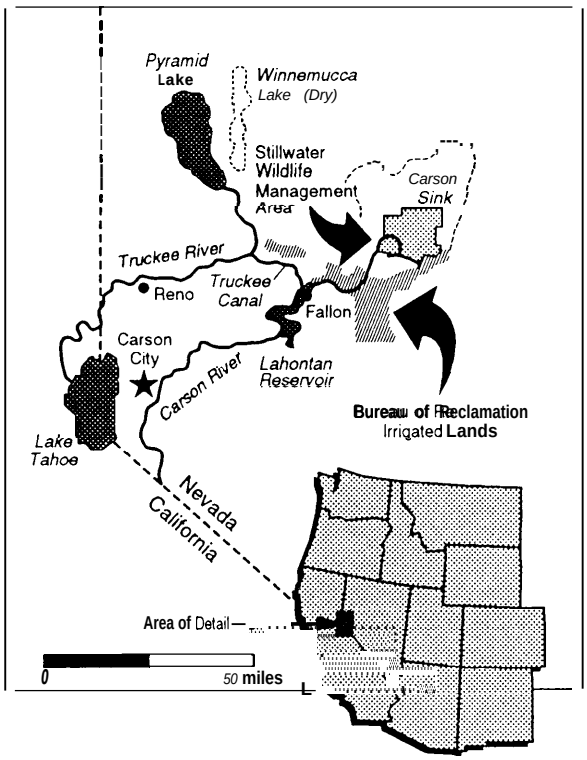
1 In the study, 15 refuges were considered: IONational Wildlife Refuges, 4 State Wildlife Management Areas, and 1 privately managed wetland area within the central valley hydrologic basin of California.

2 For example, if farmers occupying an area near a dam and reservoir have traditionally pumped 10,000 gallons (9,500 liters) a year for irrigation and a nearby municipal area has only recently begun pumping from the reservoir, the farmers would receive their water allocation first in drought years, when the reservoir might not be abfe to supply all claims on the water.

3 To convert acres to hectares, multiply by 0.405.

Stillwater National Wildlife Management Area



SOURCE: National Research Council, 1992. (Reprinted with permission from R.E. Morns, Permissions Managers, National Academy Press, Aug. 31, 1993.)

stream of the Truckee canal and around the lower Carson River. Until tribal lawsuits forced a change in operations in the 1980s, the project diverted more than half the flow of the Truckee River, which diminished water levels in Pyramid Lake and completely desiccated nearby Winnemucca Lake. The project also diverted water from the Carson River, which reduced the flow to the wetlands in Carson Sink. Two different Native American tribes with claims for water rights have been affected by the Newlands Project The Pyramid Lake Tribe has long maintained a traditional fishery downstream of the Truckee Canal on the lower Truckee River and in Pyramid Lake. The Tribe argues that the lake should be maintained at its historic levels to support the fishery as well as to protect the cui-ui, an endangered fish species that the tribe considers sacred. The Fallen Indian Reservation is on the Carson River side of the Truckee Canal. The reservation contends that the irrigation water it was promised in exchange for surrendering most of the reservation lands when the Newlands Project was constructed has never been delivered. The tribe wants water in order to sustain agriculture on the reservation. Municipal users in the fast-growing Reno metropolitan area on the Truckee River upstream of the Canal continue to clamor for more water from the Truckee because local groundwater can provide only about one-fifth of the municipal demand. Despite storage at several reservoirs upstream of the city, there is not enough water to maintain normal flows to the city in the event of a 2- or 3-year drought.

Finally, there are the needs of wetlands and wildlife. It is estimated that before human settlement wetlands covered more than 85,000 acres in the Carson Sink (including the Stillwater wetlands), while separate wetlands surrounded Pyramid Lake and Winnemucca Lake. Water diversions to operate the Newlands Project have threatened the entire system. On the Truckee River side, completely drying out Winnemucca Lake destroyed aquatic and wetland habitat. Water diversions also lowered the water levels in Pyramid Lake, which allowed the formation of a delta that blocks spawning of the threatened Lahontan cutthroat trout and diminishes habitat for the endangered cui-ui. On the Carson Riverside, water diversions diminished the Stillwater Marsh and surrounding wetlands to 40,000 acres over several decades. Despite diminished water flows, the Stillwater wetlands still play a critical role in protecting waterfowl and migratory birds. They support 90 percent of the Nevada snow goose population during part of the year, as well as thousands of white pelicans and tundra swans. Half the population of canvasbacks ducks on the Pacific Flyway pass through Stillwater NWMA, as well as one-third of the dowitohers (a Water bird similar to snipes and sandpipers). Stillwater also harbors one of the world's largest nesting colonies of white-faced ibis (1 18).

*(Continued on **next page**)*

Box 5-G-Competition for Water: The Case of the Stillwater National Wildlife Management Area-(Continued)

Ironically, efforts starting in the 1960s to improve the operating efficiency of the Newlands Project in order to conserve water for tribal claims, restore Pyramid Lake, and protect the cui-ui and cutthroat trout have further diminished the Stillwater wetlands. After water flows from the Carson River had been diverted, runoff from agricultural fields became a major water source for the marsh. As improved efficiency cut the amount of runoff, more wet!ands dried out. The various water diversions, combined with recent droughts, have reduced the marshes in the Stillwater NWMA to an area of only 4,000 to 6,000 acres. In 1989, The Nature Conservancy purchased water rights on 150 acres of marginal farmland to support Stillwater conservation efforts, but that supplied only a fraction of the water needed to restore the area.

The conflict over water in the Truckee-Carson, which started early in the century, grew to such proportions that Congress finally stepped in to help negotiate a settlement. The Truckee-Carson-Pyramid Lake Water settlement Act (P.L. 101-618), passed in 1990, established a new allocation of water rights that attempts to balance the competing uses and claims for the water. The act will allow water to be reallocated from agricultural to other uses by increasing the operating efficiency of the Newlands Project and by retiring up to 23 percent of the agricultural land it serves. Municipal users will be able to purchase water rights from agricultural users. Congress authorized the Fish and Wildlife Service to purchase water rights from willing sellers in amounts sufficient to maintain 25,000 acres of Stillwater wetlands in perpetuity.

Stillwater NWMA does not yet have all the water it needs, but at least there is now a mechanism for acquiring it. A drier climate linked to greenhouse warming could delay, or even prevent, the restoration effort because drought conditions would likely lead to increased demands for agricultural and municipal water conversions. If conditions become dry enough, however, water prices may rise high enough to drive some adjacent farmlands out of production, potentially freeing some water supplies. On the other hand, if urban growth in Reno continues at the present rate, municipal uses could well absorb any water released from agriculture. Indeed, in the event of a prolonged drought in which water supplies become critical, demand for municipal water could challenge the legislative settlement that now supplies Stillwater wetlands with water rights.

The distribution of limited water among competing uses will continue to be a complicated and controversial task as the climate changes. "The West is defined . . .by inadequate rainfall," notes Western author Wallace Stegner. "We can't create water, or increase the supply. We can only hold back and redistribute what there is." Congress has intervened to ensure that at least some water will remain to nourish 25,000 acres of Stillwater refuge wetlands in perpetuity. Whether other western refuges will reap any rewards from similar redistribution remains to be seen.

SOURCES: National Research Council, *Water Transfers in the West: Efficiency, Equity, and the Environment* (Washington, DC: National Academy Press, 1992); The Nature Conservancy, "Turning on the Tap at Stillwater," *Nature Conservancy, vol. 40,* July/August 1990, pp. 28-29.

THE PROBLEM OF CLIMATE CHANGE: A SHIFTING CLIMATE OVER A STATIC MAP

The conditions that accompanied natural climate changes in the past are significantly different from those expected to accompany human-induced climate changes in the future (see ch. 2). Climate zones are expected to shift significantly at unprecedented rates during the next century. A warming of 5.4 OF (3 'C) by the year 2100 could shift optimal climate regimes for some species roughly 200 to 300 miles (300 to 500 kilometers)[14]

[14] To convert miles to kilometers, multiply by 1.609.

Box 5-H-Water and Natural Areas Under Climate Change

Water is important for natural areas for a variety of reasons. More than 75 percent of wildlife and fish species in the arid West depend on riparian (riverside) habitat at some point in their lives (43, 140). The Nation's dwindling wetlands (including those in riparian areas), which provide critical habitat for popular game and many endangered species and numerous services such as flood control, depend on adequate water flows (see vol. 2, ch. 4). In addition, instream water flows have become a primary concern for many types of outdoor recreation such as recreational fishing, waterfowl hunting, canoeing, shoreline camping, and sightseeing (15, 110).

For example, the wetlands in California's central valley provide essential habitat for migratory birds, resident wildlife, and several threatened and endangered plant and animal species. These wetlands contain 10 National Wildlife Refuges, 4 State Wildlife Management Areas, and several privately managed wetlands and are a critical part of the Pacific Flyway, a migratory route ranging from Mexico to Canada (142). Over 10 million waterfowl and other migratory birds pass through the Central Valley wetlands every year (142). Water supplies are controlled by dams and water-delivery systems. Water withdrawals and diversions for agriculture and other development activities have reduced the wetlands in this area from over 4 million acres to roughly 300,000 acres (1.6 million to 122,000 hectares)[1] (142). Biologists stress that unless a dependable supply of water is maintained, waterfowl and wildlife could significantly decline (142).

Climate change and water supplies-If climate change leads to drier conditions, pressures to divert water to sustain growing cities and agriculture could contribute to additional habitat decline, increased species losses, and reduced recreational opportunities. Efforts to secure water for fish and wildlife and other environmental purposes have increased in recent years. Securing water rights for Federal natural areas would help ensure that the functions of these areas are not sacrificed in the future and are given consideration in times of water shortage.

Water rights and Federal natural areas-Water rightsfor Federal natural areas can be obtained at the State or Federal level. Most States have passed laws that recognize instrearn flows for the benefit of fish and wildlife as a legitimate "beneficial use" under the prior appropriation doctrine in the West (see vol. 1, ch. 5, for more details). The Federal Government Can try to secure water for the benefit of fish and wildlife by obtaining water rights under State law just as any other landowner in a State can. However, unless purchased from more-senior rightsholders, these rights would be junior, meaning they would be among the first to be sacrificed under extreme situations (123). Water law also varies considerably from State to State. Instream flows can also be considered under the National Environmental Policy Act (P.L. 91-190), under the Endangered Species Act (P.L. 93-205) (during critical habitat designation), while acquiring State permits, or relicensing darns (1 10).

Normally, the allocation of water is determined by State water law, but the Federal Government has exercised its power to claim "implied" water rights for "lands withdrawn from the public domain and reserve[d] for a federal purpose" *(Cappaert v. United States as cited*by 123). Consideration of the purposes for which the land was reserved and whether water is necessary to carry out those purposes are important factors in determining whether Federal water rights were indeed "implied" when the land was reserved. Under this rule, only lands reserved from the public domain are eligible for Federal reserved water rights; lands purchased or otherwise acquired by the Federal Government from outside the public domain are not eligible. In addition, only unappropriated water can be claimed, the right is prioritized by the date of the reservation, only water sufficient to carry out Federal purposes Is granted under the right, *and* the right is lost if it is not put to immediate use (123).

Because they were reserved from the public domain, Federal water rights maybe claimed for most National Parks. Even though the National Park Service states that it "will assert claims to reserved federal water rights for water quantities determined to be the minimum amounts needed to protect the primary purposes of a given park" (153), these rights have not been quantified for most National Parks, and there is no policy or program in place to quantify necessary instream flows (110).

1 To convert acres to hectares, multiply by 0.405.

(Continued on next page)

Box 5+1-Water and Natural Areas Under Climate Change--Continued)

Although it is a matter of considerable controversy, Federal water rights are currently not reserved for Wilderness Areas because it is not dear whether they are areas "reserved" for a Federal purpose or simply a special management designation. In addition, it is debated whether the creation of water rights is necessary to carry out the purposes of the Wilderness Act (P.L. 88-577) (123). Water rights for most of the early Wilderness lands were not an issue because many of these areas included headwaters, and, therefore, water supplies were not at risk from upstream diversions. However, recent and potential future designations include areas in the arid West that lie downstream from other water users. Increased demands for water from population growth of climate change could increase pressure to divert water that now feeds Wilderness areas and could escalate the debate surrounding water rights for Wilderness Areas.

In many cases (especially in the West), the Fish and Wildlife Service has acquired water rights for National Wildlife Refuges with land purchases and applied for rights under State law (147). However, these rights are often very "junior" or of low priority compared with those of other water-rights holders, and they are subject to varying State water laws. As a result sufficient water may not reach a refuge in water-stressed times. In addition, the water flowing into many western refuges is in upstream reservoirs that are controlled by other agengies or subject to certain limits that dictate the amount of water available to the refuge. Federal water rights have been reserved for some refuges. Currently, 78 refuges west of the Mississippi River have Federal reserved water rights, but these rights have not been quantified for most refuges (147).

Unlike other laws governing natural areas, the Wild and Scenic Rivers Act (P.L. 90-542) expressly claimed Federal water rights in the amounts necessary to preserve the values for which the rivers were designated, and authorized condemnation of existing rights, if necessary, to carry out the act. However, to date, no designation of a river has included the condemnation of existing water rights (123).

SOURCE: Office of Technology Assessment, 1993.

northward and 1,600 feet (500 meters)[15] upward in elevation (58, 94). In response, plants and animals may either migrate to more suitable locations, adapt to new climate conditions, or decline and possibly face extinction (see box 2-E) (91, %). Groups of species will not all respond the same way, so the species composition found in any given area will likely change (46, 172).[16] Climate conditions for which some species are best adapted could shift out of natural areas that are now protected and into adjacent (or even distant) areas that are more developed, fragmented, or subject to different management regimes. However, although climate zones and ecosystems may shift in response to climate change, the legislatively established boundaries of protected natural areas are generally fixed (see fig. 5-l).

- **Vulnerability**

Natural area vulnerability to climate change depends largely on why the area is **valued** and on the nature of the existing complex interactions among climate and ecological systems. Therefore, although some general risks can be identified, it is difficult to determine exactly which

[15] To convert feet to meters, multiply by 0.305.

[16] Though it is not clear exactly how species will respond to a change in their optimal climatic regime, paleoclimatic evidence and modeling analysis suggest that species may migrate at different rates, and that some species may not be able to migrate or adapt to new conditions fast enough (40, 46, 172).

federally protected natural areas are most at risk from climate change. Protected areas established primarily to protect unique geologic features such as cliffs, gorges, or canyons-the Grand Canyon National Park and the Craters of the Moon National Monument, for example-are not immediately vulnerable to changes in temperature, moisture, and carbon dioxide (CO_2) concentration (81).[17] However, some of these areas are also valued for their vegetation and wildlife. Natural areas valued for wildlife protection, biodiversity conservation, and wildlife-related recreation are vulnerable to climate change to differing degrees depending on the sensitivity of species to climate change; the number of species the area protects; the amount of human disturbance in the area; the size, shape, and environmental diversity of the area; and the nature of surrounding lands.

The disparity between shifting ecosystems and stationary natural area boundaries places protected natural areas at risk in three distinct ways: 1) the character of an area could change, 2) biodiversity and endangered species could experience diminished protection, and 3) the quality of other services, such as recreation, may be diminished. These three types of changes may occur to varying degrees on different natural areas. Areas that are small, long and narrow (exposing more "edge" relative to the area protected), and unbuffered; areas already under significant stress; or areas with rare or climate-sensitive species will be more vulnerable to climate change. Many studies (28, 58, 97, 161) have determined that coastal ecosystems, alpine ecosystems, arctic ecosystems, and mid-continent wetlands may be particularly vulnerable to climate change because these areas are sensitive to sea level rise, temperature change, sea-ice melting, and drought.

N. CUTLER

Arches National Park, in Utah, pays tribute to the geologic history of the West. This unique desert ecosystem is greatly influenced by weather and climate extremes.

Changed Character

Plants and animals make up an essential part of the scenic and recreational values of natural areas-bighorn sheep and alpine flowers are part of the attraction of Roe@ Mountain National Park in Colorado, while a distinctive array of resident and migratory waterfowl makes the Ding Darling National Wildlife Refuge on Sanibel Island in Florida one of the most popular natural tourist attractions in that State. Even in a constant climate, biotic processes that have shaped these areas are not static, but these changes generally occur much more slowly than those projected to occur under climate change (see ch. 2). As a result, climate change may threaten the distinctive character of many natural areas, particularly those set aside for ecological attributes, as species move in and out of fixed natural area boundaries. To the extent that a distinctive character is valued, more intensive management measures may be required to maintain the ecological conditions for some species or habitats. On the other hand, it may not be possible or may eventually become too costly to maintain certain species and habitats over the long term regardless of management intensity.

17 Climate conditions do play an important role in the long-term processes of erosion that have shaped the Grand Canyon, but that is on a geological rather than a human time scale.

Dimikshed Protection of Biodiversity and Endangered Species

Many natural areas are already islands in a sea of development and human activity. The landscape outside protected natural area boundaries may be fragmented and offer little suitable habitat for species able to migrate. Moreover, if few habitat types are available within the preserve, then species have even fewer alternatives as climate changes (89). As a result, some species may decline in number or become extinct. Although not necessarily designed specifically for the protection of species and biodiversity, the Federal system of natural areas now plays a big role in protecting habitat for rare and endangered species and preventing additional species loss and decline. Species that leave the boundaries of protected natural areas in their attempts to find suitable climate may no longer be protected. Thus, to the extent that federally protected natural areas are valued for nurturing biodiversity and protecting endangered species, changes in climate may threaten and diminish their value.

Several types of species have been identified as particularly vulnerable to climate change, including rare or threatened species, migratory species (species that rely on appropriate habitat throughout their range), species that disperse slowly or over very short distances, and some species in alpine and coastal communities (see ch. 2). Table 5-4 summarizes the kinds of species and ecosystems most at risk from climate change. Endangered species may be especially at risk because they are already significantly stressed and many require a narrow band of environmental conditions for survival. The Endangered Species Act (P.L. 93-205) is currently the primary mechanism for protecting these species. Federally protected natural areas may have difficulty fulfilling their roles of endangered species protection in the future under climate change. As a result, pressures to protect species may increasingly shift to Federal lands not currently protected as natural areas and lands under other ownership, if those lands are suitable for species habitat. Box 5-D **highlights** implications for this act under climate change.

Diminished Ability to Provide Other Services

Species shifts that occur in a changing climate will likely affect wildlife-related recreation in existing natural areas. Many waterfowl habitats already require intensive management to provide for recreational hunting. Natural shifts in waterfowl migration patterns pose problems for wildlife management in some States.[18] Species valued for hunting that move out of protected preserves will decrease the population of game available in the preserve. On the other hand, rare or endangered wildlife that moves out of protected natural areas and into private or multiple-use lands may be more susceptible to hunting and poaching, making their survival more tenuous. Consequently, opportunities for watching wildlife, photography, and nature study could be diminished in many protected natural areas. One assessment of future recreation supply and demand indicates that, for many reasons, wildlife-related recreation may be in the shortest supply relative to demand of all outdoor recreation by the middle of the next century (131). Climate change is likely to compound this problem if it makes wildlife more susceptible to decline.

Adaptability

Whether a natural area can "adapt," that is, persist and thrive, under climate change, depends somewhat on what species live within its boundaries, but also on the management efforts that help or inhibit adaptation. Climate-induced changes in species composition, pest outbreaks, and the frequency and intensity of fire and drought will complicate the management of protected natural areas. The challenge for managers will be to conserve the processes and resources that characterize a natural area given that the boundaries of

18 M. Bean, Senior Attorney, Environmental Defense Fund, personal communication, March 23, 1993.

Table 5-4-Species and Ecosystem Types Most at Risk from Climate Change

Ecosystem, species, or community type	Risk factor
Ecosystem or region type	
Arctic communities	Likely to warm faster; many species in the high arctic depend on food chains based on sea ice, which could be lost if sea ice melts.
Montane and alpine communities	Small, isolated habitat; no migration path; sensitive to temperature and precipitation changes.
Coastal communities	Vulnerable to sea level rise; sensitive to increased salinity.
Wetlands in arid and semi-arid environments	Isolated, small: sensitive to precipitation changes.
Species or community type	
Geographically localized species (refugia) (e.g., the American burying beetle, found in coastal areas of Massachusetts)	Isolated population--climate change could make habitat unsuitable for the entire population.
Populations at the edge of their range (e.g., sugar maple refugia in the Caddo Canyons of Oklahoma)	May be most sensitive to shifts in the climate regime; will be first to experience unsuitable climate regime (some peripheral populations could expand if climate conditions become more favorable).
Species dependent on timing of snow and/or ice melt	Availability of water at specific times is crucial for successful breeding; earlier melt means less water is available during summer months.
Rare or endangered species	Often localized and isolated populations; vulnerable to any habitat changes; vulnerable to cumulative threats.
Migratory species	Dependent on appropriate habitat throughout their entire migratory ranges.
Genetically impoverished species	Less able to adapt to environmental changes through natural selection.
Poorly dispersing species (e.g., freshwater mussels)	Migrate slowly.

SOURCES: J.A. McNeely, "Climate Change and Biological Diversity: Policy Implications," in: *Landscape-Ecological Impact of Climatic Change, Boer,* Matthias, M. Rudolf S. de Groot (eds.) (Amsterdam, Netherlands: IOS Press, 1990), pp. 406429; R.L. Peters and J.D.S. Darling, "The Greenhouse Effect and Nature Reserves," *Bioscience, vol.* 35, No. 11, December 1985, pp. 707-717.

the protected lands are freed but that species may move through, over, or around them. In addition, as species shift, managers will have to decide what changes should be assisted (e.g., finding suitable habitat for certain species) and what should be left to "natural processes. " Climate change may bring into question the general management philosophies of different management regimes (see box 5-A). To incorporate long-term climate change considerations into overall land-management decisions, the following areas need to be examined: 1) the management of natural and human-caused disturbances, 2) Federal land-acquisition and land-use incentive programs, and 3) the information base that guides management decisions.

Disturbance-hfanagefnent Challenges

Pests, nonindigenous species, fire, and human use pose the greatest disturbance threat to ecosystems under climate change.

Pests and nonindigenous (exotic) species. It is likely that climate change could accelerate the spread of undesirable plants, insects, and pathogens (128). Usually, indigenous species are better adapted to the environment and compete successfully with introduced species, thus, most undesirable exotic species do not become established. However, under climate change, many nonindigenous species considered undesirable are predicted to be favored (see ch. 2) (72). Thus, Opportunistic weedy species, pests, and disease-carrying organisms may replace or infect indigenous species (95, 128, 161).

Invasion of nonindigenous species can have profound effects on biological diversity. For example, in the western United States, bunch grasses, sagebrush, and other species dominated the arid region of southern Idaho before human settlement. Now, cheatgrass, an annual grass introduced from Europe, dominates the region (28). Cheatgrass is valuable as forage in the spring, but in the summer, it becomes flammable and worthless as forage. The Fish and Wildlife Service estimates that nonindigenous species have contributed to the decline of roughly 30 percent of the listed endangered species in the United States (9). Increased invasions under climate change pose a significant problem to natural area management.

National Parks emphasize the maintenance of historically, naturally occurring species within their boundaries. The current policy explicitly states that species that move onto the park as a result of direct or indirect human activity are not considered "native" (i.e., indigenous to the park) and that "non-native species will not be allowed to displace native species if this displacement can be prevented by management" (153). Under a strict application of this policy, trees or other organisms that migrate into a park in response to climate change would be considered ' 'nonnative. " Such a policy might be desirable today to stem the spread of weedy and undesirable species, but a three-pronged problem could emerge under climate change: 1) control of undesirable nonnative species may become more costly in the future if these species are favored under climate change, 2) policies may prevent "naturally" migrating species from moving into parks, and 3) efforts to protect existing or historical species composition, if not impossible, may become more difficult and costly. In short, what is considered "exotic," or nonnative, today may become ''native" under climate change. For the case of migration, it may be useful to distinguish exotic but nationally indigenous neighbors from exotic and nationally nonindigenous neighbors.

The Fish and Wildlife Service policy on nonindigenous species is not as clear as the National Park Service policy. Clarification of this policy could aid future management decisions under climate change. Although FWS policy maintains that the National Wildlife Refuge System exists for the "protection and management of plants and animals native to the United States," this policy makes no regional distinctions among "native" species and is heavily qualified elsewhere in other FWS policies: "[t]he attainment of natural diversity is not an overriding objective of refuge management, but it should be an underlying consideration for all. . . management activities" (143). This tension reflects the fact that many refuges are actively and intensively manipulated to attain certain objectives that may or may not conflict with efforts to protect "native" species.[19] Other ''nonnative" species, including pests, not purposefully introduced or already present on refuge lands are controlled when they interfere with refuge objectives (128). Thus, despite a policy to consider natural diversity on refuge lands and a policy to protect ''native,' or indigenous species, some tolerance for "nonnative" species is allowed and sometimes encouraged.

[19] For example, "nonnative" grasses may be planted in refuges ''when native grassland management will not achieve the refuge waterfowl production objective" (144).

The policy regarding nonindigenous species is also unclear for Wilderness Areas.[20] Given the general 'hands-off" management philosophy for most Wilderness Areas, increased invasions and infestations of nonindigenous species under climate change could be considered consistent with wilderness-management objectives. Yet, significant change caused by such invasions could also be interpreted as diminishing the wilderness character and wilderness values of the area. Noxious farm weeds (i.e., pests that damage agriculture plants), which are defined by State agencies and may or may not be indigenous to the area, can be controlled on Forest Service Wilderness when they threaten lands surrounding the wilderness. Nonindigenous wildlife species already established on Bureau of Land Management Wilderness Areas ''may continue where they enhance the wilderness character of a particular wilderness''[21]; however, management of nonindigenous plant species has not been explicitly addressed (139). Forest Service Wilderness Area policy does not permit control of "pests" except in cases where resources on adjacent lands are threatened or if the pest is nonnative and contributes to a significant loss of the wilderness resource (129). Only control measures that have the least adverse impact on the wilderness area can be taken.

Fire Management. Tree-ring studies in Sequoia and Kings Canyon National Parks in California have shown that regional intense and frequent fries have been associated with drought events in the past (116). Climate change could increase the frequency and intensity of fires for natural areas if droughts become more frequent and if forest dieback accelerates and/or spreads.[22] Several problems could emerge. Pressures to suppress all fires in natural areas could intensify (despite a change in the natural fire regime), and costs of fire control could consequently increase.[23] Removal of fuel buildup may become more important for catastrophic-fire prevention, but as areas become drier and drier, it becomes dangerous to bring heavy machinery into dry forested areas to remove fuel because sparks and motors may easily ignite frees. In addition, some fire-control measures could damage natural area values. Finally, efforts to maintain the 'natural' function of fire in ecosystem development in protected natural areas may be severely hampered.

Fires have been recognized as an important natural process that shapes an ecosystem as its components evolve over time (67, 177). In recent years, lightning-ignited frees have been allowed to bum naturally in National Parks, if life or property are not seriously threatened. This natural fire policy was subject to considerable scrutiny after the 1988 fires in Yellowstone National Park (see box 5-I). Dry, hot weather conditions combined with years of fire suppression and excessive fuel buildup caused over 740,000 acres of the park to bum (167). A National Fire Management Policy Review Team was established by the Secretaries of Agriculture and the Interior to review fire policies for parks and other federally protected natural areas and to make recommendations for fire management in the future. The team's report reaffirmed the positive role of fire in ecological processes for natural areas, but urged that the policies be clarifled and strength-

[20] However, management policies for Wilderness Areas under the jurisdiction of the National Park Service generally follow management policies for NPS natural areas. Some of these policies maybe more strict than wilderness management policies in other Federal agencies,

[21] It is not clear how the determination is made that a species "enhances the wilderness character' of a Wilderness Area.

[22] An example of the combined impacts of drought and disease spread is evident in the Blue Mountains of Oregon. The parched conditions in the West bave left drought-intolerant Douglas-firs vulnerable to disease spread. Currently, over 50 percent of many forests and Wilderness Areas in these mountains arc dead or dying (133). The area has been described as a tinderbox for wildfires (see box 6-E for *more detail).*

[23] To implement the Fire Policy Review Team's recommendations and to effectively carry out a comprehensive, safe fire-management program, both the Forest Service and the Park Service have stated that substantial increases in funds and personnel are needed (165).

Box 5-l-The Yellowstone Fires of 1966: Harbinger of Climate Change and Fire Management Conflicts

The Yellowstone fires of 1966 illustrate how changes in climate may pose probiems for natural area management. After nearly a century of fire-suppression policies on Federal lands, scientists and managers recognized fire as an important part of ecosystem health and function. Recent policies for Federal natural areas aim to reintroduce the natural role of fire by allowing naturally ignited (and some human-ignited) fires to burn under certain conditions, as long as life and property are not threatened. Although this policy had been relatively uncontroversial since the early 1970s, the fires in Yellowstone in 1966, and others like them, quickly brought such seemingly sound policies into question. Climate changes that result in fire-favorable conditions could move the natural "fire regime" toward more frequent and/or intense fires. The resulting implications for natural areas are twofold. First, efforts to maintain the natural role of fires could be hampered. Second, increased risks to life and property caused by fire could require more costly fire-control and -prevention measures.

Fire management in National Parks has evolved over the past century. The first experiments allowing lightning-caused fires to burn (prescribed natural fires) occurred in 1972, and by 1976, over 75 percent of Yellowstone was designated a natural fire zone. For 16 years, 235 fires were allowed to burn. The largest fire burned 7,400 acres (3,000 hectares)[1], but the majority burned an acre or less. Because there was no loss of life, property, or endangered species, the existing fire policy was considered a successful, tried, and tested management practice by 1966.

The 1960s were marked by drought conditions for most of the Rocky Mountain region. However, peculiar weather patterns over Yellowstone brought drier winters and wetter summers, which stemmed some drought impacts. The spring of 1966 was beginning to look like the beginning of another wet summer. Although June was a time of moderate drought, in July, the National Weather Service forecast normal precipitation levels for the rest of the summer. However, by July 15, managers knew that the fire danger was extremely high; the decision was made on July 21 to suppress all fires.

The dangerous fire situation was not a result of summer drying alone. Six dry, cold fronts that pushed through the area created winds that helped the fires spread quickly. In addition, the fires did not die down at night, when humidity usually slows fire movement.

When the fires finally died in September, over 1.4 million acres of the Yellowstone ecosystem region were affected by fire-representing 10 percent of the entire ecosystem and 36 percent of Yellowstone National Park itself (67). Over 9,500 fire fighters were in action at peak fighting time, and the cost of suppression efforts totaled over $120 million. Even so, many speculate that the suppression effort did not significantly reduce the total area burned. instead, 0.25 inches (6 mm) of precipitation on September 11 was largely responsible for ending the fires-not human techniques. Wildlife losses were minimal considering the extent of the fires: less than 1 percent of the summer elk population was lost, and nine bison, two moose, and four grizzly bears died. Native vegetation has quickly reoccupied burned areas, and the diversity of plants and animals in the area is just as high as it was before the fires. Yellowstone visitor rates have not been affected by the fires-the numbers of visitors in 1969 and 1990 were higher than ever before and reached 3 million for the first time in 1992.

Because there were no large fires under the natural fire-management policy before 1966, managers and the public were not prepared for a grand-scale fire. Public perception of the fires as destructive to park resources and local economies, and the possibility that the fires could spread to inhabited areas evoked harsh criticism of fire-management policies of the National Park Service and other Federal agencies. To address these criticisms, the Secretaries of Agriculture and the Interior established a Fire Management Policy Review Team to "determine the appropriate fire policies for national parks and wildernesses which address the concerns expressed by citizens and public officials about the management of fires on these lands as a result of the Yellowstone fire situation" (136).

1 To convert acres to hectares, multiply by 0.405.

The review team found that the basic approach of allowing natural fires to play a role in ecological processes was sound, but that policies regarding the treatment of wildfires needed to be refined. As a result, the agencies have amended their policies to clarify procedures, improve coordination, and tighten criteria for using and managing prescribed fires. For example, prescribed fires in Forest Service Wilderness Areas must be contained within a specified perimeter, and resources must be available at all times to keep the fire in the prescribed area (1 73). To be allowed to burn, fires in the National Parks must meet a set of criteria that include drought and size considerations. When these criteria are not met the fire is to be considered "wild" and must be suppressed (79). However, problems remain in implementing an effective, coordinated prescribed fire program (165). Interpretation of the review team's recommendations has not been uniform across land-management agencies, leading to inconsistencies and revealing a lack of coordination *in* areas with common boundaries (3, 34, 79). Lack of adequate funding, personnel, and equipment as well as internal resistance from some land managers have also been cited as impediments to implementing a more controlled and coordinated prescribed-fire program (40).

If climate change leads to shifts in the natural fire patterns for some regions or leads to weather situations conducive to large fires, it may be more difficult to allow fire to behave as a natural process in natural areas; t here may be more pressure to control the fire regime and suppress large "natural" fires.

SOURCES: The Office of Technology Assessment, 1993; J.D. Varley and P. Schullery, "Reallty and Opportunity In the Yellowstone Fires of 19SS," in: *The Greater Yellowstone Ecosystem*, R.B. Keiter and M.S. Boyce (eds.) (New Haven, CT: Yale University Press, 1991).

ened (136).[24] Despite the review team's recommendation that Federal agencies should cooperatively develop prescribed fire programs and contingency plans, there have been problems in achieving a truly coordinated program across agencies (165). Lack of funding, personnel, and equipment, and a resistance to instituting a prescribed fire policy among some agency personnel have also been cited as impediments to implementing an effective, safe, prescribed fire program (34, 40, 165).

Although these policies pertain to both natural and prescribed fires, use of prescribed fires is not encouraged in some National Parks because of the policy to let natural processes govern to the extent possible (67). (However, prescribed fires are more widely used in other National Parks to control unnatural fuel buildup.[25]) Prescribed fires are also not widely used in Wilderness Areas, especially during drought conditions, when fire risks are high.[26] Ironically, this could be the very time that most ecologically significant fires have occurred in the past. Removing trees to reduce fuel loads is allowed only in emergency situations in some Wilderness Areas. Fire management in protected natural areas presents a dilemma to managers: to minimize fire risk during dry years, many fires are suppressed and few are ignited. Yet, multiple dry years without frees result in greater fuel buildup and very high risks of catastrophic fires.

Human-Use Management. In recent years, reports on the condition of the National Parks have cited overcrowding and damage from visitor use as among the main threats to park resources (17, 154, 158). Because the parks were estab-

~ NPS and all agencies with jurisdiction over Wilderness Areas (including FWS, the Forest Service, and BLM) have revised their policies to allow "prescribed" fires (human or lightning ignited) to burn only under specific conditions as stated in a Fire Management Plan. All fires that do not conform to the specified conditions of the plan (e.g., they become more intense or spread outside the specified fire perimeter) are considered "wildfires" and are to be suppressed (79, 155, 173).

25 D. Parsons, Research Scientist, National Park Service, Sequoia and Kings Canyon National Parks, personal communication, March-April 1993.

26 J.T. Williams, Branch Chief, Fire Use and Fuels, Fire and Aviation Management, USDA Forest Service, personal communication, March 22, 1993.

J. MATTEY

Lakes, ponds, rivers, and wetlands provide excellent opportunities for canoeing and other aquatic sports. This salt marsh along the Potomac River harbors crabs, osprey, blue herons, and bald eagles, and serves as a nursery for young fish.

lished by the Organic Act to allow visitor use, pressure to keep them open to all visitors is high despite the resource damage caused by overuse. Although NPS maintains a policy of restricting use if necessary to "prevent derogation of the values and purposes for which the park was established," restricting visitor use remains controversial (153).

Under the Wildlife Refuge Administration Act (P.L. 9044) and the Refuge Recreation Act (P.L. 87-714), recreational uses such as hunting, fishing, and boating are allowed on the National Wildlife Refuges if the use is "compatible" with the primary refuge objectives. A use is compatible if it does not materially interfere with or detract from the purposes for which the refuge was established (6).[27] However, compatibility judgments are subjective. A 1989 General Accounting Office (GAO) survey of refuge managers showed that about one-third of all uses considered "harmful' by refuge managers were permitted as a result of political or community pressures (163). Several other harmful activities occurring on wildlife refuges are not under FWS authority (e.g., military air and ground exercises) or are included as one of the purposes for which the refuge was designated (e.g., oil drilling), thus limiting the ability of refuge managers to protect refuge values. Since the GAO study, the Fish and Wildlife Service has implemented several actions to correct public-use problems including enhanced coordination with other agencies and the alteration of use patterns on many refuges."

Because of the mandate to maintain the pristine condition of Wilderness Areas, these areas carry the most restrictions with regard to human use. The number of visitors is limited and generally only foot and horse travel is allowed. Wilderness areas still face threats from human use in the form of eroded trails, litter, and trampled vegetation (l64). As demands for wilderness-related recreation increase, these trends are likely to worsen (131).

Acquisition Policies

Climate change may also bring into question current land-acquisition policies for federally protected natural areas. Future land-acquisition decisions could consider the implications of climate change. For example, will the area persist under climate change, and will it buffer existing natural areas or serve as abridge to other areas for migrating plants and animals? Should corridors (habitat that connects existing protected natural areas) be encouraged? Should the edge of species ranges be acquired and protected? Should habitats such as coastal wetlands be acquired if they are likely to become submerged as sea level rises? Should protected areas be established along elevational and latitudinal gradients to provide for migration?

Federal Acquisition Programs. The Federal Government continues to acquire substantial amounts of land for its various protected natural

27 However, some uses that frequently interfere with other refuge purposes, such as cattle grazing and oil drilling, are authorized by law when the refuge is established.

28 Robert Schallenberger, Chief, Division of Refuges, U.S. Fish and Wildlife Service, personal communication, March 1993.

Box 5-J-Possible Funding Sources for Conservation Programs

User f-These fees are politically attractive because, ideally, those who value the resource the most pay for its protection. However, there is often strong opposition to such fees, especially for use of Federal lands. Also, in the case of wildlife-related activities, it is often difficult to identify the "user."

- *Recreation* fees(for Federal land use)--Many federally protected natural areas and Federal multiple-use lands charge fees for recreation: entrance fees, camping fees, concessioner fees, and seasonal and annual passes for National Parks. Voluntary donations are also accepted. However, some contend that the fees are either too low or do not feed directly intobetter management of the natural area (101). Some National Parks (e.g., Great Smoky Mountains National Park) have legislation that prohibits entrance fees.
- Excise *taxes* modeled on Pittman-Robertson and Dingell-Johnson programs-These taxes establish funds to protect game and fish habitat, respectively, by imposing a tax on hunting and fishing equipment. Possible additional targets for excise taxes include fuel for motorized vehicles (off-road vehicles and lawn mowers) and back-country recreational equipment.

Mitigation fees-These fees have great potential as a funding source. The idea is to tax or charge a fee on items or activities that are harmful to wildlife but that are perceived as necessary to society. The funds can then be targeted for protecting wildlife habitat through acquisition or matching grants and for obtaining water for natural areas.

- *Land and Water Conservation Fund-This* fund is already in place and is the most widely used fund for protection of wildlife and endangered species habitat. A certain percentage of revenues from oil drilling and exploration on the Outer Continental Shelf (OCS) is placed in the fund for land acquisition and species protection. OCS activities provide 85 percent of LWCF funding. However, appropriated amounts have been about one-third of the authorized amount in recent years.
- Fees on new development of *nonrenewable resources (e.g.,* oil and gas, minerals, and geothermal energy)-Eleven States have such programs in place.
- *Development and impactt fees--For* example, developers who want to build insensitive habitat could be made to contribute to a fund used to protect wildlife habitat elsewhere. Similarly, donation to a conservation fund could be required for road-construction activities.
- *Mandatory land* dedication--California cities can require developers to dedicate 3 to 5 acres (1.2 to 2.0 hectares)[1] of open space for every 1,000 people the development will accommodate. A similar program can be established at the Federal level for new development that uses Federal money. At the Federal level, wetland mitigation is required for development activities that destroy wetlands under Section 404 of the Clean Water Act (P.L. 92-500) (see ch. 4 and vol. 1, box 5-C).

Voluntary donations-These can be a good source of revenue, especially when the donator benefits indirectly from the donation through, say, enhanced business activity. However, voluntary funds are unpredictable and subject to economic fluctuations and competition with other voluntary programs. Wildlife advocates stress that voluntary donations should be used to supplement other funding sources, but should not be the sole funding source (168).

- *Recreation-enhancement taxes-Manufacturers* of recreation equipment may pay voluntarily to a fund that benefits the activity for which equipment is used.
- Income tax check-offs-Typically, there is a box that can be checked on income tax forms to dedicate money for conservation efforts. Many States have successfully initiated this type of checkoff, but it appears that competition with other checkoff boxes has limited its success.
- *Land or land easement donations-Tax* deductions or property tax relief may encourage donation of land or easements under which property is protected.

1 To convert acres to hectares, multiply by 0.405.

(Continued on next page)

Box 5-J-Possible Funding Sources for Conservation Programs-(Continued)

General funds-Congress can appropriate funds for wildlife and natural area conservation. However, appropriations are also subject to short-term economic fluctuations and competition with other programs.

- The Fish *and* Wildlife Conservation *Act of* 1980 funds--This act was established to provide up to $5 million in financial assistance to States for nongame wildlife conservation. However, the act has not appropriated any money since its enactment, even though many States are ready with conservation programs should the funds be made available.
- *Highway-trust-fund appropriations--these* could be targeted for natural area protection.
- *Partnerships and incentives program--The U.S.* Department of Agriculture's Forest Service has initiated several partnership and incentives programs aimed at encouraging private and State conservation and stewardship efforts through matching-grant and other Federal assistance programs (see ch. 6).

SOURCES: President's Commission on Americans Outdoors, *Americans Outdoors: The Legacy, The Challenge* ('Washington, DC: Island Press, 19S7); S.D. Vickerman, "State Wildlife Protection Efforts: The Nongame Programs, in: "*In Defense of Wildlife: Preserving Communities and Corridors* (Washington, DC: Defenders of Wildlife, 19S9), pp. S7-96.

area systems. Land can be *acquired* for inclusion in a Federal natural area system in a variety of ways: through purchase, condemnation, donation, exchange with private landowners, or transfer from another Federal agency. Direct purchase (where the cost is paid) is not the most common method for acquiring lands. For example, FWS and NPS have each acquired only 2 percent of their land base since 1965 through direct land purchases (124). Land exchanges, easements, and purchase of partial interests are more common. (Box 5-J describes some possible funding mechanisms for conservation projects.)

Funds for most acquisitions come from the Land and Water Conservation Fund (LWCF), though additional funds from the Migratory Bird Conservation Fund and the North American **Wetlands** Conservation Fund are available to the Fish and Wildlife Service. Since the LWCF was established in 1964, the Departments of Interior and Agriculture have spent $3.6 billion for land acquisition and have given $3.2 billion to the States for their conservation programs.[29] Between 4 and 5 million acres of private land have been acquired by the Federal Government through the LWCF over the past 25 years (86). Although $900 million has been authorized for the LWCF each year since 1978, actual appropriations have averaged less than one-third of the total authorized amount in recent years (see fig. 5-7) (86).

Each land-management agency has different procedures and criteria for acquiring land. NPS does not have an overall, long-term acquisition plan. It determines acquisitions on a case-by-case basis considering the following criteria: 1) degree of national significance, 2) degree of suitability and feasibility, and 3) appropriateness of NPS protection over State or private protection. Generally, preference is given to ecosystem types that are not already represented in the system; are less stressed, damaged, or fragmented; and are of sufficient size and shape to "ensure long-term protection of resources and to accommodate public use" (153). Congress must also authorize any new additions to the National Park System.

Acquisitions for the National Wildlife Refuge System follow the Land Acquisition Priority System (LAPS), a systematic priority-setting scheme developed by FWS. Under this system, areas for acquisition are targeted if they contain endangered species, fishery resources, migratory bird habitat, significant biodiversity, or nationally

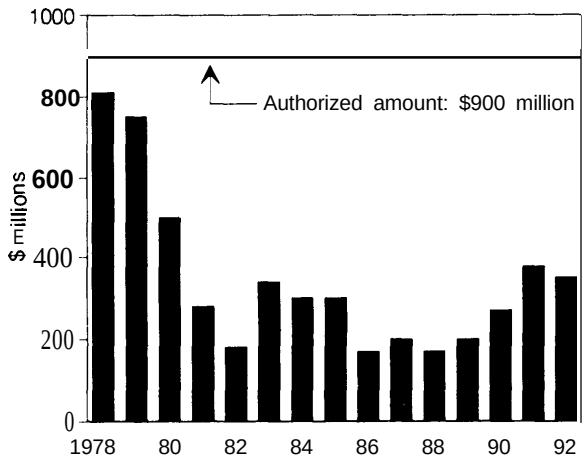
29 Of this total appropriated amount, up to 60 percent can be made available as matching funds to the States for private land acquisition.

significant wetlands. Acquisitions for each target area are authorized by separate congressional mandates such as the Endangered Species Act and the Emergency Wetlands Resources Act (P.L. 99-645) (150). Criteria for target areas include whether the size of the land will meet immediate habitat requirements and whether the area is accessible to the public; however, fragmentation and long-term needs are not primary considerations.

Additions to the National Wilderness Preservation System (NWPS) usually include lands already under Federal ownership that have been recommended by the major land-management agencies. Thus, additions to the NWPS usually require a change in management status rather than ownership. Like additions to the National Park System, new Wilderness Area designations must be approved by congressional legislation. Ideally, the most important criteria for new additions to the NWPS are whether the area: 1) "generally appears to have been affected primarily by the forces of nature; 2) has outstanding opportunities for solitude or a primitive or unconfined type of recreation; 3) has at least five thousand acres of land or is of sufficient size as to make practicable its preservation and use in an unimpaired condition; and 4) may also contain ecological, geological or other features of. . . value' (P.L. 88-577). Each of the major land-management agencies has been directed to evaluate its lands for additions to the system. However, because of conflicts among resource-use groups and wilderness advocates, many areas are still under consideration and have not yet been designated (102).

Federal Incentive Programs. In addition to Federal acquisition programs, several incentive programs are in place to protect natural areas and to augment the Federal system of natural areas. The Federal Government can use up to 60 percent of the Land and Water Conservation Fund to help States plan, acquire, and develop needed land and water areas. Once a comprehensive plan has been approved, the Federal Government may provide up to 50 percent of the costs of the project.

Figure 5-7-Authorizations and Total Annual Appropriations of Land and Water Conservation Fund



SOURCE: National Research Council, 1993.

Although many of these projects are primarily recreation projects, some do have substantial benefits for wildlife (6).

Through the Federal Aid in Wildlife Restoration Act of 1937 (the Pittman-Robertson Act, P.L. 99-396), Federal financial and technical assistance is provided to the States for acquisition, restoration, and maintenance projects for wildlife habitat or for developing a fish and wildlife resource-management plan. Up to 75 percent of project costs are paid by the Federal Government, and the rest is paid by State matching grants. The Federal portion of the cost is paid primarily through revenues from excise taxes on hunting equipment. As a result, most projects are aimed at benefiting game species. The Federal Aid in Fish Restoration Act of 1950 (the Dingell-Johnson Act, P.L. 100448) is a similar act that provides up to 75 percent of the costs to the States for projects or management plans pertaining to fish through revenues from excise taxes on fishing equipment and related items. In both cases, the Federal money is dispersed to the States with little guidance about how it should be used.

The Fish and Wildlife Conservation Act of 1980 (P.L. 96-366) sought to fill the gaps in the Pittman-Robertson, Dingell-Johnson, and Endangered Species Programs by providing protection through a similar matching-grant program for species that are not game and not endangered. However, the program is funded at the Federal level with direct congressional appropriation (unlike the fish and game acts, which are funded by taxes), and no money has ever been appropriated for this purpose since the law was passed in 1980. Under this program, the Federal Government would provide up to 75 percent of the costs to the States of preparing a comprehensive management plan for all vertebrate species. This law—already on the books--could be funded and amended to encourage an ecosystem-level approach to management by including protection for plant and invertebrate species and by requiring States to prepare ecosystem-management plans before receiving funds.

In addition to these grant and cost-sharing programs, other Federal programs provide easements and other incentives for resource protection. The Environmental Conservation Acreage Reserve Program, which combined the Conservation Reserve Program and the Wetlands Reserve Program in the Food, Agriculture, Conservation, and Trade Act of 1990 (P. L. 101-508), encourages owners to enroll certain wetlands and highly erodible lands in the program in return for easement payments and access to cost-sharing programs. In addition, the "Sodbuster" and "Swampbuster" programs established by the Food Security Act of 1985 (P.L. 99-198) and the Food, Agriculture, Conservation, and Trade Act seek to combat erosion and wetland destruction by withholding Federal benefits if erodible lands are planted or wetlands are converted. (See chs. 4 and 6 for more detail on these programs.) These Federal programs encourage State and private landowners to manage lands in particular ways. The programs could be used to augment the existing Federal system of natural areas while accomplishing their broader environmental goals and without changing landownership patterns.

Research, Inventorying, and Monitoring

There are many gaps in our understanding of ecosystem structure and function. The Ecological Society of America's (ESA's) Sustainable Biosphere Initiative identified five priority areas in need of increased ecological research: 1) ecological causes and consequences of changes in climate, soil, water chemistry, and land-use patterns; 2) 'ecologica1 determinants and consequences of biodiversity and the effects of global and regional change on biological diversity; 3) definition and detection of stress in natural and managed ecosystems; 4) restoration of damaged systems; and 5) management of pests, pathogens, and disease on a sustainable basis (70, 85). (See box 5-K.)

Our ability to detect and verify resource changes and climate impacts is insufficient. Nevertheless, there are some notable programs (highlighted in box 5-L) that are beginning to bridge the information gaps and could serve as building blocks for future programs. These programs include the Environmental Protection Agency's (EPA's) Environmental Monitoring and Assessment Program, FWS'S Gap Analysis Project, and the National Science Foundation's (NSF's) Long-Term Ecological Research Program.

In early 1993, President Clinton announced the establishment of a National Biological Survey (NBS) in the Department of the Interior.[30] Although the scope and structure of the NBS is still in the formative stages, there are indications that the NBS will consolidate the biological research, inventorying, and monitoring activities for the Department of the Interior into a free-standing,

30 Representative Gerry Studds, D-MA, introduced H.R. 1S45 to establish the National Biological Survey in the Department of the Interior on April 22, 1993. The President's FY 1994 budget requested that $179,445,000 be transferred from the eight DOI bureaus to the NBS. H.R. 2520, appropriations for DOI and related agencies for FY 1994, suggests transferring $163,604,0(X).

Box 5-K—The Sustainable Biosphere Initiative: Articulating an Ecological Research Agenda for Global Change

Responding to the need for definitive scientific priorities in a world of constrained research dollars and a rapidly deteriorating environment, the ecological research community, through the Ecological Society of America, has identified three areas of high-priority research that address fundamental ecological questions as well as concerns about the sustainability of the biosphere: global change, biological diversity, and sustainable ecological systems. The societyhasformalized these priorities in a program called the Sustainable Biosphere initiative (SBI). SBI is a "call to arms" for ecologists as well as a framework for the "acquisition, dissemination, and utilization of ecological knowledge which supports efforts to ensure the sustainability of the biosphere" (70). SBI is envisioned to be broader than a basic research program by contributing to efforts in research, education, and environmental decision making.

Several of the research areas identified by the Office of Technology Assessment (OTA) as important for understanding the nature of climate impacts on natural areas and ecosystems in order to maximize adaptation possibilities (such as restoration ecology and climate-ecosystem interactions) are also identified as high-priority research areas by SBI. The key research topics identified by SBI are listed below (70):

- the ecological causes and consequences of global climate change,
- the effects of global and regional change on biodiversity,
- indicators of ecological responses to stress,
- biological inventory,
- the biology of rare and declining species,
- the restoration of ecological systems,
- the ecology of disease spread,
- the consequences of land and water-use change,
- the causes and consequences of changes in atmospheric, soil, freshwater, or marine chemistry (including changes in carbon dioxide), and
- the development and application of ecological theory to the management of ecological systems.

The Sustainable Biosphere initiative fosters the application of good science to large-scale questions and the use of scientific knowledge to solve critical management issues. An interagency Working Group has been formed to enhance communication and interaction between agencies and to promote decisions that solve critical management issues in away that recognizes the need for sustainable ecological systems.

The Interagency Working Group has identified two interagency demonstration projects, one in south Florida, and one in the Southwestern U. S., focused on the Rio Grande Basin. The vision is to use these projects to demonstrate that several agencies (regulatory, scientific, and management based; Federal, State, and local) plus academia can work together to meet a common objective: sustainability of critical ecological systems.

SOURCES: J. Lubchenco et al., "The Sustainable Biosphere Initiative: An Ecological Research Agenda," *Ecology*, vol. 72, No. 2,1991, pp. 371-412; Office of Technology Assessment 1993.

nonregulatory bureau (5). This change provides an opportunity for the Department to seriously examine its existing and future research needs, improve existing programs, eliminate ineffective ones, and address gaps in research, inventorying, and monitoring that have developed over the years. An examination of existing research programs, as they relate to climate change would contribute to this process by identifying the gaps and strengths of existing research efforts that are important for the long-term management of Federal protected areas and other natural areas.

Research. Although ecological research is one of the overall priorities in the United States Global Change Research Program (USGCRP), relatively little research is being supported that

Box 5-L-Building Blocks for Integrated Information Systems

The U.S. Environmental Protection Agency's (EPA's) Environmental Monitoring and Assessment Program-The Environmental Protection Agency (EPA) launched the Environmental Monitoring and Assessment Program (EMAP) program in 1967. It is aimed at: 1) estimating the current condition of the Nation's ecological resources, 2) monitoring indicators of pollutant exposure and habitat condition, and 3) providing periodic summaries and interpretive reports on ecological status and trends to resource managers and the public (162). The program stemmed from EPA's Science Advisory Board recommendations for a comprehensive program to monitor the status and trends of ecosystems so that environmental problems can be anticipated. This program could be used to help detect and monitor climate-induced changes in the environmental EMAP is meant primarily to provide a "national overview" of ecological status and trends. Because of the large grid size for monitoring, it is not a substitute for intensive, site-specific monitoring that maybe required for actual land management.

The program is organized by resource category: estuaries, Great Lakes, surface waters, wetlands, forests, agroecosystems, and arid ecosystems. The monitoring program for forests is the most developed so far. Several ecological indicators are measured at each monitoring site. *Condition indictators* represent the ecological condition or physical attributes of an organism, population, community, ecosystem, or landscape (e.g., vegetation and species). *Stressor Indicators* can be measured to indicate contact with specific stressors or to quantify natural processes and human-caused events that may affect biota and their habitats (e.g., pollutants). Data are acquired through field surveys, remote sensing (e.g., satellite images and aerial photography), and other monitoring programs. Much of this work is carried out in conjunction with other Federal agencies including the U.S. Department of Agriculture (USDA), the Department of Interior (DOI), the Department of Energy (DOE), the National Oceanic and Atmospheric Administration (NOAA), and the National Aeronautics and Space Administration (NASA). EMAP also draws on other monitoring initiatives, such as the Forest Health Monitoring Program of the USDA's Forest Service and the U.S. Geological Surveys (USGS's) National Water Quality Assessment Program. Twelve Federal agencies and 19 States are participating in EMAP through imperative agreements.

EMAP activities are not limited to monitoring. Other main components of the program include integration and coordination activities that aim to ensure uniform, high-quality sampling and assessment methods, consistent documentation, and effective information management. Research is under way to help improve EMAP through pilot projects. The entire program, when fully implemented, should cost about $100 million annually.[2]

The U.S. Fish and Wildlife service's Gap Analysis Pro]ect-in 1991, the U.S. Fish and Wildlife Service initiated the Gap Analysis Project (GAP), which was intended to aid in State and Federal wildlife acquisition and protection efforts by identifying areas of high biodiversity that are not under formal protection (107)[3] This "pro-active" strategy aims to stem the accelerated rates of extinctions by allowing managers and planners to protect species-rich areas and unprotected vegetation types before they are threatened and on the brink of extinction.

GAP uses information from The Nature Conservancy (a private, nonprofit conservation organization), the Forest Service, the Bureau of Land Management USGS, State agencies and Heritage Programs,[4] and satellite images to map the potential distribution of plants, vegetation cover types, terrestrial vertebrates, endangered and candidate species, and other indicator species to identify areas of potential species richness and uniqueness

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1 It is not clear how this program will contribute to ordrawfromthe inventory and monitoring activities of the new National Biological Survey in the Department of the interior.

2 E.A. Martinko, Director for the Environmental Monitoring and Assessment Program at the Environmental Protection Agency, letter to the Office of Technology Assessment, Oct. 14, 1992.

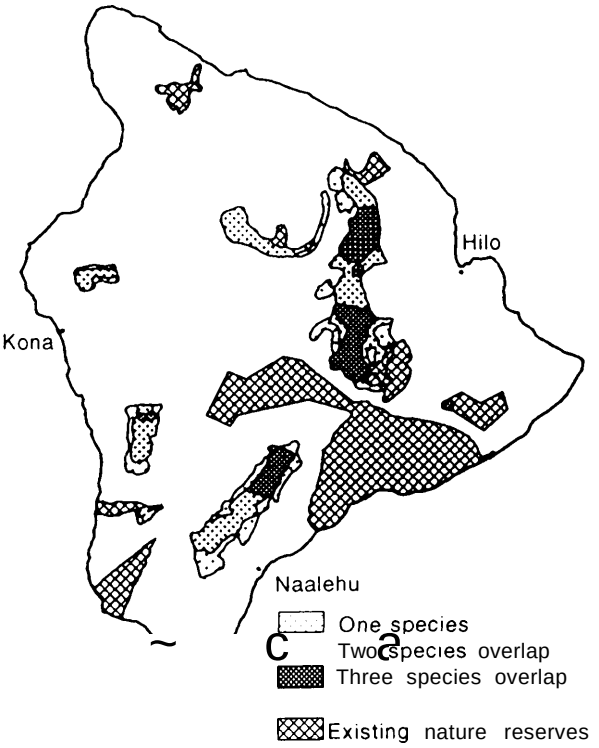
3 it is possible that GAP activities will become part of the new National Biological Survey.

4 State Heritage Programs are cooperative programs between State agencies and The Nature Conservancy for conducting State-wide biological Inventories.

(109). These distributions are overlain with regions under official protection by the State or a Federal agency on a computerized map. The resulting composite reveals "gaps" in protection-areas with high diversity that are not currently protected (see figure at right). This can then help resource managers target protection efforts to maximize the protection of biodiversity.[5]

GAP provides only a general picture of biological resources. Data used for GAP analysis may be incomplete because remote areas were not inventoried, outdated because inventories have not been conducted recently, or too limited because only certain indicator species have been mapped. For these reasons, the vegetation maps produced by GAP maybe best suited as a cost-effective tool for directing more comprehensive biological inventories and for providing a preliminary guide for agency acquisitions, easements, or cooperative agreements. Although localized species may be "missed" with the broad-brush approach, supporters of GAP assert that it could "ensure that the vast majority of species never become endangered."

GAP Analysis Example: Distribution of Endangered Hawaiian Finches in Relation to Existing Nature Reserves on the Island of Hawaii in 1982



SOURCE: National Park Service, 1993.

The National Science Foundation's Long-Term Ecological Research Program-The National science Foundation (NSF) has had a long term research and monitoring program in place since 1980, the Long-Term Ecological Research (LTER) Program. This was the first major program established to provide sustained and systematic support for iong-term studies in ecology (42). Research at each of 17 sites in the United States (and 2 in Antarctica, see figure, next page) combines monitoring activities with basic research focused on five core areas: patterns of primary production, distributions of selected populations, patterns and control of organic-matter accumulation, patterns of other inputs and movements of nutrients through the soil and waters, and patterns and frequency of site disturbance. Because many of these processes require time scales of decades to centuries, LTER projects address spatial and temporal scales normally outside the range of ecological research programs. For this reason, LTER activities may be especially important for climate change-related ecological research.

The LTER program is different from long-term activities in other agencies because it is more rooted in basic research and relies on the peer-review process to ensure continuation of research activities at each site. Because of this focus, the LTER sites were chosen by the quality of research proposals submitted to NSF, not simply by location. However, the existing 19 sites do represent a variety of ecosystem types and degrees of human disturbance (42). Research varies from site to site, but standardized measurements, methods, and software are

[5] S.D. Vickerman, presentation at Managing Western Lands in a Changing Climate, OTA-sponsored workshop held Juiy 1992, National Center for Atmospheric Research, Boulder, CO.

(Continued on next page)

Box 5-L–Building Blocks for Integrated Information Systems-(Continued)

becoming an integral part of the program. Many stations have already produced major scientific findings in watershed disturbance, lake acidification, and climatology.

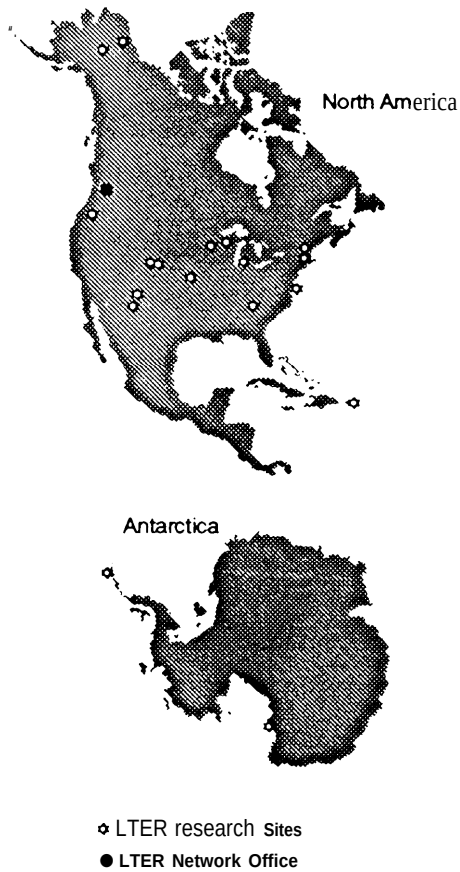
A new plan is being developed for future LTER activity, "LTER 2000," that will create a Global Environmental Research Network. The number of NSF-supported LTER sites will be increased, and links will be made to other sites supported by other Federal agencies to cover key biomes, habitats, and areas lacking adequate coverage.

Because LTER provides sustained, long-term support for basic ecological research, this program could be one appropriate vehicle for expanding and encouraging needed ecological research on climate impacts and responses, as well as for providing long-term baseline information for detecting climate changes in some ecosystems.

The Federal System of Research Natural Areas (RNAs)--This system was established by the U.S. Forest Service in 1927 for conducting nonmanipulative research on a variety of ecosystem types. In the 1930s, the National Park Service (NPS) expanded the idea and began to establish "research reserves" (7). The effort later evolved to include areas for experimental management. A 1974 report of the Federal Committee on Research Natural Areas called for:

- the completion of "the existing National System of Natural Areas, with full representation of major ecosystems, to provide sites for studies of naturally functioning systems that can serve as ecological reference points for baseline monitoring, and as controls for experimental research" and
- 'the National System of Ecological Research Areas, to provide sites for manipulative experiments, management testing, and observations of the results of human impact" (57).

The National Science Foundation's Long-Term Ecological Research Network



SOURCE: Long-Term Ecological Research Network 1993.

The idea of a network of Ecological Research Areas that fully represents the range of ecosystems throughout the United States was articulated in a 1975 report by The Nature Conservancy (57). This vision has only partially been fulfilled. The committee has not met since 1979, the integrated system of Ecological Research Areas never

materialized, and the existing system of RNAs, a subset of the Ecological Research Areas, is not coordinated and is not representative of major U.S. ecosystems (7, 33). There are now about 340 RNAs constituting roughly 5 million acres (2.1 million hectares)[6] of land under various Federal ownerships, although most RNAs arewith the Forest Service. Because RNAs are under the purview of various agencies and because there is no legislative or institutional mechanism to guide management of the system, the RNA system remains a disjointed collection of lands with no overarching management direction.

If the original vision for RNAs is revived, these areas could become an ideal and important part of natural area conservation under climate change. These areas could function as centers for research on impacts of climate change as well as vehicles for studying natural adaptation. However, because RNAs are typically small (14 to 9,000 acres), they should not be solely relied on for long-term protection (1 74).

The Nature Conservancy's National Natural Heritage Program-The National Natural Heritage Program is an inventory program coordinated by The Nature Conservancy, but implemented by state conservation agencies. The goal of t he program is to maintain a "permanent and dynamic atlas and data bank on the existence, identity, characteristics, numbers, condition, status, location, and distribution oft he elements of natural biological and ecological diversity . . . " (86). Rather than attempting to catalog all biological resources, efforts are targeted toward "the last of the least and the best of the rest": rare, endangered, and vulnerable species (86). Comprehensive (though slightly less detailed) inventories are also conducted for communities and ecosystems within each state.

State participation in the program is entirely voluntary, and except for some private start-up funds, funded primarily by the States. Generally, TNC provides training, standards, procedures, and methods and facilitates coordination with other States while the State conservation agencies are primarily responsible for conducting the actual inventories. Heritage programs have been established in all 50 States. Because the program has been in place and refined for nearly 20 years, because it is national in scope, because it has active State participation, and because the methodologies have been established, this program could serve as a model for a federally based inventory and monitoring effort.

Geographic Information Systems-A Geographic information System (GIS) is a computer-based tool used to manipulate and analyze spatial data such as topography, soils, and vegetation. With a GIS, digitized thematic data can be entered, stored, transformed, measured, combined, retrieved, and displayed. Various databases containing information on flora and fauna topography, soils, geology, and hydrology are standardized and overlaid to display a composite picture. The relative ease in analyzing and displaying these data can allow planners and managers to explore and anticipate the results of various planning decisions at various spatial scales.

GISs have been used to predict the occurrence of populations of certain species, to identify potentially suitable sites for certain species, to estimate the quality and quantity of some habitats, to quantify changes in landscape patterns, and to examine some spatial interrelationships (e.g., distances to various habitats could be computed for different conservation strategies). In addition, because "GIS could be used to identify areas undergoing the most rapid change in which conservation needs might be most crucial," it could be a valuable tool for land management and planning under climate change (86). Although use of GISs is increasing, it varies substantiality among Federal agencies, and the extent of interagency coordination is not clear (86).

The Terrestrial Research Interest Group (TRIG)-The Terrestrial Research interest Group (TRIG) is an ad hoc coordinating committee of Federal agencies and other organizations that conduct terrestrial research. Formation of this informal group was spurred by the perception that research on terrestrial impacts of climate change was not adequately addressed in the Global Change Research Program (GCRP). TRIG seeks to provide a forum for the exchange of information on terrestrial research efforts (including climate change research efforts) and to develop a strategy by which these research efforts can be coordinated (65). The strategy includes identifying relevant geographical regions, management concerns, information needs, and scientific research

6 To convert acres to hectares, multiply by 0.405.

(Continued on next page)

Box 5-L-Building Blocks for Integrated Information Systems-(Continued)

needs and developing plans for efficiently coordinating research efforts and linking them to management and for effectively managing data (65).

Although this group is not a funded entity and its members are volunteers, several efforts are under way to help coordinate research activities across agencies. These efforts include the identification of major issues for terrestrial research and management including issues relating to climate change, and the development of an overall strategy document. Because many of the agencies voluntarily involved in TRIG are also represented on the Committee on Earth and Environmental Sciences in the office of science and Technology Policy, TRIG could help facilitate coordination and collaboration between agencies on both research and management issues. However, further expansion of this group would require some formalization so that members could devote more time to coordinating activities.[7]

The Consortium for International Earth Science Information-The Consortium for International Earth Science Information (CIESIN), a nonprofit corporation, was established in 1969 by FY 1990 appropriations for National Air and Space Administration (NASA) as one of the nine data centers for the Earth Observing System, the satellite component of NASA's Global Climate Change Program. By establishing this corporation, the Federal Government sought to broaden the information-management programs and facilities planned for NASA's Earth Observing System (EOS) and to take the lead in creating an integrated information network accessible to decisionmakers at all levels of government (23). However, in 1993, the Senate Committee on Appropriations deleted the full FY 1994 budget request for CIESIN (CIESIN received $75 million in FY 1993)[8] citing a lack of program focus and duplication of effort with the National Science Foundation.

As a part of its missbnio CIESIN was directed to investigate ways to improve data utilization and management for global change. This effort encompassed several functions: 1) develop and maintain the Socio-Economic Data Applications Center for EOS, 2) foster research on the human dimensions of global change, 3) link existing environmental and global change data centers, 4) serve as an international gateway to scientists, educators, and policy makers, 5) conduct regional cause-and-effect studies of global change, and 6) provide data to other international programs and research efforts. Many of these plans were never implemented.

The Terrestrial Ecosystems Regional Research and Analysis Laboratory (TERRA)--TERRA is an interagency research laboratory formed in 1992 under a Memorandum of Understanding (MOU) agreement between the USDA's Agricultural Research Service, Soil Conservation Service, and Forest Service and the US. Geological Survey in the Department of the Interior. As a part of the global change research activities in these agencies, TERRA is organized to "provide a mechanism for strengthening the linkages between terrestrial ecosystem, atmospheric, and human process components of large-scale ecosystem models" (1 17). The objective of the Laboratory is to provide scientific information in support of national and regional decisionmaking that cuts across scientific disciplines and conventional agency responsibilities; TERRA hopes to characterize the interactions between land use, ecological resources, and land management through the development and analysis of regional models (39). It is hoped that these models will ultimately be able to "test" the consequences of various policies and management decisions affecting natural resources by predicting changes in the distribution and nature of terrestrial ecosystems and developing quantitative methods of assessing ecosystem sustainability under various climate change and land-use-change scenarios. To facilitate information transfer to land managers, TERRA envisions creating a "neutral" facility where scientists, managers, and other stake holders can work with the models to help address regional issues and problems.

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7 J.A. Kelmelis, U.S. Geological Survey, letter to the Office of Technology Assessment Sept. 14, 1992.

8 J.R. Lousma, president and CEO of CIESIN, letter to the Office of Technology Assessment Oct. 8, 1992.

SOURCE: Office of Technology Assessment, 1S83.

addresses the uncertainties surrounding the impacts of climate change on ecosystems (see ch. 3). Funding for climate change research within DOI has not been well-supported. In FY 1993, NPS was the only DOI agency to request any increase in USGCRP funding (from $2.6 million to $3.7 million between FY 1992 and FY 1993) (25, 26). DOI was the only participating department that requested a decrease in USGCRP funding in FY 1993 and FY 1994 (25, 26).

Much remains to be discovered about how and to what degree climate factors influence wildlife and plant species, how wildlife interactions enhance or inhibit their ability to adapt, how various changes in vegetation and landscape affect species populations, or what makes a species sensitive to climate change. More generally, little is known about how to facilitate adaptation through either reserve or corridor design, although educated guesses can be made. Transplantation and restoration ecology may become important for saving and protecting more species in a changing climate. However, this discipline is relatively new. Some techniques are not well-developed and others are not widely known (see boxes 5-M and 4-A). The National Research Council (85), the Council on Environmental Quality (30) and the Ecological Society of America (70) have all called for increased efforts in ecological research, especially on larger spatial and temporal scales. One of the functions of the NBS might be to implement research on a large, ecosystem basis (5).

Research for the National Park System is conducted in each individual park unit, through the 10 regional offices, and through some 23 Cooperative Park Study Units with various universities. However, no research is systematically conducted throughout NPS (83). In addition, it is not clear that the existing research efforts are adequate for meeting current management needs, much less management needs for the future. The National Park Service's component of the USGCRP (NPSGCRP)[31] seeks to "provide predictive and holistic understanding of the effects of global change on species populations, ecological communities, watershed processes and landscape dynamics through the coordinated use of parks and benchmark research sites within large [biogeographic areas]" (22). Research activities are centered around the biogeographic area (BGA) concept developed by Unesco's[32] Man and the Biosphere Program (MAB) (see box 5-F), and most NPS research activities for global change take place in U.S. MAB Biosphere Reserves. Although this effort is innovative because it is one of the few USGCRP programs to take a regional approach to climate change research, its scope remains relatively limited, and the program has proceeded more slowly than planned. In addition, scientific research beyond the scope needed for short-term, site-specific management does not receive much support from NPS (83). ''The NPS science program is unnecessarily fragmented and lacks a coherent sense of direction, purpose, and unity," according to a recent study (83).

Most research for the Fish and Wildlife Service aims to aid management efforts and objectives at each refuge. Consequently, "research on systems and species most susceptible to consequences of global climate change is lacking" (66). Research activities at the Fish and Wildlife Service are conducted through 13 national research centers and 89 field stations. The Cooperative Research Program of FWS facilitates cooperative research between FWS, State wildlife agencies, and about 41 universities. Climate change research efforts take place under the FWS Global Change Research Program (FWSGCRP), which seeks to establish a reference base to clearly demonstrate and assess the extent, magnitude, and rate of ecological impacts of global change and to assess the significance of global climate change on FWS resources, especially coastal ecosystems,

31 This program, along with other NPS research activities, is slated to become part of the National Biological Survey.

32 United Nations Educational, Scientific, and Cultural Organization.

Box 5= M-Restoration Ecology: Giving Nature a Helping Hand Under Climate Change

Changes in climate will likely alter the balance of plants and animals that now characterizes natural areas, and could be accompanied by any number of changes in the physical environment including more erosion, flooding or drying, and more frequent or more intense fires. The impacts of climate change will pose a dilemma for managers of natural areas, who must balance the conflicting needs of protecting a specific set of resources, such as endangered species or migratory waterfowl habitat, with the goal of allowing natural ecological processes to proceed (see box 5-B). In some areas, managers may decide that the need to maintain a specific habitat may call for active efforts to protect the plants and animals already in place and to restore habitat that is damaged. In other cases, habitat that has already been damaged by pollution, road building, water diversions, erosion, timbering and grazing, overuse by visitors, and fragmentation (see box 5-E) may now contain the most favorable climate conditions for some species or communities; managers may attempt to add such sites to the boundaries of natural areas and restore them to increase the chances that a given community will survive. In both cases, restoration will be a key part of the management strategy.

Ecological restoration is the attempt to fully restore ecosystems by recreating the entire community of organisms that originally inhabited them. It is different from habitat creation, reclamation, and rehabilitation-each of which can involve manipulation of a small set of species. Restoration involves recreating both the form and the function of a natural ecosystem that is integrated with t he landscape in which it occurs. Restoration varies from site to site, but generally involves two major steps: site preparation to restore desired physical, chemical and water conditions, and biological manipulation including the reintroduction of absent native plant and animal species To begin with, the site is prepared by clearing unwanted vegetation (nonindigenous species), removing contamination, adding topsoil if necessary, and, possibly, grading to create a varied topography. Vegetation is planted, either with seeds from nearby sources of native species or by transplantation of plants from another site. In some cases, measures to restore vegetation maybe more passive--a prepared site maybe allowed to reseed naturally from the surrounding areas or from seed that has remained dormant on-site. However, natural regeneration may be difficult in areas where native species are no longer prevalent or where invasive nonindigenous species are likely to take root quickly. In many cases, animals are allowed to migrate into the area of their own accord, under the assumption that once native vegetation is reestablished, animals will follow. In the case of endangered species, however, managers may devote considerable effort to rearing the species off-site and reintroducing them into the restored habitat.

Early efforts to go beyond simple reclamation and reforestation in attempts to restore full ecosystems were pioneered by ecologists at the University of Wisconsin Arboretum in the 1930s. Researchers there began exploring techniques for restoring the full array of species and functions to prairies and forests that had been cleared for agricultural use. Long-term research on the plots established there continues to yield new information on restoration techniques. Since then, restoration has been applied with varying degrees of frequency and success on other ecosystem types ranging from savanna and shrubland to coastal salt marshes, freshwater wetlands, and rivers and lakes.

One impetus for the development of restoration techniques has been an increasing demand by the Federal Government. Restoration is called for in three separate contexts--regulation, planning, and management. Restoration has entered the regulatory arena through the permit requirements of Section 404 of the Clean Water Act (P.L. 92-500), in which restoration of wetlands can be demanded to compensate for activities that destroy wetlands (see ch. 4), as well as through the requirements covering reclamation of surface mines. Restoration may be part of the planning and construction of federally supported projects as required by the National Environmental Protection Act (NEPA; P.L. 91-190), under which potential damages to the environment and alternatives for mitigating those harms must be evaluated. Finally, restoration is part of ongoing management efforts of many Federal natural areas to combat problems such as overuse by visitors and to protect and restore habitat for endangered species.

An Example of Ongoing Federal Restoration Efforts-More than 3,000 species of wildlife and fish live on Bureau of Land Management (BLM) lands, including 216 federally listed threatened and endangered species and 1,200 candidate plant and animal species BLM manages more fish and wildlife habitat than any other organization. These highly diverse habitats encompass deserts, rangelands, mountains, forests, and tundra.

In 1988, BLM launched an action-oriented program aimed at the more efficient management of the fish and wildlife resources on public lands. The program, Fish and Wildlife 2000, seeks to "ensure optimum populations and natural abundance and diversity of wildlife resources on public lands by restoring, maintaining, and enhancing habitat conditions." A related BLM effort, the Riparian-Wetland Initiative for the 1990's, which was launched in 1991, focuses on restoration and maintenance projects for riparian areas and wetlands with the goal of having over 75 percent of these areas in functioning order by 1997 (138). BLM has utilized a variety of outreach and cooperative programs with States and private citizens to achieve its goals in habitat restoration and improvement efforts. This collaborative approach with partners is enabling BLM to stretch Federal funds and accelerate on-the-ground management and restoration efforts.

BLM estimates that the Fish and Wildlife 2000 will require about $90 million per year for 10 years and the Riparian-Wetlands Initiative will require a total of $127 million for full implementation. However, these programs have not obtained the funds or personnel requested to date. The FY 1993 budget for *Fish and Wildlife 2000 is some $36* million, or about one-third of the planned funding level. Despite this, BLM has made substantial progress in several areas. In California, efforts are under way to restore the hydrologic function and improve the habitat quality for the Modoc sucker on a 9-mile (16-km) segment of Cedar Creek. In Montana, 3,800 acres (1,520 hectares)[1] of wetlands are to be created in native prairie to increase nesting habitat for waterfowl. In addition, other vegetation management is planned to create habitat for a variety of other species in this area.

Despite the increasing demand for restoration techniques, restoration ecology is still a young science. Problems encountered in restoration include site selection, survival of transplanted flora and fauna inadequate nutrient supplies for plant growth, and pest invasions (83). Restoring an ecosystem to its former condition requires a detailed understanding of the numerous components and functions that characterize it; for many types of ecosystems, ecological knowledge is incomplete at that level of detail. To date, restoration research has tended to focus primarily on techniques of reestablishing species composition and community structure. The functional values of restored areas, although widely recognized, are seldom evaluated. For example, it has not been shown that restored wetlands maintain regional biodiversity and recreate functional ecosystems (83). Considerable research is needed in many areas of basic ecological interactions as well as further experimentation on a wide array of ecosystems to ensure that the practice of restoration yields predictable and desired results.

Even as restoration techniques are being refined, the potential for climate change raises new challenges. Past restoration efforts have generally sought to recreate self-sustaining ecosystems in their original conditions-the way they were before human actions disturbed them. But as climate changes, the environmental conditions that originally shaped an ecosystem may fundamentally change, so that an ecosystem restored to its original or natural condition may no longer be self-sustaining. Whereas ecologists are trained to think of ecosystems as dynamic and evolving, much of our natural resource legislation focuses on saving a particular resource in a particular place-a freeze-frame in the film of ecosystem evolution. At what point should restorationists take t hat snapshot? To what should an ecosystem be restored if t he climate has changed around it? As species migrate in response to a changing climate, which will be considered the native species, and which will still be considered nonindigenous? What are the implications of introducing new species that maybe more adapted to the new climate conditions? A changing climate will test the boundaries of the Nation's present thinking about species and ecosystems.

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1 To convert acres to hectares, multiply by 0.405.

SOURCES: J.L. Berger and L.A. Riggs, *Ecological Restoration and Non-Indigenous* Speck, contractor paper prepared for the Office of Technology Assessment, August 1991; W.R. Jordan, R.L. Peters, and E. E?. Allen, *Ecological Restoration* as a Strategy *for Conserving Biodiversity,* contractor paper prepared for the Office of Technology Assessment, January 19SS; National Research Council, *Restoration of Aquatic* Ecosystems (Washington DC: National Academy of Sciences Press, 1992).

prairie pothole wetlands, and priority fish and wildlife (147). Support for these important research efforts has waned. In FY 1993, $3.1 million was allocated for the FWSGCRP program, representing a 14 percent decrease from FY 1992.

There is no coordinated research program for the Wilderness Preservation System. All research activities for Wilderness Areas are subsumed in the research programs for the agency that administers each area. However, research activities in place in Wilderness Areas may provide useful information to guide future management under climate change (e.g., monitoring forest health or improving understanding of ecosystems). Only one climate change project, Ecological Change in Environmentally Stressed Ecosystems of the Western and Northern United States, has been funded ($1 million) at BLM despite the large acreage it administers (270 million acres). The Forest Service maintains a larger global change research program (FSGCRP) ($22 million). FSGCRP focuses on four research elements: 1) gas and energy exchange between the biosphere and atmosphere; 2) disturbance ecology; 3) ecosystem dynamics; and 4) human activities and natural resource interactions. FSGCRP is conducted through five regional programs, each addressing the four research elements (134). Because funds are limited, activities tend to focus on immediate management concerns and popular or controversial species (66).

Inventorying and Monitoring. Inventorying and monitoring are extremely important for detecting changes in natural areas (97, 126, 166). However, inventory and monitoring efforts for Federal natural areas are inconsistent, uncoordinated, and often incomplete for establishing a baseline assessment of resource status and for monitoring changes over the long term. NPS maintains a policy to inventory and monitor its resources, and most park units have written descriptions of the plants and animals occurring on park lands. However, NPS inventorying and monitoring efforts are extremely varied in scope and quality from unit to unit, and data are not standardized or properly cataloged (83, 115, 177). Monitoring efforts are often directed at "popular" species and undertaken for management considerations, rather than at representative species and for studies of long-term trends (115, 177). Less than 30 percent of all National Parks maintain adequate data for addressing management questions or for making informed management decisions (154). In 1992, NPS started a program to conduct more complete inventories of NPS lands, and this program is likely to continue under the direction of the new National Biological Survey.

The Fish and Wildlife Service has, possibly, the most complete inventory of the animal species that occur on the lands it manages because of its strong biological focus. Most vegetation inventory efforts focus on wetlands through the National Wetlands Inventory Program. Most wildlife inventory and monitoring efforts emphasize waterfowl, endangered species, and game species. Nongame species receive limited attention (66). Few refuges monitor activities on important adjacent lands, so data sets are incomplete and not representative of the whole ecosystem (66). Some

U.S. FOREST SERVICE

Many western rangeland have been overgrazed by cattle (land on right side of fence), causing declines in biodiversity, loss of soil richness, and increased erosion. Some of these ecosystems are under continuous stress and utilized beyond their carrying capacity.

managers only inventory animals found on the refuge, and some inventory both animals and plants. There is no explicit statutory mandate to conduct inventory and monitoring activities on Wildlife Refuges (66).

There is no systematic mechanism for inventorying and monitoring resources in the Wilderness Preservation System as a whole. Inventory and monitoring efforts for Wilderness Areas are generally subsumed in the inventories of each land-management agency that contains them. Most efforts focus on the most visible impacts, whereas monitoring for more subtle changes in air quality and vegetation status are ignored because adequate funds and personnel are not available. Both the Forest Service and BLM have explicit statutory mandates to inventory their resources, including those in Wilderness Areas. Despite this mandate, many units have not been inventoried (164), and the most detailed inventories are conducted for timber resource lands-not Wilderness Areas (66). Only about 15 percent of BLM-administered land has been inventoried according to minimum standards for vegetation set by USDA's Soil Conservation Service. Less than 5 percent of BLM lands have been inventoried for their wildlife habitat, according to BLM's Habitat Inventory and Classification System, and less than 5 percent of BLM riparian areas and wetlands have been inventoried, according to a parallel inventory system for wetlands (66). In addition, a comprehensive listing of fragile or endangered species is not available, and very few species are included in BLM's Threatened and Endangered Species Data System (66).

Since the early 1980s, the Forest Service has promoted a system--called "Limits of Acceptable Change'—for detecting changes in the conditions of wilderness resources and for guiding management activities. Under this step-by-step approach, issues of concern are identified, indicators of condition are chosen, standards for the condition of wilderness resources are set according to these indicators, and management activities are designed and chosen based on the entire evaluation (113). However, the success of this management tool relies heavily on complete and accurate inventories and routine monitoring of changing conditions. According to a 1988 survey, 76 percent of wilderness managers had not used this tool for wilderness management (164).

In response to the public's concern about a wide range of environmental impacts, such as acid rain and the subdivision of large forest tracks for residential use, Congress directed the Forest Service to initiate a program to monitor the health of the Nation's forests (Forest Ecosystems and Atmospheric Pollution Act of 1988, P.L. 100-521). Forest health monitoring under this act is carried out by the Forest Service, EPA, and State forestry agencies (132).

POLICY OPTIONS

The Policy Challenge

Climate change threatens the security of the Nation's investment in natural areas. Substantial land, money, and time have been invested in establishing various systems of natural areas throughout the country to ensure that they are protected for future generations to enjoy. A variety of problems, such as fragmentation, pollution, and overuse, faces natural areas today, and climate change will likely compound these problems and pose new threats to protected natural areas.

The optimal climatic regime for many natural area resources may shift to well outside the legislatively established boundary that protects them. It is not clear how climate change will affect certain species in protected natural areas, but it is certain that species composition will change, and that research to establish baseline information and to detector anticipate that change is currently inadequate to inform decisionmaking. It is also unclear which species will adapt, migrate, or become extinct. However, it is clear that development and fragmentation around and within natural areas are already contributing to

species loss and greatly inhibit any ability to adapt or migrate. Climate change may affect the ability of land-management agencies to protect biodiversity and rare species and provide certain types of recreation opportunities. This may affect the ability of land-management agencies to protect biodiversity and rare species and provide certain types of recreational opportunities.

The management philosophies and preservation goals for natural areas may simply be untenable under climate change and may have to be modified. To minimize loss of some resources, intervention, protection, and acquisition approaches may need to be altered. With the high level of uncertainty surrounding the nature of climate change and its regional impacts, it is difficult to identify exactly what should be done to minimize adverse effects on natural areas. However, climate change presents a long-term strategic dilemma for natural area management that needs to be considered now (see box 5-B). Although estimates cannot be made of how much of which types of habitat will be lost, some types of habitat loss due to the dual impacts of climate change and human activity will likely occur despite attempts to adapt.

While addressing threats that are currently affecting federally protected natural areas, there are many ways to prepare for climate change in natural areas that will minimize its impacts.

Congress could help combat the factors that might inhibit adaptation to climate change by approaching land management on a larger, ecosystem-oriented level. Although the definition of "ecosystem management' or how it should be implemented is not clear, some models are beginning to emerge that generally include large-scale management and cooperation. Congress could help agencies combat stresses that could inhibit adaptation to climate change by building from or supporting existing research and development models, by supporting research and monitoring on a regional scale, by supporting Federal agency activities that seek to pursue the ideals of ecosystem management, and by providing incentives for States and private landowners to participate in ecosystem-oriented programs. Many of the options described below could be used to further the ecosystem management concept.

The following policy options fall into two broad categories: strategic information gathering and enhanced protection. Despite this categorization, which splits "research" and "management' issues, the need for strong links between the two cannot be stressed enough. Research that might help guide future management of protected natural areas is not useful if the information is not made available and effectively communicated to managers and decisionmakers.

Strategic Information Gathering

A better understanding of how ecosystems change over time, interact with one another, and respond to climate variables and management activities is a necessary frost step in coping with climate change in natural areas. The policy options for research and for inventorying and monitoring are summarized in table 5-5.

Table 5-5-Options for Strategic Information Gathering

Research

- Increase funding for the "Ecological Processes" research area in the U.S. Global Change Research Program.
- Make research on natural resources a key component of a broadened global change program.
- Direct the National Academy of Sciences, the Office of Science and Technology Policy, or an independent commission to assess the applicability of ongoing environmental research to provide long-term guidance for natural resource protection under climate change.
- Support coordinated research in federally protected natural areas.

Inventorying and monitoring

- Create a national program for inventory and monitoring.
- Create a line item in agencies' budgets for inventory and monitoring activities.
- Direct agencies to identify principal gaps in inventory and monitoring activities within existing programs.
- Support programs that have the most urgent inventory and monitoring needs.

SOURCE: Office of Technology Assessment, 1993.

Strengthen *Research Efforts*

Even if climate scientists determine the exact rate and nature of climate change tomorrow, land-management experts would not know how to respond appropriately. Research in federally protected natural areas is currently focused on immediate management issues, and very little research is being done to provide fundamental, long-term data (e.g., on species response and sensitivity to various climate variables, species interactions and dependence on one another, restoration ecology, preserve design, corridor design and effectiveness, and transplantation ecology).

A commonly cited solution for accommodating species shifts in a fragmented landscape is to facilitate species or ecosystems migration by establishing corridors or by transplanting species to their ''appropriate' new range. Although theoretically possible, the knowledge base for such options is very incomplete. Pilot projects are ongoing in some places, especially for wetlands (see box 4-A). Research activities that do address these issues are often carried out in centers separated from where management and decision-making take place, so they are less able to directly influence management.

Option 5-1: *Increase funding for the "Ecological Processes' research area in the U.S. Global Climate Research Program. The* Subcommittee on Global Change Research under the Committee on Earth and Environmental Sciences (see fig. 3-1) has prioritized global change research for all scientitfic disciplines to help guide Federal funding of the U.S. Global Change Research Program (USGCRP). Under this structure, "Ecological Processes" is the third-highest (out of seven) national priority research area for global change (see fig. 3-2). However, 17 percent of the USGCRP budget is allocated for research under ecological systems and dynamics. In 1993, of this $224 million, 66 percent ($148 million) is for NASA programs, 15 percent ($37 million) is for USDA (25), and 4 percent ($9 million) is for DOI.

Increased funding for land-management agencies to carry out ecological research related to global change (e.g., larger spatial and longer temporal scales) would more directly address management concerns. Whatever the funding source, relatively modest funding increases spread over a few years could significantly help to advance the understanding of ecological systems under climate change (see ch. 3).

Option 5-2: *A-fake research on natural resources a key component of a broadened global change program.* Arguably, research that would most help prepare for climate change in natural areas (i.e., on reserve design, migration patterns, and translocation ecology) is not applicable solely to the climate change problem. Such research would also be valuable for other environmental goals such as preserving biodiversity, conserving rare species, and mitigating impacts from landscape fragmentation. In fact, climate change may not be the most compelling reason to conduct the kind of research needed for long-term protection of natural areas. Therefore, the existing USGCRP, now primarily a climate research program, may not be the most appropriate mechanism for promoting natural resources research that has significant application to a much broader set of global environmental problems.

On the other hand, no other mechanism coordinates research on global-scale environmental problems across the Federal Government under a prioritized scheme to accomplish specified scientific goals and objectives. USGCRP offers the best alternative to agency-by-agency research on global environmental problems. If USGCRP is expanded to address broad issues of global change, it could better promote research for long-term protection of natural areas on several fronts. (See ch. 3 for more discussion of these issues.)

Option 5-3: *Direct the National Academy of Sciences, the Office of Science and Technology Policy (OSTP), or an independent commission to assess the applicability of ongoing environmental research to provide long-term guidance for*

natural resource protection under climate change and other global changes. It *is* evident that one of the most prudent approaches to natural area conservation under climate change is more coordinated management on the ecosystem or regional scale. This approach would also help address threats to biodiversity and maximize possibilities for species survival under climate change. However, relatively little research is being done on ecosystem or regional-level interactions (30, 70)---most research is site- or species-specific. Several efforts in various agencies could be supported and expanded to facilitate ecosystem-level research (see boxes 5-F and 5-L).

Several recent studies have called for an assessment of U.S. environmental research (see ch. 3). The Federal Government spends about $900 million on environmental research annually.[33] Although this figure is huge (almost as much as the entire USGCRP budget; see ch. 3), the term "environment" is also quite broad. It is unclear how much of the research is applicable to unmanaged ecosystems, and how much is coordinated to provide answers for long-term problems like climate change and biodiversity. A task force could attempt to categorize this pot of money for environmental research in several ways: How much is being spent on various natural resources: air, water, land, wildlife, soil, forests, crops? How much is being spent on various environmental problems: pollution, biodiversity loss, climate change, contamination, hazardous waste, natural disasters? How much is being spent on long-term issues?

A study conducted by the National Academy of Sciences, OSTP in the Office of the President, or an independent commission could examine programs addressing these areas, including programs within USGCRP, and suggest how they could be expanded, augmented, or integrated. Such a study could build on NSF's ongoing analysis of environmental research (unpublished).

Option 5-4: *Support coordinated research in federally protected natural areas. The* research programs for Wilderness Areas, National Parks, and National Wildlife Refuges are uncoordinated or inadequate. Because the agencies that administer these areas have traditionally been seen as management agencies, scientific research has not been a high priority--except to address immediate, agency-by-agency management concerns. However, with the uncertain impacts of climate change coupled with existing threats on natural area resources, informed management decisions will be nearly impossible in the future without a strong research effort. The National Academy of Sciences has recommended the development of a National Environmental Research Plan (85). This plan would set a research agenda and identify agency responsibilities.

NSF's Long-Term Ecological Research Program conducts basic ecological research and long-term monitoring at 18 sites (see box 5-L). This program could be investigated as a model for long-term research in the Federal system of natural areas. Although LTER research is not formally focused on management activities, much of this basic research has contributed to a better understanding of specific sites with direct implications for future management (42). NSF also supports basic research in areas such as sensitivity of species to climate change and restoration and translocation ecology.

A formal mechanism for linking research results to management decisions and planning should be incorporated into any natural areas research agenda. There is a danger that if research responsibility is taken away from the land-management agencies without sufficient links to management in place, land managers will not be aware of or will even be uninterested in scientific results that could lead to more effective management.

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33 J. Gosz, Executive Secretary, Subcommittee on Environmental Biology, Committee on Life Sciences and Health, Federal Coordinating Council for Science, Engineering, and Technology, personal communication, Sept. 14, 1993.

Strengthen Inventorying and Monitoring Efforts

Adequate information about the existing state of U.S. resources in natural areas and elsewhere is an important element in a strategy to address the impact of climate change in these areas. Baseline information on species and their ranges are not available for all species or species types in the United States. In addition, virtually no information is available on land-use patterns that might affect those species. Inventory and monitoring programs are usually the last to get funds and the first to be cut in a budget crisis (83, 177). Many monitoring programs that have been established in protected natural areas have been discontinued because of personnel changes, policy alterations, or budget cuts (177).[34] Baseline information is needed on the status and trends of vegetation cover, plant distributions, animal distributions, soils, and water resources to detect and monitor climate-induced changes. All Federal agencies conduct some type of inventory as a matter of policy, but these efforts vary widely in completeness and quality, are not consistently implemented and funded, and are not coordinated at the national or even agency level. In addition, many species and ecosystems are not found in the Federal system of preserved areas and, therefore, they are not included in any Federal inventory and monitoring efforts. The Federal Government could play a key role in improving inventory and monitoring activities.

Option 5-5: *Create a national program for inventory and monitoring.* A nationwide inventory and monitoring program with consistent and comparable inventory methods across all Federal and State agencies would help assess the state of the Nation's resources. Such a program could help facilitate regional planning by providing a broad understanding of the resources within various regions, guiding Federal acquisition and conservation incentive programs, and detecting large-scale changes in natural areas.

An interagency task force could evaluate existing efforts, identify shortcomings, and outline a national program that addresses gaps in data gathering. Nationwide minimum standards, methods, and, possibly, reporting procedures for inventory and monitoring activities could be developed. All Federal agencies with land-management responsibilities could be required to adhere to these standards, and States and private organizations could be encouraged to adopt these standards as an eligibility requirement for receiving conservation-oriented Federal grants. The National Biological Survey within the Department of the Interior could help integrate activities within DOI and serve as a liaison with other groups. Although the NBS could take the lead in this effort, it is essential that the Forest Service and other USDA agencies, the National Science Foundation, the Environmental Protection Agency, and the Department of Energy be included in the task force. In addition, State agency representatives and private organizations, with existing inventory programs, such as The Nature Conservancy should also be included. Several existing efforts, such as EPA's Environmental Monitoring and Assessment Program (EMAP), the U.S. Fish and Wildlife Service's Gap Analysis Project (GAP) program, and The Nature Conservancy's National Heritage Program, could be expanded or incorporated into an integrated Federal effort (see box 5-F). At the request of the Secretary of the Interior, the National Research Council has formed the Committee on the Formation of the National Biological Survey to study these issues.

A national inventory and monitoring program should include a clearinghouse, possibly through NSF or NBS (see box 5-L), for storing and evaluating information so that it would be easily accessible to interested parties.

[34] For example, in FY 1993, BLM eliminated 6 of its 16 acid-rain stations to release about $30,000 for other BLM activities. Several of the six stations had been in operation for 10 yearn and had been maintaining data sets to monitor the health of forests and the effects of acid rain. Continuation of this longer-term record was lost as a result of these cuts.

In developing a nationwide comprehensive inventory and monitoring system, it is important to ensure that the minimum standards and methods can be reasonably applied to all types of land under all types of ownership and management. Many National Parks and other protected natural areas, for example, have special inventory and monitoring needs, depending on their missions and specific legislative purposes (e.g., managing threatened and endangered species or encouraging visitor use). Whatever standards are developed should allow enough flexibility to accommodate the needs of individual areas while achieving national objectives.

Finally, a concerted effort to connect, in a timely manner, the information contained in a national inventory and monitoring program to the resource management and land-use planning process is vital. If these connections are not adequately addressed, the gap between research and management could increase with the establishment of a separate research agency in DOI.

Option 5-6: *Create a line item in agencies' budgets for inventory and monitoring efforts.* A line item in agency budgets will ensure that inventory and monitoring is receiving consistent, adequate, and long-term attention. However, although a budget line item may help ensure more specific attention to the activity, it does not guarantee consistent or long-term funding. It may, in fact, become a more visible target for cutting in budget-stressed times. NSF's Long-Term Ecological Research (LTER) Program is funded on 5-year cycles (see box 5-L). A similar funding cycle for other agency programs might help give them more long-term funding stability.

Option 5-7: *Direct agencies to identify principal gaps in inventory and monitoring activities within their existing programs.* Congress could address inventory and monitoring issues at the agency level by focusing on the essential information that is missing from existing programs. Agencies could be directed to develop a priority list for inventory and monitoring needs with cost estimates. This priority list could be used to guide funding decisions for agency activities over a period of time. However, it is likely that these lists will vary according to each agency's missions.

Option 5-8: *Support programs that address the* most urgent *inventory and monitoring needs.* A national-scale survey of the Nation's biological resources (even if it is a broad-brush survey) is needed now to help foster regional land-use planning and to provide better protection, now and in the future, for the Nation's natural areas. Remote-sensing technologies and geographical information systems (GISS) are powerful tools that provide regional information on biological resources, topography, and land use. The Fish and Wildlife Service's **Gap** Analysis program synthesizes information from satellites, State heritage programs, and Federal agencies to identify vegetation-cover types, potential habitat for particular species, and areas of potentially high species richness as well as information on land-use and protection status (see box 5-L). Support for this program could produce a crude national inventory by **1998.** Although EPA's EMAP project is another national-scale inventory and monitoring program that may be valuable in detecting long-term trends and assessing the status of various resources, methodologies are still being developed. Land use and ownership are currently not part of the program, and its spatial resolution may be too coarse to guide regional-scale planning.

Enhanced Protection

Federally protected natural areas are a haven for some species, and they have become a central part of species-protection efforts. But natural areas and the habitats they protect are not immune to human disruption-habitat destruction, pollution, and other stresses threaten more and more species with extinction (126), and climate change may exacerbate these stresses. Many federally protected natural areas are already too small to contain functioning ecosystems for many large animals (29, 51, 76). Because of these combined factors, existing natural areas may be less able to

protect species in the future; other currently unprotected lands may become more important for species survival. Protection for existing and future natural areas can be enhanced in several targeted ways through both direct and indirect Federal actions and by encouraging multi-government-level partnerships. Options for enhanced protection are summarized in table 5-6.

Table 5-6—Options for Enhanced Protection

Direct Federal action (acquisition and management)
- Direct agencies to modify their criteria for land acquisition to include underrepresented ecosystems, long-term survivability and connecting or enlarging land parcels.
- Increase appropriations for the Land and Water Conservation Funds to give States and agencies more power to acquire land and provide easements.

Indirect Federal action (incentives and cost-sharing)
- Use current conservation incentive programs administered by the Secretaries of Agriculture and Interior to enhance the Federal effort to protect natural areas.
- Encourage ecosystem-level conservation at the State level by funding the Fish and Wildlife Conservation Act of 1980 (P.L. 96-366).

Multilevel partnerships
- Use "cooperative research and management funds" to foster cooperative management among agencies.
- Create a Federal Coordinating Council for Ecosystem Management.

SOURCE: Office of Technology Assessment, 1993.

Direct Federal Action

Direct Federal action-such as revising agency mandates and modifying criteria used for acquisition, land transfers, and exchanges-could be used to enhance the Federal system of natural areas and make them less vulnerable to climate change.

Acquisition policies for the National Park Service and the Fish and Wildlife Service do consider biological diversity and reflect a desire to include a variety of ecosystem types. In addition, all agencies that administer natural areas have some kind of size requirement in their acquisition policies that gives preference to larger areas for protection. No acquisition policy gives preference to areas that are adjacent to or link existing natural areas-a criteria that could greatly benefit the preservation of natural areas in the future. Biodiversity is not considered in USDA Forest Service and BLM wilderness designations. In addition, although a variety of ecosystems is federally protected, there is little duplication and many ecosystems types are still unprotected. One study revealed that of 135 ecosystem types, 24 percent were inadequately represented and 7 percent were not represented in any Federal land system (see figs. 5-8 and 5-9).[35] Another study of just the Wilderness Preservation System found that of 233 ecosystem types, 65 percent were found to be inadequately represented (occurring on less than two units of 1,000 acres or more) and 21 percent were not represented (32).[36]

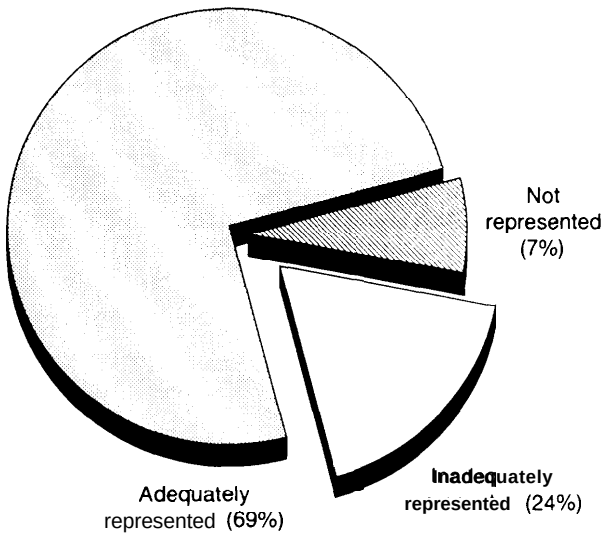
Research Natural Areas (RNAs), first officially established in the 1970s as lands from each land-management agency designated for special research and monitoring, were to form a system that would have representatives of all ecosystem types (57) (see box 5-L).[37] The Federal Committee on Ecological Reserves, established by the Johnson administration, was to explore possibilities of expanding the RNA system to include additional Federal lands as well as State, local, and private lands, and to develop guidelines and criteria for management. Though it has not been formally disbanded, the committee has not met since 1979 due to lack of funding and staff (7).

35 The study used 1982 ownership maps based on Kuchler's Potential Natural Vegetation Types (33). "Inadequately represented" meant that relatively small acreages were protected in the Federal system of protected lands (includingNational Forests and BLM-administered Public Lands as well as Indian reservations).

36 This study used a slightly different delineation of ecosystem types as specified for the Forest Service's wilderness evaluations.

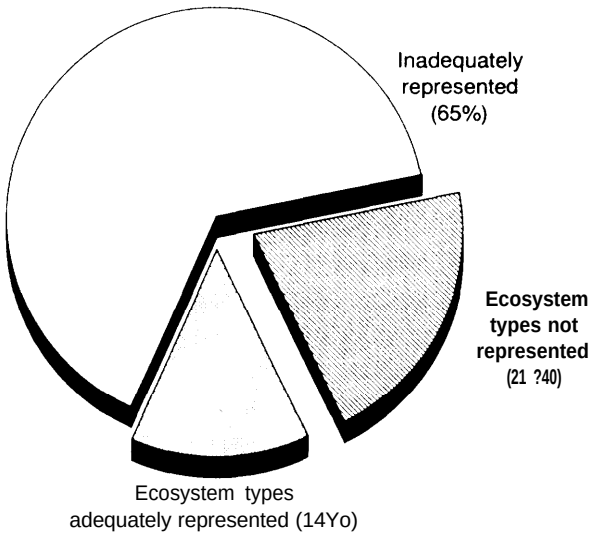
37 Although both the USDA Forest Service in the 1920s and the National Park Service in the 1930s set aside some Of their lands for research and monitoring, these lands did not become part of a coordinated Federal system of Research Natural Areas until the 1970s.

Figure 5-8-Ecosystem Types Represented on Federal Land



SOURCE: Office of Technology Assessment, 1993.

Figure 5-9-Ecosystem Types Represented in National Wilderness Areas



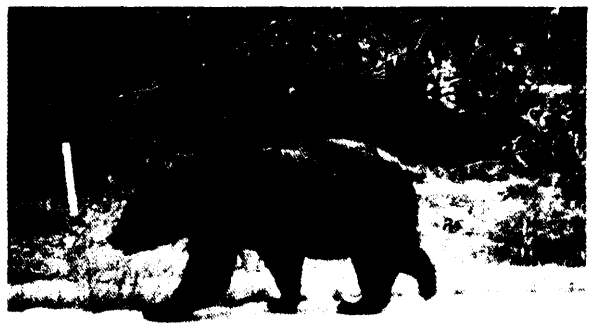
SOURCE: Office of Technology Assessment, 1993.

Because Federal acquisition means that lands are removed from the local tax base, the potential exists for negative third-party effects on the local economies in areas where land acquisitions take place. The main Federal program to compensate for this loss, the payment-in-lieu-of-tax program, may not be perceived as adequate compensation in some counties (127). In addition, Federal land acquisition is a particularly volatile issue in the West. Many local communities perceive Federal acquisition as a "taking" of their land and, effectively, an invasion of their "right" to it. Therefore, there may be substantial political resistance to new acquisitions in some areas. Congress could avoid, or at least temper, some of these conflicts by protecting corridors or adjacent lands through easements or other incentives where land does not change ownership.

Option 5-9: *Direct agencies to modify their criteria for land acquisition to include under-represented ecosystems, long-term survivability and connecting or enlarging land parcels.* Congress could revitalize the Federal Committee on Ecological Reserves or create another committee with representatives from Federal agencies, environmental groups, States, and citizen advisory groups and direct it to conduct a study to determine what ecosystem types are not adequately represented in the Federal system of reserved and protected lands. Congress could direct the managing agencies to develop long-term strategic "protection plans" for each federally protected natural area system. When designating new Wilderness Areas, National Wildlife Refuges, establishing new National Parks, or acquiring additions, agencies should target areas containing high natural biological diversity, unrepresented ecosystem types, areas with climate-sensitive species, areas with unique biotic communities, and areas adjacent to existing protected areas. It is not the explicit policy of any land-management agency (except the Fish and Wildlife Service) to target future acquisitions to protect or augment existing holdings and make them larger, to link holdings together, or to maximize the variety of ecosystems or the level of

biodiversity.[38] Yet, effectively enlarging protected areas, creating appropriate migration corridors, and ensuring that all ecosystem types are under a protection system are frequently cited as the best ways to begin preparing natural areas for climate changes (13, 29, 94, 96, 111, 161). However, whether or not an area can ultimately be managed or acquired to protect a natural area may depend more on political factors than on ecological factors because of the potential for negative third-party effects.

Protection strategies could include options for securing and quantifying necessary water for natural areas (see box 5-H) and for helping to mitigate internal and external stresses. Agencies could outline how survivability would be achieved through integrated and coordinated efforts with other Federal agencies as well as with State, local, and tribal governments and private organizations.



Fragmentation of habitat, by human development in remote and wild areas, has led to the dispersal and decline of many species. Wildlife that depend on corridors of habitat for food and cover have been forced to survive with severely limited resources.

Indirect Federal Programs

The Federal Government has initiated several programs that encourage State and private landowners to protect the natural resources on their land. These programs were initiated for a variety of reasons: to slow erosion, to slow wetland loss, or to protect game species. Few of these programs are designed to augment the Federal protection effort. And, with the exception of programs for game species, there are few Federal "incentive" programs to protect species while populations are still healthy. Addressing both or either of the other issues would create more coherent programs better suited to aid the Federal effort to protect natural areas while at the same time achieving the broad goals for which the programs were established.

Option 5-10: *Use current conservation incentive programs administered by the Secretaries of Agriculture and Interior to enhance the Federal effort to protect natural areas.* Numerous incentive programs already in place aim to encourage land conservation. The Conservation Reserve Program and the Wetlands Reserve Program offer easements to landowners who enroll highly erodible lands and wetlands into the program (see ch. 4). The Federal Aid to Fish and Wildlife Restoration Programs (the Dingell-Johnson and Pittman-Robertson programs) are Federal-State cost-sharing programs funded by excise taxes on fishing and hunting equipment for projects that benefit fish and game. The Forest Service's Forest Stewardship Program encourages forest conservation by providing financial assistance to private landowners to prepare and implement an approved stewardship plan. However, none of these programs are targeted to augment the Federal effort embodied in the Federal natural area systems. Many of these programs could be used to effectively enlarge protected natural areas, to create links between habitats, or to preserve biodiversity or special vegetation types on private land.

Administering agencies could give preference to lands that are adjacent to, link up with, or otherwise augment federally protected land.

38 In designating new Wilderness Areas and National Parks, however, some consideration is given to unrepresented Or underrepresented ecosystem components.

Alternatively Congress could increase the easement benefits or the Federal share of payment offered for desirable lands.

Option 5-11: *Encourage ecosystem-level conservation at the State level by funding the Fish and Wildlife Conservation Act of 1980. Federa1 laws are* now in place to protect both game species and endangered species on non-Federal land, but there is no mechanism to protect species between the two extremes of "hunted" or "totally protected" until they decline to the point of near extinction. The Fish and Wildlife Conservation Act passed in 1980 could fill a large gap in the Federal protection effort and help minimize species loss under climate change. This act establishes a cost-sharing program with the States for nongame wildlife-conservation projects. Funding for the program must be congressionally appropriated, but no money has ever been appropriated. The program could augment Federal protection efforts especially if geared more broadly to protect ecosystems rather than individual species.

Partnerships Among Different Agencies and Levels of Government

Because of shortages in funds and lack of large pieces of available land to establish new protected natural areas, protection of natural area resources will require unprecedented levels of coordination and cooperation in management and research among Federal agencies; State, local and tribal governments; private landowners; and interest groups. There are many examples of innovative protection mechanisms to draw on in establishing effective partnerships. Most use a graded management system, where the innermost areas receive the most strict protection and more uses are allowed for the outer areas. This is the management scheme supported by Unesco's Man and the Biosphere program (MAB), The Nature Conservancy's Last Great Places Initiative, and the Pine Barrens National Preserve in New Jersey. All of these programs and others are outlined inbox 5-F. A high degree of local participation and support, willingness **to** compromise, and adequate compensation for those who sacrifice development rights are vital to project success (68, 168). Congress could encourage cooperative efforts and spur local support by funding cost-sharing programs and challenge grants, by linking a portion of agency funds with cooperative efforts, and by offering other incentives, such as income tax breaks, to those who are willing to participate in conservation and protection programs.

In addition, partnerships are becoming a popular way to enforce the Endangered Species Act (P.L. 93-205). Under Section 10 of the revised act, a party may be permitted some destruction of an endangered or threatened species if a habitat conservation plan (HCP) is prepared with the cooperation of Federal, State, and local governments to arrange for the "permanent' protection of critical habitat elsewhere. The development of an HCP often results in the establishment of a federally protected natural area. If this method becomes more widely used to protect endangered species, the Federal Government will need to ensure that national interests are protected during negotiations. (See box 5-D for a more detailed discussion of the Endangered Species Act and HCP.)

Whatever the protection mechanism, efforts should aim to create a diverse network (regionally and biologically) of protected areas of maximum size (111). Although federally protected natural areas will remain the focus of conservation efforts, a complete, diverse, and representative preserve network will require consideration of other Federal systems as well as State and private holdings.

Option 5-12: *Use "cooperative research and management funds" to foster cooperative management among agencies.* Under the current funding structure, there is little financial incentive for Federal land managers to actively participate in cooperative ventures with other agencies, State governments, or private parties. Congress could appropriate a certain sum of money for each agency with terrestrial research and management

responsibilities. These monies could be used for multiagency or multigovernment-level projects that address identified research priorities. Congress could also appropriate funds for regionally based, cooperative pilot projects. These projects could include the development of interagency strategic kind-management plans.

Many programs already in place in some agencies could be expanded and supported with these funds. Both the Forest Service and BLM have Challenge Cost Sharing Programs in which matching funds are made available to the States for habitat-improvement projects. HCPS under the Endangered Species Act are developed through a coordinated effort with Federal agencies, landowners, industry, environmental groups, and developers. Although not centered in any Federal agency, Unesco's MAB is an example of a regional research effort involving many Federal agencies.

Option 5-13: *Create a Federal Coordinating Council for Ecosystem Management.* Congress could build from the idea that produced the Federal Coordinating Council for Science, Engineering, and Technology, to create a Federal Coordinating Council for Ecosystem Management that would provide a forum for facilitating cooperative management at the national level. This council could evaluate interagency projects and make recommendations regarding needed collaboration. Such an evaluation may identify the extent of existing research or activity in this area, and enable an easier identification of areas in need of more emphasis. Although this council could be effective in facilitating integrated activity at the national level, the successful implementation of national programs would rely on incentives and support for "ecosystem management," or cooperation at the land-management (grassroots) level.

FIRST STEPS

Because money to implement all the above options and the scientific understanding of how climate change will affect natural areas are limited, the following frost steps represent reasonable actions for facilitating adaptation to climate changes in natural areas. The first steps identified here are those that meet one of several criteria:

—they should be undertaken early because they will take a long time to complete;
—they address "front-line," or urgent, issues that need attention first in order to make informed policy decisions in the future;
—they can be approached through mechanisms already in place or efforts already underway;
—they are beneficial for reasons other than helping to prepare for climate change; or
—there is a near-term 'target of opportunity."

These first steps begin to address the research, monitoring, and protection needs identified in this chapter. By starting with these options, the Nation can respond to the impacts of climate change in federally protected natural areas while strengthening its commitment to natural area protection in general. These are first steps to pursue because of present climate change concerns; they are not all the things one could do to prepare natural areas for the future impacts of climate change.

- Use the National Biological Survey to assess biological and ecological inventory and monitoring needs. A nationwide 'map' of biological resources, topography, land use, and protected areas is needed now. Future strategies to protect natural areas and their resources will require a national picture of what biological resources currently exist and where they are located, what lands are under protection, and how adjacent lands are used. Simply, a baseline resource map is necessary before detection of long-term changes in resource conditions can be made and protection efforts modified. A national inventory and monitoring program would also

be beneficial for protecting endangered species and biodiversity.

The new National Biological Survey in the Department of the Interior is the closest mechanism to a single, multiagency, national effort to address global change issues for biological resources. Because the NBS is in its formative stages, it presents a clear opportunity to implement some of the options outlined above. However, unlike the U.S. Geological Survey, the only agency that deals extensively with geological research and information, there are several agencies outside DOI with responsibilities for biological resources. The ideal, nationwide NBS program would effectively incorporate the activities of these other agencies as well as State and private organizations (see box 5-L). To do so, the NBS will have to create a formal mechanism to link and coordinate with activities in other agencies.

Because most basic ecological research is funded through NSF, that agency should be actively and formally involved in any comprehensive ecological research. Other agencies that manage biological resources should also be involved. This office could be charged to produce a document that synthesizes the condition of the Nation's biological resources and the state of the scientific understanding about how they work and interact.

Congress could ask the NBS to develop a priority plan for expanding protection of natural areas to include all ecosystem types and areas with environmentally sensitive species and high biological diversity. The plan could incorporate a variety of techniques including acquisition, easements, cooperative management, incentive programs, and cost-sharing programs.

- Support basic research on key gaps in our understanding of ecosystems, such as: 1) past climate changes and corresponding species responses, 2) restoration and translocation ecology, 3) the effectiveness of corridors and buffer zones, 4) the development of ecological models, and 5) the effect of elevated CO_2 on assemblages of plants and animals. Basic research in these areas is needed now to determine how species might respond to climate change and how to best provide for their protection in the future. Agencies could attempt to redirect existing funds in the USGCRP or procure new funds for addressing these basic ecological research needs under the "Ecological Processes" research area (see ch. 3). Alternatively, NSF, whose mission is to support basic scientific research, could take the lead in supporting these research areas outside the auspices of USGCRP. The new NBS could also be an appropriate vehicle to use in addressing some of the research that directly relates to land-management issues.

- Conduct a review of ecological research within USGCRP and across Federal agencies, evaluate how much long-term ecosystem-level research relevant to climate change, biodiversity and other multidecadal problems is being done, and identify important gaps. A review of all research conducted on "natural resource" has not yet been compiled across the Federal agencies. Existing analyses suggest a great deal of money is spent on research relevant to the environment but how much is useful to understanding long-term ecological problems (such as biodivesity and climate change) is not known.

  Further, there is currently no mechanism for consolidating results from disparate research efforts into "general patterns and principles that advance the science and are useful for environmental decisionmaking. Without such synthesis studies, it will be impossible for ecology to become the predictive science required by current and future environmental problems" (70).